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MINETA TRANSPORTATION INSTITUTE

TOD and Park-and-Ride: Which is Appropriate Where?

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Mineta Transportation Institute

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16. Abstract

Despite the sharp drop in transit ridership throughout the USA that began in March 2020, two different uses of land near transit stations continue to be implemented in the United States to promote ridership. Since 2010, transit agencies have given priority to multi-family residential construction referred to as transit oriented development (TOD), with an emphasis on housing affordability. In second place for urban planners but popular with suburban commuters is free or inexpensive parking near rail or bus transit centers, known as park-and-ride (PnR). Sometimes, TOD and PnR are combined in the same development. Public policy seeks to gain high community value from both of these land uses, and there is public interest in understanding the circumstances and locations where one of these two uses should be emphasized over the other. Multiple justifications for each are offered in the professional literature and reviewed in this report. Fundamental to the strategic decision making necessary to allocate public resources toward one use or the other is a determination of the degree to which each approach generates transit ridership. In the research reported here, econometric analysis of GIS data for transit stops, PnR locations, and residential density was employed to measure their influence on transit boardings for samples of transit stops at the main transit agencies in Seattle, Los Angeles, and San José. Results from all three cities indicate that adding 100 parking spaces close to a transit stop has a larger marginal impact than adding 100 housing units. Previous academic research estimating the higher ridership generation per floor area of PnR compared to multi-family TOD housing makes this show of strength for parking an expected finding. At the same time, this report reviews several common public policy justifications for TOD as a preferred land development emphasis near transit stations, such as revenue generation for the transit agency and providing a location for below-market affordable housing where occupants do not need to have a car. If increasing ridership is important for a transit agency, then parking for customers who want to drive to a station is an important option. There may also be additional benefits for park-and-ride in responding to the ongoing pandemic.

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All the analysis, conclusions, and recommendations in this report are the sole responsibility of the two report authors named.

Cover image: Google Earth image (Landset/Copernicus) showing a park and ride structure with 377 parking spaces for transit customers located next to a King County transit oriented development with 322 housing units in three buildings with 415 parking stalls underneath for residents and visitors. This location is within the designated urban center of Redmond, Washington. A bus transit center with service from two agencies is in the foreground with a skate park visible to its right.

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Executive Summary

Transit ridership in America in the cursed year 2020 went from flat or falling to crashing decisively. Even before dropping precipitously in March 2020 to a low level of essential travel by those without alternatives in the pandemic retreat from multi-passenger, socially-undistanced vehicle use, public transit ridership across the USA had been sliding downward since the beginning of 2015. Total transit ridership at the end of 2019 was only at 2006 levels. The 21st century's highest ridership levels found just before the 2008 recession were not sustained across the dozen years before the pandemic took ridership over a cliff.

So falling transit ridership is an issue. This report assesses two kinds of land uses that are intended to support greater transit ridership, no matter how the pandemic plays out in the 2020s.

One redevelopment strategy for land near transit stations is multi-unit residential construction, a key component of transit oriented development (TOD), also known as smart growth and walkable urbanism. As an alternative to TOD in less dense areas, or as a complement to TOD in any location, free or inexpensive car parking (park-and-ride, PnR) serves to motivate drivers to board transit. There is public interest in implementing one or both of these development strategies when and where it is cost-effective. There is also public interest in understanding the circumstances and locations where one of these two land uses should be emphasized over the other.

Assessment of TOD and PnR as alternative strategies for land use near transit stations is influenced by preferences in state and local public policy. In that regard, a consistent local government and transit agency focus in the three cities studied in this project—San José, Los Angeles, and Seattle—has been on increasing transit market share by building more affordable housing near transit stations. At the same time, but less intense, there is also interest in PnR, which is fueled by customer use filling the capacity of parking facilities in many suburban locations. However, in California and Washington State, attention has shifted away from parking expansion for transit customers since 2010 because of state and local government policy to reduce vehicle miles traveled (VMT).

PnR has a number of benefits for regional mobility improvement:

- PnR expands the reach of a fixed-route transit network to customers who live beyond the limits of coverage, thus providing a benefit not only to those citizens living in the outer regions of the service territory, but also to the regional economy as a whole by making employment opportunities more accessible. Research reported by the University of Minnesota analyzing the Minneapolis region shows that worker access to employment opportunities expands geographically with PnR.
- At the same time, PnR serves to suppress solo driving into city center transit destinations and tends to reduce vehicle miles traveled on corridors leading to them.

- Through marketing efforts and facility locations close to disadvantaged populations, PnR capacity can be targeted to serve pockets of low-income, mobility-deprived residential regions, who may find that parking next to a transit stop is a more affordable commuting arrangement than buying or renting a residence near walkable access to transit.
- Pricing based on passenger load can be used to manage demand while maintaining affordability and ensuring some available parking capacity throughout the day for travelers who cannot arrive at the very beginning of morning peak.
- PnR can be successfully combined with TOD that shares parking spaces between TOD residents and incoming PnR customers. Careful design that separates heavy flows of commuters' vehicles from pedestrians and bicycles is important.
- Suburban PnR is compatible with outbound micromobility options for those arriving by fixed-route services and wanting to reach dispersed destinations not served by fixed-route transit.

However, a public policy aiming to de-emphasize PnR and focus more attention and resources on TOD has emerged for a number of reasons:

- PnR can be expensive to provide, and full cost recovery through parking fees has not been embraced as the standard practice, despite growing awareness of the misallocated resources that arise from free parking as described by Professor Donald Shoup.[1]
- Some PnR facilities operating at much less than full capacity leads to a perception that PnR is a poor public investment.
- As a typical transit agency practice, stand-alone PnR engenders construction and operating costs that fall on the agency, while the costs of new housing near transit stations are not typically borne by transit agencies under current policies. Instead, transit agencies can gain cash from selling or leasing land near stations for private sector housing. Frequently, existing or new PnR capacity is incorporated and paid for by the developer as part of TOD projects under these arrangements.
- Even though market-rate housing near transit stations has higher rents or purchase prices, public agencies with legislative authorization have devised ways to develop below-market-price affordable housing near transit stations.
- Anti-car sentiment among public transit planners and leaders, based on the environmental impacts of vehicle emissions and public policies to reduce VMT, has led to more interest in TOD, where residents will walk, cycle, ride scooters, or ride local transit to boarding points, compared to PnR.

- Since 2018, the traditional TOD quarter-mile circle of walkability around transit stations has expanded to a radius of one mile or more, and is now called TOC for transit oriented communities. This change is due to the advent of electric bikes and scooters.
- Under pressure from rising costs and falling revenues, transit agencies recognize ridership gains as a two-edged sword, generating larger subsidy requirements if new routes or higher frequency services have to be established to serve customers at the PnR lots near the region's edge. In contrast, lower incremental subsidies may be experienced by filling up existing bus and rail routes having ample capacity with TOD-generated ridership closer to major transit destinations in central business districts.

Fundamental to strategic decision making to direct public resources toward one use or the other on transit-adjacent land is a firm grasp on the degree to which each generates transit ridership.

The answer to the question of how much to emphasize parking or housing near transit stations as a force for more ridership is clear when addressed simplistically: less space and lower infrastructure costs are associated with creating a parking space than with creating a housing unit.

In the new research reported here, econometric analysis was employed to measure the influence of residential density and proximity to park-and ride on transit boardings for a sample of transit stops in San José, Seattle, and Los Angeles. Using negative binomial regressions[2] in all three study areas, results indicate that within a quarter-mile of transit stops, the presence of 100 parking spaces in an existing PnR has a stronger positive marginal impact on ridership than the presence of 100 housing units. The analysis describes this effect in multiple ways. In summary, the computed marginal influence on the morning weekday transit ridership of these 100 PnR spaces is about twice that of 100 nearby housing units for Santa Clara Valley Transit and Los Angeles County Metro and four times stronger for King County Metro. This effect is an average across the entire network.

The first two decades of the 21st century have revealed a public policy preference in the three studied cities for transit oriented development over park-and-ride. However, the public interest in promoting ridership on public transit and the analytically demonstrable strong effect of PnR as an influence on ridership mean that parking is always an important option to consider. Pay-to-park facilities combined with managed capacity utilization in both parking and the transit coaches are options to boost ridership anywhere in the transit network, especially toward the edges of the network.

Furthermore, the research in this report includes preliminary considerations of the opportunities in a pandemic era for assembling and controlling ridership at major park-and-ride transit service access points as a managed way of providing safe levels of personal spacing in boarding areas and aboard transit coaches.

I. Goal of the Research

Using data from three large US transit agencies—Santa Clara Valley Transportation Authority serving San José, King County Metro serving Seattle, and Los Angeles County Metro—quantitative analysis was performed to compare two strategies applied near transit stations to increase transit ridership: increasing residential housing density and adding park-and-ride capacity.

One motivation for this study is a 2016 report[3] from the Transit Cooperative Research Program (TCRP) of the Transportation Research Board (TRB) that surveyed 37 US transit agencies about their use of park-and-ride as a means to provide customers with access to transit. These researchers noted, "A primary finding of this synthesis is that there is limited research that documents the impact of parking policies on transit ridership… there is a need to evaluate the existing data to understand the impact of parking policies on transit ridership."

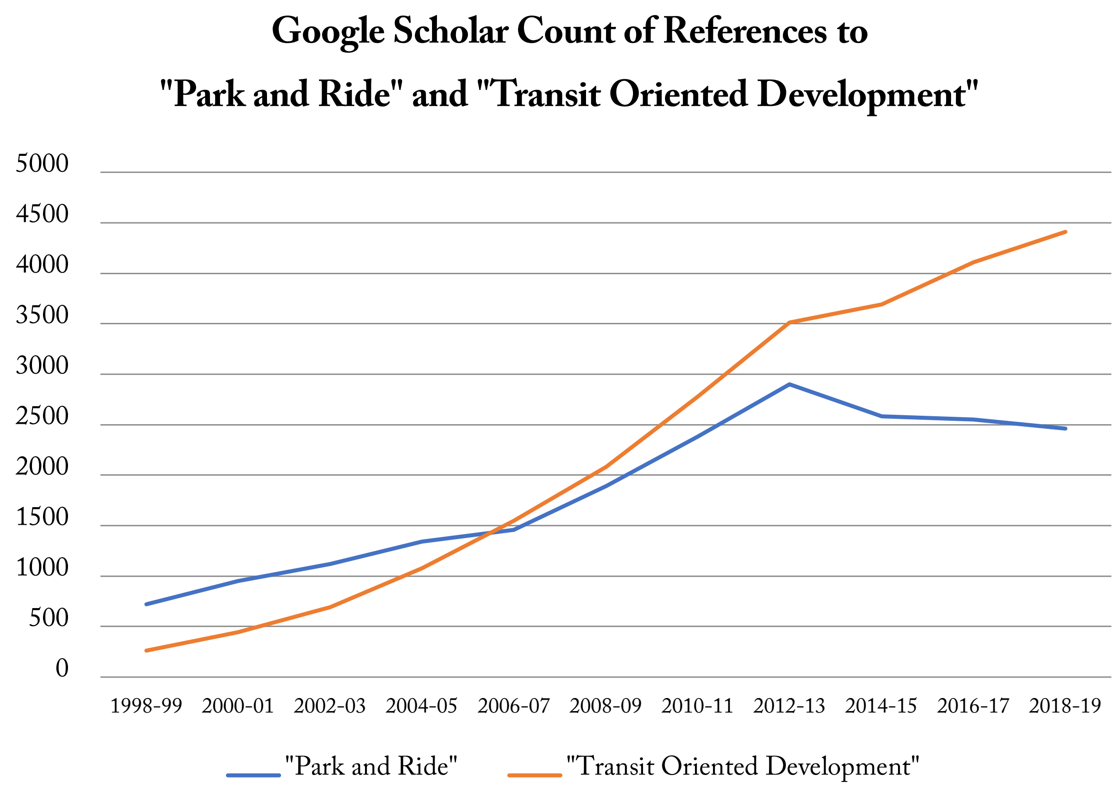
In their synthesis, authors Jacobson and Weinberger also remarked,

> *The most significant debate is over the question of whether to develop the areas surrounding the station, with one author arguing that development densities would have to be unacceptably high in most jurisdictions in order to surpass the transit ridership associated with park-and-ride (Duncan 2010)[4] and others providing the counter argument that the best way to increase ridership is by developing such station areas (Willson and Menotti 2007).[5]*

1.1 Shift of Academic Interest from PnR to TOD

A count of citations in the academic literature reveals growing interest in TOD relative to studies of PnR, as shown in Figure 1, which depicts mentions, in the Google Scholar aggregation of academic literature, of the terms "transit oriented development" and "park and ride" during the period 1998 to 2019 in two-year increments.[6] "Park and ride" exceeded "transit oriented development" by about three to one in 1998–99, but in 2006–07, TOD citations exceeded PnR citations and continued growing in subsequent years. Park-and-ride references showed a declining pattern beginning in 2014–15 and continued falling off through 2018–19.

Figure 1. Rising Scholarship for TOD; Falling Off for PnR



Source: PnR and TOD academic citations from Google Scholar

Despite the evidence that PnR is a topic of declining interest, the authors of the present study believe, like Professor Don Shoup in his 2018 book, *Parking and the City*, "that parking is worth taking seriously… parking affects whatever people do care strongly about, such as affordable housing, climate change, economic development, public transportation, traffic congestion, and urban design."[7] All these topics are touched upon in the present report.

The research reported here also builds on the 2016 Niles-Pogodzinski study for the Mineta Transportation Institute[8] that found initial suggestive evidence that parking near public transit stops in Seattle and San José bears a stronger positive relationship to transit ridership than housing density near public transit stops.

The present study tested the following propositions with regression analysis:

- Both parking and residential population density are positive influences on transit boardings. This was confirmed.
- Marginal additions of parking spaces near transit stops are a stronger influence on boardings than marginal additions of population density. This was confirmed.
- The influence of parking on boardings wanes as stops are closer to downtown. This was partially demonstrated in the present research for VTA.

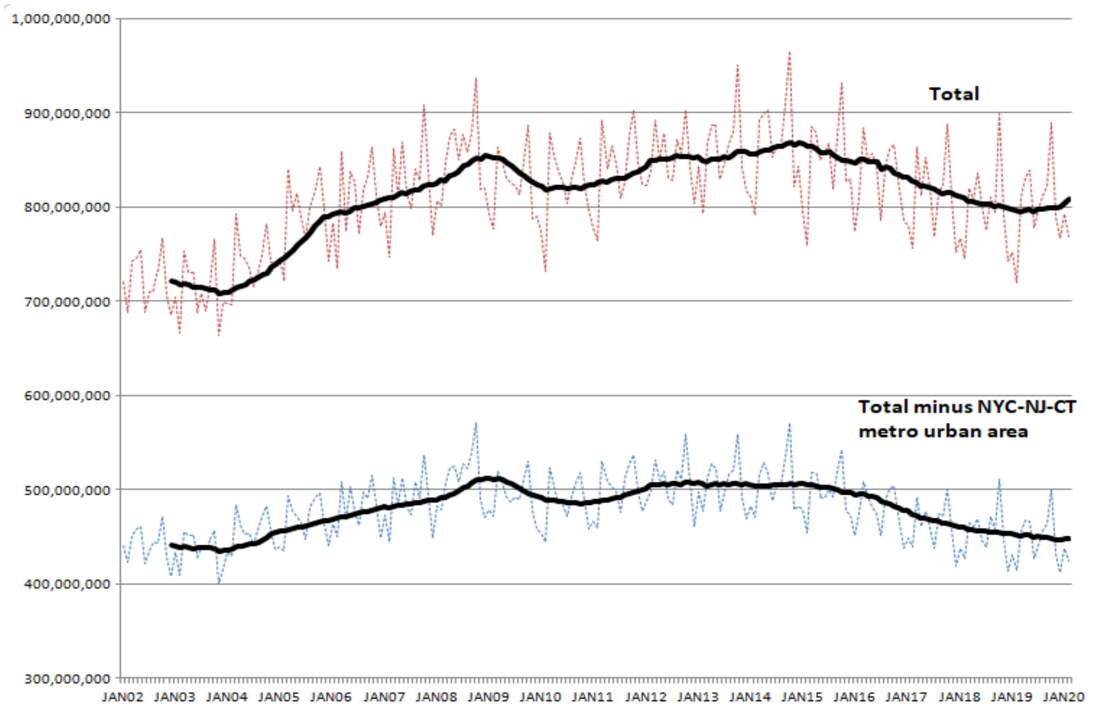
- The influence of parking on ridership varies with the overall use of transit in the service territory as measured by transit ridership per capita. The influence of parking on ridership relative to the influence of population density is stronger in service territories where there is more transit parking per capita. The results in the data from three agencies examined in this study suggest that this is true, although three agencies alone do not prove this conclusively.

The results of the research in the present study and the earlier Niles-Pogodzinski study are meant to inform public decision making on the allocation of resources to the investment options of TOD (using housing density as a surrogate) and PnR on the land near bus and rail transit stations.

Ridership on transit is measured by vehicle boardings, also known as unlinked person trips, which are reported by US public transit agencies every month to the United States Department of Transportation, Federal Transit Administration.[9] There is great interest among transit professionals and urban leaders in finding new ways to promote a greater transit mode share as measured by boardings, which then means less use of personal vehicles. Long-term reduction of miles traveled in personal cars and light trucks is a legislatively established goal in both Washington State and California.

But there has been decreased transit use, even without considering the pandemic of 2020. As shown in Figure 2, public transit boardings across the USA have been trending downward since 2014 and are now below the high point of the 21st century that was reached at the beginning of the fourth quarter of 2008, just before the recession began that same year.

Figure 2. Monthly Transit Ridership in the US, 2002–2020



Source: US National Transit Database

Transit as of the end of 2019 and the first two months of 2020 was experiencing monthly ridership levels like those in 2006, despite the 13 years of population growth and economic expansion since then. The top line in Figure 2 shows monthly boardings for the bus and rail modes of public transit for all of the transit agencies and cities in the US. Because the New York City metropolitan area has such a dominant share of transit service and ridership, it is customary to break out all the other agencies and cities separately, which is done by the lower line in Figure 2.

Later in this report, recent boarding trends are reviewed for the three case study agencies, showing a similar pattern of transit use decline, more marked in California than in Washington State. Understanding how station area land use can support ridership is important for maintaining the viability of public transit systems in America. A later section describes why this issue is even more important in the pandemic era.

II. Two Urban Strategies: TOD and PnR

In an urban region with public transit, two distinct strategies stand out for gaining transit ridership. They are distinguished by what is built in the vicinity of stations.

- Transit Oriented Development (TOD): Taking steps to motivate the private sector to construct station-adjacent zones of high-density housing and business within walking distance of where travelers get on and off the trains and buses.
- Park and Ride (PnR): Building, leasing, or otherwise contracting for car parking facilities near transit stations to serve travelers who are not living within convenient walking range of boarding points.

Both PnR and TOD can exist near the same station, but implementation of both together can present site design challenges: parking facilities within TOD zones generate car traffic, especially in the twice-daily peak commuting periods, that can detract from the safety, quietness, air quality, and other features of the pedestrian-friendly experience sought in such zones. As explained by Dittmar and Ohland's book-length guide to best practices in transit oriented development,[10] "Parking (a node function) may be at odds with neighbors who complain about increased traffic in their neighborhood (a quality of place concern) … The seemingly mundane issue of parking epitomizes the tension between node and place."

On the other hand, the four TOD project examples from King County shown below in Figure 16 combine both strategies: housing near the station and parking for non-TOD residents.

Park-and-ride facilities—sometimes surface parking lots and sometimes multi-story structures—provide parking for transit passengers arriving from a trip origin located beyond an acceptable walking distance from the transit pick-up point. The passenger drives to the PnR facility, typically in the morning, and then later returns by transit to retrieve her car and drive home. More formally, "Park-and-ride facilities are staging locations that provide intermodal transfer points for travelers between single-occupancy automobiles and other transportation modes."[11]

As adapted from a 2017 comprehensive Transportation Research Board report on park-and-ride decision making,[12] the following reasons for government investment in park-and-ride facilities are apparent:

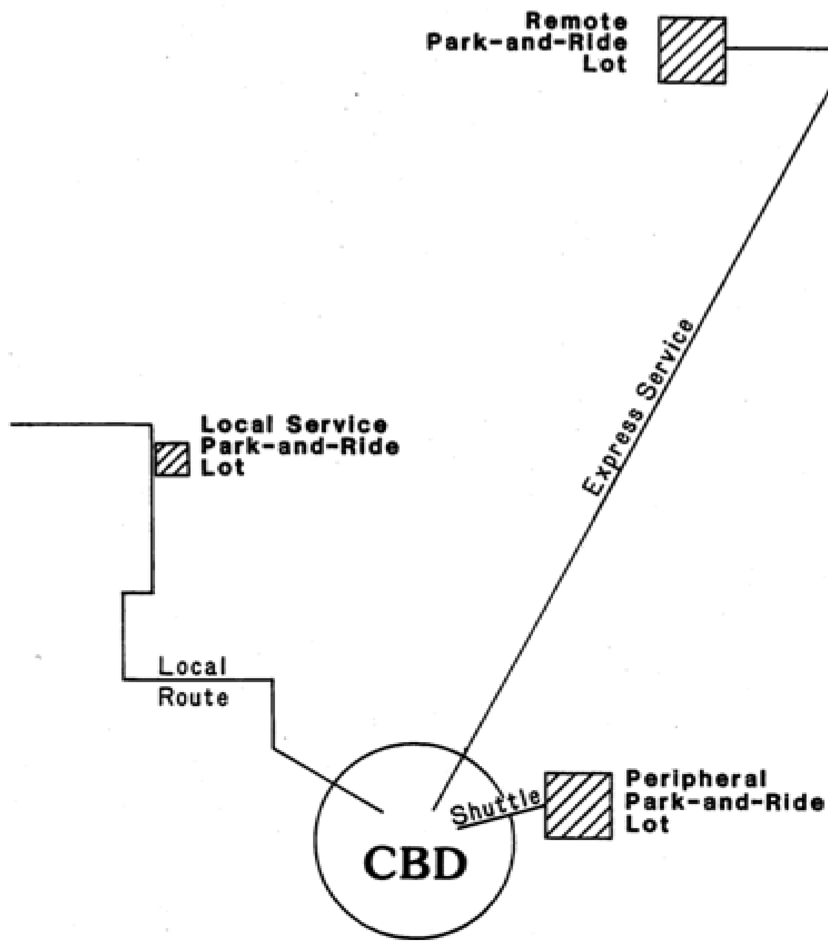
- Provide optional convenient access to transit by those daily commuters who's most preferred and convenient mode to and from home is a private vehicle that is parked reliably and securely for the day.
- Support drive-to-transit commuting that could appeal to travelers who might otherwise choose to drive all the way to their destination.

- Increase the productivity of bus operations measured in boardings per service hour by concentrating transit rider demand at a smaller set of access points and thus makes transit service in low-density areas more efficient.
- Support the shift of parking away from the central business districts (CBDs) and other dense activity centers served by transit, and also suppress congested traffic flows on road corridors leading to those destinations.
- Offer the potential for some PnR customers to reduce vehicle miles traveled and the associated vehicle emissions.
- In addition to public transit access, can be explicitly authorized by the facility owner to provide convenient and safe meeting points for carpool and vanpool users where arriving commuters can leave some cars parked for a period of hours or days. (This study focuses on public transit access; for a historically significant review of PnR covering both transit and carpooling use, see TCRP Report 95, Chapter 3.)[13]

Park-and-ride service at train stations and bus transit centers is a straightforward government response to citizens who want to drive from their homes at the beginning of a trip to a destination served by public transit. This method of access parallels the common patterns for travelers going on an airline trip: airports commonly have nearby parking facilities where travelers leave their cars while on a flying trip.

Three broad location scenarios for park-and-ride are shown in Figure 3, created in the 1970s. Remote park-and-ride facilities are placed on the edges of a network. Further in the network closer and to important destinations are potential location serviced by local buses that most customers would walk to reach. These types of PnR facilities are the ones most often targeted for conversion to TOD. Finally, there is a now-rare type of PnR called a peripheral facility near the edge of a downtown area that is served by smaller buses shuttling back and forth between parking and blocks within the main central business district. Both of the latter types are now out of favor with public authorities because of their effect in motivating private automobile use in urban areas where transit service is available.

Figure 3. Historical Conception of Remote, Local, and Peripheral Park-and-Ride Lots



Source: North Central Texas Council of Governments[14]

Travelers driving cars typically have the option of driving past the park-and-ride lot to go all the way to their destination, but there are a number of reasons why deciding to park and board transit may be attractive. In many urban regions that final trip leg beyond the park-and-ride often requires driving on congested roads to a destination characterized by even more congestion, plus the financial pain of paid parking. For commuters who decide to use park-and-ride, saving money is anticipated and achieved by avoiding fuel cost, parking charges at the destination, and wear and tear on one's private car. If the public transit provides comfortable seating in a pleasant, safe vehicle, the benefits are greater. It may be the case that reaching the transit access adjacent to the PnR by means other than driving is slow, expensive, or otherwise very difficult for the transit customer. In other words, for the PnR customer, a judgement is typically on hand that there is no convenient bus operating from near the traveler's residence to the transit station. Leaving the PnR site at the end of the workday may entail the same issues in the reverse direction. If the transit service between the PnR facility and the commuter's final destination in the morning comes frequently and is fast, it could be the case that the PnR and transit combination is the fastest, most reliable transport means. Research from TRB published in 2017[15] found that many PnR facilities on the outer edges of transit networks throughout North America were filled up on weekdays.

Park-and-ride at the edge of transit networks often operates at the interface of two forces in urban development: smart growth densification and urban regional sprawl, both explained later in Table 12. Such facilities, as illustrated by "Remote Park-and-Ride Lot" at the top of Figure 3, are usually located in low-density areas of a metropolitan area. However, PnR facilities located deeper inside an urban region are a landing zone for car-driving residents of suburban sprawl, who arrive seated in their personal mobility machine for low density living to transfer onto mass transit, a fundamental characteristic of high density smart growth.

Urban Transfer Points

The first to promote the benefits of transfer points around cities was Dr. Bernhard Mees. In 1932 he wrote the following in his dissertation "Traffic Issues for the Big City":

With a general parking ban, there are three options for entering the city:

> *1. People search for parking space at or near the destination.*
>
> *2. They leave their car at home and go to the city by train, tram or bus; as a result, there is less traffic on the road, but a number of cars are also worthless to the owners for a large part of the day.*
>
> *3. You drive by car to the border of the hidden inner city, park there and continue by public transport. This reduces congestion, as mentioned under No. 2, but saves time compared to the options listed under No. 1 and 2.*

Source: CROW, "Transfer points - Experiences with Park & Ride (P + R) in the Netherlands," brochure, http://www.crow.nl/parkeren.

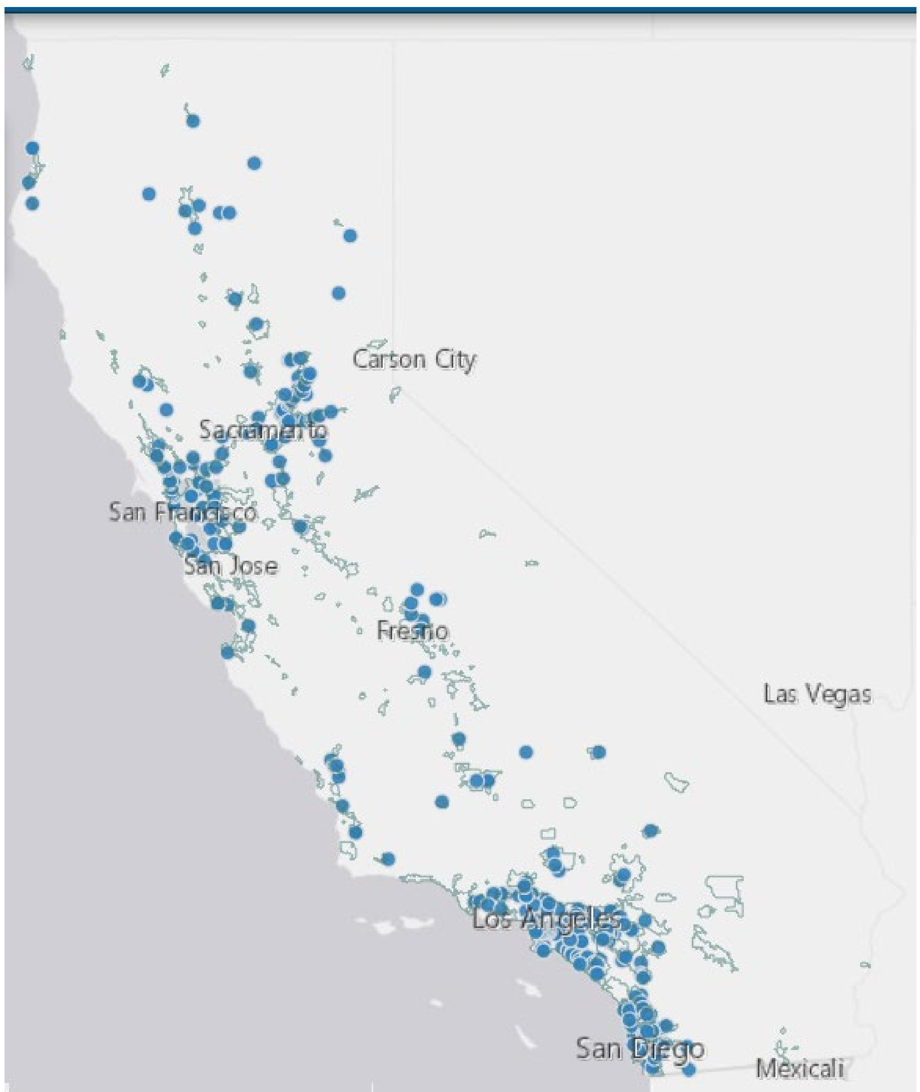
2.1 Government Support for Park and Ride

There is a complicated interplay between state and local government in the provision of park-and-ride facilities in Washington State and California. In these two states, PnR facilities were first established along state highways under state government legal authority. Both state governments have historically focused on PnR as a tool for highway capacity management, intending to divert some car drivers to choosing carpools or buses. Since moving people along city streets in buses is a more efficient use of road lanes than moving people in automobiles, PnR supports the same principles of street use geometry that US transit specialist Jarrett Walker invokes as a primary justification for public transit funding.[16]

A generalization of this law is that carpools and vanpools, termed "high occupancy vehicles" or HOVs, are more efficient than single occupant vehicles (SOVs). This more efficient use of road space by larger vehicles or vehicles carrying more people than just a driver is precisely what has historically motivated state transportation agencies like WSDOT and Caltrans to build park-and-ride lots along state highways. Park-and-ride lots provide fixed locations where SOV drivers can arrange to meet up with more efficient vehicles—bus, van, or carpool—and leave their own behind for the day. Assembling SOV drivers into groups to use a different vehicle is a logistics problem that requires pre-arrangement, but commuting is a daily routine activity that facilitates such arrangements.

California DOT noted in a 2005 report[17] that the state owned 367 PnR lots widely scattered but concentrated in or near urban areas, as shown on the map in Figure 4. The report indicated that "The California BusPool Project was created to identify potential PnR and HOV improvements that would enhance express bus services in the State's metropolitan areas … a consulting team identified 181 potential projects [for $2.3 billion estimated cost] capable of positively impacting ridership on public transit bus routes that utilize Caltrans HOV facilities and P&R Lots." An assessment undertaken by Caltrans in 2010[18] did not identify any performance improvements linked to PnR projects, although there is a published methodology[19] for conducting a benefit-cost analysis. The number of Caltrans PnR facilities has shrunk to 326 as of 2019, with some having been turned over to local transit agencies.[20]

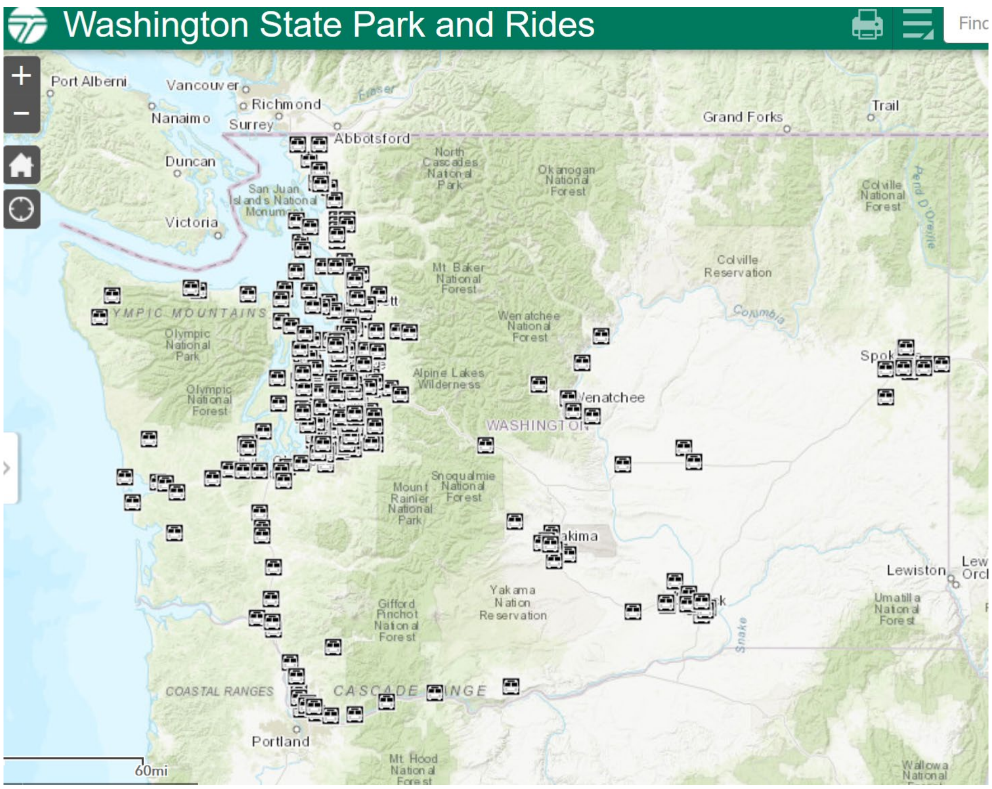
Figure 4. California Park and Ride Lots



Source: Caltrans GIS Data[21]

Washington State DOT has loosely inventoried 350 PnR facilities along state highways, offering up to 60,000 parking spaces,[22] shown in Figure 5. Ownership is varied, including many of the multiple county public transit agencies and sometimes private land owners. Many of these facilities are owned by the State DOT; a few are designed primarily for meet-ups of drivers to form shared ride arrangements, with many others provided by county transit agencies. As shown on the map, most of these facilities are located in the Seattle-Tacoma urban region of the state. A subset of these facilities that were turned over to King County Metro Transit for operation is part of the data analyzed in this report.

Figure 5. Park and Ride Facilities in Washington State



Source: Washington State Department of Transportation[23]

Washington State DOT asserts on its Transportation Systems Management and Operations Website that PnR facilities provide a wide range of benefits:

- *Increased transit ridership*
- *Improved safety and security for transit riders*
- *Reduced travel times and increased travel time reliability for transit vehicles and potentially for all vehicles*
- *Reduced fuel consumption*
- *Eased congestion by reducing the number of trips for people driving alone*

- *Long-term and specific benefits may include:*
    - *An established transit infrastructure that supports more permanent transit-oriented housing and business development*
    - *If successful in moving people from single-occupancy to high-occupancy vehicles, well designed and located park and rides may result in reduced congestion.*[24]

In 1986, WSDOT contracted with the University of Washington for an evaluation of its PnR facilities operated by King County Metro (KCM). The results found that as a group, they are cost-effective, providing benefits to transit customers, KCM, and drivers on the highway.[25] The number of lots has expanded since then; parking capacity growth was 20% between 2005 and 2017.[26]

Most of the use of park-and-ride is for the weekday journey to work or school, but no trip types need be excluded, including medical appointments, employment interviews, attendance at entertainment and social events, and many other common activities.

The American Public Transportation Association infrastructure database for 2018—with somewhat intermittent coverage based on an inspection of the records—reported that there are 1,324,182 all-day parking spaces serving customers at 287 rail and bus transit agencies in the US and Canada.[27]

There is extensive deployment of PnR in Europe, including the United Kingdom, Germany, the Netherlands, and Norway.[28] A major emphasis in Europe is the reduction of car traffic in congested city centers.

2.2 Transit Oriented Development Basics

TOD is a widely promoted concept that means taking action to stimulate and create multi-unit residential and multi-story commercial development near rail transit stations (primarily) and bus transit centers (sometimes), with both modes usually serving routes with frequent, high-capacity service.[29]

Transit oriented development (TOD) is described by the Federal Transit Administration of the United States Department of Transportation as follows:

> *Transit-oriented development, or TOD, includes a mix of commercial, residential, office and entertainment centered around or located near a transit station. Dense, walkable, mixed-use development near transit attracts people and adds to vibrant, connected communities.*
>
> *Successful TOD depends on access and density around the transit station. Convenient access to transit fosters development, while density encourages people to use the transit system. Focusing growth around transit stations capitalizes on public investments in transit and provides many benefits, including:*

- *increased ridership and associated revenue gains for transit systems*

- *incorporation of public and private sector engagement and investment*
- *revitalization of neighborhoods*
- *a larger supply of affordable housing*
- *economic returns to surrounding landowners and businesses*
- *congestion relief and associated environmental benefits*
- *improved safety for pedestrians and cyclists through non-motorized infrastructure*

TOD primarily occurs when regional or local governments encourage it through land use planning, zoning laws, and changes to building codes, among other things. When a TOD coincides with a federally funded transit project, FTA may provide financial assistance, technical assistance, training, and other resources to complement the regional or local TOD.[30]

The most important reason for urban planning to focus on TOD is the ample research evidence that residents living within walking distance of transit access use cars less frequently and take more transit trips than residents of zones where transit service is sparse and car usage is the main remaining option.[31] More transit use and less automobile use reduce vehicle miles traveled (VMT) and the costs associated with VMT, including greenhouse gas (GHG) generation, emissions of the EPA-established criteria air pollutants,[32] and injuries and fatalities from crashes.[33] Active, healthier lifestyles from walking and more bicycle use are also associated with TOD.[34]

2.3 Juxtaposing PnR and TOD

TOD and PnR are alternative land uses near transit stations, and they are both techniques for generating ridership. They are compared later, in Section VI of this report, via measuring the marginal impact on ridership of increased parking versus more residential density at transit stops. But the two land uses are different in several ways.

- Different target ridership markets: PnR serves travelers who are not within walking distance of a station, even in many cases on the fringes of the transit agency's service territory or outside it, while TOD is meant to serve residents who are living near transit stations by means of placement within walking distance of places to board the trains or buses.
- Public versus private investment: PnR facilities are typically built and maintained with funding from transit agencies or other government agencies, while TOD residences are usually built by private developers who are paying transit agencies for the land being used. Atypically, where the transit agency does not own the land near the transit hub, a private-sector developer could build transit-adjacent housing or fee-supported parking facilities independently of government, although under the influence of municipal and other government regulations.

- Different commitments to ridership: PnR spaces are usually dedicated exclusively for transit users. In contrast, TOD residents may or may not use transit service on any given day, although the target market is usually expected to be households where at least one member uses transit for daily commuting.

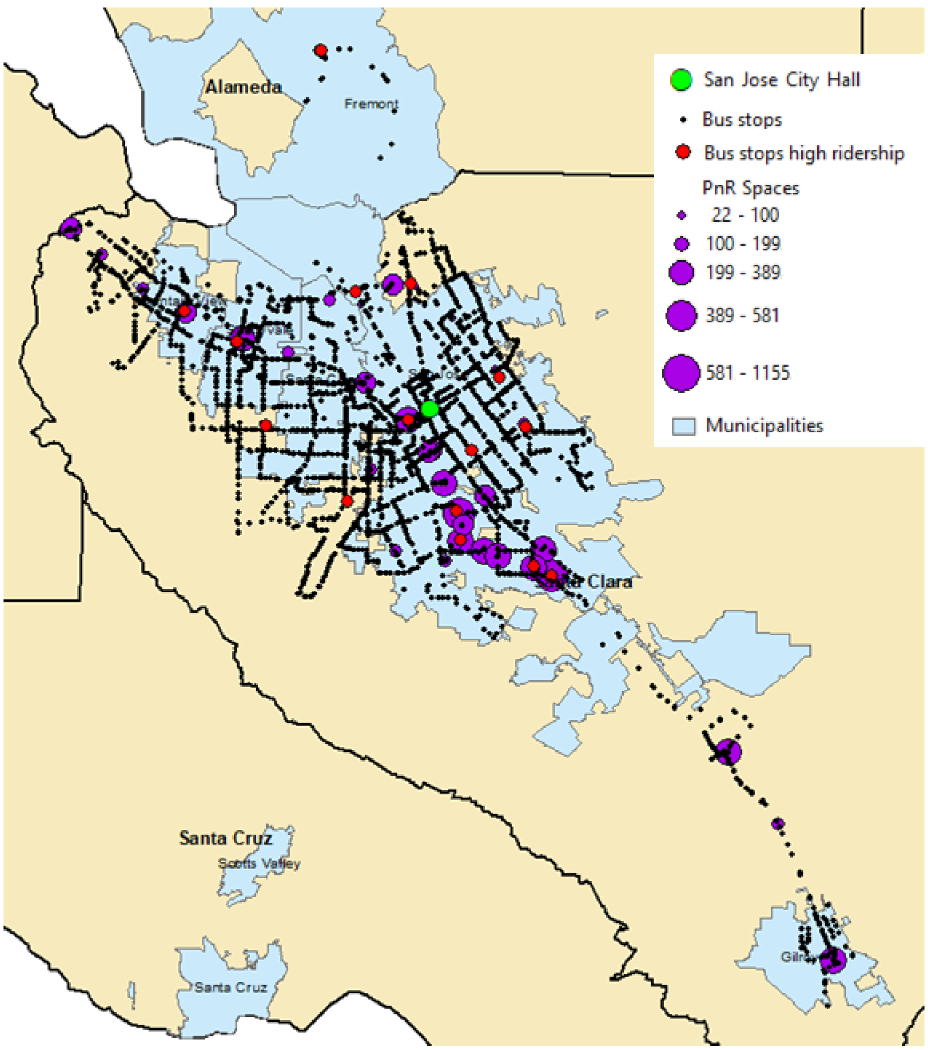
III. Overview of the Three Case Study Agencies

The transit agencies that are the focus in this report are the same ones that the authors studied in an earlier research project;[35] these contexts were selected because the authors are familiar with them and two of them are nearby for personal observations by the report authors.

From smallest to largest, the three agencies are Santa Clara Valley Transportation Authority (VTA), serving the City of San José and surrounding communities; King County Metro (KC Metro), serving the City of Seattle and surrounding cities; and Los Angeles County Metro (LA Metro) serving the City of Los Angeles and surrounding cities.

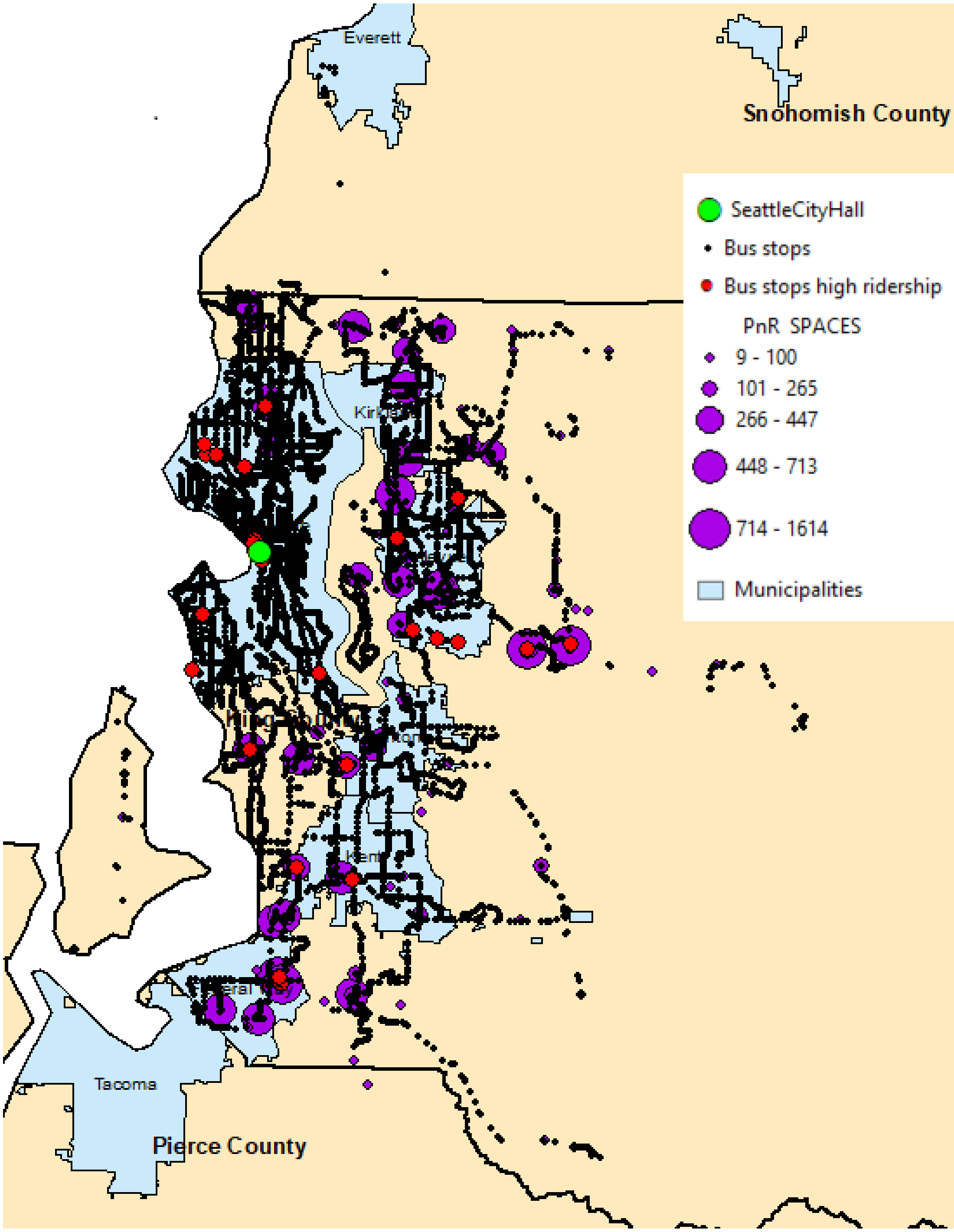
Maps produced by the researchers in Figure 6, Figure 7, and Figure 8 show the transit stops and park-and-ride facilities analyzed in the three agencies. Most of the high-ridership bus stops shown for VTA and LA Metro are also rail transit stops.

Figure 6. Transit Stops and PnR Analyzed for Santa Clara Valley Transportation Authority



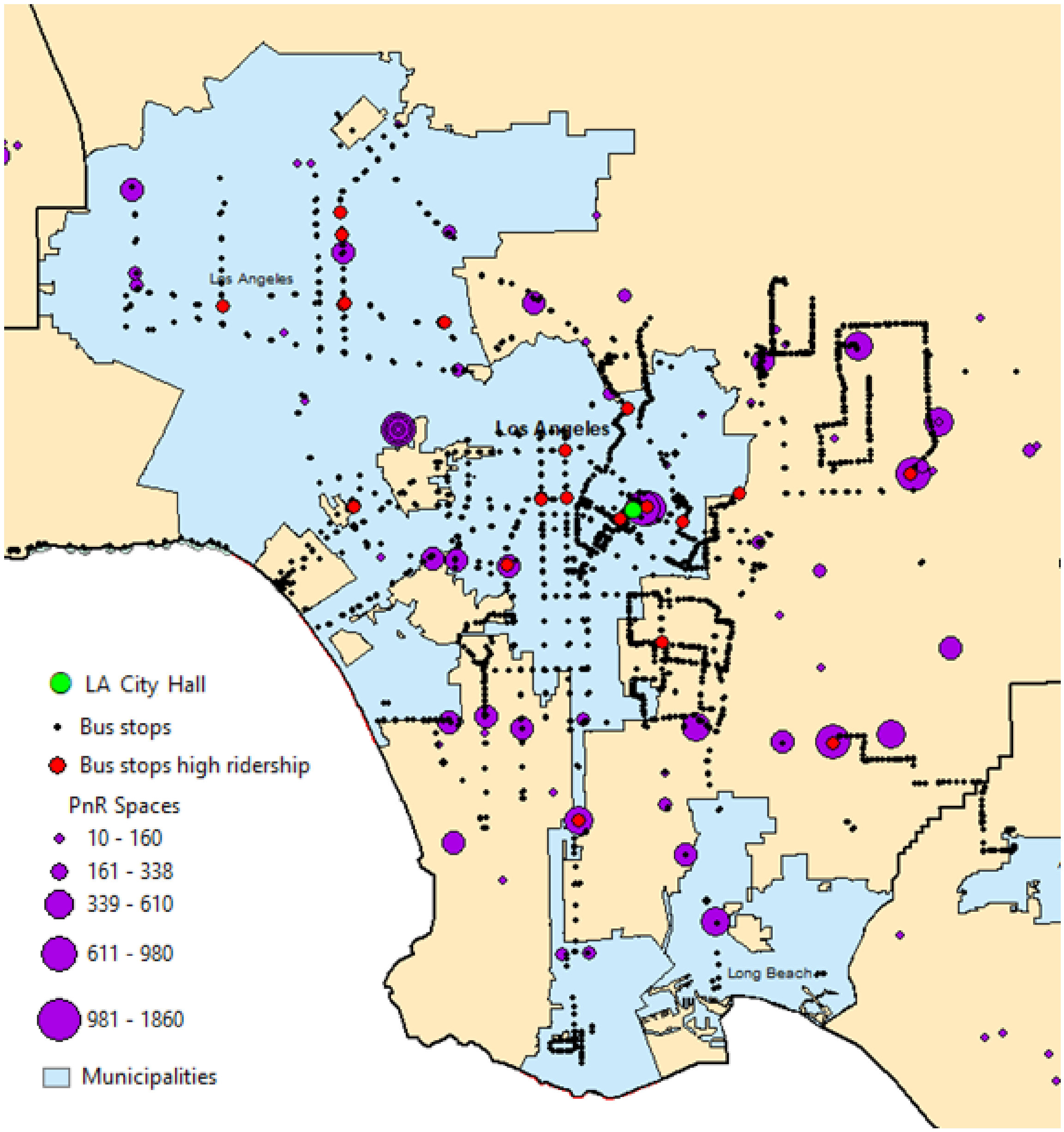
Source: J.M. Pogodzinski from GIS files provided by VTA

Figure 7. Transit Stops and PnR Analyzed for King County Metro



Source: J.M. Pogodzinski from GIS files provided by King County Metro

Figure 8. Transit Stops and PnR Analyzed for Los Angeles Metro



Source: J.M. Pogodzinski from GIS files provided by Los Angeles County Metro

Table 1. Transit Agency Comparison

Agency	Service Area Population[36]	Annual Boardings 2017[37]	Annual Boardings per Capita	Daily Ratio of Car Commuters to Transit Trips[38]	30-minute or Less Work Commute Market Share in MSA[39]
VTA	1,938,000	39,137,607	20	17.2	49.4%
KC Metro	2,189,000	127,954,193	58	5.8	45.9%
LA Metro	10,160,000	407,153,682	40	8.9	47.0%

The following list summarizes the site characteristics displayed in Table 1.

- Population of VTA and KC Metro service territories are similar. LA Metro area has five times the population of the other two.
- KC Metro has three times the boardings per capita of VTA, and fifty percent more boardings per capita than LA Metro.
- KC Metro has three times the transit market share of VTA, and more than twice that of LA Metro.
- Of the three transit providers, KC Metro is the top in transit boarding and the last in car commuting. VTA is the highest in car commuting and last in transit boarding. LA Metro is in the middle on both measures.
- Across the driving and transit modes, the proportion of commuters in the three territories who have a daily one-way journey of 30 minutes or less is remarkably similar in the range of 46% to 50%

Ridership trend data are shown later for all three agencies.

IV. Park and Ride in the Three Agencies

Table 2 characterizes the scale and performance of park-and-ride in the three transit service areas examined in this report. One immediate observation is that a small fraction of total ridership comes from park-and-ride in these three systems. Parking facility utilization is much higher in Seattle and Los Angeles than in San José.

At the same time, transit is a small fraction of urban mobility in most US cities aside from New York. Transit becomes a bigger part of mobility in urban zones where car access is discouraged through reduced and expensive parking and where high-quality transit service is readily available—that is, zones of smart growth.

Nevertheless, suburban regions of urbanized areas define the US geographic market for park-and-ride, and the market is strong and growing. While central cities were growing faster in the early part of the 2010–18 decade, suburban growth has returned as of the last part of the decade, as described by an analysis of US Census data conducted at the Brookings Metropolitan Policy Program.[40]

Table 2. Characteristics of Park-and-Ride Service for Three Case Study Public Transit Agencies

Agency	Weekday Boardings[41]	Park-and-Ride Locations[42]	Park-and-Ride Capacity[43]	Population per PnR Space	PnR Use[44]	PnR Capacity Usage[45]	PnR Spaces to Boardings Ratio	Filled PnR Spaces to Boardings Ratio
VTA	128,320	41	11,721	165	4,806	41%	9.1%	3.7%
KC Metro	419,522	136	26,253	83	19,976	76%	6.3%	4.8%
LA Metro	1,334,930	87	23,222	438	16,952	73%	1.7%	1.3%

The following observations are pertinent in the table of PnR characteristics.

- King County Metro has more PnR locations, capacity, and usage than the other two agencies, although the population of its Metropolitan Area is much smaller than LA Metro's and is comparable to VTAs.
- Across all three agencies, available PnR capacity measured by the number of parking spaces is below ten percent of boardings, and PnR usage is below five percent of customer boardings.
- VTA has the highest availability of PnR spaces as a fraction of ridership, but the other two agencies have about 80 percent more usage measured as a fraction of capacity.

4.1 VTA Park and Ride

As described in the 2019 VTA Congestion Management Plan, "VTA maintains 41 park-and-ride lots in twelve different cities throughout Santa Clara County. The lots connect commuters with VTA's light rail system, Caltrain, Capitol Corridor, Altamont Commuter Express, and several express bus routes."[46] The capacity of these lots is approximately 11,700, with 41% average utilization, the lowest within the set of case study agencies.

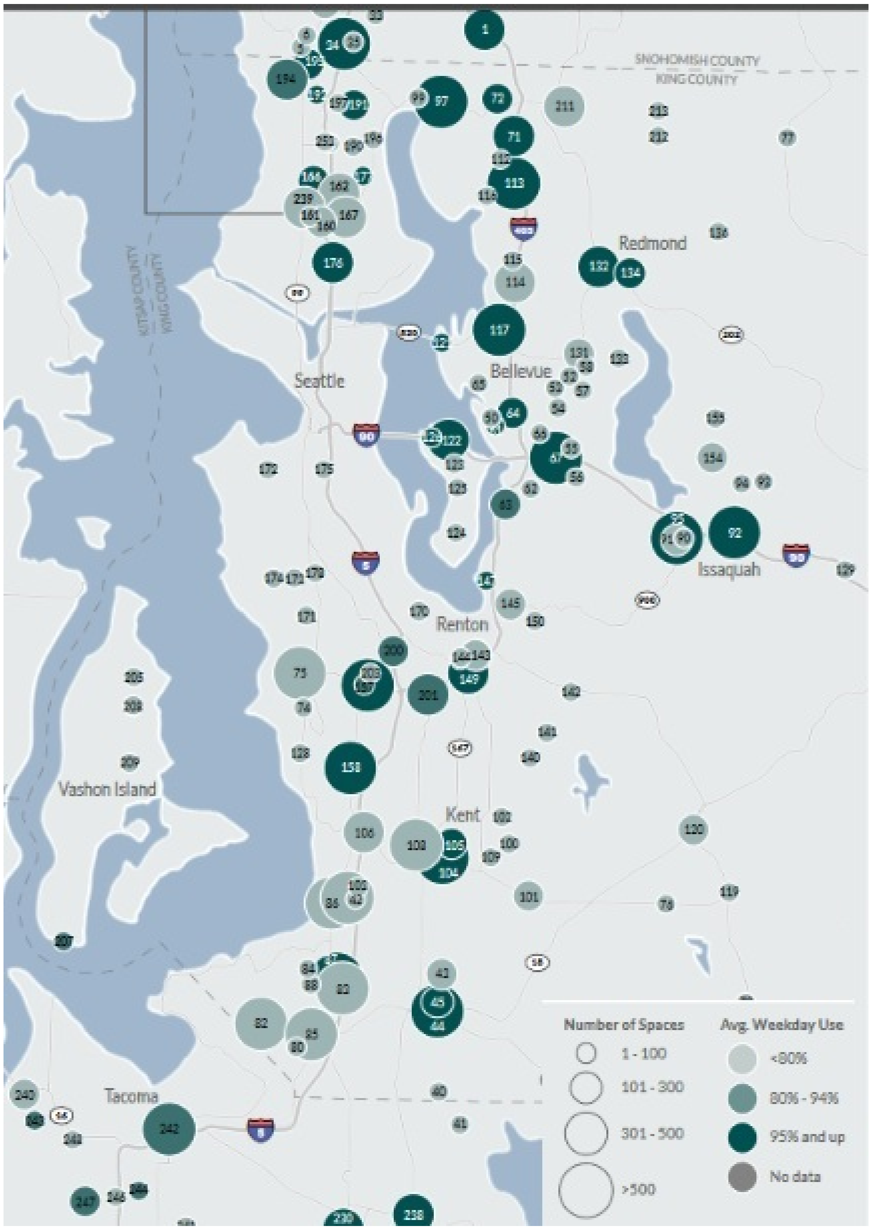
As described in a 2018 policy document for the agency's board of directors, "VTA has essentially run an experiment over the past couple decades to see if ample provision of free parking will attract transit riders; the current low level of light rail transit ridership demonstrates that it does not."[47]

As a response to consistently empty parking spaces at park-and-ride facilities in its service territory, VTA instituted a program of engaging with private developers to convert portions of selected parking lots into new residential and commercial development that enjoy the attractiveness of being well served by VTA's transit lines. The intent is to simultaneously generate real estate leasing or sales revenue and new transit customers, while at the same time continuing to support those present customers who do park at the underutilized facilities. Twenty-one such sites are targeted for this treatment, encompassing a total of 7,525 parking spaces. A survey made in June 2018 found that only approximately 3,800 of those spaces are "actively used."

4.2 King County Metro Park and Ride

King County Metro operates 136 park-and-ride facilities with approximately 26,000 spaces filled on average to 76% capacity during the workweek morning, according to visual surveys. A map of the locations is shown in Figure 9 that indicates the many facilities that operate near capacity.

Figure 9. Park and Ride Lots in King County Metro Transit Territory



Source: Washington State Department of Transportation[48]

In addition to the facilities shown in this map is a new program operated in cooperation with a private parking management company to provide commuters with paid parking spaces located in apartment complexes that are near transit stops.[49]

In an arrangement with another parking management vendor, King County Metro has an additional program at selected popular and crowded facilities to provide reserved spaces for HOV vehicles at no charge, and for solo drivers for a fee of $60 to $90 per month. As described by KC Metro, the permit parking program offers customers more reliability in finding a place to park in the designated arrival period (weekdays from 4 AM to 10 AM), after which the spots are released for use by any transit customer.[50]

Another program emphasis of KC Metro is Right Size Parking, an analytical effort to generate data on parking supplied and parking used in commercial and multi-family residential buildings throughout the county. The county describes the program this way.

> *Right-sizing parking means striking a balance between parking supply and demand. Although field data collection found some projects that were not oversupplied, on average parking was found to be oversupplied with 1.4 spaces built per dwelling unit but used at only about 1 space per unit. Applied to a typical suburban project with 150 units, the result is roughly $800,000 spent to build unused parking. …Over-building parking supply leads to increased automobile ownership, vehicle miles traveled, congestion and housing costs. In addition, it presents barriers to smart growth and efficient transit service.*[51]

Detailed information at the parcel level is used to influence city jurisdictions with an oversupply of parking to reduce requirements for new construction. The program also includes influencing building owners to join with the parking management company to provide paid parking during the day for transit customers.

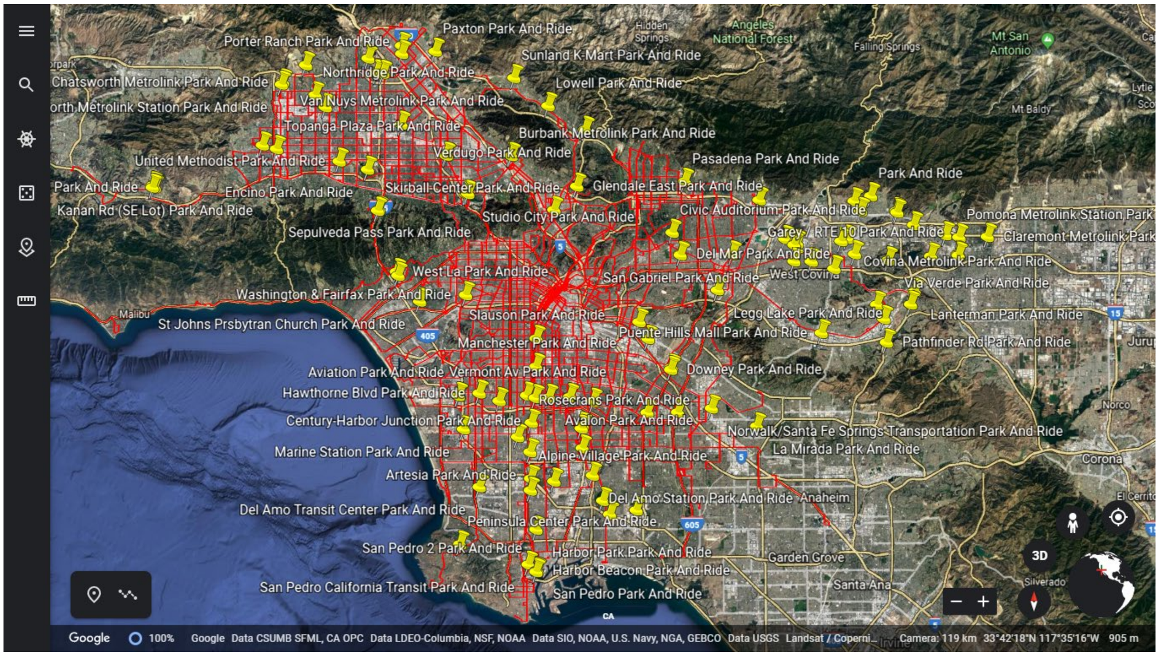
A deep and independent analytical review of the utilization of King County PnR facilities published in 2019[52] found high, growing demand for PnR and important support from the bus-riding public, especially "young adults, senior citizens, and low-income people."

4.3 LA Metro Transit Park and Ride

In 2020, the on-line Los Angeles County Metro FAQ on parking reports, "Metro operates 89 parking facilities serving 56 transit stations and totaling more than 25,000 parking spaces throughout Los Angeles County. Metro's parking facilities accommodate more than four million cars every year providing an important first/last mile connection for Metro patrons."[53] The authors of this report found 179 PnRs that could be geocoded in the LA Metro service area, with some operated privately or by other government agencies. Inconsistencies in counting and reporting are legion across all three case study sites.

The LA Metro web lists 161 separate park-and-ride facilities, with many provided by other jurisdictions or privately. These are shown on the map in Figure 10. Historically they have been free of charge, and many still are as of 2020, but starting in 2017, general access to some of the lots experiencing 90 percent or higher occupancy required a fee of $3 per day. Earlier, in 2003, a preferred parking program began in which transit customers could pay a fee for a guaranteed spot to be held open until 11 AM on weekdays.[54]

Figure 10. Map of LA County PnR Facilities



Source: Google Earth[55]

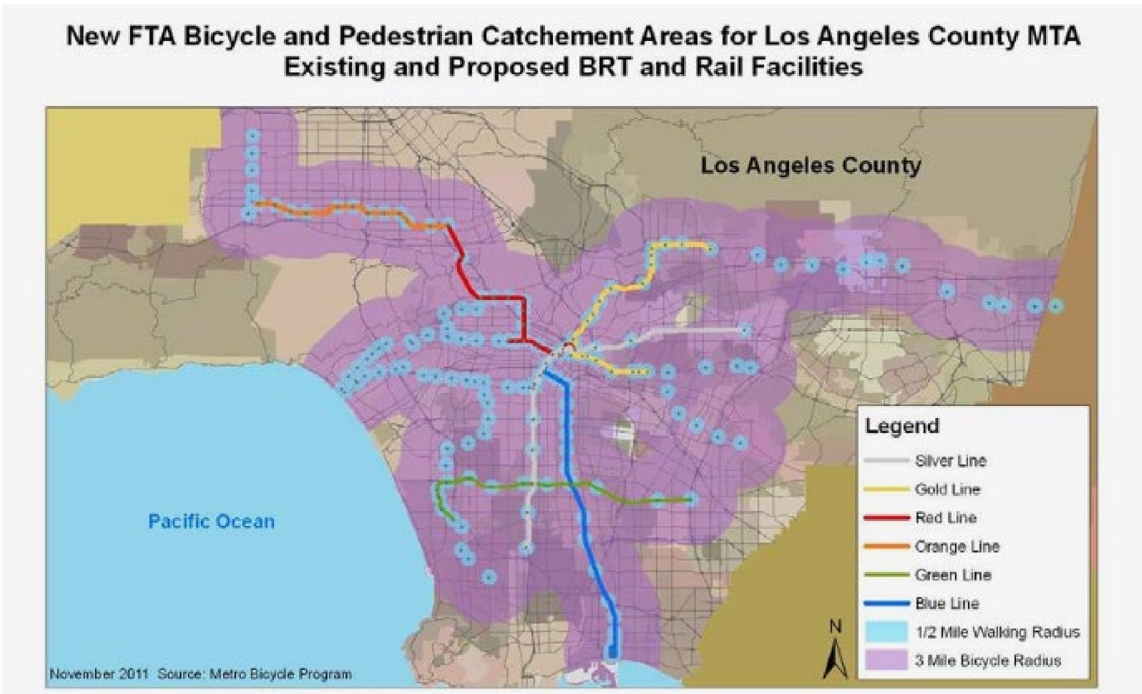
Metro, in an FAQ for its customers,[56] claims it "extensively studied factors like parking supply and demand, commuting costs, operating and maintenance costs for parking facilities, and rates of nearby parking to develop Metro's parking fees." The agency notes that the three dollar per day rate is a bargain compared to the cost of parking in downtown Los Angeles plus expenditures for gasoline, car maintenance, and insurance, not to mention all the time driving in traffic.

A Metro staff briefing in November 2017 explained that the goal of transit-supportive parking is to provide parking for transit customers with paid parking to "control parking demand." The agency's key objectives include "ensuring that there are no negative impacts to ridership, that there is no significant increase in overall commute time, and that there is increased availability of parking spaces for transit users." Metro reported 13% of transit customers use park-and-ride, 38% are dropped off at stations, 37% arrive by bus, and 22% walk to stations. About 63% of PnR patrons live at least two miles from their preferred station, so 37% live within two miles. Sixty-nine percent report a household income of at least $50,000.[57]

The same briefing noted Metro's interest in maintaining a "Partnership with Surrounding Communities." This partnership includes notifying transit patrons of parking restrictions in the area surrounding the transit station, seeking ways to share transit parking with surrounding community users in non-peak transit hours, and promoting alternative modes of transportation to access transit stations.[58]

With regard to alternative, non-automobile access, the 2011 LA Metro System Wide On-Board Origin-Destination Study noted that half of all transit riders are transit-dependent, belonging to households that do not own any vehicles.[59] Active transportation modes such as foot, bicycle, or wheelchair are the dominant access modes for 85% of system access/egress instances at rail/BRT stations and over 95% of total system access instances. Half of users have access to a car; of whom about 20% choose to use PnR. However, half of those parking are close enough to walk or ride a bicycle, based strictly on distance, without estimating bicycle ownership or ability to walk. Metro has calculated that bicycle catchment distances equaling a three-mile radius around rail and BRT stations provide very extensive coverage of the service territory, as shown in Figure 11.

Figure 11. Bicycle Access Catchment Areas for LA Metro Rail and BRT Stations

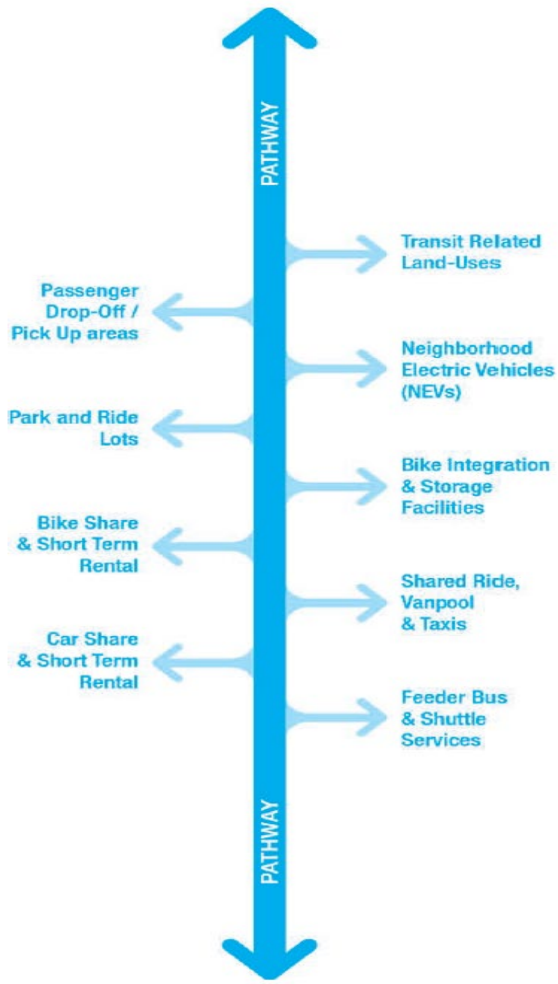


Source: LA Metro Transit[60]

LA Metro and the Southern California Association of Governments developed a First Last Mile Strategic Plan in 2014. A key finding from the research is the low usage of station parking compared to transit ridership overall: "parking facilities support only 6.2% of Metro Rail users, and only 3.8% of Metro BRT users. Of this relatively small user group half live close enough to walk or bike to stations."[61]

LA Metro is taking steps to discourage car parking for customers whose trips originate within a short distance of system access. Figure 12 is a creative graphic from the agency showing the various non-driving means customers use to reach transit that the agency is taking steps to encourage.

Figure 12. Pathway Concept, 2014 First Last Mile Strategy



Source: LA Metro[62]

LA Metro overall comes across as ambivalent on PnR. There is a project list from 2015 that includes "Expand the park & ride network in Los Angeles County to meet the current and latent demand of discretionary transit riders to use regional public transportation services" as a project.[63] On the other hand, a major consulting effort in 2018 to determine ways to boost ridership across the region came out with a final report, *Ridership Growth Action Plan* that did not mention park-and-ride at all.[64]

More recently, an on-record description of LA Metro's Parking Management Program in May 2020 makes clear that PnR is important to the agency, as shown in Figure 13.

Figure 13. Presentation Slide from LA Metro Staff

Source: May 2020 Transit Advisory Committee Meeting[65]

V. TOD Status for the Three Agencies

This section reviews the status of TOD within each of the three agencies we examine in the case studies. The policy stance and details of policy implementation to achieve TOD implementation are considered.

LA Metro has 18 intentional, policy-motivated TOD projects in existence; KC Metro has 10; VTA has 35.[66] All three agencies are intending and planning for more.[67]

Some existing residential projects go back three decades, as shown in Table 3.

Table 3. Early TOD Projects in San José and Los Angeles

Rail Line	Name of Project (Station)	Year Opened	Housing Units
VTA LRT	River Oaks (River Oaks)	1991	1,214
VTA LRT	Winfield Hill (Almaden)	1994	228
VTA LRT	Homes at Almaden Lake (Almaden)	1994	84
VTA LRT	Apartments at Almaden Lake (Almaden)	1994	144
VTA LRT	Fior Di Monte (Oakridge)	1995	250
LA Blue Line	Bellamar (5th & Pacific)	1990	160
LA Blue Line	Pacific Court (Long Beach Transit Mall)	1992	142
LA Blue Line	Grand Central Market (4th & Hill)	1995	120

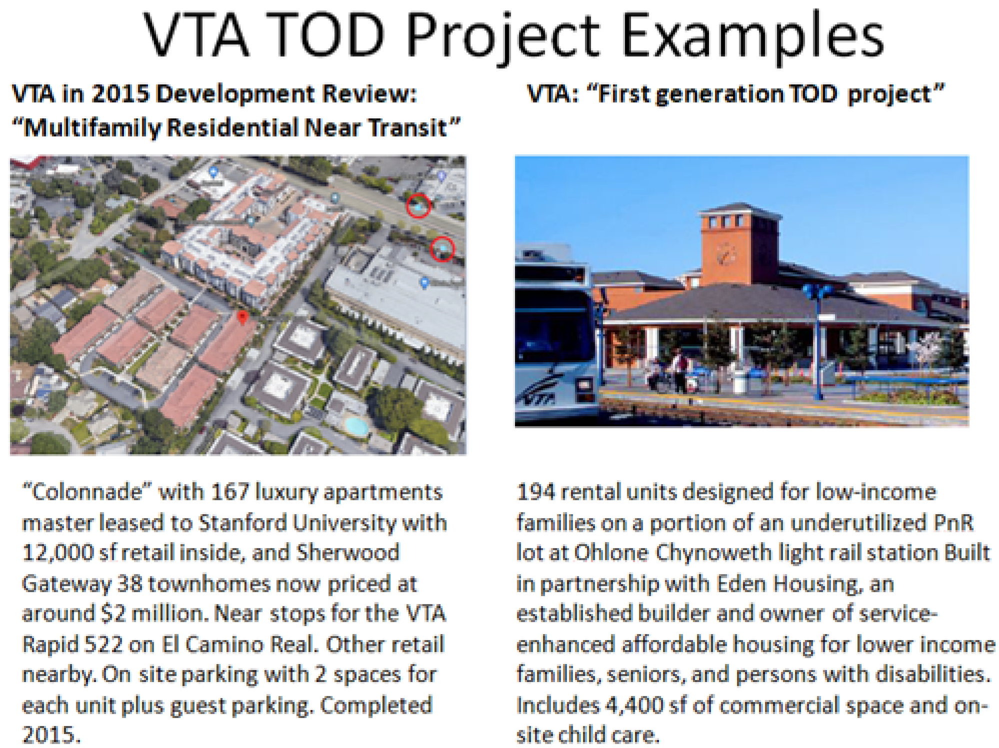
Source: Research by authors compiled from several sources[68]

5.1 TOD in Santa Clara County

As the Congestion Management Agency (CMA) for Santa Clara County, VTA reviews and comments on all development plans in the county on how well they integrate land use and multimodal transportation. The local jurisdiction decides whether or not incorporate VTA's input in the final plan. Historically, this was the main VTA involvement in TOD.

TOD residential development has become more deliberate since the turn of the 21st century. Figure 14 shows examples of two recent transit oriented developments located within the City of San José.

Figure 14. Two VTA TOD Project Examples[69]



Source: VTA

As mentioned earlier, VTA has a joint development strategy for underutilized PnR lots that (as of this writing) is focused on developing TOD on 25 properties the agency owns throughout Santa Clara County—mostly surface PnR lots that are underutilized compared to their capacity. VTA seeks to negotiate partnerships and long-term ground leases with private-sector developers.

The goals of the joint development strategy are to:

> *Increase ridership overall and throughout non-commute periods.*
>
> *Leverage TOD projects as catalysts to create equitable and complete Transit-Oriented Communities around transit stations, including affordable housing production.*
>
> *Generate revenues to sustain transit capital investment and operations.*[70]

At least twenty percent of the housing is required to meet a definition of "affordable" in the context of the Santa Clara County market. In 2018, the status of existing parking at PnR sites to be redeveloped required that development must be "consistent with local jurisdiction plans and zoning, as well as preservation of parking used by VTA transit riders."[71] However, by the fall of 2019, the "preservation of parking" was replaced by more flexible language stating that

> *Each individual site will be analyzed through the VTA Parking Model (created by industry expert Nelson\Nygaard) which reviews ridership gains created by TOD, weighs parking supply and demand, measures potential impacts of removal of parking and provision of paid parking,*

and calculates farebox and revenue benefits of TOD. The model results in net new ridership and annual revenues data to assist VTA staff in making informed recommendations to the VTA Board for station area parking strategies. The VTA Parking Model establishes optimal site-specific parking recommendations that:

a. Consider the potential increase in ridership and revenue benefits associated with TOD;

b. Compare the projected increase in land value and fare revenue versus the capital and operating costs of future parking alternatives;

c. Quantify the opportunity to accommodate new riders arriving by shuttle, taxi, transportation network company (ride-hailing) services, and other first/last mile solutions; and

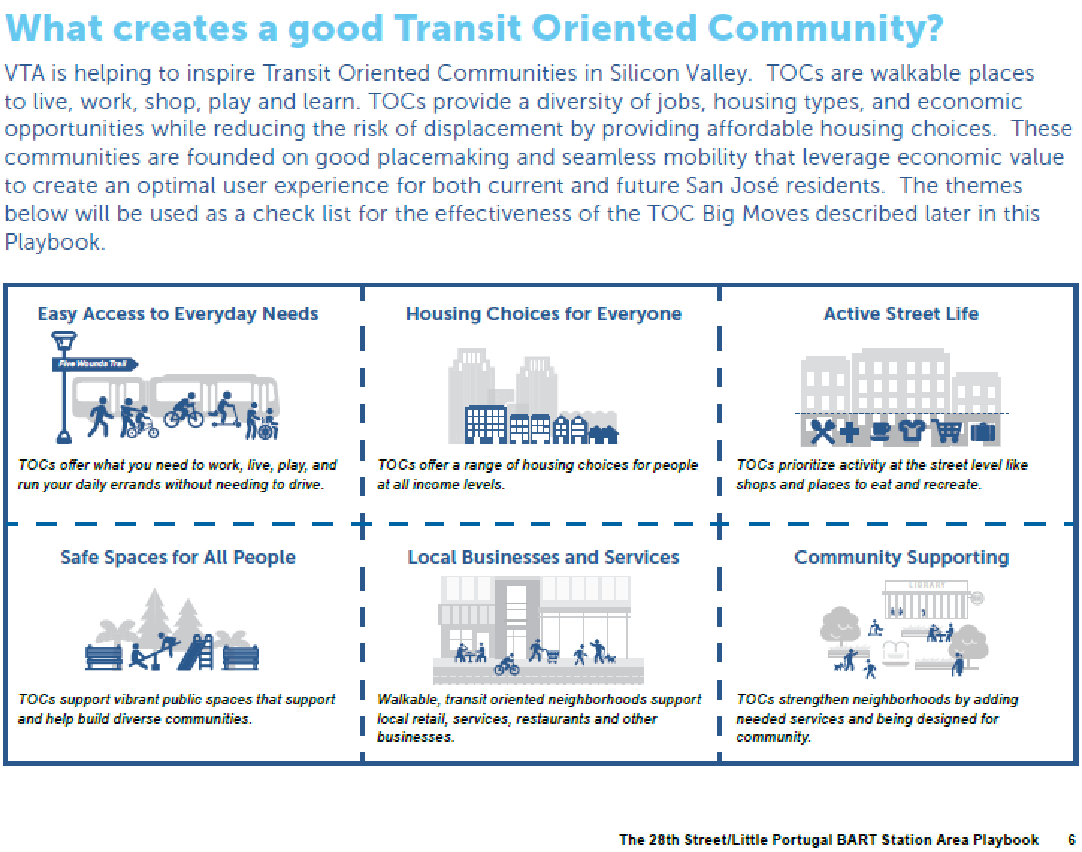
d. Measure collective net increases to ridership.[72]

While the VTA Parking Model is not otherwise visible in public documents, from the description here, it appears similar to one shown later in Figure 20.

VTA in 2019 began placing a deliberate focus on "transit oriented communities," facilities with a wider geographic scope of interest around transit stations, from a quarter-mile radius out to a mile or more. This approach is being taken in the Phase 2 extension of the BART heavy rail line further into the City of San José and VTA service territory with four new stations: two with PnR, two without. This future extension, now in design, follows the Phase 1 extension just opened on June 13, 2020, at two stations with large PnR structures having capacities of over 1,000 vehicles each.[73] None of this PnR in support of the BART network is measured in the research of this report.

The scope of TOC as of July 2020 is illustrated in Figure 15, a VTA diagram published in a report describing detailed intentions to shape land use around a forthcoming Phase 2 BART station in the City of San José.

Figure 15. VTA Description of Transit Oriented Community


What creates a good Transit Oriented Community?

VTA is helping to inspire Transit Oriented Communities in Silicon Valley. TOCs are walkable places to live, work, shop, play and learn. TOCs provide a diversity of jobs, housing types, and economic opportunities while reducing the risk of displacement by providing affordable housing choices. These communities are founded on good placemaking and seamless mobility that leverage economic value to create an optimal user experience for both current and future San José residents. The themes below will be used as a check list for the effectiveness of the TOC Big Moves described later in this Playbook.

Easy Access to Everyday Needs

TOCs offer what you need to work, live, play, and run your daily errands without needing to drive.

Housing Choices for Everyone

TOCs offer a range of housing choices for people at all income levels.

Active Street Life

TOCs prioritize activity at the street level like shops and places to eat and recreate.

Safe Spaces for All People

TOCs support vibrant public spaces that support and help build diverse communities.

Local Businesses and Services

Walkable, transit oriented neighborhoods support local retail, services, restaurants and other businesses.

Community Supporting

TOCs strengthen neighborhoods by adding needed services and being designed for community.

The 28th Street/Little Portugal BART Station Area Playbook 6

Source: VTA[74]

5.2 TOD in King County

The Puget Sound Regional Council, the metropolitan planning organization that encompasses King County and three other counties along Puget Sound, has built its long-range regional transportation plan around a TOD concept labeled Growing Transit Communities.[75] This fundamentally means putting as much residential development as possible within walking, cycling, and scooter range of high-capacity transit stations, which in the Seattle area means light rail, commuter rail, high-frequency bus service, or peak period express bus service.

King County Metro has engaged in combining PnR with multi-unit housing on the same property for over a decade, as illustrated by the four projects in Figure 16, as well as a pilot TOD project being set up by Washington State Department of Transportation in Kirkland, Washington, described later in Chapter X. In all cases where PnR was in place on the property, there was no reduction in the amount of PnR parking provided.

Figure 16. Four King County Metro TOD Examples

Source: King County Metro[76]

The evolving King County Metro station development strategy can be summarized in 2020 as follows.[77]

- Focus on Transit Oriented Community (TOC) places designed to motivate people to drive less and access transit more.
- TOC goes beyond TOD with strategies that extend beyond developments at stations.
- Where Metro provides transit service but does not own property, the agency still wants to promote and facilitate transit supportive land use.
- The State Constitution does not permit government agencies like Metro to discount the rental or sale price of land, even if the goal is to achieve affordable housing.
- The intent of TOCs is to promote equity and sustainable living by:
    - offering a mix of uses that supports transit ridership by all income levels,
    - paying special attention to the impacts of gentrification and associated displacement,
    - influencing appropriate building densities, parking policies, and urban design that creates and supports accessible neighborhoods connected by multimodal transit,
    - serving vulnerable users and protecting their safety through design, and

- ensuring investments provide equitable benefits that serve local, disadvantaged, and underrepresented communities.

- On County property near transit boarding points, work with jurisdictions to maximize development capacity and reduce parking requirements.
- On private property in nearby TOCs, Metro advocates for low parking ratios supported by high-frequency transit service and multimodal access.
- Support present park-and-ride customers in alignment with preferences of local elected officials, but also offer first/last mile multimodal services that compensate for reduced parking.
- Reduce GHG emissions by lowering overall parking supply and favoring non-motorized access.
- Set the goal that 40 percent of Metro properties include affordable housing.

5.3 TOD in Los Angeles

LA Metro has a joint development program that focuses on turning agency property into transit oriented development. As stated in an LA Metro fact sheet, "Joint Development (JD) is the real estate development program through which Metro collaborates with qualified developers to build transit-oriented developments on Metro-owned properties."[78]

Examples of early results from this program are illustrated in Figure 17.

Figure 17. Four LA Metro TOD Examples

Source: LA Metro[79]

A summary description from LA Metro of its station development strategy includes these transit oriented community policy goals:

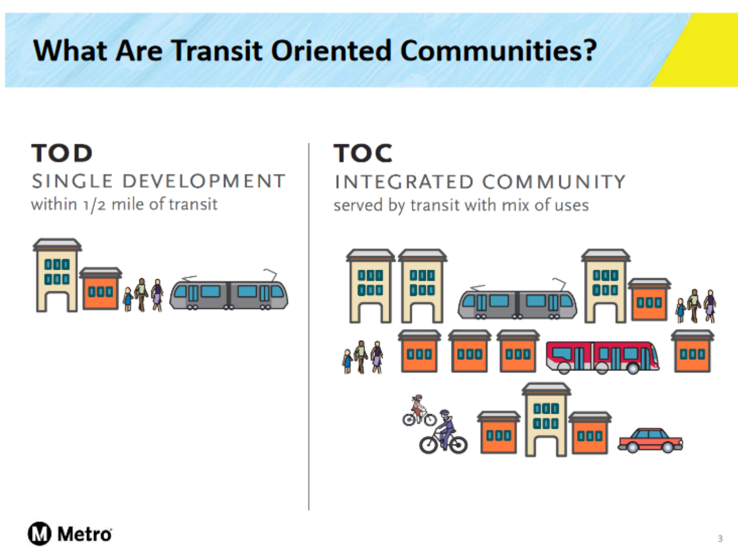
- *Increase transportation ridership and choice;*
- *Stabilize and enhance communities surrounding transit;*
- *Engage organizations, jurisdictions and the public;*
- *Distribute transit benefits to all; and*
- *Capture value created by transit.*[80]

LA Metro's Joint Development Policy sets a portfolio-wide goal of developing 35% of its properties for affordable housing. Developers seeking to deliver affordable housing can qualify to pay a reduced price for the land. The discount is capped and links the level of discount to the performance in creating affordable housing. Up to a 35% discount is possible based on performance toward a goal expressed as a percentage of affordable units.

Like the King County and Santa Clara County transit agencies, LA County Metro is moving toward a greater focus on "transit oriented communities" instead of mere "transit oriented development." Metro Transit Oriented Communities is defined as a "Land use planning and community development program that seeks to maximize access to transportation as a key organizing principle and promote equity and sustainable living by offering a mix of uses close to transit to support households at all income levels, as well as building densities, parking policies, urban design elements, and first/last mile facilities that support ridership and reduce auto dependency."[81]

Figure 18 illustrates the wider geographic scope of TOC compared to TOD.

Figure 18. LA Metro Illustration of Transit Oriented Communities Compared to TOD



Source: LA County Metro[82]

Metro's process of converting the transit hub in North Hollywood into a TOD/TOC project illustrates the agency's declining interest in supporting PnR in zones targeted for density. As a terminus node for the Orange Line BRT heading west and the Red Line subway heading east, the North Hollywood site in 2020 provides transit customers with a 1,000 car surface park-and-ride, and is well used. The redevelopment is planned for 1,500 housing units, plus office and retail space and two acres of public open space.[83] The original specifications for the development in 2015 were: "Metro requires that existing parking lot on Parcel 1 be replaced with 2,000 transit-dedicated parking spaces available to Metro transit customers during peak travel hours. Joint use of transit parking during non-peak hours will be considered."[84] After choosing Trammel-Crowe as developer and negotiating a plan, Metro announced that transit parking was to be reduced down to between 800 and 1,000 spaces.[85] Within another few years, the official planning study produced by the developer in concert with the City of Los Angeles issued in June 2020 puts the transit parking at 750 spaces, which could potentially be nearby and off site.[86]

In summary, an assessment across all three of the case study agencies suggests that PnR is in place and being maintained, but the main agency-wide focus is the expanded version of TOD known as transit oriented communities, especially for transit centers that are positioned geographically well inside the boundaries of the transit network. TODs, having a quarter-mile radius of interest around transit stations, are being discarded in favor of transit oriented communities (TOCs), which have a half- to one-mile radius of developmental interest that provides an expanded focus on micromobility options like bicycles and scooters.

This report turns now to an analysis of how PnR parking influences ridership in San José, Seattle, and Los Angeles.

VI. Econometric Analysis of Ridership Influences

6.1 Model Motivation

Boardings at a stop during the morning commute depend on demographic, economic, and transit-systemic factors. The relevant business, economic, and demographic variables are measured within the catchment area (which is taken to be walking distance) of the stop.[87] The demographic factors include the number of housing units within walking distance of the stop. The business and economic variables include the number of jobs in the catchment area and the median household income in the catchment area. The main transit-systemic factors examined are the proximity of the stop to a park-and-ride lot, the distance of a park-and-ride lot from the central business district (identified as city hall[88]), and whether the stop is associated with a light rail line.[89]

6.2 Data

Transit Agency GIS and Related Files

The authors obtained GIS files of lines and stops (including, where relevant, light rail lines and stops) from each transit agency (King County Metro [KCM], Santa Clara Valley Transportation Authority [VTA], and Los Angeles Metropolitan Transportation Authority [LA Metro]). Additionally, the authors obtained data on the location and capacity of park-and-ride lots in each agency's service area (and, in some cases, beyond the service area). The park-and-ride lot locations and attributes such as the number of parking spaces were obtained from a variety of sources (in some cases from the transit agency, in some cases from Caltrans, and in some cases from other sources, such as regional planning or transportation agencies). Appendix A lists the specific sources for each transit agency-related GIS layer.

Transit Agency Ridership Data

The authors obtained ridership data (in various formats) from each transit agency. Specifically, stop-level data were obtained on boardings and alightings at a stop, typically aggregated either monthly, quarterly, or annually for several recent years, and identified by weekday service and commute times. Some data, such as ridership data for VTA, were disaggregated by stop daily and by time of day. Ridership data for 2017 were employed in the analysis.

Census Data

For the service area of each transit agency, the authors obtained demographic and economic statistics (such as median household income and number of housing units) from the American Community Survey (ACS) at the census tract level, as well as business statistics (such as the number of jobs) at the ZIP Code Tabulation Area (ZCTA) level from the from Census ZIP Code Business Patterns dataset.[90] (The ZCTA level was chosen for the business statistics because this is the lowest aggregation level at which these data are available.) Additionally, Census mapping data were used to identify the boundaries of cities and related governmental entities.

6.3 Methodology

Broadly speaking, the same methodology was followed for each transit agency.

First, the ridership data related to the morning weekday commute boardings were associated with stops in the system.

Then, the catchment areas of those stops were identified. The catchment areas selected for this study are quarter-mile buffers around each stop. In planning practice, a quarter-mile is taken as acceptable walking distance to reach a bus stop, and a half-mile is used for rail stations and buses with the route designated for faster service with dedicated lanes and signal pre-emption.[91] Since most of the stops for this study are associated with ordinary bus service, a quarter-mile buffer was deemed appropriate.

Then the economic and demographic statistics that applied to a catchment area were estimated based upon the proportion of the quarter-mile buffer around a stop that overlapped a Census geographic area (such as a census tract or ZCTA). The methodology differed slightly depending on whether the variable being estimated was measured in absolute terms or as an average that applied to the entire Census geographic area. If the variable was measured as an average that applied to the entire Census geographic area (such as median household income), the average variable was estimated as the weighted mean of each Census geographic area the catchment area intersected. If the variable was measured in absolute terms, the amount that applied to the catchment area was estimated as the proportion that the catchment area was of the Census geographic area. Formulae and a numerical example for both types of computations are shown below. For variables measured as averages, one set of weights is employed; for variables measured in absolute terms, a different set of weights is employed.

The first set of weights comprises the fraction of the catchment area that falls in each Census geographic area. These weights are denoted by w_j and defined by

$$w_j = \frac{A_j}{Area_{catchment}^{stop}}$$

for j=1, 2,…,k where k is the number of Census geographic areas that the buffer intersects. The sum of these weights over all Census geographic areas the catchment area intersects is 1, i.e.,

$$\sum_{j=1}^{k} w_j = 1.$$

The second set of weights is the fraction that the catchment area intersecting a particular Census geographic area is of that Census geographic area. These weights are denoted by f_j, and they are defined by

$$f_j = \frac{A_j}{Area_j^{CG}}$$

for j=1,2,…,k where k is the number of Census geographic areas that the catchment area intersects. These weights are positive but do not sum to a constant.

For variables measured as averages, the estimated variable in the catchment area is given by expression (1) below (involving only the w_j weights). For variables measured in absolute terms, the estimated variable in the catchment area is given by expression (2) below (involving only the f_j weights). In these expressions, V_j is the value of the average variable (e.g., median household income) in Census geography j, and N_j is the absolute number (e.g., of jobs, workers, or housing units) in Census geographic area j.

$$(1)\ V_{stop}^{estimate} = \sum_{j=1}^{k} w_j V_j$$

$$(2)\ N_{stop}^{estimate} = \sum_{j=1}^{k} f_j N_j$$

Figure 19 illustrates the estimation method with Table 4 listing all the numbers in the figure. The figure shows three census geographic areas, CG_1, CG_2, and CG_3. $Area_j^{CG}$ indicating the area of CG_j for j=1,2,3. The red dot indicates a stop (located within CG_2), and the green circle shows the boundary of the quarter-mile buffer around the stop. The quarter-mile buffer intersects each of the Census geographic areas. The area of overlap between each Census geographic areas and the quarter-mile buffer is A_j (for j=1,2,3). The sum of the areas is $Area_{catchment}^{stop} = \sum_{j=1}^{3} A_j = \pi r^2 \approx$ 0.2 miles (the approximate area of a circle with a radius of 0.25 miles).

Suppose V_j is the number of some variable measured as an average (such as median household income) in Census geographic area j. An estimate of the average of this variable in the catchment area of the stop is:

$$V_{stop}^{estimate} = \left\{\left(\frac{A_1}{Area_{catchment}^{stop}}\right)V_1\right\} + \left\{\left(\frac{A_2}{Area_{catchment}^{stop}}\right)V_2\right\} + \left\{\left(\frac{A_3}{Area_{catchment}^{stop}}\right)V_3\right\}.$$

This is just

$$V_{stop}^{estimate} = \{w_1 V_1\} + \{w_2 V_2\} + \{w_3 V_3\}.$$

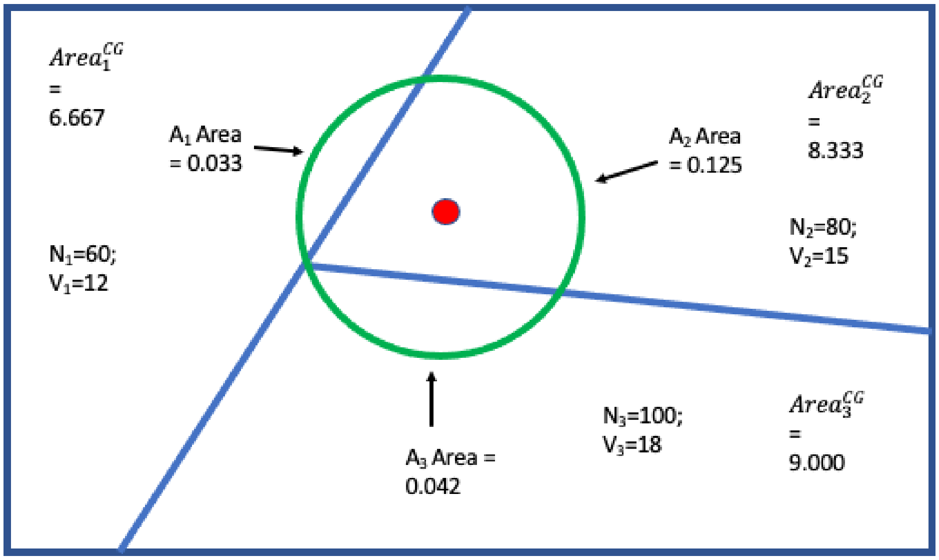
Suppose N_j is the number of some variable measured in absolute terms (such as jobs, labor force, or housing units) in Census geography j. An estimate of the number of this variable in the catchment area of the stop is:

$$N_{stop}^{estimate} = \left\{\left(\frac{A_1}{Area_1^{CG}}\right)N_1\right\} + \left\{\left(\frac{A_2}{Area_2^{CG}}\right)N_2\right\} + \left\{\left(\frac{A_3}{Area_3^{CG}}\right)N_3\right\}.$$

This is just

$$N_{stop}^{estimate} = \{f_1 N_1\} + \{f_2 N_2\} + \{f_3 N_3\}.$$

Figure 19. Allocation of Land Area Around a Transit Stop



Source: J.M. Pogodzinski

Table 4. Numerical Example for Allocation of Land Area Around a Transit Stop

A1	0.033	**w1**	0.16666667
A2	0.125	**w2**	0.625
A3	0.042	**w3**	0.20833333
SUM	0.200	**SUM**	1
CG1	6.667	**f1**	0.005
CG2	8.333	**f2**	0.015
CG3	9.000	**f3**	0.00462963
SUM	24.000	**SUM**	0.02462963
N1	60		
N2	80		
N3	100		
V1	12		
V2	15		
V3	18		
N_{est}	0.896		
V_{est}	15.125		

Source: J.M. Pogodzinski

6.4 Variables in the Analysis

The variables in the analysis are listed in Table 5 along with their expected sign and significance in the regressions reported below. The descriptive statistics of the entire sample for each transit agency are given in Appendix B.

Table 5. Explanation of Variables

Variable Name	Meaning	Expected Sign in Regression	Expected Significance in Regression
AM_Boardings_Int	Morning weekday boardings at a stop rounded to the nearest integer value	N/A	N/A
EMP_stop	Estimated employment in the catchment area around a stop	?	?
HU_stop	Estimated housing units in the catchment area around a stop	+	strong
MedHHInc	Estimated median household income in the catchment area around a stop	-	weak
LRDummy	A dummy variable which equals 1 if the stop is a light rail stop	+	strong
QMiDummy	A dummy variable which equals 1 if the stop is within a quarter-mile of a park-and-ride lot	N/A	N/A
Dist_PnR	Distance to the nearest PnR facility	-	strong
Size_PnR	Number of spaces in the nearest PnR facility	+	strong
PnR_small	A dummy variable indicating this is a small park-and-ride lot for the reference system (up to 25th percentile)	+	strong
PnR_medium	A dummy variable indicating this is a medium sized park-and-ride lot for the reference system (between the 25th and 75th percentile)	+	strong
PnR_large	A dummy variable indicating this is a large park-and-ride lot for the reference system (above the 75th percentile)	+	strong
inter_QMiDummy_ DIST_cityhall	Quarter-mile dummy interacted with distance of a park-and-ride lot from City Hall (as a measure of distance to the Central Business District)	+	weak

The Dependent Variable: Morning Weekday Boardings

The approach in this research is *cross-sectional* (covering a single time period, e.g., a month, a quarter, or a year) and *stop-level* (namely, the variables are observed for specific stops or the catchment areas around specific stops). The dependent variable is the morning boardings at a stop on a weekday. The boardings are monthly, quarterly, or annual averages and are rounded to the nearest integer because the negative binomial regression method requires integers (and, fundamentally, boardings are integers). The dependent variable, *AM_Boardings_Int*, is observed at the stop level.

Independent Variables: Economic, Demographic, and Business Variables

The following demographic, economic, and business variables measured are employed in absolute amounts in the analysis:

> *EMP_stop*: an estimate of the total number of jobs in the catchment area around a stop.
>
> *HU_stop*: an estimate of the total number of housing units in the catchment area around a stop.

The catchment areas are quarter-mile buffers around each stop. To estimate the number of jobs, the number of housing units, or the number of workers in the catchment area around a stop, the authors determined (using the Tabulate Intersection tool in ArcGIS) the intersection of the quarter-mile buffer with the Census geographic areas at which the economic, demographic, or business variable was observed. Data about housing units in the catchment area come from census-tract-level ACS data. For employment, the authors relied on Census ZIP Code Business Patterns data. The ZCTA is the lowest level of aggregation at which jobs data are observed.

If the quarter-mile buffer around a stop fell within a single census tract or ZCTA, the proportion of the Census tract or ZCTA within the quarter-mile buffer was determined, as was the proportion of jobs, or housing units, or labor force that corresponded. If the quarter-mile buffer around a stop fell within several census tracts or ZCTAs, the proportion of each census tract or ZCTA within each buffer was used, and the fraction of the buffer contained in each census tract or ZCTA computed as a weighted average of the proportional amounts of jobs, or housing units, or labor force that correspond to that fraction.

In addition, *MedHHInc* (the median household income in the catchment area around a stop), measured as an average for the census geographic area is used in the analysis. Data about median household income are census tract-level ACS data.

Independent Variables: Variables Related to Park-and-Ride

Three characteristics of park-and-ride lots are incorporated into the analysis:

- Proximity of a park-and-ride facility to a stop;
- The capacity (number of spaces) in the park-and-ride facility; and
- The distance of the park-and-ride facility to the central business district.

The first two characteristics are incorporated by constructing several variables related to the size of the nearest park-and-ride facility and its proximity to a stop. The third characteristic comes in through the construction of another variable. These park-and-ride-related variables are explained below.

In order to investigate influence on ridership at a stop of proximity to a park-and-ride facility in a way that promotes comparison to housing, employment, and income effects, three kinds of variables were constructed to capture the size and proximity of a park-and-ride facility to a stop.

First, a variable is constructed for each stop that is equal to the size of the nearest park-and-ride facility if there is a park-and-ride facility within a quarter-mile of the stop and zero otherwise. For this variable, most values are zero because most stops are not within a quarter-mile of any park-and-ride facility.

Second, dummy variables are constructed corresponding to proximity of a stop to a park-and-ride facility within a specific capacity (number of spaces) range. Because the size distribution of park-and-ride facilities across the transit agencies differs markedly, separate park-and-ride size-related dummies are created for each agency. A park-and-ride facility is referred to as "small" if it is between the 0^{th} and 25^{th} percentile of park-and-ride facilities for the transit agency service area. "Medium"-sized facilities were between the 25^{th} and 75^{th} percentile. "Large" facilities were those above the 75^{th} percentile. Thus, in reporting the econometric results, *PnR_small*, *PnR_medium*, and *PnR_large* correspond to different size ranges depending on the transit agency. The *PnR_small* dummy variable is 1 if there is a small park-and-ride facility within a quarter-mile of a stop, 0 otherwise. Similarly, the *PnR_medium* dummy variable is 1 if there is a medium-sized park-and-ride facility within a quarter-mile of a stop, 0 otherwise. The *PnR_large* dummy variable is 1 if there is a large park-and-ride facility within a quarter-mile of a stop, 0 otherwise. Again, for these variables, most stops are associated with a zero value because most stops are not within a quarter-mile of any park-and-ride facility.

Third, a distance-decay specification (related to a gravity model) is used. For each stop, a variable *Size_PnR* represents the size of the nearest PnR facility and *Dist_PnR* represents distance to the nearest PnR facility. In this specification, no stop has a zero value for either variable.

There is also evidence in the literature[92] that suburban park-and-ride facilities impact ridership more than park-and-ride facilities closer to the city center. A constructed variable measures the distance of a park-and-ride facility from City Hall (treated as the location of the Central Business District) if the stop is within a quarter-mile of a park-and-ride facility. The variable is 0 if the stop is not within a quarter-mile of any park-and-ride facility and is equal to the straight-line distance between City Hall and the associated park-and-ride facility if the stop is within a quarter-mile of that park-and-ride facility.

Independent Variables: Transit-System-Specific Variable

The variable *LightRailDummy* appears in two of the three transit system cases—the ones for which data are on hand for this variable. *LightRailDummy* is one if the stop is a light rail stop, zero otherwise.

6.5 The Econometric Model

Three alternative econometric specifications are employed, differing by the PnR variables employed. These alternative specifications demonstrate the robustness of the main conclusions about the relative impact of park-and-ride variables and housing density variables.

The first specification is:

$$\begin{aligned} AMBoardings &= \beta_0 + \beta_{MedHHInc} MedHHInc + \beta_{Emp} Employment_{stop} \\ &+ \beta_{HU} HousingUnits_{stop} + \beta_{SPACES} SPACES * QMiDummy \\ &+ \beta_{QMi-Dist\_CityHall} QMiDummy * Dist_{CityHall} + \beta_{LR} LightRailDummy + \epsilon \end{aligned}$$

This specification employs absolute values of business, economic, and demographic variables (income, jobs, and housing units) to measure the impact of the demographic, economic, and business variables, the interaction between quarter-mile dummy variables and size of the nearest PnR facility to measure park-and-ride effect, the interaction between the quarter-mile dummy and the distance of the PnR facility from city hall to measure the "suburban" effect, and a dummy variable to measure the light rail effect.

The second specification is:

$$\begin{aligned} AMBoardings &= \beta_0 + \beta_{MedHHInc} MedHHInc + \beta_{Emp} Employment_{stop} \\ &+ \beta_{SPACES-small} SPACES_{small} * QMiDummy + \beta_{SPACES-medium} SPACES_{medium} \\ &* QMiDummy + \beta_{SPACES-large} SPACES_{large} * QMiDummy \\ &+ \beta_{QMi-Dist\_CityHall} QMiDummy * Dist_{CityHall} + \beta_{LR} LightRailDummy + \epsilon \end{aligned}$$

This specification employs absolute values of business, economic, and demographic variables (income, jobs, and housing units) to measure the impact of the demographic, economic, and business variables, the interaction between quarter-mile dummy variables and size categories to measure park-and-ride effect, the interaction between the quarter-mile dummy and the distance of the PnR facility from city hall to measure the "suburban" effect, and a dummy variable to measure the light rail effect.

The third specification is:

$$
\begin{aligned}
AMBoardings &\\
= \beta_0 &+ \beta_{MedHHInc}MedHHInc + \beta_{Emp}Employment_{stop} \\
&+ \beta_{HU}HousingUnits_{stop} + \beta_{SPACES}SPACES \quad + \beta_{DIST\_PnR}DIST_{PnR} \\
&+ \beta_{QMi-Dist\_CityHall}QMiDummy * Dist_{CityHall} + \beta_{LR}LightRailDummy + \epsilon
\end{aligned}
$$

This specification employs absolute values of business, economic, and demographic variables (income, jobs, and housing units) to measure the impact of the demographic, economic, and business variables, the size of the nearest PnR facility and the distance to the nearest PnR facility to measure park-and-ride effect, the interaction between the quarter-mile dummy and the distance of the PnR facility from city hall to measure the "suburban" effect, and a dummy variable to measure the light rail effect.

Negative binomial regression is used in this analysis because the outcome variable is a count variable which exhibits overdispersion. Negative binomial regression is a generalization of Poisson regression, and Poisson regression coefficients are computed in the course of computing negative binomial regression. The Poisson regression technique is particularly robust.[93]

6.6 Descriptive Statistics: Overview

Ahead of presenting the estimation results, this section briefly discusses the descriptive statistics of the three transit agencies in the analysis.

All stops in the King County Metro and VTA systems are included for which data about ridership could be matched to the stop level. King County Metro has the largest number of stops of any of the transit agencies in the analysis (6,525 observations for all variables). For VTA, data on 3,034 stops were obtained. Although LA Metro has more than 14,000 stops, the only examined stops were ones that served the 400 to 999 bus routes and rail lines. Hence, for LA Metro, there are 2,421 observations. Descriptive statistics for all transit agencies are presented in Appendix B.

Median household income around stops is highest for VTA (about $108,000) and lowest for LA Metro (about $57,500), with King County Metro at about $92,500. These figures reflect the differences in overall average incomes in the three Metropolitan Statistical Areas.

The number of housing units and labor force volume in the catchment area of a stop differ significantly across the three transit agencies. Both are highest for LA Metro which is consistent with the overall pattern of density across the metropolitan areas.[94]

6.7 The Econometric Results

Three specifications of the econometric model of ridership were estimated. In each specification, the dependent variable is weekday morning boardings. The econometric results for all three transit agencies for each of the three specifications tell similar stories and are generally in line with expectations. The specifications differ by how park-and-ride is represented. In the first model, the effects of park-and-ride are gauged by a single dummy variable that examines whether there is a park-and-ride lot within a quarter-mile of a stop. In the second model, the effects of park-and-ride are gauged by defining three categorical variables to examine the effects of the size as well as the proximity of a park-and-ride lot. In the third model, we use a distance-decay formulation which treats both size and proximity as continuous variables.

Negative binomial regressions, a generalization of Poisson regressions, are estimated for each agency. The Poisson regression is estimated in the course of estimating the negative binomial regression; the values of the log-likelihood statistics can be used to determine which technique is more appropriate. For each transit agency, the dependent variable, weekday morning boardings, exhibits overdispersion—the variance of the dependent variable is greater than the mean. (Overdispersion is commonly observed in empirical datasets.) Therefore, negative binomial regression is the appropriate technique as opposed to Poisson regression.[95]

The estimated coefficients of the negative binomial regression are reported as well as the values of these coefficients converted into *incidence rate ratios* (*IRR*). Robust standard errors are used to determine whether the coefficient estimates are statistically significant.

Poisson and negative binomial regressions estimate *expected boardings* as a function of the independent variables, including proximity to and size of a park-and-ride facility; the number of workers or housing units or jobs within walking distance of a stop; and the level of income within walking distance of a stop. These variables appear in some form in the regression specifications.

Following Cameron and Trivedi,[96] the coefficient estimate of a negative binomial regression can be interpreted as semi-elasticities. The semi-elasticity interpretation says that one more unit of, say, housing results in a (coefficient*100) = x% increase (decrease) in expected boaredings. The IRR has a multiplicative interpretation. A one unit change in the independent variable changes the expected boardings by a factor equal to the IRR.

The semi-elasticity interpretation is rooted in the fundamental mathematics of the Poisson distribution and the maximum likelihood estimation method. The Poisson distribution posits that the expected value of the dependent count variable conditional on the independent variables is the exponent of the dependent variables multiplied by the true coefficient values.

Thus, for Model 1, Table 6 reports the semi-elasticity percentages in column (4). For each transit agency, the percentage associated with an additional space within a quarter-mile of a stop is greater than the percentage associated with an additional housing unit.

Table 6. Model One Results

Semi-elasticity interpretation				
(1)	(2)	(3)	(4)	(5)
Transit Agency	variable	coefficient	Percent change for 1 unit increase	Multiplicative IRR interpretation = increase in boardings due to one more unit given by multiplying by this factor
VTA	HU	0.0011078	0.11	1.0011
	Spaces	0.0025563	0.26	1.0026
KCM	HU	0.0011137	0.11	1.0011
	Spaces	0.0044252	0.44	1.0044
LAMetro	HU	0.0005059	0.05	1.0005
	Spaces	0.0009344	0.09	1.0009

For Model 2, the presence and size of a park-and-ride facility is represented by three dummy variables: a dummy variable representing the presence of a small park-and-ride facility (PnR_small_QMdummy) within a quarter-mile of a stop, where small means a park-and-ride facility between the 0th and 25th percentiles of park-and-ride facilities in the sample; a dummy variable representing the presence of a medium-sized park-and-ride facility (PnR_medium_QMdummy) within a quarter-mile of a stop, where medium means a park-and-ride facility between the 25th and 75th percentiles of park-and-ride facilities in the sample; and a dummy variable representing the presence of a large park-and-ride facility (PnR_large_QMdummy) with a quarter-mile of a stop, where large means a facility in the 75th percentile or greater of park-and-ride facilities in the sample. All three variables appear in the regression equation because most stops are not within a quarter-mile of any park-and-ride facility.

Table 7. Model Two Results

Semi-elasticity interpretation			Red font means coefficient is not statistically significant	
(1)	(2)	(3)	(4)	(5)
Transit Agency	variable	coefficient	Percent change for 1 unit increase	Multiplicative IRR interpretation = increase in boardings due to one more unit given by multiplying by this factor
VTA	HU	0.0011622	0.12	1.001163
	PnR_small_Qmdummy	1.208337	120.83	3.347911
	PnR_medium_Qmdummy	1.314632	131.46	3.723381
	PnR_large_Qmdummy	1.839639	183.96	6.294268
KCM	HU	0.0011119	0.11	1.001112
	PnR_small_Qmdummy	0.911137	91.11	2.487149
	PnR_medium_Qmdummy	2.88291	288.29	17.8662
	PnR_large_Qmdummy	4.192991	419.30	66.22057
LAMetro	HU	0.0005195	0.05	1.00052
	PnR_small_Qmdummy	0.1423743	14.24	1.153008
	PnR_medium_Qmdummy	1.012922	101.29	2.753636
	PnR_large_Qmdummy	3.83E-06	0.00	1.000004

A "one-unit increase" as applied to the park-and-ride variables in this table should be understood as creation of a small, medium-sized, or large park-and-ride facility within a quarter-mile of a stop. The increase in expected boardings due to the creation of such a facility ranges in factors (IRRs) of roughly 2.75 to 66 across the three agencies (looking only at the statistically significant coefficient estimates). The effect of additional housing units is entirely consistent with the results previously shown in Table 6.

Model 3 shown in Table 8 is a distance-decay model (a sort of gravity model). Each stop in the system has a park-and-ride facility associated with it—the park-and-ride facility that is nearest to the stop even though that might be a very great distance. The size of the nearest park-and-ride facility is also associated with each stop. The effect of park-and-ride is expected to be positively related to the size of the park-and-ride facility and negatively related to distance from the park-and-ride facility. One advantage of the distance-decay model is that every stop has associated park-and-ride characteristics. A potential disadvantage is that the effect of park-and-ride may fall off dramatically with distance: past 0.75 miles or 1 mile, the proximity and size of a park-and-ride facility is likely to be irrelevant to boardings. This would make estimating the effects problematic because the vast majority of stops are not within even one mile of a park-and-ride facility.

The results, again cast is semi-elasticity terms, seem to support this thinking. Table 8 is analogous to the two previous tables.

Table 8. Model Three Results

Semi-elasticity interpretation			Red font means coefficient is not statistically significant	
(1)	**(2)**	**(3)**	**(4)**	**(5)**
Transit Agency	**variable**	**coefficient**	**Percent change for 1 unit increase**	**Multiplicative IRR interpretation = increase in boardings due to one more unit given by multiplying by this factor**
VTA	**HU**	0.0009869	0.10	1.000987
	Quantity	0.0004374	0.04	1.000437
	Distance to PnR	0.0000769	0.01	1.000077
KCM	**HU**	0.0010964	0.11	1.001097
	Quantity	0.0005757	0.06	1.000576
	Distance to PnR	-6.09E-06	0.00	0.9999939
LAMetro	**HU**	0.0004762	0.05	1.000476
	Quantity	0.0000309	0.00	1.000031
	Distance to PnR	-0.0000198	0.00	0.9999802

The effect of housing units is entirely consistent with the results obtained using the other specifications in this analysis. The effect of the size of the park-and-ride facility is considerably smaller than the estimates for Model 1 (the closest analog to Model 3). This is to be expected, because the effects of size of the facility are determined for *all* stops, not just those within a quarter-mile. Distance to the park-and-ride facility is expected to be positive if the "suburbanization" effect holds.

6.8 Summary of Econometric Results

Table 9 compares the results for the three transit agencies across all three model formulations with a view toward assessing the relative strength of different determinants of expected ridership. Generally, our assessments are rooted in the semi-elasticity interpretation. In some cases, especially for some dummy variables, the assessment is best expressed in terms of the incidence rate ratios (IRRs).

Table 9 is divided into two panels: the left (blue-shaded) panel presents factors or incidence-rate ratios of the variables, whereas the right (salmon-shaded) panel presents percent changes in expected boardings for the change in units of the dependent variable indicated in the column "given units." Numbers in a red font do not reach statistical significance at the five percent level.

Table 9. Results Summary

		Factors (IRR)			Percent Changes for Given Units			
		VTA	KC METRO	LA METRO	Given Units	VTA	KC METRO	LA METRO
	MODEL 1							
1	Med HH Inc Lo	1.45	1.34	1.18				
2	Med HH Inc Hi	0.67	0.86	0.72				
	MODEL 2							
3	Med HH Inc Lo	1.49	1.32	1.19				
4	Med HH Inc Hi	0.71	0.86	0.73				
	MODEL 3							
5	Med HH Inc Lo	1.46	1.28	1.19				
6	Med HH Inc Hi	0.58	0.83	0.78				
	Being a Light Rail Station							
7	MODEL 1	11.58	NA	53.86				
8	MODEL 2	11.01	NA	55.86				
9	MODEL 3	13.08	NA	59.69				
	Housing Units in Catchment Area							

		Factors (IRR)			Percent Changes for Given Units			
		VTA	KC METRO	LA METRO	Given Units	VTA	KC METRO	LA METRO
10	MODEL 1	1.001108	1.001114	1.000506	100	11.1	11.1	5.1
11	MODEL 2	1.001163	1.001112	1.00052	100	11.6	11.1	5.2
12	MODEL 3	1.000987	1.001097	1.000476	100	9.9	11.0	4.8
	Jobs in the Catchment Area							
13	MODEL 1	1.000119	1.000038	1.000003	100	1.2	0.38	.030
14	MODEL 2	1.000124	1.000039	1.000001	100	1.2	0.39	.015
15	MODEL 3	1.000145	1.000047	1.000002	100	1.4	0.47	.017
	Creating a:				Given Units	VTA	KC METRO	LA METRO
16	Small PnR	3.347911	2.487149	0.5295166	1	121	91	-64
17	Medium PnR	3.723381	17.8662	1.153008	1	131	288	14.
18	Large PnR	6.294268	66.22057	2.753636	1	184	419	101
	Range of Capacity				Spaces	VTA	KC METRO	LA METRO
19	Small PnR				range	0 - 110	0 - 25	0 - 72
20	Medium PnR				range	111 - 425	26 - 393	73 - 366
21	Large PnR				range	> 425	> 393	> 366
					Given Units	VTA	KC METRO	LA METRO
22	Spaces in Existing PnR in Catchment Area	1.00256	1.004435	1.000935	100	26	44	9
	Comparisons Spaces in Existing PnR vs. HU				Given Units	VTA	KC METRO	LA METRO
23	MODEL 1	1.00145039	1.0033173	1.00042878	ratio	2.3	4.0	1.8
24	MODEL 2	1.00139538	1.00331931	1.00041478	ratio	2.2	4.0	1.8
25	MODEL 3	1.00157145	1.00333434	1.00045878	ratio	2.6	4.0	2.0
	Comparison of PnR by Size vs. 100 HU				Given Units	VTA	KC METRO	LA METRO
26	Small PnR				ratio	11	8	-13
27	Medium PnR				ratio	12	26	3

		Factors (IRR)			Percent Changes for Given Units			
		VTA	KC METRO	LA METRO	Given Units	VTA	KC METRO	LA METRO
28	Large PnR				ratio	17	38	20
	Suburbanization Effect				Given Units	VTA	KC METRO	LA METRO
29	MODEL 1	1.000037	1.000008	1.000005	4 miles	0.24	0.16	0.03
30	MODEL 2	1.000002	0.999983	1.000004	4 miles	0.01	-0.36	0.02
31	MODEL 3	1.0001	1.000033	1.000024	4 miles	0.64	0.70	0.15

Source: Report authors

Red font means coefficient is not statistically significant

Rows 1 through 6 of Table 9 present the IRRs for income for Models 1, 2, and 3. Income was divided into three categories: low, medium, and high. Low income means income below the 25th percentile in the transit agency service area, while high income is income above the 75th percentile in the transit agency service area. The medium income category was the hold-out, so the IRRs reported are the factors by which expected boardings will be multiplied for someone in the low or high income category compared to the medium income category. If the IRR is greater than one, then being in the category means expected boardings increase. If the IRR is less than one, then being in the category means expected boardings decrease. As expected, for all transit agencies, the low-income category has IRRs above one, and the high-income category has IRRs less than one (with one IRR, for KC Metro, being insignificant). The results for each transit agency are consistent across the different specifications and consistent with the overall American Community Survey statistics for the use of transit by different household income groups in Los Angeles as shown in Table 13 later. The results in Table 9 are less consistent with ACS results from San José and Seattle that show both high-income and low-income households using transit at higher levels than mid-range households, so further investigation on this point is warranted.

Rows 7 through 9 of the left-hand panel refer to IRRs for rail transit stations in the two California cities. Being a light rail station is associated with greater expected boardings. The results are consistent for each transit agency and large compared to the effect of income. The factors are especially large for LA Metro, where the analysis left out some of the local bus routes. The ridership boost for rail compared to bus ridership is not surprising, and the consistency across all three model formulations validates the overall approach taken in this study.

Rows 10 through 12 show that for housing in the catchment areas, the IRRs are all greater than one, as are the IRRs for jobs in the catchment areas shown in rows 13 to 15 (except that those for LA Metro are not statistically significant). To facilitate comparison, we computed, shown in the right-hand panel, the percentage effects of adding 100 housing units or 100 jobs in the catchment areas. From the right panel, it is clear that the effect of housing units is greater than the effect of jobs, because the analysis is focused on morning boardings, which will be most influenced by travelers commuting to their place of work, as opposed to leaving the workplace, which would be more of an influence on evening peak period boardings.

As shown in rows 10 to 12, the modeled marginal effect of adding 100 housing units within walking distance of transit stops in the VTA and King County territories increases expected transit boardings by about 11 percent. In LA Metro territory, the impact of 100 more housing units would be around five percent.

The next rows of Table 9 refer to park-and-ride facilities, categorized in rows 16 to 18 by size category dummies: large, medium, and small. What those categories mean in the number of spaces for the PnR facilities of each agency is presented in the next three rows, 19 to 21.

For VTA and King County, the larger the PnR, the larger is the effect on expected boardings. For LA County, the small PnR variable has a negative and significant effect and the medium variable has an insignificant effect. Row 18 results show that a large PnR within a quarter-mile of a stop results in a 184% increase in expected boardings at the stop for VTA, a 419% increase in expected boardings for KC Metro, and a 101% percent increase in boardings for LA Metro.

Then, in row 22, the analysis shows the effect of adding 100 spaces to existing PnR facilities in the limited number of catchment areas near transit stops where such parking exists. The effect is 26% more morning boardings at a nearby stop in VTA territory, 44% in King County territory, and 9% in LA Metro territory. These percentages are strikingly larger than the effect of adding 100 housing units in the three agency territories: 11% for VTA, 11% for KC Metro, and 5% for LA Metro. The comparison raises the important consideration that a PnR space is likely cheaper and faster to add than a TOD housing unit, an issue covered later in this report.

The next six numbered rows, 23 to 28, compute ratios of the marginal effect of PnR versus housing units in influencing ridership. Rows 23 to 25 on the right side of the table show the ratio that is computed by dividing the corresponding entry in row 22 (influence of 100 parking spaces) by the entries in rows 10 through 12 (influence of 100 housing units). Rows 26 to 28 compute a ratio formed by the entries in rows 30 to 32 (influence of PnR by size) divided by the average of the entries in rows 10 through 12 (average influence of 100 housing units across the three models).

The larger the computed ratio in rows 23 to 28, the greater the marginal influence of additional parking close to transit stops compared to the influence of additional housing. The dominance of parking is strongest in King County, and least in LA County, with Santa Clara County in between. In all cases, larger PnR facilities have more influence than smaller ones.

Considering the average across the three models listed in rows 23 to 25, the marginal influence ratio on ridership of 100 spaces in an existing PnR facility over 100 nearby housing units averages 2.4 for VTA, 4.0 for King County Metro, and 1.9 for LA Metro.

LA Metro illustrates the curious result in row 26 of small PnR facilities having a negative effect on ridership. This should be taken up in future research. The reason may be the omission of many local bus routes in the LA County analysis.

Rows 29 to 31 give estimates for a suburbanization effect. The five out of nine results with positive coefficients are consistent with the hypothesis that more suburban park-and-ride facilities—measured by distance from the downtown city hall—attract more riders. For example, the interpretation of results in row 31 is that expected boardings at a stop increase by 0.64 percent for every additional 4 miles of distance from City Hall for VTA, by 0.70 percent for every additional 4 miles of distance from City Hall for King County, and by 0.15 percent for every additional 4 miles of distance from City Hall for LA Metro. These results measure a statistically significant marginal boost in ridership for PnR further away from the city center, but this is visible in only one of the model formulations. The coefficient is insignificant in three out of nine estimations, and in one case (KC Metro, Model 2) it is negative and significant. The inconsistency in results across the three model formulations points to a need for further work to illustrate what is going on. One alternative hypothesis counter to a suburbanization effect is that some transit customers find PnR attractive no matter where it is provided along a transit line, even well within the network, where transit access is widely available within walking distance.

6.9 Further Discussion

One can see throughout these results that King County Metro shows the strongest differential impact of PnR, with VTA somewhat less, and LA least of all, in some cases to the point of invisibility.

Table 10. Performance of the Three Transit Agencies

	VTA	KC Metro	LA Metro
Transit ridership per capita	20	58	40
PnR parking space per 1,000 population	6	12	2.3
Usage of PnR capacity	41%	76%	73%
Filled PnR spaces to ridership	4%	5%	1%
Ratio of car commuters to transit trips	17	6	9

Source: Information transferred from Table 1 and Table 2

Table 10 compiles data from earlier Table 1 and Table 2 in this report, with some rounding for clarity in comparisons. The remainder of this section provides some speculation on how these overall performance characteristics of transit and PnR explain the differences in the strength of the measured dominance of parking over housing density as correlated with ridership.

Table 10 shows King County Metro standing out from the two California cities with highest ridership per capita, the highest number of PnR spaces per capita, and by two different measures, the greatest usage of PnR. These dominant numbers for KCM align well with the dominance of PnR over station area population density for motivating ridership in that agency's territory shown via the econometric analysis results in Table 9.

Lines 23 to 25 in Table 9 show that the dominance of marginal PnR over marginal housing is less strong in the territory of VTA and Los Angeles Metro than in King County Metro. This comports with the data in Table 10. VTA's ridership per capita is the lowest out of the three, as is its demonstrated usage of PnR per capita. San José has high automobile use compared to transit with PnR more available per capita than in LA, but the PnR is unused to a much greater degree than in LA.

The dominance of marginal PnR over marginal housing in LA Metro territory shown in Table 9 is similar to the results from VTA. In Table 10, Los Angeles shows the lowest availability of PnR parking per capita and lowest use of PnR compared to ridership, but the PnR capacity it does have is well used, almost at King County levels. LA Metro's ridership per capita is double that of VTA. The way that PnR influence in LA becomes insignificant or goes negative in smaller parking facilities (lines 16, 17, 26, and 27 in Table 9) suggests that customers walking to transit instead of using neighborhood facilities is more common than in San José, but that additional PnR spaces near the end points of transit lines in LA would help boost ridership.

The authors do not intend the econometric analysis in this report to be a criticism of the strong emphasis in all three studied agencies on expanding TOD housing near transit stops. At the same time, the quantitative analysis in this report provides evidence that PnR overall and in general is a stronger positive force for ridership than housing units near transit stops, and that where PnR is possible and acceptably consistent with other public policies, it should be considered.

VII. Policy Analysis for TOD and PnR

The remainder of this report takes into account what the econometric analysis reveals, and merges the key findings with a variety of other considerations found in academic and other research literature that bear on the policy issues that transit agencies, local governments, and planning organizations contend with in deciding how to allocate resources—money and organizational attention—between park-and-ride and transit oriented development.

In this chapter we highlight the framework for the broad policy choice between emphasizing TOD over park-and-ride, or the opposite emphasis. In the next two chapters we examine in detail the specific policy justifications for TOD and park-and-ride.

The three case study urban regions already include TOD at some station locations, and PnR at others. There are also some stations with a combination of both.

But for agencies throughout California and in the rest of North America, the rest of this report considers issues at the system level concerning what type of transit access—park-and-ride or TOD—should be added, given that decisions should be made within the context of planning for mobility across the entire transit network and even beyond the reach of the network.

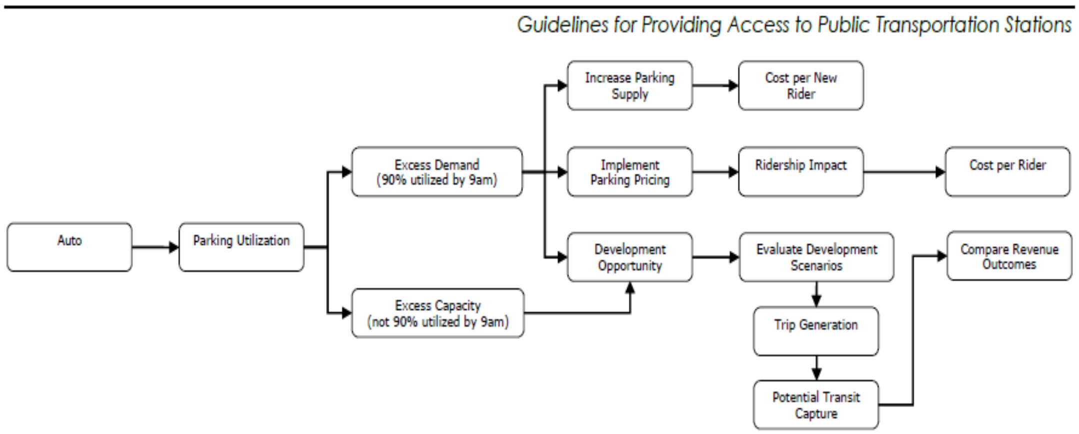
The details of station area development for parking or TOD are not the focus of this study. There is ample literature on that topic, including how to choose the location and size of parking facilities. For example, TCRP Report 153, *Guidelines for Providing Access to Public Transportation Stations*[97] provides guidance for both PnR and TOD in separate chapters. Similar coverage is provided in TCRP Report 192, *Guidebook on Planning and Managing Park-and-Ride,*[98] which includes a full chapter titled "Strategic Planning for Park-and-Ride" and another chapter called "Transit-Oriented Development." However, neither of these two works address how much to emphasize one or the other type of transit access across a network.

One way of looking at the park-and-ride issue is at the station level. The framing at this level of analysis goes as follows. There is land available near an existing or planned transit station—should land be reserved for park-and-ride or TOD or used for some other purpose, or just left alone?

A similar question comes up for existing stations that already have park-and-ride nearby. Should the parking be expanded? Should some of the parking be turned into residential development attractive to citizens who would like to be able to walk to the train or bus?

Examples of such determinations made on a station-by-station basis are shown next. In Figure 20, the flow chart shows another research project's conception of the issues that should be considered in strategizing about whether to convert parking capacity at a single station to residential development at that station, based on present use of parking and the ability of the line to absorb more passengers.

Figure 20. Evaluation of TOD as a Substitute for PnR at an Individual Transit Station



Source: TCRP 153, Appendix C[99]

Table 11 shows an example of methodology for determining the financial impact of reducing parking capacity at a single heavy rail station of the Bay Area Rapid Transit system, BART.

Table 11. Example of Methodology for Determining Financial Impact of Reduced Capacity at PnR Facilities

	Revenue Factors	60% BART Replacement Parking	75% BART Replacement Parking
A	Net change in ridership	1698	1841
B	Net change in annual fare revenue	$1,357,302	$1,470,932
C	Net parking revenue	$114,471	$142,768
D	Land value	$20,999,055	$19,524,872
E	Cost of replacement parking	$17,596,600	$22,552,600
F	Annual ground rent after parking costs	$340,246	($302,773)
G	Reduction in parking operating cost	$60,195	($34,964)
H	Annualized capital costs for intermodal facility and placemaking elements	$500,000	$500,000
I	**Net annual impact (B+C+F+G-H)**	$1,372,213	$775,964

Source: 2006 consultant report describing options for TOD takeover of South Hayward BART station's PnR spaces[100]

Such decisions can be—and often are—made on a station-by-station basis. However, more fundamental considerations of public policy influencing resource allocation come from examining the role of both housing and parking across the entire transit network.

Instead, the issue addressed in this study is the strategic question of when, where, and how much across a transit agency's entire network should parking be emphasized for customer access to transit versus the alternative or complementary use of agency resources to create more residential TOD near stations? In a real-world environment of limited resources, where and when should one type of access be emphasized over the other?

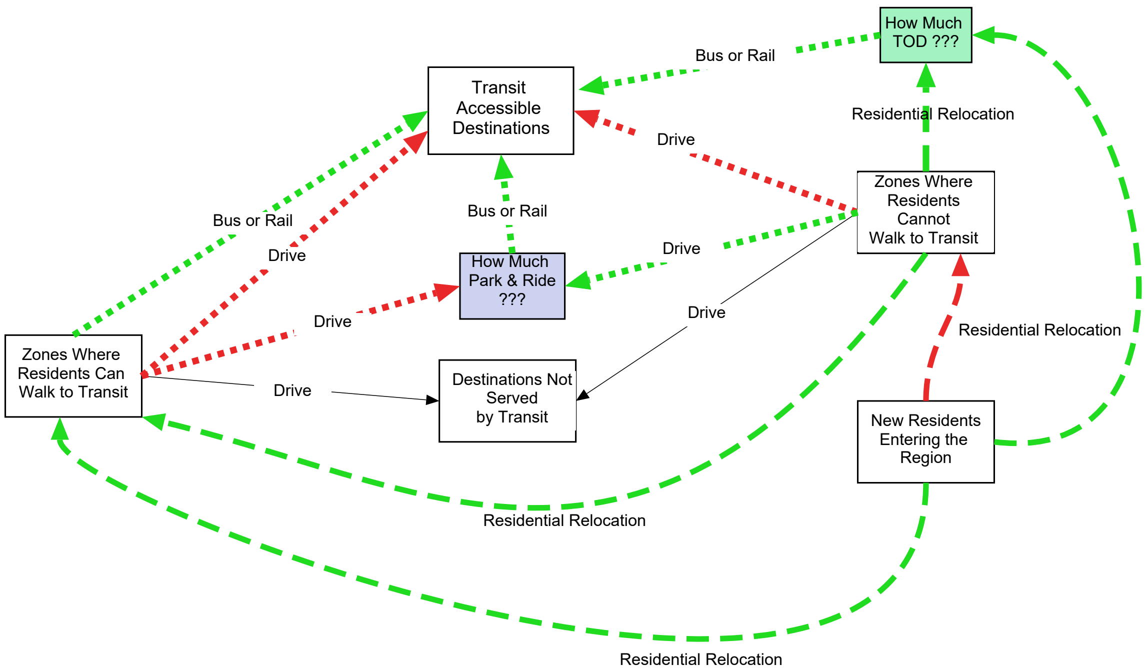
Fundamental priority-setting for station area developments is reasonably based on policy at the level of the entire transit service district. Recall that the three agencies studied in this report all have documented policies that bear on priorities for promoting non-motorized, active mobility and reduced private car use in the vicinity of transit stations. TOD was clearly emphasized at the beginning of 2020, before the pandemic struck.

The aim in this report is to find the essence of the strategic choice that goes beyond detailed facility design and operational competence. How can government leaders decide how taxpayer dollars and public management attention are to be allocated between parking at transit stations and housing at transit stations? As Nelson et al. pointed out two decades ago, "For the purpose of gauging the success of TOD, it is important to distinguish between local (station-area) benefits and costs, and corridor or regional benefits and costs."[101] Similarly, it is important to consider the overall effect on corridors and the region that come from commuter use of PnR facilities.

Figure 21 lays out the strategic landscape of transit network access for transit agencies and communities in which they are embedded. Green colored lines depict travel behaviors that are sought by mainstream urban public policy, falling into two categories: riding on public transit, and choosing to live in residential locations where public transit use is more convenient and likely to be used. Some red colored lines are travel behaviors to be discouraged: travel by automobile when public transit options exist. The right-most red line illustrates that in the long run, development of new residential neighborhoods should be discouraged in places where use of transit is not an available or convenient option.

TOD is a long-range strategy. As shown in the diagram, new TOD creates new walk-to-transit opportunities for new or existing residents who would be willing to move into new housing. Residents looking to move their households have the opportunity to seek out existing residential areas with transit access, even that which is not created with TOD intent. Convincing households to relocate into TOD housing is likely a bigger challenge than attracting existing commuters to a parking place near transit that is already in place, ready to serve. PnR with available parking space creates immediate opportunities for citizens in existing residential areas to drive to transit stations and ride where they need to go. PnR serves many residential locations, whether or not they are within walking distance of transit service already.

Figure 21.   Strategic Landscape of Transit Network Access



Source: Niles and Pogodzinski original graphic

By focusing on comparing idealized forms of the two access methods, the analysis goes beyond the details of implementation. Instead, different levels of challenge and risk that influence the choice between the two tactics are discussed. Tradeoff scenarios for TOD versus PnR are considered given idealized forms of each that provide affordable access to high-quality transit service providing reliable mobility to employment locations and services.

VIII. Policy Justifications for TOD

The econometric analysis demonstrates that parking near transit stops is a stronger force for marginal ridership enhancement than housing density. Yet as also illustrated in a previous section, numerous transit-relevant documents from government sources show that the authorities in the three case study regions are now emphasizing TOD over PnR, even while continuing to provide PnR.

Transit oriented development is alleged to be very popular by leading scholars who study and teach about it. As noted by Cervero et al. in *Beyond Mobility*:

> *TOD's growing popularity lies in part in its broad appeal. If there is any place on the city map where nearly everyone agrees that it makes sense to concentrate urban growth, it is in and around rail stations and major transit stops. Everyone—politicians, environmental advocates, real estate developers, or lay citizens—relates to the idea that putting trip origins and destinations within walking distance of stations is beneficial environmentally, socially, and economically.*[102]

The sources of transit agency and urban planners' preference for TOD over PnR in the vicinity of transit stations are summarized in the following list:

- Support for smart growth land development near transit stations;
- Support for regional growth-containment within designated zones, and growth constraints outside of these zones;
- Support for the public policy goal of VMT reduction;
- Support for agency financial sustainability;
- Support for equity in allocation of transit resources.

This section explains this list with some reliance on issue analysis laid out by APTA in *Transit Parking 101*[103] include system considerations, land use considerations, and environmental issues.

8.1 Smart Growth

TOD is intended to implement urban planners' preferred vision for the vibrant, walkable, livable places that characterize the smart growth philosophy of urban development as described in Table 12, with public transit provided and utilized as a dominant mode of mobility, including within a TOD or TOC zone and traveling between different zones. At the same time, TOD zones can be allocated to provide space for more housing units in a growing city that needs them, while not supporting growth in automobile ownership and use. This appeals to anti-car and anti-parking sentiment found in a segment of the urban population.

By aligning closely with the smart growth concept, TOD provides a contrast to the theme of sprawl, bearing on many aspects of the contrast illustrated in Table 12, which is adapted from a presentation by transit advocate and analyst Todd Litman.

Table 12. Characteristics of Transit Oriented Development Align with Smart Growth

	Smart Growth	Sprawl
Density	Higher-density, clustered activities	Lower-density, dispersed activities
Land use mix	Mixed land use	Single-use, segregated land uses
Scale	Human scale; Smaller blocks and roads, more local services, for pedestrian access	Large scale; Larger blocks, wider roads, more regional services, assuming automobile access
Services (shops, schools, parks)	Local, distributed, smaller; Accommodates walking access	Regional, consolidated, larger; Requires automobile access
Housing types	Diverse, compact housing such as townhouses and apartments	Primarily single-family housing
Transport	Multimodal and supportive of walking, cycling, and public transit	Automobile-oriented; Poorly suited for walking, cycling and transit
Transport connectivity	Highly connected roads, sidewalks and paths, and good connections between modes	Poorly connected networks, with numerous dead-end streets, few paths, and inadequate intermodal connections
Parking supply	Lower parking supply, higher parking prices	Parking facilities are abundant and usually free
Street design	Complete streets supporting diverse modes and activities	Streets designed to maximize motor vehicle traffic volume and speed

Source: Adapted from Todd Litman [104]

Walking, cycling, or riding to a transit station within a TOC is an environmentally sustainable transportation practice, consuming less energy and taking less public right-of-way than driving a car. TOD can be targeted for implementation in locations where public policy seeks walk-up and roll-up access for transit riders, both consistent with the smart growth transit access pattern.

Smart growth is described by Christopher Leinberger as "walkable urbanism," and he provides proof from surveys that this urban development pattern is attractive to about half the US market that looks to live in urban areas, with the other half more interested in "drivable suburbanism."[105]

8.2 Cars in Smart Growth

This section notes the role of cars in providing equitable access to employment and other opportunities that supplement the access provided by public transit agencies. Certain passenger requirements require private car support also.

Leading TOD academic scholars emphasize that they are not anti-automobile. For example, Cervero et al. in *Beyond Mobility* emphasize support for car mobility:

> *The private automobile is one of the world's great inventions, providing unprecedented levels of personal mobility. It allows people to move effortlessly about the city, on demand, whenever desired. The car is also the most sensible means of travel for many trips, such as hauling bags of groceries and weekend excursions to the countryside. Nor are we arguing against future road building. Being stuck in traffic hardly contributes to good urbanism and livable communities...*
>
> *Throughout this book, we argue for the planning and design of cities and the pricing and management of transportation resources in ways that reduce the excessive reliance and sometimes seemingly indiscriminate use of private cars to go anywhere and everywhere…*
>
> *The idea of balancing is to design cities in ways that reduce wasteful travel and encourage judicious automobility. It does not mean ceasing future road construction or ignoring the need for efficient freight logistics in industrial corridors. We believe compact, mixed-use, walkable communities that focus on place-making and quality of environment are wholly compatible with building and maintaining functional and efficient networks for motorized travel. We are most likely to do so by striking a better balance between mobility and place in the future planning and design of cities.*[106]

Of course the availability of car parking at "places" that are origins and destinations of car travel – even within a zone characterized by smart growth – is an essential part of "functional and efficient networks for motorized travel" mentioned in the preceding quotation.

Further evidence that cars have a place in smart growth comes from the interest of housing developers in TOD zones to provide parking spaces for cars owned by multi-unit building tenants who may ride on transit to work but who want their car for other trip purposes, such as weekend excursions to recreation destinations outside the city, as noted by Cervero et al in the quote above..

There are a variety of personal circumstances that would cause individuals to use private automobiles instead of transit for some trips, irrespective of trip purpose. For example, for some adults their pets, service animals, and children are more easily accommodated in a private automobile than in a transit vehicle. Also, automobiles provide important mobility support to some disabled individuals having restrictions on their ability to walk who find driving an automobile necessary for efficient daily functioning, sometimes with mobility devices like wheelchairs or electric scooters as easily unloadable cargo for use at destinations.

Some people living in TOD housing near transit still drive to work. As an example of motivation for car use, research by the University of Minnesota Accessibility Observatory[107] has found that, for a household in the New York Metropolitan Area in 2015, only eight percent of jobs reachable by car in 30 minutes could be reached by transit in 30 minutes. For a 60 minute commute, the figure is 19 percent. Not surprisingly, for all other US metro areas, the accessibility ratio is lower, often much lower. In the Atlanta metro area, for example, the analogous ratios are one percent and three percent. This is simply because employment locations are widely dispersed, roads go by all of them, and transit does not serve or even pass close to all of them.

A final point on car mobility comes from a 2020 research study published in *Transportation Research Part A* that "examines whether private vehicle access is associated with the quantity and quality of out-of-home activities in which low income individuals participate." The study used "pooled data from multiple time use surveys drawn from the Netherlands, Canada, Spain, and the United Kingdom." The research found:

> *A lack of private vehicle access is associated with significantly less frequent out-of-home activity participation, both in the aggregate and for seven of the twelve individual activities. Moreover, the activities most likely to be foregone are generally associated with high subjective well-being, suggesting that constrained mobility comes with significant emotional costs….Overall, the findings suggest that the lack of a private vehicle is deleterious for quality of life, raising troubling questions about inequity possibly arising when people are denied access to vehicles for economic reasons.*[108]

While a car-free or car-light life is a commendable choice for urban residents, the examples in this section highlight why smart growth and walkable urbanism need to accommodate a range of personal mobility choices. Note that in multi-adult households living in a TOD or TOC residence, only one of the adults may be a regular transit user, while one or more others have circumstances judged by them to require having regular access to a private automobile, requiring a parking space nearby for convenient use.

8.3 VMT Reduction

VMT reduction is an important municipal, regional, and statewide public policy goal related to urban smart growth. As of this writing, state and regional governments in both California and Washington State have a mandate to reduce VMT.[109]

TOD's replacing PnR is considered by some to be a way to pursue the goal of lower automobile usage and reduced VMT. Research-generated statistics have consistently shown that residents of TOD drive cars less often and for fewer miles than people who do not live in TOD, even owning fewer cars per household on average.[110]

Support for VMT reduction may be more intuitively compatible with TOD than with PnR, since TOD generally means people walk to transit and PnR means driving to transit. However, this is always a question of empirical research from case to case, since the travel behavior of TOD residents and suburban automobile commuters is subject to wide variation. For example, PnR motivates many customers to take a short drive to get a bus or train, rather than driving a longer distance into a central business district. A case study of the potential of TOD as a replacement for PnR to reduce VMT along the light rail line in Charlotte, NC, showed potential to reduce VMT at PnR stations not well used and closer to the city center, but not in the suburban stations closer to the end of the line.[111]

Nelson et al. provided caution about the VMT reduction derivable from TOD in their study of regional effects of TOD on driving to non-work destinations:

> *Although support for transit-oriented development is based, in large part, on the assumption that when venues for nonwork activities are located at TOD station areas more people will use transit, there has not been a careful analysis of the actual spatial environment for nonwork activity and the travel patterns it engenders. The consumer marketplace for goods, services, eating out, and leisure activities in a metropolitan region is exceedingly large, varied and geographically dispersed. …The number and location of, and the spatial relationships for, the myriad nonwork venues is the result of growing prosperity, technological innovation, and a highly adaptive entrepreneurial market that seeks to satisfy consumer needs and wants. Nonwork activities, which now account for approximately two-thirds of all personal travel, will continue to grow in variety as wealth and prosperity spread, and as the nation becomes more ethnically diverse. Since the consumer marketplace for goods and services will inevitably provide many more places to go than mass transit can effectively serve, the success of TOD as measured by less automobility cannot be taken for granted. Even the choice of mode for the work trip is determined in large measure by nonwork activities, as people make stops during the commute to shop, drop off and pick up family members, and conduct personal business.*[112]

This section as well as the previous one illustrates the existence of individual personal mobility needs and passenger requirements that limit the ability of TOD to reduce private automobile use.

8.4 Targeting of Transit Ridership

TOD potentially provides targeting of a type of ridership that transit agencies would prefer to serve for reasons of efficiency, namely, off-peak ridership along both the time dimension and the direction of travel. This widening of the transit market comes when transit service is very high-frequency throughout the day and goes to many destinations, both work and non-work, including second and third shifts.

TOD can be targeted for implementation at or near stations along sections of a transit line that are showing a light level of ridership despite having plenty of capacity. These could be located in former industrial areas that are no longer active and would be prime locations for new residential development.

8.5 Agency Financial Self-Interest

Over the past decade, transit agencies have started to consider whether the most beneficial use of the station-adjacent land they own would be to sell or lease the property to real estate interests to build and operate residential property rather than providing free or low-cost parking.

Consider this scenario. Suppose there is a well-used PnR facility generating high ridership and demonstrating obvious demand for more parking to support transit patronage. Suppose there is vacant land owned by a transit agency nearby the existing PnR facility. If the transit agency or other government unit were to build more parking spaces, then this might require a level of transit service to support the additional commuters that creates an unacceptably heavy capital and operating resource commitment.

In comparison, the transit agency could sell that vacant land to a residential development company with a proviso that housing units would be built with a low ratio of parking spaces per unit, with sales or rental leasing targeted at residents who have below-average car ownership. Given that transit services often operate at a deficit, the agency may make the judgement that adding just a few new riders from a TOD is more advantageous to the agency than the alternative of adding many new riders from PnR investment and taking on costs for both additional PnR infrastructure and associated transit service for new customers.

In other words, because housing is a higher-value land use than parking, transit agencies owning surplus land near existing transit stops would likely find selling the property to TOD developers more fiscally advantageous than investing transit agency resources in park-and-ride.

TOD is assumed by its proponents to generate more economic activity and tax collection than expanding car parking capacity. TOD generates real estate sales or leasing revenue to the transit agency. Property and sales tax revenue is generated as well, some of which results in more funding for the transit agency. At the same time, there is potential for capital and operating support of transit from TOD developers, builders, and operators.

On the other hand, surface parking can be a fast-to-implement interim use of land near transit stations while waiting for other more productive land uses to become ripe, such as TOD. PnR in this way amounts to productive land banking that prevents land uses that are inimical to public transit use.

8.6 Equity for Low-Income and Non-Car-Driving Customers

Governments in North America typically focus on serving the mobility-disadvantaged as an element of support for social equity. This concept overlaps with the US Federal requirement called, in short, Title VI, which is the part of the Civil Rights Act making discrimination based on race, color, or national origin to be illegal. But supporting equity in mobility also extends to serving low-income, and the physically disabled, which overlap with the senior citizen, military veteran, and homeless populations. PnR can run counter to social equity if the service patterns supported by investment in park-and-ride facilities tilt overall transit service delivery away too much from the needs of low-income, mobility-disadvantaged households and individuals toward car-owning markets for whom transit is an amenity.

As a counterpoint, it should be noted that the majority of low-income households have access to car travel.[113] Furthermore, Census data on mode split for the journey to work in the metropolitan urban areas of the three case study sites in this report reveal that automobile use dominates in the lowest income category of commuters as well as the higher income categories. Table 13 illustrates that for households at an income level of $25,000 or less, the ratio of commuting by car (including solo plus carpool) to transit is 9 to 1 in Los Angeles, 15 to 1 in San José, and 7 to 1 in Seattle.

Table 13. Work Trip Mode Shares for Three Metro Areas across Three Household Income Levels

	LA	LA	LA		San José	San José	San José		Seattle	Seattle	Seattle
	$0 to $25K	$25K–$65K	$65K +		$0 to $25K	$25K–$65K	$65K +		$0 to $25K	$25K–$65K	$65K+
Solo driving	66.2%	79.0%	81.1%		67.0%	77.3%	78.1%		63.2%	70.8%	68.1%
Carpool-vanpool	11.9%	9.3%	6.9%		13.2%	11.2%	8.7%		11.3%	10.2%	8.6%
Transit	8.8%	3.7%	2.1%		5.2%	3.3%	4.3%		10.25%	9.0%	10.35%
Walk	4.3%	1.7%	1.3%		4.2%	1.5%	1.2%		5.7%	3.4%	3.4%
Taxi-bike	3.0%	1.9%	1.8%		3.9%	2.5%	3.0%		2.2%	1.9%	2.7%
Work at home	5.8%	4.4%	6.7%		6.6%	4.2%	4.6%		7.5%	4.6%	6.8%
TOTAL	100%	100%	100%		100%	100%	100%		100%	100%	100%
Ratio of Driving to Transit	8.9	23.9	41.7		15.5	27.0	20.1		7.3	9.0	7.4

Data source: American Community Survey, 2018 five-year estimates

The statistics in Table 13 illustrate that there is a significant car-commuting population in the lowest tier of household income. Other research and statistics illustrate that the fraction of low-income households in the suburbs is expanding,[114] with the Bay Area of California being an example. While a public policy goal in the three areas studied in this report is the expansion of low-income, no-car residential living in TOC zones with walkable access to public transit, evidence suggests that a significant low-income, car-commuting population is already established in the suburbs.

From a region-wide perspective, as described throughout this report, TOD is considered by many transit thought leaders in the three case study cities to be a more equitable use of limited agency resources than PnR because it emphasizes walking or cycling to transit instead of private vehicle ownership and use for driving to transit. However, among the significant number of low-income households with access to cars, there arises the hypothesis that the majority would find PnR access to transit more economically and socially advantageous than competing for the chance to relocate into a limited number of "affordable" TOD residences within walking distance of transit. Addressing this hypothesis was beyond the scope of the research project behind this report. However, it's clear that geographically-coded data sets indicating the regional location and stated mobility interests of such households should be a critical input to public policy-based decisions on allocating resources to TOD versus PnR if equitable treatment is an objective.

There is much more substance than outlined here in the quest for equitable transit service delivery, but it is beyond the scope of the research for this report. Since public transit in the US is largely framed as a social service, equity considerations are important in a transit agency's choices of market emphasis in allocating transit resource across TOD and PnR.

8.7 Housing Affordability

As another aspect of equity, TOD is an opportunity to use agency-owned land for affordable, high-density residential housing at a transit-served place in a sector of the region where it would not otherwise be attractive.

Affordable housing is a regional challenge in the three case cities, as illustrated in Table 14 showing an excerpt from a 2019 (third quarter) compilation of the least affordable metropolitan housing markets in the United States, measured by the ratio of median housing purchase price to median annual household annual income. Los Angeles and San José are the least affordable housing markets in the country.

Table 14. Sample of Major Metropolitan Housing Markets Ranked by Affordability

Metropolitan Market	Median House Price/Median Household Income
Sacramento & Fresno, CA	5.2
New York, NY-NJ	5.4
Seattle, WA	5.5
London, UK	8.2
San José, CA	8.5
Los Angeles, CA	9.0
Vancouver, BC, Canada	11.9
Hong Kong, China	20.8

Source: 2020 Demographia International Housing Affordability Survey[115]

There is plenty of evidence that gentrification and rising residential real estate values tend to occur around high-quality transit access marked by TOD as a natural condition.[116] This dynamic makes providing affordable housing as part of TOD expensive and difficult, but certainly worthy as a commitment of public resources, as illustrated in the programs described earlier in Chapter V.

All of the three case study transit agencies link TOD to affordable housing by requiring that a percentage of the units in TOD residential projects on land leased from the agency meet a definition of affordability. As a response to urban environments with expensive housing, subsidies from local or state governments are necessary to make such projects financially viable for private for-profit or non-profit developers.

8.8 Transit Advocates' Preference for TOD

TOD residential and commercial uses are preferred by smart growth advocates over PnR facilities. For example, Kenworthy and Schiller,[117] who prefer to describe park-and-ride with the term "drive to transit" in contrast with "walk to transit," advocate that transit agencies "improve local transit so that transit riders don't have to become motorists."

To many observers and analysts, expenditure on PnR facilities represents acceptance and support for sprawling suburban lifestyles and the carbon emissions of private motor vehicles, when the public interest would be better served if land use around stations were developed into facilities where people live, work and play, and walk to transit.

Here are some examples.

In a 2015 essay criticizing Metro's original insistence on 2,000 PnR spaces at the North Hollywood PnR redevelopment project described earlier, transit advocacy blog LA Streetsblog noted:

> *If Metro is really committed to fostering great place— or "Transit Oriented Communities" as [Metro CEO] Phil Washington urges— then the agency will need to show a greater commitment to great first-last mile connections, to housing, to great public spaces. In recent years, North Hollywood has become a great walkable neighborhood. Metro's joint development should build on that walkability.*
>
> *If Metro is going to require about $50 million worth of improvements from developers, it's better to invest that money in housing, and first/last mile connectivity for walking, bicycling, bike-share, etc. Better to build great places that Metro riders will want to go to… not just a massive ocean of parking.*[118]

Los Angeles area resident and transit advocate Donald Shoup, a UCLA professor who is prominent for his published research on the negative impacts of free parking on urban mobility,[119] stated in an interview with a journalist from the blog Market Urbanism:

> *I think park-and-ride schemes are another way to subsidize cars. It would be better to devote the land around transit hubs to denser development. If parking is provided, it should be on the periphery of the development, not adjacent to the transit stop, so commuters walk past all the stores and restaurants on their way to and from their cars. And drivers should pay the market price for parking, so transit riders who don't drive to the transit stations don't have to subsidize the transit riders who do park at the stations.*[120]

As a Bay Area example from a transit advocacy point of view, consider a long essay by Benjamin Schneider in *SF Weekly*, "BART Beats NIMBYs, But Not at Every Station." The story opens, "There's something incongruous about stepping off of a packed BART train into a vast parking facility. The fact that the very same stations that allow so many people to get around without a car are themselves surrounded by cars does not make for great symbolism."

Further into the story, "In the early days, when BART bragged about providing every rider a seat, it made sense to provide facilities of parking at its stations. But as the Bay Area has grown, it has become more difficult to justify all of those homes for cars when homes for people are so hard to come by."

This opinion-laden report calls out empty PnR facilities as "asphalt deserts" needing "high-density, low-parking, mixed-income development" that first require "state or regional-level mandates that can be summarized very succinctly: build the housing near the transit."[121]

Transit advocates in Seattle have worked since 2010 to reduce or eliminate parking at the Northgate transit hub that had provided parking for bus commuters since 1970 when the addition of a light rail line—originally opening in 2006, now delayed until 2021—was being planned: Smart growth advocates at the Seattle Transit Blog editorialized, "Scarce transit dollars would be better spent on pedestrian access that connects the Northgate community and that promotes active modes of transportation. With new parks, better sidewalks and crossings, library and community center investments, improvements to zoning and ironically, removal of parking minimums, we have already started down the right path. Building a parking garage on scarce station-adjacent land commits Northgate to a continued focus on cars and takes away space to grow an urban center. We can do better for Northgate, and we can do better for our investment in mass transit in Seattle."[122]

Table 15 shows a summary from a professional paper by known transit advocates titled "Parking for Transit Oriented Development" that tilts toward a strategic preference for TOD over PnR. The point being illustrated in the table is that PnR is best seen as a time-limited, temporary interim land use for reserving land adjacent to stations that should be used for TOD later as the transit network matures. Notice that "ridership gains" from both PnR and TOD are noted, with TOD generating additional off-peak and reverse-commute ridership.

Table 15. “Advantages of Different Approaches to Park-and-Ride Provision”

<table>
<tr><th>Focus on Park-and-Ride</th><th>Park-and-Ride as an Interim Strategy</th><th>No Park-and-Ride – Focus on TOD/Other Access Modes</th></tr>
<tr><td>Original BART system</td><td>BART (SF Bay Area) 2005-
WMATA (Washington, DC region)</td><td>Metrorail (Arlington County, VA)
SkyTrain, Vancouver
Seattle LINK light rail</td></tr>
<tr><td>Emphasis on node</td><td></td><td>Emphasis on place</td></tr>
<tr><td colspan="2">Ridership gains from park-and-ride</td><td></td></tr>
<tr><td></td><td colspan="2">Ridership gains from TOD
TOD generates off-peak and reverse-commute ridership</td></tr>
<tr><td>Significant peak period traffic congestion
Roadway infrastructure reduces pedestrian access to stations</td><td></td><td>Little traffic congestion from access trips
Less roadway access infrastructure needed
Better pedestrian acces</td></tr>
<tr><td>Appeal to affluent suburban voters and sprawl developers may be necessary to achieve regional vote</td><td>Political difficulties in not fully replacing parking</td><td>Benefits lower-income households without cars</td></tr>
<tr><td>Effective use of land that is impractical for TOD – freeway interchanges, airport zone, toxins, etc.</td><td>Lease or sale revenue from land for joint development</td><td>Higher transit system productivity
Higher local economic returns</td></tr>
<tr><td colspan="2">“Free” capital money from federal government to build parking</td><td></td></tr>
<tr><td>No operating money required for shuttle connections</td><td colspan="2">Sales and property tax revenues from TOD</td></tr>
</table>

Source: Tumlin and Millard-Ball, 2010[123]

8.9 Challenges for TOD

There are complexities that sometimes emerge for an agency pursuing TOD on valuable station-adjacent land it owns. A variety of public and private actors are involved.[124] Each of the issues in the list below is a potential source of delay and controversy in creating TOD. The complexity of the TOD development process compared to alternative investments in PnR or other acceptable transit-adjacent alternatives may require the transit agency to invest in added staff capability, or specialized consulting assistance. The list is not presented as a set reason to avoid TOD, but rather in order to make the point that designing and implementing TOD requires industrial-strength effort.

- Existing land use near the station may already support affordable housing, and development would be a case of gentrification creating displacement of existing households for the creation of housing unaffordable for the existing station neighbors.
- There may be political opposition to the density and the type of housing that would be in the TOD.

- The noise and air pollution generated by some kinds of trains and buses juxtaposed with nearby residential housing and walkable urbanism create an unattractive physical environment for the daily lives of some consumers.
- Eliminating station parking that may be available already near the station can lead to spill-over “hide and ride” parking in existing neighborhoods not part of the TOD project, if curb use is not managed.
- Potential risk of association of TOD with an overall failure to grow ridership, but this is balanced with the potential for notable ridership growth. The forecasting of ridership growth is likely to reflect uncertainties in project outcomes even before ground is broken.
- Potential risk of TOD real estate development outcome failure comes along with TOD implementation, including excessive vacancy rate as tenancy builds up, but balanced with the positive political potential of agency association with a TOD land use success.
- The cost of development and maintenance of the agency staff skills necessary to pursue and manage TOD development on agency property needs to be recognized in budgeting for a new TOD effort.

IX. Policy Justifications for PnR

Having covered the justifications and difficult issues for TOD in the previous section, the analysis next turns to justifications for PnR.

9.1 Growing Transit Ridership

For all the talk of growing transit ridership as a reason for TOD, and despite the ample evidence that people who reside in TOD housing units ride transit more consistently than people who do not, PnR is a stronger program for ridership growth than TOD if one is comparing generally the two methods of putting people close to places for boarding and exiting transit coaches. A main reason is that parking spaces for people who drive to transit consume less ground space than residential apartments for people who live close to transit.

Parking generates more ridership per square foot of land development than TOD at acceptable densities. A filled PnR slot is at least one transit boarding, and sometimes more. One can assume 1.2 occupants in arriving cars at PnR, with TOD housing units generating transit customers at the rate of one boarding per unit. Without regard to where construction resources originate, building 100 parking spaces to gain 120 new transit riders is less expensive than building 120 apartments to gain the same number of new riders. A pro forma calculation by the consulting firm CDM Smith in 2012 found that a property of 10,000 square feet adjacent to a rail transit station under reasonable assumptions would generate 69 transit trips per day from PnR spaces, or alternatively, 12 to 16 transit trips if 1,550-square-foot apartments were built on the property.[125] In the 2012 TCRP Report "Guidelines for Providing Access to Public Transportation Stations," the number of daily transit riders per thousand square feet for PnR land use was estimated to be from five to seven, while residential land use was estimated to generate transit riders in a small range from one to 1.5 boardings per thousand square feet.

The summary from the TCRP authors is:

> *Per square foot, residential and office development are likely to generate significantly fewer riders than would an equivalent amount of park-and-ride. High-rise residential or office development could generate more ridership than park-and-ride space, if sufficient demand existed to justify high-rise development.*
>
> *There are of course many important reasons for providing TOD, other than ridership. TOD can improve the character of an area, make it more cohesive, and possibly attract economic development to an area. But it, too, will require some parking, and it generally should not be viewed as a replacement of needed parking space.*[126]

In summary, assuming zoning, permitting, and funding issues are comparable, parking spaces used to store cars for twelve hours per weekday are easier, cheaper, and quicker to build than residences that would generate equivalent passenger volume. An illustration of this point is the opening of

PnR garage structures with over one thousand spaces each at the two new BART stations in Santa Clara County in June 2020.[127] Any TOD affordable housing expansion around these stations is a longer and more difficult project—the subject of many years of planning discussions past, present, and future.[128]

Avoiding parking structures and simply going with surface parking lots reduces cost and provides more flexibility for later conversion to TOD. On the other hand, parking on high-value land is best provided in structured, multi-level parking to consume less land per parked car.

Underlining the points in this section, the econometric analysis in the three agency case studies documented above in Chapter VI illustrated that the marginal benefit of parking has a stronger association with ridership than housing or population.

9.2 Operational Productivity

Transit agencies enjoy a more efficient service pattern when collecting riders at PnR locations rather than along thinly settled routes in low-density residential zones that inevitably show low ridership per service hour. In an earlier case study of King County, Niles and Pogodzinski[129] found that across the 53 Seattle Eastside suburban bus routes, 50,000 transit service hours (worth $17 million) were saved annually as of 2015 because of the bus passenger who are picked up at PnR facilities instead of at non-PnR bus stops. Compared to bus service picking up widely dispersed suburban customers, the efficiency of public transit taking commuters to their jobs and schools is enhanced by these customers driving themselves to collection points at PnR facilities.

9.3 Serving Transit Customers in Drivable Suburbia

PnR is popular with suburban commuters as a way of reaching transit. Reports of PnR facilities operating at capacity at terminus and intermodal stations in San José, Seattle, and Los Angeles provide indications of the appeal of PnR to commuters where catchment areas extend beyond the reach of transit lines. PnR in these locations grows the virtual reach of the transit network beyond where the routes go.

PnR supports suburban customers who are taxpayers and who have chosen TOD-inappropriate residential locations for any number of socially and personally beneficial reasons, such as affordable housing and access to healthy recreational activity. Some of these customers may come from politically important suburban jurisdictions and demographics which have voted to fund public transit service and expect to be served. This market may include customers who would only decide to access transit by driving to stations with parking.

Individual underutilized PnR facilities exist, suffering more than one of several potential negative issues—poor transit service at a facility, vandalism and theft during unguarded hours of unmonitored parking, personal insecurity (real or perceived) of commuters arriving or leaving, a catchment with low population of commuters going where the transit goes, or poor visibility from the highway. If the owning or managing agency does not care enough to focus on correction, or shutting down the facility, problems may fester.

While both TOD and PnR in suburban locations make bus transit more productive by having the customers come to an assembly point to board the bus, PnR is more compatible with existing suburban patterns and density of land use, which is exemplified by single-family homes and automobile travel trips out of the home beyond easy walking distance.

The graphic in Figure 22 shows the 2017 journey-to-work mode share for all of census tracts in Santa Clara County, showing the majority under five percent market share, largely the result of transit not being within a five- to ten-minute walk of most Census tracts. Driving to transit at a park-and-ride makes sense for people living in the Census tracts shown on the right side of the graphic.

Figure 22. Transit Mode Share in Santa Clara County Census Tracts Ranked from Highest to Lowest Share

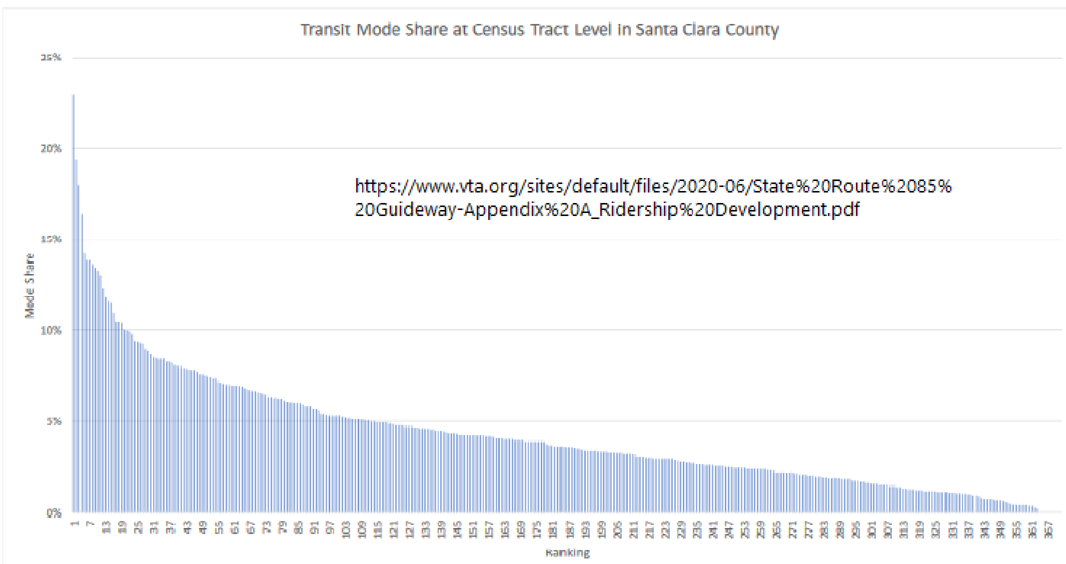


Figure A-4 ACS Transit Mode Share

Source: US Census, ACS 5-Year Estimate Data, 2017, Study team calculations

Source: VTA[130]

Still, parking facilities with free or relatively affordable parking next to points of transit boarding directly supports ridership at any location in the network. This is indicated by the experience at the King County Metro lots at the Northgate urban center or the Green Lake Park and Ride, both well inside the City of Seattle street grid and inside the Metro transit network. On the other hand, underutilized PnR facilities well within the network are present in both San José and Los Angeles.

9.4 Serving Disadvantaged Populations

Some transit customers—such as certain segments of the physically disabled and senior citizens who use cars as their main means of mobility—find driving short distances to park at transit centers to be their preferred means of access. They may seek access to transit from their homes exclusively by means of travel in a motor vehicle. When private motor vehicle driving by this class of customers is considered safe and appropriate, then PnR would certainly be much more economical for the transit agency than serving this category of customer using ADA alternative access via paratransit.

Following analysis of demographics, and assuming availability of land, PnR capacity could be arranged to serve suburban pockets of low-income, mobility-deprived residential regions, who may find that parking next to a transit stop is a more affordable commuting arrangement than buying or renting a residence near walkable access to transit. As noted earlier, Census data show that a majority of low-income households own or have access to cars for commuting.

9.5 Suppressing Automobile Travel and Urban Parking

Like TOD, PnR can be thought of as a program for reducing the volume of traffic and VMT in commuter corridors, and for providing support for car parking restrictions at transit destinations.[131] This view of PnR goes well with public policy to control parking in urban districts with service by transit coming in from all corridors. It also goes well with state and regional policy to reduce VMT.

On the other hand, TOD suppresses VMT by becoming a residential district where less driving is initiated because transit is so readily available within walking distance, and few cars from TOD residents show up in transit destinations. This is an entirely different mechanism than PnR diverting car commuters underway into PnR facilities short of the ultimate destinations.

9.6 Rationalizing Parking Management with Pricing

Transit customers are disappointed if their PnR facility destination is frequently full by 7 AM in the morning before they want to arrive. There are many cases in the three case study cities of PnR facilities that fill up that early. But PnR attracting a high level of parking demand that frequently exceeds capacity can be managed via pricing best practices that balance affordability with the maintenance of some available parking capacity throughout the day for off-peak travelers.

In Washington State, there are legal barriers to charging for parking in some facilities. The historical tradition of not charging for PnR parking makes King County Metro in that state reluctant to build more. Note this report from the *Seattle Times* in 2017:

> *But … considering the price of building new parking, they [Metro staff] say there are more desirable ways to maximize space and improve transit access. New parking stalls can cost $30,000 to $75,000 each to build, according to Metro.*
>
> *Here's a cost-benefit analysis by the transit agency:*

> *Doubling the system's current park-and-ride capacity, which includes about 25,000 spots at 137 sites, for instance, would cost $615 million. Ridership, in turn, would increase by less than 5 percent, Metro says.*
> *That cost-benefit ratio is "not as favorable" compared with other investments, Metro spokesman Scott Gutierrez said. Spending money to increase the speed and reliability of service instead, such as by adding new bus lanes, would have a higher return on investment, he said.*[132]

King County Metro is assuming that the agency would bear the full cost of building the additional PnR capacity and then would provide it as free parking. However, while in 2017 there was no legal authority for Metro charging customers for parking, there is no broader public policy excuse for not paying for construction and managing capacity within these facilities through a system of user pricing.

Pricing is best integrated with transit pricing as an add-on, demonstrated as workable in the Bay Area Rapid Transit system and the Washington, DC, Metrorail system. There can be different tiers of fee collection depending on reservation status. Discounts for arriving HOVs help to bring in more transit customers with fewer cars. An important principle to pursue is keeping out-of-pocket parking fees charged to commuters below their cost of car commuting plus parking at employment center destinations.

With what some would call high cost parking rates, kiss-and-ride drop-offs would be encouraged as would motivation for cycling and other non-auto access modes. Revenue from fees can recover the costs of facility operations and maintenance, including the provision of security for cars that are unattended for a full day while the owners are commuting or at work. And most importantly, if legally authorized, the facility could potentially provide value at daily rates that go beyond covering just the cost of operating the parking facility.

As an example, Kepaptsoglou and colleagues developed a research-based pricing scheme for a PnR lot at the central subway station in Athens, Greece, incorporating a multi-layered pricing schedule covering a variety of parking circumstances, including different lengths of time and purpose.[133] Pricing varies according to this schedule:

- Lower charges for metro users;
- Higher charges for other users;
- Unified rates for weekends;
- Pricing as a function of parking duration:
    - Short duration parking: 0–7 hours;
    - Long duration parking: 7–10 hours;
    - Excess duration parking: over 10 hours.

As offered in 2020 by King County Metro in some facilities, PnR can be managed with incentives that give priority in parking and best access to carpools and vanpools. Providing reserved space at a premium price to SOV drivers is another popular strategy chosen by some commuters, another service found in King County.

PnR also provides an opportunity to offer the amenity of electric vehicle charging as a revenue-generating public service.

The absence of PnR pricing can exacerbate inequities in regional transit funding if the additional costs of park-and-ride services are charged to the entire network instead of to the fraction of users who are the beneficiaries of this particular service.

9.7 Objections to PnR

Transit agencies paying to build and operate park-and-ride facilities is a costly enhancement to a transit service that already is not recovering its costs from the fare box. Building PnR is an expensive way for transit agencies to gain additional ridership if there is insufficient cost recovery through parking fees collected from users, which is typically the case, including for the three agencies in this report.

PnR facilities generate nearby road traffic, local peak hour congestion, and air emissions from travelers getting to transit.

Although a main opportunity created by PnR located on the periphery of the agency's service territory is gaining customers coming from beyond where the transit agency's vehicles provide service, a difficult issue arises when the agency sees customers of a park-and-ride facility coming from nearby neighborhoods within the transit agency service territory that are within a short distance of the parking spaces being utilized, thus consuming a resource that is intended for customers originating further away. LA Metro found that many users of PnR come from distances that support walking and bicycling, competing for parking spaces intended for more distant customers.

An illustration of commuter behavior not matching policy intent is provided in a 2020 study that began with concern about the minimal mode-shifting effect of expanding PnR in the highly automobile-dependent Brisbane, Australia, urban region. The researchers found that new PnR facilities tended to draw most users from those who drove from home locations within walking distance of transit service to their final destination, rather than intercepting commuters driving in from areas with no walkable access to transit. The researchers found "that parking and riding is typically on the rise nearer to rapid transport nodes and so too is driving direct to the workplace, while relying only on HOV (including buses and trains) is declining within these spaces."[134]

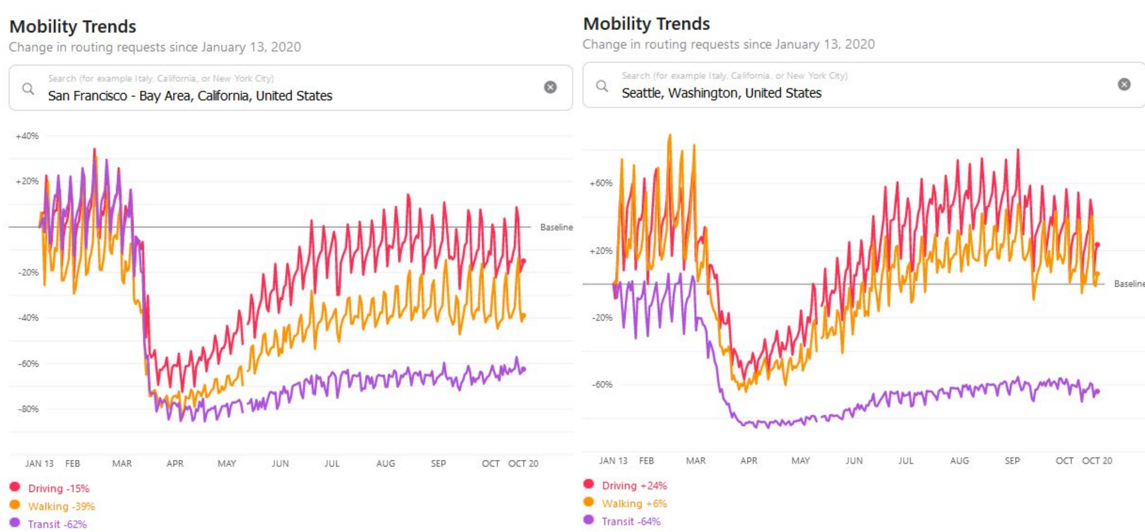
Researchers[135] have found traffic issues inimical to smart growth arise with PnRs if not sufficiently addressed through traffic engineering in site design: for example, traffic congestion in morning and evening peaks from passengers entering or leaving the PnR facility. Beyond the immediate facility access, local automobile traffic generation may not be sufficiently well managed by road authorities not under the control of the transit agency.

Authorities may not want to support consumption of transit capacity at the edges of the network at the expense of walk-on riders closer to the center of the network. Public transit maintains a major orientation to delivering travelers to central business districts, university campuses, and other places of high employment and higher education, which—if smart growth policies are being followed—tend to be well within the boundaries of the transit service territory.

9.8 Responding to the COVID-19 Pandemic

Internet search services such as Google reveal that since March 2020, the use of park-and-ride facilities as sites for the administration of drive-up COVID-19 tests has become common in the US, Canada, the UK, and elsewhere. As shown in Figure 23, public transportation usage has plunged since March 2020 leaving ample capacity for lines of cars in PnR facilities needed less by transit customers and more for critical public health services.

Figure 23. Mobility Trends Showing Plunging Interest in Riding Transit since the Beginning of the Pandemic in March 2020[136]



Source: Apple Computer Mobility Trends Report

Going forward, more importantly, PnR may provide opportunities to assist public transit agencies to maintain health and safety for its customers as the agencies deal with the requirement to restructure vehicle loadings and service frequencies in response to public health guidelines on consumers maintaining personal distance and wearing masks. Work is underway on high-tech solutions to keep the air inside coaches virus-free at controlled levels of loading, but the implementation will take time.[137] Vehicle passenger loads may be forced to be smaller aboard each coach to increase physical distance between transit patrons. At the same time, rising demand may motivate transit agencies to decrease headways between vehicles to maintain line haul passenger volumes when each coach carries fewer people than before. These changes will make service more expensive per customer boarding, and this in turn may lead to some routes being cancelled.

Based on an understanding of transit dynamics, the research team for this project suggests transit agencies consider this service concept: services between the edge of the network and its core immediately surrounding major employment destinations can potentially be maintained by concentrating resources on a limited number of routes with boarding points at PnR facilities at or near the edge. A limited number of organized boarding points at PnR facilities could be places of efficiency and safety by setting up controlled passenger queuing for safe boarding of coaches, offering limited loads boarding quickly in the morning peak commute period. Registration of riders for contact tracing purposes could be required. Kiss-and-ride drop offs, and parking for HOV car loads of neighbors in a shared bubble of confident health status, could be encouraged as safe and efficient ways for customers to connect to the transit network, as long as vehicle capacity controls consistent with social distancing are maintained. Park-and-rides could become the front lines for supporting suburban commuters who are confident that buses with passenger load control and other sanitation measures are good and safe ways to get to work. American Public Transportation Association has issued research-based evidence that a reasonable safety level is possible for transit customers in the pandemic that began in 2020 and may continue even beyond 2021.[138]

This suggested service concept will become even more important if the pandemic drives more population growth into the fringes of urban regions where PnR access to the transit network is more important than in the denser parts of the region closer to employment zones that transit is set up to serve. As of this writing, some experts on urban dynamics, for example Richard Florida,[139] are predicting that dense urban housing may become much less popular as a result of the pandemic, reinforcing the existing growth trend in the suburbs caused by families seeking more affordable housing than what is found closer to employment centers.

X. Combining TOD and PnR at a Station

TOD and PnR may be viewed as alternative or complementary strategies. They are alternative strategies in the sense that, given government and private commercial budget constraints and limited available land, doing more TOD could mean doing less PnR. For example, providing rush hour ramp access to parking spaces at a TOD for transit users who do not live nearby could reduce TOD's quiet, pedestrian-friendly ambience for the occupants of the residential multi-unit housing that are essential to attracting tenants.

On the other hand, co-locating TOD and PnR with synergy in mind can (in theory) make TOD in mixed commercial and residential settings less expensive: PnR may increase the number of visiting shoppers providing service and retail sales revenue at TOD commercial enterprises. Furthermore, there are examples across America of parking spaces for daily commuters coming from miles away placed close by transit stations that also have multi-story residential and commercial space nearby. Examples in Washington State include the Northgate urban center in Seattle and the Redmond suburban downtown to the east. Park-and-ride can support mixed-use development with parking capacity shared between various uses by time of day: residents who drive to work, transit riders who arrive by car, and visitors who are not transit customers. There are other examples of combined parking and TOD housing at a station location in the three case study areas.

Washington State as of 2020 is responding to a public policy trend of combining TOD and PnR, a combination being pursued across all three of the case study sites in this research project. In 2017, the Washington State Legislature requested a study of how to fit TOD housing into a 500 capacity PnR lot along a suburban expressway passing through the Seattle suburb of Kirkland.[140] The lot is now owned by the State DOT but operated by King County Metro. A new express bus service is planned on this highway and will have a station stop at this location. One of several configurations of market-priced apartments, subsidized affordable apartments, and office space is planned to replace 200 parking spaces, adding 600 structured parking spaces for a total additional parking capacity of 900 cars. The project is complicated to put together because of a variety of state legal restrictions that need to be dealt with before the project can proceed, as well as the need for coordination with transit authorities, the City of Kirkland, and participants from the private sector who will design, build, and finance the construction of five- or six-story buildings.

Dense, walkable, vibrant TOD with limited, unobtrusive parking for residents makes station areas more attractive for residents and non-driving transit customers than trying to incorporate PnR parking lots as well. By their nature, PnR facilities may generate significant road traffic in peak commuting periods at the start and end of normal working hours, which degrades the attractiveness of TOD. Parking for drive-up transit customers can discourage walking if the station area reserved for parking presents itself as a physical barrier for those walking to reach the boarding areas for transit vehicles—a design issue for station areas that have PnR and TOD combined in one facility.

XI. Matching Park and Ride to Geography

This section lists the summary of steps to take to ensure that PnR has an appropriate place alongside TOD in a transit agency's playbook and in the region's urban transportation plan.

Seeking to make the growth of an urban region more sustainable through investments in new TOD projects and new PnR facilities requires consideration of needs that are a function of geographic location:

- In the dense urban core, land values, congestion-reduction intent, and rich availability of transit service work against PnR.
- At the ends of existing transit lines, terminus stations, PnR makes sense as an intermediate destination for car commuters coming toward the city.
- At the terminus of future potential transit lines, PnR can be planned as a key part of ridership generation that supports fulfillment of rider forecasts.

As an example that acknowledges the tradeoff between growing ridership in dense parts of the service territory and providing service throughout the less dense parts, Table 16 shows the categorization of actual and potential rail station locations in the Denver metropolitan region with some judgements on the appropriateness of TOD or PnR for each geographic category.

Table 16. Station Typologies in Denver Region: Characteristics and Conditions for Development of TOD and PnR

Typology	Examples from Denver Region	Land Use Density	Employ-ment Density	Resi-dential Density	Accessibility/ Service Levels	Conditions for TOD	Conditions for PnR
Urban Core	Downtown Denver and Downtown Boulder	Very high	Very high	High	Very high	Ripe: at a level that the market will support	Not sensible
Urban	Downtown Arvada/Belmar/Longmont; areas of Broadway' Federal, and Colfax in Denver; DU campus; Anschutz campus; Denver neighborhoods	High	High	High	High	Ripe: at a level that the market will support	Limited & premium priced
Suburban Mixed	Northglenn Marketplace Mall; US 36 and Sheridan Park-n-Ride area; Broomfield Plaza; Colorado Marketplace Shopping Center (Thornton)	Medium	High	Medium	Medium	As a component of existing or new urban centers	Close call; depends on policy objectives and intent to influence commuting patterns and transit loads into the urban core
Suburban Residential	Residential areas of Lone Tree; Highlands Ranch; Northglenn; Thornton; Aurora; Littleton; Parker; Lakewood; Brighton.	Low	Low	Medium	Low/Med	Around station area appropriate for a residential market that exists	Supporting upstream catchment area that can be supported with transit service at PnR locations
Rural	Western US Hwy 285 corridor; I-70 Corridor; front range communities (except Golden); plains communities	Very low	Very low	Very low	Very low	Around station area appropriate for a residential market that exists	At access points for transit to high-density urban locations

Source: Table from a Denver RTD planning document[141] with additional columns added by Niles and Pogodzinski

XII. Policy Considerations for Station Area Land Use

The alternatives of emphasizing the construction of well-managed, responsibly priced park-and-ride facilities on the edge of the transit network versus initiating aggressive steps to accelerate private-sector activity to build affordable TOD housing on land near transit stations can be considered strategic policy choices for allocating limited public funds.

Table 17 summarizes the dichotomy in the issues surrounding TOD versus PnR that have been discussed so far in this report.

The 2015 APTA Guide "Transit Parking 101"—outlining some key considerations in deciding between parking and TOD—begins with this conventional wisdom: "Transit trips begin and end with at least one other mode of transportation. People walk, bike, take a connecting bus, or drive. Transit customers may use one or more of these modes at the beginning of a trip and other modes at the end of the trip. The assumption that parking facilities for auto access to transit should always be provided has given way to a more balanced approach to planning and building intermodal connections."

Table 17. Summary of Issues in Deciding Between PnR and TOD

Station Area Development Option	Best Geographic Locations	Strongest Justifications	Collateral Benefit	Significant Negatives	Collateral Negatives	Efficiency in Generating Transit Ridership
Build park-and-ride capacity in surface lots or parking structures	Suburban	• Meet customer expectation for this form of transit access. • Fill existing or planned transit capacity with customer. • Reduce car use in transit corridors and at transit destinations.	• Potential parking fee revenue. • Popular support for a somewhat less car-intensive, multimodal mobility style. • Support for non-transit demand for parking off-peak.	• Cost of construction and maintenance. • Public criticism of congestion impacts on roads near facilities or aboard coaches from peak passenger loadings. • Visible waste of land and capital investment if PnR is not well used.	• Public criticism of agency support for car-intensive lifestyle. • In terms of resources required for management of parking, demand exceeding capacity. • Customer demand at outlying PnR may overwhelm transit capacity at TOD stations closer to employment centers.	• High • Usage rules can require that all parked car occupants ride transit. • Land use per transit rider is low compared to TOD.
Build TOD residences	Urban core	• Significant revenue to transit agency from land sales or occupancy leases. • Meeting consumer and political expectations for this residential option.	• Visible support for less car-intensive lifestyles. • Great location for affordable, below-market housing,	• Real estate business risks: cost overruns; excessive vacancy rate.	• Implicit support for gentrification and displacement. • Risk of higher housing costs.	• Low • Some but not all residents will ride transit. • Land use per transit rider is high compared to PnR.

This section is intended for transit agencies and regional transportation leadership seeking trade-offs in a balanced approach to the particular station area development options of TOD and PnR. Other potential improvements, such as agency reorganization, fare changes, route re-design, network expansion, or new transit vehicles, are outside the scope of this report.

12.1 Two Strategic Directions to Consider

Assume an urban area contains these typical elements, all found in the three case study service territories:

1. Areas and corridors of strong origins and destinations for public transit, with transit stops and service provided in these areas and corridors.
2. Central business district being the leading transit destination.
3. Vast areas of lower density where transit use is weak and automobile-oriented mobility is strong.
4. Across the urban region, the dominant mode of private driving.
5. A population of mobility-disadvantaged people identified in known locations.
6. Some well used and perhaps over-used park-and-ride locations existing in lower-density areas with transit provided for trips into the denser zones. These PnR facilities are a point of intermodal transfer between transit and private automobiles.
7. Some less-used PnR facilities are candidates for change.

Given the framing just described, two paths of emphasis in maintaining expanding transit usage can be contrasted:

1. PnR emphasis: Pull back on scheduled fixed-route transit service in low-density, automobile-oriented parts of the region, and focus on expanding the capacity and use of the existing PnR gateways to the transit network, adding new PnR locations, and reinforcing special on-demand services for non-car transit access. Leave housing development to the private sector, including consideration of proposals for TOD on underutilized PnR facilities. PnR facilities amount to multimodal mobility hubs focused on connecting two modes; other modes such as cycling and car/van pooling can be supported as well.[142]
2. TOD emphasis: Freeze further development of PnR; manage existing PnR for greater financial sustainability based on user fees; expand station area development programs to create more multi-unit housing and walkable urbanism near transit stations, including consolidating or shrinking land use for parking to make new footprints for

market-rate and below-market affordable housing. Expand the TOD focus outward from easy walking distance to support cycling and other rolling mode access makes transit stations the center point of transit oriented communities.

12.2 Strategic Issues

As a first strategic issue bearing on station area land development, there is an important concept of target population, meaning the subset of the wider population that might be served somehow by public transit. There are different ways to appeal to any target population with different efficiencies. If one started with a blank slate, it would be sensible to locate bus stops at places where residences are densely concentrated, and also to place bus stops where jobs are densely concentrated. TOD creates new residences in an effort to create or enhance customer density, and thus to make the target population bigger.

Can one do PnR instead? If one takes the location of people as given, the suburbs have people located in outlying areas that are less densely populated. If it is worthwhile to try to attract this target population, at some point, the marginal dollar spent expanding a suburban PnR generates more ridership that the dollar spent expanding an existing TOD.

For many environmentalists, emphasizing PnR for suburban taxpayers living in the transit district outside of walking distance to high-quality transit is considered a force for increasing VMT. For this line of thought to be realized, park-and-ride has to be considered guilty of encouraging low-density land use at the edges of service territory. A potential compromise of transit performance can be caused by PnR exhibiting an excessive emphasis on driving from beyond the edges of the network as a source of transit customers, rather than customers arriving by walking, cycling, feeder buses, and other access modes from points more within the boundaries of the service network. In other words, a park-and-ride facility that generates more transit ridership following its opening can be accused of compromising transit performance if the same transit ridership could have been generated by a different access investment that was not as dependent on motor vehicle driving to provide customers. This point raises the question of where the boundary of analysis for a transit access investment should be drawn, and what should be included in the analysis.

One important caveat on the development of agency land next to transit stations is the importance of understanding the capacity of the transit service running by the site. For station development to make sense, there has to be passenger capacity that supports incremental ridership additions from what is to be developed: either TOD that will generate more transit riders, or a PnR facility in which parking is focused on transit-riding customers going aboard at this site. Expanding capacity means adding more bus or train trips on the schedule, which has implications for operating cost.

Thus, when and where transit ridership should be expanded is an important issue that bears on the decision to provide PnR or TOD access. Under pressure of rising costs and falling revenues, transit agencies recognize ridership gains as a two-edged sword, causing an expansion of subsidy requirements if transit capacity has to be expanded to serve customers arriving in the morning at

PnR facilities on the outer edge of the transit network. For little or no expansion of subsidized service, the better opportunity for agency sustainability may be to fill up existing routes showing excess capacity with TOD-generated ridership closer to major transit destinations in central business districts.

12.3 Accessibility Arguments

A 2019 book by Levine and colleagues[143] makes the case for understanding the growing importance of accessibility for transportation planners. It argues the importance of destinations as the primary reason for travel, not the trip itself.

Accessibility to destinations is provided by a combination of mobility, connectivity, and physical proximity.[144] "Mobility" refers to physical movement of people with all of its characteristics, including travel time, reliability, mode, and environmental impact. "Connectivity" refers to the various means of delivery of goods and services, including both physical delivery and telecommunications applications, but not the connectivity of road networks and not the ease of connections between transit lines or between modes, which fall under mobility. "Proximity" refers to the spatial pattern and density of land use over which travel and delivery destinations are dispersed.

The common word usage of urbanists, criticized in the Levine book, has mobility and accessibility as alternative choices for urban design emphasis, with mobility considered synonymous with vehicle roads. Urbanists characterize accessibility by the proximity afforded by compact development that supports human movement by walking, cycling, and transit.

In contrast, because of the massive existing use of cars in suburban residential zones, the Levine book provides clarity with its suggestion to place accessibility at the top of a hierarchy that has multimodal mobility, proximity, and connectivity as alternative means to achieve accessibility. Precisely because of automobile dominance in large swaths of the urban landscape, accessibility defined in this precise and technical way is worthy of prime consideration in the existing multimodal transportation system's intentional development and its market-driven evolution.

TOD supports accessibility for its residents with a combination of walkable proximity and transit mobility. This style of development supports some citizens' preference to live and to travel within an urban region without always using a car.

PnR supports accessibility in a different manner than TOD, but it nonetheless supports accessibility to important destinations. PnR supports proximity to transit mobility on the edges of the transit network for users living beyond a walkable catchment area of station proximity and therefore lowers the time and money cost needed to reach usual or new employment centers and other destinations served by the transit network. PnR supports some travelers' preference to reduce automobile driving in congested or otherwise difficult segments of a total journey where transit provides convenient mobility.

In support of the accessibility justification for PnR, a 2019 research study[145] in the Minnesota Twin Cities urban region of Minneapolis and Saint Paul found the bus-PnR mixed mode combination provided three times the suburban workers' access to employment opportunities than the walk-to-transit mode by itself. For those able to ride in or drive a private vehicle, regional park-and-ride locations throughout the suburbs of the Twin Cities metro area make public transit more competitive with door-to-door automobile commuting for access to employment locations.[146]

Further research would probably verify that this benefit would apply to the urban regions of California, Washington, and other states. A 2018 study in the United Kingdom found overall benefits in a case study of bus-based PnR in Chelmsford, even while recognizing that the reduction of driving into the city center was exceeded by driving to reach the parking locations.[147]

In summary, the strategic choice of whether to emphasize TOD or PnR is influenced by the form of accessibility sought and the choice of the targeted consumer cohort.

12.4 No Congestion Relief Either Way

Transit oriented development (TOD) and park-and-ride (PnR) are two distinct urban design strategies to provide transit access, but they operate to stimulate transit boardings in different ways.[148] TOD creates urban environments in which people reside, work, and shop, and residents are motivated to leave and arrive by transit since access to a station is nearby, within walking distance. PnR is a facility at a transit station that exists for the purpose of allowing citizens who own cars to gain access to transit by driving to the station to go someplace else—perhaps even another station one or two stops away with TOD surrounding it.

Reduction of traffic congestion is not likely to be a measurable result from the relatively small fraction of commuters riding transit accessed at park-and-ride facilities instead of driving, as long as driving cars into downtown and other major employment destinations is allowed, and assuming significant numbers of commuters return to normal working hours as the 2020 pandemic eventually recedes in dense employment centers.

Differently than the traffic dynamic seen from PnR, TOD influences congestion by creating zones where cars are not always necessary and sometimes limited or even banned. By virtue of transit access being nearby at a walkable distance, TOD residents arriving and departing from their homes without driving a car are supported and encouraged. Outside of TOD or larger TOC zones, the fraction of peak travel that TOD residents influence by their mode choice of transit is likely miniscule relative to commuter volumes originating in sprawling suburban bedroom communities. Furthermore, if parking facilities inside TOD zones are made available to visitors driving cars from the outside, local congestion within transit oriented communities may result.

No regional traffic modeling that the authors are aware of has found relief from traffic congestion coming from expansion of PnR or TOD.

As explained in the pre-pandemic era by Anthony Downs,[149] the dynamics of peak highway capacity are a formidable force making ongoing congestion from commuter car traffic difficult to suppress. The source of congestion is the existence of normal working hours honored by a high percentage of downtown workers or factory workers in employment centers that are the focus of transit services. The fact of starting and ending times being similar for businesses in concentrated employment centers has productivity benefits because face-to-face human interaction is facilitated when people are present at the same time in the same place. This practice causes peak congestion for the flows into employment center on weekday mornings, and then later flows away from employment centers at the end of the workday.

As explained most cogently by Downs, there is a "triple convergence" that fills new empty spaces on highways caused by the cars removed when a peak period road commuter switches to become a new transit rider. Another car driver is nearly certain to appear predictably to fill the new road space from one of three sources: a person who is traveling on the shoulder of the peak who would rather be in motion during the peak time; a person who moves from a slower less crowded route to a route made easier because of transit riders; or a commuter who quits riding transit in favor of a car that moves better because of people using transit instead of driving. To this list can be added a fourth source of new traffic: at-home, part-time teleworkers who would really rather drive into the office during the peak instead of working at home until after peak before driving in.

While Downs did his writing in pre-pandemic years, his conclusions remain valid, since as of this writing, car traffic volumes, after dropping lower during the pandemic, are rising to previous levels, as shown above in Figure 23 for the case study cities.

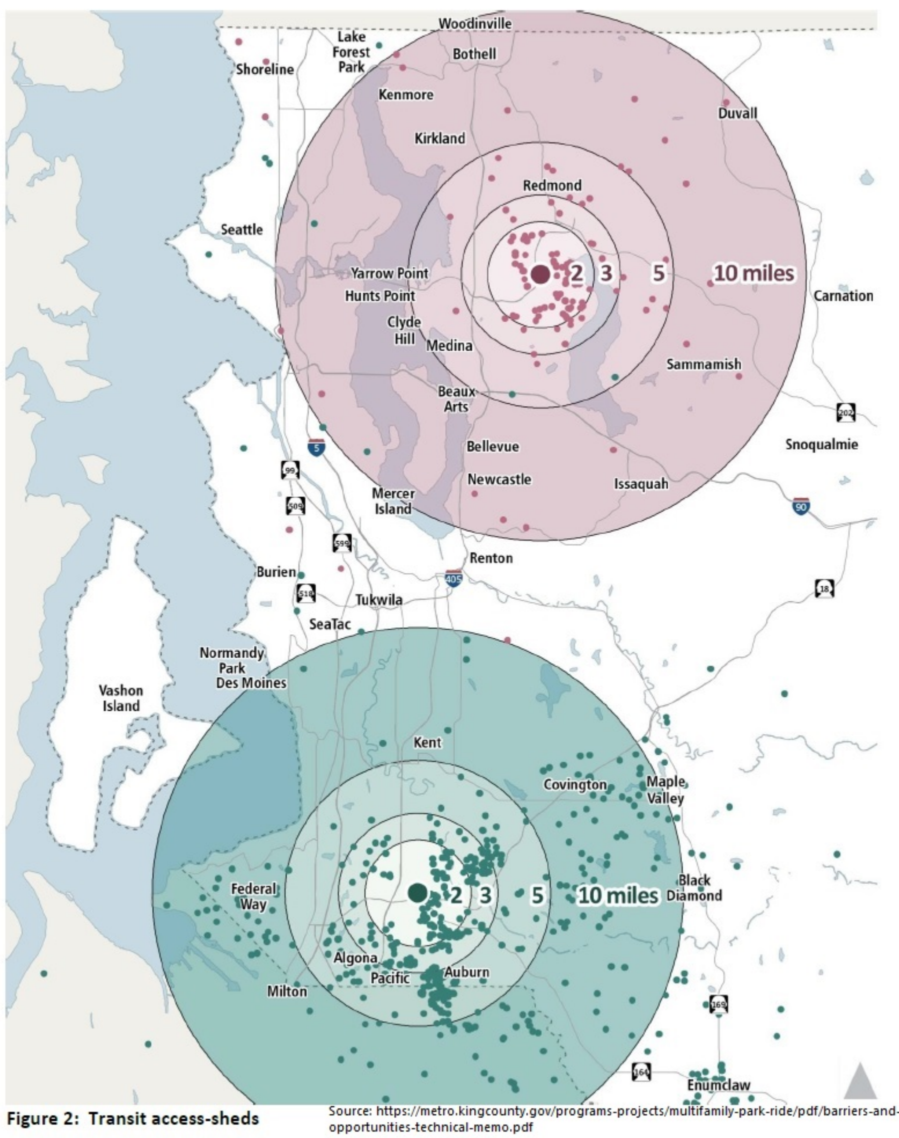
12.5 Uncertain VMT Reduction

As covered earlier, there is a plethora of research that demonstrates that people who live in TOD residential properties drive less across all trip purposes than people who do not live in TODs.[150] At the same time, a daily commuter who parks near a transit station generates an amount of VMT to reach the station, and then takes a transit trip that covers a distance that eliminates any additional VMT from being generated on the complete commuting trip. This usually, but not always, means that the PnR-using transit customer is generating less VMT than would be the case if she were driving the entire round trip from home to work. An easily visualized exception would occur if the PnR were geographically displaced significantly off of the direct driving path and at the same time were very close to the transit destination point.

But a theoretical lifestyle comparison can also be made between the VMT in this two-mode trip and the lower amount of VMT that would accrue if she were to make a residential choice that resulted in her living within the TOD zone and leaving her car parked all week because walking and taking transit were her new daily mobility habit. On a regional scale, the VMT implications arise from considering the degree to which PnR and TOD are motivating two distinct lifestyles that have contrasting amounts of VMT generated, with TOD motivating low-VMT, transit-oriented lifestyles, while the availability of PnR generates high-VMT lifestyles based on sprawling home locations located well outside the edges of the transit network.

One opportunity in PnR usage management is to discourage short driving trips to PnR facilities in order to focus on serving longer distance trips where walking, cycling, or hopping on a local bus is less available or appropriate. Driving a short distance to access a transit station may be preferred by a commuter for a variety of private reasons which there is no public policy reason to discourage. License plate surveys do show some customers arrive from close distances, as illustrated in the starting locations of customers in two King County PnR facilities shown in the map in Figure 24. The experience of Brisbane, Australia, mentioned earlier, revealed this problem as well. In fact, use of PnR by customers with short distance origins could be managed via registration of regular customers and pricing.

Figure 24. Home Locations of PnR Customers at Two King County PnR Facilities

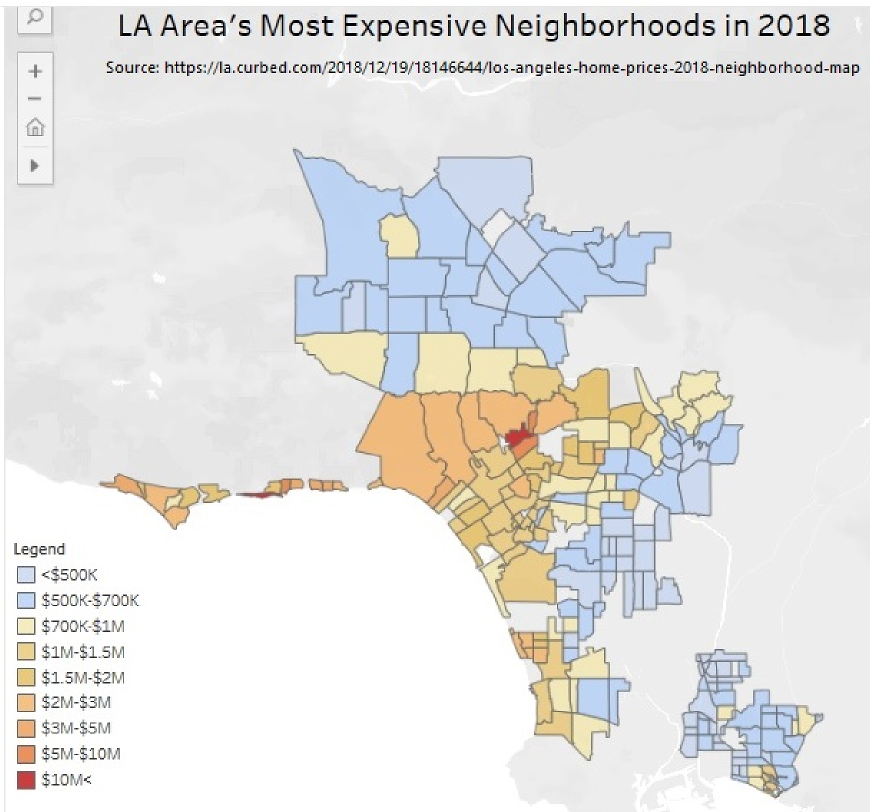


Source: Consultants' technical memo to King County Metro[151]

12.6 Addressing the Housing Affordability Crisis

Meeting the affordable challenge by intentional subsidized affordable housing at transit stations is celebrated public policy, but it does not address the fact that many people having already moved to suburban locations further away from in-city employment districts to find affordable housing. Maps of housing prices in west-coast US cities like Los Angeles, illustrated in Figure 25, show that lower prices obtain in the suburbs as the crow flies away from the city center. This dynamic in turn means that much affordable housing is not within walking distance of transit.

Figure 25. Housing Affordability in Los Angeles



Source: Curbed Los Angeles Blog, December 19, 2018[152]

The choice of living within walking distance of transit is associated with a price premium on housing. Commuters accessing transit by driving to PnR may be considered an inferior second choice, but the supply of subsidized TOD housing within walking distance of boarding points for buses and trains does not meet the demand for affordable places to live. Affordable housing in TOD zones within walking distance of transit stations is a relatively modest contribution to the affordable housing crisis that plagues San José, Seattle, and Los Angeles.

Zones of walkable urbanism may hopefully be reached on public transit, but transit access is not logically required between such zones, nor needed to reach such zones from low-density areas. Zones of affordable housing generated by the economic dynamic of private-sector development of lower-value suburban land can include intentionally designed zones of vibrant, walkable retail, service, commercial offices, entertainment, and recreation accessible by walking from parked automobiles left in lots and structures around the edges. Insignificant public transit access would not block success. For example, the Disney parks in California and Florida are surrounded by acres of parking, but there are walkable, no-car zones inside their boundaries, with internal personal mobility provided by various modes of transit, including buses, ferries, and monorail. Similarly, car mobility in combination with PnR for all-day car storage on the edges of the typical citywide transit network can provide the intermodal interface between sprawl and the legacy denser development that can be better economically served by a transit network.

How best to provide more affordable housing in urban regions like the three studied here is beyond the scope of this report. Programs to build it near transit stations in walkable urbanism do exist, as the three case study cities illustrate. Yet forces of the market are generating affordable housing in locations not located near transit access, reflecting the suburbanization of poverty. Households in this second group are likely to need cars, and some of those cars are likely to be found during the workday in PnR. There is evidence that PnR supports accessibility to employment locations. As described in the section above on Accessibility Arguments.

As a concluding point on strategy, the level of investment in new transit facilities and services, any real estate transactions yielding affordable TOD housing, and any decisions to expand PnR should all reflect the context of the total system and the region it serves, including government choices made to give equitable support for the mobility-disadvantaged. There is good research on hand that suggests government services helping those lower-income households coping with the reality of economic hardship and car-dominated suburban living are worthwhile.[153]

All these points notwithstanding, neither TOD nor PnR has made large-scale, visible contributions to housing affordability measured by the crisis levels found in the three case study cities as of this writing, as shown in Table 14. The data show that San José, Seattle, and Los Angeles have high priced housing relative to income compared to other world cities. This raises the question of whether the broad, ongoing public policy emphasis on promoting densification of residential living near transit stations is a cause of higher housing prices and non-affordability for residents, but that is a question outside the scope of this study.

12.7 Weak Links Between Policy and Performance

The signaling of a government's policy preferences to the general population is perhaps a more important effect than the empirical relationships of each station treatment to the amount of car driving and transit riding that actually results. In other words, PnR reinforces the point that living in the suburbs and accessing transit via driving to a station is supported as one way to live. On the other hand, an emphasis on TOD signals that the option to live near a station and walk to it is a different way to live that the government supports and encourages. The leaders of the local democracy in which a transit agency is embedded may decide to prefer one approach or the other based on values and hopes. However, the effectiveness of policy hinges on how people behave, and what performance results obtain from the behavior are uncertain, as illustrated in Table 18.

Following up on consideration of the distinctions that result from emphasizing TOD or PnR in regional development, an important caveat is that at the urban regional level, the causal linkages are weak between policy-motivated changes on the one hand, and overall resulting regional performance across typical sustainability measures on the other. In other words, for example, changes in the public transit infrastructure and services such as more PnR, or changes in private infrastructure such as TOD, may not yield large desired changes in measures of sustainability, efficiency, and mobility, because of the influence of many exogenous environmental and economic variables that policy-makers are not able to control sufficiently. The COVID-19 pandemic beginning in 2020 is an obvious example. Another important example of an exogenous influence is the likely deployment of technological improvements in automobile travel from several sources: growing energy efficiency, applications of automation, and wireless connectivity, all potentially making car mobility even more attractive to consumers than it is now.[154]

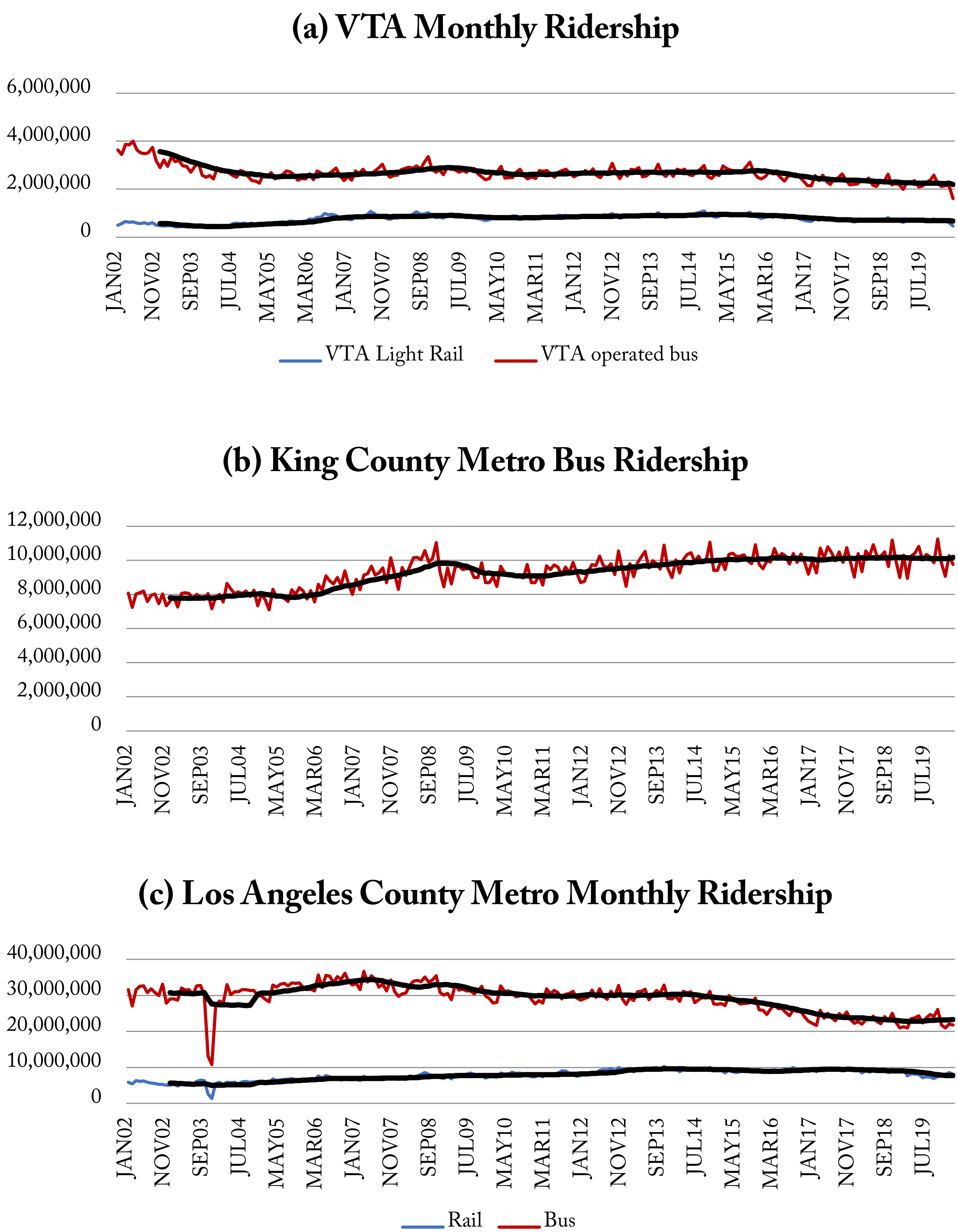
Table 18. Illustration of Weak Linkages Between Action and Improved Performance

Potential public policy-motivated changes bearing on performance metrics	*Influences not controlled by governments stand in the way of changes bringing about improved performance*	*Improvements sought in these performance metrics that are not easily achieved via public policy*
• Geographic coverage of transit service • Frequency of transit service • Span of transit service • Reduce or increase PnR at boarding points within the service area • Increase or reduce PnR facilities on the service area periphery serving outlying regions • Setting fees for PnR parking • More TOD at boarding points • Supply and price of parking in employment centers • Land use zoning	• Demographic changes • Economic changes • Entrepreneurial innovation • New technology applications • Political dynamics • Unexpected effects of planned changes • Unforeseen events • Misunderstood influences revealed	• Transit mode share in corridors or zones or agency-wide • Economic viability of the transit agency • Travel time and reliability in congested commuter corridors, or generally • VMT in the region or in transit influence zones • Air quality in the region • GHG emissions in the region • Housing affordability • Services to mobility disadvantaged • Private vehicle ownership and use

Source: Created by Niles and Pogodzinski

As one illustration of weak linkages, the three case study agencies have been focusing first on PnR, and then on TOD, for over two decades as of this writing. Yet in Los Angeles and San José, transit ridership has not seen growth, and even in Seattle bus ridership growth has been modest since 2014, as shown in the plots of monthly ridership since 2002 in Figure 26, and before the COVID-19 pandemic.

Figure 26. Monthly Transit Ridership since 2002 in the Three Studied Agencies



Source: US National Transit Database

The weak linkages of policy-motivated programs to performance results have already been illustrated earlier in this section in the discussions on how PnR and TOD bear on congestion relief and on affordable housing.

XIII. Summary: TOD versus Park-and-Ride as Alternatives

Argument for a TOD Residential Density Strategy

- TOD, closely aligned with smart growth and walkable urbanism, influences transit ridership positively by creating new residential neighborhoods well served by public transit boarding/egress points within walking distance.
- TOD can be a policy-driven, revenue-generating substitution for PnR on available land that has parking facilities that are underutilized. Dedicating agency land to TOD generates new forms of revenue on a scale beyond riders' fare payments.
- TOD supports low-VMT lifestyles of residents who choose to live in TOD. If parking is managed at a low level through pricing and limits on supply, VMT caused by visitors to the site can be limited as well. These reductions amount to implementation of the car-limiting smart growth urban strategy and are a visible manifestation of intent to move away from urban private motor vehicle use.
- While it requires great effort and typically complex partnerships and deal-making across multiple public-sector bodies and private-sector development and financial institutions, affordable housing built near transit boarding areas provides a counter-force to the natural tendency of real estate valuation to rise within walking distance of transit stations.

Argument for a Park-and-Ride Strategy

- PnR facilities influence ridership positively if matched with transit service that goes where potential travelers in the planned customer catchment zones seek to go. PnR attracts and can sustain the ridership needed to justify public expenditure on new or existing high-capacity transit lines, whether rail or bus. Parking spaces should be priced to generate agency revenue supporting transit's financial sustainability, including coverage of construction and operating costs of station-adjacent parking.
- PnR provides transportation connections for person trips that go between zones of smart growth and the sprawling, car-dependent suburbs. It expands the geographic reach of the transit network by attracting riders from areas not well served by transit routes. It will also attract customers who could use bus or microtransit on-demand services to reach the facility, but who seek a faster or more reliable trip.
- PnR serving residential markets on the outer residential zones of a transit service territory support reduced VMT in and around inner-city employment centers and other transit destinations, and in the road corridors leading to transit destinations. PnR reduces vehicle use at congested transit destinations, an especially important goal when parking at those destinations is limited.

A summary of reasons to prefer either PnR or TOD as a regional strategy is based on leadership judgement regarding the best path of mobility development, with contributing factors for both shown in Table 19, with all information derived from existing literature as noted in the references. This table provides guidance if limits on resources force a choice. Across the three studied agencies in this report, both strategies are being pursued.

Table 19. Linkage of Mobility Goals and Problems to PnR or TOD Emphasis

TOD Emphasis Supports	PnR Emphasis Supports
New revenue source for transit agency	Access to transit network for suburban customers
Restraint of private car mobility	Efficient ridership growth
New locations for subsidized no-car housing	VMT reduction in the CBD and commuter corridors
Enlarged use of active modes and non-motorized access to transit	Transit operational productivity for serving low-density zones
Promotion of exemplary residential densification	Sustainable, priced, private car parking for access to transit

Source: Judgement of authors

Based on the econometric analysis in Chapter VII, this report concludes that park-and-ride is a more efficient and effective way to grow ridership than transit oriented development.

Despite the public policy justifications for TOD being preferred as a development emphasis near transit stations, if increasing ridership at transit access points is sought, parking there is always an important option to be considered. The subsidy for transit customers to park should be added to the public subsidy covering their ride on buses and trains, and both should be managed as a totality in light of transit's policy justification for supporting complete trips from any doorway to any other doorway in the transit taxing district. Pay-to-park facilities with price-managed capacity combined with fare-managed provision of capacity in the transit coaches is a reasonable multimodal combination for anywhere in the transit network.

This report noted earlier that Washington State DOT found the park-and-ride system around Seattle in the late 1980s to be cost-effective. In a survey of park-and-ride users and usage in the Bay Area published in 2005, scholars from University of California Transportation Center (UCTC) at University of California–Berkeley noted in conclusion,

> *The findings confirmed that park-and-ride lots need to be discussed as part of any policy dealing with the growth of transit in the San Francisco Bay Area. These facilities are widely used by different demographic groups around the region, and they are in dire need of maintenance and upgrades. The rating questions as well as focus group discussions pointed to the need for making parking lots safer, well lit, and comfortable places to wait. Cleanliness and the lack of security were mentioned as issues that need to improve. Many lots are oversubscribed or fast approaching capacity, and there is a need to come up with new ways to increase parking supply.*[155]

Fifteen years later, this comment remains valid. In 2020, with a pandemic underway with uncertain prospects of ending, government policy in both Washington State and California now emphasizes getting commuters out of their cars and onto transit in the face of consumers' overwhelming preference for automobile usage. Supplementing the complex efforts to generate affordable housing developments near transit with an additional focus on price- and reservation-managed park-and-ride on the fringes of the transit network comprises a multimodal, equitable approach to reducing VMT. Expensive parking and a pedestrian-cycling emphasis in downtown employment centers have arrived to make driving less desirable. It makes more sense than ever to provide places where suburban drivers starting out from beyond where transit goes can find the option to stop short of congestion further down the highway, park, lock up, and board COVID-safe, capacity-managed transit vehicles for the rest of the daily journey.

Appendix A: Sources of Transit Agency-Related GIS Layers

Santa Clara Valley Transportation Authority

Data for VTA GIS files (stops, lines, light rail stations and platforms, and park-and-ride lots) were obtained through the VTA Open Data portal (https://data.vta.org/). Likewise, ridership data for 2014-2017 was obtained through the VTA Open Data portal. Additional GIS files related to park-and-ride lots were obtained through the Metropolitan Transportation Commission Open Data portal (https://opendata.mtc.ca.gov/datasets/park-and-ride-lots-2007).

King County Metro

Data for KC Metro GIS files (stops, lines, and park-and-ride lots) were obtained through the King County Open Data portal (https://gis-kingcounty.opendata.arcgis.com/). Ridership data was obtained by email from King County Metro via John Niles request of KC Metro staff member Jack Whisner.

Los Angeles Metro

Data for LA Metro GIS files (stops and lines) were obtained through the LA Metro GIS Developer website (https://developer.metro.net/docs/gis-data/overview/). Ridership data was obtained from LA Metro via Erik Sachs. Additional data about park-and-ride facilities was obtained from 511.org (https://go511.com/ParkAndRide/Index). Park-and-Ride lots were geocoded using the Texas A&M University geocoding service (http://geoservices.tamu.edu/).

Note

Ridership count data measured morning transit boardings in the three agencies. Different numbers of days were counted for the dependent ridership variables in the different agencies, as visible in the differences across the "AM_Boardings_Int" descriptive statistics for the three agencies in Appendix B.

Appendix B: Descriptive Statistics of Transit Agency Samples

VTA					
Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
AM_Boardings_Int	3,034	94.2	329	1	6460
MedHHInc	3,034	107944	35010	21908	244239
HU_stop	3,034	555	261	4.04	1721
EMP_stop	3,034	742	1022	10.7	10132
LRDummy					
0	3,034	0.961	0.193	0	1
1	3,034	0.039	0.193	0	1
PnR_small_QMiDummy					
0	3,034	0.981	0.138	0	1
1	3,034	0.019	0.138	0	1
PnR_medium_QMiDummy					
0	3,034	0.970	0.170	0	1
1	3,034	0.030	0.170	0	1
PnR_large_QMiDummy					
0	3,034	0.974	0.158	0	1
1	3,034	0.026	0.158	0	1
inter_QMiDummy_DIST_cityhall	3,034	886	4235	0	46663
QMiDummy	3,034	0.075	0.263	0	1
Spaces	3,034	259	209	22	1155
Dist_PnR	3,034	2182	1837	11.9	16826
MedHHInc_Low					
0	3,034	0.750	0.433	0	1
1	3,034	0.250	0.433	0	1
MedHHInc_Medium					
0	3,034	0.500	0.500	0	1
1	3,034	0.500	0.500	0	1
MedHHInc_High					
0	3,034	0.750	0.433	0	1
1	3,034	0.250	0.433	0	1

Note: The boarding count for VTA covered the total of all weekday mornings in October 2017.

King County Metro					
Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
AM_Boardings_Int	6,525	17.5	55.3	0	1084
MedHHInc	6,525	92530	32989	0	222500
HU_stop	6,525	540	620	13.8	6145
EMP_stop	6,525	933.9	2786.6	1.87	26587
PnR_small_QMiDummy					
0	6,525	0.994	0.077	0	1
1	6,525	0.006	0.077	0	1
PnR_medium_QMiDummy					
0	6,525	0.984	0.127	0	1
1	6,525	0.016	0.127	0	1
PnR_large_QMiDummy					
0	6,525	0.992	0.089	0	1
1	6,525	0.008	0.089	0	1
inter_QMiDummy_DIST_cityhall	6,525	1905	11820	0	165589
QMiDummy	6,525	0.030	0.172	0	1
Spaces	6,525	195	233	9	1614
Dist_PnR	6,525	6787	5395	19.3	60156
MedHHInc_Low					
0	6,525	0.747	0.435	0	1
1	6,525	0.253	0.435	0	1
MedHHInc_Medium					
0	6,525	0.495	0.500	0	1
1	6,525	0.505	0.500	0	1
MedHHInc_High					
0	6,525	0.758	0.428	0	1
1	6,525	0.242	0.428	0	1

Los Angeles Metro					
Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
AM_Boardings_Int	2,421	4.82	23.6	0	535
MedHHInc	2,421	57529	27173	0	198559
HU_stop	2,421	920	713	0	4528
EMP_stop	2,421	1305	2399	8.42	28036
LRDummy					
0	2,421	0.960	0.195	0	1
1	2,421	0.040	0.195	0	1
PnR_small_QMiDummy					
0	2,421	0.989	0.105	0	1
1	2,421	0.011	0.105	0	1
PnR_medium_QMiDummy					
0	2,421	0.974	0.158	0	1
1	2,421	0.026	0.158	0	1
PnR_large_QMiDummy					
0	2,421	0.973	0.163	0	1
1	2,421	0.027	0.163	0	1
inter_QMiDummy_DIST_cityhall	2,421	855	4021	0	39361
QMiDummy	2,421	0.06	0.24	0	1
Spaces	2,421	385	425	18	1860
Dist_PnR	2,421	3139	2548	6.85	16547
MedHHInc_Low					
0	2,421	0.750	0.433	0	1
1	2,421	0.250	0.433	0	1
MedHHInc_Medium					
0	2,421	0.500	0.500	0	1
1	2,421	0.500	0.500	0	1
MedHHInc_High					
0	2,421	0.750	0.433	0	1
1	2,421	0.250	0.433	0	1

Abbreviations and Acronyms

ACS	American Community Survey of the US Census
ADA	The Americans with Disabilities Act, signed into US law on July 26, 1990
APTA	American Public Transportation Association
BART	San Francisco Bay Area Rapid Transit
Caltrans	California Department of Transportation
EPA	Environmental Protection Agency
FTA	US Federal Transit Administration
KC Metro	King County (Washington State) Metropolitan Transit Authority
LA Metro	Los Angeles County Metropolitan Transportation Authority
MPO	Metropolitan Planning Organization (a Federal designation)
MTC	Metropolitan Transportation Commission (MPO for the San Francisco Bay Area, including Santa Clara County)
NASEM	US National Academies of Sciences, Engineering, and Medicine
NTD	National Transit Database (maintained by FTA)
PnR	Park and Ride
PSRC	Puget Sound Regional Council (MPO for Seattle Tacoma region, including King County)
TCRP	Transit Cooperative Research Program of TRB
TOC	Transit-Oriented Communities
TOD	Transit Oriented Development
TRB	Transportation Research Board of NASEM
VTA	Santa Clara County, Valley Transportation Authority
WSDOT	Washington State Department of Transportation

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