From: BRIAN CHAMBERS
Sent: Thursday, May 19, 2022 6:23 PM
To: Planning <Planning@a2gov.org>; Lenart, Brett <BLenart@a2gov.org>; Higgins, Sara <SHiggins@a2gov.org>; Disch, Lisa <LDisch@a2gov.org>
Subject: Parking Regulation Amendments and Comprehensive LandUse Update

Brett and Planning Commission:

Thank you for the in-depth discussion on my comments to your Parking Regulation Amendment regarding TC1 parking structures.

While it is after the fact, I'd like to provide a recent research article, 'Comparative Case Studies of Parking Reduction at Transit-Oriented Developments in the USA' - Transportation Research Record - 2021 - Vol 2675 - National Academy of Sciences - Transportation Research Board.   See attached.

Bottom Line Upfront :

This study addresses the question of parking supply and demand at transit-oriented developments (TODs) through comparative case studies of seven TODs in the U.S.A.

As far as the authors can determine, this is one of the first studies to estimate peak parking generation rates for TODs.

This paper estimates vehicle parking reductions associated with TODs, defined as dense, mixed-use developments proximate to high-quality transit, as compared with conventional suburban development.

The results indicate that, in almost all cases, the TODs in the sample supply much less parking than is called for in ITE guidelines. Despite these supply restrictions, demand for parking at TODs is well below the supply. That is to say, TODs are generally over-parked.

The operative phrase is: 'proximate to high-quality transit'.   AAATA's upcoming millage request is therefore on the critical path.

Having listened to your discussion on the '3 cars / 1,000 SF of building floor space' it is still unclear to me where how this maximum standard was determined. Presuming the targeted housing densities are in the 3,500 - 5,500 unit range for the State and Eisenhower parcels (see my previous email on TOD best practices for 'village' scale bus-line transit), there are many mixed use TOD style developments around the nation from which lessons learned and best practices can be extracted.

I will share this concern and paper with City Council when the proposed ordinance changes are on their agenda.

Also, regarding your proposed resolution on the Comprehensive Land Use Update, I found the scope and basis for the resolution phenomenal! The elements that addressed equity, climate and sustainability, as well as affordability were all entirely in-line with my professional and personal beliefs and values.

One might even call it 'aggressive' (ha!) - BRAVO !

On that basis I am looking forward to being an enthusiastic supporter and advocate for it as it goes to Council

Thank you for your great work on these challenging Ann Arbor land use and development policy issues.

Yours for equity-based sustainable development,

Brian Chambers, Ph.D.
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Research Article

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Comparative Case Studies of Parking Reduction at Transit-Oriented Developments in the U.S.A.

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Abstract

This study addresses the question of parking supply and demand at transit-oriented developments (TODs) through comparative case studies of seven TODs in the U.S.A. As far as the authors can determine, this is one of the first studies to estimate peak parking generation rates for TODs. Developments are often characterized in relation to "D" variables—development density, land use diversity, urban design, destination accessibility and distance to transit. The seven TODs studied in this project are exemplary when it comes to the Ds. At the overall peak hour, just 51.2%–84.0% of parking spaces are filled. Because of limited use of shared parking, even these exemplary developments do not achieve their full potential. At the overall peak hour, parked cars would fill just 19.5%–69.4% of parking spaces if the developments were built to Institute of Transportation Engineers (ITE) standards. With one exception, peak parking demand is less than 60% of the parking supply guideline in the ITE *Parking Generation* manual. A sixth D, demand management (parking management), is mixed at the TODs studied. For one thing, there is a dearth of shared parking, though opportunities abound. Another area in which parking policies are not always smart is in bundled residential parking. At some TODs, a parking space/permit comes with each apartment whether the renters want it and use it or not. Such parking is effectively free. A third area in which parking policies are not always smart is in free commercial parking, the counterpart of bundled residential parking.

Parking is expensive to supply, especially as land values rise. Numerous studies suggest that much of the U.S.A. is already over-parked, that is, parking supply is greater than demand (*1*, *2*). At a certain point, mandatory parking minima can distort land markets by mandating the provision of parking in excess of what the market would supply or would be demanded at peak times. This may inhibit infill and redevelopment, or make new development prohibitively expensive. On parking supply and demand, some favor the elimination of minimum parking requirements imposed by local governments allowing the market to decide what level of parking makes economic sense (*3*).

In this regard, the Institute of Transportation Engineers (ITE) trip and parking generation manuals have been used as guidebooks to estimate the impacts of proposed developments on an area's transportation system. While the ITE guidelines are the most widely used source of information for trip and parking generation estimates of new developments in the U.S.A., a series of recent trip and parking generation studies for transit-oriented developments (TODs) report significantly lower vehicle trip generation rates than those in the ITE manual (*4*–*7*). Nevertheless, it is still unclear whether and to what extent parking generation rates would be reduced in TODs.

This study addresses the question of parking supply and demand at TODs through comparative case studies of seven exemplary TOD cases in seven regions of the U.S.A.: Redmond TOD in Seattle; Rhode Island Row in Washington D.C.; Fruitvale Village in San Francisco-Oakland; Englewood TOD in Denver; Wilshire/Vermont in Los Angeles; Orenco Station in Portland; and Mockingbird TOD in Dallas. Comparative case studies are defined as "the analysis and synthesis of the similarities, differences and patterns across two or more cases

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that share a common focus or goal in a way that produces knowledge that is easier to generalize about causal questions" (*8*).

The remainder of this paper is structured as follows. First, we provide a review of limited studies that measured the transportation benefits of TODs (in terms of parking reduction), quantitatively. TODs are then defined with eight criteria and potential TOD cases that meet all criteria in seven diverse metropolitan regions are identified. Then, parking generation at TODs in these seven regions is measured, using field observation of parking occupancy counts and an intercept survey of people visiting the study areas. The aim, in particular, is to determine how much less parking is required at TODs than the new ITE *Parking Generation* manual (5th Edition) suggests for auto-oriented developments generally. The original version of this paper compared the parking supply guidelines in the ITE *Parking Generation* manual (3rd Edition) with the authors' findings on peak parking demand at TODs. Comparing these findings with the parking supply guidelines in the 5th Edition, in the current version of this paper, it can be seen that ITE has made a serious and successful effort to improve the publication (at least with respect to low-impact developments such as TODs). The last section presents the conclusions and provides some policy recommendations.

Literature Review

The question of how much reduction of vehicle trip and parking demand occurs with TOD is still largely unanswered in the literature. Everyone agrees that there should be some reduction, but is it 20%, or 40%, or more? Since trip and parking generation are interconnected, first a brief review of studies on trip generation at TODs is presented in this paper, and then a review of the literature on parking generation in detail.

Surveying 17 housing projects near transit in five U.S. metropolitan areas, Cervero and Arrington (*9*) found that vehicle trips per dwelling unit were substantially below ITE's estimates. Over a typical weekday period, the surveyed housing projects averaged 44% fewer vehicle trips than the numbers estimated by using the ITE manual (3.754 versus 6.715). Another study, by the San Francisco Bay Area Metropolitan Transportation Commission, found that residents living near transit generated half as many vehicle miles traveled as their suburban and rural counterparts (*10*). At the same time, Bay Area residents living in developments near transit are reported to have higher rates of transit trips than those living at greater distances (*10–12*), especially for commuting trips (*11, 13–16*).

Studies show that vehicle ownership is lower in transit-served areas than those that are not transit-served (*11*, *12*). In relation to parking generation at transit-served sites, the third edition of the ITE *Parking Generation* manual notes that the study sites on which the manual is based are "primarily isolated, suburban sites" (*17*). By comparing parking generation rates for housing projects near rail stops with parking supplies and with ITE's parking generation rates, Cervero et al. (*4*) found there is an oversupply of parking near transit, sometimes by as much as 25%–30%. Oversupply of parking spaces may result in an increase in vehicle ownership (*9*). This is supported by the strong positive correlation between parking supply and vehicle ownership (*18*, *19*) and automobile use (*18*, *20*, *21*). However, subsequent versions of the ITE *Parking Generation* manual made significant improvements in study site selection and included center city core, dense multi-use urban, general urban/suburban, and rural sites.

The authors' review of the Transport Research International Documentation (TRID) database found few resources on parking at TODs. One team of researchers, Edgar et al., sought to "understand the tension between access (parking and otherwise) and transit-oriented development (TOD) and learn how practitioners successfully resolved these tensions" (*22*). They conducted a survey to learn of parking policies and TOD practices in five regions: San Francisco/Oakland, Denver, Los Angeles/South Pasadena, San Diego, and Boston. They found that parking could be a source of tension in areas where land value is at a premium, density is high, and transit riders are accustomed to large park-and-ride lots. Too much parking may interfere with the human design of a TOD and compromise what should be a pedestrian-friendly environment.

The parking policy recommended by Martin and Hurrell (*23*) is one of "constrained" parking that is not included in leases or other TOD operational costs. This will result in the greatest line-haul ridership for the TOD. In addition, they recommended that transit riders pay for parking once parking capacity is reached to cover maintenance costs for the parking lot or garage. The idea here is that when riders have to pay for parking, they demand less of it.

In the case study by Ewing et al. (*6*), simply put, TODs (even the most auto-oriented) were found to create significantly less demand for parking and driving than do conventional suburban developments. With one exception, vehicle trip generation rates were about half or less of what is predicted in the ITE *Trip Generation* manual. Automobile mode shares were as low as one-quarter of all trips, with the remainder being mostly transit and walk trips.

Data and Method

Defining TOD

TODs are widely defined as compact, mixed-use developments with high-quality walking environments near transit facilities (*24*). The first three criteria used to select TODs for this study are consistent with the definition above. TODs must be: (i) relatively dense (with multistory development); (ii) mixed use (with residential, retail, entertainment, and sometimes office uses in the same development); (iii) pedestrian-friendly (with streets built for pedestrians as well as autos and transit, with public spaces like plazas and parks) Five additional criteria are added in this study to maximize the utility of the sample and data. TODs must be (iv) adjacent to transit (literally abutting and therefore integrally related to transit); (v) built after a high-quality transit line was constructed or proposed (and therefore with a parking supply that reflects the availability of high-quality transit); (vi) fully developed or nearly so; (vii) have self-contained parking; and (viii) initially developed by a single developer under a master development plan.

By self-contained parking, we mean having dedicated parking, in one or more parking garages or lots, for the buildings that comprise the TOD. This criterion is dictated by the need in this study to measure parking demand for the combination of different land uses that comprise the TOD. The criterion precludes TODs in a typical downtown that share public parking with non-TOD uses. This obviously constitutes a limitation on our study's external validity, but one that is self-imposed. In a typical downtown with public parking, it is impossible to tell which parked cars are associated with which land uses. Thus, our findings will be most applicable to the many proposed and self-contained TODs in less urban or more suburban locations.

Selecting TOD Cases

Given the eight criteria, exemplary self-contained TODs in seven regions of the U.S.A. were selected These seven regions were selected based on the presence of high-quality transit and on sampling convenience. The authors' original consulting partners (Fehr & Peers and Nelson\Nygaard) have branch offices in these regions, which expedited the data collection for the sampled sites.

The first step was to ask the consulting partners' branch offices to identify candidate sites within their regions that met the eight criteria. Concurrently, regional transit operators, metropolitan planning organizations (MPOs), or both, in the seven regions were contacted with the same question. A surprising number of transit agencies and MPOs have staff specifically dedicated to promoting TODs. These were contacted, informed of the criteria, and asked for the best local examples of TOD.

The second step was to review candidate sites with Google Earth imagery to check for clustering of buildings around transit stations, typically with well-defined boundaries. This was followed by the use of Google Street View to establish that TOD criteria (dense, mixed use, pedestrian-friendly with self-contained parking) were actually met. Several top candidate TODs were ranked in this manner for each metropolitan area.

The final step was to visit each of the metropolitan areas and, once there, take transit from one candidate station area to the next. In each location, the authors walked around and through the development to determine whether the criteria were in fact met, and went to the property management office to obtain contact information. A photographic record of each development was also made. In virtually all cases, the relative ranking of sites changed with the on-the-ground inspections.

In the TOD selection phase, the process got messy. One practical consideration was the decision to obtain approval from property managers to conduct these studies, particularly because researchers would be going into their parking garages at all hours to conduct parking occupancy counts. Another practical consideration was budgetary. Some of the selected TODs were so large and had so many building entrances that the consultants would have exceeded their sub-consultant budgets if these had been included in our sample. Ultimately, seven TODs were identified —one in each region—that met the criteria and were feasible to study. In only one case, Mockingbird TOD, were the authors denied access to private property.

The decision to limit the sample mostly to smaller TODs suggests that these case studies may underestimate the potential trip and parking reductions associated with TOD. This is the case because smaller developments have limited potential for internal capture of trips, which is to say, limited numbers of trips that both begin and end within the TOD. While it is certainly possible that residents of Redmond TOD (Seattle—see below) will dine in the Indian restaurant that is part of the development, with so few trip attractions within the development, it seems more likely that they will dine, when they dine out, elsewhere within downtown Redmond. Orenco Station, in contrast, offers a much more complete set of attractions. Published work elsewhere shows that larger developments have higher rates of internal capture (*25*).

Table 1 provides statistics on the intensity of development for the seven TODs studied in the paper. Floor area ratios (FARs) for commercial development (which are calculated as commercial floor area divided by acreage of commercial and mixed uses) are relatively low, while gross residential densities exceed the guidelines in most transit-oriented design manuals (*26*). The typical TOD has ground floor retail and apartments above, meaning that the commercial FAR is generally limited to 1.0, while the residential density depends on the number of stories. Fruitvale Village and Mockingbird TODs, with their heavy concentration of office developments, are exceptions to the low FAR rule. But the very

Table 1. Statistics on the Intensity of Development for the Seven Case Study Sites

Case study site	Region	Gross area (acres)	Gross residential density (units per gross acre)	Net residential area (acres)	Net residential density (units per net acre)	Gross commercial floor area ratios (for retail and office uses)
Redmond TOD	Seattle	2.5	129	2.5	129	0.11
Rhode Island Row	Washington, D.C.	6	46	6	46	0.27
Fruitvale Village	San Francisco	3.4	14	3.4	14	0.94
Englewood	Denver	30	15	10.7	41	0.25
Wilshire/Vermont	Los Angeles	3.2	140	3.2	140	0.27
Orenco Station	Portland	60	32.4	60	32.4	0.10
Mockingbird TOD	Dallas	8.7	24.3	1.2	162	0.83

Note: TOD = transit-oriented development.

substantial reductions in vehicle trips and parking demand documented in this study suggest that very high density/intensity of development is not necessarily a requirement for success.

Interestingly, what distinguishes Orenco Station from the other six TODs is its scale. All but Englewood TOD are less than 10 acres in size. The entirety of Orenco Station is 237 acres, and even the portion featured in this study is about 60 acres. The scale suggests that a much higher proportion of trips will be internal to the development, a good thing from a transportation and physical activity standpoint. However, it also suggests that part of the development will be at a considerable distance from the transit station, which means that the average transit mode share may be lower since transit use falls off with distance from a station. It may also suggest a decline in transit use because, unlike the other six TODs studied, not all of the housing will be multifamily on a large site like Orenco Station. A large site ordinarily requires a mix of housing types for rapid land absorption and, in fact, our study area includes a single-family attached product.

Data Collection

A data collection plan and protocols were developed for the TOD sites. By hiring surveyors and locating separate teams of surveyors at the TOD sites, three types of travel data were collected: (a) a full count of all persons entering and exiting commercial/residential buildings, (b) a brief intercept survey of a sample of individuals entering and exiting the buildings, and (c) parking inventory and occupancy surveys of all off-street parking accessory to the commercial and residential uses of the building and the co-located but separately managed off-street parking facility owned and operated by transit agencies for day use by transit riders. It should be noted that the first two types of travel data were used for different studies about the trip generation rates at TODs (*6*, *24*, *25*). On-street parking abutting or inside TODs was included in the parking demand numbers.

Figure 1. Count locations at Orenco Station (intercept surveyors circulated around these locations).

All survey and trip count data were recorded on location in each TOD site between 7:30 a.m. and 9:00 p.m. on typical days of the week—such as Tuesday, Wednesday, and Thursday. Parking utilization was surveyed at each facility approximately every two hours during this period. An "overnight" count of parking occupancy was conducted at both the parking garage and the transit park-and-ride lot from 11:00 p.m. to midnight to determine parking occupancy during the anticipated period of peak utilization associated with the predominant residential uses. Figure 1 shows a map of count locations at Orenco TOD area for survey and trip count data collection.

Parking supply and demand recorded for each TOD site were compared with the number of parking stalls as well as occupancy rates from the 2019 ITE *Parking Generation* manual (5th Edition). For the commercial component, the ITE's guidelines for the average parking-supply ratio were determined by building use. For example, the ITE's guideline for the average parking-supply ratio for a general office building is 3.0 spaces per 1,000 square feet ground floor area (GFA). The average peak period parking demand is 1.63 vehicles per 1,000 square feet GFA during a typical weekday at a dense mixed-use urban area with a standard deviation of 0.32, a range of 0.97–2.33, an 85th percentile value of 2.14, and a 33rd percentile value of 1.55. Note that the ITE *Parking Generation* manual does not provide guidelines for some commercial uses like hair salons. In this case, the closest analog in the ITE *Parking Generation* Manual, "710: General Office Building" was chosen (it is not a very good analog, but it was the best available, and it has a trip generation rate that is very similar).

Results

The parking demands for different land uses during the survey day are shown in Figure 2. Parking occupancy rates for the seven TODs were calculated using ITE land use categories and aggregating parking supply and demand into broader categories. These cases show that the peak period of parking demand is different for each land use. For the transit park-and-ride, demand was very high at midday. More than 90% of parking spaces were occupied from 8:00 a.m. to 3:00 p.m. The demand dropped down to less than 20% occupancy after 8:00 p.m.

Residential demand for parking peaked overnight, from 10:00 p.m. to 8:00 a.m. Demand started to decrease during the day and reached its lowest point between noon and 4:00 p.m., then started to increase again after 4:00 p.m. Commercial demand for parking was low during the day and increased after 6:00 p.m.

The peak period for transit parking was daytime, while the peak periods for commercial and residential parking were evening and night, respectively. Given this fact, there is a real opportunity for sharing parking spaces among these different uses, something which is realized at present at Rhode Island Row, Englewood TOD, and Orenco Station, but not at other TODs, such as Redmond.

At the Redmond TOD, the two-level parking garage/structure has 415 stalls located below the residential component of the project. The parking garage includes 379 stalls for building residents and 36 public parking stalls, with three signed for "new residents," three for "guests," four for "carpools," and 26 for "retail" customers and employees. There is also a separate parking garage for transit users who are parking and riding the buses across the street. For the transit park-and-ride, demand was very high at midday. More than 90% of parking spaces were occupied from 8:00 a.m. to 3:00 p.m. The demand dropped down to less than 20% occupancy after 8:00 p.m. Residential demand for parking peaked overnight, from 10:00 p.m. to 8:00 a.m. Demand started to decrease during the day and reached its lowest point between noon and 4:00 p.m., then started to increase again after 4:00 p.m. Commercial demand for parking was low during the day and increased after 6:00 p.m. Demand for commercial parking peaked at 10:00 p.m. Apparently renters of apartments were using commercial parking overnight to avoid monthly parking charges. The peak period for transit parking was daytime, while the peak periods for commercial and residential parking were evening and night. Given this fact, there is a real opportunity for sharing parking spaces among these different uses, something which is not realized at present at this site.

At the Rhode Island Row TOD, the Metro park-and-ride has its own parking structure. Parking garages in the TOD itself are shared among residential, commercial, and Metro users. For the Metro park-and-ride, demands were very high at midday. More than 90% of the parking spaces were occupied from 9:00 a.m. to 3:00 p.m. The demand dropped quickly after that, to around 30% occupancy after 8:00 p.m. The authors surmise that residential users are filling those spaces overnight. This is a way to avoid the monthly parking charges that they would otherwise pay. However, the full benefits of shared parking are still not attained because many of the parking spaces in the two TOD garages are reserved for Metro parkers. The parking occupancy rate for the two TOD garages never exceeds 68%. If there were true shared parking between TOD residents and Metro parkers, the peak occupancy rate would be higher outside of working hours.

Including the spaces in the Wal-Mart parking lot, the Englewood TOD contains seven parking lots and structures for approximately 2,810 parking spaces within CityCenter. The West Block North Parking Structure is designated for the residents of 901 Apartment Complex and the employees of its retail and office uses. For the West Block South Parking Structure, it is assumed that the parking demand of RTD transit users and commercial users falls in the same proportion as their parking supply. Demand for RTD park-and-ride was high at midday. About 90% of the parking spaces were occupied from 9:00 a.m. to 2:00 p.m. Demand dropped quickly, reaching a low of less than 10% occupancy after 8:00 p.m. Demand for residential parking was low at midday; just 40% of the residential parking spaces were occupied from 8:00 a.m. to 2:00 p.m. Demand started to increase after 2:00 p.m. and peaked at midnight. The peak occupancy rate was 77%. Demand for commercial parking was highest at midday but still far short of capacity. About 60% of the parking spaces were occupied from 10:00 a.m. to 2:00 p.m. Demand dropped to

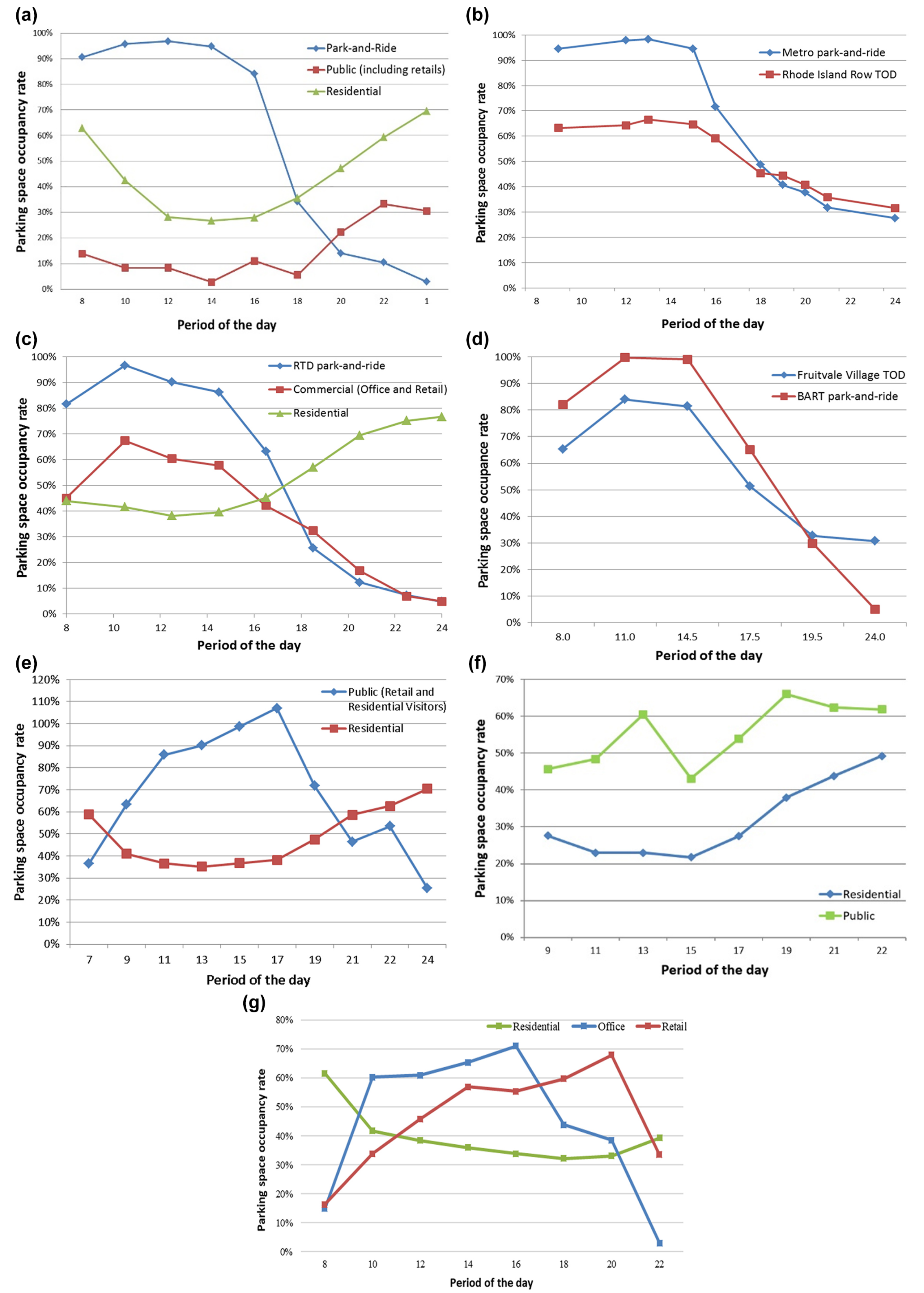

Figure 2. Parking space occupancy rates for different uses at the seven sites: (*a*) Redmond TOD, Seattle, (*b*) Rhode Island Row TOD, Washington, D.C., (*c*) Englewood TOD, Denver, (*d*) Fruitvale Village TOD, San Francisco, (*e*) Wilshire/Vermont TOD, Los Angeles, (*f*) Orenco Station TOD, Hillsboro, OR, and (*g*) Mockingbird TOD, Dallas, TX.

Note: TOD = transit-oriented development; RTD = regional transportation district; BART = bay area rapid transit.

less than 20% occupancy after 8:00 p.m. From the standpoint of commercial parking, Englewood TOD is overparked. There would clearly be benefits to having more parking shared among uses.

At Fruitvale Village TOD, the BART park-and-ride parking structure and lots are independent. However, it is not possible to distinguish residential from commercial uses in the parking garages for the development, so we consider them as a whole. For the BART park-and-ride, demand was high at midday. Almost 100% of the parking spaces were occupied from 11:00 a.m. to 2:00 p.m. Demand dropped quickly after that, reaching a low of 5% occupancy at midnight. Parking demand at the TOD garage was also high at midday. More than 80% of the parking spaces were occupied from 11:00 a.m. to 2:00 p.m. Demand dropped to around 30% occupancy after 8:00 p.m., when most of the parked vehicles likely represent residential demand. Overall parking occupancy rates at Fruitvale Village TOD are higher than at Redmond TOD. This finding clearly shows the benefit of sharing parking among different users at TODs.

The Wilshire/Vermont TOD also clearly shows the benefit of sharing parking among different users at TODs. At Wilshire/Vermont TOD, there is no dedicated parking for Metro users. The parking garage has separate parking for residents and public uses (retail and residential visitors). The occupancy rate for residential parking was about 60% in the morning, then demand dropped during the day to less than 40%. Demand started to increase after 5:00 p.m. and peaked at midnight. The peak occupancy rate was 70%. For the public uses (retail and residential visitors), demand increased during the morning until the parking was fully occupied at about 2:00 p.m. Demand dropped after that to around 50% occupancy after 9:00 p.m. and 25% at midnight.

At the Orenco Station TOD, there are parking lots, parking structures, and on-street parking. This study categorizes parking as either residential or public, including park-and-ride and commercial users. The residential parking demands are low at midday and peak at night. Around 25% of the parking spaces are occupied from 9:00 in the morning to 3:00 in the afternoon. The demand starts to increase after 3:00 p.m. until it hits a peak at midnight. The peak occupancy rate is about 50%. The public parking demands vary during the day. The demand increases from about 45% at 9:00 a.m. until it hits its morning peak at 12 noon. The morning peak occupancy rate is about 60%. The demand drops to about 40% at 2:00 p.m. and starts to increase again until it hits its afternoon peak at 6:00 p.m. The afternoon peak occupancy rate is about 65%. Finally, the demand drops to about 60% at 10:00 p.m. The parking occupancy rate for public parking is higher than residential parking which again shows the benefit of sharing parking among different users at TODs. The high occupancy rate for public parking overnight suggests that some residents are parking in public spaces to avoid monthly parking charges. The peak parking occupancy rates are still only 65% of the parking supply, however, meaning that even in this TOD with relatively low parking ratios, parking is oversupplied.

The actual parking supply at the Mockingbird TOD is 1,463 spaces, which is 86% of the ITE recommended rate. As with the other six TODs, the parking occupancy for the residential building follows a declining trend during the day, with the lowest occupancy rate reported at 6:00 p.m. It turns to an increasing trend after 8:00 p.m. when the residential use is at its highest level. The retail and office demands are at the lowest level at 8:00 a.m. with an increasing trend during the day. Demand for office and retail parking eventually peaks between 4:00 and 8:00 p.m. and declines to less than a half after 8:00 p.m.

All of the featured TODs have apartments in multistory buildings, so that is the land use category for which TOD residential parking supplies are compared with the ITE supply guideline. Supply is relatively easy to measure except where there is shared parking. In Redmond, Englewood, and Wilshire/Vermont, in the south garage at Rhode Island Row, in some of the mixed-use buildings at Orenco Station, and in Mockingbird TOD, residential users have their own parking garages or lots, or have sections of garages reserved for them. Only in Fruitvale, and in the north garage at Rhode Island Row, is residential parking shared with commercial uses. For computing supply per dwelling unit, the total number of residential parking spaces and the total number of apartments are also used, not just the occupied apartments. The total number of apartments is easier to determine.

Table 2 compares residential parking supply and demand for the seven TOD cases. Peak demand for residential parking is more difficult to estimate than parking supply. Unlike for parking supply, only occupied apartments were used to compute the number of parking spaces per dwelling unit. The assumption was also made, where parking is shared, that residential parking demand peaks in the late night/early morning hours when apartment dwellers are presumably all at home, and commercial and transit users presumably have left. The peak demand for parking ranges from 0.44 spaces per occupied dwelling unit at Rhode Island Row (south garage) to 1.29 spaces per occupied dwelling unit at Englewood. From Table 2, the occupancy of residential parking spaces (peak demand divided by actual supply) ranges from 54.3% at Rhode Island Row (south garage) to 80.6% at Englewood. This reflects the character of the residential development and the mixed-use nature of the setting, more than the presence of the commuter rail station at a considerable distance.

Table 2. Residential Parking Supplies as a Percentage of ITE *Parking Generation* Manual Guidelines, and Residential Peak Parking Demand as a Percentage of Actual Supply

Study site (TOD)	ITE supply (spaces per unit)	TOD supply (spaces per unit)	TOD peak demand (occupied spaces per unit)	TOD supply as % of ITE supply	TOD peak demand as % of TOD supply
Redmond	1.2	1.19	0.86	99.17	72.27
Rhode Island Row	1.2	0.81	0.44	67.50	54.32
Fruitvale	1.2	NA	1.02	NA	NA
Englewood	1.2	1.6	1.29	133.33	80.63
Wilshire/Vermont	1.2	1.1	0.81	91.67	73.64
Orenco Station	1.2	1.08	0.63	90.00	58.33
Mockingbird	1.2	1.15	0.71	95.83	61.74

Note: TOD = transit-oriented development; ITE = Institute of Transportation Engineers; NA = not available.

Table 3. Aggregate Parking Supply as a Percentage of ITE *Parking Generation* Manual Supply, and Aggregate Peak Parking Demand as a Percentage of Actual Supply

Study site	Aggregate peak parking demand as % of actual supply	Aggregate peak parking demand as % of ITE guideline
Redmond	73.5	69.4
Rhode Island Row	63.6	40.1
Fruitvale	84.0	19.5
Englewood	58.3	48.4
Wilshire/Vermont	66.8	53.3
Orenco Station	51.2	54.3
Mockingbird	55.4	59.5

Note: ITE = Institute of Transportation Engineers.

A final set of comparisons captures the potential of these exemplary developments to conserve on parking relative to ITE parking supply guidelines. This is the most extreme comparison, comparing peak demand for these mixed-use developments with supplies. Parking utilization across residential, commercial, and mixed-use parking areas was summed for the hour when occupancy is at its highest for residential and commercial uses. Transit park-and-ride parking was not included in this comparison. At most of the TODs studied, dedicated garages or lots are provided for transit users. The two exceptions are Englewood and Orenco Station, where transit users share parking with commercial users in the civic center garage at Englewood and in the Vector parking garage at Orenco Station.

The first part of the comparison (aggregate peak demand compared with aggregate actual supply) indicates the degree to which these developments are over-parked relative to their theoretical potential. From Table 3 it can be seen that, at the overall peak hour, just 51.2%–84.0% of parking spaces are filled. The latter is for Fruitvale, which has shared parking for residential and commercial uses. Because of limited shared parking, even these exemplary developments (except Fruitvale) do not achieve their full potential.

The second part of the comparison (aggregate peak demand compared with aggregate ITE parking supply) indicates just how wildly over-parked these developments would be if parking were built to ITE guidelines rather than scaled back for alternative mode use (walking and transit use). From Table 3, at the overall peak hour, parked cars would fill just 19.5%–69.4% of parking spaces if built to ITE standards. Simply put, TODs create significantly less demand for parking than conventional suburban developments. With one exception, peak parking demand is less than 60% of the parking supply guideline in the ITE *Parking Generation* manual.

Conclusion and Policy Recommendations

This paper estimates vehicle parking reductions associated with TODs, defined as dense, mixed-use developments proximate to high-quality transit, as compared with conventional suburban development. Our results indicate that, in almost all cases, the TODs in the sample supply much less parking than is called for in ITE guidelines. Despite these supply restrictions, demand for parking at TODs is well below the supply. That is to say, TODs are generally over-parked.

Developments are often characterized in relation to D variables. The Ds all have an effect on travel demand

(*27*). The first three Ds—development density, land use diversity, and urban design—were coined by Cervero and Kockelman (*22*). Two additional Ds—destination accessibility and distance to transit—were included in later research (*27–29*). Other Ds include demand management and demographics.

The seven TODs studied in this project are more or less exemplary when it comes to the Ds. All contain a diverse land use mix, though Fruitvale could use more residential development and Redmond, in particular, could use more commercial development. All have public space and other pedestrian-friendly features, making them well designed. All minimize distance to transit, literally abutting transit stations. Fruitvale, Rhode Island Row, and Orenco Station are served by three of the best rail systems in the nation, and thus have exemplary destination accessibility via transit. Wilshire/Vermont and Fruitvale Village have exemplary bus accessibility as well. All but Englewood and Mockingbird TOD provide some affordable housing, and thus attract the demographics most likely to use transit.

A sixth D, demand management (parking management), is mixed at the TODs studied. For one thing, there is a dearth of shared parking, though opportunities abound. Fruitvale Village, Orenco Station, and the north garage at Rhode Island Row share residential and commercial parking in the sense that the same spaces can be used at different hours by different users. In other cases, residential and commercial users may occupy the same garage, but with spaces reserved for one use or another (commercial at Redmond, residential at Wilshire/Vermont). And only Englewood and Orenco Station share parking between TOD and transit park-and-ride users. Again, they may share a garage as at Rhode Island Row, but spaces are reserved for transit park-and-ride users. At all surveyed developments except Orenco Station, transit has its own, exclusive park-and-ride garage, lot, or both. The authors do not imply that some reserved parking is not warranted for marketing reasons, but the extent of reserved parking in these otherwise smart developments came as a surprise.

Another area in which parking policies are not always smart is in bundled residential parking. A parking space/permit comes with each apartment in Englewood and Wilshire/Vermont, whether the renters want it and use it or not. This parking is effectively free. Fruitvale has a hybrid parking policy, where the first space/permit comes with the apartment and a second space (if renters want one) costs them \$90 per month. Very few renters opt for the second space—evidence that unbundled parking suppresses parking demand. Only in Redmond and Rhode Island Row is parking totally unbundled. In Redmond, reserved parking spaces are leased for \$95 per month (\$90 at the time of our study); and in Rhode Island Row, reserved parking spaces are leased for \$150 per month. Note that some of the developments at Orenco Station (e.g., the Platform district) have unbundled (and shared) parking.

A third area in which parking policies are not always smart is in free commercial parking, the counterpart of bundled residential parking. Redmond, Englewood, and Orenco Station have free commercial parking. Of the other six, Rhode Island Row charges commercial parkers \$2 per hour or a maximum of \$24 per day (or \$4.50 for early birds). Comparable charges for Fruitvale Village are \$3 per hour and a maximum of \$12.50 per day; and for Wilshire/Vermont, the charge is \$6 per hour and a maximum of \$30 per day. All in all, except at Wilshire/Vermont, parking charges are modest.

Despite practical findings from the seven TOD cases, the limitations of this study should be acknowledged. The limitations of this study include: (i) the small sample size because of labor-intensiveness of data collection; (ii) low external validity led by a small sample size; (iii) an inability to account for internal capture of trips within these TODs; (iv) failure to take the phenomenon of residential self-selection into account; (v) failure to consider the seventh D variable—demographic characteristics of residents at the TOD sites; and (vi) failure to capture parking demand off-site, unless the residents parked on a street abutting the development.

Nevertheless, as far as the authors can determine, this is one of the first studies to estimate peak parking-generation rates for TODs. Several findings of this study have applications in TOD planning. If a TOD already exists and is, for example, being expanded (like Fruitvale Village), planners should to conduct the same types of counts and intercept surveys as in this study to estimate the performance characteristics of the expanded TOD. The same idea would apply to new developments going in near existing TODs. Planners probably should conduct studies at those TODs to gain the best possible estimates for new developments nearby. Redmond TOD and Rhode Island Row TOD, and their respective transit stations, have spawned nearby developments that may mirror the statistics of these particular TODs, perhaps with small adjustments since the new developments are not directly adjacent to the stations, as the sampled TODs are.

For planned TODs around other stations, in the same or other regions, the statistics in this paper may be used in tandem with regional travel model forecasts for a particular TOD or its respective traffic analysis zone. Regional travel models can capture the effects of transit service at a particular site, but do not capture the full effects of the D variables on travel demand or parking demand. On the other hand, the parking generation rates in this paper are actual (not modeled) values that reflect all the D variables of particular TODs, but are particular to these developments and their contexts. Whether they apply to TODs with different D variables and different contexts will always be debatable. That is why the authors advocate that both modeled regional travel model forecasts and actual trip and parking generation rates for TODs should be considered in the planning of other TODs.

The preceding discussion leads to a re-acknowledgment of the main limitation of this study, and a partial solution to the problem of finding an appropriate match for any new TOD that might be proposed. The only way to increase the external validity (generalizability) of this effort is to expand the sample of TODs studied, particularly including larger TODs with higher internal capture rates. In theory, at some point, a sample of TODs large enough for statistical analysis would be obtained. Trip and parking reductions relative to ITE guidelines could be modeled in relation to D variables for the TODs themselves, their contexts, and their type of transit service (heavy rail transit, light rail transit, commuter rail transit, streetcar, and bus only). Given the high cost of the associated data collection efforts, however, the authors doubt that their collective efforts will ever produce a statistical sample. Therefore, the best that can be hoped for is a mix of TODs that represents most of the common variations on the TOD theme. The authors think it particularly important that more LRT systems be represented in the sample, since these are systems that seem to be generating most of the TOD activity.

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Author Contributions

The authors confirm contribution to the paper as follows: Study conception and design: R. Ewing; data collection: R. Ewing; analysis and interpretation of results: R. Ewing, K. Kim, S. Sabouri, F. Siddiq; draft manuscript preparation: R. Ewing, K. Kim, S. Sabouri, F. Siddiq, R. Weinberger. All authors reviewed the results and approved the final version of the manuscript.

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Data Availability Statement

Data supporting the findings of this study are available from the authors on request.

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