Comparative Case Studies: Trip and Parking Generation at Orenco Station TOD, Portland Region and Station Park TAD, Salt Lake City Region

Reid Ewing
Department of City & Metropolitan Planning
University of Utah
375 S 1530 E, Room 235, Salt Lake City, UT 84112
Tel: 801-581-8255; Fax: 801-581-8217; Email: ewing@arch.utah.edu

Guang Tian
Department of Planning and Urban Studies
University of New Orleans
302 Milneburg Hall, 2000 Lakeshore Drive, New Orleans, LA 70148
Tel: 504-280-6521; Fax: 504-280-6272; Email: gtian@uno.edu

Keunhyun Park
Department of Landscape Architecture and Environmental Planning
Utah State University
4005 Old Main Hill, Logan, UT 84322-4005
Tel: 801-803-9547; Fax: 801-581-8217; Email: keunhyun.park1@gmail.com

Preston Stinger
Fehr & Peer Associates
2180 S 1300 E #220, Salt Lake City, UT 84106
Tel: 385- 282-7064; Email: p.stinger@fehrandpeers.com

Word count (without reference): 5500 words text + 6 tables/figures x 250 words (each) = 7,000 words
No of references: 26

Submission Date:

ABSTRACT

The subjects of this comparative case study are Orenco Station, a much acclaimed transit-oriented development (TOD) in the Portland region, and Station Park, a transit-adjacent development (TAD) in Salt Lake City region. We also draw on earlier trip and parking generation studies of five exemplary TODs around the U.S. The peak parking demand at the Orenco Station TOD is less than one half the Institute of Transportation Engineers (ITE) suburban parking supply guidelines. Also, vehicle trip generation rates are about half what is suggested in the ITE guidelines. These results comport with the earlier TOD trip and parking generation studies. Vehicle trip generation rates at the Station Park TAD show a smaller reduction but still substantial due to the mixed-use nature of Station Park. Parking generation rates at Station Park are also lower than the ITE guidelines.

Keywords: transit-oriented development, transit-adjacent development, comparative case studies, trip generation, parking generation

INTRODUCTION

This paper presents a comparative case study, defined as "the analysis and synthesis of the similarities, differences and patterns across two or more cases that share a common focus or goal in a way that produces knowledge that is easier to generalize about causal questions" (*1*). One subject of this comparative case study is Orenco Station, on the west side of the Portland metropolitan area in the suburban city of Hillsboro, OR. Orenco Station may be the most acclaimed freestanding TOD (as opposed to infill TOD) in the nation. The other subject of the comparative case study is Station Park, a mixed-use development abutting a commuter rail station on the north size of the Salt Lake City region in the suburban city of Farmington, UT. Station Park labels itself a TOD, but projects as a giant shopping center with a commuter rail station at one corner and a pedestrian-oriented village core in the center.

LITERATURE REVIEW

The question of how much vehicle trip and parking demand reduction occurs with TOD is still largely unanswered in the literature. Everyone agrees that there should be some reduction, but is it 10 percent or 20 percent or 30 percent or more?

In practice, vehicle trip generation for different land uses is guided by the ITE *Trip Generation Manual*. However, the manual states that "At specific sites, the user may wish to modify trip-generation rates presented in this document to reflect the presence of public transportation service, ridesharing, or other TDM measures; enhanced pedestrian and bicycle trip-making opportunities; or other special characteristics of the site or surrounding area" (*2*). This kind of modification is seldom done in practice.

One study found that vehicle trips generated by housing projects near transit were 44% lower than estimated using the ITE *Trip Generation Manual* (*3*). Other studies found that vehicle miles traveled (VMT) generated by residents living near transit were 20% to 50% less than their non-TOD or rural counterparts (*4*; *5*; *6*). Part of the vehicle trip and VMT reduction may be due to mode shifts – a shift from automobile to transit and walking or biking. Studies have found that residents living in developments near transit have higher rates of transit uses than residents living at greater distances (*6;7*; *8* ;*9*). Particularly, many studies report more transit use made by residents living close to transit for commuting purposes (*7;10*; *11*; *12*;*13*) and one study reported both more active and transit trips made by new residents in TODs for amenities and leisure (*14*). However, all these results are reported specific to multifamily housing developments, not mixed-use developments near transit. To our knowledge, there are only two studies of vehicle trip generation at TODs (commonly defined as mixed-use developments)(*15*; *16*).

In practice, parking generation is guided by the ITE *Parking Generation* manual. However, it notes that study sites upon which the manual is based are "suburban sites with isolated single land uses with free parking" (*17*). Studies show that vehicle ownership is lower in transit-served areas, compared to their non-transit-served counterparts (*7*; *9*). A study found that there is an oversupply of parking for housing projects near transit, sometimes by as much as 25-30 percent (*18*). Oversupply of parking spaces may result in an increase in vehicle ownership (*3*). This is supported by the strong positive correlation among parking supply, vehicle ownership, and automobile use (*19*; *20*;*21*; *22*). Again, these studies mostly were conducted for residential developments near transit, except one that was done for rail-served TODs. Loo et al. (*23*) studied the connection between rail transit ridership and car ownership at rail-served TODs, but they did

not examine parking demand. To our knowledge, there is only one study of parking demand at mixed-use TODs (again, defined as mixed-use developments – (*16*)), the others being for residential developments near transit.

Simply put, Ewing et al.'s case study TODs--even the most auto-oriented one--were found to create significantly less demand for parking and driving than do conventional suburban developments. With one exception, peak parking demand in these TODs was less than one half the parking supply guideline in the ITE *Parking Generation* manual. Also, 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. Building on our previous efforts, the current study differs in terms of large project size (60 acres for Orenco Station and 115 acres for Station Park), inclusion of TAD, and more in-depth analysis as a comparative case study.

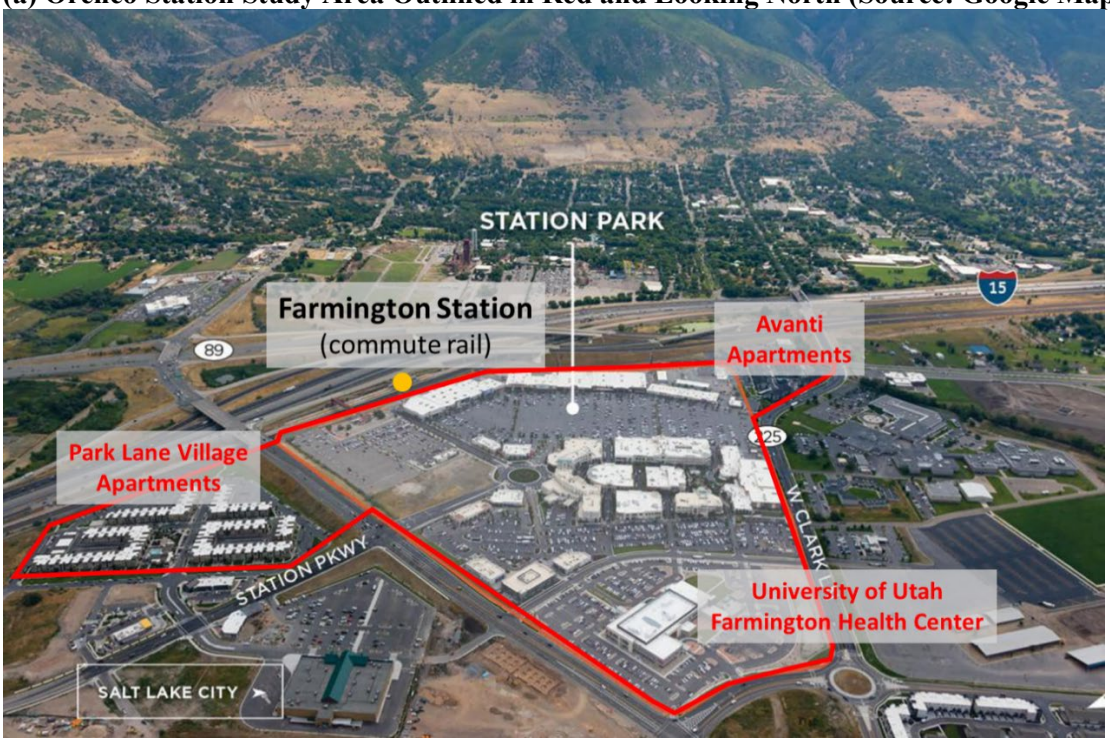
STUDY AREAS

Like the first five case studies, Orenco Station is more or less exemplary of the D variables featured in the built environment-travel literature (*24*) (see Figure 1 (a), Table 1). It contains a **diverse land use mix**, with residential, commercial, and public uses. It has public spaces, ample sidewalks, street trees, curbside parking, small building setbacks, and other features that make it **well designed** from a pedestrian standpoint. It **minimizes distance to transit**, literally abutting a light rail transit (LRT) station. It is served by one of the best transit systems in the nation, giving it exemplary **destination accessibility via transit**. It provides affordable housing, and thus attracts the **demographics** most likely to use transit and walk. It has **high residential density** relative to the region in which it is located. And some of its buildings have parking management policies that can be considered progressive, these falling under the heading of **demand management**.

Station Park does not perform as well as the other developments with respect to the Ds (see Figure 1 (b)). It can be classified a couple of ways. In terms of land uses, Station Park is probably most similar to a lifestyle center, defined as a shopping center that combines the traditional retail functions of a shopping mall with leisure amenities oriented towards upscale consumers. However, it does have three other uses that are not common in lifestyle centers, those being a supermarket, a hotel, and a medical facility. And it has a pedestrian-oriented village core.

Classified by its transit connection, Station Park is more of a TAD (transit adjacent development) than a TOD. Huge parking lots dominate the space between the commuter rail station and other components of the development. The big box component of Station Park turns its back on the commuter rail station. It was not that way in early versions of the site plan, when the most walkable components were oriented toward the commuter rail station. Station Park does not contain residential development within its main development boundaries. Transit accessibility to the rest of the region via commuter rail and bus is limited compared to the transit accessibility of Orenco Station via its light rail line. All parking at Station Park is abundant and free.

(a) Orenco Station Study Area Outlined in Red and Looking North (Source: Google Maps)



(b) Station Park Study Area Outlined in Red and Looking East (adapted from CenterCal Properties website)

FIGURE 1 Study areas.

TABLE 1 Net and Gross Residential Densities, and Floor Area Ratios for Commercial Uses, for the First Five TODs Studied and Orenco Station

TOD	Region	Gross Area (acres)	Gross Residential Density (units per gross acre)	Net Residential Area (acres)	Net Residential Density (units per net acre)	Gross Commercial FAR (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 (study area)	Portland	60	32.4	60	32.4	0.10
Station Park (study area)	Salt Lake City	115	4.1	20	23.3	0.23

DATA COLLECTION

For Orenco Station, the data were collected between 7:30 am and 9:00 pm on Tuesday, May 23, 2017. For Station Park, the data were collected between 7:30 am and 9:00 pm on Tuesday, May 9, 2017. Parking occupancy counts were conducted even later than that to capture peak residential parking demand. We scheduled data collection for a time when Portland State University and the University of Utah were still in session and before final exams, as we made a decision early on to use urban planning students for the counts and surveys. That was a wise decision. Not only were students less expensive than random part-time employees hired through a temporary employment agency (which would charge a fee for service on top of hourly wages), but the students were more conscientious in their data collection because, as urban planning students, they understood the value of the study.

Forty-eight students from PSU were employed at Orenco Station for up to 14 hours on that one day, at a total one-day cost of almost $12,000. Twenty-four students from U of U were employed at Station Parking for up to 14 hours on that one day, at a total one-day cost of almost $6,000.

The multimodal transportation planning firm of Fehr & Peers developed a data collection plan and protocols. The firm also managed data collection in the field and subsequent data entry for three types of travel data: (1) full counts of all persons entering and exiting the buildings that make up the TODs, (2) brief intercept surveys of samples of individuals entering and exiting the buildings that make up the TODs, and (3) parking inventory and occupancy surveys of all off- and on-street parking accessory to the commercial and residential uses of the TODs.

The intent of this approach was to develop an accurate measure of total trip generation associated with the commercial and residential uses at the site, as well as complementary travel survey and parking utilization data that provide a picture of the mode of travel, origin/destination, parking location – if applicable – and purpose for all trips to and from the buildings throughout the course of the day.

As a first step, surveyors noted whether the subject was observed “coming” or “going” to/from the buildings and the type and location of entrance/exit used, and recorded the time of

intercept by checking a box on the data collection form associated with one of four 15-minute periods per hour.

People leaving the building were asked: (1) "How do you plan to get to your next destination?" (e.g., by what mode of travel?), (2) What is the purpose of your trip? (e.g., "Going home," "Going to work," "Shopping," or "other"), and (3) How many destinations are you visiting while in Orenco Station/Station Park.

People arriving at the building were asked: (1) "How did you get here?" (e.g., by what mode of travel?), (2) What is the purpose of your trip? (e.g., "I live here/coming home," "coming to work," "shopping," or "other"), and (3) How many destinations are you visiting while in Orenco Station/Station Park.

Surveyors counted and attempted to intercept only individuals observed walking to or from an entrance to the TOD or TAD buildings. Individuals waiting for the bus or train, or walking between the station and park-and-ride lot, were not counted or surveyed.

RESULTS

Mode Shares

The final mode shares for Orenco Station TOD are 45.8 percent walk, 2.5 percent bike, 3.9 percent bus, 16.0 percent rail, and 31.4 percent auto. According to the 2011 Oregon Household Activity Survey, the regional mode shares for Portland metropolitan area are 17.6 percent walk, 2.8 percent bike, 5.6 percent transit, and 70.9 percent auto. Compared to the regional mode shares, Orenco Station TOD has a significant mode shift, a shift from auto to walk and transit. Orenco Station TOD has 2.6 times higher percentage of walk trips than the regional average, and 3.6 times higher percentage of transit (bus and rail) trips than the regional average.

As one would expect, the mode shares vary across the study area (see Figure 1 (a) for reference). In Zone 1, closest to the LRT station, the transit mode shares are highest (21.1 percent for rail, and 5.3 percent for bus). In Zone 3, farthest from the LRT station and sitting right on Cornell Road, the auto mode share is highest (61 percent). In Zone 2, in the center of the study area, the walk share is highest (56.7 percent).

Interestingly, in Zone 3, the bike mode share is significant at 4.9 percent. This is not too surprising since the neighborhood to the north and east is very bicycle-friendly, and distances are great enough to make bicycling to the Town Center an attractive option. The bike mode share for this portion of Orenco Station is higher than the shares recorded at the previous five TODs studied (*16*).

The final mode shares for Station Park TAD are 3.6 percent walk, 1.2 percent bike, 1.4 percent bus, 4.1 percent rail, and 89 percent auto (Table 3). According to the Utah 2012 Household Travel Diary survey data, the mode shares in Wasatch Front region are 3.1 percent walk, 1.9 percent bike, 4.5 percent transit, and 90.2 percent auto. Compared to the regional mode shares, Station Park TAD has very similar mode shares.

Trip Generation

Orenco Station TOD

The actual trip generation counts from the survey did not distinguish residential trips and commercial trips. It is not possible to distinguish them when land uses are as mixed, both vertically and horizontally, as they are at Orenco Station. To compare the observed trip

generation with ITE's benchmarks, we combined all estimated trips for different uses into a total that could be compared to ITE.

At Orenco Station, there were 13,094 person trips and 6,358 vehicle trips observed in Zones 1 and 2 for the day of the survey (7:30 am til 9:00 pm). Those trips were generated by the occupied residential units, 1,841 units (115 units occupied in Hub 9 Apartments, 239 units occupied in Rowlock Apartments, 193 units occupied in Vector Apartments, 167 units occupied in Platform 14 Apartments, 284 units occupied in Tessera Apartments, 210 units occupied in Club 1201 Condominiums, 62 units occupied in Q Condos, 413 units occupied in Nexus Apartments, 113 units occupied in Orchards at Orenco I & II Affordable Apartments, 45 units occupied in Alma Gardens Affordable Apartments), and 48,261 sq. ft. leased commercial space. The occupied residential units were computed by multiplying occupancy rates, provided by the property managers, times the total number of units.

For trip generation rates of the residential and commercial uses in our study area, we used the most appropriate ITE land use categories. For example, by reviewing the ITE land use definitions, and perusing restaurant menus on-line, we placed the many restaurants on-site in one of three categories—"931 Quality Restaurant" or "932 High-Turnover (Sit-Down) Restaurant" or "933 Fast-Food Restaurant without Drive-Through Window"—and then assigned them the corresponding daily trip generation rates from ITE's *Trip Generation Manual*.

The matches were not always perfect or even close, so in those cases, we assigned the Orenco Station commercial use the most analogous (in our judgment) ITE land use category. A difficult match, for example, was the Kumon Math and Reading Center at Orenco Station. We assumed its trip generation pattern across the day, hours of operation, and daily trip totals would be very different from the ITE school categories such as "530 High School." The best match we could find in this case, and it is approximate at best, is the trip generation associated with the category "590 Library."

Based on ITE's trip generation rates, the Orenco Station TOD (60-acre study area) would be expected to generate 10,859 daily vehicle trips if it were a typical suburban development without transit (see Table 5). The actual vehicle trips we observed on the survey day totaled 6,358, which is 58.6 percent of the ITE expected value.

Station Park TAD

For Station Park, our trip generation counts from the survey distinguished residential trips from commercial trips, but not retail trips from office trips. To compare the actual trip generation with ITE's benchmarks, we will separate residential trips and combine all commercial into a total that can be compared to ITE.

There were 42,172 person trips and 30,692 vehicle trips observed for the whole day of the survey. 2,215 person trips and 1,515 vehicle trips were generated by the occupied residential units, 450 total units. 39,957 person trips and 29,177 vehicle trips were generated by the commercial spaces, which occupy 1,037,340 sq. ft.

For the trip generation rate of some commercial uses at the Station Park TAD, we used "630 Clinic" for the medical center (Farmington Health Center), "715 Single Tenant Office Building" for the stand-alone office building (Vista Outdoor), and "310 Hotel" for the hotel (Hyatt Place) from the *Trip Generation Manual*.

We considered all the other commercial uses (including retail and restaurant, smaller offices, theater, and bank) as a whole as a shopping center and used "820 Shopping Center" for its trip generation rate. We treated the other commercial uses as a shopping center because there

are so many lessees, some occupying very little space, and many without appropriate ITE land use categories. Station Park meets the basic ITE criteria for a Shopping Center:

> Shopping centers, including neighborhood centers, community centers, regional centers and super regional centers, were surveyed for this land use. Some of those centers contained non-merchandizing facilities, such as office buildings, movie theaters, restaurants, post offices, banks, health clubs and recreational facilities…

It would have made no sense to treat the individual commercial uses separately when they are obviously part of an integrated whole.

Based on ITE's trip generation rates, the residential uses in the Station Park study area would be expected to generate 1,939 daily vehicle trips. The actual vehicle trips for the residential we observed on the survey day was 1,515, which is 78.1 percent of the ITE expected value. Based on ITE's trip generation rates, the commercial uses at Station Park would be expected to generate 39,138 daily vehicle trips. The actual vehicle trips for the commercial uses we observed on the survey day was 29,177, which is 74.5 percent of the ITE expected value. This is the highest percentage of the ITE value of any development studied. Station Park is a TAD, not a TOD. The effect of transit on the vehicle trip reduction is limited.

Parking Generation

Orenco Station TOD

Residential parking supply and demand recorded for the Orenco Station TOD project were compared to the number of parking stalls as well as occupancy rates from the 2010 ITE *Parking Generation* manual. There are 10 apartment and condominium projects at Orenco Station TOD. Each of them has its own parking garage, parking lot, and/or designated on-street parking.

The average actual parking supply for all residential units in the apartments and condominiums of the Orenco Station TOD is 2,098 spaces total or 1.08 parking spaces per unit. The average parking supply for the residential uses at Orenco Station TOD is lower than the average by ITE's guideline (1.59 spaces per unit). Note that these numbers exclude shared residential-public parking spaces both on-street and in parking garages. Also note that we have included only spaces in parking garages for Club 1201 condos, even though many residents park in their driveways, often using their garages for storage. If we included driveway space as well as garage space, the parking ratio for the Orenco TOD would increase to 1.21 parking spaces per unit.

The peak occupancy of parking spaces in all the residential parking areas is at 10:00 pm. We were not able to get permission to collect parking occupancy data for Nexus Apartments and Q Condos. These two residential complexes are excluded in the parking demand analysis. For the residential component of the Orenco TOD, the peak parking demand relative to occupied units is 0.63 spaces/occupied unit. The actual demand (860 spaces) is much lower than both the ITE estimate of 1,770 (occupied units only) based on the average parking generation rate and the ITE estimate of 1,537 (occupied units only) based on the ITE regression equation. Based on the latter, residential uses in Orenco generate only 56 percent of the ITE peak residential rate. Note that these numbers exclude shared residential-public parking spaces both on-street and in parking garages.

If ITE guidelines were followed, the public uses at Orenco Station would be supplied with 419 parking spaces and would occupy 240 spaces at peak times. A comparison of ITE

supply and demand to actual supply and demand for public uses at Orenco Station is not possible, unless we assume that all of the shared parking is occupied by public (commercial) users. That seems to violate the basic idea of shared commercial-residential parking. Therefore, we refrain from making this calculation.

While we cannot estimate public parking supply and demand due to shared parking arrangements, we can get very accurate values for total parking supply and demand, including shared parking. Meeting ITE supply guidelines, the TOD, excluding Nexus and Q Condos for which we do not have parking demand data, would have a total of 2,849 parking spaces. The actual number of parking spaces, again excluding these two projects, is 2,326 spaces. Therefore, public parking at Orenco Station TOD is supplied at 81.6 percent of the ITE guideline.

We cannot compute a meaningful peak period demand value for Orenco Station TOD from ITE data because residential and public (commercial) uses peak at different times of day. We can, however, determine the total demand for parking at the single hour when parking occupancy is highest, which turns out to be at 10 pm at night. At that time, 1,190 spaces were occupied in the portions of the Orenco Station TOD for which we have demand data, excluding Nexus and Q Condos. Therefore, at that particular hour, about half (51.2 percent) of all parking spaces at Orenco Station were occupied. Orenco Station is actually oversupplied with parking relative to its theoretical shared parking potential. The actual peak demand is only 41.8 percent of the ITE supply guideline. If Orenco had been built to ITE guidelines, parking would have been oversupplied by more than 100 percent.

Station Park TAD

At Station Park, parking at Park Lane Village is essentially bundled, that is, covered by the rent. Designated covered parking spots can be rented for $25/month and there is no limit on how many one unit can rent. Otherwise, residents and guests can park for free in unassigned spaces, either on-street or in parking bays.

Parking at Avanti is also essentially bundled. Some units come with garages, some with covered spots, and some with no parking. For units coming with parking spots, no additional parking charge is levied beyond the basic rent. For units without parking spots, assigned carports can be rented for $50/month and assigned garages can be rented for $150/month. Otherwise, residents and guests can park for free in unassigned spaces, either on-street or in parking bays.

The peak occupancy of parking spaces is 11:00 pm (the time of the last count). The numbers of spaces filled at that hour are 74 for the Avanti Apartment Complex parking lot with an occupancy rate of 90.2 percent and 362 for the Park Lane Village Apartment Complex parking lot with an occupancy rate of 81.5 percent. Thus, for the residential at Station Park, the peak parking demand relative to occupied units is 0.97 spaces/occupied unit. The actual demand (436 spaces) is lower than the ITE estimate of 540 (occupied units only) based on the average parking generation rate and higher than the ITE estimate of 418 (occupied units only) based on the regression equation.

As with most shopping centers, parking at Station Park is free and unassigned. Different uses share parking at different times of day. For example, office uses occupy most of the parking spaces at the southwestern lot during the day, while entertainment uses (restaurants and the movie theater) occupy most of the spaces in the evening. Under a parking easement, evening users can overflow into the parking lot directly in front of the health center. Under another parking easement, shoppers can overflow into the park-and-ride lot directly in front of the rail station.

There is a total of 1,150,140 sq. ft. of commercial space at the Station Park TAD, 1,037,340 sq. ft. of which were leased at the time of this study. The total number of parking spaces for the entire Station Park development (including the health center but excluding the park-and-ride lot, which was not being used by shoppers on our visits to the site) is 4,348.

The closest analogs to the Station Park commercial uses in the ITE Parking Generation manual are "630 Clinic" (Farmington Health Center), "701 Office Building" (Vista Outdoor), "310 Hotel" (Hyatt Place), and "820 Shopping Center" (all the other commercial uses at Station Park). According to the ITE manual, the parking supply for these commercial uses would be 5,004 spaces. The actual parking supply at the Station Park TAD is 4,348 total spaces for all commercial uses. The actual parking supply is 86.9 percent of ITE parking supply guideline.

According to the ITE's guideline, the average total peak period parking demand for the commercial uses would be 2,572 spaces, only for leased spaces. The actual peak period parking demand of the commercial uses at the Station Park TAD was 1,848 occupied spaces during the one hour with the highest parking demand on the survey day, which is 71.9 percent of the ITE's peak parking demand estimate.

COMPARATIVE RESULTS

Table 2 compares the final mode shares for the Orenco Station TOD and Station Park TAD to those of the previous five TODs studied (*16*). Orenco Station TOD has a higher walk mode share than the others, something we anticipated due to the size of the site and exchange of trips within the site. Its transit mode share is at the low end of the sample range, something we also anticipated. Overall, Orenco Station TOD's auto share of trips compares favorably with the others. Station Park TAD has the lowest walk and transit mode shares among the seven sites we studied. This is not surprising for a TAD. The effect of transit on the mode shares is limited by the distance from the rail station to the core of the development, the poor quality of the walking environment between the two, and the only passable quality of transit service (with limited available routes and service frequency).

TABLE 2 Average Mode Shares for TODs Studied

TOD	*Count*	*Count for modes*					
		Walk	*Bike*	*Bus*	*Rail*	*Auto*	*Other*
Redmond	1,981	18.9%	1.7%	13.0%	NA	64.9%	1.5%
Rhode Island Row	8,451	16.6%	0.3%	9.3%	27.2%	42.5%	4.0%
Fruitvale	16,558	28.3%	4.3%	15.2%	26.1%	23.0%	3.1%
Englewood	14,073	19.2%	3.8%	3.3%	13.6%	59.7%	0.2%
Wilshire/Vermont	11,043	27.4%	2.2%	21.1%	20.1%	25.9%	3.4%
Orenco Station	15,495	45.8%	2.5%	3.9%	16.0%	31.4%	0.4%
Station Park	42,172	3.6%	1.2%	1.4%	4.1%	89.0%	0.6%

Table 3 compares vehicle trip reductions for the Orenco Station TOD and Station Park TAD to those of previous five TOD sample. The actual vehicle trips we observed to/from/within the Orenco Station TOD on the survey day totaled 58.6 percent of the ITE expected value. This is not as deep a discount as in some of the smaller TODs studied originally, but is deeper than the discount for Englewood, the largest and most auto-oriented TOD in our original study. As posited above, the size of the site and mix of housing types may militate against a very low vehicle trip generation rate. The actual vehicle trips we observed to/from/within the Station Park

TAD on the survey day totaled 74.7 percent of the ITE expected value. This is the highest vehicle trip rate relative to ITE among the seven sites we studied. Still, it achieves a 25.3 percent vehicle trip reduction as a mixed-use development. It provides an opportunity to drive and park once, and then walk to multiple destinations within the development.

TABLE 3 Average Vehicle Trip Reductions Relative to ITE Rates

TOD	*ITE vehicle trips*	*Actual vehicle trips*	*% of ITE trips*	*% reduction*
Redmond	1,767	661	37.4%	62.6%
Rhode Island Row	5,808	2,017	34.7%	65.3%
Fruitvale	5,899	3,056	51.8%	48.2%
Englewood	13,544	9,460	69.8%	30.2%
Wilshire/Vermont	5,180	2,228	43.0%	57.0%
Orenco Station	10,859	6,358	58.6%	41.4%
Station Park	41,077	30,692	74.7%	25.3%

Table 4 compares residential parking supply and demand for the Orenco Station TOD and Station Park TAD to those of previous five TOD sample. The parking generation rate for Orenco Station, on a per dwelling unit basis, is the lowest of all TODs studied except Rhode Island Row. It reflects the character of the residential development right next to the LRT station. They are mid-rise apartments. Parking is shared and unbundled. Note, again, that the calculations for Orenco Station only include reserved spaces for residents. Additional parking is available in shared parking arrangements. The parking generation rate for Station Park, on a per dwelling unit basis, is the lower than the ITE guideline. It 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 4 Residential Parking Supplies as a Percentage of ITE, and Residential Peak Parking Demand as a Percentage of Actual Supplies

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	2.0	1.19	0.86	59.5%	72.3%
Rhode Island Row	1.4	0.81	0.44	57.9%	54.3%
Fruitvale	1.4	NA	1.02	NA	NA
Englewood	1.4	1.6	1.29	114.3%	80.6%
Wilshire/Vermont	2.0	1.10	0.81	55.0%	73.6%
Orenco Station	1.6	1.08	0.63	68.0%	51.2%
Station Park	1.4	1.13	0.97	80.7%	82.9%

Finally, Table 5 compares total parking supply and demand for the Orenco Station TOD and Station Park TAD to those of previous five TOD sample. As with the rest, peak parking demands for both sites are less than half of the ITE supply guideline. However, comparing actual parking supply and demand at Orenco Station and Station Park, peak parking demands are lower

(relative to supply) than the original five TODs. Only Englewood even comes close. Put another way, Orenco Station and Station Park are the two most over-parked of the seven sites.

TABLE 5 Aggregate Parking Supplies as a Percentage of ITE Supplies, and Aggregate Peak Parking Demand as a Percentage of Actual Supplies

TOD	*Aggregate peak parking demand as % of ITE guideline*	*Aggregate peak parking demand as % of actual supply*
Redmond	41.6%	73.5%
Rhode Island Row	32.7%	63.6%
Fruitvale	19.0%	84.0%
Englewood	45.8%	58.3%
Wilshire/Vermont	33.0%	66.8%
Orenco Station	41.8%	51.2%
Station Park	35.5%	41.2%

DISCUSSION

How might the statistics in Tables 2 through 5 be used to plan for other TODs? The statistics represent default values, to be used when better estimates are not available. For planned TODs, the statistics 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 typically do not capture the full effects of the D variables on travel demand. By D variables we mean development density, land use diversity, street design, destination accessibility, and distance to transit for a particular TOD. These are known to affect travel choices (*24*;*25*; *26*). On the other hand, the mode shares, trip generation rates, and parking generation rates 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 we say 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.

Perhaps conservatively, one could set a floor on alternative mode shares and percentages trip and parking reductions equal to the minimum values for the six TODs, or could set a cap on these equal to the maximums from these TODs. Also, one could look for the best match to a particular TOD being proposed from among the sample of TODs. Obviously, any application of these statistics would ideally involve triangulation in light of regional travel demand model forecasts and MXD model estimates.

We acknowledge the following limitations to this study. The first and most important is the small sample size. These are truly case studies, as opposed to a cross-sectional sample. Due to labor-intensiveness of data collection (two people at each entry point to a TOD, one to count and the other to survey), the sample is limited to six TODs and one TAD.

Related to this is limited external validity. External validity is the extent to which the results of a study can be generalized to other situations, in this case, to other TODs. In particular, TODs we studied including Orenco Station TOD are exemplary in that they meet the definitional criteria we established at the outset. In particular, the fact that they literally abut transit stations suggests that they represent the best case for TOD, except perhaps in a downtown setting. Let it

suffice to say that, unless a planned or proposed TOD shares essential characteristics with a TOD in this sample, generalization will be hazardous.

A third limitation is an inability to account for internal capture of trips within these TODs. Internal trips are trips that begin and end within a mixed-use development. The majority of the TODs studied are small and, we argue elsewhere, likely have low internal capture rates. It is hard to imagine, except perhaps at the three larger developments: Englewood, Orenco Station, and Station Park, anyone doing anything but walking within the sample of TODs. Actually, we did ask a third question in our intercept surveys. We asked how many destinations were visited within the development. The results show that 40 percent of visitors to Station Park have more than one destination within the development; the average number of stops within the development on a single visit is 1.95, or almost two. The results show that 15 percent of visitors to Orenco Station have more than one destination within the development; the average number of stops within the development on a single visit is 1.19.

A fourth limitation is related to the phenomenon of residential self-selection. Residential self-selection occurs when people who would use transit anyway elect to live in a TOD. The literature strongly suggests that not everyone living in a TOD does so for the transit connection. But many probably do. If there is ever a case where self-selection is likely to be powerful, it is at developments that offer immediate, high-quality transit options. While the transportation statistics from these case studies can be used to plan individual TODs, which will likewise benefit from self-selection, these statistics probably (due to self-selection) overstate the benefit to the region as a whole in having TODs. Again, these self-selectors would be inclined to use transit anywhere, so there is not as much impact on regional mode shares or vehicle trips or perhaps even parking demand as the statistics imply.

We call for additional research on trip and parking generation at TODs. TODs, as we have defined them, are an increasingly common development type. In our home region of Salt Lake City alone, there are plans for nine TODs similar to those studied, including adjacency to rail stations. This study is a follow up of the earlier case studies by the authors at five exemplary TODs across the U.S. But creating a respectable sample of TODs with trip and parking data is too big a task for us to undertake alone.

ACKNOWLEDGEMENT

The authors acknowledge financial support for this study from the Utah Department of Transportation and logistical support from the main developers of Orenco Station and Station Park, the Holland Property Group and CenterCal Properties.

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contributions to the paper as follows: Study conception and design: R. Ewing; data collection: R. Ewing, G. Tian, K. Park, P. Stinger; analysis and interpretation of results: G. Tian, K. Park; draft manuscript preparation: R. Ewing, G. Tian, K. Park. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Goodrick, D. Comparative Case Studies: Methodological Briefs-Impact Evaluation No. 9 (No. innpub754). UNICEF Office of Research,2014. https://www.unicef-irc.org/publications/754/ Accessed September 11, 2017.

2. Institute of Transportation Engineers (ITE). *Trip generation manual (9th ed.).* Washington, DC: ITE, 2012.
3. Cervero, R., & G.B. Arrington. Vehicle trip reduction impacts of transit-oriented housing. *Journal of Public Transportation,*2008. 11(3): 1–17. http://dx.doi.org/10.5038/2375-0901.11.3.1
4. Nasri, A., & L. Zhang. The analysis of transit-oriented development (TOD) in Washington, DC and Baltimore metropolitan areas. *Transport policy*, 2014.32:172-179. doi:10.1016/j.tranpol.2013.12.009
5. Park, K., Ewing, R., Scheer, B., & S. Khan. Travel Behavior in TODs vs. non-TODs: Using Cluster Analysis and Propensity Score Matching. *Transportation Research Record: Journal of the Transportation Research Board,* In Press.
6. San Francisco Bay Area Metropolitan Transportation Commission (SFBAMTC). *Characteristics of rail and ferry station area residents in san francisco bay area: Evidence from the 2000 bay area travel survey*. Oakland: Metropolitan Transportation Commission, 2006. http://www.mtc.ca.gov/planning/smart_growth/stars/Executive_Summary_BATS2000_Station_Area_Residents_Study.pdf. Accessed September 11, 2017.
7. Faghri, A., & M. Venigalla. Measuring Travel Behavior and Transit Trip Generation Characteristics of Transit-Oriented Developments. *Transportation Research Record: Journal of the Transportation Research Board*,2013. No. 2397, pp. 72 –79. http://dx.doi.org/10.3141/2397-09.
8. Olaru, D., & C. Curtis. Designing TOD precincts: accessibility and travel patterns. European *Journal of Transport and Infrastructure Research*,2015. 15(1): 6-26.
9. Zamir, K., Nasri, A., Baghaei, B., Mahapatra, S., & L. Zhang. Effects of Transit-Oriented Development on Trip Generation, Distribution, and Mode Share in Washington, DC, and Baltimore, Maryland. *Transportation Research Record: Journal of the Transportation Research Board*,2014. No. 2413, pp. 45–53. doi: 10.3141/2413-05.
10. Arrington, G.B., & R. Cervero. *Effects of TOD on housing, parking, and travel (TCRP Report 128)*. Transportation Research Board, Washington, D.C., 2008.
11. Cervero, R. Transit-based housing in California: evidence on ridership impacts. *Transport Policy,* 1994. 1(3): 174–183. doi:10.1016/0967-070X(94)90013-2.
12. Lund, H.M., Cervero, R., & R.W. Wilson. *Travel characteristics of transit-oriented development in California*. California Department of Transportation, Sacramento, CA,2004. http://staging.community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-lund-cerv-wil.pdf. Accessed September 11, 2017.
13. Lund, H.M., Willson, R., & R. Cervero. A re-evaluation of travel behavior in California TODs. *Journal of Architectural and Planning Research*,2006. 23(3): 247–263.
14. Langlois, M., van Lierop, D., Wasfi, R. A., & , A. M. El-Geneidy, Chasing Sustainability: Do New Transit-Oriented Development Residents Adopt More Sustainable Modes of Transportation?. *Transportation Research Record: Journal of the Transportation Research Board*, 2915. No.2531, pp. 83-92. http://dx.doi.org/10.3141/2531-10.
15. Handy, S., Shafizadeh, K., & Schneider, R. *California Smart-Growth Trip Generation Rates Study*. University of California, Davis for the California Department of Transportation,2013. http://nacto.org/docs/usdg/smart_growth_trip_generation_rates_handy.pdf. Accessed September 11, 2017.

16. Ewing, R., Tian, G., Lyons, T., & K. Terzano. Trip and Parking Generation at Transit-Oriented Developments: Five US Case Studies. *Landscape and Urban Planning*, 2017.160: 69-78.
17. Institute of Transportation Engineers (ITE). *Parking generation (3rd ed.).* Washington, DC: ITE, 2010.
18. Cervero, R., Adkins, A., & C. Sullivan. Are suburban TODs over-parked? *Journal of Public Transportation*, 2010. 13(2): 47–70. doi: http://dx.doi.org/10.5038/2375-0901.13.2.3.
19. Chatman, D.G. Does TOD need the T? On the importance of factors other than rail access. *Journal of the American Planning Association*, 2013.79(1): 17–31. doi:10.1080/01944363.2013.791008.
20. Guo, Z. Does residential parking supply affect household car ownership? The case of New York City. *Journal of Transport Geography*, 2013.26: 18–28. doi:10.1016/j.jtrangeo.2012.08.006
21. Weinberger, R. Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive. *Transport Policy*,2012. 20: 93–102. doi:10.1016/j.tranpol.2011.08.002
22. Weinberger, R., Seaman, M., & C. Johnson. Residential off-street parking impacts on car ownership, vehicle miles traveled, and related carbon emissions: New York City case study. *Transportation Research Record: Journal of the Transportation Research Board*, 2009.No. 2118, pp. 24–30. doi: 10.3141/2118-04.
23. Loo, B. P., Chen, C., & E. T. Chan. Rail-based transit-oriented development: lessons from New York City and Hong Kong. *Landscape and Urban Planning*,2010. 97(3): 202-212. https://doi.org/10.1016/j.landurbplan.2010.06.002
24. Ewing, R., & R. Cervero. Travel and the built environment: a meta-analysis. *Journal of the American planning association,*2010. 76(3): 265–294.
25. Ewing, R., Greenwald, M., Zhang, M., Walters, J., Feldman, M., Cervero, R., & J. Thomas. Traffic generated by mixed-use developments—Six-region study using consistent built environmental measures. *Journal of Urban Planning and Development,* 2010. 137(3): 248–261.
26. Tian, G., Ewing, R., White, A., Hamidi, S., Walters, J., Goates, J.P., & Joyce, A. Traffic generated by mixed-use developments—13-region study using consistent built environment measures. *Transportation Research Record: Journal of the Transportation Research Board,* 2015. No. 2500, pp. 116–124. http://dx.doi.org/10.3141/2500-14.