Assessing Park-and-Ride Efficiency and User Reactions to Parking Management Strategies

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Abstract

Increasing the number of spaces at overutilized park-and-rides often is not possible due to budgetary and other constraints. Instead, transit agencies may instead seek to maximize the number of people that are able to use the existing spaces through various parking management strategies. Unfortunately, the efficiency of park-and-rides is difficult to measure, so agencies cannot accurately quantify existing use or improvement after parking management strategies have been applied. This study proposed and tested a method to measure the person-efficiency of park-and-ride lots through an onsite audit. Additionally, a user survey was proposed to confirm the audit results and unveil reactions to parking management strategies to increase person-efficiency. The onsite audits and user surveys were conducted at several overutilized park-and-ride lots in the Central Puget Sound Region of Seattle, Washington. The results show that the person-efficiency can be measured easily, and several potential avenues to increase person-efficiency of park-and-rides are identified.

Keywords: *Park-and-ride lots, parking management, parking pricing*

Introduction

Park-and-ride lots have become a prominent feature of dense metropolitan regions in the United States since their emergence in the 1930s (Noel 1988). These facilities are used to promote the use of higher-occupancy transit vehicles in urban areas by providing commuters with a more convenient means—driving—to access transit service (Turnbull 1995). Although there are some mixed findings in the literature (Meek et al. 2008, 2010), increased transit use generally is related to decreased vehicle miles traveled and other negative externalities associated with automobile use (van der Waerden et al. 2011). Park-and-rides also are associated with additional benefits to users and transit agencies, including convenience, reduced trip costs, increased travel comfort,

aggregation of transit demand, and faster commercial transit speeds (Bowler et al. 1986; Noel 1988). Although some disadvantages exist—specifically, transfer of congestion from one area to another, underutilization, increased congestion due to induced travel demand, and contribution to sprawling land use patterns (Parkhurst 2000)—park-and-rides are generally viewed positively in urban transportation systems.

Existing practitioner guidebooks provide well-established guidelines for implementing park-and-ride facilities (Bowler et al. 1986; Bullard and Christiansen 1983; Turnbull 1995). The majority of more recent research literature focuses on methods to optimally locate these facilities within an existing network (Aros-Vera et al. 2013; Faghri et al. 2002; García and Marín 2002; Horner and Groves 2007) or idealized network structures (Liu et al. 2009; Wang et al. 2004). However, little guidance exists to address a rapidly-emerging problem: the overutilization of capacity-constrained park-and-rides. This is a significant issue that affects many major metropolitan regions with well-developed transit and park-and-ride systems. For example, an audit of existing lots in the Puget Sound Region reveals that approximately 19,700 of the available 25,367 parking spaces at park-and-ride lots (78%) are used on a daily basis, and over half of these lots are either full or nearly so (King County Metro Transit 2014). The average lot utilization rates in Snohomish and Pierce counties are 87% and 77%, respectively. Historical data also reveals that the demand for these facilities is steadily increasing and is likely to continue in the future. Another documented example (Shirgaokar and Deakin 2005) suggests that overutilization is a problem within the San Francisco Bay Area, where 4 of 7 surveyed locations had utilization rates greater than 90%.

Whereas full parking spaces are a sign of well-used facilities, lack of parking space availability means that the lots are not able to serve additional commuters. A potential solution to address this problem is to increase the number of parking spaces; however, doing so is expensive and can be unpopular in some neighborhoods. Instead, agencies are beginning to recognize the need for other types of parking management strategies at park-and-rides to increase the number of people that are able to use the overutilized facilities to access transit (Habib et al. 2013; Hendricks and Outwater 1998). Agencies are considering strategies that prioritize multiple-occupant vehicles over single-occupant vehicles (SOV) so that the same number of spaces can serve more people. Although such policies might cause some choice transit users to abandon transit altogether, the net benefit still might be positive if these policies increase the total number of people who are able to use the park-and-rides to access transit.

Unfortunately, agencies generally have little to no data on the number of people served by parking spaces at park-and-rides since there is no well-established methodology to estimate the person-efficiency of these lots. Agencies also do not know how users may react to potential parking management strategies. In light of this, the purpose of this study was to propose a method to measure the person utilization of parking spaces at existing commuter park-and-ride lots and assess user feedback to strategies designed to increase the number of people who can be served by these facilities. The estimates of person utilization were obtained through an onsite audit of the use of existing facilities, and these estimates were confirmed using user intercept surveys conducted at these facilities. Additionally, the intercept survey provides more insight on how existing park-

and-rides are used and user feedback on proposed parking management strategies. Both were tested as some of the busiest park-and-ride lots in the Central Puget Sound Region.

The remainder of this paper is organized as follows. The following section describes the audit methodology used to assess park-and-ride passenger efficiency. Next, the user survey and general results are described. Then, user responses to parking management strategies are summarized. Finally, concluding remarks are provided.

Audit to Assess Park-and-Ride Passenger Efficiency

Transit agencies typically measure park-and-ride lot utilization as the fraction of parking spaces occupied by vehicles or the total number of transit boardings per parking space. However, the former does not measure how many people use the lot, and the latter includes transit boardings by users that did not use a parking space.

In this study, we focused on the average number of people served by each parking space, which we define as the person-efficiency. This person-efficiency also is equal to the average passenger occupancy of vehicles that actually park at the lot for transit purposes. Unfortunately, agencies do not have a well-established methodology to calculate the person-efficiency of park-and-ride lots. In this paper, an onsite audit is proposed to measure person-efficiency of park-and-ride spaces. The remainder of this section describes the audit procedure and summarizes the results of a set of case studies performed at park-and-rides in the Puget Sound region of Seattle.

Methodology

In this methodology, observers track the movement of people and vehicles into the park-and-ride facility during a peak period. An observer is placed at each of the vehicle entry points into the park-and-ride lot such that they can see how many people are inside each entering vehicle. The observers record the total number of entering vehicles and number of people within these vehicles for the observation period. Observers also are placed near well-used drop-off locations to record the total number of kiss-and-ride drop-offs, K , that occur within the parking areas. Figure 1 provides a schematic that illustrates how vehicles use the lot and what vehicles should be observed.

FIGURE 1.
Schematic of audit to assess
person-efficiency of
park-and-rides

Denote the number of vehicles and people entering the park-and-ride facility during the observation period as C_{in} and P_{in} , respectively. A simple estimate for the person-efficiency of parking vehicles is provided by:

$$\text{Person-Efficiency} = (P_{in} - 2K)/(C_{in} - K) \quad (1)$$

The denominator in Equation (1) represents the number of vehicles parking at the lot during the observation period. It is equal to the difference between the total number of vehicles entering and the number of kiss-and-ride vehicles that enter but do not park. The numerator represents the total number of people using parking spaces and is equal to the number of people entering in a vehicle minus the number of people involved in kiss-and-ride drop-offs. For this latter number, we assumed that each drop-off involves just two people: the driver and the passenger being dropped off. The data collection team noted that this was the case for almost all kiss-and-ride maneuvers that were observed. Note that, in this procedure, the estimate of person-efficiency includes drivers of carpools/vanpools that pick up passengers inside the park-and-ride lot and leave. In reality, these drivers park only temporarily before leaving and they should not be included in the person-efficiency measurement. A more complicated procedure to account for these carpools/vanpools is provided in (Gayah et al. 2014). However, the two values are remarkably close; therefore, the more straightforward method is provided here for practitioners to estimate person-efficiency for existing park-and-ride lots.

Results

The onsite audit procedure was conducted for nine commuter park-and-ride lots in the Puget Sound area (see Figure 2 for a map of the lots). The audits were conducted in the AM peak hours of weekdays during the weeks of October 21 and November 4, 2013. Table 1 presents the raw data and estimates of lot utilization, defined as the fraction of parking spaces filled at the end of the data collection period (which generally took place from 5:00-10:00am), and estimated person-efficiency of parking spaces at each of the lots. These lot utilization values account for vehicles present during the lot at the start of the audit and already-parked vehicles that exit during the audit time period (e.g., night shift workers returning home from work). As can be seen, the majority of the facilities became completely filled (described as 100% of the parking spots being occupied by vehicles) during the data collection period. Of the three lots that did not completely fill, two (Auburn Station and Issaquah Transit Center) were audited on a Friday, when travel demands can be expected to be lower than normal. Even so, more than 80% of the spaces at these locations were used, suggesting that they are at or near capacity on typical weekdays.

FIGURE 2.
Map of park-and-ride
facilities considered

Red pin indicates survey only; yellow pin indicates survey and onsite audit.

TABLE 1.
Summary of
Onsite Audit Data

Lot	Parking Spaces	C_{in}	P_{in}	K	Lot Utilization	Time Lot Completely Filled	Person-Efficiency (EQN 1)	Fixed-Route Transit Users
Auburn	633	549	594	23	85.8%	–	1.042	96%
Eastgate TC	1,614	1,643	1,795	125	90.8%	–	1.018	96%
Federal Way TC	1,190	1,334	1,578	149	100.0%	7:40 AM	1.080	92%*
Issaquah Highlands	1,000	1,160	1,322	122	100.0%	9:10 AM	1.039	84%
Issaquah TC	819	741	832	62	82.3%	9:15 AM	1.043	95%
Lynnwood TC	1,368	1594	1,880	213	100.0%	7:25 AM	1.053	88%*
Mercer Island	447	530	639	74	100.0%	7:50 AM	1.077	95%
Overlake TC	222	282	333	47	100.0%	7:35 AM	1.017	99%
Sumner	343	288	318	20	100.0%	5:40 AM	1.037	88%*

* Estimates may be inaccurate due to lot geometry.

In general, the person-efficiency values are very near 1; the highest is just 1.080 passengers per parked car. This suggests that the majority of people parking at these facilities arrive at the park-and-rides in an SOV. Although such a result is not surprising, it provides quantitative data with which lot managers can use to justify the implementation of parking management strategies designed to promote carpooling and multi-occupant vehicle use at these facilities.

Table 1 also provides an estimate of the fraction of people who parked and went on to use fixed-route transit options (bus, train, or local fixed-route shuttles). This was determined by members of the audit team, who observed where vehicle occupants went after parking at the park-and-ride facilities. Only about 2% of users were noted as leaving the lot for non-transit purposes. Users that did not proceed to the transit boarding area or adjacent offsite establishments were identified as using flexible transit options such as carpools or vanpools. At some locations, the lot geometry made it difficult to estimate the fraction of parking users that used fixed transit options; these lots are denoted with an asterisk in Table 1.

User Intercept Survey

A user intercept survey was conducted to learn more about park-and-ride users at each of the lots, as well as to capture their feedback/reactions to the implementation of new parking management strategies to increase person-efficiency. This section describes the survey tool and its coverage, the characteristics of park-and-ride users who responded, travel information, and reasons for using the park-and-rides. A detailed overview of the full survey results can be found in Gayah et al. (2014).

Description of Survey and Coverage

The primary goal of the survey was to collect information on how park-and-ride users actually use these facilities (i.e., to confirm the audit results) and their reactions to potential parking management strategies. The survey was broken down into several thematic categories:

- Transit Pass Ownership
- Origin and Destination
- Travel Time
- Mode Entering and Mode Exiting
- Current Park-and-ride Use Preference
- Bicycle and Pedestrian Preference
- Pricing Strategy Preference
- Carpooling Preference
- Socioeconomic Information

The survey was distributed at 17 sites, including the 9 at which the onsite audit was performed, in the AM peak hours of weekdays during the weeks of March 4 and March 11, 2014 (see Figure 2). To maximize the number of responses, users were provided with two options to complete the survey: a paper survey that could be completed onsite or a card with website link to a mobile-phone-friendly electronic copy of the survey that could be completed later. The data collection team was located near the primary transit stops at each lot (since this location had the largest congregation of people); however, the team strived to provide every park-and-ride user with an opportunity to complete the survey. Carpoolers/vanpoolers were the most challenging groups to survey onsite, as they tended to gather at the more remote locations of the park-and-ride lot. To address this, the website link also was emailed to the set of registered vanpool users for several of the lots (Eastgate TC, Issaquah Highlands, Kenmore, South Kirkland, and Tukwila) via emails from King County Metro.

A summary of the survey distribution by lot is provided in Table 2. More than 3,300 unique surveys were collected; about 2,000 were paper surveys, and the remaining 1,300 were completed online. The last column of Table 2 presents the ratio of the total number of surveys collected to the total number of parking spaces available at each lot, which was used as a measure of survey penetration. The survey had an average “penetration” of about 25% of the total number of parking spaces across all facilities. At individual park-and-ride facilities, the penetration rate ranged between 11% and 40%.

TABLE 2.
Summary of Survey Data
Collection

Lot Name	Total Completed Surveys	Paper Surveys	Online Surveys	Lot Capacity	Penetration Rate
Auburn	172	121	51	633	27.2%
Eastgate TC	348	146	202	1,614	21.6%
Federal Way TC	283	217	66	1,190	23.8%
Issaquah Highlands	396	217	179	1,000	39.6%
Issaquah TC	284	197	87	819	34.7%
Kenmore	121	20	101	603	20.1%
Lynnwood TC	305	221	84	1,368	22.3%
Mercer Island	108	53	55	447	24.2%
Overlake TC	80	54	26	222	36.0%
Puyallup	165	105	60	432	38.2%
South Everett	148	132	16	397	37.3%
South Kirkland	223	159	64	852	26.2%
Sumner	138	75	63	343	40.2%
Tacoma Dome	262	88	174	2,283	11.5%
Tukwila International Blvd.	199	159	40	600	33.2%
Tukwila P&R	33	11	22	255	12.9%
Tukwila Station	76	45	31	208	36.5%
Total	3,341	2,020	1,321	13,266	25.2%

User Characteristics

The majority of survey participants were between the ages of 25 and 55. Participants were evenly split by gender. About half lived in households with two or fewer members. Household income was fairly uniformly distributed between annual salaries of \$30,000–\$150,000+; only 3% of participants made less than \$30,000 per year. More than 99% of participants had at least a high school diploma, and 67% of participants had some form of college degree. There was no apparent link between education level and preference toward public transit use. The majority of survey participants had access to a working vehicle, with 98% of respondents having at least a single working vehicle in their household, and 86% of respondents having at least two working vehicles in their household. The average auto sufficiency—defined as the number of cars per household member—was 1.02 vehicles/person, and nearly 60% of respondents had more than one car per household member. Across individual modes, those that drove to the park-and-ride had average auto sufficiency values of 1.02 vehicle/person, and kiss-and-ride drop-offs had very similar average auto sufficiency values (about 0.98 veh/person). These metrics indicate that the vast majority of park-and-ride users were not captive transit users.

The majority of the participants (94%) indicated that they had an ORCA (One Regional Card for All) card, used to pay bus and train fares in the Puget Sound region. Of the ORCA cardholders, 77% received some form of transit subsidy, which supports the finding that park-and-rides are used because they help save money. Subsidized transit users might not be as sensitive to pricing strategies as others, since a significant portion of their transit fare was being subsidized. Since so many received ORCA cards at a reduced rate, allowing users to pay for parking with their ORCA card might not significantly disincentivize SOV use, as many individuals would not experience the full pricing effect.

Travel Information

As expected, the majority of trips at the park-and-ride lots were commute trips to work (94.4%), with the next highest trip purpose being commute trips to school (3.2%). This would suggest that park-and-ride users regularly used the lots, confirmed by the fact that the average use of park-and-rides by survey respondents was nearly 4.5 times per week. This usage frequency was quite consistent across all individual facilities, as statistical t-tests confirmed that the mean value at each lot did not significantly differ from the overall mean value across all lots. Trip origin information was used to estimate distances traveled to the park-and-ride location. The majority of origins (71%) were located within 5 miles of the park-and-ride facility, and the average distance traveled to the park-and-ride lots was 4.1 miles. Those who parked at the lot had a slightly smaller mean travel distance (3.7 miles), but the distribution between those who parked and all other users was similar.

The clear majority (nearly 74%) of participants arrived to the park-and-ride in an SOV. Of the remaining participants, the highest uses appeared to be bus (indicating the park-

and-ride is a transfer location) (8%) and kiss-and-ride drop-off (7%). The ratio of drop-offs to entry in a parked vehicle (SOV, carpool or vanpool) was about 0.085, which is generally in line with the ratio of K to P_{in} in Table 1. These data also suggested that the lots are being used primarily for their intended purpose, which is to access transit. The majority of the users surveyed exited the lot by a fixed-route transit mode: either bus (72.2%) or train (20.4%). Flexible transit—e.g., carpool (0.5%) and vanpool (2.8%)—use was about half that indicated by the onsite audit; however, as previously indicated, these users were the most difficult to reach with the survey. Finally, the fractions of fixed and flexible transit users were consistent across both the set of total users and the set of users who parked a vehicle at the facility.

Since we specifically were concerned with the person-efficiency of the park-and-ride lots, we also examined the distribution of entry modes considering only those participants arriving by modes that required both a car and parking space: drive alone, carpool, or vanpool. For this set of parked vehicles, 93% entered in an SOV, which is consistent with the onsite audit results. Table 3 provides a comparison between the fraction of SOVs parking at the lots estimated from the survey and onsite audit. In most cases, this fraction is between 90–100%; however, Overlake TC and Sumner have single-occupant parking percentages near 85%, indicating that higher levels of carpool/vanpool activities may occur at these locations. A chi-square test was performed to see if this fraction was statistically equal across all lots. The resulting p-value was >0.01 , which suggested that the distribution was not statistically different across all facilities. Therefore, there is not enough statistical evidence to suggest that Overlake and Sumner are statistically different from the average distribution of all lots.

The estimated SOV parking fractions obtained from the onsite audit data also are provided in Table 3 for comparison with those obtained through the surveys. In most cases, SOV fractions obtained from the audit are slightly higher than the fractions obtained from the survey; however, in general, the two values are consistent. The audit estimates do not fall within the 95% confidence interval obtained from the survey data for Auburn, Eastgate TC, Issaquah Highlands, Overlake TC, and Sumner. Of these, only Eastgate TC, Sumner and Overlake TC have significant differences (i.e., differences greater than 6%) between the audit and survey data. Reasons for these discrepancies might include self-selection bias for the users who chose to respond to the surveys, differences in park-and-ride facility during the audit and survey periods, and estimation inaccuracies during the onsite audit process.

TABLE 3.
Fraction of Single-Occupant
Vehicles Parking at Each Lot

Lot Name	SOV Fraction (Survey)	LB of 95% CI	UB of 95% CI	SOV Fraction (Audit)
Auburn	91.3%	84.2%	95.3%	95.5%
Eastgate TC	91.7%	87.8%	94.4%	98.1%
Federal Way TC	93.1%	89.0%	95.7%	89.8%
Issaquah Highlands	92.9%	89.7%	95.2%	95.8%
Issaquah TC	95.4%	92.1%	97.3%	96.0%
Kenmore	93.1%	86.4%	96.6%	---
Lynnwood TC	92.8%	88.3%	95.7%	94.3%
Mercer Island	93.2%	85.9%	96.8%	91.9%
Overlake TC	84.2%	72.6%	91.5%	98.3%
Puyallup	93.0%	86.9%	96.4%	---
South Everett	96.5%	91.4%	98.6%	---
South Kirkland	93.4%	88.5%	96.3%	---
Sumner	84.1%	75.0%	90.3%	94.7%
Tacoma Dome	96.4%	93.1%	98.2%	---
Tukwila International Blvd.	95.0%	90.0%	97.5%	---
Tukwila P&R	100.0%	-	-	---
Tukwila Station	90.4%	81.5%	95.3%	---
All	93.0%	92.0%	94.0%	---

LB = Lower Bound; UB = Upper Bound; CI = Confidence Interval

Use of Park-and-Rides

Survey participants were asked to identify all the reasons they used park-and-ride facilities from the following list:

- No parking at destination (34.9% agreement)
- Driving takes too long (44.9% agreement)
- Environmental reasons (36.1% agreement)
- To save money (77.1% agreement)
- Can relax on transit (59.6% agreement)

Unsurprisingly, a majority of users indicated that they use park-and-rides for the convenience and relaxation opportunity provided within transit vehicles. A third of respondents indicated that they used park-and-rides because of the lack of parking availability at the destination. This category included three potential options that a park-and-ride user might experience: the complete lack of parking spaces, the lack of employer-provided parking spaces, or the lack of free parking. Further differentiation among these three options was not included in the survey to simplify its presentation. About half of participants indicated that they used park-and-rides because driving takes too long. Since transit trips typically take longer than driving (in terms of door-to-door

travel time), this further suggests that people value transit for longer trips since they can focus on other tasks. For example, they can work and relax on the transit vehicle on the way to work, which is generally not possible while driving.

Survey participants also indicated reasons they used a specific park-and-ride lot. It appears that convenience was the primary reason for selecting a particular park-and-ride lot, since users generally selected park-and-ride lots that were closer to their origin (64.3% agreement) and those that provided express transit service (39.2%). Many also indicated that they selected the park-and-ride simply because it was the closest transit station (24.9%). Very few (4.5%) indicated that they selected a particular lot because they could not find parking at their desired lot, which suggests that park-and-ride users might not try new lots if their preferred lot becomes full. This was verified, as only 31.0% of users indicated that they would drive to another park-and-ride if parking was not available at the lot at which they were surveyed. The remaining participants indicated they would park nearby and walk to the lot (19.7%), drive directly to their destination (29.5%), or were either unsure or would use another method (21.6%). Only 2% of participants indicated that they would not make this trip if parking was not available at the park-and-ride, which is reasonable since these are primarily commute trips to work or school.

User Response to Efficiency Strategies

The user intercept survey also included several questions to assess user reaction to various parking management strategies that might be considered by the Washington State Department of Transportation (WSDOT) and related agencies for parking management at park-and-rides in the future. One set of questions focused on willingness to pay for parking, another focused on carpooling alternatives, and another focused on bicycle/pedestrian alternatives.

Willingness to Pay for Parking

Three questions were included to gauge willingness to pay: (1) to park at the facility (general parking fee); (2) to reserve a guaranteed space; and (3) to reserve a guaranteed space located a 10–15-minute walk offsite. The first question directly asked respondents if they would still park at the park-and-ride facility if a parking fee was implemented and, if they answered yes, how large a fee would they be willing to pay to park (\$1–\$5/day in \$1 increments). Similarly, users were asked the maximum amount they would be willing to pay to reserve a guaranteed parking space at the park-and-ride facility or a guaranteed parking space located a 10–15-minute walk away from the facility. The guaranteed spaces would be reserved for use only by the users that paid for these spaces (in advance), as if they were able to “rent” the spaces ahead of time. Pricing of guaranteed spaces located a 10–15-minute walk away from the park-and-ride facility was included to assess how much users might pay for parking spaces at multi-family developments near park-and-rides, a strategy being piloted by WSDOT. If a user was not willing to pay anything or not willing to park a 10–15-minute walk away, a value of

\$0.00 was used. This direct method was used to reduce the time required to take the survey and to alleviate concerns that pricing was imminent at these locations (which was a concern of WSDOT and the other agencies that supported the survey). This was a limitation of the pricing questions, as users could simply state that they would not be willing to pay anything to park at these facilities. For this reason, the magnitude of the willingness to pay might not represent actual willingness to pay. Instead, the relative magnitudes across different types of willingness to pay are likely to reveal preferences among different pricing strategies.

Unsurprisingly, park-and-ride users were generally unwilling to pay for the (currently free) parking spots. Only 28% were willing to pay for existing spots or guaranteed spots located at an offsite location. That fraction increased to 46% if the parking fee would guarantee a parking space within the lot itself. Of those willing to pay, respondents indicated they would pay an average of about \$1.50 for existing spots at the lot or guaranteed spots a 10–15-minute walk away and \$1.83 for a guaranteed spot at the lot itself. Thus, it appears that whereas almost twice as many people are willing to pay for a guaranteed space, they are not willing to pay significantly more for these guaranteed spaces. However, the provision of guaranteed spaces might make the implementation of parking fees more palatable to park-and-ride users.

Alternatives to Avoid Parking Fees and Promote Carpooling

Survey participants were asked if they would be willing to (1) carpool to a lot if carpools were exempt from paying a parking fee, (2) carpool to a lot if carpools were provided guaranteed parking spaces, and (3) park 10–15 minutes away if a guaranteed free parking space was available there. The results of the first two questions were about the same: half of the respondents indicated they would not consider carpooling to avoid parking fees or to obtain guaranteed parking spaces, about one-quarter indicated they would be willing to consider carpooling if carpools did not have to pay a parking fee or were provided guaranteed “carpool-only” parking spaces (which is promising since current carpooling rates to these facilities were very low, about 5% based on the survey responses), and the remainder indicated they either already carpool (5%) or were unsure (20%).

Since these locations are already overutilized, providing guaranteed parking spaces for carpool users would take spaces away from single-occupant drivers. However, about 40% of the respondents indicated that they would be willing to park at a satellite location a short walk away to obtain a guaranteed space. This suggests that if increasing capacity at the park-and-ride itself is not an option, offsite capacity improvements nearby could be beneficial to accommodate overflow demand. Therefore, it might be a good idea to entice SOVs to park at these locations to free up carpool-only spots at the main lot. It should be noted that this strategy is especially promising, as conversations with park-and-ride users during the survey process revealed that many users already do this when the lot is full; i.e., park-and-ride users already park either on the street or in nearby parking lots when the park-and-ride is full and walk to the station. Formal

overflow parking at adjacent locations might be an efficient strategy to increase the use of park-and-rides without significant infrastructure investments.

Bicycle/Pedestrian Alternatives

Another potential strategy to reduce SOV parking is to add bicycle lockers and/or to improve bicycle and pedestrian access at the individual park-and-ride facilities. Participants were asked if these improvements would make them more willing to bike/walk to the park-and-ride. Overall, the responses suggested that these improvement strategies are not promising: only 12% would be more willing to bike if bicycle lockers were provided, and only 17% would be more willing to bike/walk if better pedestrian/bicycle access were provided.

Potential for Transit Access to Park-and-Ride Facilities

In general, transit access to the park-and-ride facilities is very small (only about 8% of users arrive to the lots using local transit options). One potential strategy to improve the person-efficiency of park-and-ride lots is to entice more SOVs to access the park-and-ride through local transit vehicles (e.g., buses). However, local buses may not be a feasible option for many travelers due to their trip origin and location of current local transit routes: if transit service is not available at their origin, users must drive (often alone) to the nearest park-and-ride to access transit service.

To assess the potential for transit use to increase parking efficiency, maps of the set of origins of all single-occupant drivers were created using the origin information from the user intercept survey for each park-and-ride facility. These maps were then used to determine what fraction of single occupant drivers had feasible transit alternatives. As an example, consider the trip origins identified for the Tukwila International Boulevard Station shown in Figure 3. Each unique origin is shown by the red marker on the figure, and the relevant portions of the local bus lines serving this facility are drawn on the map. Only bus routes that provided service during the AM peak hours that these trips were actually made were considered. Figure 3 reveals that a significant fraction of origin markers lie either directly on existing transit lines or very close by. Drivers at these locations potentially could be served by transit if bus stops along these lines were located near the origin markers. Several origins are isolated and located well away from the park-and-ride facility, e.g., the set of origins directly east and southwest of the park-and-ride marker; it probably would not be feasible to dedicate transit service to serve these origins. Although not perfect, maps such as these created using detailed survey data from park-and-ride users could provide agencies with vital information on how many parking spaces could be freed up by enticing park-and-ride users to use local transit service to access the park-and-ride.

FIGURE 3. Tukwila International Boulevard Station with origins and transit routes

For each lot, the fraction of SOV origins that lie along existing local transit routes was estimated (see Table 4). Note that origin markers often overlap, as survey participants were asked only for the nearest major intersection to their origin. Since each marker near a transit line was counted only once, the results in Table 4 are conservative. The origins initially were disaggregated by the number of trips made from that origin per week; however, the vast majority of users were commuters that made 4–5 trips per week, so this disaggregation did not offer any additional insights. Furthermore, we considered only origins directly on transit routes or within 0.1 miles of the route.

TABLE 4.
Summary of Origins with
Potential Transit Service

Lot Name	Number of Unique Origins	Number of Origins along Existing Transit Lines	Fraction with Potential Transit Access
Auburn	60	15	25.0%
Eastgate TC	207	67	32.4%
Federal Way TC	150	48	32.0%
Issaquah Highlands	219	27	12.3%
Issaquah TC	181	37	20.4%
Kenmore	78	14	17.9%
Lynnwood TC	135	24	17.8%
Mercer Island	69	34	49.3%
Overlake TC	37	18	48.6%
Puyallup	86	23	26.7%
South Everett	88	2	2.3%
South Kirkland	126	38	30.2%
Sumner	52	5	9.6%
Tacoma Dome	162	33	20.4%
Tukwila International Blvd.	90	20	22.2%
Tukwila P&R	33	7	21.2%
Tukwila Station	39	4	10.3%

Several facilities have very high fractions of origins for which transit access may be possible: Eastgate TC, Federal Way TC, Mercer Island, Overlake TC, and South Kirkland. At these locations, the promotion of transit to access the park-and-rides may be a feasible way to improve park-and-ride efficiency. Furthermore, pricing strategies at these locations could be supplemented with transit map information to provide users with an alternative to avoid the parking fee and still use transit at the park-and-ride. Several other facilities have very little potential for transit as an alternative access mode: Sumner, South Everett and Tukwila Station. At these locations, pricing might be less palatable, as users do not have feasible transit alternatives to avoid paying the parking fee.

Of course, these results are not perfect. We were not able to identify if these routes were sufficiently “connected” to the origins by sidewalks or bicycle lanes. This would be critical for users to access the bus line. Furthermore, information was not available on the passenger occupancies of these buses, so we could not identify if sufficient space was available on these buses to serve new passengers. Finally, it was not clear if amenities such as benches or shelters were available at these bus stop locations, although we do not know if bus users in the Puget Sound Region highly value these amenities. Nevertheless, this mapping method provides initial insight into which park-and-ride lots have the most potential to serve those who drive alone to the park and ride by transit.

Concluding Remarks

Overall, this project collected and analyzed data at 17 of the busiest park-and-ride facilities in the Central Puget Sound Region to provide more detailed information on how these facilities are used. A methodology was proposed to assess the person-efficiency of parking spaces at these lots, measured as the passenger occupancy of parked vehicles. These data confirm prior expectations that most parked vehicles had just a single occupant and provides empirical justifications for the implementation of parking management strategies to improve parking efficiency. A user intercept survey confirmed that the estimates of person-efficiency from the audit was fairly accurate. The survey also revealed that the majority of users parked at these facilities for transit purposes. Fixed-route transit (such as bus or train service) was dominant, although heavy carpool/vanpool use was noted at several lots. If these flexible transit uses are not desired, then steps will have to be taken to prohibit these uses. However, these informal uses still can lead to reduced car travel (and the associated reductions in negative car-related externalities), so alternative space should be provided for carpool/vanpool formations to occur if banned at these lots.

The user survey also revealed reactions to potential parking management strategies. For example, users generally are not willing to pay to park at these (already free) lots; however, they are more willing to pay if this fee could reserve a parking space in advance, even if it was located a 10–15-minute walk away from the park-and-ride location. About a quarter of survey participants indicated that they would be willing to consider carpooling to avoid a parking fee; therefore, a targeted carpooling initiative along with pricing of SOVs could be an effective means to improve person-efficiency at these lots. The survey data suggest that providing reserved carpool spaces and allowing carpools to avoid parking fees generally would have the same impact. Thus, providing these types of prioritization strategies at overcrowded lots should significantly improve person-efficiency. Unfortunately, users did not indicate that improving bicycle and pedestrian access/facilities would significantly improve travel to the park-and-ride lots by these modes. Instead, it appears that resources to improve these facilities should be dedicated elsewhere if improved person-efficiency is the primary objective. Another way to improve efficiency is to divert SOVs to transit alternatives to access the park-and-ride. This would free-up parking spaces at these overutilized locations, which then can be dedicated to carpool vehicles to provide them with priority. As suggested by the data, there are significant fractions of single-occupant drivers who have feasible alternatives using existing transit routes.

A limitation of the survey was that respondents were asked directly about their willingness to pay for various types of parking fees. By doing so, park-and-ride users might underestimate their true willingness to pay for the already free parking spaces. Future work might instead provide respondents with a set of scenarios with different parking fee structures and amenities (including guaranteed spaces for a parking fee) to be understand their true willingness to pay for parking and park-and-ride facilities.

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