State Revenue Implications of Ferry Capacity Utilization*

A Case Study of The Fauntleroy Ferry Terminal

Jeremy Cooper
Economic Analyst
Affirma Consulting
jeremydcoop@gmail.com

Theo S. Eicher
Professor of Economics
University of Washington
te@uw.edu

Version 2.0
January 23, 2018

*WSF scanner ticketing data were first requested as part of a student data-visualization project in 2012. Further data requests in 2017 are the basis for this report. We thank Pat Call, Jar Lyons, Mark VanDevander, Kathy Abascal, Jan Stephens, Chengjun Zhang, Lisa Ballard, and many others who commented on the substance covered in earlier on drafts. We also thank Sharon Nelson, Jan Angel, Eileen Cody, Michelle Caldier, Joe Fitzgibbon and Jesse Young for joint comments on a previous version of this study.

Executive Summary

Delays at the Fauntleroy ferry terminal increased as vehicle traffic declined secularly since the early 2000s. Ferry capacity increased since 2007, but ferry capacity utilization decreased significantly during rush hours. During the summer of 2017, the vehicle line backed up regularly beyond the mile marker to congest Fauntleroy Way. Delays and capacity underutilization are shown to cause revenue losses to Washington State due to forgone vehicle and passenger revenues. These losses accumulate in addition to commuters' time costs. These features of the system are present primarily when the system is stressed, as is the case during the summer months or during traffic events on nearby interstate highways. This study focuses on the system's bottlenecks that are exposed under stress.

Concurrent with these data trends, Washington State Ferries' (WSF) own reports of operational efficiency have come to diverge sharply from commuters' perceptions. WSF reports improved operations, while community outreach events have turned heated as unprecedented numbers of commuters attend to vocalize their discontent about longer ferry lines, increased delays, and decreased rush hour ferry capacity utilization.

How can such dichotomous realities exist for commuters and WSF? What is the source of decreased vessel capital utilization and can we quantify its financial impact? This study identifies specific problems and endeavors to propose solutions based on public records requests. These requests led to the analysis of 18 million observations from WSF's electronic ticket scanner data at the Fauntleroy Terminal, dating back to the introduction of electronic scanners in 2007.

Proposed Recommendations

I) The 2017 summer trial of new loading procedures was motivated by erroneous WSF data evaluation. Based on corrected pilot data, the summer trial should not have been initiated. The summer trial itself has not been fully evaluated; nevertheless, procedures have been extended indefinitely. Our evaluation of the first month of the new procedures cannot replicate the reported WSF figures. We find no improvements and recommend that future data analyses designed to motivate/evaluate operational changes be conducted by independent data consultants, engaged at arm's-length through Washington State not WSF.

II) Vehicle demand at the Fauntleroy terminal consistently exceeds vessel capacity starting with the 1:40pm ferry and lasting until the 6:35pm ferry during the summer. WSF should redefine Mo-Fri "peak time" as 1-7pm (not 3-6pm, as is current policy).

III) WSF is evaluated by its on-time performance, not by its vessel capacity utilization. This evaluation metric distorts the incentive structure. When ferries depart with excess capacity, Washington State incurs revenue losses while WSF's budget is unaffected. Washington State should provide incentives to WSF by evaluating on-time performance *and* exact capacity utilization (by vessel and by departure times).

IV) WSF does not possess an accurate account of each vessel's capacity utilization; it does not collect the necessary data. We recommend that WSF establishes "Vehicles on Ferries" as the single, exact measure of capacity utilization. Cameras already installed/focused on vessel bows/sterns can be leveraged to send video feed to open-source traffic-count software to obtain exact capacity utilization. This approach would also resolve issues at the port of

Vashon, where vehicle counts are currently entirely absent and subject to speculation (this leaves to guesswork the plan/design of the morning rush hour schedule).

V) Delays and underutilized vessels create State revenue losses due to decreased demand for ferry services. We calculate the "congestion elasticity" that indicates how much ferry demand declines when ferry service is cut, capacity utilization declines, and delays increase. A 1% reduction in vessel capacity utilization (implying longer wait times during times of excess demand) is estimated to reduce vehicle ferry demand by 0.9% and passenger ferry demand by 0.5%. This implies that WSF rush hour vessel underutilization, delays, and long wait lines are estimated to cost the State about $120,000 per summer month in lost revenues.

VI) Operational changes are at the core of any improvements in capacity utilization. We suggest an alternative ferry schedule-algorithm to optimize vessel departures, loadings, and capacity utilization. The alternative schedule could imply 500 additional vehicle spaces per day and 30-minute departure intervals. Ferries would depart *each port* (F, VSH, SW) every 30 minutes, and *each vessel* would travel a "pendulum" route F→VSH→SW→VSH→F. *Each vessel* departing Fauntleroy would transport 70% VSH and 30% SW vehicles (the exact percentage allocation would be chosen to reflect each destination port's traffic share). The Fauntleroy dock would empty with each loading to prevent staging/loading bottlenecks at the dual destination port.

VII) GoodToGo! *including* open-road fare collection at the Fauntleroy terminal should be adopted (as recommended by extensive 2012 and 2014 WSF studies). The loading efficiency gains would alleviate exactly the bottlenecks that are prone to arise at a dual-destination dock that also features insufficient loading slips and an undersized vehicle staging area. Contrary to previous WSF suggestions, Coastguard security objections to GoodToGo! open-road fare collections can be addressed; the Coastguard *already approves* security screening procedures at the Vashon/Tahlequah terminals that are *identical* to the mechanics of open-road tolling.

GoodToGo! revenue reductions, due to lost passenger revenues, are not prohibitive as previous consultants and WSF reports have asserted without study. Lost passenger revenues are offset substantially by wage savings (due to the absence of toll booths) and/or by a small reduction in the farebox recovery rate from 56% to 53% (which would still far exceed, for example, King County Metro's 30% farebox recovery rate). The congestion elasticity also suggests that more efficient loading could further offset lost passenger revenues.

GoodToGo! holds distributional issues: at this point, reduced Wave2Go fares cannot be directly adopted by GoodToGo!. Passengers would gain (due to the absence of passenger tolls) while disabled and senior drivers could lose Wave2Go discounts unless GoodToGo! is modified to allow for discounted fares.

GoodToGo!'s elimination of passenger fares increases incentives to substitute public transport for vehicle commutes, which would alleviate West Seattle traffic congestion. More efficient loading through open-road toll collection could further reduce the long lines on Fauntleroy Way, which would also alleviate West Seattle congestion.

"The ferry system will rely on hard data to determine if the proposed measures will make a difference."

Brian Mannion, Communications Manager, WSF
Vashon Beachcomber quote, 5/30/17

Introduction

This study examines the traffic and revenue patterns at the Fauntleroy Ferry terminal in West Seattle, WA. Bottlenecks in the ferry system occur with great regularity during high traffic periods when boats must be filled to capacity to handle the demand for ferry services. Summers are periods where high demand stresses the system with great regularity; hence much of our discussion below pertains to summers. The analysis is equally applicable, however, to any period when demand stresses the Fauntleroy terminal operations. We seek to understand the State budgetary implications of bottlenecks caused by wait lines, ferry delays, and vessel capacity utilization. Data from electronic scanners were obtained from Washington State Ferries (WSF) to understand rush hour loading dynamics. In the process, we attempt to replicate WSF data analyses of recent pilots and trials. The study isolates the problems we encountered, presents findings and suggests tangible solutions.

The May 2017 Pilot of New Operational Policies and Procedures

In May 2017, Washington State Ferries (WSF) conducted a four-day pilot to test the efficacy of a new ticket collection procedure. The new procedure included an additional resource, a "splitter," to assist the existing police officer coordinating traffic in front of the toll booths. At the same time, quick electronic hand-scanners were eliminated to force even pre-ticketed vehicles to stop at single-destination toll·booths. Single destination toll booths increase the likelihood that both booths are blocked, while the elimination of quick-scan positions, together with the additional stop at a toll booth, increases scan time.[1] WSF announced that the new operational measures were designed to "speed up vehicle processing at Fauntleroy and alleviating backups that increasingly stretch far beyond Fauntleroy."

[1]The blocked toll booth syndrome is exacerbated by the second procedural change in 2 years: elimination of the "bypass lane" after the May 2016 trial. WSF asserts the bypass lane is unsafe; we been unable to find accurate documentation of the safety hazards.

The WSF Communications Manager promised WSF would:

- "Rely on hard data to determine if the proposed measures will make a difference."
- "Evaluate the number of spaces filled on each boat compared to the total number of cars that pass through the toll·booth at peak demand."

The staffing of the new "splitter" position that was newly created to accelerate loading is no longer observed with regularity. It is somewhat unclear what the motivation for this resource was, since the police officer is already fulfilling the very same tasks that are also assigned to the new splitter.[2] This observation should not detract from the fact that the tasks performed by the officer are a crucial determinant of loading efficiency. Especially when single destination boats are at the dock, access to toll booths is easily congested and the officer serves a critical function walking up the ferry wait line on Fauntleroy Way to direct vehicles to the proper toll booths.

On June 6, 2017, WSF announced, "the pilot project might not have looked or felt different to individual ferry users. But in the big picture, a big difference was made."[3] When commuters wondered why lines seemed longer, WSF's Communications Manager explained, "as it gets busier, we can move faster, and there can be longer waits." This explanation is difficult to follow, perhaps because of the second hand quote, but WSF did not meet its own standards and report the number of spaces filled on each boat to support the assessment.

WSF did, however, report a *decline* in the number of vehicles processed per minute during "peak times" (3pm-6pm) from 4.2 to 4.1. The WSF Communications Manager suggested the ferry system "broke even" with the new operating procedure even though the reported decline in vehicles processed per minute implies a reduction in the total number of processed vehicles from 756 to 738 during the trial's rush hour.[4] This translates into about 400 fewer cars per month during rush hour.

---

[2]The splitter "informs drivers of tollbooth availability for specific destinations and pre-ticketed vehicles. Informs tollbooths and traffic director of upstream conditions on Fauntleroy Way. Informs drivers of current terminal conditions, such as schedule disruptions or wait times."

[3]A West Seattle Blog reporter attended the meeting and provided notes that we paraphrase below, see. WSF's posted notes are no longer available at the website. The notes were, however, archived by third parties here and here In addition to the PowerPoint slide deck included in the article above, a summary of the meeting is available.

[4]There are 180 minutes from 3-6pm, so 4.2 cars/min * 180 = 756; 4.1 cars/min *180 = 738, respectively

Simultaneously, WSF reported that the number of vehicles processed during rush hour (3-6pm) *increased* dramatically from 639 to 725, but did not provide an explanation as to why these totals directly contradicted the reduction in vehicles processed per minute. WSF Communication Manager explained, "loading with the new procedures was more efficient than current procedures. The big takeaway is that during the pilot, we were able to move an average of 85 more cars per three-hour period compared to baseline data every day." [5]

As commuters noted that the WSF report of increased vehicles processed ran counter to their experiences, WSF Director of Operations Greg Faust explained there had been "a bit of a mental hiccup … we overthought some things … plus there was some weird traffic, opera on Vashon," and "there was one sailing in the 3pm vicinity where they did reduce the number of empty spaces, though you're not going to fill that boat, ever." The WSF Communications Manager suggested, "we weren't moving cars at a faster clip, but we were moving more cars." He explained the dichotomy of the commuter experience and the WSF reports with the difference between "what you [commuters] see behind the wheel and what they [WSF analysts] see evaluating the big picture." "In the car, all you see is the cars in front of you."

WSF declared the pilot a success and announced a long "trial" to commence June 20, 2017. The trial is still ongoing to date. On balance, the WSF figures and explanations were difficult to follow. A few weeks later WSF corrected its pilot evaluation. Instead of a substantial increase in the vehicles processed, WSF now reports a decline.

The Pilot Correction

The results of the pilot were not corrected until late summer, however. Instead of loading 85 additional vehicles, WSF's own hard data confirmed commuters' experiences behind the wheel: vehicles processed during rush hour declined during the May pilot (from 744 to 739). The pilot should have never been scaled up in June 2017. The trial procedures continue to date, although they have not been comprehensively evaluated.

Commuters who experienced the May pilot and the June/July/August trial behind the wheel were aware that the new operations measures had increased the complexity and duration of

[5] Note that the Beachcomber article and the West Seattle Blog article reproduce facsimiles of the same WSF slide deck from the same meeting. They were presumably downloaded at different times, as they report different figures.

the loading process. Lines seemed longer than before, and ferries seemed to depart substantially under capacity during rush hour. An entire Facebook account became dedicated to photos of undercapacity sailings as ferries departed strikingly empty and wait lines stretched for miles up the Fauntleroy Way (see Appendix B).

The Summer 2017 Trial and Data

On June 19, 2017, WSF commenced a summer trial to implement the failed May pilot procedures. As Facebook pages lit up with photos of long wait times, long ferry lines, and undercapacity sailings, WSF declared the first 4 weeks of the trial a success. To date, WSF has not released comprehensive figures evaluating the summer "trial," beyond the first month's report. Furthermore, WSF has yet to report results for the key evaluation metric it had set for itself: "the number of spaces filled on each boat."

In August 2017, WSF argued that the new operational procedures should be continued (and they continue to this day) because the new procedures "did not make it better, but did not make it worse." To support the assessment, WSF reported that "daily ticket redemptions Mo-Fri, 3-6pm from the third week of June to the third week of July rose from 635 in 2016 to 638.5 in 2017" Vashon's standing room only crowd at WSF's September community outreach event had a different experience. Many comments suggested either the evaluation metric or the data were faulty, given the long ferry lines, wait times, and under capacity ferries during the summer of 2017.[6]

Table 1: Comparison of Total and Per-Minute Vehicle Scans

	Date (Mo-Fri Only)	Time Period	Total Cars Processed	Cars Processed Per Rush Hour	Cars Processed Per Minute
2017 (trial)	Mo 6/19/2017 - Fri 7/21/2017	3pm – 6pm	13,939	580.8	3.2
2016 (base)	Mo 6/20/2016 - Fri 7/22/2016	3pm – 6pm	13,981	582.5	3.2

[6]The heated community outreach events coincided in 2017 with resignations of long standing citizens serving on the WSF advisory committees. See reports in the Seattle Times and the Vashon Beachcomber.

Our analysis of the WSF data shows that the number of cars processed actually declined during the first 4 weeks of the summer trial:[7] overall, the new procedure processed fewer cars, but the difference is slight. The Table 1 does not speak, however, to capacity utilization or delays, which are addressed below.

Data analysis is not the core mission of WSF and the meaningful, annual analysis of millions of observations and their patterns is difficult. Our analysis has also not yet explored the full depth of these data. WSF electronic scanner data are a treasure trove, but as with any organization, evaluation of such technical nature and of the success of procedural changes should be undertaken by outside evaluators who are assured length relationships with WSF.

SUMMARY 1: WSF justifications and evaluations for new loading procedures were based on incorrect data analysis. In addition, the revised WSF pilot and trial results cannot be replicated with data from public records requests. WSF has not reported key metrics it had set for itself ("spaces filled on each boat").

SOLUTION 1: Future data analysis used to motivate operational changes should be conducted by independent consultants engaged by Washington State. The outcome of this analysis should be reported to the public in a transparent, replicable fashion.

[7]We also analyzed the data from June 19 – August 30 (when a disruptive two-boat schedule went into effect). Results are similar. Here it is important to note that our figures of cars processed during rush hour are substantially lower than WSF's. This may be due to several reasons:

- WSF data likely included all non-passenger scans Mo-Fri 3-6pm (we are not privy to the details of their analysis). Motorcycles, vanpools, and carpools should, however, be excluded from the analysis. They add only noise to the evaluation since they do not pass through the toll booth and are therefore unaffected by the new loading procedure. Any variation in motorcycle, vanpool, or carpool scans from 2016 to 2017 thus reflects only fluctuations in annual use, not changes in operational efficiency.
- Not only the weekend, but also July 4 must be excluded
- WSF scanners are well known to be so outdated that they occasionally drop their WIFI internet connections. "Offline Scans" falsely validate tickets, which leads to revenue losses of about $124,000, system wide from 1/1/2015 to 9/1/17, see WSF PDR17-2436 in Appendix A. To the degree that such scans were included in the public records request data, they are included in our analysis as they represent an actual car on a ferry. Scanners have a second, less well known, problem: they also malfunction at times to report multiple identical scans of a single vehicle. We eliminate these duplicate and triplicate scans that indicate erroneous, identical ticket scans, at identical scan locations, at identical times (to the second).
- We include only toll booth scans. Vehicle scans by handheld scanners still exist in the 2017 data, even with the new procedures that eliminate the use of handheld car scanners (perhaps they represent medical passes?). Since handheld scans in 2017 represent scans that are unaffected by the new loading procedure, they reflect only annual fluctuations in (presumably) emergency scans. Hence, they should be excluded from trial evaluation metrics.

The Red Herring

Before we commence our analysis of the budgetary implications of the Fauntleroy terminal bottlenecks, it is imperative to address a popular misconception. Given the increased vehicle congestion on King County roads, it is tempting to associate Fauntleroy terminal congestion with increased vehicle traffic. Figure 1 establishes the following:

Ia) Fact: Trend vehicle traffic to Vashon and Southworth has been *declining* since 2003.
Ib) Fact: Recent increases in Southworth traffic *cannot* be the cause of recent congestion. Southworth traffic departing Fauntleroy in 2016 was 17,000 (6%) vehicles below 2005!
Ic) Fact: Reduced ferry service *cannot* be the cause of recent congestion. Today's sailing schedules are just about identical to the early 2000s. Departure frequencies and departure times are also nearly identical.[8]
Id) Fact: Ferry capacity *increased* substantially 2004-2017. The three vessels in 2004 featured 81, 89, 89 car spaces, respectively, vs. 89, 120, 120 spaces in 2017. This increased total capacity from 12-8pm by about 500 cars.

It is thus important to note that current ferry problems cannot be connected to changes in traffic patterns, ferry schedules, or ferry sizes. If anything, these changes should have alleviated bottlenecks. While it is true that the economic recovery has led to a recent uptick in ferry demand, especially in Southworth, current levels remain significantly below those observed in the early 2000s. In addition to the economy and higher ticket prices, the introduction of commute-substitutes (e.g., the King County Passenger Ferry) and aging also may contribute to the observed demand reduction. As strong economy and population growth in the South Sound area may eventually generate greater demand especially from Southworth. At this point, however, these figures cannot be the driving forces.

--- Insert Figure 1 here ---

Here it is important to note that the most recent 2014 study of demographic dynamics for the triangle route by the Transportation Research Board suggests that the

"South Sound Corridor," which includes the Triangle Route and Pt. Defiance-Tahlequah will continue to experience a decline in ridership because "The South Sound Corridor… is experiencing an aging population, a corresponding reduction in the frequency of commuter trips, and a slow shift toward recreational and shopping trips. Although driving is still the predominant method of use on South Sound routes (more than 80 percent of weekday trips),

[8] WSF does not archive past schedules but San Juan County does. Visit sanjuanco.com and search for "Washington State Ferry Schedule" by year.

the percentage of non-motorized trips in which a vehicle was parked at the terminal increased significantly between 2006 (26 percent) and 2013 (40 percent)."

It is unclear to what degree the study included housing price pressures and associated population growth dynamics given the developments in the Seattle housing market.

Departure Delays Increased as Vehicle Traffic Declined

As vehicle traffic decreased and vessel capacity increased, ferry delays progressively increased since 2011. Figure 2 shows that during the summer of 2011 the cumulative delay for all ferries departing during rush hour never exceeded 2 hours per day. By the summer of 2016, the average cumulative delay fell between 1 and 2 hours with a number of cumulative delays exceeding even 2 hours. As we document below, increased delays were accompanied by reductions in vessel capacity utilization, which establishes the likely cause of increased ferry lines. Figure 2 highlights the operational trade-off that WSF faces during summers: maximize ferry capacity or insist on on-time departures.

--- Insert Figure 2 here ---

Ferry Delays and Wait Times

Capacity underutilization and delayed sailings produced substantially longer ferry lines and wait times. One YouTube video even documents a ferry line that exceed 3 miles, which is an estimated 700 cars. During the summer of 2017, traffic regularly backed up over one mile past the Kenney Senior Center, past the gas station on Fauntleroy Way. We show below that such delays have a direct impact on Washington State revenues.

While Figure 2 shows the cumulative delays per day, Figure 3 provides an alternative visualization of ferry delays at the Fauntleroy terminal. We plot WSF email alerts for the Fauntleroy terminal dating back to 2013. These emails inform subscribers of excessive wait times. Figure 3 plots the dates when delay alert emails were sent along with the longest delay time for that date. Figure 3 highlights that both the frequency of delays and the duration of the delays increased substantially since 2013.

--- Insert Figure 3 here ---

To put these figures into context, we can also examine the performance measures WSF produces for the legislature. Filling boats has not been mandated as a performance measure,

but only the percentage of boats departing "with less than 10 minute delays" is. This measure is called "On-Time Performance." In 2011, 95.2 percent of Fauntleroy-Vashon-Southworth trips were "on time", and by November 2017 91.8 percent of ferries were "on time" on the same route. Note that these percentages reported to the legislators in the performance report are 12-month averages, which substantially mask the summer and rush hour variations.

Capacity Utilization: Use Existing Technology to Produce Necessary Data

The WSF's legislative report evaluates the ferry system by on-time performance, not vessel capacity utilization. WSF reports only the number of cars scanned over a given period (e.g., "per day," "per rush hour," or "per minute"). This metric is insufficient to evaluate operational efficiency during rush hour at a dual destination terminal when vessel demand exceeds supply. Many cars can quickly pass toll·booths/scanners, but then sit on the dock as ferries may depart under capacity. This is especially true at dual-destination terminals (like Fauntleroy), where cars destined for port A can block/congest/delay staging/loading of cars destined for port B.

"Vehicles on Ferries" is the most accurate metric to evaluate WSF operational performance because it represents actual operational efficiency. This metric could be attained with minimal investment. WSF vessels already possess bow and stern video surveillance that can be fed into existing open-source traffic-count software to account accurately for vehicles on each vessel to establish exact capacity utilization. The approach would also resolve the issue that currently all traffic departing the Vashon terminal is based on estimates. Designing the morning schedule on anything but hard data is suboptimal.

SOLUTION 2a: The only accurate measure of capacity utilization is a count of actual vehicles on each vessel divided by the ferry capacity. Washington State should evaluate the ferry system by examining the capacity utilization on each boat during rush hour.

SOLUTION 2b: WSF can utilize existing cameras on vessels to send video feeds to open-source traffic-count software to establish an instantaneous, accurate count of capacity utilization for all vessels at all times.

Capacity Utilization: Models and Estimates

At this point, the only way to assess capacity utilization on Washington State Ferries is to use estimates. These estimates rely on scanner data and a loading model. WSF is aware that its

capacity utilization model is problematic, especially for dual destination terminals such as Fauntleroy. At dual-destination terminals, it is unknown exactly how many cars for each destination are loaded onto dual destination ferries. This muddles also all subsequent estimates for that day. Below we accept the WSF model and its assumptions/implications although we are cognizant of potential shortcomings. The WSF model assigns a physical space measure to each scanned ticket and allocates vehicles to the next departing ferry.[9] It is then possible to sum the implied vehicle spaces used on each vessel and divide that sum by the vehicle space capacity of each ferry. Before we discuss Table 2, it is important to note that the three Triangle Route ferries had capacities of 81, 89, and 120 vehicles, respectively in 2011. By 2017, the capacities were 89, 120, and 120, respectively.

--- Insert Table 2 here ---

The difference between capacity utilizations in 2017 and 2011 is stark. Table 2 highlights that capacity utilization declined substantially as delays and vessel capacity increased. Most ferries did not load close to capacity during the August 2017 rush hour. To the contrary, most sailings departed well below capacity and some even departed regularly at about 30% capacity. These figures may seem extreme, but they coincide with the multitude of documented, underutilized rush hour vessels during that time (see Appendix B). Note that Southworth-only ferries are indicated to *always* run substantially below capacity (the 2:15pm, 3:35pm, and 4.20pm). This observation should be carefully considered as any new schedule is designed. Lower capacity utilization percentages (the sum of vehicle spaces loaded divided by total vessel vehicle spaces) do not necessarily imply that WSF transported fewer vehicles in 2017 compared to 2011, since ferry capacity also increased.

SOLUTION 3: WSF's definition of "peak time" should be expanded. Rush hour starts before 3pm, namely with the 1:40pm sailing, which regularly fills to capacity. In addition, rush hour lasts well beyond 6pm as the 6:35pm ferry is regularly filled to capacity. A rush hour definition of 1-7pm seems appropriate for the summer.

[9] Each ferry is assigned an approximate number of "vehicles spaces" (e.g., Issaquah-130 class vessels have 120 vehicle spaces). Each scan is assigned a vehicle space (regular ticket = 1 space, short car ticket = 0.7 spaces, motorcycles = 0.3 vehicle space, truck ticket = 1.6 vehicle spaces). We accept the WSF model, approximations, and assumptions. We can then sum the total amount of vehicle spaces used on each ferry and divide that number by the ferry capacity on a given route at a given time of day.

Economic Implications of Capacity Underutilization: Lost State Revenues

It is a common misconception that longer wait times imply only time-cost to commuters. The misconception is based on the assumption that the demand for ferry services (e.g., the number of vehicles and passengers) is constant, and that underutilization and delays alter only commuters' arrival times at their destination ports.

There exists, however, ample evidence to indicate that the demand for ferries services is not constant. Commuters respond to delays and alter their travel plans accordingly. We show below that inefficient capacity utilization and longer wait times have tangible implications for Washington State revenues. Budgetary implications accrue only to Washington State, however; WSF does not receive a share of ferry revenues; hence, the WSF budget is insulated from these revenue implications.

Review of the Literature

Tom Domencich and Nobel Laureate Daniel McFadden (1975) first stipulated a "generalized model of commuting costs" that included direct costs (e.g., gasoline) and indirect costs (e.g., travel time). They posit that, as travel delays increase, demand for transportation infrastructure decreases, since delays impose costs that alter consumers choices (whether/how to commute).

Today the Domencich/McFadden approach is foundational in traffic congestion modeling; it is well understood, for example, that wider roads and/or reduced congestion bring about increased vehicle traffic demand exactly because of reduced travel time costs. As the "marginal value of time" (aka income) rises, travel time-costs become increasingly important determinants of transportation planning.

In a study of the British Columbia Ferry system, Verne Loose and Leonard Roueche (1979) provided the first ferry application of the commuting cost model. Loose/Roueche document that congestion-imposed costs to system users alter the demand for ferry services. The B.C. ferry system collected data on "queue length" and "overloads" (where overloads are defined

as the number of vehicles left behind after each sailing).[10] Although this study dates back to 1979, to date, WSF does not collect data on queue length and overloads. Loose/Roueche then documented that demand for ferry services declined as fares increased and vehicle demand increased as congestion (queues/delays) decreased. In their example, reduced congestion resulted in a 20% increase in demand for ferry services. This figure happens to be identical to the figure we derive below with WSF data for 2017.

The Link between Delays and Revenue Losses

How does capacity underutilization then translate into revenue losses for Washington State? From an asset-return perspective, capacity underutilization implies the suboptimal use of State investment. Ferries depreciate at the same rate whether they run at capacity or not. However, the return on investment is lower if the ferries are not filled. More relevant to the general public – and to state coffers – is that undercapacity sailings and increase wait times *directly reduce* state revenues. Delays and wait times decrease the demand for ferry services as commuters substitute with alternative routes, alternate modes of transport, or to telecommuting.

To measure the monetary effects of capacity underutilization, we use the concept of an "elasticity" (or the "sensitivity") of demand. We ask, how much the demand for ferry services changes when ferry capacity (or ferry capacity utilization in times of excess demand) changes. Through a stroke of luck, this congestion elasticity can be estimated for the Fauntleroy terminal to provide a timely estimate of the lost revenues to Washington State due to ferry capacity underutilization.

WSF provided a "natural experiment" that allows us to measure the revenue impact of capacity underutilization. On August 31, 2017, WSF's Fauntleroy terminal instituted a two-boat schedule that had been announced well in advance. The natural experiment was that ferry riders had ample time to contemplate their commute options to prepare for the upcoming service reduction. Since the service reduction would likely mean longer wait queues, increased wait times, and longer delays (as riders recalled their experiences during

[10] Interestingly, the study noted, "*As congestion increases, ships sometimes get behind schedule; a late ship will occasionally be only partially loaded to speed turnaround time in order to minimize overtime operating costs; the variation in vehicle lengths and heights makes it difficult to estimate a full load of vehicles*."

the earlier pilot/trial), the resulting reduction in demand for ferry services allows us to calculate the congestion elasticity. We can compare the demand for vehicle space on Fauntleroy ferries during the pre-announced two-boat schedule (8/31/17-9/8/17, weekdays only) with the demand for exactly the same times/days one year earlier under the normal schedule with normal ferry service.

We find that the announced 21% decline in vehicle spaces offered by WSF resulted in a 20% reduction in demand for vehicle spaces. The 20% reduction in demand is similar to the findings in the B.C. Ferry system and implies a congestion elasticity of WSF vehicle demand of 0.9. Simply speaking, for 1% reduction in service or capacity utilization, WSF loses 0.9% of vehicle customers.

Table 3: Sensitivity of Demand to Changes in Capacity Utilization

2016 3-Boat vs 2017 2-Boat Schedule First Week of September				
	2016	2017	% change	Elasticity
Vehicle Spaces	25,905	20,400	-21%	
Passengers	9,827	8,854	-10%	0.5
Cars	13,225	10,568	-20%	0.9

Note that even passenger demand is sensitive to vehicle space offered or vehicle capacity utilization. As more vehicles forgo a ferry travel, some passengers forgo ferry trips for work or leisure, either because they lost their ride, or because they also want to avoid the long wait that ferry lines impose on car passengers. It is important to keeping mind that our estimates are established at the margin during the summer (peak season), so they are unlikely to hold during the December holiday season or at other times when excess demand for ferry space does not exist.

For every 1% reduction in vehicle capacity utilization, it is estimated that vehicle demand for ferry services falls by 0.9% on the triangle route.

For every 1% reduction in vehicle capacity utilization on ferries, it is estimated that passenger demand decreases by 0.5%.

Estimates of Direct Monetary Losses

We calculate lost revenues for rush hour traffic only. Other times do not feature excess demand for ferries, so we cannot infer that a reduction in service necessarily translates into longer wait times. Assuming (conservatively), on average, 100 vehicle spaces per vessel, we impute from the capacity utilization tables that about 8,500 unfilled spaces existed on ferries in August 2017. If WSF operated such that these 8,500 spaces were filled, congestion would be alleviated. The congestion elasticities for vehicles and passengers then allow us to calculate that 7,600 additional cars and about 1,000 additional passengers would have used the ferries. This implies lost revenues to Washington State by an estimated $120,000 per summer month.[11]

SOLUTION 4: The WSF finance model should change to incorporate capacity utilization as a performance metric. Currently, WSF is provided operating funds from Washington State and is measured by on-time performance. Decreased capacity utilization discourages ferry demand and implies lost revenues to the state of about $120,000 per summer month. Since WSF does not share in the ticket revenue collections, it does not internalize the cost of capacity underutilization.

GoodToGo! and Open-Road Fare Collection: Real and Perceived Limitations

GoodToGo! is commonly mentioned as an option to improve operational efficiency at the Fauntleroy terminal. A 2012 fare media study commissioned by Washington State strongly suggested WSF should move towards GoodToGo!. GoodToGo! is currently used for many other WA State transportation assets such as the 520 bridge, the Tacoma Narrows bridge, or congestion tolling on I-405. WSF concurred in writing that GoodToGo! should be implemented as a payment system, but to date has not followed through with its own recommendation. WSF rejected, however, the recommendation of the 2012 study that GoodToGo! *open-road fare collection* should be implemented specifically on the Triangle route to eliminate toll booths to increase loading efficiency (see page 81 of the study). WSF rejected the proposal without any study or published analysis. A simple bullet point rebuttal of fewer than 60 words made vague references to revenue losses and inequity.

[11] This figure provides a general idea of the revenues lost, based on the assumptions outlined above. A full study of the elasticity and the associated revenue losses would include estimates that are specific to the departure time, destination, and ticket type, which is beyond the scope of this paper. The purpose here is simply to highlight that direct revenue implications of congestion are tangible beyond commuter delays.

In 2014, Washington State commissioned another "Joint Toll and Ferry CSC Feasibility Study." This study found that

> "*both the Ferry Division (WSF) ticketing system and the Toll Division customer service center will either be near the end of its life cycle or at the end of its contract term in 2018. After considering current and future toll and ferry operations, this report presents the following recommendations:*
> *1. Ferry fare payment with a GoodToGo! pass is feasible and should be implemented;*
> *2. WSDOT should begin immediately to develop policies for integrating a single customer account system for its ferry and toll customers; and*
> *3. WSF and the Toll Division should immediately begin work to replace their back office systems with a single, unified system that can handle ferries ticketing and reservations, tolls, and future transportation applications."*

The report rules out, however, that GoodToGo! should be implemented as an open-road toll collection procedure, arguing that

> *"ferry fares vary widely depending on the vehicle, customer and route"* and *"ferry customers are also subject to a security screen prior to boarding. For these two reasons, open-road fare collection is not appropriate for WSF customers, instead a vehicle using a Good To Go! as a payment method would still be required to stop at a booth for fare assessment and security screening prior to payment.*

We are not experts at security measures. In the interest of operational efficiency, one would expect that security measures could be developed that address "security screening requirements." This expectation is furthered by the fact that there *already exists* no "stopping at booths" for "security screening" at both the Vashon and Tahlequah ports. That is, current Coastguard compliant loading procedures at Vashon and Tahlequah are identical to open-road tolling.

Differential pricing cannot be an argument against GoodToGo! toll collection, either. Differential pricing can and has already been introduced with GoodToGo! as toll bridges in Washington State already feature differential pricing schedules. The system is already capable of locational price discrimination with open-road fare collection.

Estimates of GoodToGo!'s Lost Passenger Revenues

Two issues remain as possible obstacles to GoodToGo! implementation: loss of passenger revenues and equity considerations as discounted fares currently do not exist under

GoodToGo!. We are not aware of any WSF study that examines the loss of passenger revenues associated with GoodToGo! as compared to the cost savings as WSF economizes on both toll·booth and scanner positions. Our calculations show that GoodToGo! is indeed financially feasible:

I) The loss of passenger revenues on the triangle route would equate to $2,167,262.5, based on 2016 scanner data.
II) Based on Washington State staffing and actual wage data, we estimate that cost savings through reduced toll·booth operations would save at least $500,000 per year. If two of the current six staffed "ticket takers" could also be reassigned, savings would total $800,000. Including fringe benefits of about 20%, we estimate the cost savings to exceed 1 million per year.[12]
III) The net loss due to GoodToGo! is thus approximately $1.2 million ($2.2 million in passenger revenue losses - $1 million in wage savings). Washington State declares the share of ticket sales in total costs as the "farebox recovery rate." Lost passenger revenues, due to GoodToGo! implementation would thus imply a reduction of the WSF "farebox recovery" rate from about 56% to 53%. This is substantially higher than King County Metro Transit's farebox recovery rate of about 30%.
IV) GoodToGo! could even be financed without any reduction in the farebox recovery rate, given our congestion elasticity revenue calculations presented above. We indicated that the reduction in queues, wait times, and delays together with increased capacity utilization could increase revenues by about $120,000 per summer month.

While the farebox recovery rate might decline marginally, it is important to note that the farebox recovery metric is not an informative measure of efficiency by itself. The concept is criticized because it (i) does not weigh the farebox recovery rate by the volume of taxpayers served, (ii) ignores the contribution to economic vitality, and (iii) detracts from the absolute size of the public subsidy required. For example, ferry systems' farebox recovery rates in the US range from 6% to 92%. B.C. ferry's recovery rate is 82% but the subsidy required to run the system is substantially greater than WSF's subsidy. Other West Coast ferry systems include Golden Gate Ferries with a farebox recovery rate of 55% and the Alaska Marine Highway with a farebox recovery rate of 25%. It is also of note that the farebox recovery rate is almost exclusively used in the evaluation of public transit systems, but not in the cost/revenue calculation of public roads/highways or other public infrastructure projects, such as the annual subsidies for the (air)ports.

[12] We obtained wage and staffing data for representative bi-weekly pay periods to extrapolate annual figures.

It is important to note that Senators and Representatives of the 34th and 26th legislative district covering the Triangle route worry that a reduction in the farebox recovery rate makes this route less competitive for maintaining service and note that other routes have a higher farebox recovery rates. The legislators also point out that they have worked hard to prevent service reductions in the past. WSF Fare recovery rates in Edmonds-Kingston, Seattle Bainbridge, Mukilteo-Clinton, and Anacortes-Sidney are higher than the Triangle Route's, while Seattle-Bremerton, Pt. Defiance-Tahlequah, Anacortes-San Juan Island and Port Townsend-Coupeville are lower.

GoodToGo! Equity Implications

The remaining issue for GoodToGo is equity. The loss of discounted tickets could affect economically disadvantaged populations on Vashon and the Kitsap Peninsular. While all passengers would benefit, seniors and disabled drivers would no longer be subject to reduced rates unless the GoodToGo! structure is altered. Seniors and the disabled would have to adhere to the same tolling rules and regulations as all other drivers on Washington State's toll bridge or toll lanes.

SOLUTION 5: GoodToGo! *including* open-road fare collection at the Fauntleroy terminal should be adopted as soon as possible. The efficiency gains far outweigh the costs associated with a dual destination dock that is undersized and has insufficient vehicle staging.

- **Coastguard security objections to open-road tolling at the Fauntleroy terminal cannot be insurmountable. Current Coastguard security screening procedures at Vashon and Tahlequah terminals are *identical* to open-road tolling procedures.**
- **Reduced revenues due to lost passenger revenues are shown to be substantially offset by wage savings and minor reductions in the farebox recovery rate (which would still exceed, for example, King Country Metro's). The congestion elasticity also promises that more efficient loading would increase State revenues to further offset the passenger losses.**
- **Distributional considerations persist. Not all reduced fare programs can be adopted by GoodToGo! and Vashon/Southworth drivers would face the same rules as all other Washington residents on all other toll bridges and toll roads.**
- **GoodToGo! would substantially increase incentives to substitute public transport instead of vehicle commuting.**

An Algorithm to Optimize the Triangle Route Ferry Schedule

Ferry vehicle traffic declined, but delays increased. Ferry capacity increased but capacity utilization decreased in times of strong excess demand (rush hour). New operating

procedures were introduced, but ferry lines seemed longer. A number of options have been proposed to further optimize loading procedures.[13] In this section, we focus on one narrow aspect of operations that lends itself to algorithmic solutions: optimizing the ferry schedule design.

As noted above the WSF Director of Operation declared certain runs lost causes "…they will never be filled." This is because the departures intervals and dwell times – the times to load and unload – are simply too short to a) keep the schedule and b) fill the boat. Below we suggest an alternative schedule algorithm. The algorithm takes the current crossing times for Fauntleroy-Vashon and Vashon-Southworth as given. The algorithm is also based on actual timed vessel loading and unloading times. All parameters other than the vessel-travel-algorithm are based on parameters taken from the current schedule: (i) Fauntleroy-Vashon time from departure to departure: 25 min and (ii) Vashon-Southworth time from departure to departure: 20 min.

We present the alternative schedule algorithm only for afternoon rush hour traffic. It could be implemented in the morning/evening, too. Alternatively, the morning/evening schedule could remain. The same algorithmic principles could apply to construct a late morning/evening or weekend schedule with fewer vessels.

Details of the Alternative Schedule Algorithm

I) All ferries arrive/depart at 30-minute intervals allowing ample time to dock, unload, load, and undock.

II) All ferries sail a "pendulum" route during rush hour:
Fauntleroy→Vashon→Southworth→Vashon→Fauntleroy.

III) All ferries depart Fauntleroy transporting 70% Vashon vehicles, 30% Southworth vehicles. The exact percentage allocation would be chosen to reflect each destination

[13] A number of seemingly simple and intuitive solutions have been proposed. Among them (apart from building a larger holding dock with more loading bays) (i) a bypass lane around the toll booth to allow for quick loading of pre-ticketed passengers, (ii) separate holding lanes for Vashon and Southworth on Fauntleroy Way (perhaps one in northern the other in southern direction), (iii) designation of one toll·booth for pre-ticketed vehicles only to guaranteed constant vehicle flow through ticketing, (iv) adding a traffic light at the end of the Fauntleroy dock to block Fauntleroy traffic for about 3 minutes until ferries are sufficiently unloaded to take on new cars, (v) returning to the tried-and true method of hand scanning pre-ticketed vehicles after the toll booth and eliminating the booth stop (vi) returning to the process of having ferry workers/officers "walk the wait line" on Fauntleroy to pull cars out for either Vashon or Southworth when the dock is full and cars from the other destination are blocking access (vi) "overhead" passenger loading through terminal ramps - funds for this project at Fauntleroy had been included in the 2008 long term plan, p98).

port's traffic share; 70%/30% represents roughly current VSH/SW shares. The share could be adjusted monthly/annually to reflect actual traffic volumes to each destination.

IV) We conservatively estimate that the pendulum route requires 90 minutes for each vessel to complete. *This implies 30 minutes between departures at all times and all ports!*

V) Southworth would lose three dedicated Fauntleroy-Southworth sailings during rush hour at the benefit of 7 additional ferries from Fauntleroy during rush hour, one every 30 minutes. Southworth would also gain 6 additional ferries from Southworth, one every 30 minutes during rush hour.

VI) The Fauntleroy dock would be emptied with each boat. This reduces the chance that destination A vehicles block/congest destination B vehicles.

Below we outline the alternative schedule in three parts. First, Table 4 shows sailings by vessel, and outlines the schedule for *each boat.* Next, we report the schedule by port: Fauntleroy, Vashon, and Southworth. Finally, we indicate the number of vessels serving each port and the change in the number of departures from each terminal. Finally, we report the change in the number of vehicles that can be transported under the new schedule.

--- Insert Table 4 here ---

Implications of the Alternative Schedule Algorithm

- All ferries depart Fauntleroy with ample time to dock/load/unload in 30-min intervals.
- Departures increase for both Southworth and Vashon residents. This increase is not only for Fauntleroy departures, but also for the Vashon and Southworth ports.
- Both Vashon and Southworth lose dedicated ferries, but gain vehicle spaces to each port. In 2016, the estimated total daily average was 1368 vehicles total departing Fauntleroy, of which 885 departed for Vashon, and 482 for Southworth during rush hour. Under the new schedule, the new capacity would be 1885 (total), 1281 (Vashon), 603 (Southworth) if every ferry loads to capacity and allocates 70% to Vashon and 30% to Southworth.
- Morning/night schedules would not have to change, but could utilize the same algorithm.
- Adjustments can be made for crew changes by adding/shifting times here or there without violating the algorithm's fundamental principles.
- The alternative schedule algorithm, with the same number of vessels, with regular half-hour service to both Vashon and Southworth, would add essentially 4 additional ferry loads of cars departing Fauntleroy during rush hour.[14]

--- Insert Table 5 here ---

The schedule would also necessitate the elimination of crucial terminal bottlenecks with a traffic light at the end of the dock to facilitate unloading. Currently, unloading (and hence subsequent loading) can be delayed as the departing vehicle back up on the dock since they

[14] 1885 total vehicles transported under new algorithm minus 1368 total vehicles transported on average under existing conditions, divided by the average number of vehicle spaces on vessels (120) yields this result.

cannot exit onto Fauntleroy Way.[15] By suggesting this schedule algorithm, we seek to highlight that marginal changes to the old schedule may not provide optimal outcomes. The old schedule grew organically over the years, along with changes in vessel capacities and vehicle demands. A fresh approach, rather than modifications or simple service cuts to the existing schedule may provide improved efficiency. It is unlikely that altering an already suboptimal schedule through minor service changes or further reductions in service will result in greater WSF efficiency.

It is important to note that we addressed only the bottlenecks at key commute times: Mo-Fri during afternoon rush hour. High traffic with extraordinary wait times also exists on weekends and in the mornings. We believe that the algorithm principles can be adapted to morning rush hour, weekend rush hours, as well as to the late morning/night 2 boat schedules. The above can be seen as a "proof of concept" that can be tailored to other periods on the triangle route.

We are cognizant that many objections can be brought forth against this schedule. These limitations likely involve constraints on the number of boats in service at specific times, crew changes at specific hours, pumping of water or sewage when necessary, etc. We believe that these constraints can be adopted into the algorithm, if there is interest in optimizing the route from the ground up. At the same time, these limitations can also be used to foil further explorations of optimal schedule algorithms to justify further tinkering with broken schedules though selective service reductions.

Finally, the Fauntleroy terminal is to be upgraded in 2025. Senators and Representatives covering Triangle Districts noted in their comments on an earlier draft that they "hope that some additional capacity can be built into that plan." The current long-range plan for WSF does not include a larger dock, although WSF apparently asked for it in a Draft of the Long Range Plan in 2008. The Seattle City Council objected to a larger dock in the draft of the last WSF Long Range Plan citing Fauntleroy community and environmental concerns. The Fauntleroy community shares the heavy burden of congestion with Southworth and Vashon commuters along Fauntleroy Way. We are not aware of a study that asks whether a larger dock increases or decreases congestion,

[15] Note that the new schedule along with the 70%/30% Vashon/Southworth loading rule also requires new loading procedures that are spelled out in detail in Appendix C

although this is a topic that should be assessed. At the same time, plans are in place to assign ever-larger vessels to the Fauntleroy terminal. A larger dock may reduce congestion if it allows sufficient vehicles onto the dock to fully load vessels expediently to capacity. Under current conditions, it is seems unrealistic to expect less congestion with larger vessels and further population growth in Southworth, if the dock size is held constant.

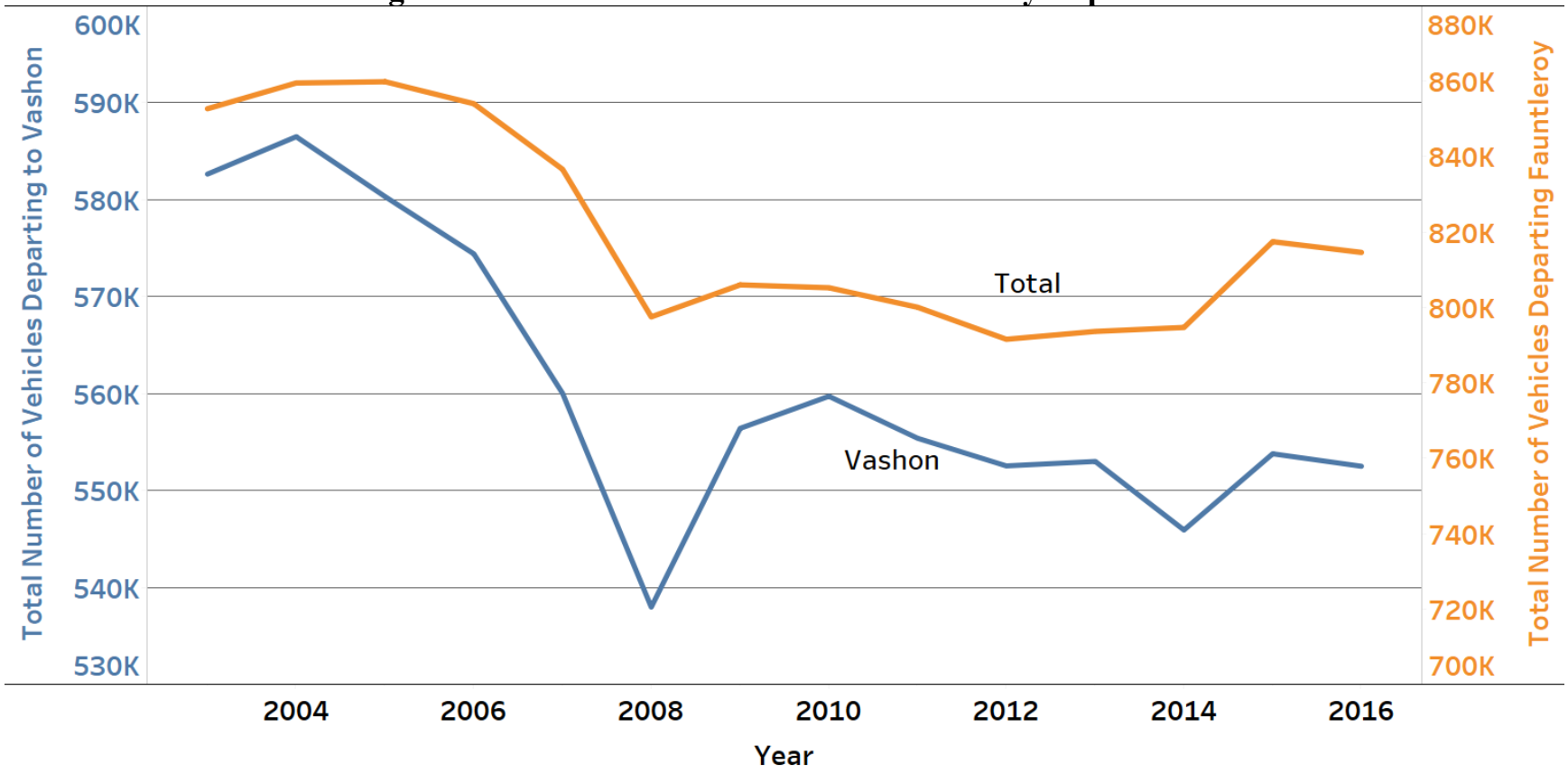
Planning for the new, 2040 WSF long-range plan has been set into motion. As best as we can tell, it does not include a larger Fauntleroy terminal as a consideration. Presentations for the new long range plan mention that 1999-2015 was the period of "expanding the WSF system" while 2009-2030 is to be a period to "maximize use of existing resources."

The 2009 long-range plan mentions a "Scenario A," enhancements to improve transit connectivity and passenger comfort at WSF terminals that includes overhead loading.

"The most significant dwell time improvements are the overhead loading projects proposed for Clinton and Fauntleroy, which continue to load passengers over the auto transfer span and are among the busiest routes in the system. These improvements will also provide passenger comfort and safety benefits that will also support the transit enhancement and mode shift goals."

This gain in loading efficiency would also provide for additional loading time, which would facilitate time performance and capacity utilization. $17 million was allocated to the Fauntleroy overhead loading project in 2009. It is unclear if the 2018 seismic improvements or the 2025 upgrade will address this issue.

Fig 1: WSF Overall Traffic Trends: Fauntleroy Departures

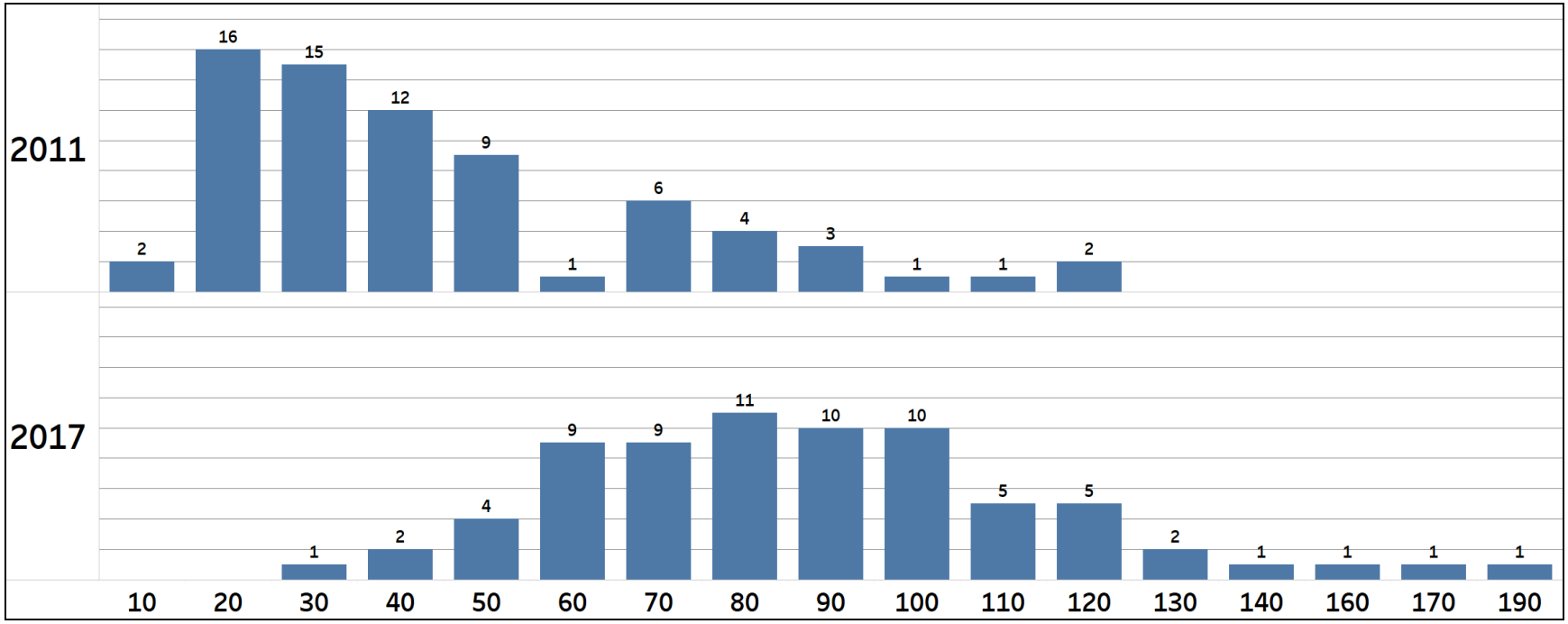


	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Vashon	582,642	586,505	580,316	574,412	560,025	537,959	556,409	559,715	555,382	552,532	552,993	545,914	553,782	552,495
Total	852,712	859,546	859,881	854,044	836,645	797,491	805,969	805,211	800,034	791,534	793,625	794,675	817,434	814,587

Source: wsdot.wa.gov/ferries/traffic_stats/[16]

[16] Web figures for Fauntleroy-Vashon are divided by 2. Web figures aggregate east and westbound ferry traffic for Vashon; since no records of actual east bound Vashon traffic exits, WSF simply doubles the number of Fauntleroy departures to obtain the totals for its website.

Fig 2: Cumulative Daily Delays at Rush Hour
Fauntleroy Terminal 1pm-7pm, June 20 - August 30



How to read this chart:

1) we calculate the *individual delays* (delays = actual departure - scheduled) for each ferry that departs between 1pm and 7pm on a given day
2) For all ferries departing between 1pm and 7pm, we sum the individual delays to obtain the *cumulative delay* for each day's rush hour.
3) Each bar represents the number of days with rush hours that have cumulative delays associated with each ten-minute interval (0-10, 10-20 etc). The bar height represents how many days had delays associated with each ten-minute interval.
4) For example, in 2011 there were 2 days when the total delay for all ferries combined during rush hour was between 0-10min.

FIG 3: WSF Email Notifications of Ferry Delays and the Associated Approximate Wait Times

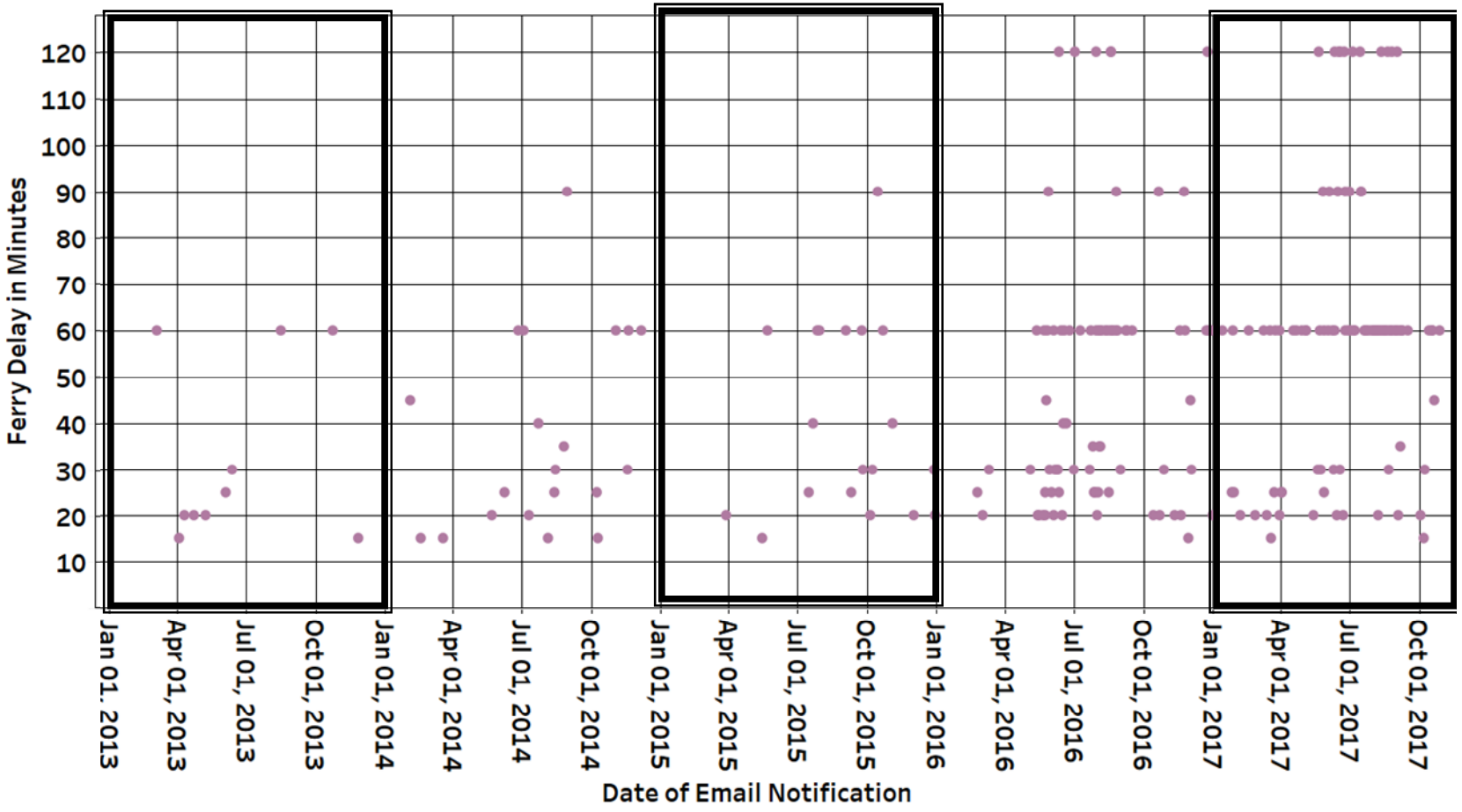


Table 2: Average Capacity Utilization, August 1st-30th (Mo-Fri)

	2017						2011				
	Mon	Tue	Wed	Thu	Fri		Mon	Tue	Wed	Thu	Fri
12:20 F_V_S	61%	64%	71%	82%	106%	12:20 F_V_S	56%	68%	68%	70%	77%
12:55 F_V	43%	57%	45%	51%	61%	12:55 F_V	47%	46%	45%	51%	55%
13:25 F_V	41%	52%	55%	55%	49%	13:20 F_V	55%	49%	60%	57%	74%
13:40 F_V_S	82%	112%	91%	109%	113%	13:40 F_V_S	76%	92%	90%	101%	120%
14:15 F___S	35%	31%	36%	28%	31%	14:20 F___S	45%	42%	55%	47%	50%
14:45 F_V	86%	78%	78%	82%	70%	14:45 F_V	98%	111%	102%	101%	88%
15:00 F_V_S	65%	69%	112%	120%	66%	15:05 F_V_S	67%	62%	59%	77%	58%
15:35 F___S	62%	53%	47%	49%	49%	15:35 F___S	103%	99%	105%	103%	92%
16:00 F_V	101%	106%	86%	87%	109%	16:00 F_V	108%	112%	108%	105%	105%
16:20 F___S	86%	98%	88%	94%	91%	16:20 F___S	85%	84%	89%	92%	89%
16:45 F_V_S	75%	77%	81%	76%	70%	16:40 F_V_S	109%	96%	109%	102%	82%
17:10 F_V	97%	115%	130%	119%	107%	17:00 F_V	102%	123%	96%	105%	79%
17:45 F_V_S	94%	78%	85%	91%	98%	17:40 F_V_S	118%	111%	127%	134%	176%
18:05 F_V	60%	65%	70%	69%	57%	18:00 F_V	79%	77%	72%	69%	55%
18:35 F_V_S	108%	117%	105%	104%	112%	18:30 F_V_S	93%	105%	91%	94%	122%
19:05 F_V	53%	65%	71%	83%	65%	19:05 F_V	99%	96%	106%	102%	97%
19:30 F_V_S	65%	73%	87%	83%	94%	19:35 F_V_S	90%	111%	111%	113%	128%

Capacity utilization is defined as the sum of all vehicle spaces loaded (obtained from scanned ticket information for each ferry) divided by the total space availability on each specific ferry. For each day of the week, each departure time averages the 4 capacity utilizations for that departure time and day for the month of August.

F_V_S, F_V, and F__S indicate Fauntleroy→Vashon→Southworth, Fauntleroy→Vashon, and Fauntleroy→Southworth routes, **respectively**

How to read this table: Take the top left-hand cell in 2017: the 61% displayed means that, for the four Mondays that had 12:20 departures in August 2017 that sailed Fauntleroy→Vashon→Southworth (F_V_S), on average 61% of the vehicle spaces were utilized.

Note: Since vehicle lengths are estimated (see text) and since the WSF capacity utilization model is imperfect, it is possible to achieve capacities exceeding 100%. We consider any ferry "filled to capacity" when capacity utilization exceeds 90%. Deeper reds indicate progressively lower capacity utilization and white cells indicate vessels filled to capacity.

Table 4a: An Alternative Schedule Algorithm
Schedule for each Boat

Boat 1			Boat 2			Boat 3		
Trip+Dwell Times	Departure Times		Trip+Dwell Times	Departure Times		Trip+Dwell Times	Departure Times	
	11:00	depart f		11:30	depart f		12:00	depart f
0:25	11:25	depart v	0:25	11:55	depart v	0:25	12:25	depart v
0:20	11:45	depart s	0:20	12:15	depart s	0:20	12:45	depart s
0:20	12:05	depart v	0:20	12:35	depart v	0:20	13:05	depart v
0:25	12:30	depart f	0:25	13:00	depart f	0:25	13:30	depart f
0:20	12:50	depart v	0:20	13:20	depart v	0:20	13:50	depart v
0:20	13:10	depart s	0:20	13:40	depart s	0:20	14:10	depart s
0:25	13:35	depart v	0:25	14:05	depart v	0:25	14:35	depart v
0:25	14:00	depart f	0:25	14:30	depart f	0:25	15:00	depart f
0:20	14:20	depart v	0:20	14:50	depart v	0:20	15:20	depart v
0:20	14:40	depart s	0:20	15:10	depart s	0:20	15:40	depart s
0:25	15:05	depart v	0:25	15:35	depart v	0:25	16:05	depart v
0:25	15:30	depart f	0:25	16:00	depart f	0:25	16:30	depart f
0:20	15:50	depart v	0:20	16:20	depart v	0:20	16:50	depart v
0:20	16:10	depart s	0:20	16:40	depart s	0:20	17:10	depart s
0:25	16:35	depart v	0:25	17:05	depart v	0:25	17:35	depart v
0:25	17:00	depart f	0:25	17:30	depart f	0:25	18:00	depart f
0:20	17:20	depart v	0:20	17:50	depart v	0:20	18:20	depart v
0:20	17:40	depart s	0:20	18:10	depart s	0:20	18:40	depart s
0:25	18:05	depart v	0:25	18:35	depart v	0:25	19:05	depart v
0:25	18:30	depart f	0:25	19:00	depart f	0:25	19:30	depart f
0:20	18:50	depart v	0:20	19:20	depart v	0:20	19:50	depart v
0:20	19:10	depart s	0:20	19:40	depart s	0:20	20:10	depart s
0:25	19:35	depart v	0:25	20:05	depart v	0:25	20:35	depart v
0:25	20:00	depart f	0:25	20:30	depart f	0:25	21:00	depart f

Each color represents a different boat

Table 4b: An Alternative Schedule Algorithm

Schedule for each Port

Depart Fauntleroy	Depart Vashon	Depart Southworth
11:00 depart f		
11:30 depart f	11:25 depart v	
12:00 depart f	11:55 depart v	11:45 depart s
	12:05 depart v	12:15 depart s
	12:25 depart v	
12:30 depart f	12:35 depart v	12:45 depart s
13:00 depart f	13:05 depart v	
13:30 depart f	13:35 depart v	
	13:20 depart v	13:10 depart s
	13:50 depart v	
	13:35 depart v	13:40 depart s
14:00 depart f	14:05 depart v	14:10 depart s
	14:35 depart v	
14:30 depart f	14:20 depart v	
15:00 depart f	14:50 depart v	14:40 depart s
	15:20 depart v	
	15:05 depart v	15:10 depart s
15:30 depart f	15:35 depart v	15:40 depart s
	16:05 depart v	
16:00 depart f	15:50 depart v	
16:30 depart f	16:20 depart v	16:10 depart s
	16:50 depart v	
	16:35 depart v	16:40 depart s
17:00 depart f	17:05 depart v	17:10 depart s
	17:35 depart v	
17:30 depart f	17:20 depart v	
18:00 depart f	17:50 depart v	17:40 depart s
	18:20 depart v	
	18:05 depart v	18:10 depart s
18:30 depart f	18:35 depart v	18:40 depart s
	19:05 depart v	
19:00 depart f	18:50 depart v	
19:30 depart f	19:20 depart v	19:10 depart s
	19:50 depart v	
	19:35 depart v	19:40 depart s
20:00 depart f	20:05 depart v	20:10 depart s
20:30 depart f	20:35 depart v	
21:00 depart f		

Each color represents a different boat

Table 5: Implications of the Alternate Schedule Algorithm: Change in the Number of Ferry Departures by Destination

Current and Proposed Number of Departures For Each Segment Of The Triangle Route (Noon - 8pm)											
Fauntleroy-Vashon		**Fauntleroy-Southworth**		**Vashon-Fauntleroy**		**Vashon-Sourthworth**		**Southworth-Vashon**		**Southworth-Fauntleroy**	
Current Departures: 15	**New Departures: 17**	**Current Departures: 10**	**New Departures: 17**	**Current Departures: 11**	**New Departures: 17**	**Current Departures: 8**	**New Departures: 17**	**Current Departures: 8**	**New Departures: 17**	**Current Departures: 11**	**New Departures: 17**
11:55	12:00		12:00	11:50	12:05	12:00	11:55	12:25	12:15	12:25	12:15
12:20	12:30	12:20	12:30	12:25	12:35	12:45	12:25		12:45		12:45
12:55	13:00		13:00		13:05		13:35	13:10	13:10	13:10	13:10
13:25	13:30		13:30		13:35		13:20		13:40		13:40
13:40	14:00	13:40	14:00	13:50	14:05		13:50	14:25	14:10	14:25	14:10
14:45	14:30	14:15	14:30	14:20	14:35	14:05	14:20		14:40	14:50	14:40
15:00	15:00	15:00	15:00		15:05		14:50		15:10		15:10
	15:30	3.35	15:30	15:25	15:35	15:25	15:20		15:40	15:45	15:40
16:00	16:00		16:00		16:05		15:50	16:05	16:10	16:05	16:10
16:45	16:30	16:20	16:30	16:25	16:35		16:20		16:40		16:40
17:10	17:00	17:10	17:00	17:10	17:05		16:50	17:10	17:10	17:10	17:10
17:45	17:30	17:45	17:30	17:35	17:35	17:35	17:20		17:40	17:55	17:40
18:05	18:00		18:00		18:05		17:50		18:10		18:10
18:35	18:30	18:35	18:30	18:35	18:35	18:10	18:20	18:30	18:40	18:30	18:40
19:05	19:00	19:30	19:00	19:00	19:05	19:00	18:50	19:20	19:10	19:20	19:10
	19:30		19:30	19:40	19:35		19:20		19:40		19:40
20:05	20:00		20:00		20:05	19:55	19:50	20:25	20:10	20:25	20:10

Each color represents a different boat

Appendix A: Public Disclosure Request WSF PDR17-2436

Offline scans, January 1, 2015 - October 12, 2017. These tables show the number of offline handheld scans by ferry terminal. An offline scan means that the device did not have an active network connection to validate the ticket when scanned. The total number of offline scans were 274,587.

WSF states that "offline handheld scans where tickets did not have a valid ride available when the scanner was able to reestablish the network connection." There were 9,422, system wide scans that are associated with lost revenues. (Puzzling is that even terminals without handheld scanners (e.g., Point Defiance) are reported to have offline scans, even offline scans that are associated with lost revenues). System wide, WSF lost a total of $124,351.33 due to the 274,587 offline scans, 9,422 of which were associated with invalid tickets.[17]

Terminal	Offline Counts
Fauntleroy	166,273
Anacortes	28,898
Edmonds	19,026
Colman Dock	16,491
Mukilteo	9,090
Orcas	8,334
Southworth	6,690
Clinton	6,021
Lopez	4,543
Pt. Defiance	2,050
Bainbridge	1,639
Coupeville	1,295
Shaw	1,122
Kingston	1,072
Pt. Townsend	1,043
Bremerton	649
Sidney	235
Friday Harbor	116
Total	**274,587**

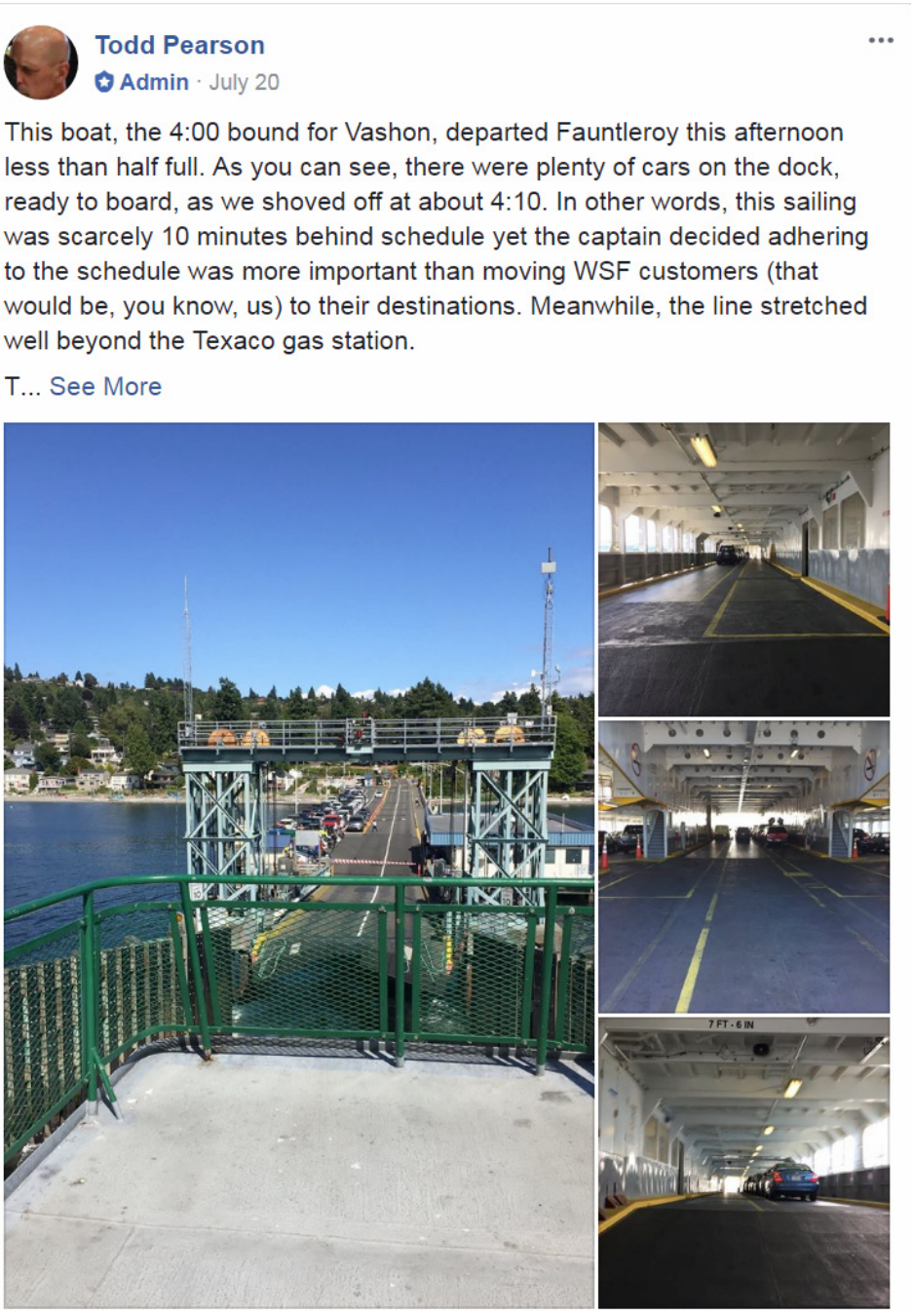
Terminal	Offline Counts	Offline Counts with Lost Revenues	%
Fauntleroy	166,273	4,952	3%
Anacortes-all-ports	43,248	1,206	3%
Edmonds-Kingston	20,098	1,034	5%
Pt. Townsend-Coupeville	2,338	29	1%
Mukilteo-Clinton	15,111	1,171	8%
Southworth	6,690	56	1%
Pt. Defiance	2,050	551	27%
Colman Dock-Bainbridge	18,779	423	2%
Total	**274,587**	**9,422**	**3%**

Mukilteo, Clinton are combined
Edmonds, Kingston are combined
Pt. Townsend, Coupeville are combined
Colman Dock, Bainbridge, Bremerton are combined
Anacortes, Lopez, Shaw, Friday Harbor, Sidney, Orcas are Combined in this table

Note that offline scans and lost tickets do not seem to be associated only with handheld scanners. Terminals like Point Defiance have no handheld scanners but WSF reports offline counts and even offline counts with lost revenue.

[17] All figures in this appendix were provided by WSF in response to Public Record Request PDR17-2436

Appendix B: Facebook Reports of Undercapacity Sailing During Rush Hour 2017
(facebook.com/groups/vashonferryadvisorycommittee)

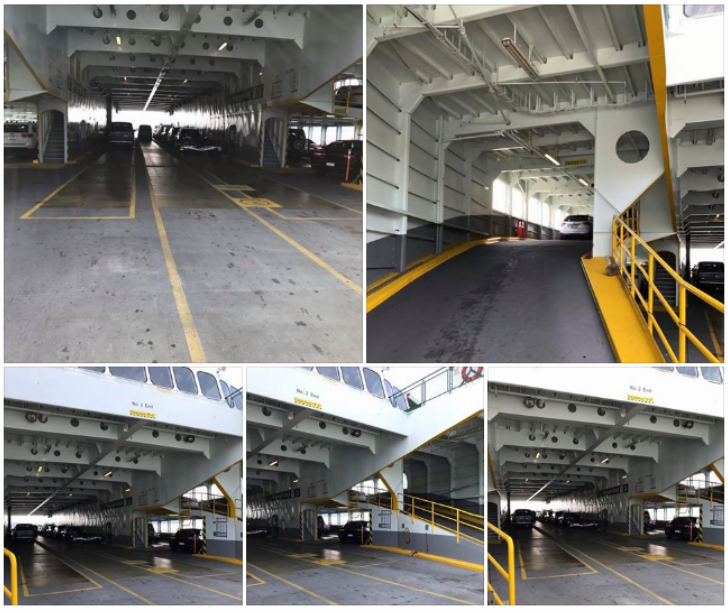


Leslie Patterson
July 28

spoken too. Just left at 7:10 and ferry not full. Sorry people in line.

Cheryl Richmond
August 12 · Biloxi, WA

3:20 pm pushed off at 3:37pm. Line all the way down Fauntleroy to 76 station. I'm driving Senior Center members back to Vashon, after a day in Ballard so we had vanpool/priority boarding... but SERIOUSLY?!



Cheryl Richmond
August 14 · Seattle, WA

4:27 pm, line up almost to the 76. You've been warned. Happy Monday! 🙄

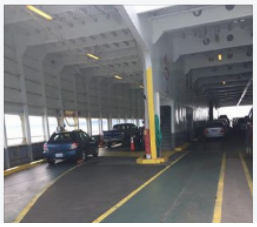
Like Comment Share

2

Susan Gress Looks like supervisors on the dock. Boats leaving full, staging in one exit lane and cars depart out of the other lane. Ferry waiting to land.
Like · Reply · 1 · August 14 at 5:05pm

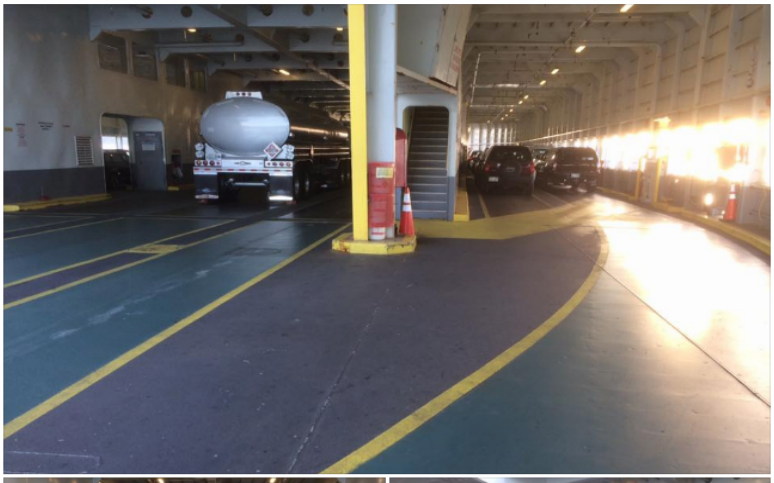
Cheryl Richmond replied · 1 Reply

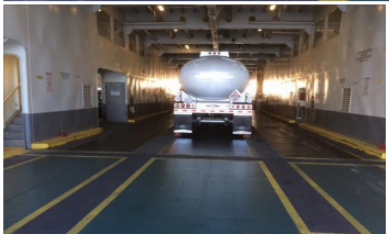
Sarah LeBlanc I was wondering why no alerts...
They were not leaving full earlier. The 3 pm left at ~3:25 pm with room. The poor tollbooth worker seemed very stressed.

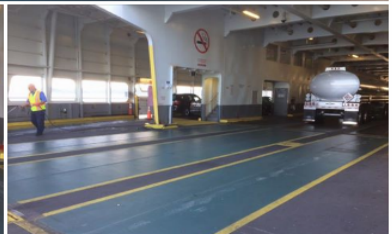


Mary Lively
August 14

7:10pm ferry left Fauntleroy on time with plenty of room for more cars.
8/14/17





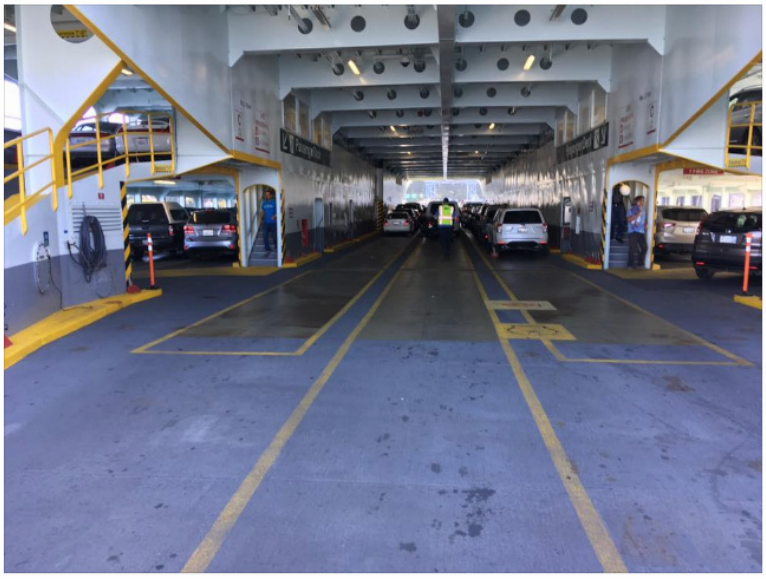


Mary Lively
August 16

4pm ferry left Fauntleroy at 4:06 with plenty of room for more cars. A police officer was walking the line telling Vashon cars to leave the line & go straight to the dock. Yay, I wish that could happen all the time. Lotta cars would have missed that ferry otherwise. I was just curious if anyone got left behind? 8/16/17

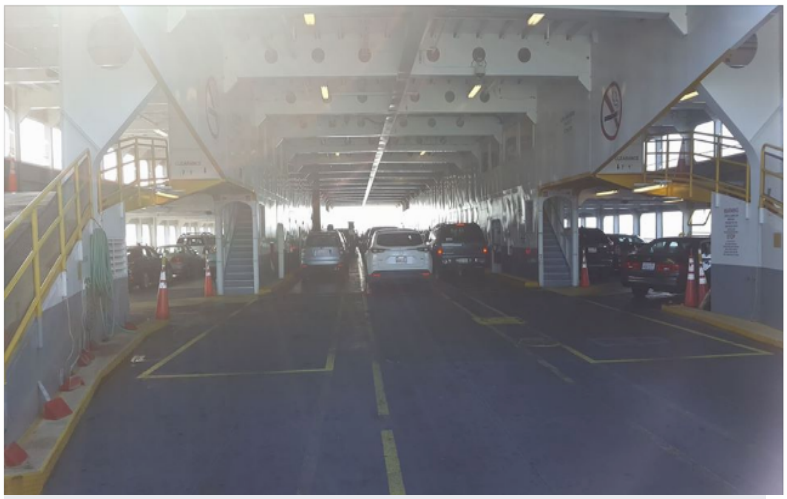
Anne Gfeller Higuera
August 16 · Biloxi, WA

Room for 20 or so on the 4:45 to Vashon.



Jill Snyder Yates
August 19 · Seattle, WA

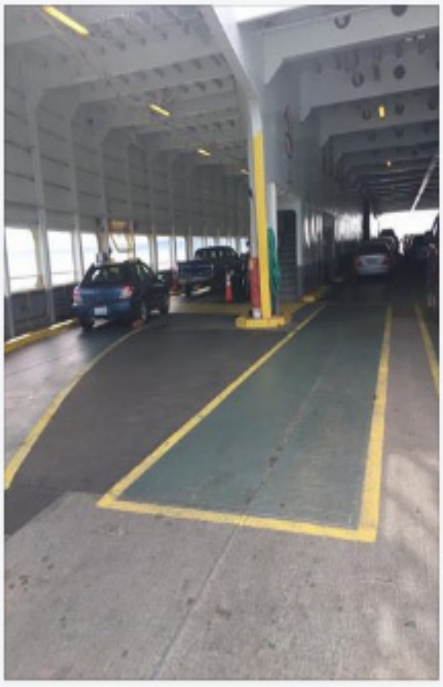
Faunt to Vashon, 4:30, leaving 4:43, not full, and cars left above the toll booth.



Cheryl Richmond
August 14 · Seattle, WA

4:27 pm, line up almost to the 76. You've been warned. Happy Monday! 🙄

Sarah LeBlanc I was wondering why no alerts...
They were not leaving full earlier. The 3 pm left at ~3:25 pm with room. The poor tollbooth worker seemed very stressed.



Tom Ackerman
August 25

3 O'clock ferry, Friday Aug 25, ferry line backed up blocks past the 76 Station, ferry about 1/3 full. Spoke at length to the very helpful ferry worker who said the problem is if there's lots of Southworth cars in line up Fauntleroy, once the dock is full they can't get the Vashon cars out of line on Fauntleroy. I asked about a second lane in Fauntleroy (one Vashon one Southworth) he said "City of Fauntleroy" won't approve. Is there an actual advisory board to brainstorm this and lobby the powers that be to fix it? There must be some innovation to apply.

Michael Golen-Johnson
August 25

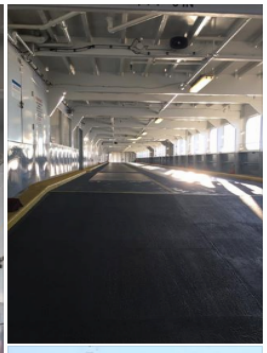
The 4pm boat was mostly full... probably coulda fit 10 more vehicles.

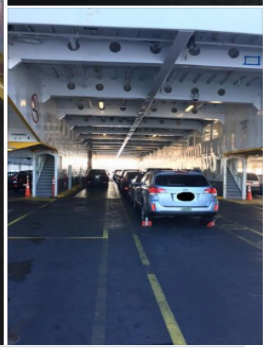
Sarah LeBlanc
August 31

Completely EMPTY upper decks and room on the lower end for at least 10 more vehicles.

Boat left Fauntleroy around 6:20 pm. I think this was supposed to be the 5:55 pm boat, but because the boats are running late, I'm not certain. Anyway...with a two hour wait this is completely unacceptable.

Governor Jay Inslee... See More





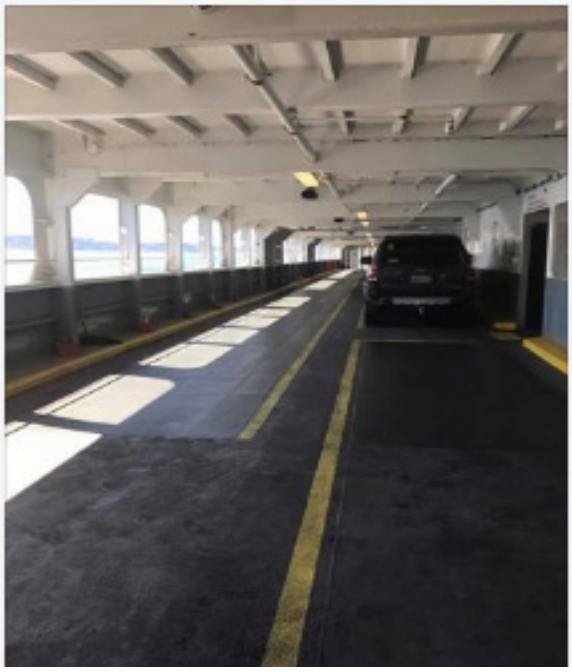
Carol Lux
September 1

Just got a notice that there is a 2 hr wait to get to the island. This is 2:30 not sure what boat this is supposed to be since they said boats are running 45 minutes behind. The boat's lower deck less then half full. Both upper decks EMPTY!!! With a 2 hr wait.

Michelle Ericksen Kline
September 1

Line is currently back to the 76 station. Line is navigating in and around parked cars. Hopefully the boats are leaving full?!? Anyone on the 1:20 who can confirm? I really wish they would at least make this whole holding lane a no parking zone during 2 boat schedule! There were already cars in line blocking southbound traffic on Fauntleroy this morning at 9:15!

Michelle Ericksen Kline Not full. Same on both sides of the upper deck. This is a vashon only 1:40. Left at about 2:00. There is another boat waiting to dock.

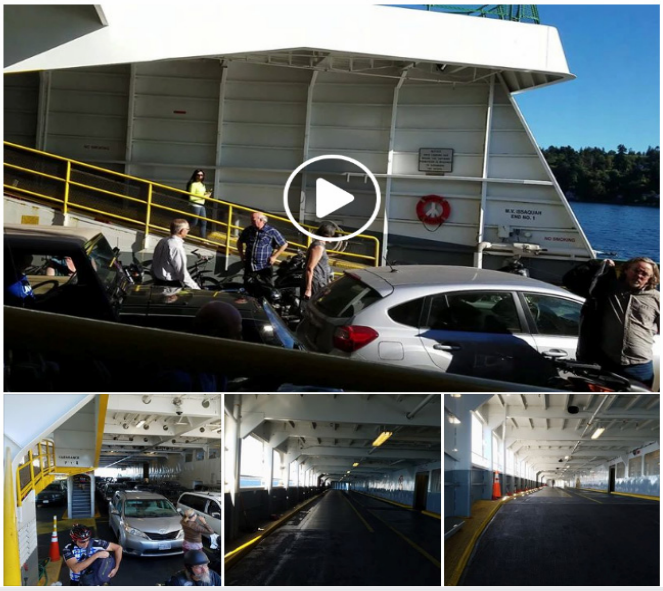


Mark Peloquin
September 2

VASHON FERRY PROBLEM!!!! - ISSAQUAH left at 4:30pm Friday Sept 1 with both upper car decks EMPTY. The 3:05pm right before left with room for 50 more cars. This is not a 2 boat problem this is a TICKET SCANNING problem.

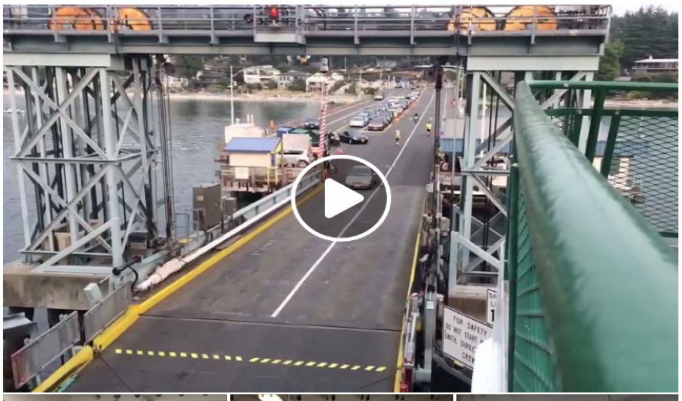
SOLUTION - We need to go back to the system where two people on foot scanned tickets. The current system where ONE person in the booth handles all ticket scanning and sales is the bottleneck!

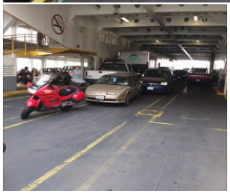
MEETING - Come to the "Public Triangle Task Force Meeting" on September 14 at 4:30pm, 9140 California Ave SW. I will have a sandwich billboard with photos of the empty decks from Sept 1. Help make our Vashon CHANGE recommendation known and heard.

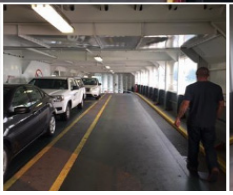


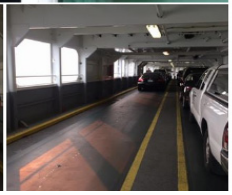
Diana Chamberlain
September 6

5:00 boat with foot-only traffic to Vashon, cars to Southworth. I meant to take a longer time-lapse but messed it up, caught the tail end (vanpools to vashon backing in). Only about 10 cars made it through the toll booths during the loading process. Two cars watched helplessly as they weren't loaded on with a fair amount of empty space on the boat.



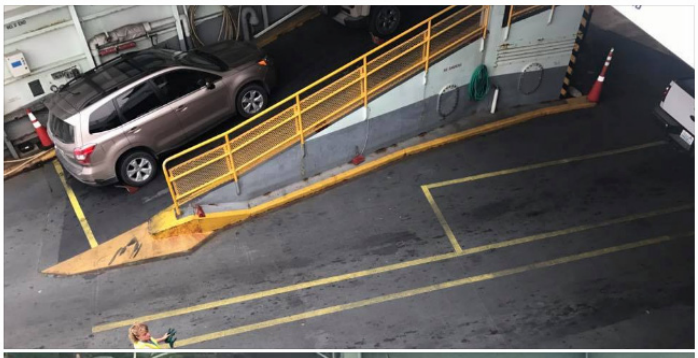


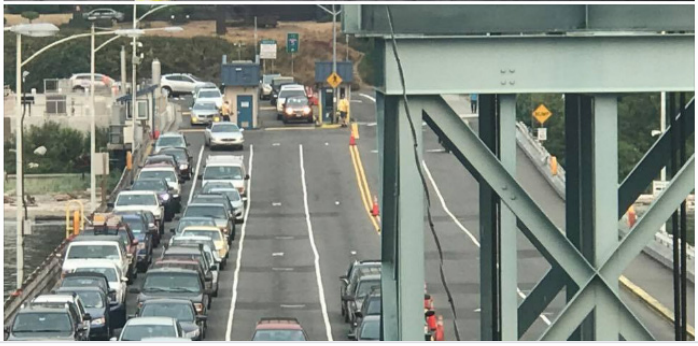




Jon Flora
September 5 · Seola Beach, WA

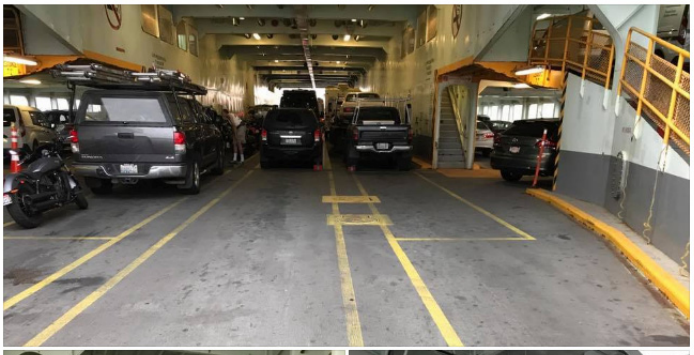
Just leaving Fauntleroy at 5:42 p.m. Not sure what boat this is supposed to be. Vessel not full, cars on dock, cars up past the park, toll booth is the clear log jam.

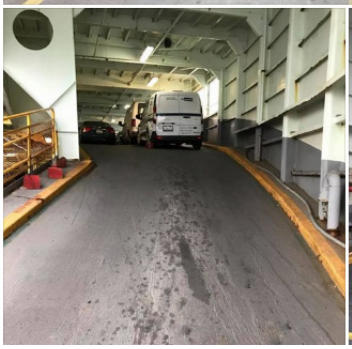


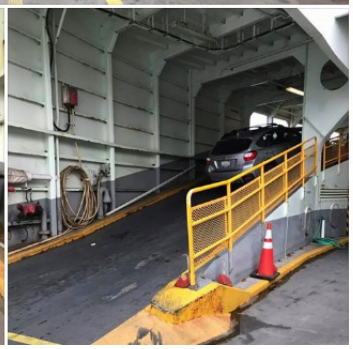


Jan Lewellen Pagel
September 6

The boat I waited two hours for - not full. It left Fauntleroy at around 6:30 and loaded Southworth along with Vashon.



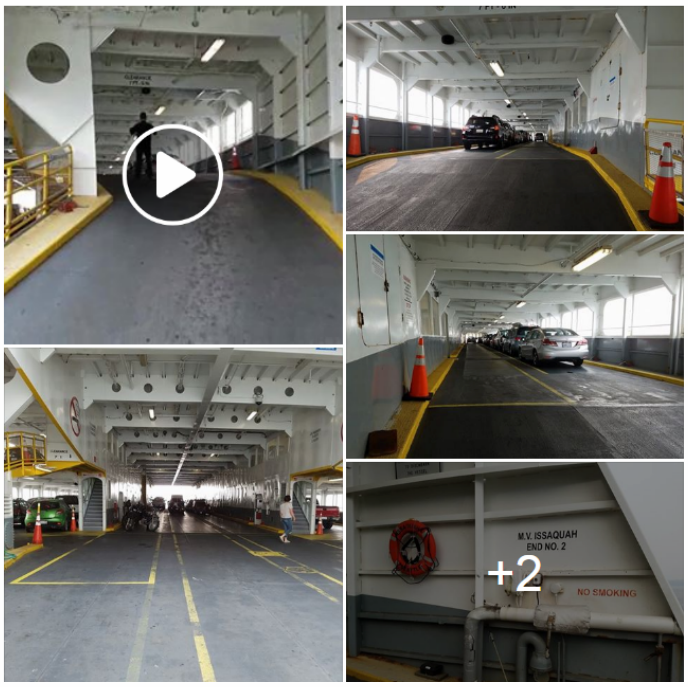




Mark Peloquin
September 7

VASHON FERRY PROBLEM!!!! - ISSAQUAH left at 3:30pm Wednesday Sept 6 with lots of EMPTY SPACE on ALL car decks.

WSF - This is NOT a 2 boat problem this is a TICKET SCANNING problem!!
... See More



Rob Mosley is at Vashon Ferry.
September 7 · Seattle, WA

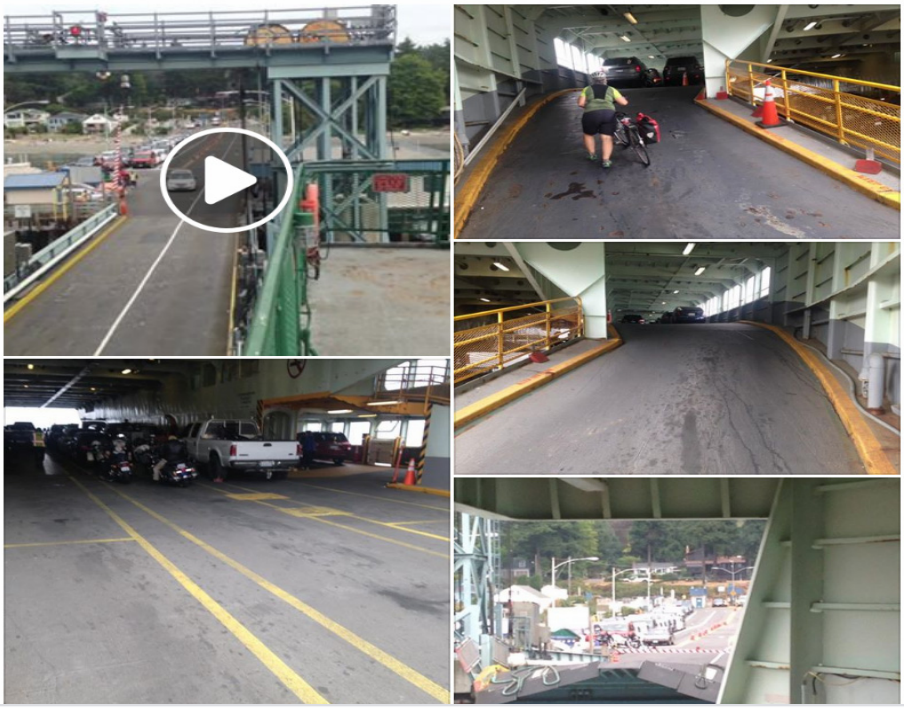
Just caught the 2:10 boat at 2:40. The line is almost to the upper Lincoln Park lot, and the boat is perhaps 25% loaded. The pics show the lower decks; the upper decks are empty. Bear in mind this is a Vashon Only run.

Gene Kuhns
September 8

4:00 PM Friday ferry, leaving at 4:05. Not sure how far the line is (I bike). They did a good job loading the dock as full as they could.

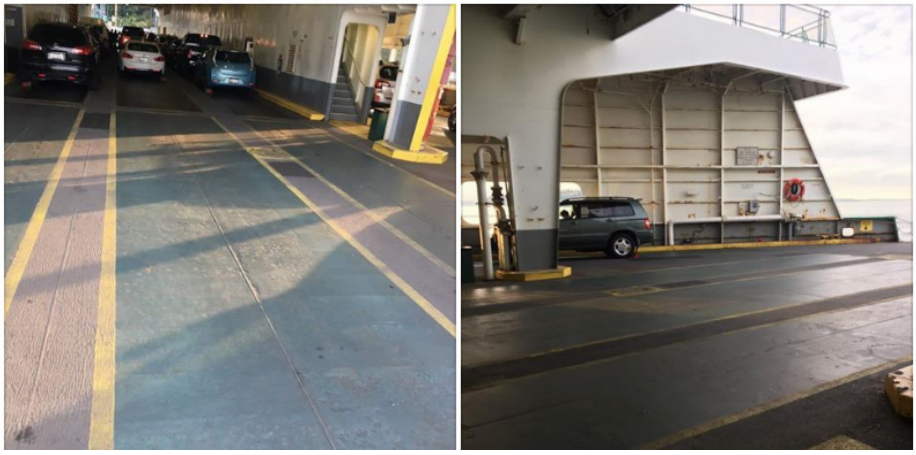
Ferry worker said they walked up the line & there were no more Vashon cars...did not know how far up they walked.

Upper deck could hold 10 more, lower deck another 10? Bottle neck is the ticket booth.

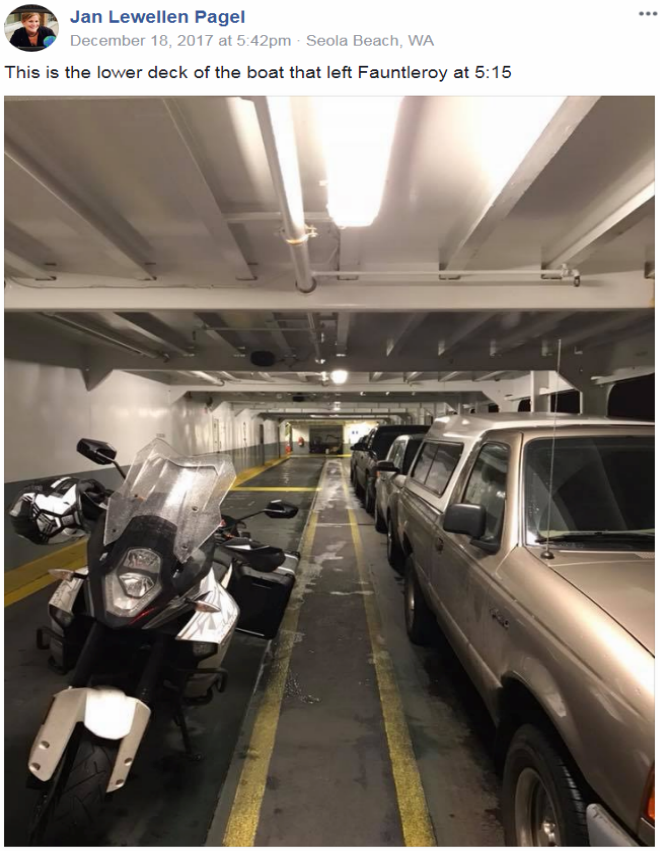


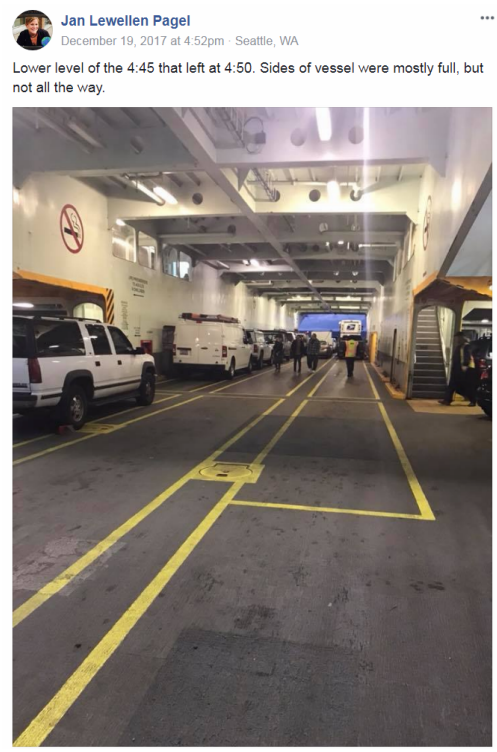
Sarah LeBlanc
September 22 at 6:36pm

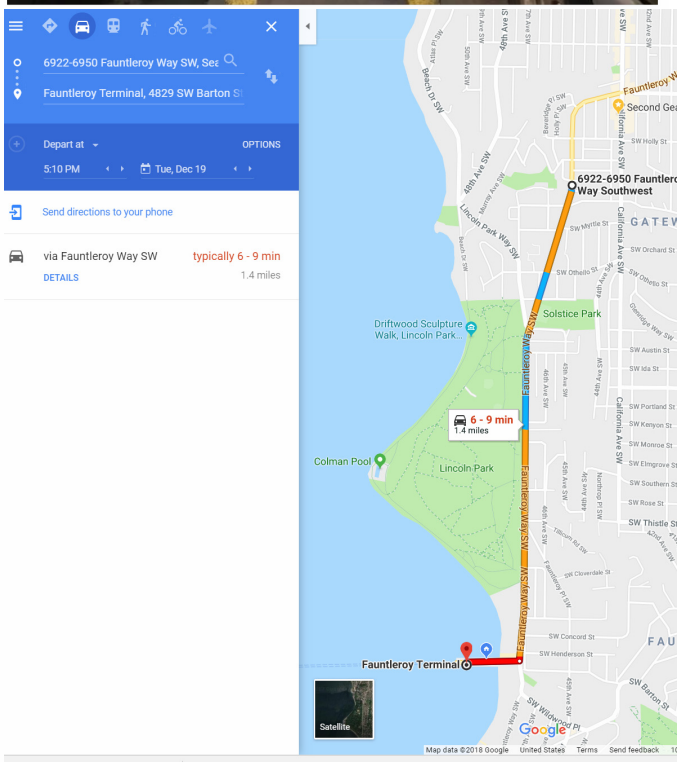
Can't even fill the Sealth. Sorry neighbors waiting in line on Friday at rush hour. This was the 6:05 pm boat. 😡



Amtrak Derailment: Detour via Fauntleroy-Southworth overloads the Fauntleroy Terminal. Ferries depart below capacity while google reports a 1.4 mile backup.







Appendix C: Loading Procedures for the suggested ferry schedule.

- There are four holding lanes on the Fauntleroy dock, with about 20 cars in each lane. Let us label the lanes "1" to "4".
- There is one extra lane, one exit lane, which can be filled as soon as the ferry is unloaded. Let us label this lane "5."

STAGING
- Two lanes would be dedicated to SW (=40 cars or 70% of a 130 vehicle space ferry)
- Two lanes would be dedicated to VSH (=40cars)
- One lane, lane 5, would also always be Vashon (=20 cars)
- In total, VSH receives two lanes + the one exit lane, + 10 cars dribbling onto the dock as the ferry is loading, which equals 90 cars (70% of a 130 vehicle space ferry).

LOADING
- In total, loading will take about 8 minutes. This is enough time for an additional 40 cars to enter the dock, approximately 30 (70%) to VSH, 10 (30%) to SW.[18]
- VSH cars load first, SW cars load last to adhere allow for proper unloading on at the Vashon terminal
- As loading commences, the exit lane is open. As the first two VSH lanes loads, cars enter the dock and only Vashon cars enter lane 5.
- 10 extra Vashon cars will dribble onto the dock once the first two Vashon lanes are loading and once lane 5 has been filled. These 10 “dribblers” are sent to the old "Vashon lane 1" which loaded first and is now empty.
- Extra SW cars that dribble onto the dock (before the two SW lanes load last) are sent to the old "Vashon lane 2," which is now empty because it loaded first. (Yes, this means there are no dedicated VSH and SW lanes. The current setup of largely dedicated VSH and SW lanes impedes loading and blocks cars entry to the dock as the ferry loads)

TIMING

The loading times are based on actual timed loading and unloading times for a 130 vehicle space ferry
- Ferry arrives
- Ferry unloads 130 cars **(3 min)** (requires police or traffic light to give priority to unloading over Fauntleroy traffic)
- Motorcycles load first **(2 min)**
- 40 cars from Vashon lane 1 and Vashon lane 2 load second **(2 min)**

A total of about 4 min passed since the ferry started to load. This represents ample time to fill exit lane 5 (20 cars) and an additional 10 cars to the old "Vashon lane 1." [Note that this requires that toll booths are no longer single destination. One toll booth is exclusively for pre-ticketed vehicles and another toll booth is for either for pre-ticketed vehicles or for those who have to purchase a ticket. This assures that there is a constant flow through toll booths.]

- The last 30 Vashon cars load from the exit lane 5 (=20 cars) along with an extra 10 cars that were sent to the old "Vashon lane 1" that loaded first **(1.5 min)**
- 40 SW cars load third **(1.5 min)**
- Passengers load fourth and last **(1.5 min)**

Total load time: about 8 min (about as much as a regular loading takes right now)

[18] The throughput of 40 cars in 8.5 minutes is greater than the average for scans per minute over the 7 hour rush hour period that were reported above. This is because “rush hour per minute scans” average zero and constant flow times at the toll booths. The scan rate is higher when cars flow onto the dock; about 6 cars per min can then be processed.