Aspirational Planning: A Statistical Model of Hawthorne Bridge and Tilikum Crossing Bicycle Ride Counts

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Abstract

Portland city planners have routinely planned for an increase in bicycle commutership and a decrease in automobile commutership. This paper discusses the latest data on Portland car and bicycle use. Portland and Multnomah County are observing an increase in single occupancy vehicle commuters, car ownership, and gasoline consumption. Bicycle use in Portland is found to have followed a logistic curve pattern since the early 1990s. The authors present an ordinary least squares model to explain bicycle ridership on the Hawthorne Bridge and the recently constructed Tilikum Crossing. When controlling for other factors such as weather and daylight, the Tilikum Crossing has added an average of 1,137 bicycle rides per day to total east-west rides across the Willamette River, some of which are diverted from the Hawthorne Bridge.

Background

"Shoeless Joe" is a novel by W. P. Kinsella that was the basis for the popular film "Field of Dreams." In the Hollywood rendition, Kevin Costner builds a baseball field on his Iowa farm after receiving a mysterious message that "they will come" if he does. The classic film popularized the colloquial expression, "If you build it, they will come."

Portland, Oregon has adopted a series of plans based on a similar premise. Critics of Portland's planning environment refer to this as "aspirational planning." Planners themselves are inclined toward this language. The Portland Bureau of Planning and Sustainability (BPS) define the goals of the City's Comprehensive Plan as "long-term outcomes the City hopes to achieve by

implementing the Comprehensive Plan. They are aspirational, expressing Portland residents' collective desires and values."[1]

Planners in Portland routinely strive for, and thus forecast for, reductions in automobile commuting and increases in bicycle commuting. In its Transportation System Plan, the Portland Bureau of Transportation (PBoT) outlines one goal that a system "lessens reliance on the automobile while maintaining accessibility."[2] In the same document, BPS states its objectives to "promote a multimodal transportation system" and "[i]ncrease public awareness of the benefits of walking and bicycling."[3]

Periodically, it is useful to assess the progress toward these aspirations. September 2015 marked the opening of the Tilikum Crossing, Portland's first new bridge to be built over the Willamette River since 1973. Representing a $134.6 million investment, it is the largest bridge in the United States that is closed to automobiles, instead supporting only mass transit, pedestrians, and bicyclists.[4,5] In many ways it is symbolic of the City's aspirational planning. In light of the historic bridge opening, this report will track Portland's overall progress on car and bicycle use, presenting a statistical model of the determinants of bicycle use on the Hawthorne Bridge and Tilikum Crossing.

Automobile Use in Portland

Since 2005, the percentage of Portland commuters using single occupancy vehicles has fallen, but the total number of commuters in single occupancy vehicles has still risen as the population grows.[6] See Figures 1 and 2.

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[1] Portland Bureau of Planning and Sustainability (BPS), "Goals and Policies," accessed April 6, 2016, https://www.portlandoregon.gov/bps/68411.

[2] Portland Bureau of Transportation (PBoT), "Transportation Element of the Comprehensive Plan," accessed April 6, 2016, https://www.portlandoregon.gov/transportation/article/370467. Pages 2-3.

[3] Ibid., pages 2-4.

[4] TriMet, "Portland-Milwaukie Light Rail Bridge Fact Sheet," August 2013, accessed April 14, 2016, http://trimet.org/pdfs/pm/Fact-sheets-timelines/PMLR_Bridge_Fact_Sheet_Aug2013.pdf.

[5] PBoT, "Tilikum Crossing: Bridge of the People," accessed April 14, 2016, https://www.portlandoregon.gov/transportation/68548.

[6] U.S. Census Bureau, "2005-2014 American Community Survey 1-Year Estimates, Table DP03," *American Community Survey*, accessed March 8, 2016, http://factfinder2.census.gov.
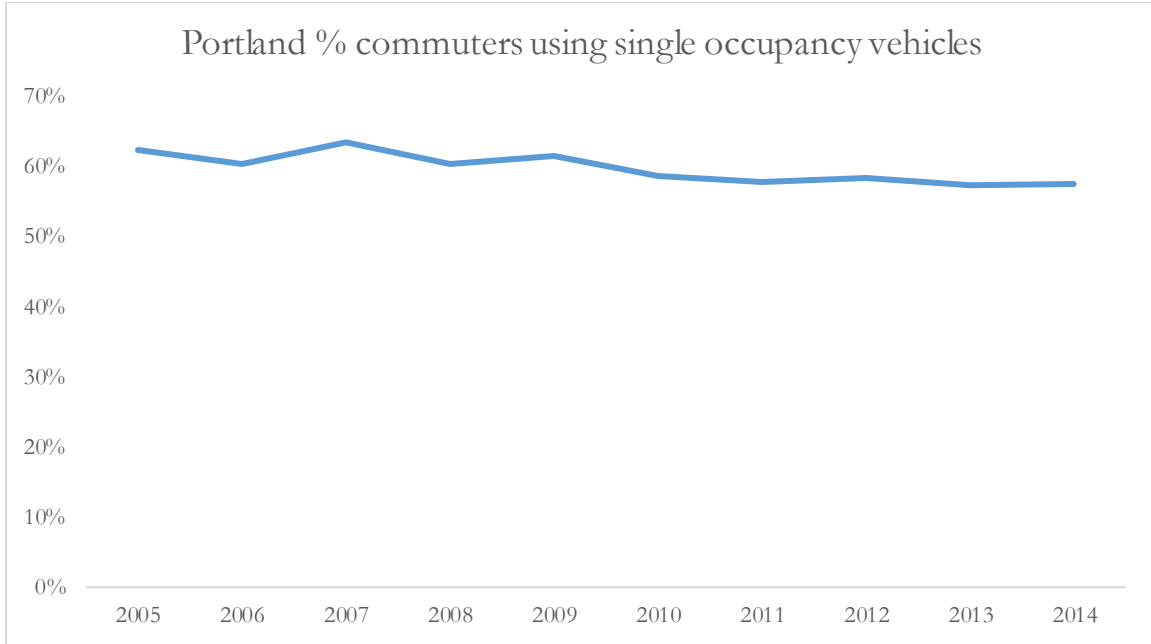
Figure 1: Portland % commuters using single occupancy vehicles

Figure 1 shows that the share of commuters using single occupancy vehicles in Portland has dropped from 62% to 58% since 2005. However, because of an increase in population, the actual number of single occupancy vehicle commuters has still risen, as seen in Figure 2. Between 2005 and 2014, the number of single occupancy vehicle commuters grew by slightly more than 27,000.

Figure 2: Portland single occupancy vehicle commuters

There are signs that overall vehicle use may rebound to pre-recession levels. Two other important indicators are car ownership and gas consumption. Automobile ownership dipped during the Great Recession, but has since rebounded to slightly outpace the growth of population.[7,8]
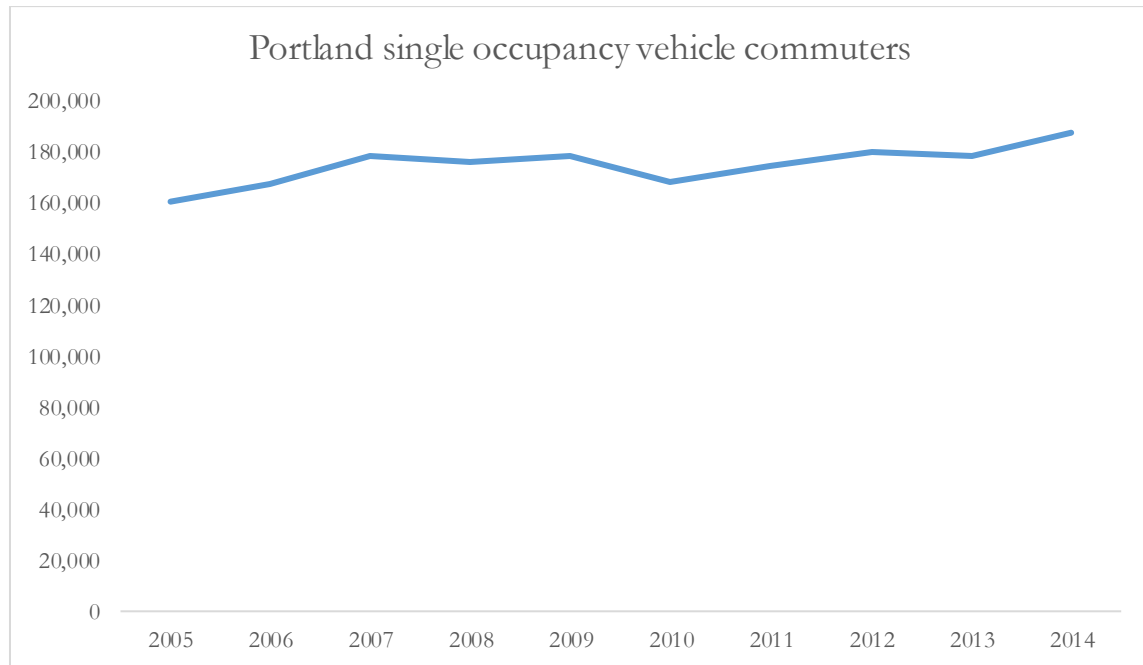
Figure 3 indicates that car registrations have grown slightly faster than population since 2013.[9,10] From 2012 to 2013, car registrations in Multnomah County increased by 2.02% while population grew only 1.08%. Growth in car registrations was again greater than population growth in 2015, with car registrations rising 2.92% and population only growing 1.53% relative to the previous year.

It is unclear whether the ratio of cars to population will return to pre-recession levels. Note also that these data are published at the county level; although Portland represents roughly 80% of the county's population, the distinction between city and county data should be observed.
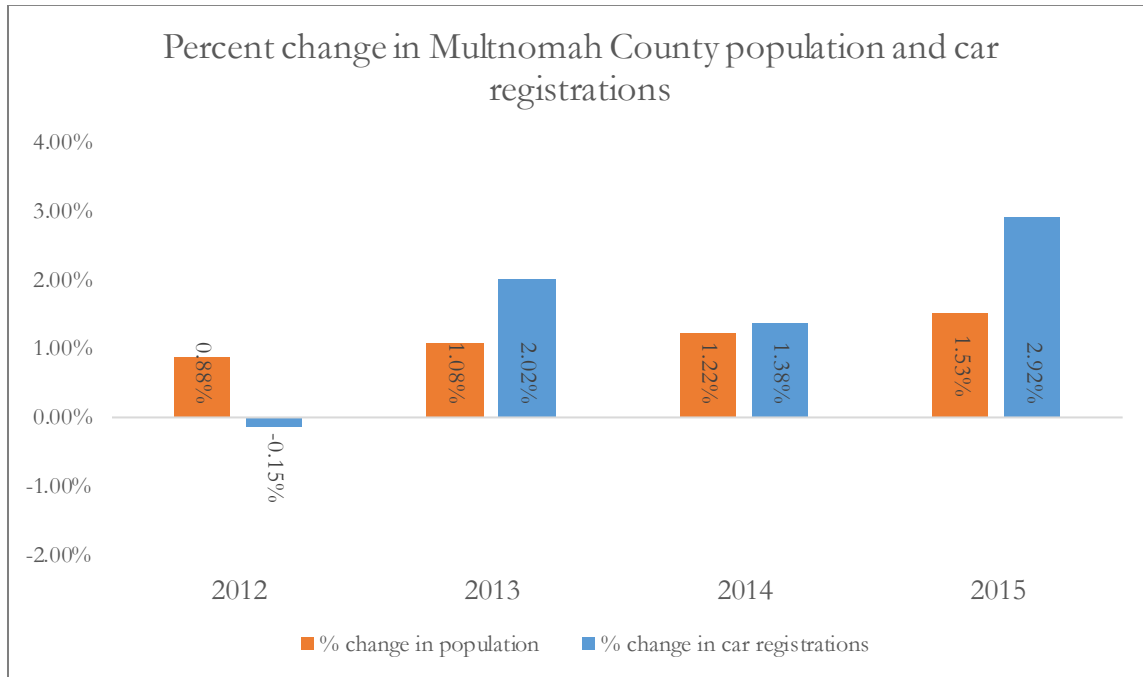

Figure 3: Percent change in Multnomah County population and car registrations

Another indicator of automobile use in Multnomah County is gas purchases. Figure 4 compares the growth in gasoline consumption to the growth in car registrations. In 2015, the growth in gasoline purchases exceeded the growth in car ownership.[11,12] Gas purchases grew by 3.83% in

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[7] Portland State University (PSU), "Population Estimates and Reports," accessed March 8, 2016, http://www.pdx.edu/prc/population-reports-estimates.

[8] Oregon Department of Motor Vehicles (DMV), "Oregon DMV Vehicle Registration Statistics," accessed March 8, 2016, http://www.oregon.gov/ODOT/DMV/pages/news/vehicle_stats.aspx.

[9] PSU, "Population Estimates and Reports."

[10] DMV, "Oregon DMV Vehicle Registration Statistics."

[11] Oregon Department of Transportation (ODOT), "Motor Vehicle Fuel Monthly Taxable Distribution Reports," accessed March 8, 2016, http://www.oregon.gov/ODOT/CS/FTG/Pages/reports.aspx.

[12] DMV, "Oregon DMV Vehicle Registration Statistics."

2015, compared to a 2.92% growth in car registrations. These data suggest that Multnomah County residents could be responding to lower gas prices, or a growth in employment, by driving more.
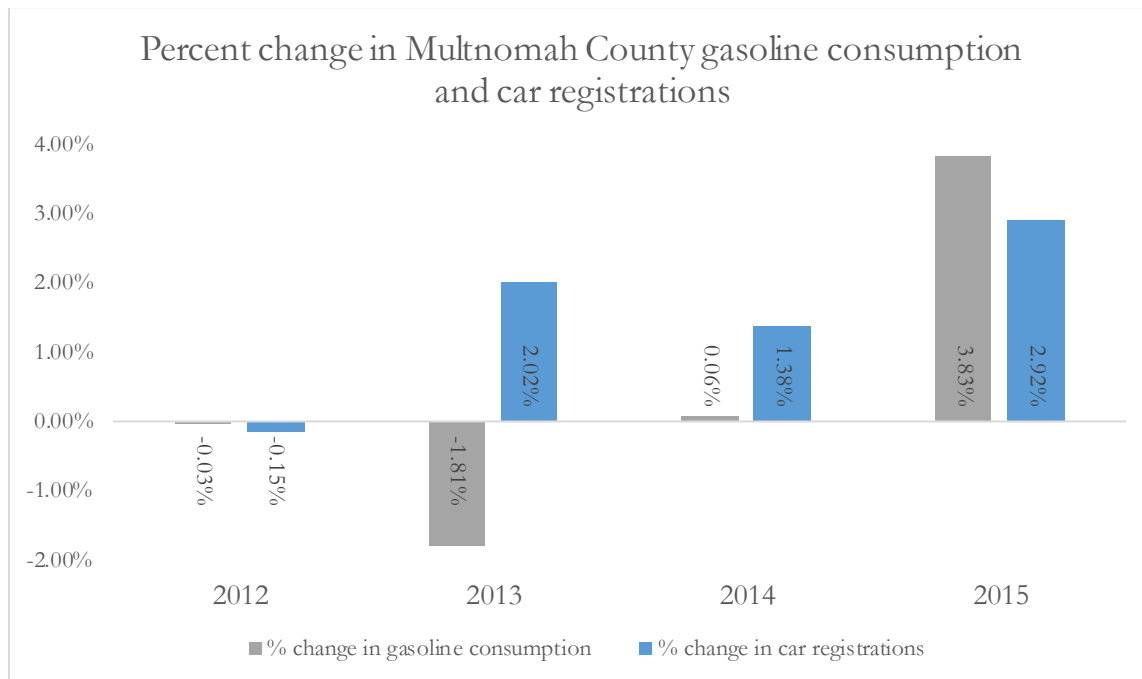

Figure 4: Percent change in Multnomah County gasoline consumption and car registrations

In light of these vehicle statistics, Portland's aspirational planning – planning to increase the number of cyclists and to reduce the number of cars – may not have been realized through current trends.

Bicycle Use in Portland

Bicycle use in Portland has appeared to follow the standard, S-shaped logistic curve model of new products. Early days are slow, followed by a period of acceleration, and finally a period of saturation. This is true for sales of television sets, epidemiological models, and even for visits to Native American-owned casinos. The standard mathematical model to explain this phenomenon is the logistic curve.[13]

Starting at a low value, PBoT citywide bicycle counts enjoyed rapid growth from 2004 to 2008 and have now settled down to the flatter portion of the curve.[14] Figure 5 displays summer bicycle traffic for the Morrison, Hawthorne, Steel, Broadway, and Burnside bridges. [15]

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[13] Ponzo, Peter, "Logistic Growth," accessed March 8, 2016, http://www.gummy-stuff.org/logistic-growth.htm.
[14] PBoT, "Portland Bicycle Count Report 2013-2014," accessed March 8, 2016, https://www.portlandoregon.gov/transportation/article/545858. Page 12. The numbers by PBoT should be treated with caution; a large portion of the estimates are derived by extrapolating 2-hour peak counts. See page 12 of that report.
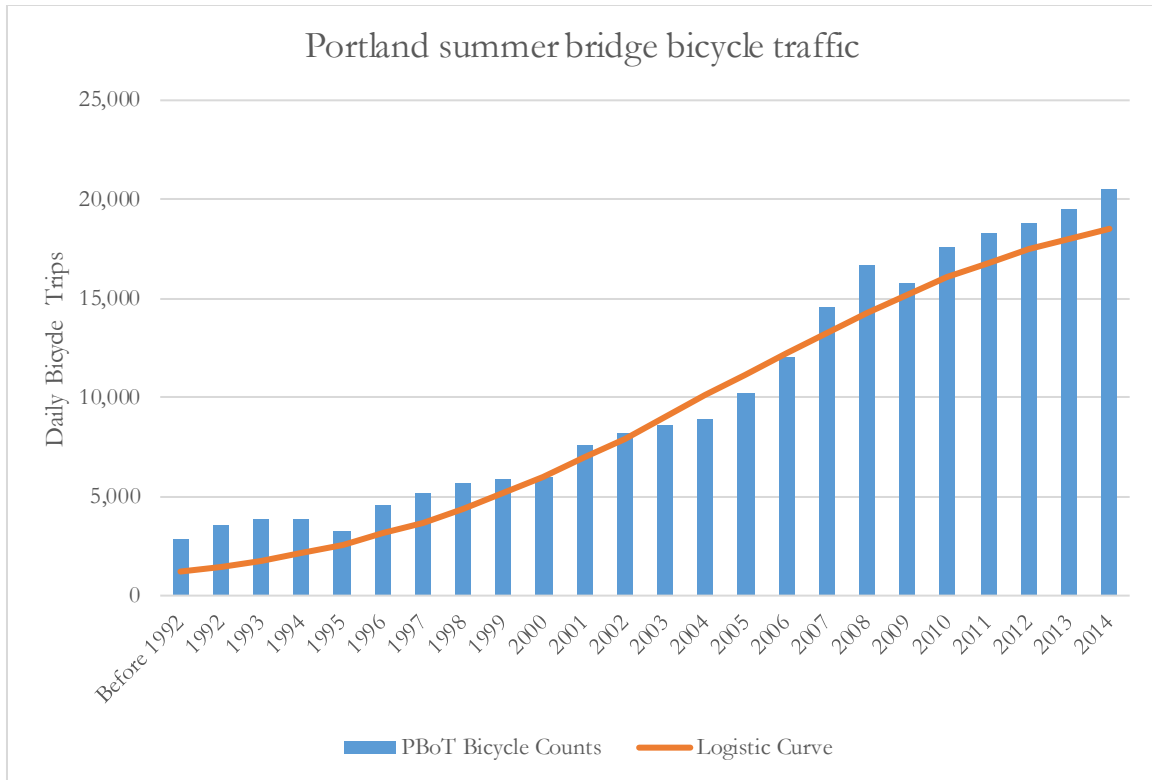[15] Ibid, page 12.

Figure 5: Portland summer bridge bicycle traffic

The standard formula for a logistic curve is:

$$Y = \frac{L}{1 + ae^{-kx}}$$

where e is Euler's number, 2.71828, L is the carrying capacity of the system (i.e. total number of rides), and a and k are parameters derived from the shape of the data. In Figure 5, the carrying capacity L is assumed at 21,000 rides, slightly higher than the peak value observed by PBoT of 20,497 daily citywide rides in the summer of 2014.

At the time of writing, PBoT has not yet released its 2015 Bicycle Count Report. However, there is reliable public data on bicycle commuting on two downtown bridges – the Hawthorne Bridge and the newly constructed Tilikum Crossing. The Tilikum Crossing, which became accessible to the public in September 2015, is the largest bridge in the U.S. that is open only to bicycles, pedestrians, rail transit, and buses. Private vehicles may not cross the bridge. Bicycle count data for the Hawthorne Bridge and Tilikum Crossing are available on a daily basis.[16,17]

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[16] PBoT, "Bike Barometer: Portland Hawthorne Bridge," accessed March 8, 2016, http://portland-hawthorne-bridge.visio-tools.com/.

[17] PBoT, "Bike Barometer: Portland Tilikum Crossing," accessed March 8, 2016, http://portland-tilikum-crossing.visio-tools.com/.
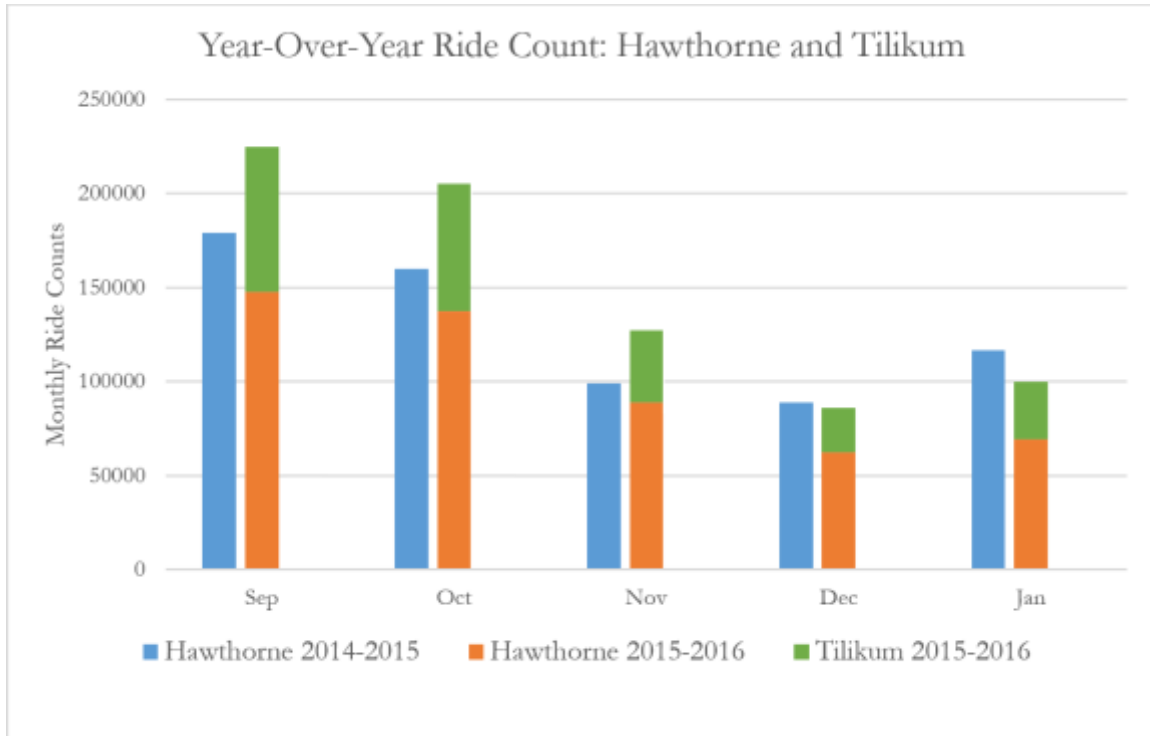
Figure 6: Year-over-year ride count: Hawthorne and Tilikum

The construction of the Tilikum Crossing yields a unique situation: although preliminary, data now exist which can indicate whether the Tilikum Crossing has delivered on its promise to increase bicycle commuting. After the Tilikum Crossing opened in September 2015, there was an initial bump in the total number of cyclists crossing the Hawthorne and Tilikum bridges, but only for three months. See Figure 6. By December 2015, the combined number of rides on the Hawthorne and Tilikum bridges was lower than on just the Hawthorne Bridge in December 2014. The same is true for January 2016 compared to January 2015.

Still, simply analyzing the raw year-over-year numbers does not account for other factors that may influence cyclists, most notably adverse weather. Sections 2 through 4 will develop an ordinary least squares (OLS) model to isolate other factors that influence cycling, such as weather and daylight, and observe the effect, *ceteris paribus*, of the Tilikum Crossing on daily east-west bicycle counts. Results should be considered preliminary, as the bridge is a relatively new transportation option for cyclists.

Policy Decision-Making: Spending on Bicycle Infrastructure

To increase bicycle use, one policy approach has been to increase bicycle infrastructure. Several statistical studies support the causal relationship between infrastructure and bicycle ridership. In 2002, Mauricio Lelerc conducted a cross-sectional study which modeled ridership as a function

of location, slope, and infrastructure type.[18] The study was repeated in 2013 by members of the Portland City Club.[19]

Portland has invested in a wide variety of possible bicycle infrastructures, such as "bike boulevards," which are designated streets with low volumes of automobile traffic where bicycles and pedestrians are given priority. The City Club study mapped the linear feet of bike boulevards across the city, which is reproduced in Figure 7.[20]
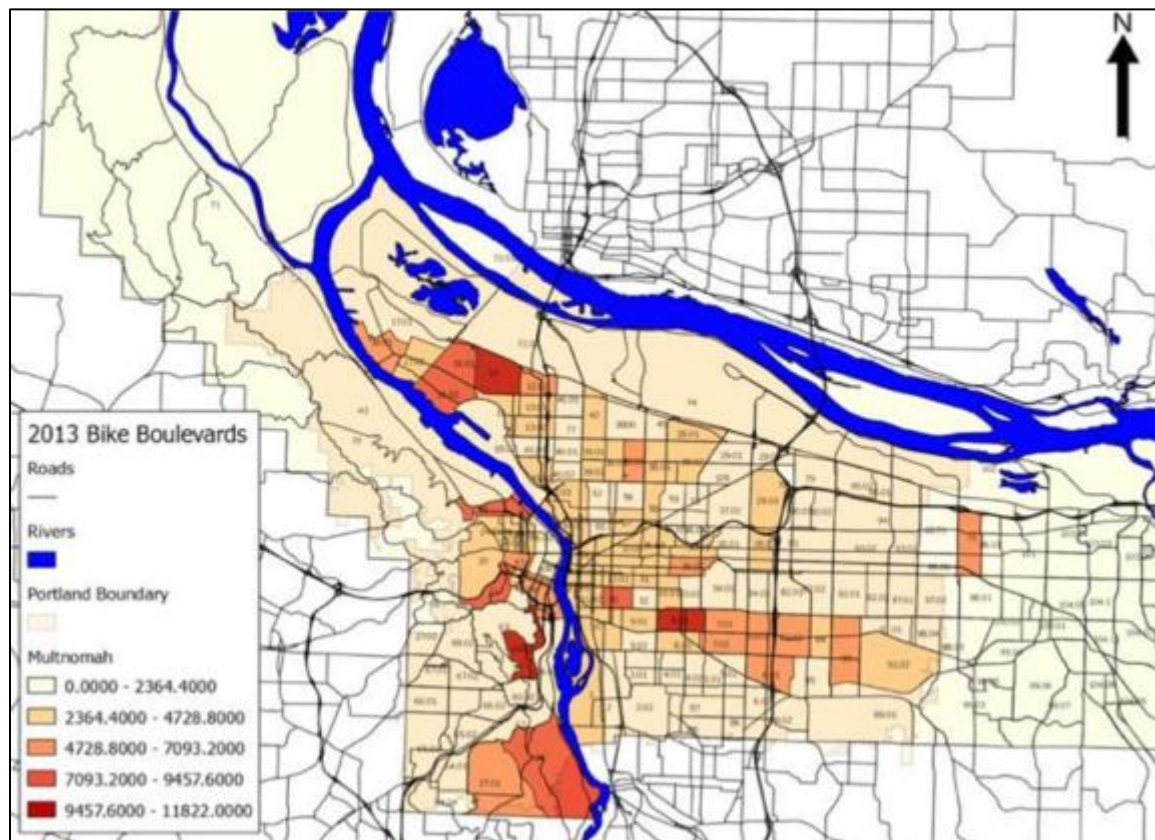
Figure 7: Linear feet of bike boulevards in the City of Portland

The Leclerc and City Club studies explained ridership by specific types of infrastructure, such as the linear feet of bike infrastructure. Only relatively safe options, such as dedicated bike paths, cycle tracks, and buffered bike lanes showed a strong positive relationship with bicycle commuting.

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[18] Leclerc, Mauricio, "Bicycle Planning in the City of Portland: Evaluation of the City's Bicycle Master Plan and Statistical Analysis of the Relationship between the City's Bicycle Network and Bicycle Commute," MURP diss., Portland State University, 2002, accessed March 8, 2016, http://web.pdx.edu/~jdill/LeClerc.pdf.

[19] Leineweber, Henry, Craig Beebe, Rob Brostoff, Pat Flynn, Pam Kane, Andrew Lee, Nancy Thomas, Carl von Rohr, Traci Wall, Daniel Keppler, Robert McCullough, and Byron Palmer, "No Turning Back: A City Club Report on Bicycle Transportation in Portland," *City Club of Portland Bulletin* 95 (2013): 1-84, accessed March 8, 2016, http://www.pdxcityclub.org/files/Reports/No%20Turning%20Back_%20A%20City%20Club%20Report%20on%20Bicycle%20Transportation%20in%20Portland_0.pdf.

[20] Leineweber et al, 2013. Page 76.

Cross-sectional methods, such as those applied in the Leclerc and City Club studies, may not be suited to study ridership on the Tilikum Bridge; the few bridges available in Southeast Portland are not easily assigned to neighborhoods or census tracts. More importantly, bridges serve broad geographic areas, so a different approach is required.

Conceptual Model and Definition of Variables

In 2013, the City Club of Portland commissioned a study of bicycling in Portland.[21] As part of that effort, an OLS model was developed to explain rides at the Hawthorne Bridge. The independent variables were average temperature, inches of daily precipitation, average wind speed, time of daylight, and a binary variable for weekends and holidays. Since there is no *a priori* reason to believe that bicyclists' response to average temperature, precipitation, or wind is linear, the model incorporated the squares of those variables in order to capture the curvature of response. Since February 2013 the model has been largely unchanged. Updated ridership and meteorological data have been added, as well as bicycle counts from the newly opened Tilikum Crossing.

With the September 2015 opening of the Tilikum Crossing, the bridge's effects on total east-west bicycle counts across the Willamette River are now observable. When holding constant the other factors that influence cycling, such as weather and daylight, has the Tilikum Crossing increased daily east-west bicycle counts, *ceteris paribus*?

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[21] Leineweber et al, 2013.

Table 1 details the variable names and their meanings.

Variable name	Variable meaning, units	Expected Coefficient Sign
Rides	Total daily rides counted on Hawthorne Bridge[22]	N/A
Tk_rides	Total daily rides counted on Tilikum Bridge[23]	N/A
Total	Sum of *Rides* and *Tk_rides*	N/A
tMean	Mean temperature, in degrees Fahrenheit[24]	+
tMean^2	Square of *tMean*	-
prcp	Total precipitation, in inches[25]	-
prcp^2	Square of *prcp*	+
windAvg	Average daily wind speed, in MPH[26]	-
windAvg^2	Square of *windAvg*	+
WkndHol	Binary variable; 1 if Weekend or Holiday, 0 else	-
Sunset	Time of sunset, Pacific Standard Time[27]	+
Order	Days from start of data set	0
Tilikum	Binary variable; 0 before Tilikum Bridge, 1 after	+

Table 1: Variable names and descriptions

We tested two models. In Model I we use *Total*, the total daily ride count on both bridges, as the dependent variable. This Model explains the Tilikum Crossing's effect on total east-west bicycle ridership. In Model II we use *Rides*, the total daily ride count on only the Hawthorne Bridge, as the dependent variable. Model II will answer the question: Has the Tilikum Crossing diverted some cycling traffic from the Hawthorne Bridge, when accounting for other factors?

We expect the effect of temperature on ridership to be positive, as cyclists are less inclined to ride in the cold. This effect is almost certainly diminishing, which is why the expected square of temperature is negative. Similarly, riders are more likely to ride during daylight hours, so we expect the effect from the time of sunset will also be positive, as higher values are associated with later sunsets. Inclement weather is measured by both precipitation and wind speed, so we expect each to have a negative effect on rides. These effects are also likely diminishing, and so the square of each will likely be positive. Since commuters comprise the majority of bike rides, we expect the weekend/holiday dummy variable to be negative. We expect the variable "Order" to have no effect on ridership because we hypothesize that bicycle rides have moved beyond the

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[22] PBoT "Bike Barometer: Portland Hawthorne Bridge." Note: it was necessary for the data from the Hawthorne Bridge bicycle counter to be estimated by doubling the number of westbound counts from January 31 through March 1, 2016, due to a mechanical failure in the eastbound traffic counter, as reported to the authors by Roger Geller and Tom Jensen of PBoT.

[23] PBoT, "Bike Barometer: Portland Tilikum Crossing."

[24] National Oceanic and Atmospheric Administration (NOAA), "Quality Controlled Local Climatological Data," accessed March 8, 2016, http://www.ncdc.noaa.gov/qclcd/QCLCD?prior=N.

[25] Ibid.

[26] Ibid.

[27] Ibid.

rapid growth phase of the logistic curve. Finally, if indeed the investment in Tilikum Crossing has had a positive effect on rides, then we expect its coefficient to be positive.

Summary Statistics

Bicycle commuting is relatively volatile, unlike other forms of commuting. Since the bicycle counter was installed on the Hawthorne Bridge on August 8, 2012, counts have ranged from a low of 32 to a high of 13,183 rides per day, with an average of 4,573. The large standard deviation of 2,106 rides per day further indicates the high variability in bicycle traffic. See Table 2.

Even the most cursory examination of the data reveals strong patterns reflecting commuting – weekday trips are much higher than on weekends and holidays, averaging 5,373 versus 2,501 rides per day, respectively. Weather is also a factor, with clear days showing many more riders than rainy days – 5,262 versus 3,485 daily rides.

	Obs	Mean	Std. Dev.	Min	Max
Rides	1301	4,573.28	2,106.15	32.00	13183.00
Tk_rides	1301	218.06	765.65	0.00	14723.00
Total	1301	4,791.34	2,166.03	32.00	17264.00
tMean	1301	55.73	12.24	20.00	84.00
tMean^2	1301	3,255.50	1,374.56	400.00	7056.00
prcp	1301	0.11	0.25	0.00	2.67
prcp^2	1301	0.07	0.36	0.00	7.13
windAvg	1301	6.73	3.58	0.80	28.70
windAvg^2	1301	58.09	72.25	0.64	823.69
WkndHol	1301	0.31	0.46	0.00	1.00
Sunset	1301	0.76	0.05	0.69	0.84
Order	1301	651.00	375.71	1.00	1301.00
Tilikum	1301	0.13	0.34	0.00	1.00

Table 2: Summary Statistics

Results

The results from OLS regression yield coefficients that are nearly all significant at the 1% level. See Table 3.

	Model I Total Rides		Model II Hawthorne Rides	
intercept	-5445.131		-4789.793	
	(733.604)	***	(634.339)	***
tMean	229.783		192.404	
	(19.235)	***	(16.632)	***
tMean^2	-1.398		-1.126	
	(0.170)	***	(0.147)	***
prcp	-3797.774		-3364.612	
	(250.387)	***	(216.507)	***
prcp^2	1324.038		1218.207	
	(159.357)	***	(137.795)	***
windAvg	-72.248		-65.216	
	(23.867)	***	(20.637)	***
windAvg^2	2.635		2.699	
	(1.158)	**	(1.001)	***
WkndHol	-2925.745		-2901.377	
	(59.176)	***	(51.168)	***
Sunset	4607.676		5148.483	
	(894.827)	***	(773.747)	***
Order	-0.153		-0.075	
	(0.093)		(0.080)	
Tilikum	1137.018		-633.717	
	(108.875)	***	(94.143)	***

Notes: Standard errors in parentheses. ** significant at 5%; *** significant at 1%

Table 3: Regression Results

In Model I, the independent variables explain 79% of the variation in rides across the Hawthorne and Tilikum bridges. All of the variables have the expected signs and all are significant at the 1% level, with the exceptions of *windAvg^2*, which is significant at the 5% level, and *Order*, the coefficient of which was expected to be insignificant.

The binary variable *Tilikum* is significant and positive. Model I estimates the existence of the new bridge has led to an increase of 1,137 rides per day when accounting for other factors such as weather and daylight.

The opening of Tilikum Crossing has had a negative impact on ridership across the Hawthorne Bridge. In the aforementioned "Year-Over-Year Ride Count," Hawthorne 2015-2016 levels were all lower than Hawthorne 2014-2015 levels. This manifests itself in Model II, where the dependent variable is comprised of only Hawthorne rides, rather than total rides. In this result, the *Tilikum* dummy variable has a significantly negative effect on rides across the Hawthorne Bridge, estimated at nearly 634 fewer daily rides on the Hawthorne Bridge after the opening of

Tilikum Crossing, when controlling for other factors. The variables in Model II explain 83% of the variation in rides over the Hawthorne Bridge.

Discussion

The results of OLS regression show that the Tilikum Crossing added 1,137 east-west rides per day, even when accounting for other factors. Further, it diverts nearly 634 daily riders from the Hawthorne Bridge, providing an alternate route.

Charting the actual ride data against the Model's predictions shows that meteorological factors are not the only variables that could have been used. Figure 8 displays Model I predicted rides versus the actual, observed total rides on the bridges.
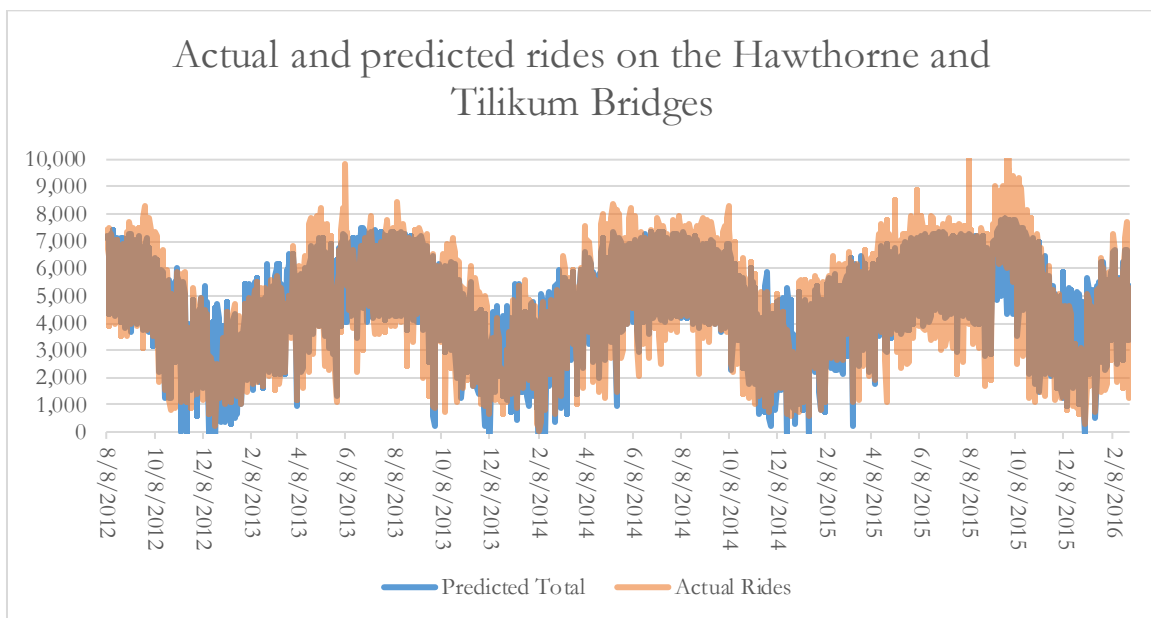

Figure 8: Actual and predicted rides on the Hawthorne and Tilikum bridges

The most obvious failing of the Model is that it predicts that riders will choose to bicycle the Hawthorne Bridge over Christmas holidays; only Christmas Eve and Christmas are assigned a 1 in the binary variable for holidays. This phenomenon is reflected by the higher predictions of rides, indicated by the blue lines, over the Christmas holidays. The Model also fails to account for unique events such as: 1) the annual nude bike ride, which crossed the Hawthorne Bridge in June 2013 and is reflected by an orange peak above predicted rides; 2) the 2015 Bridge Pedal, which appears as a similar spike in August 2015; and 3) the opening of the Tilikum Crossing, which led to higher ridership in September and October of 2015

Conclusion

The rapid growth phase of Portland bicycle ridership has developed into the slower growth of a mature product or technology, following the logistic curve. Both Roger Geller, Bicycle

Coordinator for PBoT, and the aforementioned City Club report have addressed this issue.[28] Once enthusiasm ceases to be the primary fuel of growth, careful planning and infrastructural improvements are required. The Geller study and the City Club report emphasize the use of bicycle boulevards over less secure routes where automobile traffic is present. It may be the case that the Tilikum Crossing, an infrastructure project that allows for a high degree of safety for cyclists, has actually expanded the logistic curve upward, creating a higher plateau for bicycle commuting than before.

Results from OLS regression models show that the Tilikum Crossing has added 1,137 east-west rides per day, even when accounting for other factors such as weather and daylight. Further, the new bridge has diverted nearly 634 daily riders from the Hawthorne Bridge, providing an alternative route.

The results for the Tilikum Crossing should be considered preliminary. These models' estimates are based on a relatively small time frame of five months, which means it is unclear whether the surge in ride counts was merely due to a novelty effect. Such a novelty effect could fade, or wane to the point where it would be completely offset by the decrease in ridership across the Hawthorne Bridge – implying no change in the underlying logistic curve of bicycle commuting.

Still, for the time being, this particular investment in bicycle infrastructure has undeniably increased actual ridership. The result follows a long trend in Portland. PBoT's summer bridge data show that Portland more than doubled the number of summer bridge rides between 2005 and 2014, from 10,192 to 20,497 daily rides. The question for planners is: Will these numbers plateau, or will infrastructural investments alter the underlying form of the logistic curve? Further data releases will undoubtedly shed light on these trends.

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[28] Geller, Roger, "What Does the Oregon Household Activity Survey Tell Us About the Path Ahead for Active Transportation in the City of Portland?," *Portland Bureau of Transportation*, March 2013, accessed March 8, 2016, https://www.portlandoregon.gov/transportation/article/452524.

References

Geller, Roger, "What Does the Oregon Household Activity Survey Tell Us About the Path Ahead for Active Transportation in the City of Portland?," *Portland Bureau of Transportation*, March 2013, accessed March 8, 2016, https://www.portlandoregon.gov/transportation/article/452524.

> In 2013 Geller published a white paper on non-automotive transportation in the City of Portland. The study models the citywide increase in bicycling and walking, the potential for increased growth in bicycle transportation, and the costs and benefits of future transportation mixes. He concludes that the most effective method to increase bicycle use is to improve on the city's bicycle infrastructure. Geller's conclusion is supported by other research discussed in this report, including studies by Leclerc and Leineweber et al. These three studies contribute to qualitative discussion in this report regarding bicycle infrastructure.

Leclerc, Mauricio, "Bicycle Planning in the City of Portland: Evaluation of the City's Bicycle Master Plan and Statistical Analysis of the Relationship between the City's Bicycle Network and Bicycle Commute," MURP diss., Portland State University, 2002, accessed March 8, 2016, http://web.pdx.edu/~jdill/LeClerc.pdf.

> In a 2002 thesis for a Master's in Urban and Regional Planning at Portland State University, Leclerc discusses the state of bicycle infrastructure in the City of Portland. The report finds that the City has not met the goals of its late-1990s *Bicycle Master Plan*. A statistical model is developed to explain the relationship of bikeways to the percentage of bicycle commuters per Census tract. The model supports other studies' conclusions that more bikeways are associated with a higher percentage of bicycle commuters. In addition to reports by Geller and Leineweber et al., Leclerc's study contributes to qualitative discussion in this report regarding bicycle infrastructure.

Leineweber, Henry, Craig Beebe, Rob Brostoff, Pat Flynn, Pam Kane, Andrew Lee, Nancy Thomas, Carl von Rohr, Traci Wall, Daniel Keppler, Robert McCullough, and Byron Palmer, "No Turning Back: A City Club Report on Bicycle Transportation in Portland," *City Club of Portland Bulletin* 95 (2013): 1-84, accessed March 8, 2016, http://www.pdxcityclub.org/files/Reports/No%20Turning%20Back_%20A%20City%20Club%20Report%20on%20Bicycle%20Transportation%20in%20Portland_0.pdf.

> This 2013 report was commissioned by the Portland City Club to study optimal transportation planning for bicycle infrastructure. The authors repeated the analysis by Leclerc's 2002 thesis on bicycle infrastructure. The analysis also mapped the linear feet of bike boulevards across the City. Leclerc's conclusions were supported by the City Club analysis: linear feet of bikeway were associated with a higher percentage of bicycle commuters. Along with work by Geller and Leclerc, the City Club study contributed to this report's qualitative discussion of bicycle infrastructure.

National Oceanic and Atmospheric Administration (NOAA), "Quality Controlled Local Climatological Data," accessed March 8, 2016, http://www.ncdc.noaa.gov/qclcd/QCLCD?prior=N.

NOAA publishes daily climatological data for various weather stations around the country. This database includes the average temperature, inches of precipitation, average wind speed, and time of sunset for each weather station. NOAA data for the Portland International Airport (PDX) were used for all meteorological variables in this report's models.

Oregon Department of Motor Vehicles (DMV), "Oregon DMV Vehicle Registration Statistics," accessed March 8, 2016, http://www.oregon.gov/ODOT/DMV/pages/news/vehicle_stats.aspx.

The Oregon DMV publishes statistics on vehicle registrations for the State of Oregon on a county-by-county basis. The number of passenger vehicles was used to illustrate the increase in automobiles in Multnomah County in Section 1.1 of this report.

Oregon Department of Transportation (ODOT), "Motor Vehicle Fuel Monthly Taxable Distribution Reports," accessed March 8, 2016, http://www.oregon.gov/ODOT/CS/FTG/Pages/reports.aspx.

ODOT publishes monthly information on gasoline taxes in the state, including county-level gasoline consumption in gallons. These data were used to analyze the growth in gasoline consumption in Multnomah County in Section 1.1 of this report.

Ponzo, Peter, "Logistic Growth," accessed March 8, 2016, http://www.gummy-stuff.org/logistic-growth.htm.

This article models the spread of the H1N1 virus using a logistic curve. It describes the mathematics of a logistic curve, discussing examples such as population growth, annuity growth, and the spread of disease.

Portland Bureau of Planning and Sustainability (BPS), "Goals and Policies," accessed April 6, 2016, https://www.portlandoregon.gov/bps/68411.

BPS describes the Goals and Policies of the Portland Comprehensive Plan. These specific outcomes cover issues of land use, community involvement, housing, transportation, economic development, and environmental planning. The Goals are used to describe the City of Portland's aspirational planning.

Portland Bureau of Transportation (PBoT), "Portland Bicycle Count Report 2013-2014," accessed March 8, 2016, https://www.portlandoregon.gov/transportation/article/545858.

PBoT publishes an annual report on bicycle counts in the City of Portland. The agency collects data not just on the frequency of cycling in Portland, but also on the geographic distribution, demographic distribution, response to bicycle infrastructure, response to weather, safety, and other information. Page 12 of that report presents the "Summer Bridge Traffic" of Portland, showing the daily bicycle trips on bridges in city. Data are based either on 24-hour hose counts or are extrapolated from 2-hour peak counts. Those statistics were used in this report to illustrate the logistic growth of cycling in Portland.

"Bike Barometer: Portland Hawthorne Bridge," accessed March 8, 2016, http://portland-hawthorne-bridge.visio-tools.com/.

In 2012, PBoT installed hoses on the east- and westbound lanes of the Hawthorne Bridge. These hoses count the number of times per day that a cyclist crosses the bridge. The data are updated daily and are publicly available on the web. Hawthorne Bridge and Tilikum Crossing bicycle ride counts made up the dependent variables in this report's regressions.

"Bike Barometer: Portland Tilikum Crossing," accessed March 8, 2016, http://portland-tilikum-crossing.visio-tools.com/.

PBoT installed bicycle counters as part of the construction of the Tilikum Crossing. Like the Hawthorne Bridge, the data are updated daily and are also publicly available on the web. Hawthorne Bridge and Tilikum Crossing bicycle ride counts made up the dependent variables in this report's regressions.

"Tilikum Crossing: Bridge of the People," accessed April 14, 2016, https://www.portlandoregon.gov/transportation/68548.

PBoT's official web page for the Tilikum Crossing describes it as "the largest car-free bridge in the United States." That distinction is presented in the Background section of this report.

"Transportation Element of the Comprehensive Plan," accessed April 6, 2016, https://www.portlandoregon.gov/transportation/article/370467.

PBoT discusses the Transportation Element of the Portland Comprehensive Plan. It outlines specific steps for coordination and involvement, street classifications, land use, public transportation, planning for automobile use, and transportation districts. The document is cited in this report to discuss Portland's transportation planning.

Portland State University (PSU), "Population Estimates and Reports," accessed March 8, 2016, http://www.pdx.edu/prc/population-reports-estimates.

The College of Urban and Public Affairs at PSU publishes population estimates for counties and cities in the State of Oregon. Multnomah County population estimates were used in Section 1.1 of this report.

TriMet, "Portland-Milwaukie Light Rail Bridge Fact Sheet," August 2013, accessed April 14, 2016, http://trimet.org/pdfs/pm/Fact-sheets-timelines/PMLR_Bridge_Fact_Sheet_Aug2013.pdf.

TriMet estimates the budget of the Tilikum Crossing as $134.6 million. This figure is cited in the Background section of this report.

U.S. Census Bureau, "2005-2014 American Community Survey 1-Year Estimates, Table DP03," *American Community Survey*, accessed March 8, 2016, http://factfinder2.census.gov.

As a division of the U.S. Census, the American Community Survey publishes information on the nation's demographics, employment, income, lifestyle, and other topics. Data are available at the county-level. Table DP03 of the American Community Survey, "Selected Economic Characteristics," provides commuting behavior of survey respondents. This information was used in Section 1.1 of this report to analyze Multnomah County commuting behavior.