Appendix H Level of Service (LOS) Bridge Width

The Level of Service (LOS) Study includes the following documents:

- A088367-LTR-DeckClearWidth
- A088367 Reference Widths for Bridges
- A088367 Reference Capacities for Bridges
- A088367-PPT-LOS of Urban Bridges
- A088367 Memo_MIGSvR LOS 20170324
- A088367 Memo 1 LOS per FIB32
- A088367 Memo 2 LOS per FHWA

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PROJECT	Totem Lake Connector
TITLE	Bridge Deck Clear Width Recommendation
DATE	22 March 2017
TO	Aaron MacDonald
FROM	Schaun Valdovinos, PE Dave Rodgers, PE
PROJECT NO	A088367

ADDRESS COWI North America
1191 2nd Avenue
Suite 1110
Seattle, WA 98004

TEL 206 216 3933
WWW cowi.com

Dear Aaron MacDonald,

This letter is written to describe the process used for evaluating the capacity of various deck widths that could be used for the Totem Lake Connector. Following these capacity studies, a 14-ft deck clear width is recommended. No immediate delineations on the deck surface is also recommended, but the City could decide to add a centerline at a future date to separate direction of travel.

To arrive at these conclusions, we utilized:

a. FHWA SUPLOS Model for evaluating Level of Service (LOS)
   i. This model is focused on cyclist comfort only.
   ii. We produced a case study of the new University of Washington pedestrian/cycling bridges to help with the terminology of LOS.
   iii. The LOS categories are given more descriptive names in our memos.
b. FIB 32 Walkway Capacity
   i. This European code based tool provides capacity for the bridge when it is used by dense pedestrian crowds (in which case cyclists will dismount and become a pedestrian).
c. Matrices that we developed with reference bridges at various widths
   i. Peak Hourly Volumes are reported for the various bridges.
d. 2016 Bike and Pedestrian Count Data
   i. This includes Seattle, Copenhagen, Vancouver, Calgary, and Ottawa.
   ii. Actual and average Peak Hourly Volumes seen by the counters are compared to the predicted SUPLOS calculated capacities.
   iii. Comparison against major urban bridges in the cities give an upper bound on the Peak Hourly Volume that could potentially be seen on the Totem Lake Connector in the distant future.
e. Bridge Density (Calculation)
   i. To understand how many people are on the bridge, we converted the SUPLOS volumes to density and relate that back to the FIB 32 density.
   ii. SUPLOS results in between 0.6 and 1.2 users per 40-ft of bridge length under the peak capacity.

f. Public Outreach

   i. We completed public outreach via a public meeting to obtain input on desired widths, and 14-ft clear width was the highest scoring of widths ranging from 12-ft to 18-ft.

g. Cross Kirkland Corridor Master Plan

   i. The Totem Lake area is envisioned to be a gateway, a connection to nature and the revitalized park being a potential trailhead.

Given this extensive study of user comfort, capacity, and comparing with reference examples, we can conclude that 14-ft clear width will provide comfortable long term use of the bridge. This width provides the ability for a large throughput of users on busy event days, allows for local and regional growth over the years, and maintains a comfortable pedestrian scale during low use times.

The only reason to provide a 16-ft clear width would be to allow future separation and delineation of uses (walkers and cyclists). We believe this separation and delineation would create the expectation of unfettered bicycle and pedestrian throughput at all times, and limiting available pedestrian spaces will result in greater speed differential between cyclists and pedestrians.

Totem Lake Neighborhood, Totem Lake Park and this bridge are conceived by the City to become a destination, an intersection and a mixing zone which will be served best by a flexible space that allows points of contemplation while still accommodating travelers to pass through the space.

Sincerely,

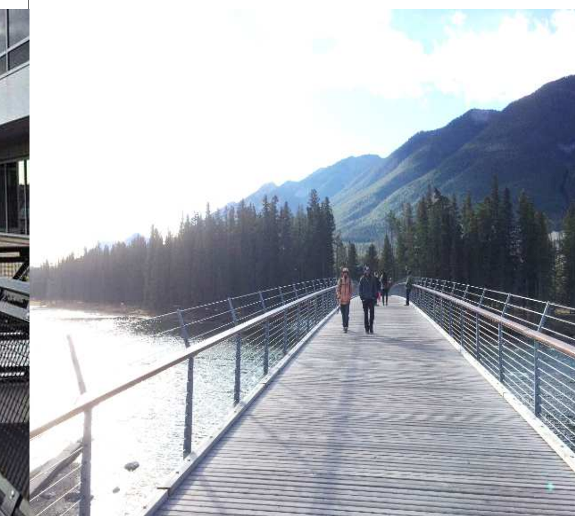
Schaun Valdovinos, PE
Project Manager
COWI North America, Inc.

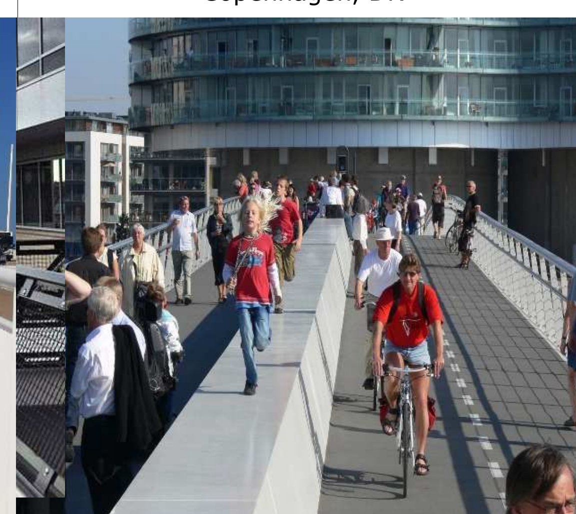
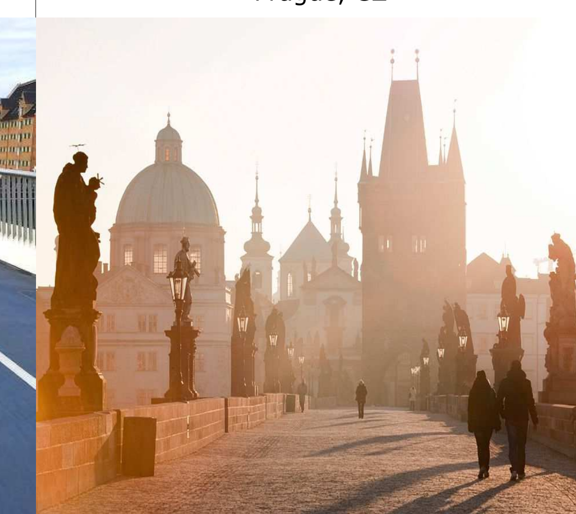
Dave Rodgers, PE, LEED AP
Principal Civil Engineer
MIG|SvR

Reference Widths of Existing Bridges

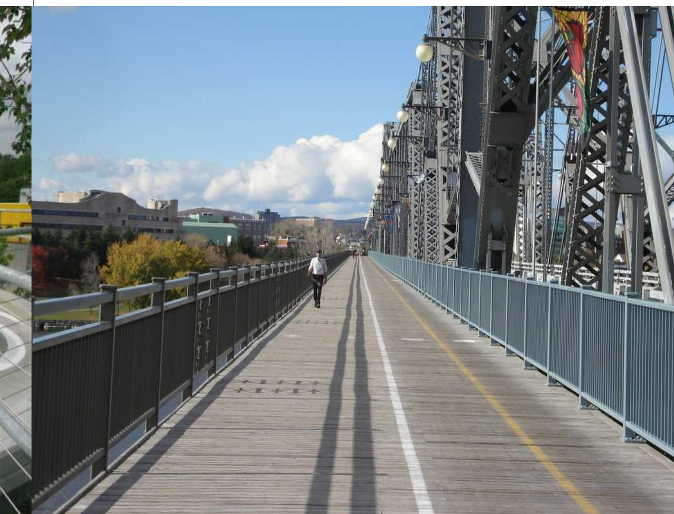
Below are examples of bridges at varying deck widths.

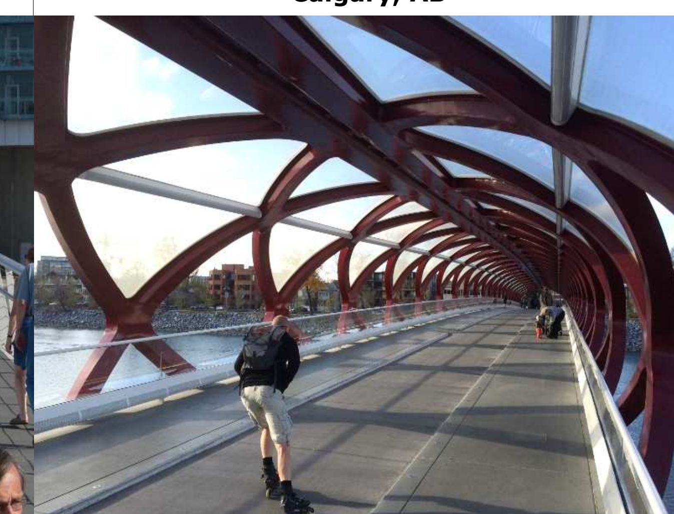
These examples can be useful in understanding the number of people that can fit within the deck width and also give an understanding of how comfortable the users may feel while on the bridge.

Name	Fremont Bridge	Squamish Pedestrian Overpass	Thomas Street Pedestrian Bridge	Bow River Pedestrian Bridge	Delta Ponds
Location	Seattle, WA	Squamish, BC	Seattle, WA	Banff, AB	Eugene, OR
Picture					
Width	6 ft*	8.5 ft (2.6 m)	10.3 ft	13 ft (4m)	14 ft

Name	New Bay Bridge	Brygge Bridge	Calgary Peace Bridge	Kissing Bridge	Charles Bridge
Location	San Francisco, CA	Copenhagen, DK	Calgary, AB	Copenhagen, DK	Prague, CZ
Picture					
Width	15.5 ft	18 ft (5.5 m)	20 ft (6.2 m)	23 ft (7 m)	31 ft (9.5 m)

Reference Capacities for Existing Bridges in Urban Environments

Name	Fremont Bridge	Brooklyn Bridge	Harbourside West Pedestrian Bridge	Trans Canada Trail, Alexandra Bridge
Location	Seattle, WA	New York, NY	North Vancouver, BC	Ottawa, ON
Picture				
Width	6 ft*	10 ft	13 ft (4 m)	14 ft*
Avg Daily Total	-	13,500	718	3,500
Avg Daily Bicycles	1,917	3,500	144	1,500
Avg Daily Peds	-	10,000	574	2,000
Peak Hourly	255 (bikes only)	-	-	-

Name	Cykelslangen (Snake Bridge)	Wing Tip Bridge	Brygge Bridge	Calgary Peace Bridge
Location	Copenhagen, DK	Mount Hope, WV	Copenhagen, DK	Calgary, AB
Picture				
Width	15 ft (4.6 m)	15 ft	18 ft (5.5 m)	20 ft (6.2 m)
Avg Daily Total	-	30,000	-	6,000
Avg Daily Bicycles	12,700	-	14,200	2,196
Avg Daily Peds	-	-	-	3,804
Peak Hourly	-	15,000 (Peds only)	-	-

LOS Categories

- **A: Excellent.** Trail has optimum conditions for individual bicyclists and retains ample space to absorb more users of all modes, while providing a high-quality user experience. Some newly built trails will provide grade-A service until they have been discovered or until their ridership builds up to projected levels.

- **B: Good.** Trail has good bicycling conditions, and retains significant room to absorb more users, while maintaining an ability to provide a high-quality user experience.

- **C: Fair.** Trail has at least minimum width to meet current demand and to provide basic service to bicyclists. A modest level of additional capacity is available for bicyclists and skaters; however more pedestrians, runners, or other slow-moving users will begin to diminish LOS for bicyclists.

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LOS Categories

- **D: Poor.** Trail is nearing its functional capacity given its width, volume, and mode split. Peak-period travel speeds are likely to be reduced by levels of crowding. The addition of more users of any mode will result in significant service degradation. Some bicyclists and skaters are likely to adjust their experience expectations or to avoid peak-period use.

- **E: Very Poor.** Given trail width, volume, and user mix, the trail has reached its functional capacity. Peak-period travel speeds are likely to be reduced by levels of crowding. The trail may enjoy strong community support because of its high usage rate; however, many bicyclists and skaters are likely to adjust their experience expectations, or to avoid peak-period use.

- **F: Failing.** Trail significantly diminishes the experience for at least one, and most likely for all user groups. It does not effectively serve most bicyclists; significant user conflicts should be expected.

LOS Categories - Summarized

- **A: Hardly used.**
- **B: Some users.**
- **C: Well used with capacity for additional users.**
- **D: Saturated.**
- **E: Some users finding alternative routes.**
- **F: Slow going for cyclists.**

SUPLOS Lookup Tables

Table 15. Shared-use path service volume look-up table, typical mode split.

Level of Service	Trail Width (feet) 8	10	12	14	16	18	20
A	24	24	24	24	70	102	125
B	49	49	110	147	191	213	229
C	49	97	198	226	282	300	315
D	109	155	267	290	362	379	392
E	167	212	328	349	436	452	464
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table shows maximum trail volume (one direction per hour) in each LOS category

Table 16. Shared-use path service volume look-up table, high bicycle mode split.

Level of Service	Trail Width (feet) 8	10	12	14	16	18	20
A	40	40	40	40	123	182	224
B	81	81	185	246	348	388	419
C	81	162	330	376	519	554	581
D	184	267	446	487	671	703	728
E	289	373	551	590	812	842	866
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A

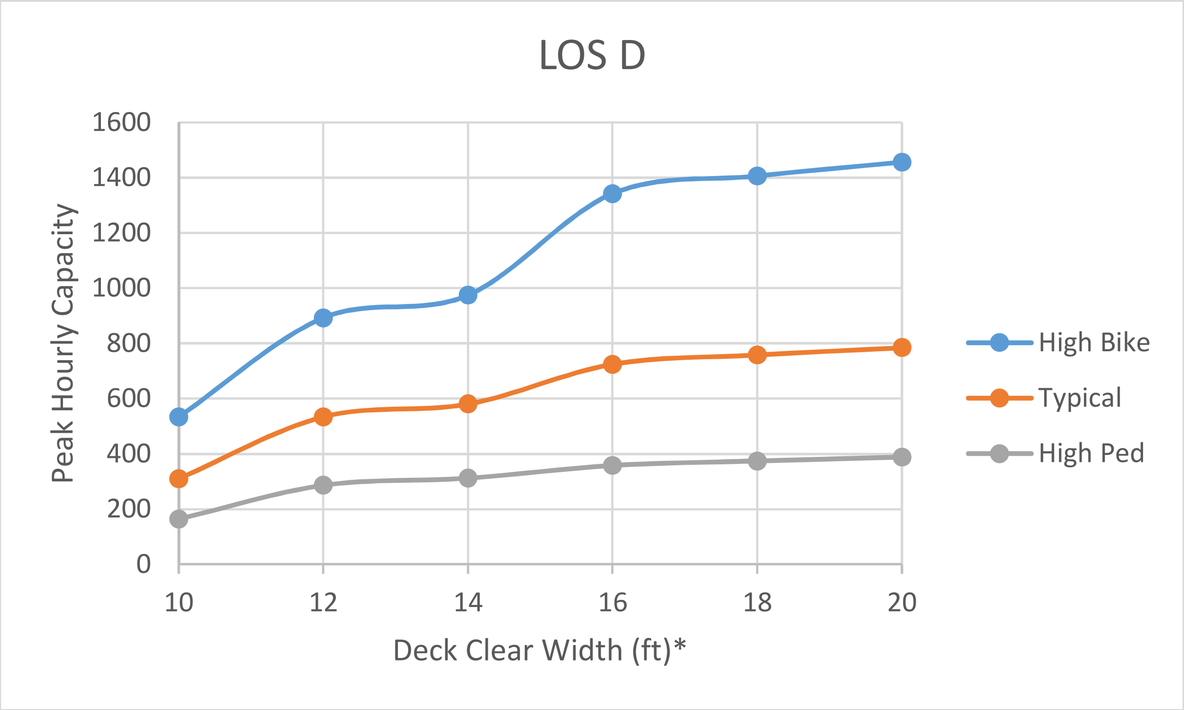
Table shows maximum trail volume (one direction per hour) in each LOS category

Table 17. Shared-use path service volume look-up table, high pedestrian mode split.

Level of Service	Trail Width (feet) 8	10	12	14	16	18	20
A	13	13	13	13	35	51	62
B	26	26	57	77	95	105	114
C	26	52	105	120	140	149	156
D	58	82	143	156	179	187	194
E	87	110	177	189	215	223	229
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table shows maximum trail volume (one direction per hour) in each LOS category

LOS D - Saturated



*Shy distance does not apply for the saturated state.

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LOS Data Summary

- Baseline Data
  - Burke Gilman Trail – 2010
  - Sammamish – 2006
  - Chicago Lakefront Trail – FHWA Study (2000-2005)
- 2016 Data
  - Fremont Bridge – Seattle, WA
  - Burrard Bridge – Vancouver, BC
  - Lions Gate Bridge – Vancouver, BC
  - Cambie Bridge – Vancouver, BC

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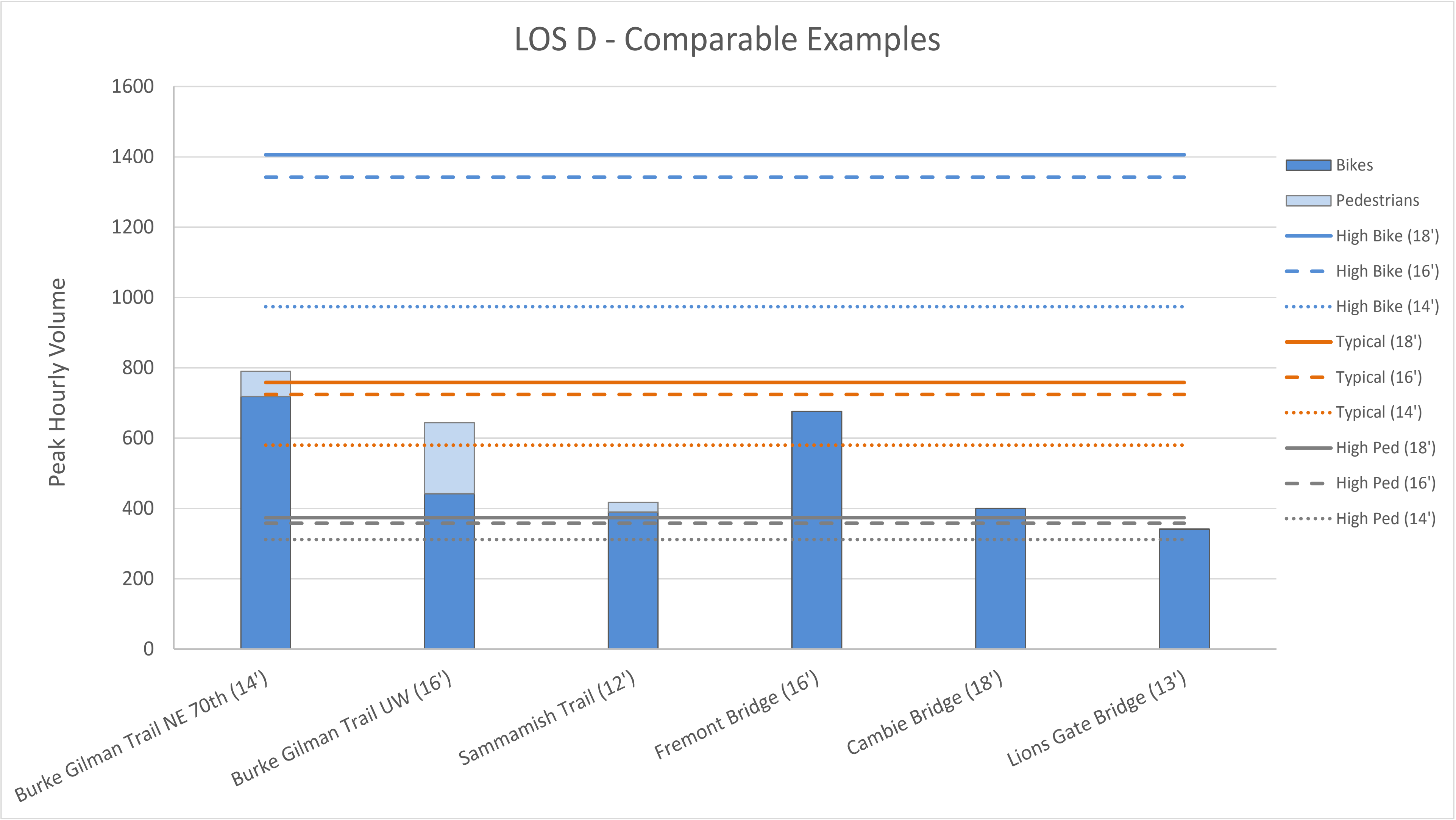
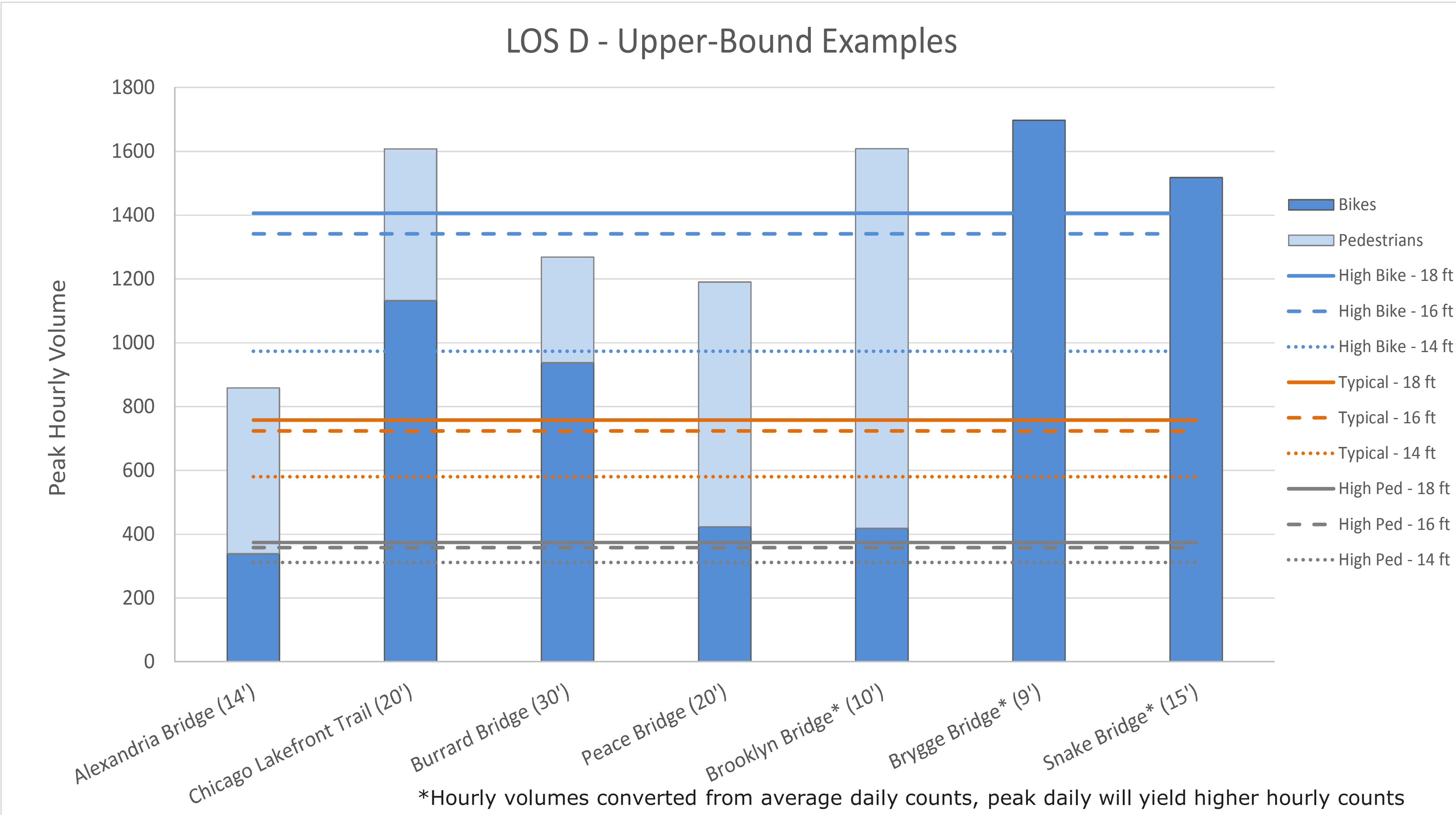
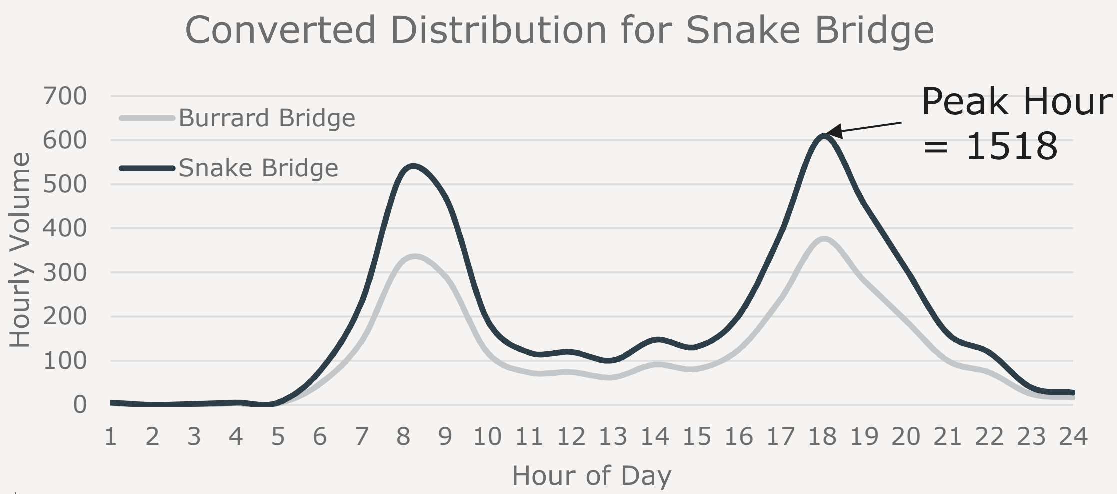

LOS D - Comparable Examples
Peak Hourly Volume
1600
1400
1200
1000
800
600
400
200
0
Burke Gilman Trail NE 70th (14')
Burke Gilman Trail UW (16')
Sammamish Trail (12')
Fremont Bridge (16')
Cambie Bridge (18')
Lions Gate Bridge (13')
Bikes
Pedestrians
High Bike (18')
High Bike (16')
High Bike (14')
Typical (18')
Typical (16')
Typical (14')
High Ped (18')
High Ped (16')
High Ped (14')


LOS D - Upper-Bound Examples
Peak Hourly Volume
1800
1600
1400
1200
1000
800
600
400
200
0
Alexandria Bridge (14')
Chicago Lakefront Trail (20')
Burrard Bridge (30')
Peace Bridge (20')
Brooklyn Bridge* (10')
Brygge Bridge* (9')
Snake Bridge* (15')
Bikes
Pedestrians
High Bike - 18 ft
High Bike - 16 ft
High Bike - 14 ft
Typical - 18 ft
Typical - 16 ft
Typical - 14 ft
High Ped - 18 ft
High Ped - 16 ft
High Ped - 14 ft
*Hourly volumes converted from average daily counts, peak daily will yield higher hourly counts

Conversion Example – Snake Bridge

- Average Daily Bicycle Count = 12,700
- Use Burrard Bridge Daily Distribution
- Ratio = 12,700/7848*934 = 1518 Peak Hourly Bikes



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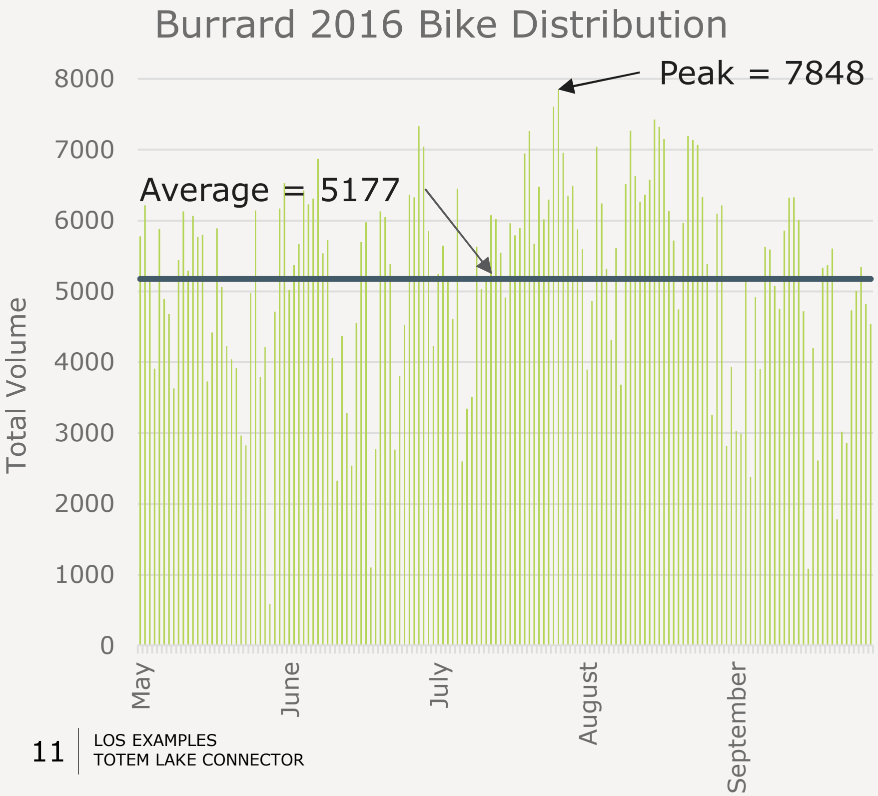
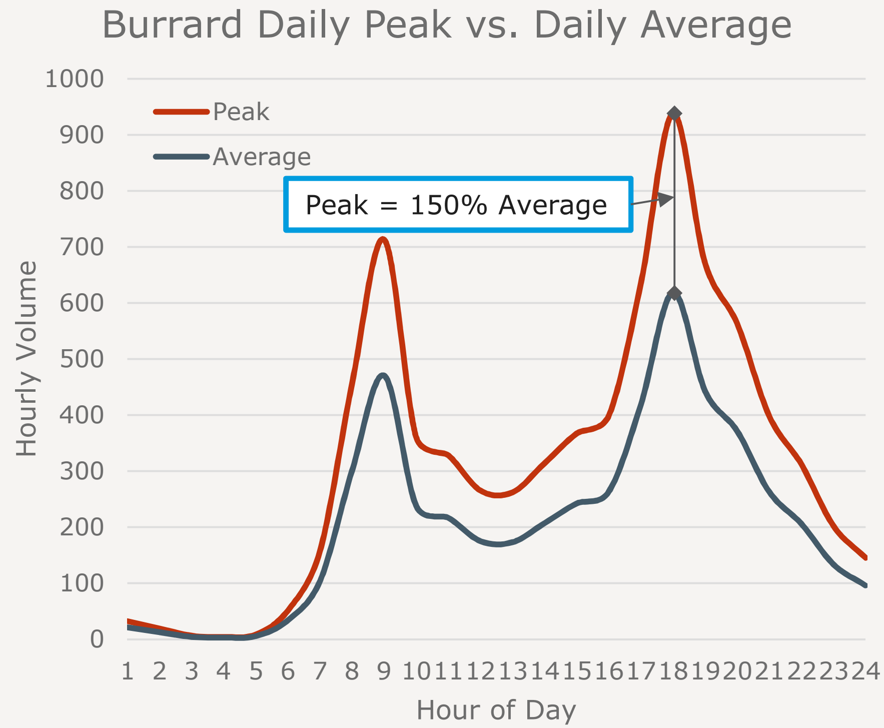
Average vs. Peak





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Bike and Ped Counts

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LOS Data/Bridge Examples

- **Burke Gilman Trail**
- Fremont Bridge
- Cambie Bridge
- Lions Gate Bridge
- Alexandria Bridge
- Burrard Bridge
- Peace Bridge

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Burke Gilman Trail

- Peak hour for Bikes: May 16, 2015 @ 10:00am
- 718 northbound bikes (of 790 total users)

data.seattle.gov Open Data Program TechTalk Blog Help Looking for Police reports? Sign In

Burke Gilman Trail north of NE 70th St Bike and Ped Counter

These sensors counts both people riding bikes and pedestrians. Separate volumes are tallied for each travel mode. Wires in a diamond formation

Manage | More Views | Filter | Visualize | Export | Discuss

	Date	BGT North of NE 70th Total	Ped South	Ped North	Bike North	Bike South
1	05/16/2015 10:00:00 AM	790	72	0	718	0
2	* 05/16/2015 11:00:00 AM	574	47	0	526	1
3	05/17/2014 11:00:00 AM	823	57	31	522	213
4	* 05/16/2015 12:00:00 PM	551	28	0	498	25
5	06/12/2016 10:00:00 AM	695	40	29	390	236
6	* 05/16/2015 09:00:00 AM	418	64	0	354	0
7	05/17/2014 10:00:00 AM	547	54	36	346	111
8	06/08/2014 12:00:00 PM	532	40	26	333	133
9	* 05/16/2015 01:00:00 PM	305	37	0	268	0
10	05/18/2015 04:00:00 PM	318	51	1	266	0
11	05/17/2015 01:00:00 PM	287	39	0	248	0
12	05/18/2015 05:00:00 PM	296	47	0	247	2
13	06/08/2014 01:00:00 PM	422	26	13	236	147
14	06/21/2014 12:00:00 PM	454	30	21	230	173

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LOS Data/Bridge Examples

- Burke Gilman Trail
- **Fremont Bridge**
- Cambie Bridge
- Lions Gate Bridge
- Alexandria Bridge
- Burrard Bridge
- Peace Bridge

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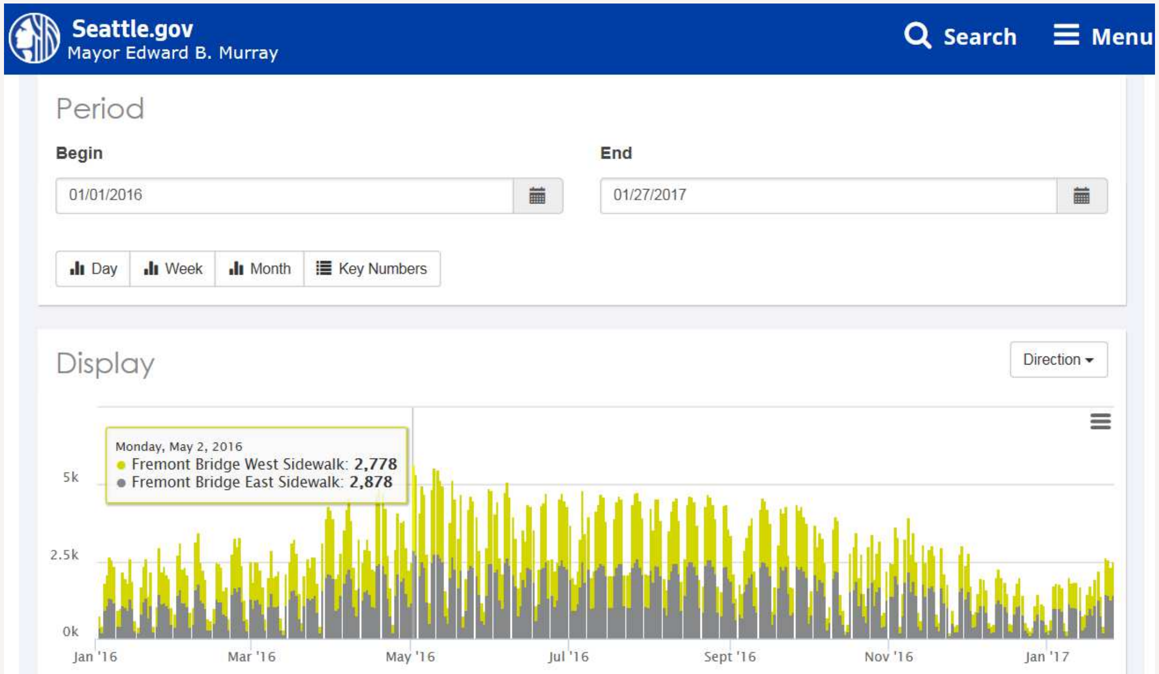
Fremont Bridge

› Daily Counts: 2,778+2,878 = 5,656 peak daily bikes



LOS Data/Bridge Examples

- Burke Gilman Trail
- Fremont Bridge
- **Cambie Bridge**
- Lions Gate Bridge
- Alexandria Bridge
- Burrard Bridge
- Peace Bridge

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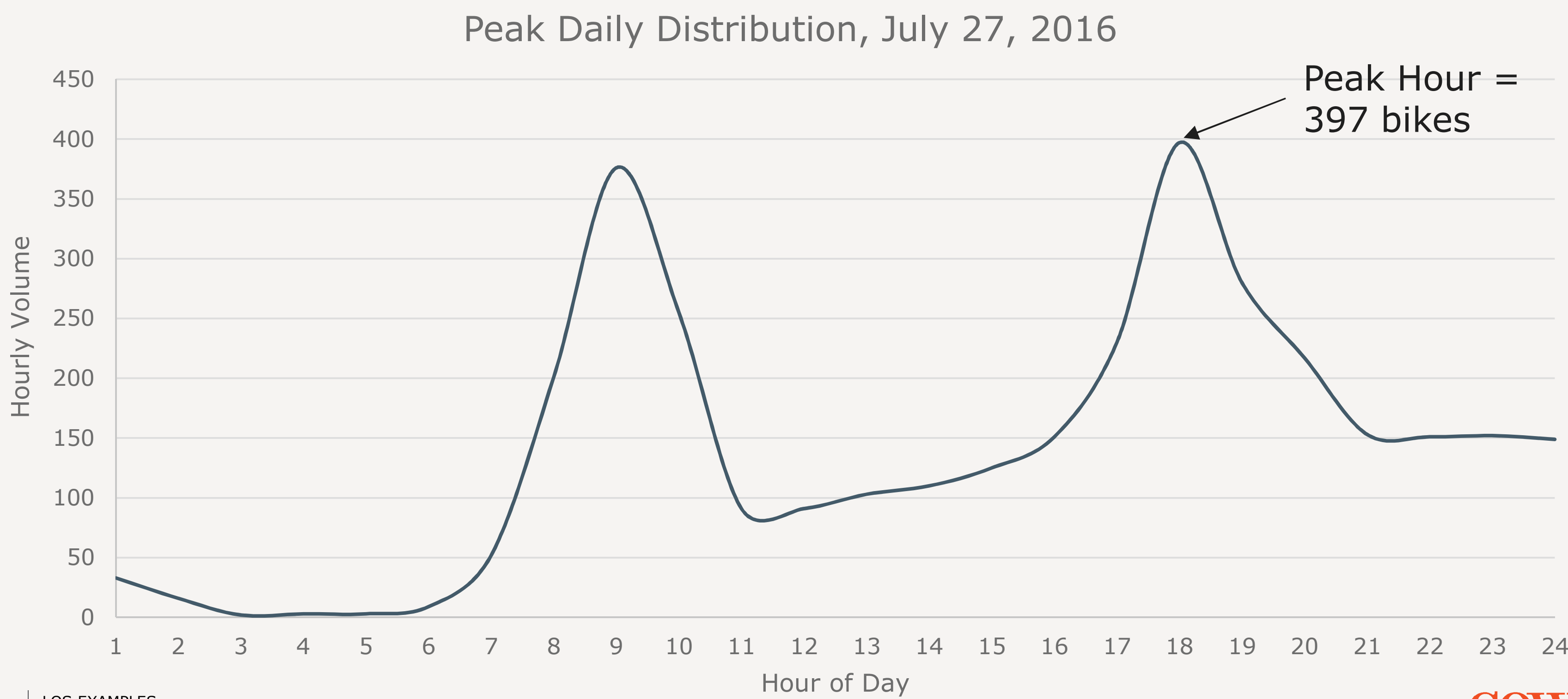
Cambie Bridge



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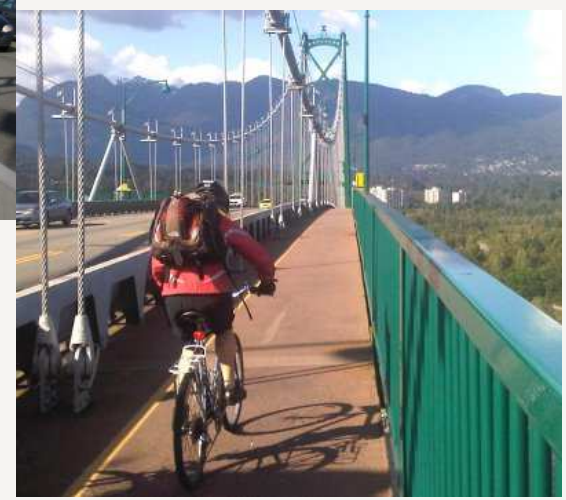
LOS Data/Bridge Examples

- Burke Gilman Trail
- Fremont Bridge
- Cambie Bridge
- **Lions Gate Bridge**
- Alexandria Bridge
- Burrard Bridge
- Peace Bridge



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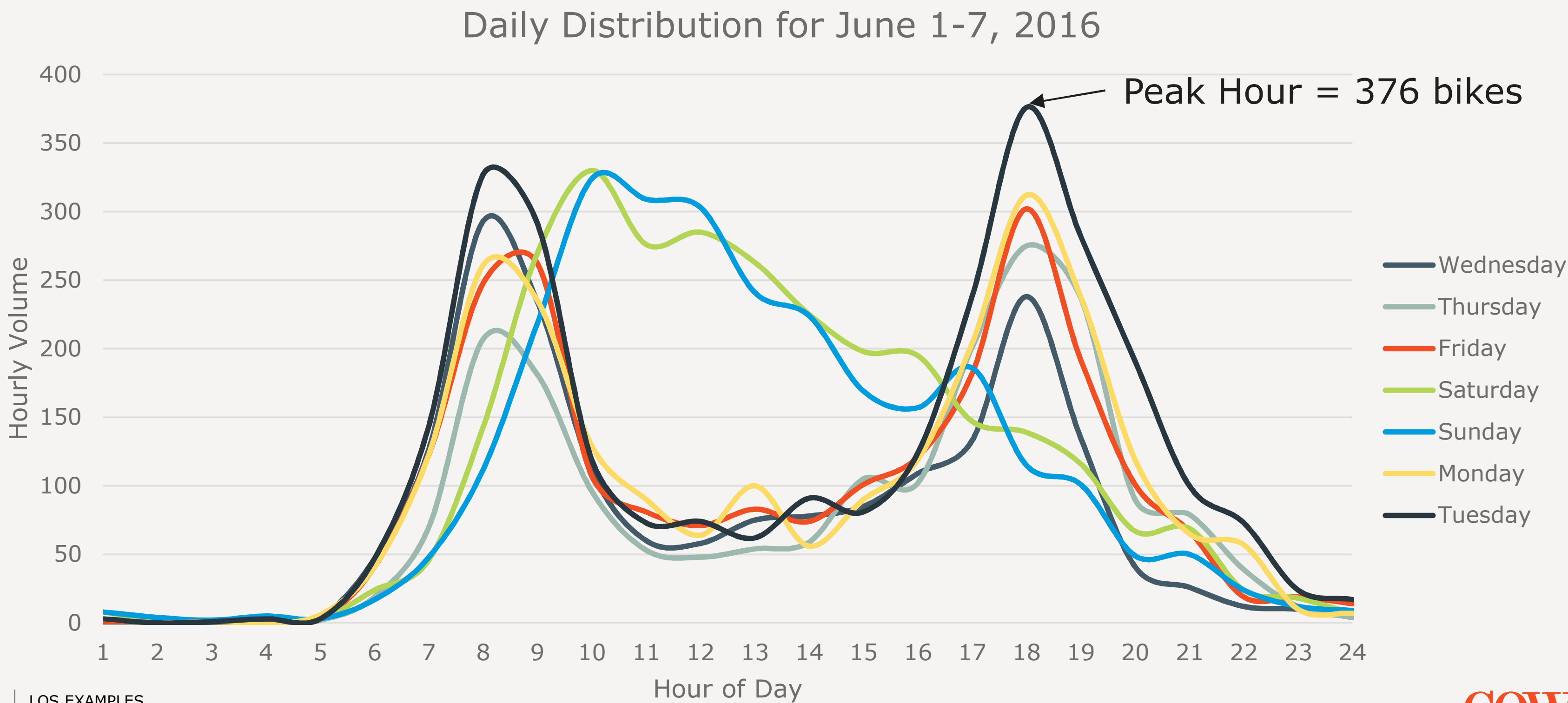
Lions Gate Bridge



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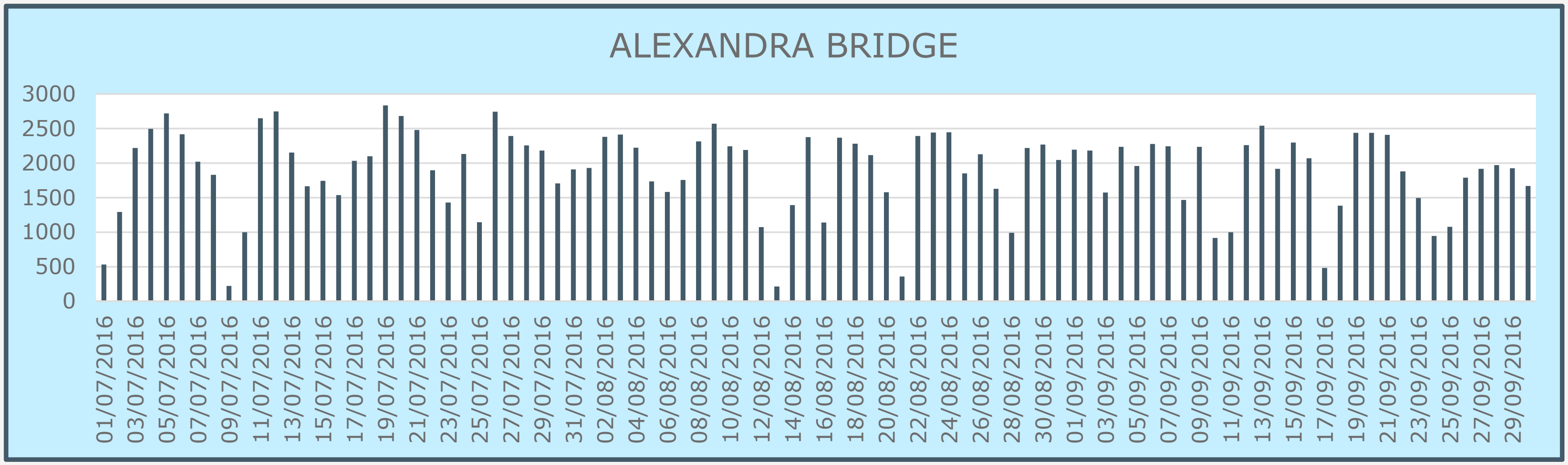
LOS Data/Bridge Examples

- Burke Gilman Trail
- Fremont Bridge
- Cambie Bridge
- Lions Gate Bridge
- **Alexandria Bridge**
- Burrard Bridge
- Peace Bridge

Alexandria Bridge

› 2000 pedestrians and 1300 cyclists, as of 2009 (per https://en.wikipedia.org/wiki/Alexandra_Bridge)

› Peak daily cyclists: 2,837 on July 19, 2016



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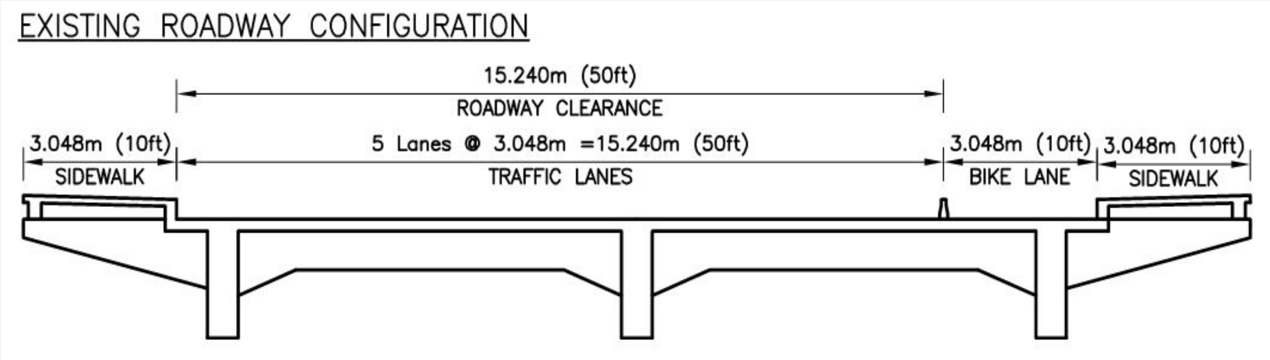
LOS Data/Bridge Examples

- Burke Gilman Trail
- Fremont Bridge
- Cambie Bridge
- Lions Gate Bridge
- Alexandria Bridge
- **Burrard Bridge**
- Peace Bridge



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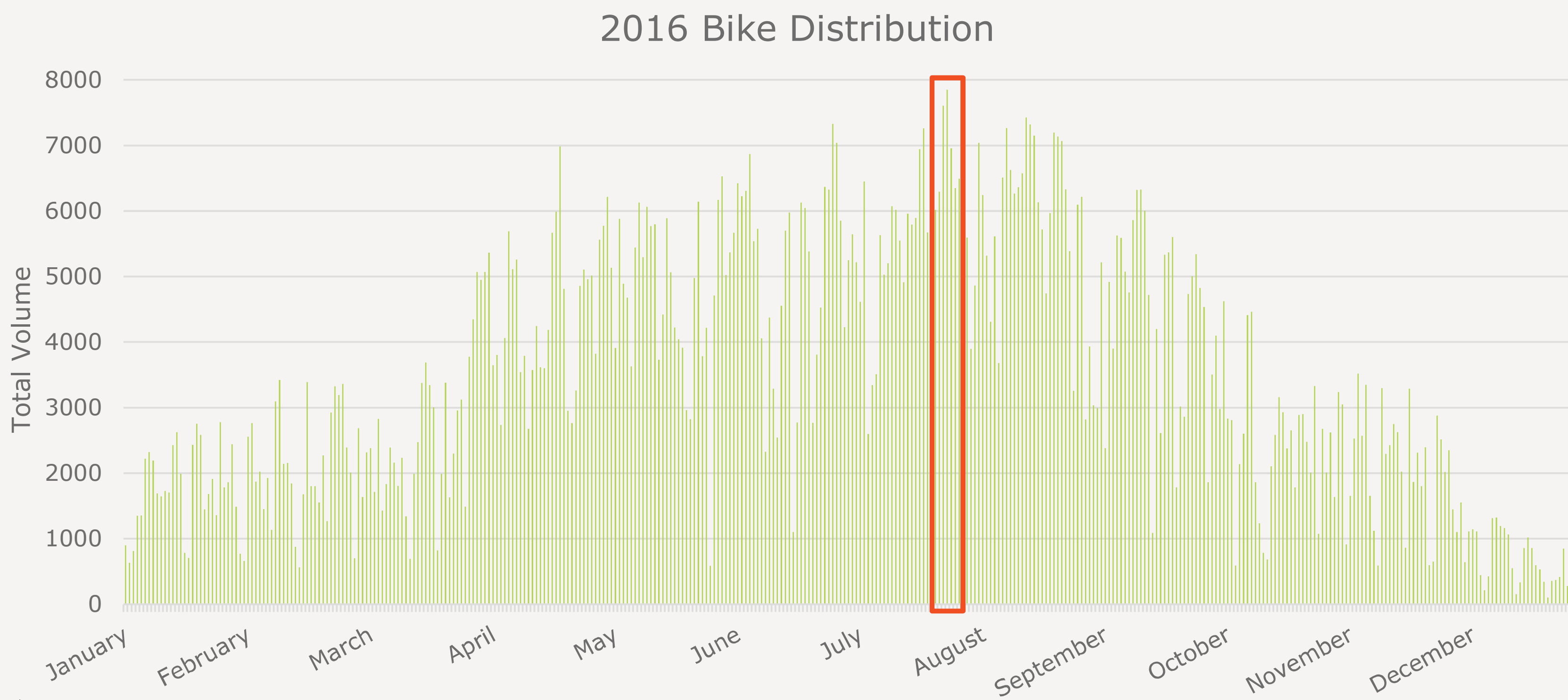
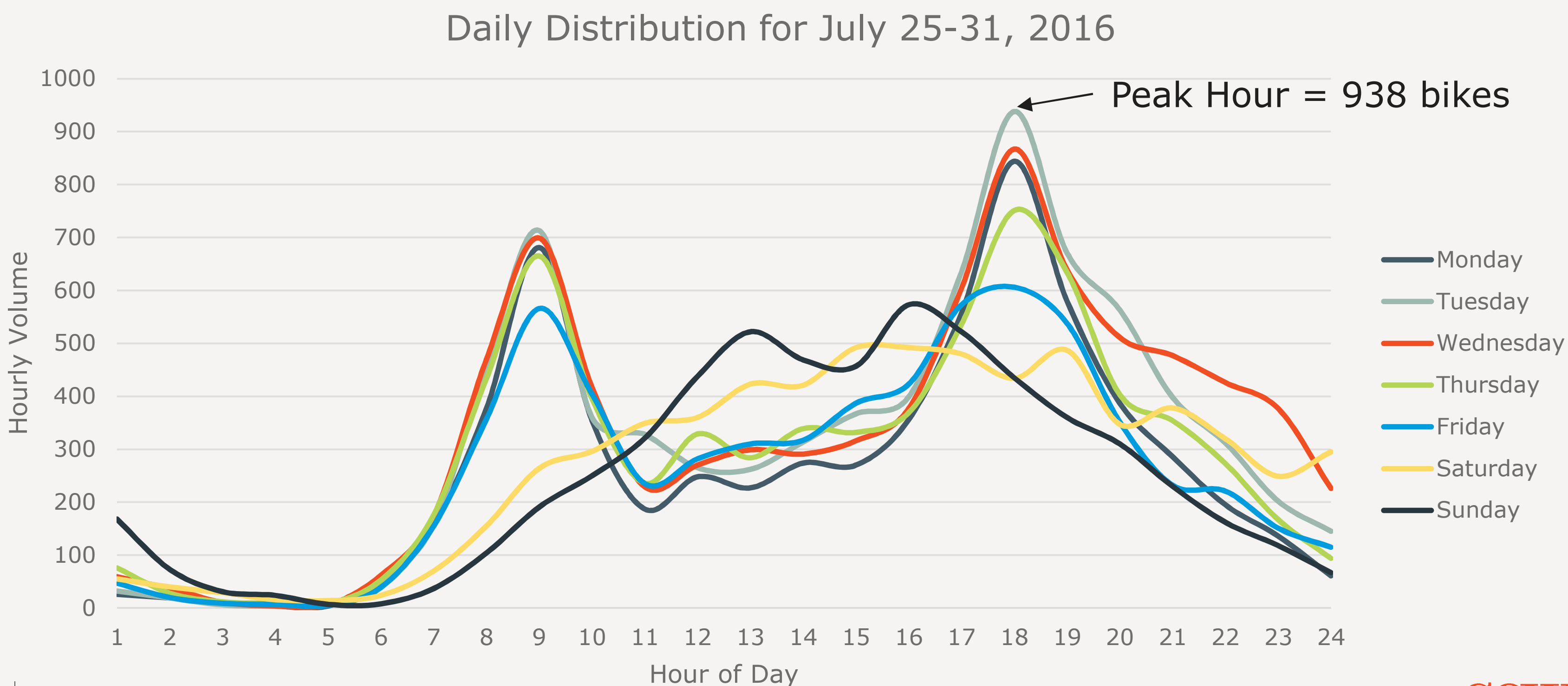
Burrard Bridge



Peak Daily = 7848, on 7/27/2016

Burrard Bridge



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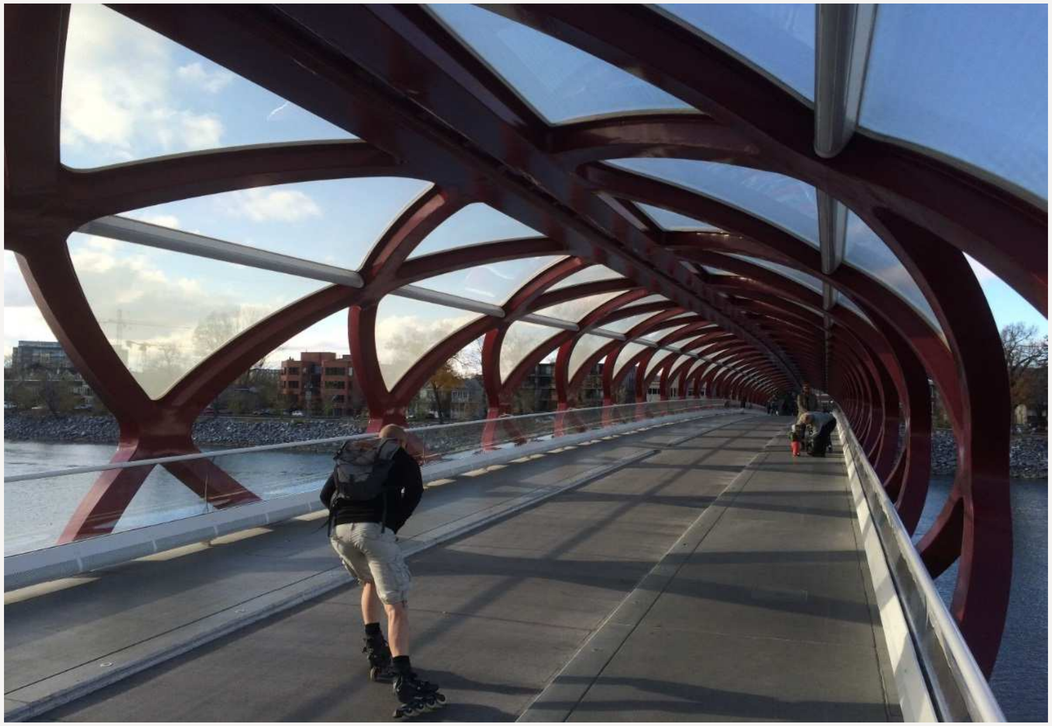
LOS Data/Bridge Examples

- Burke Gilman Trail
- Fremont Bridge
- Cambie Bridge
- Lions Gate Bridge
- Alexandria Bridge
- Burrard Bridge
- **Peace Bridge**



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Peace Bridge

Peace Bridge Cyclist Counts

From May 31, 2016 to September 30, 2016	Yesterday
278,813 Counts	**503** Counts

Period

Begin

05/01/2016

End

10/31/2016

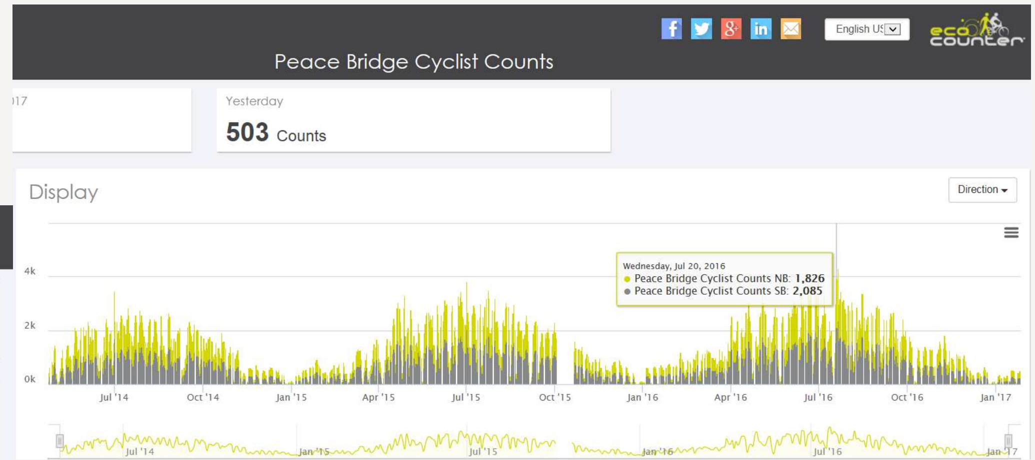
Day | Week | Month | Key Numbers

Average Traffic

Weekday	**2,196 Counts**
Weekly	**13,108 Counts**
Monthly	**52,433 Counts**

Maximum Traffic

Thursday 21 July 2016	**4,296 Counts**
Week of 18 Jul 2016	**24,795 Counts**
June 2016	**78,767 Counts**



memo

to **Schaun Valdovinos MS PE P. Eng, COWI**

from **Dave Rodgers PE LEED AP, Jennifer Lathrop RLA**

re **Totem Lake Pedestrian Bridge – Level of Service**

date **March 24, 2017**

Cross Kirkland Corridor (CKC) Trail

The Cross Kirkland Corridor is a major piece of the long term Puget Sound regional trail system vision. The gravel trail currently is used for recreation, commuting, safe routes to school, and accessing commercial areas. The trail, in its current configuration and gravel surfacing is well loved and utilized, but future volumes, especially in the Totem Lake Regional Growth area, cannot be predicted by applying a growth rate to current user volumes. For that reason, we are producing a table to allow a visual indication of trail width and user volumes with the tools available to assist in choosing a bridge width and configuration.

Comparison to Other Trails

Many of the early trails in the region were developed following American Association of State Highway and Transportation Officials (AASHTO) Guide for the Development of Bicycle Facilities. These guidelines indicated a 10 feet minimum width and as these trails have become more popular, the trails have been widened to 14 or 16 feet and even redeveloped to separate bicycle and pedestrians similar to the Burke Gilman Trail through the University of Washington. The CKC Master Plan has a discussion of the evolution of the trail width and options to accommodate growth in users by separating.

- The Burke Gilman Trail in the University of Washington in 2010 had a PM Peak hourly count of 644 (442 bikes/202 peds).
- The Sammamish River Trail at 60 Acres Park in 2006 had a peak hourly count of 418 (6.8% walkers and runners).

The peak hourly numbers we are using in the table to show a range are the low of 418 and a high of 644.

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Level of Service (LOS) - Highway Capacity Manual

With the increase in popularity of shared use paths, the need for a tool to analyze the effect of trail width, volume and user mix on the user experience was needed. The Federal Highway Administration (FHWA) developed a SUPLOS model to assist with this analysis. The model prioritizes the bicycle experience as a measure of experience quality and the results of the tool will improve the experience for all users. The tool is calibrated on an average trail width of 11 feet and may not be appropriate above 20 feet in width.

The six (6) LOS descriptions below are taken from the FHWA Evaluation of Safety, Design and Operation of Shared Use Paths Final Report, July 2006.

A: Trail has optimum conditions for individual bicyclists and retains ample space to absorb more users of all modes while providing a high-quality user experience. Some newly built trails will provide A-level service until they have "been discovered," or until their ridership builds up to projected levels.

B: Trail has good bicycling conditions and retains significant room to absorb more users while maintaining an ability to provide a high-quality user experience.

C: Trail has minimum width to meet current demand and to provide basic service to bicyclists. A modest level of additional capacity is available for bicyclists and skaters; however, more pedestrians, joggers, or other slow-moving users will begin to diminish the LOS for bicyclists.

D: Trail is nearing its functional capacity given its width, volume, and mode split. Peak-period travel speeds will probably be reduced by levels of crowding. The addition of more users of any mode will result in significant service degradation. Some bicyclists and skaters will probably be adjusting their experience expectations or avoiding peak period use.

E: Given trail width, volume, and user mix, the trail has reached its functional capacity. Peak-period travel speeds will probably be reduced by levels of crowding. The trail may enjoy strong community support because of its high usage rate; however, many bicyclists and skaters will probably be adjusting their experience expectations or avoiding peak-period use.

F: Trail is popular to the point of significantly diminishing the experience for at least one, and probably all, user groups. It does not effectively serve most bicyclists; significant user conflicts should be expected.

LOS Summary

LOS A: Hardly used

LOS B: Some users

LOS C: Well used with capacity for additional users

LOS D: Saturated

LOS E: Some users are finding alternative routes

LOS F: Slow going for cyclists

Bridge Width

When developing a bridge, expansion of the width in the future to accommodate an increase in users is expensive and prohibitive. For this reason we are studying the width of bridge against potential future trail volumes. Similar to roadways, designing a facility to a high Level of Service for peak future demand is not feasible or even desired. Therefore to evaluate trail capacity it is appropriate to target LOS D. During peak use times it is acceptable to have people move more slowly as they pass through a mixing zone or public space.

See chart below developed by running the LOS calculator for each scenario and then charting the results.

Assumptions

- Minimum width 10 feet
- Maximum width 20 feet (Maximum of LOS calculator)
- Assumed lower bound one-way volume 209 (418 total) per hour
- Assumed upper bound one-way volume 322 (644 total) per hour
- 10% Runners
- 1% Skater
- 5% Children on Bikes.
- Remaining 84% varied from 0% to 84% Pedestrians/Bike Mix

Totem Lake Pedestrian Bridge Project - 15094 - 3-02-2017
Trail LOS A-F - Shared Path Mix Options and Volumes
Assumed no centerline
Mix = Bicyclists%/Pedestrians%/Other% Other% = 10% runners, 1% skater, 5% child bikes
Reference: Federal Highway Administration Shared-Use Path Level of Service Calculator _July 2006
Note: The heavy vertical line delineates optimal calculations with the higher bike percentages.
Model is oriented to bicycle experience.

Total Volume	Bike/Ped 84%/0%	Bike/Ped 63%/21%	Bike/Ped 42%/42%	Bike/Ped 21%/63%	Bike/Ped 0%/84%	Path Width
Data BGT 322	A	C	E	E	F	20'
Data SRT 209	A	B	C	E	E	20'
Data BGT 322	A	C	E	F	F	18'
Data SRT 209	A	B	D	E	E	18'
Data BGT 322	A	C	E	F	F	16'
Data SRT 209	A	B	D	E	E	16'
Data BGT 322	B	D	E	F	F	14'
Data SRT 209	A	C	E	E	F	14'
Data BGT 322	B	E	F	F	F	12'
Data SRT 209	B	C	E	F	F	12'
Data BGT 322	C	F	F	F	F	10'
Data SRT 209	C	E	F	F	F	10'

LEGEND LOS

A	Hardly used	**BGT**	Burke Gilman Trail
B	Some users	**SRT**	Sammamish River Trail
C	Well used with capacity for additional users		
D	Saturated		
E	Some users are finding alternative routes		
F	Slow going for cyclists		

Results

Level of Service as measured by the FHWA LOS Calculator:

- LOS for bicyclist improves with increased width
- LOS for bicyclists decreases with increasing pedestrian use*
- With an incremental increase in pedestrians, there is a larger drop in LOS*

*This calculator is intended to be used for trail sections between intersections and is based solely on the experience of cyclists in a shared use condition giving no consideration to pedestrians.

Delineation: It is possible to use this table to indicate a separated use path condition for cyclists. The table indicates that you could have a very large number of cyclists in a 10 feet wide or wider facility to serve cyclist at a very high level in the near term or as part of a phased condition.

The phased condition would construct a shared use facility in the near term with lower number of users. As the Cross Kirkland Corridor is developed, as well as Totem Lake Park and the Totem Lake Urban Growth Area matures, the trail section can be delineated to divide travel direction or uses, as envisioned in the original CKC Master Plan.

At 16 feet deck width or larger, this delineation of user types could be implemented.

Case Study – University of Washington – Sound Transit Bridge

There are two overpass bridges connecting UW to the Sound Transit Station. The north bridge is 15 feet wide, curb to curb, and the south bridge is 13 feet wide. The bridges also act as a connection between the Lake Washington Loop and the Burke Gilman Trail. The two weekday peaks are around 8:00 AM and 4:00 to 6:00 PM depending on the day.

The pedestrian volumes are much higher than the bicycle volumes, which give us an example of what the FHWA SUPLOS calculator indicate as lower LOS for bikes. The bridges do not have a centerline and there are no markings such as “bikes yield to pedestrians”. Both bridges have a slight incline to the east and slope down to the west.

Observations during 6:00 PM weekday commute:

There is a mix of directions (Eastbound and Westbound) for both bicycles and pedestrians (runners and walkers). Several people had rolling luggage. Pedestrians did not follow “stay to the right” and were spread out across the bridges and groups of people (3 and 4 wide) were conversing comfortably while walking. Bicyclists approaching would assess the pedestrian speed and spacing and adjust their speed and direction accordingly. More skilled cyclists would stand up while navigating.

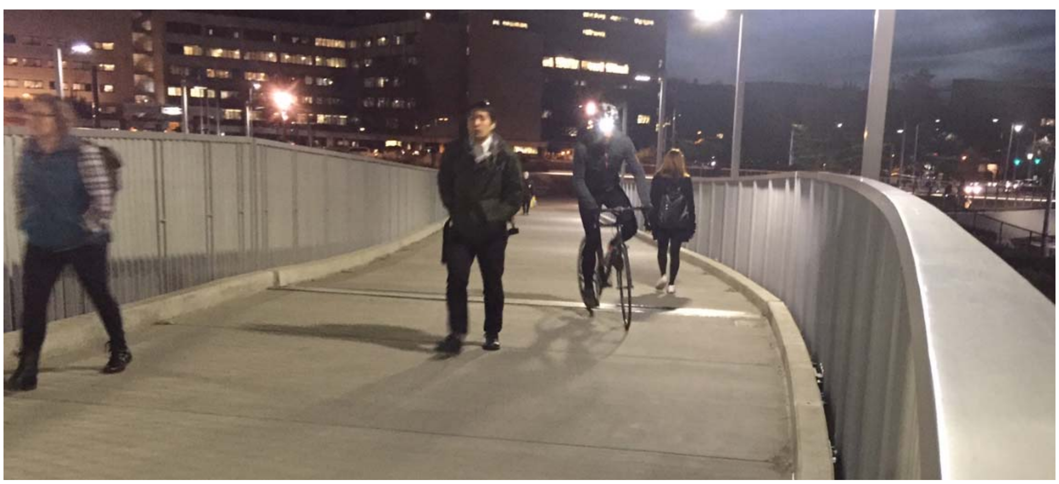
The FHWA would indicate this as a LOS E or F. If a cyclist wanted to pass through this area at peak use, they would either adjust their expectation, or change their schedule or route.

Observations indicate that people passed cautiously and predictably, just not at a free flow bicycle pace. At LOS E or F, the facility still functions well.

UW North Bridge AM Peak (2/1/17 - 8:00AM)
Total 617
Ped 585 (95%)
Bike 32 (5%)

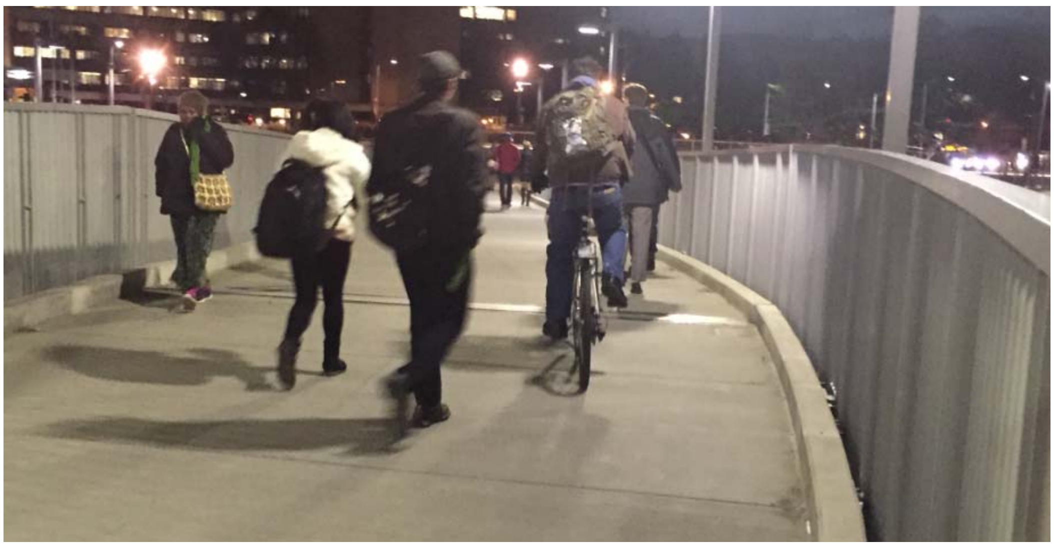
UW North Bridge PM Peak (2/1/17 - 6:00PM)
Total 610
Ped 585 (96%)
Bike 25 (4%)

UW North Bridge Daily Total (2/1/17 – 24 hours)
Total 6,196
Ped 5,784 (93.4%)
Bike 412 (6.6%)



6:00 PM North Bridge

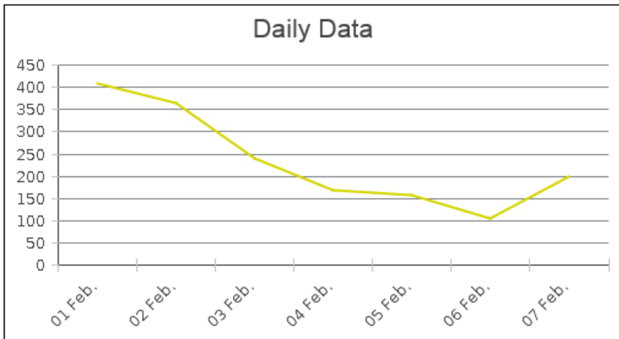

6:00 PM North Bridge

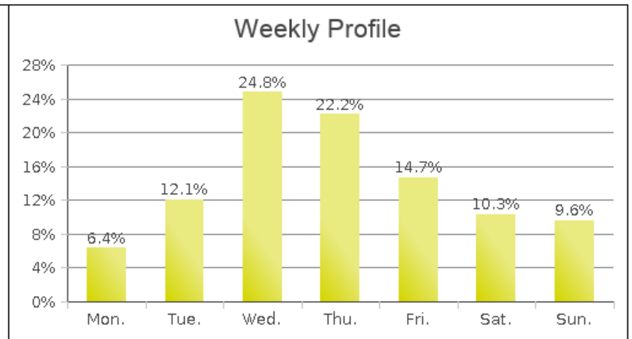

6:00 PM North Bridge

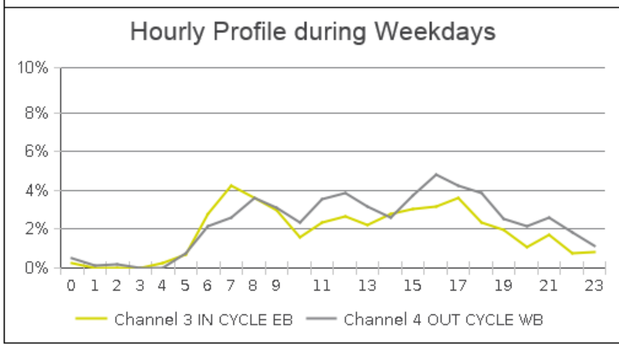
Washington State Department of Transportation

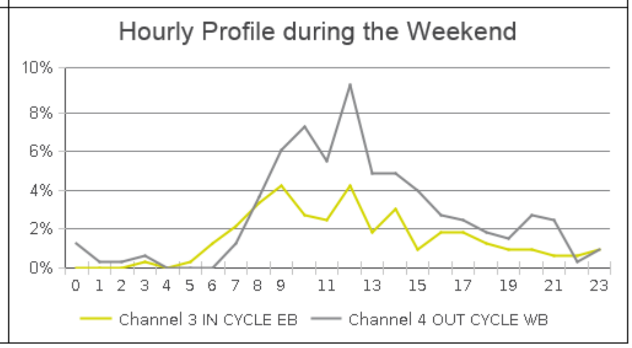
UW Transit Center North (Cyclists)

Period Analyzed: Wednesday, February 01, 2017 to Tuesday, February 07, 2017









COWI

MEMO

ADDRESS COWI North America
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TITLE	Totem Lake – Bridge Capacity per FIB 32
DATE	31 January 2017
TO	Aaron McDonald
CLIENT	City of Kirkland
FROM	Schaun Valdovinos
PROJECT NO	A088367

FIB 32 *Guidelines for the Design of Footbridges* provides useful guidelines for assessing the capacity of a pedestrian bridge.

Per the project *Basis of Design*, the Totem Lake Non-motorized Bridge is classified as Class III or Class II according to the SETRA *Technical Guide for Footbridges*. Looking at corresponding crowd density, a Class III bridge is considered to have 0.5 pedestrians/m² for dynamic response purposes. In calculating capacity, it would therefore be a reasonable starting point to use this same value for calculating capacity. Per SETRA:

> Footbridge class makes it possible to determine the level of traffic it can bear:
> Class IV: seldom used footbridge, built to link sparsely populated areas or to ensure continuity of the pedestrian footpath in motorway or express lane areas.
> Class III: footbridge for standard use, that may occasionally be crossed by large groups of people but that will never be loaded throughout its bearing area.
> Class II: urban footbridge linking up populated areas, subjected to heavy traffic and that may occasionally be loaded throughout its bearing area.
> Class I: urban footbridge linking up high pedestrian density areas (for instance, nearby presence of a rail or underground station) or that is frequently used by dense crowds (demonstrations, tourists, etc.), subjected to very heavy traffic.
>
> **Case 1: sparse and dense crowds**
>
> This case is only to be considered for category III (sparse crowd) and II (dense crowd) footbridges. The density *d* of the pedestrian crowd is to be considered according to the class of the footbridge:

Class	Density *d* of the crowd
III	0.5 pedestrians/m^2
II	0.8 pedestrians/m^2

FIB 32 also provides a density illustration. The density of 0.5 persons/m² looks like the average of the two boxed densities in the following figure:

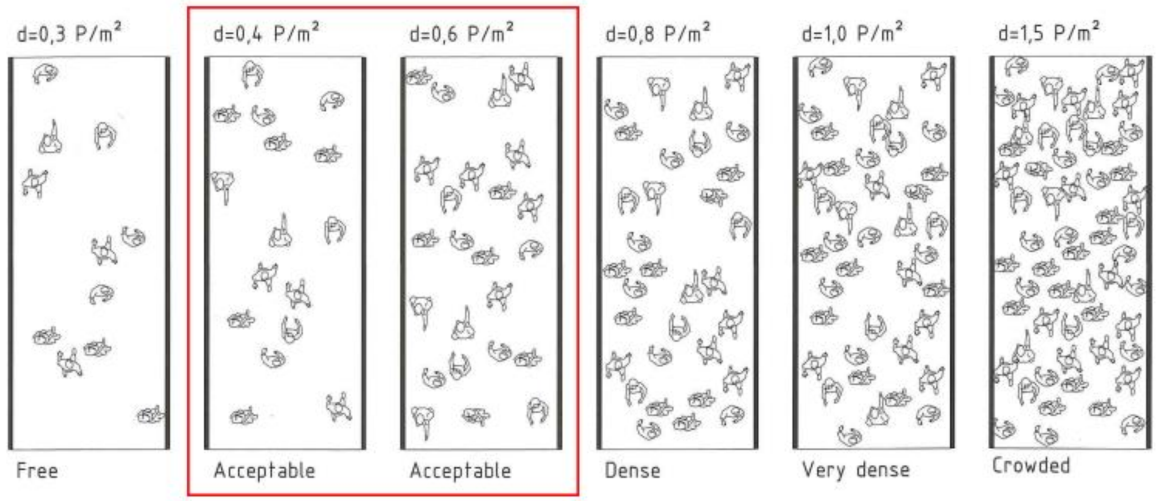

Figure 5.2 Different types of pedestrian densities [66]

The following is a remark on density from FIB 32:

> In general the walking velocity reduces with increasing traffic density. The single pedestrian has to adjust his walking velocity to the movement of the mass. First restrictions occur at a pedestrian density of 0.6 pers/m² as passing becomes more difficult. From a pedestrian density of 1.0 pers/m² the freedom of movement is greatly inhibited. The pedestrians must adjust their velocities and step frequencies to each other. If the density is about 1.5 pers/m², columns dependent on the direction of walking with a very low velocity develop. 2.0 pers/m² result in a very crowded stream where only a sliding movement with very small steps is possible. The pedestrian is not able to move on his own.

Therefore, with a density up to 0.6 persons/m², walking is not impeded. Per Table 5.3 in FIB 32, we will assess the bridge capacity using both:

- A normal walking pace of 1.5 m/s and
- A slow walking pace of 1.0 m/s.

	f_s	v_s	l_s
	[Hz]	[m/s]	[m]
slow walking	1.7	1.0	0.60
normal walking	2.0	1.5	0.75
fast walking	2.3	2.3	1.00
normal running	2.5	3.1	1.25
fast running	>3.2	5.5	1.75

Table 5.3 Typical values for step frequency, velocity and step length [37]

These walking rates are used in conjunction with FIB 32 Figure 3.1 to determine capacity. Consideration of the "turbulence" of crowd flow is described by four categories ranging from:

- "Shopping Traffic" represents a very turbulent flow where users stop suddenly and cross randomly from one side to the other, causing significant interruption to the flow.
- "Rush Hour" and "Factory Traffic" represents commuters who tend to have a more consistent rate of flow as they walk from one point to another.

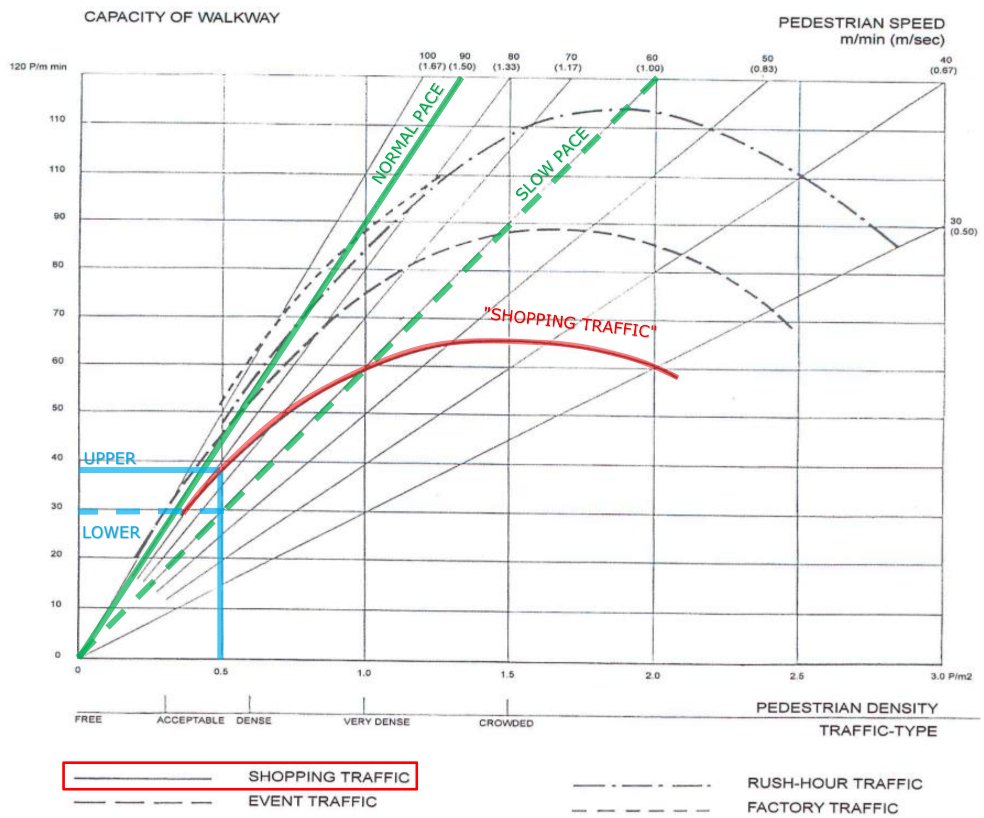

Fig. 3.1 Capacity of pedestrian walkway dependant on traffic type and pedestrian density, see [66]

The capacity is *conservatively* limited to the "Shopping Traffic" curve. This results in a range of lower to upper bound values of 30 to 38 persons per minute per meter width. Therefore, the capacity per hour is estimated as follows for widths ranging from 12-ft to 20-ft:

- 12-ft (3.65m):
  - Lower Bound = 6,570 persons/hr
    - *Calculation: 30 x 60 minutes/hr x 3.65m = 6,570 persons/hr*
  - Upper Bound = 8,322 persons/hr
- 14-ft (4.25m):
  - Lower Bound = 7,650 persons/hr
  - Upper Bound = 9,690 persons/hr

- 16-ft (4.9m):
  - Lower Bound = 8,820 persons/hr
  - Upper Bound = 11,172 persons/hr
- 18-ft (5.5m):
  - Lower Bound = 9,900 persons/hr
  - Upper Bound = 12,540 persons/hr
- 20-ft (6.1m):
  - Lower Bound = 10,980 persons/hr
  - Upper Bound = 13,908 persons/hr

It is noted that this method assumes pedestrian traffic only. It is apparent that a density of 0.5 persons/m^2 is too crowded to simultaneously accommodate bike traffic. Rather, these capacity values are associated with event traffic to understand an all-pedestrian capacity on the bridge. Any cyclists would need to "convert" into pedestrians by walking their bikes at these volume levels.

Therefore, to assess mixed-use capacities, a lighter density on the order of 0.1 persons/m^2 is selected as more representative of "typical use" conditions.

The following illustrations show how a density of 0.1 user/m^2 looks for a 14-ft wide deck over a 40-ft length (52m^2 with 6 users), with 67% pedestrian traffic and 33% bikes; and 33% pedestrian traffic and 67% bikes.

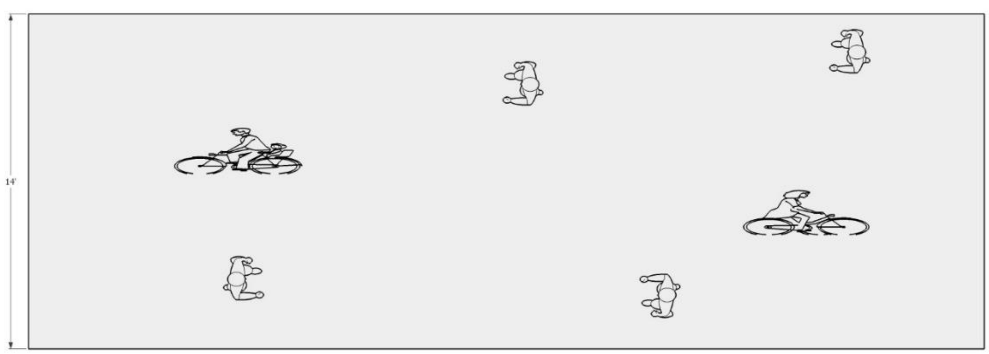

Figure showing 14-ft wide deck with 0.1 persons/m² with 67% pedestrian traffic

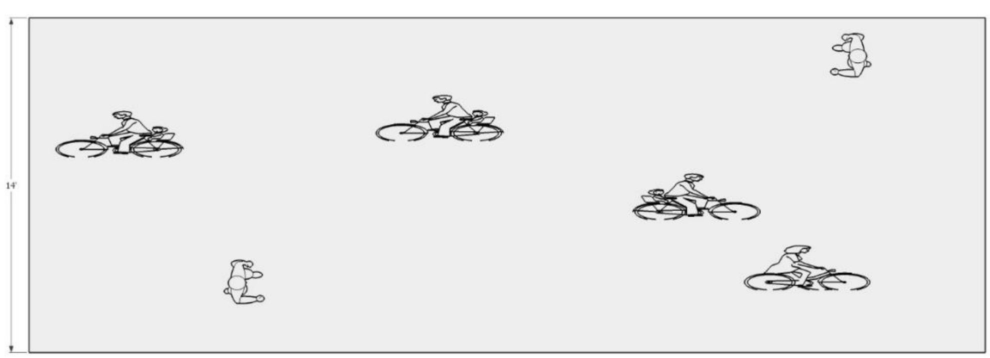

Figure showing 14-ft wide deck with 0.1 persons/m² with 67% bicycle traffic

This is repeated for a 16-ft width with a density of 0.1 user/m² (59.5m² with still 6 users). The two conditions are again assessed with 67% pedestrian traffic and 33% bikes; and 33% pedestrian traffic and 67% bikes.

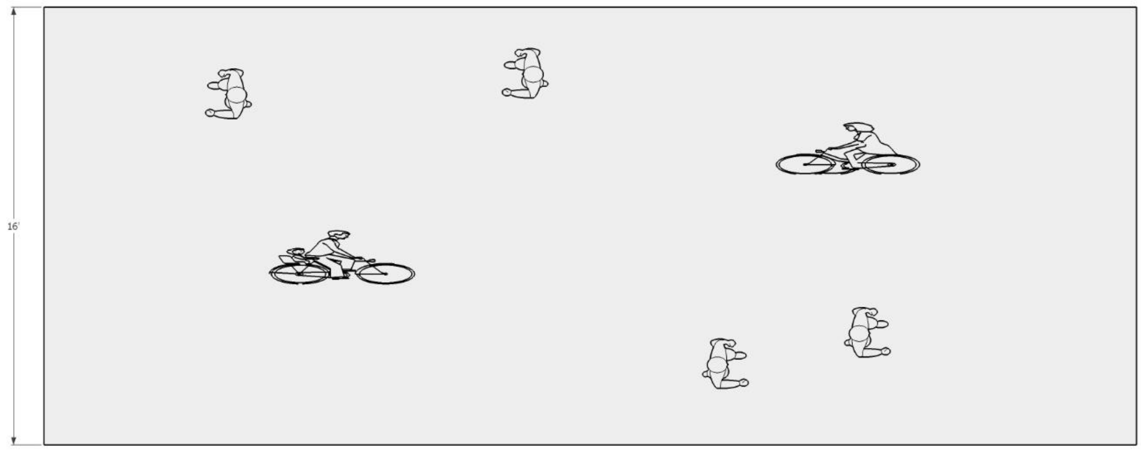

Figure showing 16-ft wide deck with 0.1 persons/m² with 67% pedestrian traffic

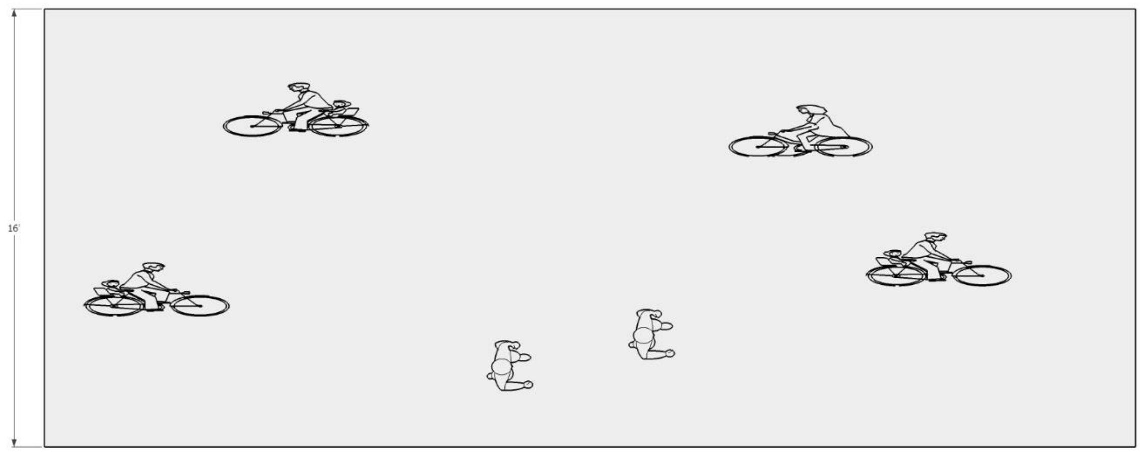

Figure showing 16-ft wide deck with 0.1 persons/m² with 67% bicycle traffic

With this density of 0.1 and the FIB Fig 3.1, we see the capacity is assessed as:

- 14-ft width with a light density of 0.1 persons/m²
    - Normal Pace = 2,040 persons/hr
        - *Calculation: 8 peds/min/m x 60 minutes/hr x 4.25m = 2,040 persons/hr*
- 16-ft width with a light density of 0.1 persons/m²
    - Normal Pace = 2,352 persons/hr

A conservative assumption in this calculation is the simplifying consideration that bicycles are traveling at the same speed as the pedestrians. This underestimates the total throughput, as bikes are more likely to be traveling at or above 10mph (4.5m/s).

A useful rule of thumb with respect to capacity of pedestrian bridges comes from the book *Footbridges: Construction Design History* by Ursula Baus and Mike Schlaich. It states:

> *Most pedestrian bridges are narrow, with decks between 3 and 4m. As a rule of thumb, 30 pedestrians per minute for every metre of deck width can cross the bridge without impeding one another. Even with the largest crowds, this figure rarely reaches 100 pedestrians per minute.*

Using the value of 30 peds/min/m width for a 14-ft (4.25m) wide deck results in a volume capacity of (30 pedestrians/min/m) x (4.25m) x (60 minutes) = 7,650 pedestrians/hr. This happens to corresponds exactly with the earlier calculated lower bound value of 7,650 persons/hr on page 3.

COWI

MEMO

TITLE	Totem Lake – Level of Service (LOS) per FHWA
DATE	31 January 2017
TO	Aaron McDonald
CLIENT	City of Kirkland
FROM	Schaun Valdovinos
PROJECT NO	A088367

FHWA has developed Level of Service calculations based on analogous highway design equations. This model prioritizes speed, so therefore penalizes higher pedestrian percentages using the bridge. This memo describes the bridge capacity based on the FHWA document *Shared-Use Path Level of Service Calculator, A User's Guide*, published in July 2006. This document provides background and instruction on the spreadsheet calculation tool called "SUPLOS", which can be used to calculate LOS for shared-use paths varying in width from 8-ft to 20-ft.

The tool is structured to address two-way, shared-use path facilities. It was not created with bicycle-only or one-way paths in mind; however, it may be applicable to paths of this nature.

Table 6 in the document provides explanation on the LOS ranges from category A to F as follows:

- **A: Excellent.** Trail has optimum conditions for individual bicyclists and retains ample space to absorb more users of all modes, while providing a high-quality user experience. Some newly built trails will provide grade-A service until they have been discovered or until their ridership builds up to projected levels.
- **B: Good.** Trail has good bicycling conditions, and retains significant room to absorb more users, while maintaining an ability to provide a high-quality user experience.
- **C: Fair.** Trail has at least minimum width to meet current demand and to provide basic service to bicyclists. A modest level of additional capacity is available for bicyclists and skaters; however more pedestrians, runners, or other slow-moving users will begin to diminish LOS for bicyclists.
- **D: Poor.** Trail is nearing its functional capacity given its width, volume, and mode split. Peak-period travel speeds are likely to be reduced by levels of crowding. The addition of more users of any mode will result in significant service degradation. Some bicyclists and skaters are likely to adjust their experience expectations or to avoid peak-period use.
- **E: Very Poor.** Given trail width, volume, and user mix, the trail has reached its functional capacity. Peak-period travel speeds are likely to be reduced by levels of crowding. The trail may enjoy strong community support because of its high usage rate; however, many bicyclists and skaters are likely to adjust their experience expectations, or to avoid peak-period use.

- **F: Failing.** Trail significantly diminishes the experience for at least one, and most likely for all user groups. It does not effectively serve most bicyclists; significant user conflicts should be expected.

Therefore, from the descriptions above, we can conclude that **LOS C & D would be the appropriate target level** to assess future capacity while maintaining adequate LOS.

- LOS A & B relate to trails that are sparsely used.
- LOS C appears to be the target for a well-used trail
- LOS D during peak hours the trail is crowded where cyclists will need to slow to navigate.
- LOS E & F are heavily used trails that become difficult to navigate on a bicycle.

Lookup tables are presented at the end of the SUPLOS Guide. These tabulate capacity for "typical" user distribution along with heavy cyclist and heavy pedestrian percentages. These are useful to quickly assess the capacity of various trail widths. It is noted that subtracting 1-ft shy distance from each side of a bridge deck is a conservative way to relate the values in the table for bridge deck widths.

Lookup tables 15 through 17 for the maximum volume associated with each LOS for various widths are reproduced below, with the three cases of "typical", "high bicycle" and "high pedestrian" mode splits. The volume numbers in the tables should be doubled to account for both travel directions per the assumption listed below the table.

Table 15. Shared-use path service volume look-up table, typical mode split.

		Deck Trail Width (feet)						
		10 8	12 10	14 12	16 14	18 16	20 18	22 20
Level of Service	A	24	24	24	24	70	102	125
	B	49	49	110	147	191	213	229
	C	49	97	198	226	282	300	315
	D	109	155	267	290	362	379	392
	E	167	212	328	349	436	452	464
	F	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table shows maximum trail volume (one direction per hour) in each LOS category

1 ft = 0.3 m

Table Assumptions
Mode split is 55% adult bicyclists, 20% pedestrians, 10% runners, 10% in-line skaters, and 5% child bicyclists.
An equal number of trail users travel in each direction (the model uses a 50%/50% directional split).
Trail volume represents the actual number of users counted in the field (the model adjusts this volume based on a peak hour factor of 0.85).
Trail has a centerline.

Table 16. Shared-use path service volume look-up table, high bicycle mode split.

		Deck Trail Width (feet)						
		10 8	12 10	14 12	16 14	18 16	20 18	22 20
Level of Service	A	40	40	40	40	123	182	224
	B	81	81	185	246	348	388	419
	C	81	162	330	376	519	554	581
	D	184	267	446	487	671	703	728
	E	289	373	551	590	812	842	866
	F	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table shows maximum trail volume (one direction per hour) in each LOS category

1 ft = 0.3 m

Table Assumptions
Mode split is 75% adult bicyclists, 7.5% pedestrians, 7.5% runners, 5% in-line skaters, and 5% child bicyclists.
An equal number of trail users travel in each direction (the model uses a 50%/50% directional split).
Trail volume represents the actual number of users counted in the field (the model adjusts this volume based on a peak hour factor of 0.85).
Trail has a centerline.

Table 17. Shared-use path service volume look-up table, high pedestrian mode split.

		Deck Trail Width (feet)						
		10 8	12 10	14 12	16 14	18 16	20 18	22 20
Level of Service	A	13	13	13	13	35	51	62
	B	26	26	57	77	95	105	114
	C	26	52	105	120	140	149	156
	D	58	82	143	156	179	187	194
	E	87	110	177	189	215	223	229
	F	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table shows maximum trail volume (one direction per hour) in each LOS category

1 ft = 0.3 m

Table Assumptions
Mode split is 25% adult bicyclists, 50% pedestrians, 15% runners, 7.5% in-line skaters, and 2.5% child bicyclists.
An equal number of trail users travel in each direction (the model uses a 50%/50% directional split).
Trail volume represents the actual number of users counted in the field (the model adjusts this volume based on a peak hour factor of 0.85).
Trail has a centerline.

Using the volumes from Lookup Tables 15 - 17, we are able to produce the graphics below that show peak hourly capacities for LOS C and LOS D. The peak capacities are shown at varying deck widths for high bike, typical and high pedestrian uses.