REVIEW DRAFT

I-5 Columbia River Crossing Partnership:
Traffic and Tolling Analysis

Identification and Evaluation Of Toll Models

Working Paper 3.1

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TOLL MODEL OVERVIEW

For the I-5 Columbia River Crossing Partnership: Traffic and Tolling Analysis, Vollmer intends to use a tolling analysis methodology that has been proven effective in previous tolling alternatives projects conducted across the country. Toll studies are often undertaken at three phases of activity:

Phase I is a preliminary "back of the envelope" review of the potential for traffic to be attracted by a new project such as a toll facility and the likely range of revenues that could be achieved at a variety of toll rates. Typically this is based upon field reviews of the area in question and available reports.

Phase II is a more refined approach to traffic and revenue estimation, more often than not using traffic assignment models developed by a local Council of Government (COG) or Metropolitan Planning Organization (MPO) to enhance the initial estimates. This more detailed analysis still relies heavily on existing sources of data and future forecasts. This phase of work generally consists of several elements:

- Review of the traffic model procedures and methodologies of the local traffic assignment model. We have worked with dozens of metropolitan models throughout the country; access to the models vary considerably as does the ability to derive output useful for the purposes of the study;
- Review of the traffic model output with particular emphasis upon the market share capture in the potential corridor of interest;
- Development of select link procedures to determine the key user characteristics in the corridor. Often there is a need to supplement the select link procedures with field counts to provide an enhanced information base (for example, few traffic assignment models deal with forecasting commercial vehicle activity in any detail);
- Development of a toll structure and toll rates appropriate for the project;
- Development of toll elasticity and optimal revenue curves to be used in forecasting future revenue.

Phase III studies are often referred to as "Investment Grade" traffic and revenue studies since they are developed in sufficient detail to be used as the basis for the financing of the project. In general, most Investment Grade Traffic and Revenue studies in metropolitan areas use the local COG or MPO land use and traffic assignment models as the basis for the work. It is sometimes necessary to partially or totally rebuild and re-calibrate the models to focus upon a specific corridor in a region, and to reflect toll diversion algorithms applied to the toll facility.

The scale of effort among the three phases of work is typically an order of magnitude apart; that is if the Phase 1 study is a 100-hour effort, the Phase II study is a 1000-hour effort, and the Phase III study is a 10,000-hour effort.

Based upon the approved work plan and the above information, the I-5 Columbia Traffic and Tolling Analysis fits into the category of a Phase 2 level of effort. Our early investigations find it likely that the existing regional model will provide reasonably appropriate results within the existing time frame.

The existing and future EMME/2 model runs that were previously generated for the I-5 Trade Corridor Partnership will be used as the basis for the tolled traffic projections. For this phase/level of tolling analysis, we are going to assume that the land use projections and forecast network improvements will remain as modeled. These toll free volumes will then be analyzed to determine the level of toll diversion that would occur under various tolling scenarios and toll collection alternatives. This data is then factored to an annual number and a traffic and revenue stream is forecast based on the underlying growth assumptions in the region.

Toll Diversion Models Available

Numerous techniques have been used over the past 50 years to estimate the amount of traffic that might be expected under various tolling scenarios:

- *Cost Per Minute Saved*. The classic approach developed in the 1930s, this method uses a curve that calculates, for given zone-to-zone movement, the amount of traffic that would use a toll facility for each cent per minute saved. The method works particularly well in determining the Optimum Toll Rate Curve for a given facility.

- *Time Ratio*. First used extensively in the 1950s, this method employs a curve indicating the percent diversion to a toll facility for a given zone-to-zone movement for a calculated Time Ratio for that movement, where the Time Ratio is the time to make a given trip on the new facility versus the time to make the trip on the existing facility.

- *Cost Penalty for Tolls in a Network Model*. In this case, the use of a given facility has a cost penalty imposed on given zone-to-zone trips to simulate the use of toll facilities in a free highway network in a computer model.

Most current traffic and revenue studies that are used for financing purposes use a toll diversion equation incorporated into a traffic assignment model in an area. The equations are based upon existing toll usage in an area, new Stated Preference surveys undertaken for the project, toll diversions from other metro areas of comparable socio-economic characteristics, or combinations of these techniques.

Toll Diversion Methodology

It is suggested that this project estimate tolled traffic and revenue by applying spreadsheet-based analyses to both existing and future EMME/2 model output. The existing (2000) and future (2020) EMME/2 model runs will be factored from the peak period to represent 24-hour volumes by using several 24-hour permanent ATR traffic count locations. As part of the traffic expansion process, it will also be necessary to expand weekday traffic into weekly and then annual traffic.

The following sets of tables represent an example of how the toll diversion methodology is applied. The example comes from a project where there is an existing toll-free road in the corridor, which will be kept as a toll-free alternative to tolled express lanes operating in the median of the corridor.

Traffic model outputs. In the following table, the outputs from the MPO's traffic model are shown for a toll-free set of roadways; as indicated in the table, the model years available were 2001 (existing) 2009, 2011 and 2015.

Table A. MPO Traffic Output

Operating Year	Calendar Year	Total Non-tolled Vehicles			
		Toll Free Road	Express Lanes	Total	Express Lane Capture Rate
	2000				
	2001	**36,800**		**36,800**	**0%**
	2002				
	2003				
	2004				
	2005				
	2006				
	2007				
0	2008				
1	**2009**	**24,300**	**66,100**	**90,400**	**73%**
2	2010				
3	**2011**	**25,600**	**70,600**	**96,200**	**73%**
4					
5					
6					
7	**2015**	**30,000**	**86,100**	**116,100**	**74%**

Note that as the express lanes open in 2009, they are expected to capture approximately 73% of the corridor traffic.

Deriving annual traffic estimates. Information from the MPO's land use inputs as well as expected network link openings is used to estimate the interim yearly changes in traffic on both the express and toll-free roads, as provided in Table B. In this example, growth in land use in the corridor drives significant traffic growth in the corridor prior to the opening of a new toll facility. The opening of the new toll free express lanes in the corridor is the cause of the drop in traffic for the parallel toll free route.

Table B. Non-tolled Vehicles

Operating Year	Calendar Year		Total Non-tolled Vehicles					
			Toll Free Road	Growth	Express Lanes	Growth	Total	Growth
	2000							
	2001	**A**	**36,800**		0		**36,800**	
	2002		43,500	18.2%	0		43,500	18.2%
	2003		50,200	15.4%	0		50,200	15.4%
	2004		56,900	13.3%	0		56,900	13.3%
	2005		63,600	11.8%	0		63,600	11.8%
	2006		70,300	10.5%	0		70,300	10.5%
	2007		77,000	9.5%	0		77,000	9.5%
0	2008		83,700	8.7%	0		83,700	8.7%
1	**2009**	**B,C**	**24,300**	-71.0%	**66,100**		**90,400**	**8.0%**
2	2010		24,950	2.7%	68,350	3.4%	93,300	3.2%
3	**2011**	**C**	**25,600**	2.6%	**70,600**	3.3%	**96,200**	**3.1%**
4	2012	**C**	26,700	4.3%	74,475	5.5%	101,175	5.2%
5	2013		27,800	4.1%	78,350	5.2%	106,150	4.9%
6	2014		28,900	4.0%	82,225	4.9%	111,125	4.7%
7	**2015**	**C**	**30,000**	3.8%	**86,100**	4.7%	**116,100**	**4.5%**

(A) Actual traffic.
(B) Project tolled highway opens.
(C) Traffic model run year.

Retention of traffic with tolls. The likely toll retention is applied to the mainline traffic to determine the traffic that would be willing to pay the toll at the rate specified. Using information from other similar projects, we assumed in this example that the opening retention would be 35% of the toll free express lanes volume in 2009, increasing to a maximum of 60% of the toll free express lanes volume, twenty years after opening (later years not shown), as presented in Table C. The example indicates that the toll-free volume of 66,100 in Table B is multiplied by 0.35 to achieve 23,135 vehicles in 2009 in Table C. Deriving this toll retention is the most critical element in this analysis. As part of performing numerous Investment Grade studies over the years, we have run traffic models for tolled and toll-free networks, comparing their results to provide the basis for our judgements. Traffic moved away from the tolled facility is moved back to the parallel toll free route.

Table C. Total Tolled Vehicles

Operating Year	Calendar Year		Total Tolled Vehicles					Express Lanes Retainage
			Toll Free Road	Growth	Express Lanes	Total	Growth	
	2000		0		0	0		
	2001	**A**	**36,800**	**0.0%**	**0**	**36,800**		
	2002		43,500	18.2%	0	43,500	18.2%	
	2003		50,200	15.4%	0	50,200	15.4%	
	2004		56,900	13.3%	0	56,900	13.3%	
	2005		63,600	11.8%	0	63,600	11.8%	
	2006		70,300	10.5%	0	70,300	10.5%	
	2007		77,000	9.5%	0	77,000	9.5%	
0	2008		83,700	8.7%	0	83,700	8.7%	
1	**2009**	**B,C**	**67,265**	**-19.6%**	**23,135**	**90,400**	**8.0%**	**35%**
2	2010		68,856	2.4%	24,629	93,300	3.2%	
3	**2011**	**B,C**	**70,274**	**2.1%**	**26,122**	**96,200**	**3.1%**	**37%**
4	2012		73,010	3.9%	28,378	101,175	5.2%	
5	2013		75,746	3.7%	30,634	106,150	4.9%	
6	2014		78,482	3.6%	32,890	111,125	4.7%	40%
7	**2015**	**C**	**80,825**	**3.0%**	**35,542**	**116,100**	**4.5%**	

(A) Actual traffic.
(B) Project tolled highway opens.
(C) Traffic model run year.
* Numbers also include elasticity for annual toll increases

Electronic Toll Collection. The project we were reviewing assumed that all vehicles would be tolled using all electronic tolling; therefore we applied another factor to the mainline volumes to account for the number of drivers who would have access to transponders and be willing to establish accounts, as shown in Table D.

Table D. Total Tolled Vehicles with ETC Assumptions

Operating Year	Calendar Year		Total Tolled Vehicles with ETC Assumptions						ETC Retainage
			Toll Free Road	Growth	Express Lanes	Growth	Total	Growth	
	2000		0		0		0		
	2001	**A**	**36,800**		**0**		**36,800**		
	2002		43,500	18.2%	0		43,500	18.2%	
	2003		50,200	15.4%	0		50,200	15.4%	
	2004		56,900	13.3%	0		56,900	13.3%	
	2005		63,600	11.8%	0		63,600	11.8%	
	2006		70,300	10.5%	0		70,300	10.5%	
	2007		77,000	9.5%	0		77,000	9.5%	
0	2008		83,700	8.7%	0		83,700	8.7%	
1	**2009**	**B,C**	**81,146**	**-3.1%**	**9,254**		**90,400**	**8.0%**	**40%**
2	2010		83,278	2.6%	10,022	8.3%	93,300	3.2%	41%
3	**2011**	**B,C**	**85,311**	**2.4%**	**10,889**	**8.7%**	**96,200**	**3.1%**	**42%**
4	2012		89,064	4.4%	12,111	11.2%	101,175	5.2%	43%
5	2013		92,772	4.2%	13,378	10.5%	106,150	4.9%	44%
6	2014		96,436	3.9%	14,689	9.8%	111,125	4.7%	45%
7	**2015**	**C**	**99,521**	**3.2%**	**16,579**	**12.9%**	**116,100**	**4.5%**	**47%**

(A) Actual traffic.
(B) Project tolled highway opens.
(C) Traffic model run year.

As shown, this ETC retention reduces the potential traffic to 40% of potential toll-payers in the opening years to more than 70% twenty years later (not shown). The traffic willing to pay a toll on the mainline in Table C (23,135 vehicles) is multiplied by 0.40 in Table D to derive 9,254 vehicles willing to pay a toll and who will secure a transponder and account necessary to use this all ETC roadway.

Traffic ramp-up. A ramp-up factor is applied in the early years as patrons become accustomed to the new facility as a toll road. For example, it often takes two or three years for the mapping in a region to reflect the opening of a new facility onto area maps (Rental car maps, Hagstroms, etc.). Most new roads take 2 to 4 years to "ramp-up" to the level assumed by the traffic model, while existing facilities changing to tolls would shift much more quickly. Table E is an example of the ramp up adjustment.

Table E. Total Tolled Vehicles with Ramp-up

Operating Year	Calendar Year		Total Tolled Vehicles with Ramp-up						Ramp-up
			Toll Free Road	Growth	Express Lanes	Growth	Total	Growth	
	2000		0		0		0		
	2001	**A**	**36,800**		**0**		**36,800**		
	2002		43,500	18.2%	0		43,500	18.2%	
	2003		50,200	15.4%	0		50,200	15.4%	
	2004		56,900	13.3%	0		56,900	13.3%	
	2005		63,600	11.8%	0		63,600	11.8%	
	2006		70,300	10.5%	0		70,300	10.5%	
	2007		77,000	9.5%	0		77,000	9.5%	
0	2008		83,700	8.7%	0		83,700	8.7%	
1	**2009**	**B,C**	**84,848**	**1.4%**	**5,552**		**90,400**	**8.0%**	**60%**
2	2010		85,784	1.1%	7,516	35.4%	93,300	3.2%	75%
3	**2011**	**B,C**	**86,944**	**1.4%**	**9,256**	**23.1%**	**96,200**	**3.1%**	**85%**
4	2012		89,670	3.1%	11,505	24.3%	101,175	5.2%	95%
5	2013		92,772	3.5%	13,378	16.3%	106,150	4.9%	100%
6	2014		96,436	3.9%	14,689	9.8%	111,125	4.7%	100%
7	**2015**	**C**	**99,521**	**3.2%**	**16,579**	**12.9%**	**116,100**	**4.5%**	**100%**

(A) Actual traffic.
(B) Project tolled highway opens.
(C) Traffic model run year.

In this example, the 9,254 vehicles in Table D are multiplied by 0.60 to reflect the reduction in expected usage to project ramp-up, producing 5,552 vehicles in 2009, as shown in Table E.

Capacity of Alternative routes. It is important to check to see if the alternate routes have the capacity to accommodate the diversion shifted from the tolled road to them; an example of this calculation is shown in Table F:

Table F. Total Tolled Vehicles with Toll Free Road Capacity

Operating Year	Calendar Year		Total Express Lanes with Toll Free Road Capacity: Toll Free Road	Growth	Express Lanes	Growth	Total	Growth	Initially, Traffic Moving out	Of 'outofcorr' Traffic Moving to EL	Percent Traffic Moving to EL
	2000		0		0		0		0		
	2001	**A**	**36,800**		**0**		**36,800**		**0**		
	2002		43,500	18.2%	0		43,500	18.2%	0		
	2003		50,200	15.4%	0		50,200	15.4%	0		
	2004		56,900	13.3%	0		56,900	13.3%	0		
	2005		63,600	11.8%	0		63,600	11.8%	0		
	2006		70,300	10.5%	0		70,300	10.5%	0		
	2007		72,000	2.4%	0		72,000	2.4%	5,000		
0	2008		72,000	0.0%	0		72,000	0.0%	11,700		
1	**2009**	**B,C**	**72,000**	**0.0%**	**5,552**		**77,552**	**7.7%**	**12,848**	**1,285**	**10%**
2	2010		72,000	0.0%	7,516	35.4%	79,516	2.5%	13,784	1,516	11%
3	**2011**	**B,C**	**72,000**	**0.0%**	**9,256**	**23.1%**	**81,256**	**2.2%**	**14,944**	**1,793**	**12%**
4	2012		72,000	0.0%	11,505	24.3%	83,505	2.8%	17,670	2,297	13%
5	2013		72,000	0.0%	13,378	16.3%	85,378	2.2%	20,772	2,908	14%
6	2014		72,000	0.0%	14,689	9.8%	86,689	1.5%	24,436	3,665	15%
7	**2015**	**C**	**72,000**	**0.0%**	**16,579**	**12.9%**	**88,579**	**2.2%**	**27,521**	**4,128**	**15%**

(A) Actual traffic.
(B) Project tolled highway opens.
(C) Traffic model run year.

Should the parallel be filled to capacity, traffic would be shifted back to the toll corridor, and other traffic would be moved out of the corridor entirely, as appropriate. For example, in the year 2015 27,251 vehicles will not be able to use the toll free road due to capacity constraints. An estimated 15% of these vehicles (4,128) will then decide to use the express lanes. Table G on the following page shows the resulting express lane volumes at 20,708.

Estimating toll revenues. Finally, the remaining tolled traffic is multiplied by the toll rate to provide daily revenues. Usually the number of days per year operating at weekday levels is calculated to determine the number of equivalent weekdays. In the example below, it is assumed that there are 289 equivalent weekdays per year, or that weekends have about half the level of weekdays. Further, the relative truck percentage is also a factor as well as the tolls for trucks to calculate the annual revenue.

Table G. Estimated Toll Revenues

Estimated Toll Revenues
(average annual weekday two-way traffic)

Project Miles	3.0
Days per year	289
Weighted Truck Toll	2.75
Truck percentage	5%
Annual Inflation	3%

Operating Year	Calendar Year		Express Lanes	Growth	Per-mile Toll Rate	Toll Charge	Revenues	Growth
	2000							
	2001	**A**			**$0.110**			
	2002				$0.113			
	2003				$0.117			
	2004				$0.120			
	2005				$0.124			
	2006				$0.128			
	2007				$0.131			
0	2008				$0.135			
1	**2009**	**B,C**	**6,837**		**$0.139**	**$0.42**	**$898,286**	
2	2010		7,516	9.9%	$0.144	$0.43	$1,017,161	13.2%
3	**2011**	**B,C**	**9,405**	**25.1%**	**$0.148**	**$0.44**	**$1,310,915**	**28.9%**
4	2012		11,859	26.1%	$0.152	$0.46	$1,702,525	29.9%
5	2013		14,001	18.1%	$0.157	$0.47	$2,070,369	21.6%
6	2014		15,667	11.9%	$0.162	$0.48	$2,386,209	15.3%
7	**2015**	**C**	**17,680**	**12.9%**	**$0.166**	**$0.50**	**$2,773,647**	**16.2%**

(A) Actual traffic.
(B) Project tolled highway opens, 2009; direct connects in 2011.
(C) Traffic model run year.
*Numbers also include elasticity for annual toll increases

This example also allows the opportunity to determine the effect of raising tolls over time and drivers' elasticity response to increasing tolls versus the underlying inflation rate.

Refinements to the Methodology

Additional area-wide traffic information provided in the EMME/2 output will be verified and expanded to represent weekly and annual conditions. During this process, we will verify that the peak periods retain the same conditions as they were modeled in the I-5 Trade Corridor Partnership work effort.

Once the 24-hour traffic volumes for the two Columbia River crossings are established, the EMME/2 model trip tables will be used to identify the origin and destination pairs at each of the river crossings. This is a key step in the process, since "through trips" will behave differently than local trips when tolls are applied. Although this working paper is not intended to address the various tolling alternatives that are available for the crossings, it is also important to have existing and forecast traffic information about commercial vehicle volumes and High Occupancy Vehicle (HOV) volumes throughout the day. This way, the tolling diversion model can be developed from the outset in order to address a wide range of tolling alternatives.

When the volumes for select vehicle type volumes are determined, we will apply toll diversion curves to volumes based on a predetermined tolling schedule. This will allow the determination of the resulting tolled traffic volumes. Since the EMME/2 model output focuses on weekday peak periods, the annual traffic and revenue amounts will be based on average weekday equivalents, in which weekend traffic volumes are equated to a fraction of a weekday volume, as discussed above.

Vollmer will use previous experience in tolling analyses to estimate the toll diversion rates of the various origin and destination pairs. If travel times are available, they will be used in establishing the relative amount of traffic retained as a tolled facility. Land use information as well as trip purpose data are important in applying these toll diversion rates. When tolls are applied, a driver could choose to change modes, carpool, consolidate trips, eliminate the trip, or make the trip and pay the toll. Many factors, such as income levels, trip purpose, trip frequency and trip length are important in determining whether or not a passenger will pay a toll.

Retention varies by time savings, trip purpose (commuter, business, recreational and social) and vehicle type (passenger car, bus, and truck). Buses are usually the least affected by tolling, as they are more easily able to pass on the toll to their customers or due to policy. Trucks react very differently to tolls, because they are not as flexible, have fewer options of travel routes and travel times, and can not always pass along the toll to their customers. For passenger cars, the vehicle type most affected by tolls, the reason why usage will decrease include:

- Shrinkage – a trip no longer being made
- Trip consolidation – car pooling will increase, drivers currently making multiple trips will combine into fewer trips with several stops during one trip;
- Change in travel mode – a trip that will use transit to avoid paying the toll. The cost of the alternate mode is part of the driver's decision to change or not. (we assume buses are a viable alternative to/from Washington)

The greatest losses may come from trip consolidation. For example, Washington residents who frequently make an extra shopping trip across the I-5 or I-205 Columbia River Bridges may combine this trip with a commuting trip. In addition, the additional toll cost may encourage them to do the shopping trip on the Washington side of the river and forego the potential sales tax savings.

In an investment grade study, equations are often developed for more than one trip purpose, since driver behavior is different by trip purpose. In this study, there is not sufficient information to prepare this type of analysis, so these reduction rates will be based on previous experience with similar regions.

Vollmer rarely has the opportunity to undertake both the spreadsheet-based models and traffic assignment models on the same project with the same set of input data (most projects select one method or the other based upon schedule and budget criteria). We recently had the opportunity in Austin, Texas to compare results of a Phase 2 study (no traffic assignment modeling, just traffic volumes, and market share analyses) to a comparable effort where toll diversion equations were incorporated into the regional model and run for a single year. The results were found to be within 10% overall, as shown in the following table:

Table H. Tolling Analysis Comparison

Tolling Analysis Comparison	**2015**	**2015**	**2015**
Location	**Non Tolled Model Output**	**Tolled Model Run**	**Vollmer Tolling Spreadsheet Methodology**
Ramp 10	11,150	4,122	2,770
Ramp 10	11,220	4,526	2,787
Mainline 4B	34,505	12,769	11,690
Mainline 4B	32,249	12,317	10,925
Mainline 4A	35,054	13,118	12,287
Mainline 4A	34,516	14,757	12,098
Ramp 7	22,935	8,118	7,070
Ramp 7	22,461	8,277	6,924
Ramp 6	2,027	800	644
Ramp 6	3,527	919	1,120
Ramp 5	8,116	2,832	2,508
Mainline 2	28,267	9,182	9,981
Mainline 2	35,990	12,473	12,708
Ramp 4	1,194	549	362
Ramp 3	6,534	2,271	1,873
Ramp 3	7,271	2,561	2,084
Ramp 2	3,322	1,820	1,359
Ramp 2	2,781	1,774	1,138
Ramp 1	11,717	4,049	3,360
Ramp 1	10,524	3,519	3,018
Mainline 1	32,353	11,205	11,156
Mainline 1	33,559	12,064	11,572
Total Free / Tolled Traffic	391,272	144,023	129,433
VA Estimate compared with Tolled Model Run - %			-10.1%
Tolled ETC Retention		**36.8%**	**33.1%**

As shown in the table, for this project, most of the comparable links were within a few percentage points of one another (compare the last two columns). We assume this level of correlation is usually close, and expect had we undertaken a broader set of similar projects, the correlation would be within a band of 30 to 40%.

Recommendations

Based upon the efficiency and relative accuracy of Vollmer's spreadsheet model approach, and recognizing the level of detail approach for a Phase II study, it is recommended that this project use the spreadsheet approach outlined above in conjunction with METRO's EMME/2 regional traffic model results. The reasons for this recommendation include:

- The spreadsheet based model meets the requirement for a Phase Two Analysis
- The model requires only a modest amount of information to derive useful outputs
- The model is very efficient in being able to be set and provide useful information quickly, thus meeting the fairly tight schedule on this project
- Prior work has shown the accuracy of results is more than adequate for a Phase Two study and become a pivot point for more detailed studies