British Columbia, Ministry of Transportation, Partnerships Division

Investment Grade Traffic & Revenue Study for the Coquihalla Highway Transportation Concession Project

Final Report

August 2003

Halcrow Group Limited
& IBI Group

Halcrow Group Limited
Vineyard House 44 Brook Green London W6 7BY
Tel +44 (0)20 7602 7282 Fax +44 (0)20 7603 0095
www.halcrow.com

Contents

1 Introduction

1.1 *History of the Highway*

The Coquihalla Highway was built in three phases during the 1980s to link the Lower Mainland with Kamloops and the Okanagan Valley. The final phase, from Merritt to Peachland, opened in 1990. Phase 1, from Hope to Merritt, is the only tolled highway in the Province. There are alternative toll free routes available to the travelling public. Phases 2 (Merritt to Kamloops) and Phase 3 (Merritt to Kelowna) are untolled.

The tolls were established in 1985 under the Coquihalla Highway Construction Acceleration Act.

Tolls have been in place since Phase 1 opened in 1986. The tolls were enacted to advance construction of the first phase of the highway so that it would be opened in time for Expo '86. The total construction costs for all three phases were $999 million. To the end of September 2001, $488 million had been collected in toll revenues, which had not paid off the interest on the $375 million borrowed to finance the accelerated construction.

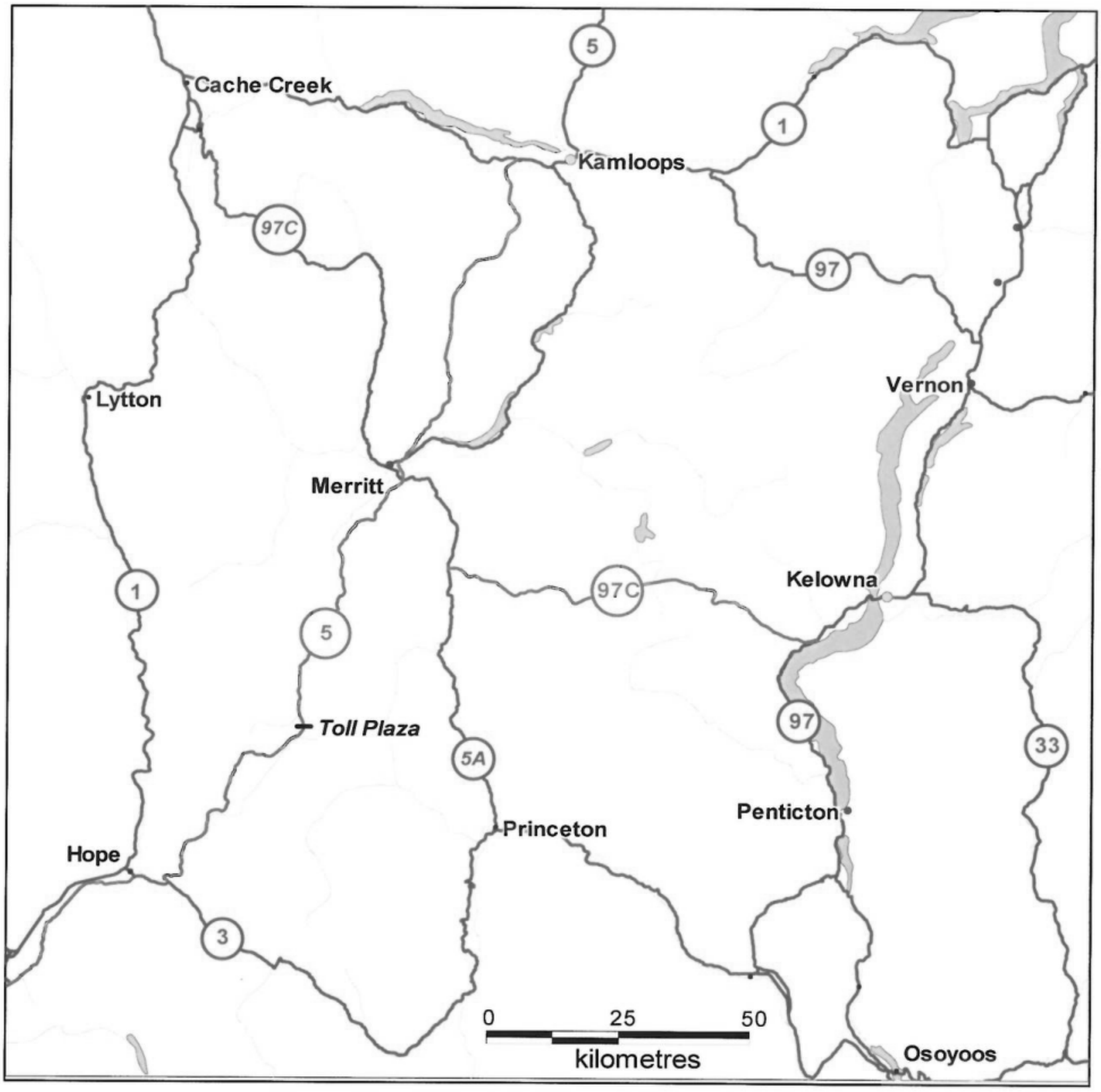
The Province has directed the Ministry of Finance and the Ministry of Transportation to undertake the next steps to effect a Coquihalla Highway public-private partnership Concession.

1.2 *Strategic Context*

As the only tolled Highway in the Province, the Coquihalla is already a business although it is not currently packaged as such in a private sector sense. It has a demonstrated revenue stream from the tolls initiated in 1986 in order to advance construction of the first phase of the highway to complete it in time for Expo '86. This revenue stream generates $25 million annually, net of the $15 million required for operations and overheads. Highway maintenance has been privatised throughout the Province, including for the Coquihalla. This helps make the Coquihalla attractive to the private sector which can apply its flexibility, financing and innovation to the Coquihalla's topographical and climactic challenges and fund the significant future expenditures required to maintain the Coquihalla as a safe and reliable highway.

The Study area showing the Coquihalla Highway as well as other highways within the corridor is shown below in Figure 1.1.

Figure 1.1 Study Area



Unlike Europe, Australia, New Zealand and the United States, Canada has few long-term concessions with the private sector to operate highways. A public private partnership for the Coquihalla should be seen by prospective bidders as an excellent opportunity to break into the Canadian market, and would position them well in the anticipation of future opportunities in British Columbia and Canada.

To maximize the return to the Province through offering the Coquihalla to a Concession operator, it is anticipated that some increase in the level of tolls charged will be required.

1.3 Deal Structure

Based on preliminary business case and financial model analysis, it is anticipated that the proposed deal structure will consist of the following elements:

- An up-front payment in exchange for a long-term Concession, in the order of 55 years, to operate the Coquihalla.
- The Province would continue to own the Crown land underlying the Coquihalla and all rights of way, would set highway standards and access rights, and retain corridor development rights.
- The Province would avoid future debt and transfer the maintenance and capital expenditure risks to the Concessionaire. The Concessionaire would have the right to collect and raise tolls, as may be determined by government.
- The improved Coquihalla would return to the Province at the end of the term.

1.4 Investment Grade Traffic & Revenue Study

The British Columbia Ministry of Transportation issued a "Request for Proposals" for the investment grade traffic and revenue study in May 2002. Halcrow Group, in association with IBI Group, were awarded the contract in June 2002 for study commencement in July 2002. The study objectives are as follows:

1. to provide an independent, investment grade assessment of potential traffic and revenue growth,

2. to provide reliable information on which to base the public sector comparator/value benchmark against which bids will be measured, and

3. to meet anticipated timelines for completing a deal should the requisite approvals be forthcoming from Treasury Board and Cabinet.

1.5 Report Structure

Following this introduction, Chapter 2 presents an analysis of the existing situation. This section describes the current network and traffic patterns in the study area and includes the results of surveys undertaken in 1999 and 2002. Chapter 3 describes the development and results of the diversion model and includes the results of the stated preference exercise undertaken in the summer of 2002. Chapter 4 outlines the traffic forecasting methodology adopted for this study, and Chapter 5 presents the traffic and revenue forecasts for the Base Case and three key alternative scenarios. Chapter 6 covers tolling systems and technology issues, whilst Chapter 7 discusses alternative tolling strategies from a revenue point of view. Finally Chapter 8 presents the results of the sensitivity tests carried out around key forecasting parameters and provides details of the alternative tolling strategy scenarios tested.

2 Analysis of the Existing Situation

2.1 *Network Description*

2.1.1 *Coquihalla Highway*

There are three distinct sections to the project road. These are illustrated, together with other major highways in the study area, in Figure 1.1. The Southern arm of the Coquihalla starts 3km to the east of Hope at the Othello Junction. From here, Highway 3 continues its eastward journey towards Princeton and Osoyoos, whilst the Coquihalla heads off in a northeasterly direction following the Coquihalla River. The highway climbs steadily until at km 44.3, the summit of this section is reached - at a height of 1244m. The sole tollbooth on the Coquihalla Highway is situated a further 6km along the route at km 52.5. The highway then begins its long descent into the Nicola Valley, following the Coldwater River.

The next major junction is reached at km 110.4. The Coldwater Interchange, just outside the town of Merritt, is the centre-point of the Coquihalla System. From here the main highway route continues its Northern route towards Kamloops, whilst those drivers wishing to reach the Okanagan Valley or Merritt turn-off to join Highway 97C/5A. Situated less than 1km north of the Coldwater Interchange is the Nicola interchange. Here is the turn-off for the 5A, an alternative route to Kamloops via Lake Nicola, and also the access to Merritt from the North. The highway initially follows the valley floor, before rising steadily to the summit of the northern section at km 144 – at a height of 1444m. There is another junction at km 161.8 to access Logan Lake and Lac de Jeune. The Coquihalla then descends slowly into the Thompson Valley, terminating at an Intersection with Highway 1, the Trans-Canada Highway, at Afton, some 6km West of Kamloops.

2.1.2 *Okanagan Connector*

From the Coldwater Interchange, the 97C/5A rises steeply in an easterly direction before swinging southwards towards Aspen Grove. This section of highway was in existence before the Coquihalla and has been upgraded to (largely) 3/4-lane single carriageway, although some short sections of 2-lane highway are still present. At Aspen Grove, km24.0, the 5A continues south towards Princeton, whilst this point marks the western terminus of the Connector. From here, the Connector heads almost due east towards the Okanagan Valley. The Highways climbs almost continuously for around 26km before reaching an undulating plateau area. This continues for around a further 37km passing the Pennask Summit (1744m) along the way. The final 23km of the Connector is a long and sometimes steep decline to the Okanagan Valley. The Connector terminates at the Drought Hill Interchange with Highway 97 just North of Peachland.

2.1.3 *Alternative Routes*

For traffic from the Lower Mainland (and beyond) and the Fraser Valley travelling to Kamloops and beyond, the two main route choices are to use either the tolled Coquihalla Highway or the untolled Trans-Canada Highway (Highway 1), through the Fraser and Thompson River Canyons, via Lytton and Cache Creek. Travelling between Hope and Kamloops, the Highway 1 route is approximately 73km longer than the Coquihalla route and around an hour longer in journey time. The Canyon route is less exposed than the Coquihalla Highway however, which can be adversely affected by severe winter weather.

For traffic from the Lower Mainland (and beyond) and the Fraser Valley travelling to the Central and Southern Okanagan Valley, the two main route choices are to use either the tolled Coquihalla Highway and the Okanagan Connector or the Crows Nest Highway (Highway 3) to Keremoes, Highway 3A from Keremoes to Kaleden and then Highway 97. Travelling between Hope and Kelowna, the Highway 3 route is approximately 70km longer in distance and around an hour and a quarter longer in travel time than the Coquihalla route. Between Hope and Penticton however, the Highway 3 route is around 20km shorter if still slightly longer in journey time terms by about 10 minutes on average.

At the moment, only the Hope to Merritt section of the Coquihalla Highway is tolled. One of the objectives of this study however is to look at the possibility of additional tolling facilities on the currently un-tolled sections. In this case alternative routes to the un-tolled sections become important. For trips between Merritt and Kamloops, Highway 5A provides a slightly longer and slower alternative route to the Coquihalla Highway. For trips between Merritt and Kelowna, there is little route choice – avoiding the Connector would involve a huge detour via Kamloops. For trips between the Okanagan Valley and Kamloops (and beyond), there is a clear route choice between the Connector/Coquihalla Highway route and the Highway 97/1 route. Even without a toll, the choice is marginal for trips between Kelowna and Kamloops, whilst trips from the Northern Okanagan are much more likely to use the Highway 97/1 route.

2.2 *Survey and Count Data*

A comprehensive set of survey and count data, from a variety of sources was utilised by the study. These are summarised below:

Summer 1999 Origin-Destination Survey (IBI on behalf of MoT).

- 1113 "short" interviews carried out at the tollbooth
- 1307 "long" interviews at rest areas and gas stations on Highway 1, Highway 3 and Highway 5 (including 311 on the Coquihalla Highway)

Summer 2002 Stated Preference (SP) Surveys (Halcrow/IBI for this study).

- 136 Truck Driver SP Interviews at Laidlaw and Hunter Creek Weigh Scales
- 262 Car Driver SP Interviews at Merritt Tourist Information Centre, Kamloops, Cache Creek and Princeton

Summer 2002 Origin-Destination Survey (Halcrow/IBI for this study).

- 102 O-D interviews on Highway 3 in the Princeton Area

Summer 2002 Truck-Turning Counts (Halcrow/IBI for this study).

- One-Day truck turning count at the junction of Highway 1 (TCH) and Highway 97 at Cache Creek

Spring 2003 Light Vehicle Origin-Destination & Frequency Survey (Halcrow/CTS/IBI for this study)

- 1680 O-D interviews carried out at the tollbooth

Permanent MoT Classifying Count Sites

Temporary Classifying Counts Undertaken in October 2002 for this study

Other Permanent MoT Count Sites

The location of these sites is shown in Figure 2.1.

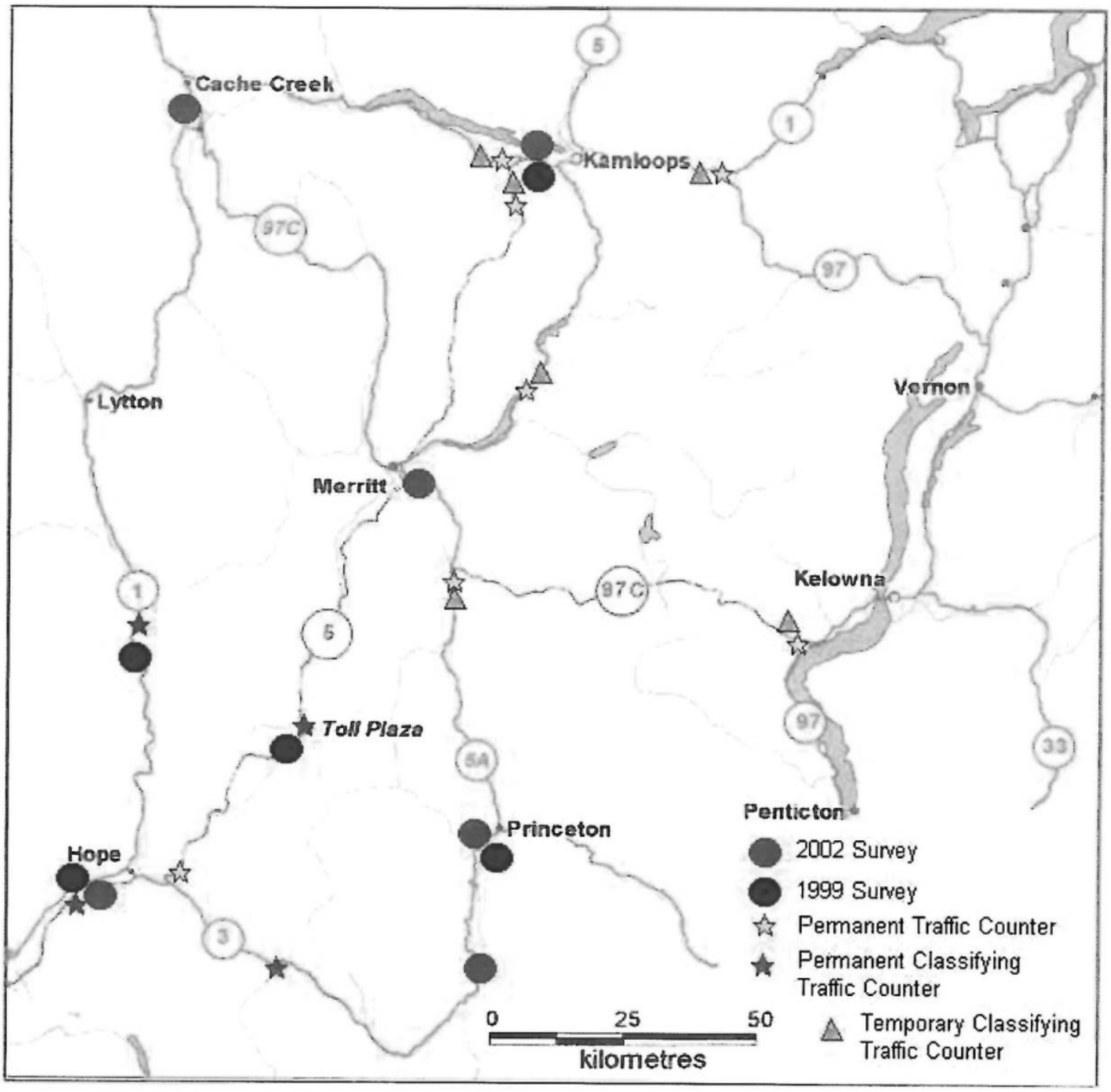


Figure 2.1: Traffic Survey and Count Locations

2.3 Current Traffic Volumes and Patterns

2.3.1 *Tollbooth Traffic Volumes*

In 2001, a total of 2,900,875 paying vehicles passed through the Coquihalla tollbooths, equating to an annual average daily traffic volume of 7,948 vehicles. Of this total, 84% were passenger vehicles (cars, pick-up trucks and RVs) and 13% were trucks with 4 axles or more (toll categories 4&5). Smaller trucks with 2-3 axles counted for 2% of the total traffic, whilst motorcycles counted for less than one half of one per cent of total traffic. In revenue terms, Category 1 vehicles provided 56.5% of the total revenue, whilst Categories 4 & 5 together account for 40.1% of the total revenue. The remaining 3.3% of revenues are derived from Categories 2, 3 and 6. These figures are shown in Table 2.1 below, and diagrammatically in Figures 2.2 and 2.3. Given that the volumes of traffic in Categories 2, 3 and 6 are extremely low, and their contribution to overall revenue small, the traffic forecasting study focuses on Categories 1, 4 and 5.

Toll Category	Annual Traffic Volume	Percentage of Total Traffic	Toll Tariff	Annual Revenue	Percentage of Total Revenue
Light Vehicles	2,443,056	84.2	$10	$24,430,560	56.5
2-Axle Trucks	26,175	0.9	$20	$523,500	1.2
3-Axle Trucks	29,293	1.0	$30	$878,790	2.0
4/5-Axle Trucks	215,450	7.4	$40	$8,618,000	19.9
6+Axle Trucks	174,944	6.0	$50	$8,747,200	20.2
Motorcycles	11,957	0.4	$5	$59,785	0.1
Total Traffic	**2,900,875**	**100.0**		**$43,257,835**	**100.0**

Table 2.1. Annual Coquihalla Traffic Volumes 2001

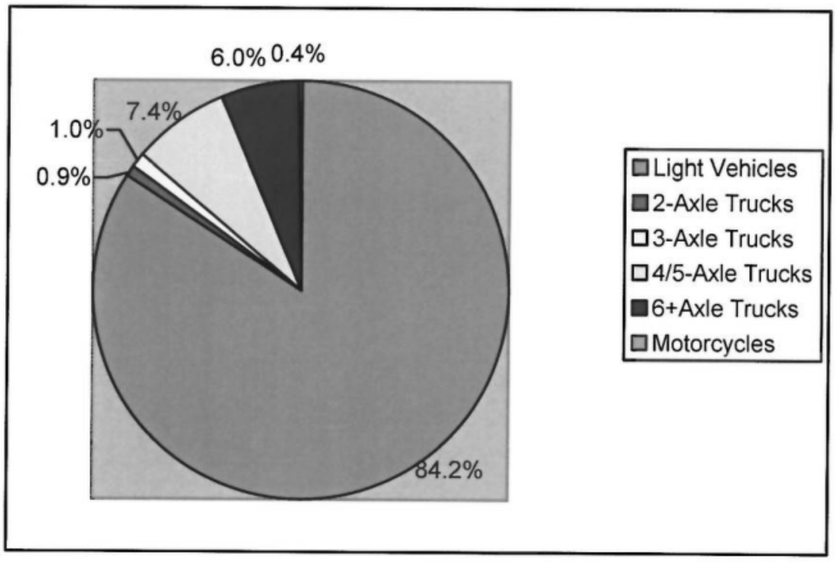


Figure 2.2: 2001 Traffic by Toll Category

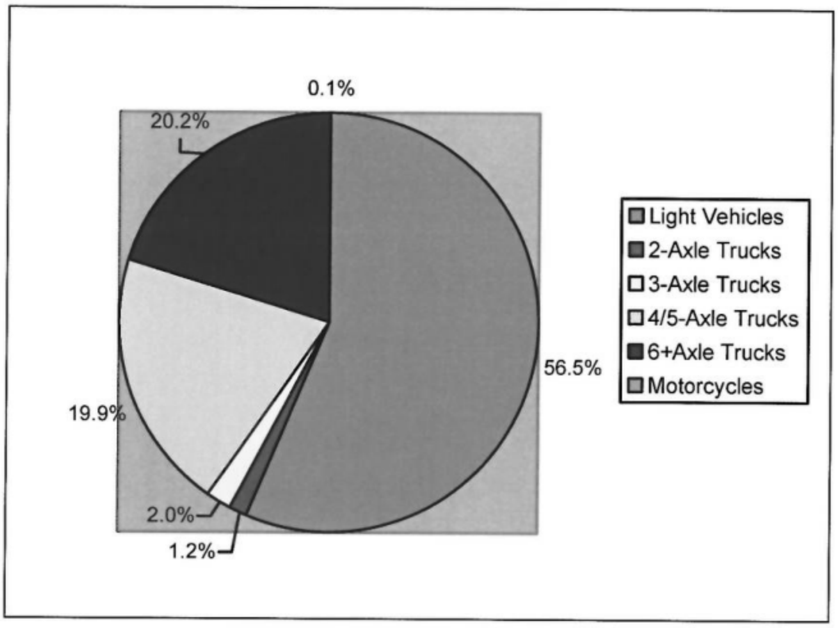


Figure 2.3: 2001 Revenue by Toll Category

2.3.2 *Seasonal Traffic Volumes*

Light vehicle traffic on the Coquihalla Highway is highly seasonal as illustrated by Figure 2.4 below, showing total monthly light, heavy and total vehicle volumes in 2001. Heavy vehicle traffic varies less throughout the year.

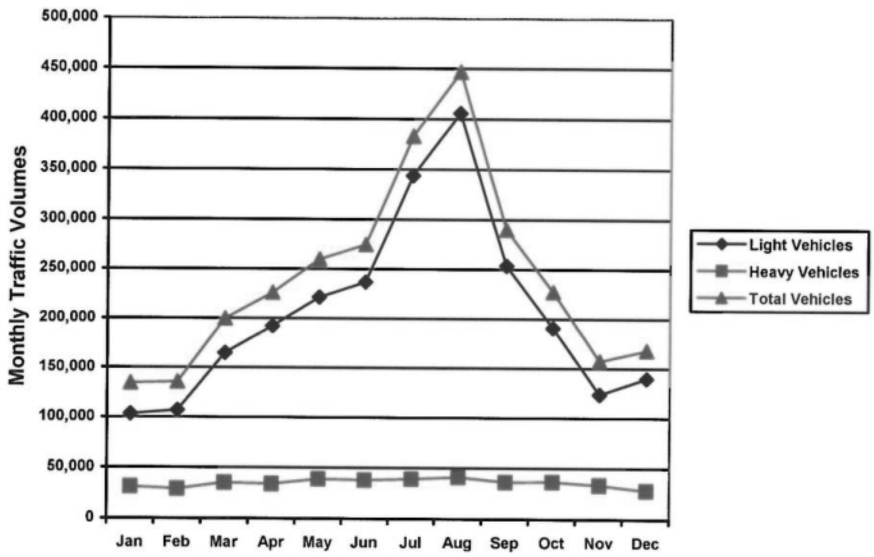


Figure 2.4: Monthly Traffic Variation

Light vehicle traffic is also heavily weighted towards weekend traffic, as illustrated in Figure 2.5 below.

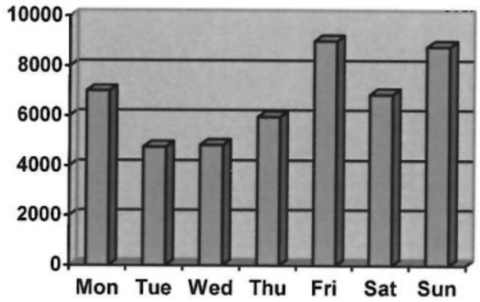


Figure 2.5: Annual Average Daily Light Vehicle Traffic by Day of the Week

Truck traffic is highest during the midweek period.

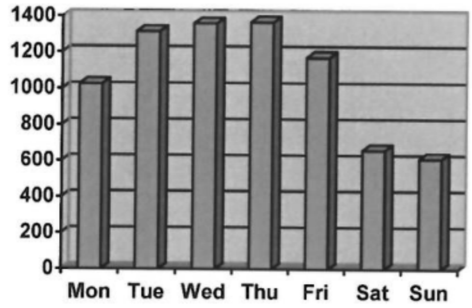


Figure 2.6: Annual Average Daily Truck Traffic by Day of the Week

2.3.3 *Traffic by Section of the Coquihalla Highway*

As well as information from the tollbooth, permanent traffic counters are in place on all three sections of the Coquihalla Highway measuring total traffic volumes. Classifying loops were also laid in October 2002 to measure the percentage of large vehicles using the Merritt-Kamloops section and the Okanagan Connector. From these sources, estimates of annual traffic volumes for each section, by heavy and light vehicles have been derived.

Coquihalla Section	AADT	Light Vehicles	Trucks	Percentage Trucks
Hope to Merritt	7950	6765	1150	16.1
Merritt to Kamloops	6156	5319	837	13.6
Connector	3792	3428	364	9.6

Table 2.2: Traffic Volumes by Section of the Coquihalla (2001)

The tables shows that truck traffic on the Merritt-Kamloops section and the Connector combined are only slightly higher than truck traffic on the Hope-Merritt section. This suggests that there is very little truck traffic using the other arms of the Coquihalla Highway that does not already pass through the tollbooth. By contrast, total light vehicle traffic on the two arms combined is significantly higher than light vehicles traffic volumes passing through the tollbooth. This suggests that there is a significant volume of local traffic on the other arms not currently passing through the tollbooth (about 2,000 vehicles per day on average). The largest proportion of this is made up of local traffic between the Merritt and Nicola Valley area and Kamloops

2.3.4 *Traffic by Journey Purpose*

Origin-Destination surveys were carried out at the tollbooth, and other locations, in the summer of 1999. A total of 1,116 drivers were interviewed at the tollbooth, of which 1,055 were car drivers. No surveys were carried out during the winter, but using adjustment factors based on changing trip purposes and monthly traffic volumes, the annual split of car traffic by trip purpose can be estimated. Table 2.3 or figure 2.7 shows that the leisure market dominates light vehicle traffic on the Coquihalla. The "other" trip purpose includes shopping, personal business and visiting friends and family.

Trip Purpose	Split From Summer Survey	Estimated Annual Split
Work Related	11%	15%
Short Vacation (4 nights or less)	44%	37%
Long Vacation (more than 4 nights)	43%	30%
Other	14%	18%
Total	100%	100%

Table 2.3: Summer and Estimated Annual Car Trip Purpose Split

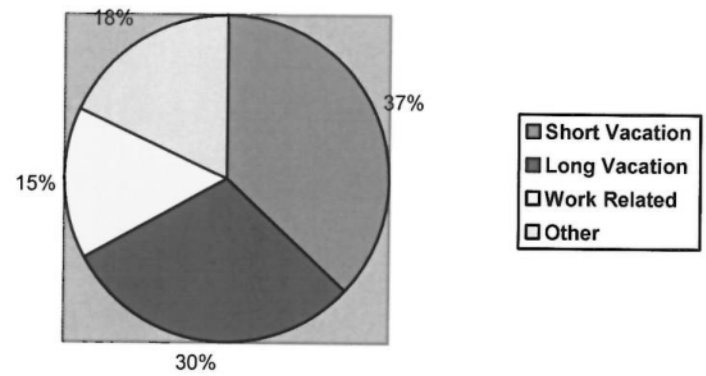


Figure 2.7: Estimated Annual Car Trip Purpose Split

2.3.5 *Trip Frequency*

Infrequent users dominate traffic on the Coquihalla. It is estimated that annually, only around 4% of cars on the Coquihalla Highway travel more than four times per month. Figure 2.8 shows the frequency of trips reported by interviewees at the tollbooth in 1999.

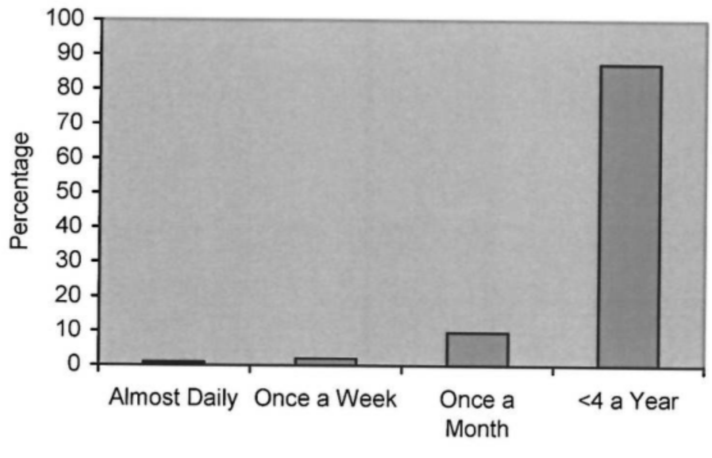


Figure 2.8: Coquihalla Trip Frequency

2.3.6 *Pattern of Traffic Movements*

Table 2.4 below table shows the origins and destinations of light vehicle traffic surveyed at the Coquihalla Toll Booth in August 1999. *It should be noted that the surveys were weighted more heavily in favour of northbound movements.*

Location	Origin (%)	Destination (%)
Vancouver Island/ South Coast	7%	4%
Lower Mainland	43%	38%
Hope Area	1%	0%
Okanagan	16%	19%
Thompson-Nicola	14%	16%
Rest of BC	3%	3%
Alberta	11%	14%
Other	6%	5%
Total	100.0	100.0

Table 2.4 Origin and Destination of trips on the Coquihalla Highway, August 1999.

This data are presented graphically in Figures 2.9 and 2.10 overleaf.

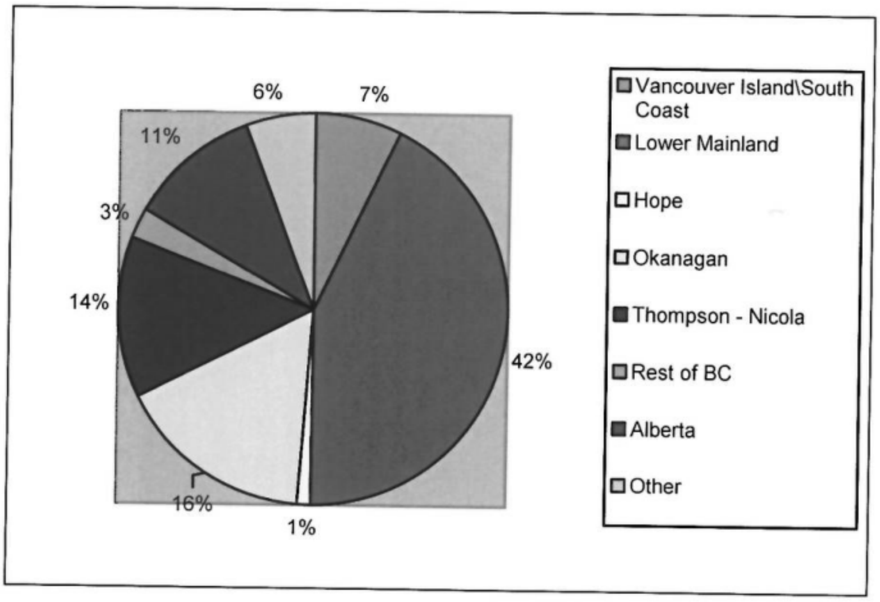


Figure 2.9: Origin of Trips using the Coquihalla Highway, August 1999.

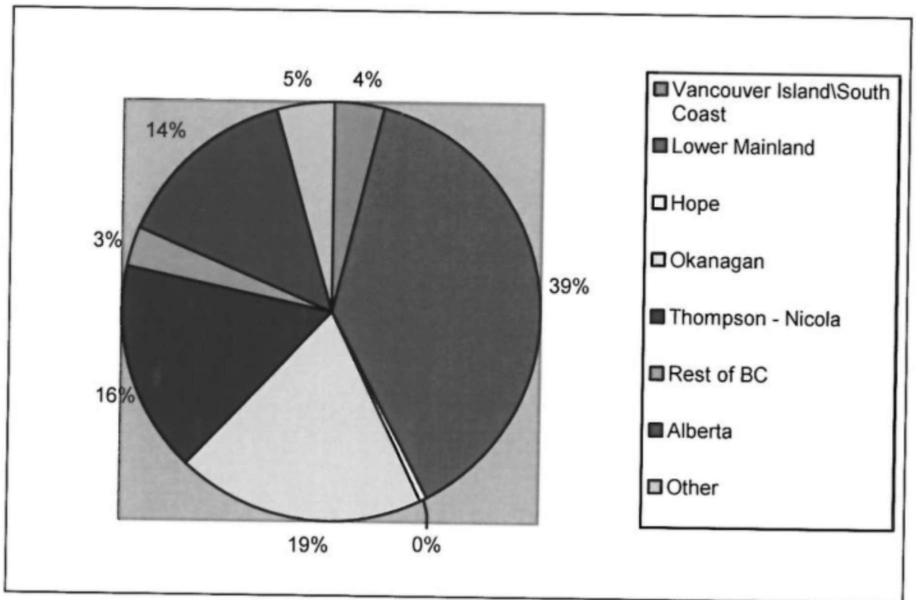


Figure 2.10: Destination of Trips using the Coquihalla Highway, August 1999.

In contrast to light vehicles, a greater proportion of truck movements are long-distance in nature. Table 2.5 below summarises the main truck movements on the Coquihalla Highway, as derived from the 2002 truck SP surveys and limited number of truck interviews undertaken at the tollbooth in 1999.

Movement	Percentage
Internal British Columbia	40
British Columbia – Alberta	40
British Columbia – Other Provinces	20

Table 2.5: Coquihalla Truck Movements

The origin and destination of all traffic passing through the Coquihalla tollbooth in Summer 2002, by traffic zone, is shown diagrammatically in Figure 2.11 overleaf.

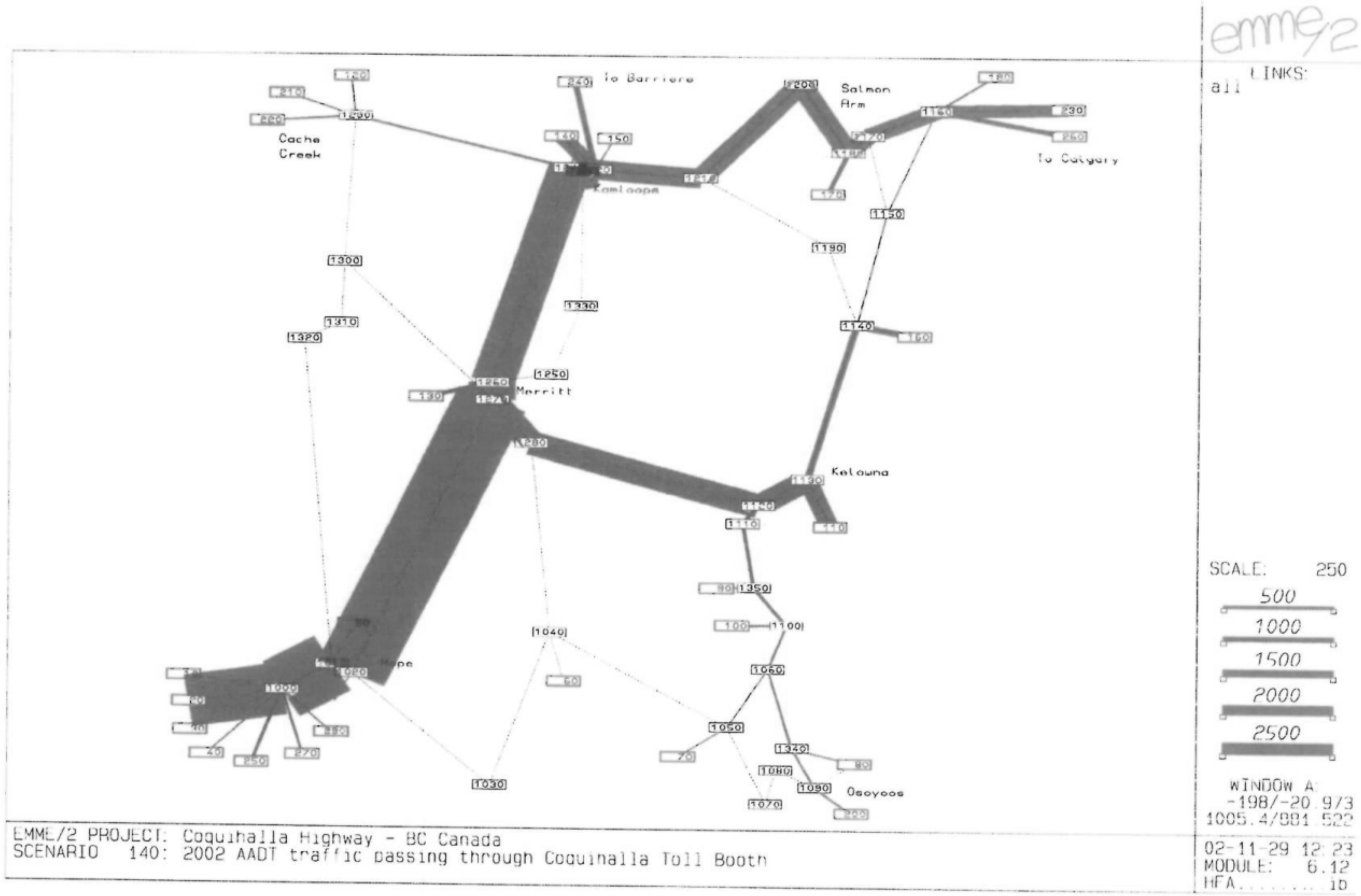
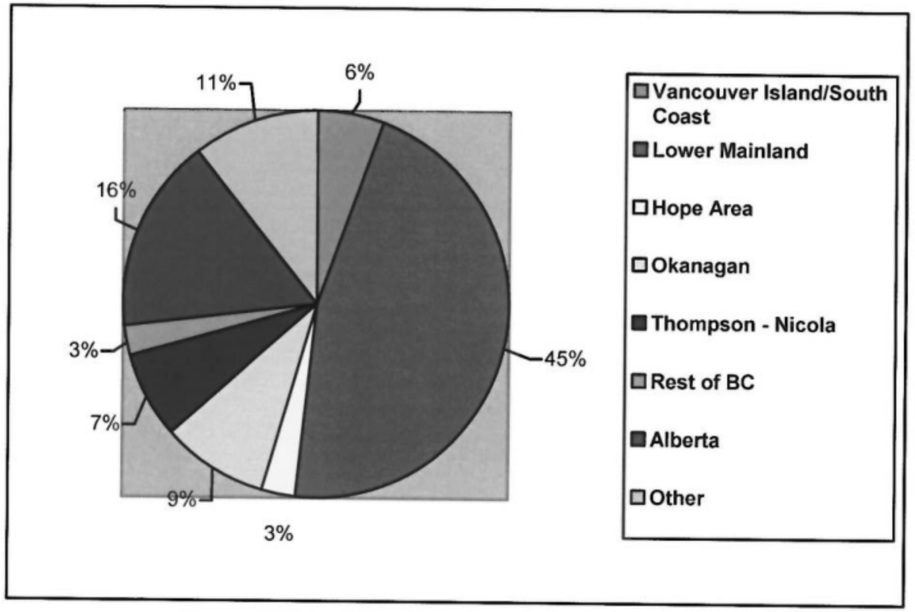


Figure 2.11: Coquihalla Tool Booth Traffic Origins and Destinations, Summer 2002

2.4 *Residency of Travellers on the Coquihalla Highway*

Figure 2.12 shows the place of residence of travellers on the Coquihalla Highway. The figures are derived from the summer 1999 surveys, adjusted to represent annual averages. The figure shows that around half of all users are from the Lower Mainland and Vancouver Island, and around 20% of users are from the interior of BC.



3 Base Year Diversion Model

3.1 *Overview*

The diversion model is the key tool used in investigating the demand and revenue effects of different tolling strategies and tariff structures. The model takes the form of a series of "curves" which predict the "capture rate" of the Coquihalla Highway of total traffic in the corridor at different levels of toll, for each key market segment. The diversion model itself has been developed in a spreadsheet format, taking inputs from an EMME2 network model, current demand data derived from surveys and counts, and behavioural parameters such as the value of time calculated from the results of the stated preference surveys carried out in the summer of 2002. The model has been calibrated so that it reproduces the observed split between the Coquihalla Highway and alternative highways in the corridor.

The model structure and process is shown in Figure 3.1 overleaf.

The diversion model calculates the generalised cost (time and cost) for each trip within a market segment, within the corridor using the tolled route verses the non tolled route. These costs are then passed into a logit formula that predicts the likely capture rate for each movement on the Coquihalla Highway.

The modelled market segments are as follows;

- Car
    - i) Work Related Trips (Business)
    - ii) Short Vacation (<=4 nights)
    - iii) Long vacation (>4 nights)
    - iv) Other Trip Purposes
- Trucks (Toll Classes 4&5)

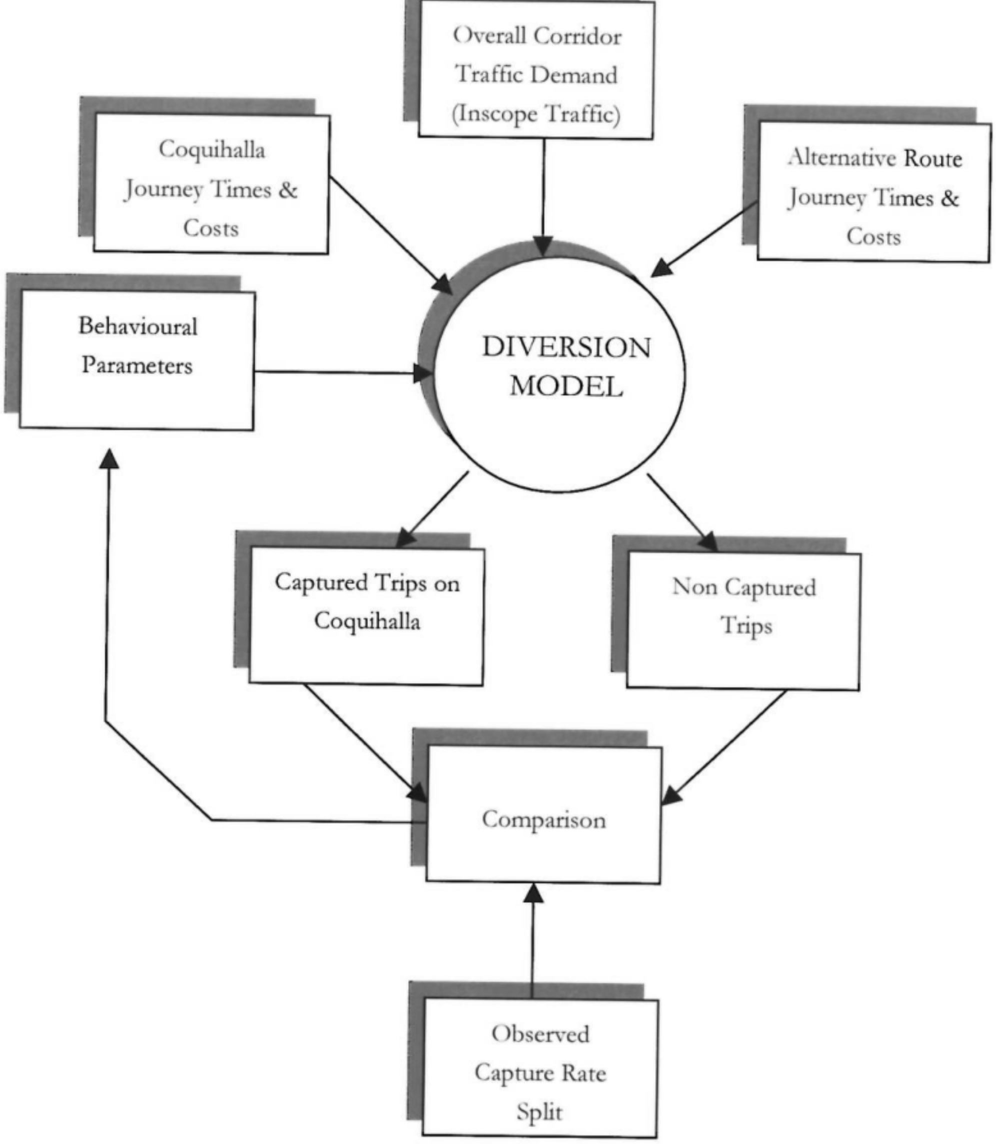


Figure 3.1: Diversion Model Structure and Process

3.2 *Model Description*

The diversion model takes the form of a logit probability model, shown mathematically below:

P_{toll} = probability of choosing the toll road option

$$= \frac{\exp(U_{toll})}{\exp(U_{toll}) + \exp(U_{non-toll})}$$

where:

U_{toll} = Utility of toll road alternative = a*journey time + b*journey cost + k

$U_{non-toll}$ = Utility of non-toll road alternative = a*journey time + b*journey cost

and

a = the "weighting" drivers place on journey time when making the route choice decision

b = the "weighting" drivers place on journey cost when making the route choice decision

k = the "weighting" drivers place on the extra benefits of an improved road (safety etc) when making the route choice decision

The inputs into the diversion model are;

- Average journey times by each route
- Perceived costs for each route (including fuel and tolls)
- Other perceived benefits of using one route over another (eg. increased safety, ease of driving etc.)
- The values, or weightings, drivers place on each of those elements (or attributes) of the journey above when making the route choice decision.

The diversion model uses the following data to predict the capture rate on the tolled highway;

- Current demand by each O-D pair and market segment
- Average journey times for both the tolled and the non-tolled route
- Distances for both the tolled and non-tolled highway routes
- Values of time for each market segment
- Vehicle Operating Costs for each vehicle class
- Tolls for each vehicle class where applicable

3.3 Model Development

3.3.1 *Emme/2 Network Model*

A traffic network model of the study area was built using the Emme/2 transport planning software. The model features a mathematical and graphical representation of the highway network in the study area. Journey times and distances in the model were derived from journey time surveys carried out on all the key routes and derived from maps and assumed average speeds by route type for other less important links. Since traffic volumes are generally low in the study area, fixed times and speeds have been assumed. The network model is used to provide journey times and distances for each origin-destination zone pair using the tolled Coquihalla Highway as well as the non-tolled alternative. Hence for any O-D pair, a journey time and distance was calculated by using the tolled Coquihalla Highway route and also the non-tolled Highway route. These data were then used as inputs in the diversion model.

The model network is plotted in Figure 3.2 overleaf.

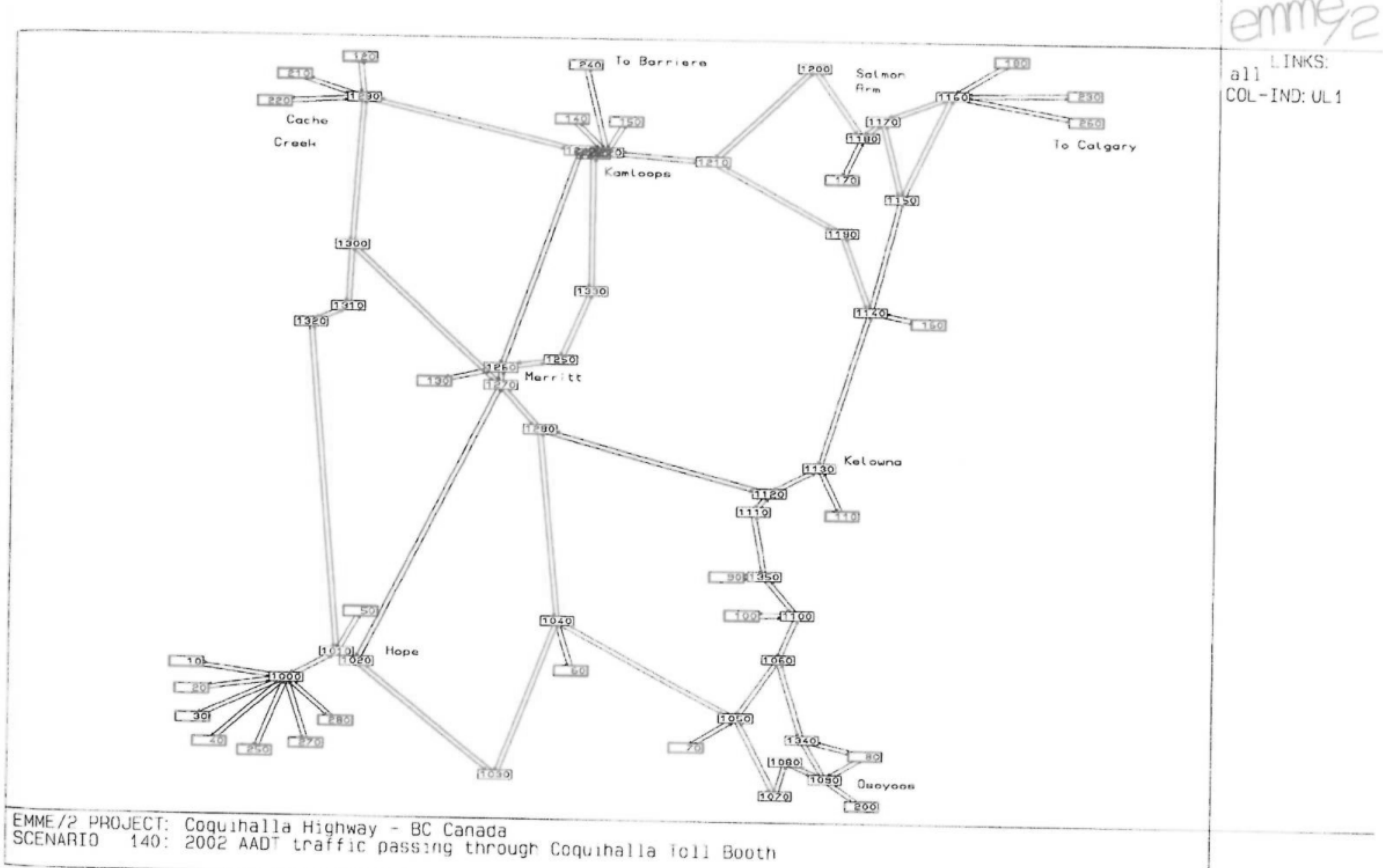


Figure 3.2: Network Model Plot

Traffic demand in the study area is represented by the number of vehicle trips between each pair of traffic zones. The model area has been split up into a total of 27 traffic zones representing key demand areas and route-decision points. The list of zones used in the model and the corresponding location that each zone represents is shown in Table 3.1 below and graphically in Figure 3.3.

Model Zone Number	Area Represented
10	Vancouver Island / South Coast
20	GVRD
30	Squamish-Lillooet
40	Central Fraser Valley
50	Hope
60	Princeton
70	Keremeos
80	Southern Okanagan
90	Summerland
100	Enderby
110	Central Okanagan
120	South Cariboo
130	Merritt
140	Kamloops
150	North Thompson
160	North Okanagan
170	Salmon Arm
180	Revelstoke / Golden
200	Kootenay
210	Cariboo
220	Northern BC
230	Southern Alberta
240	Northern Alberta

250	Washington
260	Rest of Canada
270	Rest of USA
280	Other International

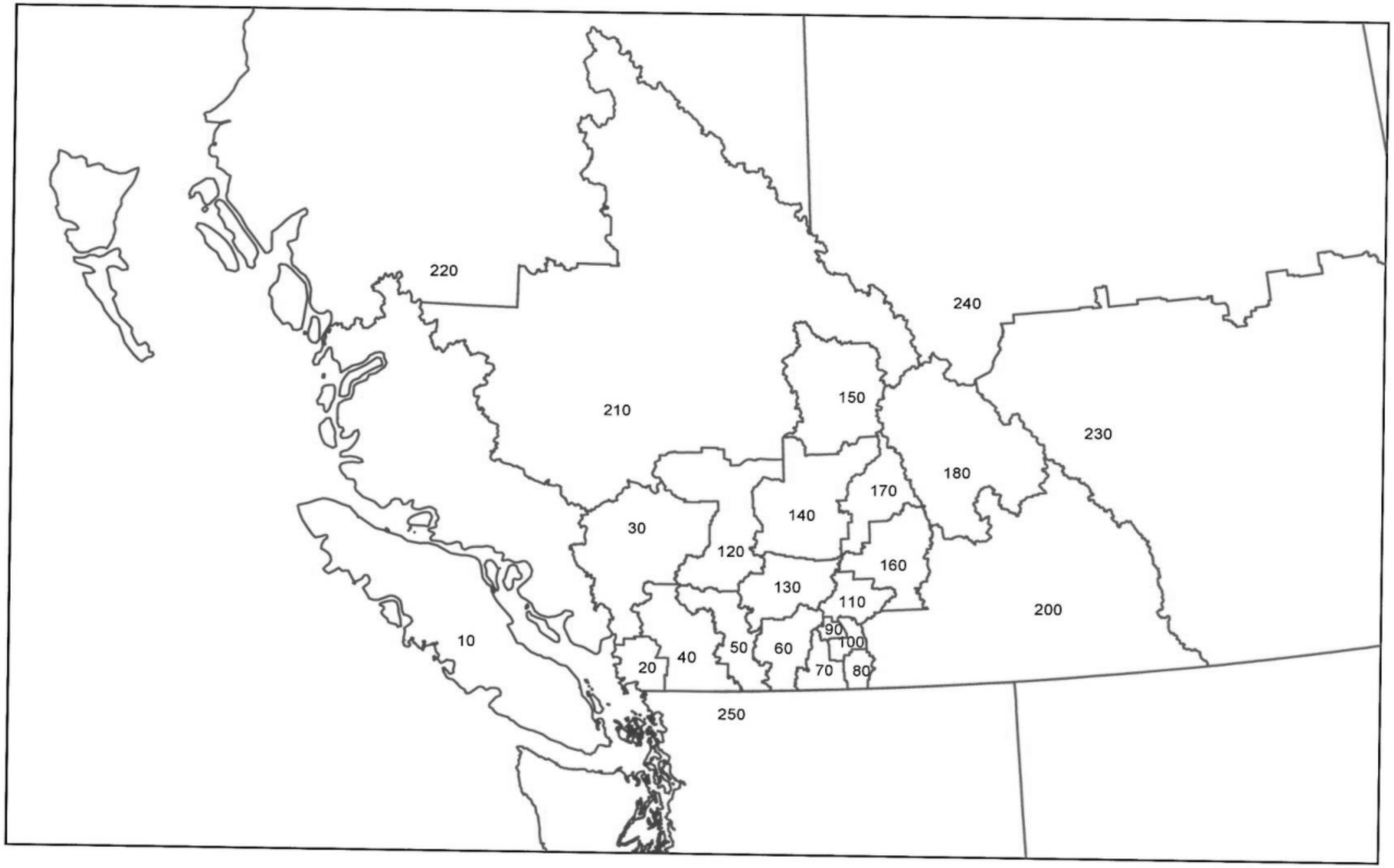
Table 3.1: Traffic Model Zones

In the diversion model it was found that the spread of trips across zones was too thin to support analysis by market segment at the zonal level. Zones were grouped into the following sectors therefore to produce a more robust sample.

Sector	Location	Zones contained within sector
300	Lower Mainland, Vancouver Island and Fraser Valley	10, 20, 30, 40, 50, 250, 270, 280
310	Merritt Area	130
320	Cariboo & Northern BC	120, 210, 220
330	North Thompson & Northern Alberta	140, 150, 240
340	Salmon Arm, Revelstoke & Southern Alberta	170, 180, 230, 260
350	North and Central Okanagan	110, 160
360	South Okanagan	90, 100
370	Keremeous & Kootenay	70, 80, 200
380	Princeton	60

Table 3.1: Traffic Model Sectors

Figure 3.3: Traffic Zone Map



3.3.2 *Deriving Current Demand*

Travel demand pattern in the corridor was derived using the origin-destination data collected in 1999 and 2002. This survey information was then "expanded" to match classified vehicle counts at the Coquihalla tollbooth, Highway 1 at China Bar, and Highway 3 at Nicolum, for July 2002. A second level of sub-expansion ensured that truck movements in the base year trip matrix replicated observed truck volumes at other key locations in the study area, such as on the non-tolled arms of Coquihalla and turning movements at Cache Creek.

3.3.3 *Behavioural Parameters*

Behavioural parameters for the diversion model were derived from stated preference surveys carried out in the summer of 2002. The surveys are used to derive the "weightings" that drivers place on each attribute of the trip (time, cost, quality of drive etc). These weightings essentially form the "shape" of the diversion curve. The most important part of the SP interview is the "game playing" section, where drivers are invited to trade-off timesaving (via a new toll highway) versus increased cost, in eight theoretical (but realistic) scenarios. Costs in the stated preference experiment were expressed as a combination of tolls and gasoline. A specialist software package ALOGIT was used to analyse the results of the surveys, the outputs from which are a series of parameters for each trip variable.

The resulting parameter estimates for each market segment are presented in Table 3.2 below together with an associated "t" statistic. A parameter estimate with a "t" statistic of +/- 1.96 or more is considered to be statistically significant at the 95% confidence interval.

Market Segment	Journey Time Parameter (per minute)	t-stat	Journey Cost Parameter (per $)	t-stat
Car Business	-0.04008	-11.1	-0.1579	-9.2
Car Short Vacation	-0.0282	-11.0	-0.1769	-12.4
Car Long Vacation	-0.0248	-12.2	-0.1861	-15.4
Car Other	-0.02244	-8.5	-0.1969	-11.9
Trucks ~ Toll Classes 4&5	-0.01806	-12.4	-0.04002	-12.5

Table 3.2: Journey Time and Cost Parameter Estimates from ALOGIT

The table shows that the parameter estimates for both journey time and cost for all market segments are statistically significant. Dividing the time parameter by the cost parameter allows a "value-of-time" to be derived for each market segment

Market Segment	Value of Time ($ per hour)
Car Business	15.23
Car Short Vacation	9.56
Car Long Vacation	8.00
Car Other	6.84
Trucks ~ Toll Classes 4&5	27.08

Table 3.3: Values of Time by market segment

The derived values of time for each market segment appear reasonable and follow a logical pattern. For example, one would expect business travellers to have the highest values of time amongst car drivers and likewise one would expect people on a short vacation to have a higher value of time than those on a long vacation.

It is common in stated preference exercises that a further parameter is included; sometimes know as the mode constant (or "k"), which encapsulates all the other less tangible benefits or disbenefits of a particular route. In the case of a toll road study, whereby the toll road is presented as a higher standard road compared to the alternative, this "k" factor would represent the value drivers place on such attributes as improved safety, reliability or ease of driving over and above the more tangible benefits of time or cost savings. The "k" factor was initially included in the analysis, but it was found to be very small and statistically insignificant. This suggests that there is some counter-balancing factor acting against the toll road option in the minds of some respondents – probably due to a general reluctance to pay tolls. If "k" factors are found not to be significant in the analysis of stated preference data, it is common practice to derive them separately (if necessary) from observed behaviour in the model calibration process.

3.3.4 *Vehicle Operating Costs*

The diversion model also takes into account perceived vehicle-operating costs. This represents the perceived marginal vehicle operating costs per kilometre. This does not equate to the full economic operating costs as drivers usually only take into account fuel costs when making a route choice decision, rather than full total costs including such items as wear and tear on tyres etc. Within the model, perceived VOC for cars were taken from the Canadian Automobile Association figures for average fuel and oil costs per kilometre. Truck perceived VOC figures were calculated from the average fuel consumption figures reported in the truck driver SP survey. The resulting VOC figures used in the model are shown below.

Vehicle Class	Vehicle Operating Cost ($ per km)
Light Vehicle	0.08
Heavy Vehicle	0.33

3.4 *Model Outputs*

The output from the diversion model is a "curve", which shows the likely probability of drivers choosing the Coquihalla Highway over alternative routes at different levels of toll tariff. There is a curve for each market segment and each OD pair (providing there are a significant number of trips in each of those "cells"). The probability of drivers choosing the Coquihalla Highway is multiplied by the base level of demand to arrive at an aggregate forecast of traffic on the Coquihalla Highway at a given toll tariff.

3.5 *Model Calibration*

As discussed above, the output from the diversion model is a series of diversion curves. Since the Coquihalla is already open however, and people are already making the route-choice decision, we can plot one or more points on that curve. So for example we know that at the current toll rate, and the current savings in time and travelling distance, around 90% of light vehicle drivers travelling between the Lower Mainland and Kelowna choose the Coquihalla Highway over the Highway 3 alternative route via Princeton. In the calibration process, we compare the route choice split predicted by the model for the current situation with the observed route-choice split. The model parameters can then be adjusted so that the two match. We can now place much more confidence in the ability of the model to accurately predict the effects of changes to the toll tariffs or tolling strategies than if we were relying on a purely theoretical model. In effect, we are calibrating stated preference data, using revealed preference data.

The following table shows the initial and final parameters after calibrating against the revealed preference data.

Parameters	Initial	Final Calibrated
<u>Values of Time ($/hour)</u>		
Car Business	15.23	15.23
Car Short Vacation	9.56	10.52
Car Long Vacation	8.00	8.00
Car Other	6.84	7.52
Trucks ~ Toll classes 4&5	27.08	29.79
<u>VOC ($)</u>		

Light Vehicles	0.08	0.08
Heavy Vehicles	0.33	0.33
<u>Cost Coefficients</u>		
Car Business	-0.1579	-0.1579
Car Short Vacation	-0.1769	-0.1769
Car Long Vacation	-0.1861	-0.1861
Car Other	-0.1969	-0.1969
Trucks ~ Toll classes 4&5	-0.065	-0.065
<u>Quality Bonus ($)</u>		
Car Business	0	0
Car Short Vacation	0	4
Car Long Vacation	0	0
Car Other	0	2
Trucks ~ Toll classes 4&5	0	0

Table 3.4: Parameter values used for calibrating diversion model

The table shows that only minor adjustments to the parameters were necessary to achieve a good fit between observed and modelled behaviour. Initially, the model was slightly under-predicting the Coquihalla Highway capture rate for the "Car Short Vacation", "Car Other" and "Truck" market segments. Inflating the value of time by 10% for these market segments and introducing a toll road "quality bonus" (k factor) for the "Car Short Vacation" and "Car Other" market segments allows an excellent fit across most origin-destination pairs and market segments. The results of the calibration exercise, showing modelled versus observed capture rates for each market segment and each origin-destination sector pair, are shown in Table 3.5 below.

Sector	Sector	Observed % of Trips		Modelled % of Trips		Difference (M-O)
		Not Captured	Captured on Hwy 5	Not Captured	Captured on Hwy 5	Captured on Hwy 5
<u>Car Business</u>						
300	310	0.0	100.0	5.7	94.3	-5.7
300	320	90.0	10.0	94.2	5.8	-4.2
300	330	9.0	91.0	10.9	89.1	-1.9
300	340	20.1	79.9	10.9	89.1	9.1
300	350	6.3	93.7	9.0	91.0	-2.7
300	360	100.0	0.0	60.3	39.7	39.7
300	370	85.0	15.0	98.1	1.9	-13.1
	Total	**29.0**	**71.0**	**31.4**	**68.6**	**-2.4**
<u>Car Short Vacation</u>						
300	310	11.9	88.1	6.0	94.0	5.9
300	320	78.0	22.0	89.6	10.4	-11.6
300	330	11.3	88.7	10.9	89.1	0.4

300	340	9.5	90.5	10.9	89.1	-1.4
300	350	7.9	92.1	9.6	90.4	-1.7
300	360	65.4	34.6	53.8	46.2	11.7
300	370	89.8	10.2	96.1	3.9	-6.3
	Total	**25.3**	**74.7**	**28.3**	**71.7**	**-3.0**
Car Long Vacation						
300	310	14.7	85.3	17.9	82.1	-3.2
300	320	95.0	5.0	94.7	5.3	0.4
300	330	22.6	77.4	28.4	71.6	-5.8
300	340	35.5	64.5	28.4	71.6	7.1
300	350	15.1	84.9	26.5	73.5	-11.4
300	360	96.2	3.8	75.4	24.6	20.8
300	370	91.4	8.6	97.9	2.1	-6.5
	Total	**43.5**	**56.5**	**46.0**	**54.0**	**-2.4**
Car Other						
300	310	14.3	85.7	13.2	86.8	1.1
300	320	93.8	6.2	93.2	6.8	0.6
300	330	18.1	81.9	22.1	77.9	-4.0
300	340	34.5	65.5	22.1	77.9	12.4
300	350	17.5	82.5	20.5	79.5	-3.0
300	360	83.6	16.4	69.8	30.2	13.8
300	370	90.4	9.6	97.4	2.6	-6.9
	Total	**43.1**	**56.9**	**43.5**	**56.5**	**-0.4**
Trucks ~ Classes 4 & 5						
300	310	0.0	100.0	15.8	84.2	-15.8
300	320	96.0	4.0	98.7	1.3	-2.7
300	330	24.2	75.8	30.0	40.0	-5.9
300	340	29.2	70.8	30.0	70.0	-0.8
300	350	29.1	70.9	27.6	72.4	1.5
300	360	62.3	37.7	87.6	12.4	-25.3
300	370	85.3	14.7	99.7	0.3	-14.4
	Total	**48.3**	**51.7**	**53.0**	**47.0**	**-4.7**

Table 3.5: Diversion Model Validation

A summary of the model validation for three key movements is shown in Table 3.6 below. The three key movements are:

Sector 300 (Lower Mainland and beyond)	to	Sector 330 (Kamloops Area & Highway 5 North)
	to	Sector 340 (Salmon Arm Area and Highway 1 East)
	to	Sector 350 (Central & Northern Okanagan Valley)

Vehicle Type	Observed	Modelled
Total Cars	82.5	81.2
Total Trucks	71.5	70.4

Table 3.6: Summary Validation of Diversion Model

3.6 *Model Results*

Once the diversion model had been calibrated and validated against observed capture rates on the Coquihalla Highway, it was possible to produce diversion curves for each market segment showing how demand and revenues vary as the toll level is increased or decreased. The resulting "curves" for the car market segment are shown in Table 3.7 below and graphically in Figures 3.4 to 3.9. The "Car Total" curve is the sum of each car market segment, weighted to match the estimated annual traffic mix of each market segment. Demand and revenue at the current toll levels are presented as an index of 100. The revenue maximising toll for each market segment is highlighted in bold.

Toll Level ($)	Car Business		Car Short Vacation		Car Long Vacation		Car Other		Car Total	
	Demand	Revenue	Demand	Revenue	Demand	Revenue	Demand	Revenue	Demand	Revenue
0	111.7	0.0	115.8	0.0	135.7	0.0	132.0	0.0	125.0	0.0
2	109.7	21.9	113.2	22.6	130.4	26.1	126.7	25.3	121.1	24.2
4	107.6	43.1	110.4	44.2	124.3	49.7	121.0	48.4	116.7	46.7
6	105.4	63.2	107.4	64.4	117.4	70.4	115.0	69.0	111.9	67.1
8	102.9	82.3	103.9	83.1	109.3	87.4	108.0	86.4	106.4	85.1
10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12	96.6	115.9	95.4	114.5	89.4	107.3	90.8	108.9	92.7	111.2
13	94.7	123.1	92.8	120.6	83.8	108.9	85.7	111.4	88.7	115.3
14	92.6	129.6	90.0	126.0	**77.9**	**109.0**	**80.3**	**112.5**	84.4	118.2
15	90.3	135.4	86.9	130.4	71.8	107.7	74.7	112.1	80.0	120.0
16	87.7	140.4	83.6	133.8	65.7	105.1	68.9	110.3	**75.4**	**120.6**
18	82.1	147.7	**76.2**	**137.2**	53.7	96.6	57.1	102.8	65.8	118.4
20	**75.5**	**151.0**	67.9	135.8	42.5	84.9	45.6	91.2	56.0	112.1
22	68.2	149.9	58.9	129.6	32.6	71.8	35.2	77.4	46.6	102.6
24	60.2	144.5	49.6	119.1	24.4	58.6	26.3	63.1	37.9	91.0
26	51.9	135.0	40.6	105.5	17.9	46.5	19.1	49.8	30.1	78.3
28	43.7	122.5	32.2	90.3	12.9	36.1	13.6	38.2	23.4	65.6
30	36.0	108.0	25.0	74.9	9.2	27.6	9.6	28.7	17.9	53.7

Table 3.7: Car Toll Level Diversion

The diversion model predicts that revenue is maximised for car market segments at a toll level of between $15 and $16.

Table 3.8 shows the diversion "curve" for the truck market segment. In this context trucks are defined as all trucks with 4 axles or more and the truck toll level is taken as the average toll tariff for toll categories 4 and 5, which is currently $45.

Toll Level *	Demand	Revenue
0	140.3	0.0
5	137.0	15.2
10	133.8	29.7
15	130.6	43.5
20	127.3	56.6
25	123.5	68.6
30	119.1	79.4
35	113.9	88.6
40	107.5	95.6
45	100.0	100.0
50	**91.3**	**101.4**
55	81.5	99.6
60	71.1	94.8
65	60.4	87.2
70	50.0	77.8
75	40.5	67.4
80	32.0	56.9
85	24.8	46.9
90	18.9	37.9
95	14.3	30.1
100	10.6	23.6

Table 3.8: Truck Toll Level Diversion

* Indicates the average of toll tariff for classes 4 & 5

The table shows that the current toll levels for large trucks are very close to the revenue maximising position. In fact the model predicts that the revenue maximising average toll for large trucks would be around $49. An average truck toll of $49 however, would yield only a further 1% in revenues compared to the current toll levels.

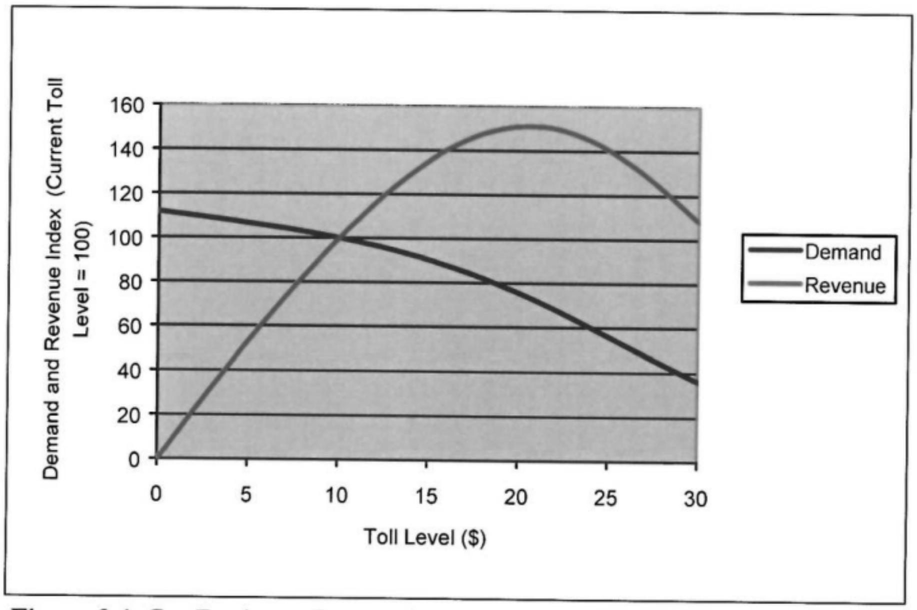


Figure 3.4: Car Business Demand and Revenue Diversion Curves

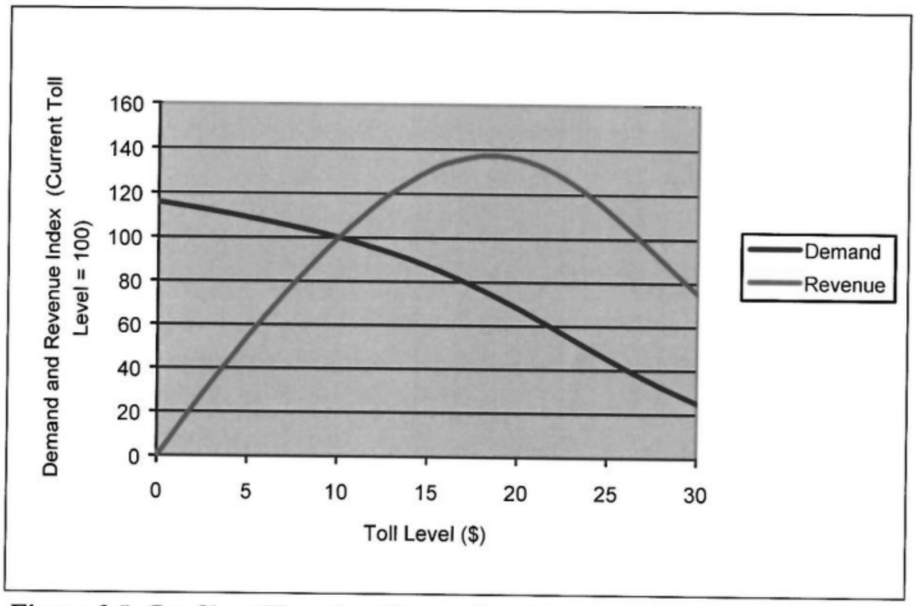


Figure 3.5: Car Short Vacation Demand and Revenue Diversion Curves

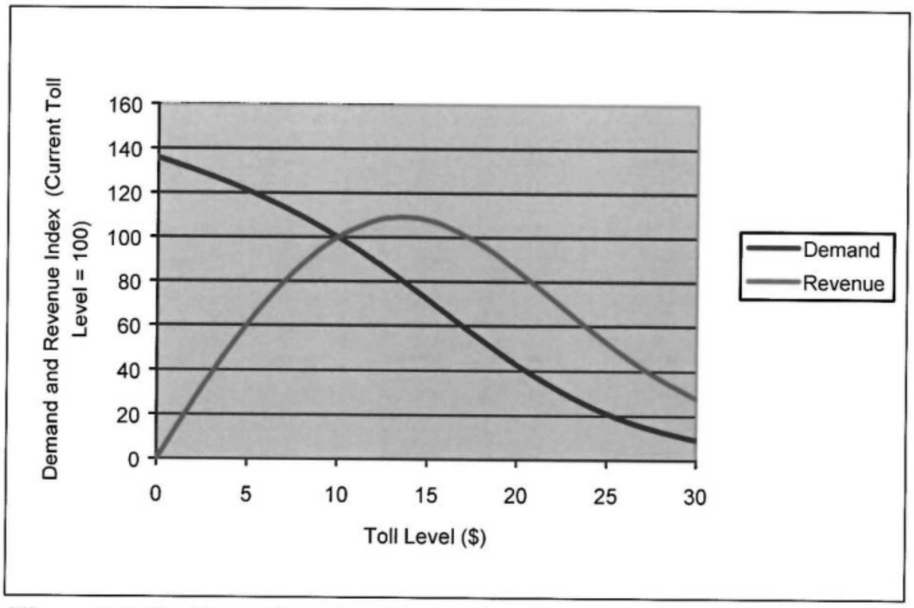


Figure 3.6: Car Long Vacation Demand and Revenue Diversion Curves

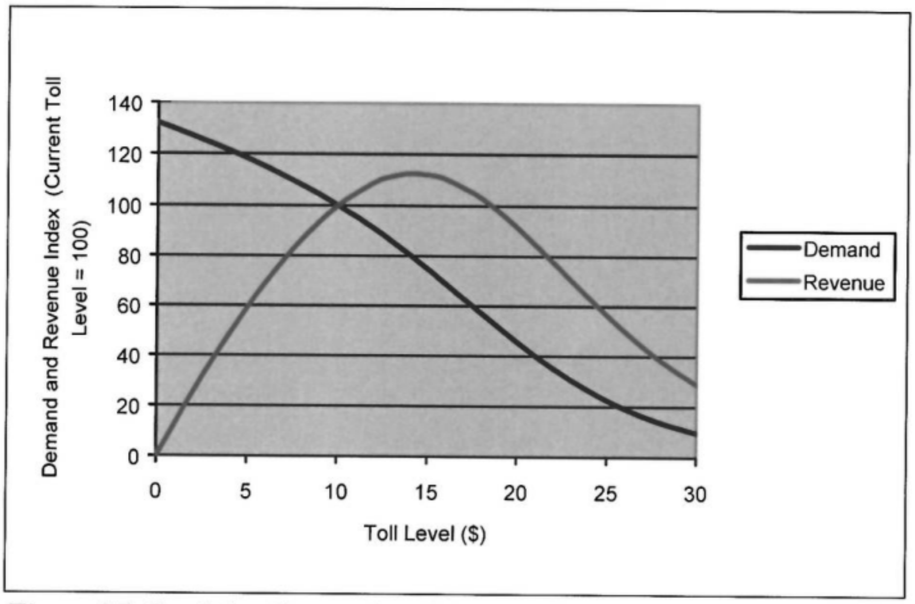


Figure 3.7: Car Other Demand and Revenue Diversion Curves

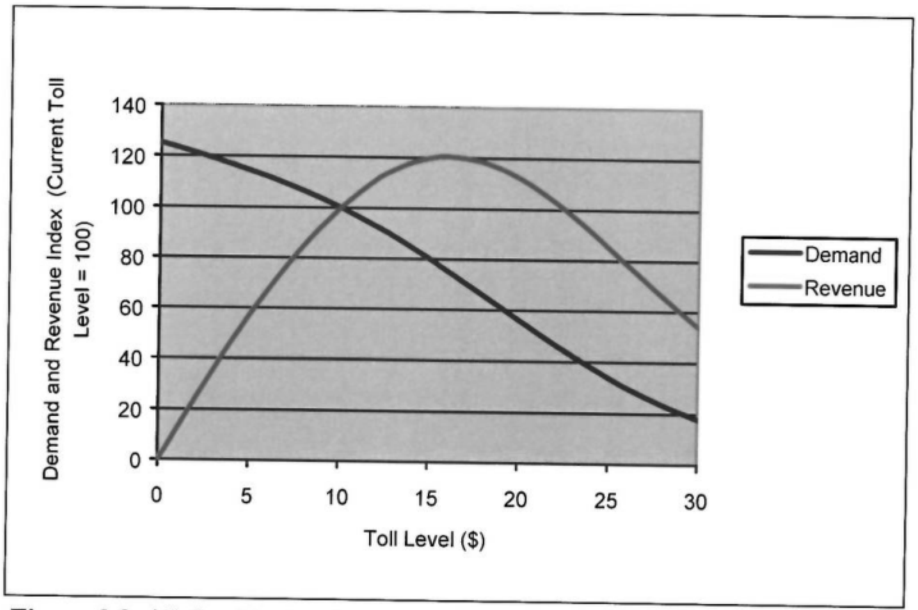


Figure 3.8: All Car Market Segments, Demand and Revenue Diversion Curves

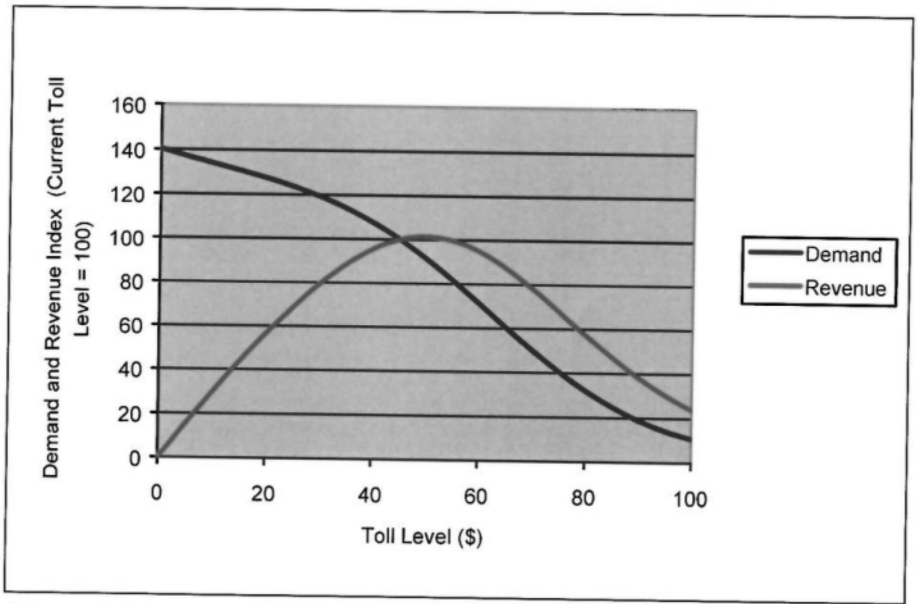


Figure 3.9: Trucks (Classes 4 & 5), Demand and Revenue Diversion Curves

4 Forecasting Methodology

4.1 *Introduction*

Background traffic growth is driven by economic, demographic and social developments in the area. In a stable society with an advanced economy, traffic volumes may fluctuate from year to year, but generally traffic volumes tend to increase over time.

Traffic forecasting generally involves the following steps:

- Collate historical traffic growth over time
- Compare traffic growth with changes in key explanatory variables over the same time period
- Where possible, develop mathematical relationships between traffic growth and the key variables to explain the historical growth
- Obtain forecasts of the explanatory variables
- Apply the mathematical formulae to predict traffic growth in the future.

Traffic on a particular route may also be affected by infrastructure changes such as improvements to alternative routes or increased modal competition. In the case of the Coquihalla Highway, the most important considerations are background traffic growth in the corridor and traffic growth on the Coquihalla Highway itself due to increased diversion from alternative routes as the real value of the toll has decreased over time, and to a lesser extent, increased competition from airlines. The following sections of the report look at each of those areas in turn.

4.2 *Historic Traffic Growth on the Coquihalla Highway*

4.2.1 *Passenger Vehicles*

Traffic growth on the Coquihalla Highways for passenger vehicles between 1987 and 1991 is shown in Figure 4.1 below.

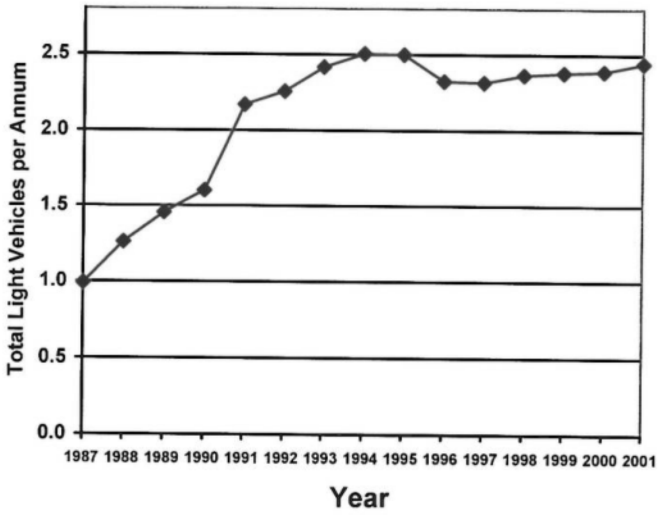


Figure 4.1: Light Vehicle Growth on the Coquihalla

The figure shows that traffic grew rapidly in the early years following opening in 1986, corresponding to the "ramp-up" period and the opening of new sections. The big jump in traffic between 1990 and 1991 is explained by the opening of the Okanagan Connector. Since 1991 however, traffic growth has been much lower, apart from a sharp increase in traffic between 1993 and 1995, which was followed by a sharp dip in 1996. Traffic growth between 1991 and 2001 averaged 1.2% per year, whilst the corresponding figure for the period 1996 to 2001 is 1.0% per year.

4.2.2 *Large Truck Traffic Growth*

The growth in large truck vehicles passing through the Coquihalla Highway tollbooths is shown in Figure 4.2 below.

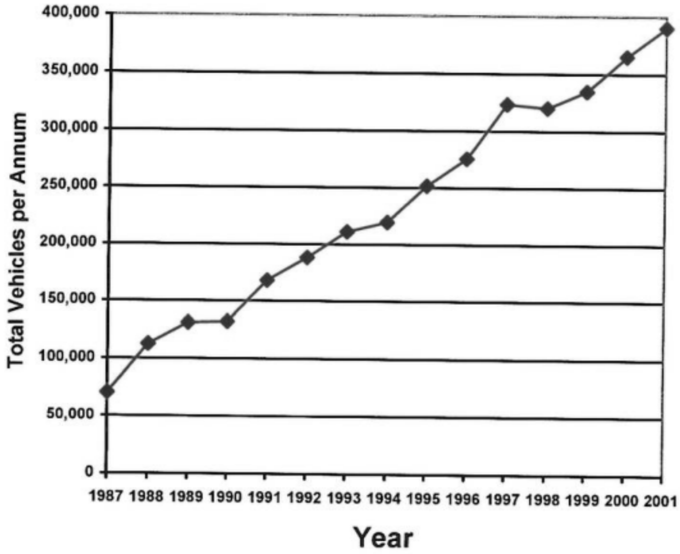


Figure 4.2: Large Truck Traffic Growth on the Coquihalla

In contrast to passenger vehicles, Figure 4.2 shows that large truck growth on the Coquihalla has been consistently strong. Between 1991 and 2001, the number of large trucks passing through the Coquihalla tollbooths increased by 8.8% per annum on average. The corresponding figure for the period 1996-2001 is 7.2% per annum.

4.2.3 *Traffic Growth by Section*

Figure 4.3 below shows the growth in total traffic volumes at the tollbooth, on the Okanagan Connector and on the Merritt-Kamloops Section. The figure shows that the growth patterns on all three arms of the Coquihalla have been fairly similar. Within the overall similar pattern however there are a couple of observations worth noting:

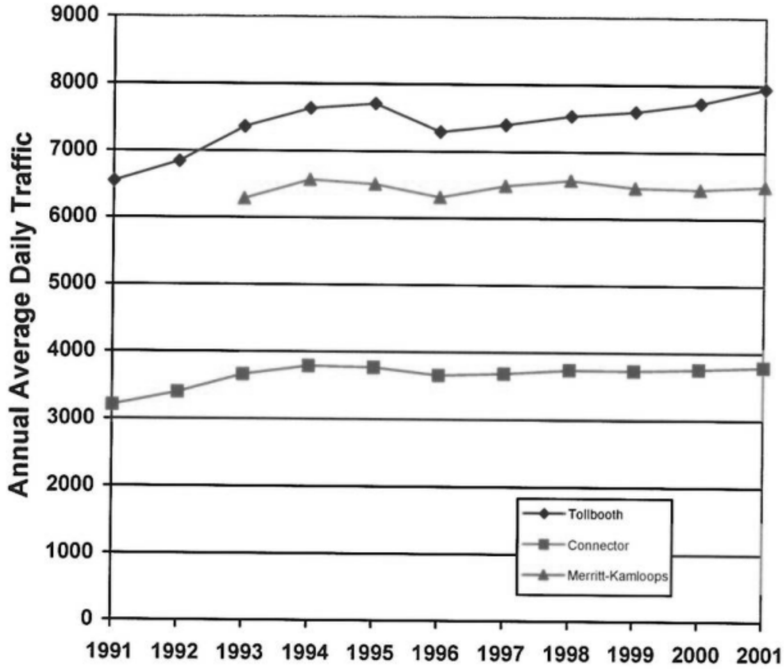


Figure 4.3: Traffic Growth by Section

1. Since 1993, total traffic at the tollbooth has grown by 8%, whilst traffic on the Connector and the Merritt-Kamloops sections has grown by only 3.7% and 3.2% respectively

2. The sharp drop in traffic in 1996 was most pronounced at the tollbooth itself (on average –500 vehicles per day), and least pronounced on the Connector (-100 vehicles per day). Average daily traffic on the Merritt-Kamloops section fell by around 200 vehicles per day in 1996 compared to 1995.

4.2.4 *Traffic Growth by Season*

Traffic growth by season is shown for light and heavy vehicles respectively in Figures 4.5 and 4.6 below. The graphs re-iterate the highly seasonal nature of light vehicle traffic on the Coquihalla, whilst showing that heavy vehicle traffic is less affected. What Figure 4.5 does not show is that the sharp drop in light vehicle traffic in 1996 was concentrated in just 4 months, namely July, September, October and December. Interestingly during 1993-1995, July traffic volumes were as high as, if not higher than, August traffic volumes, whereas typically they are 10-15% lower. Heavy vehicle traffic on the Coquihalla behaved somewhat erratically between 1997 and 2001 – this is probably due to varying weather conditions during those years – it is known for example that 1999 was a particularly bad year for road closures due to extreme weather.

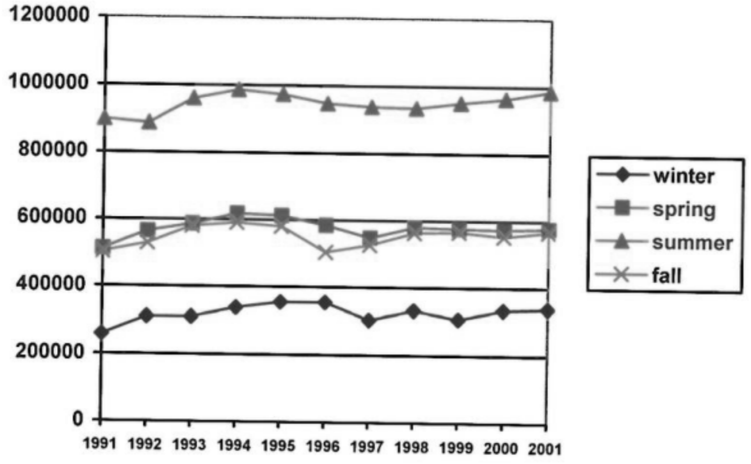


Figure 4.4: Seasonal Traffic Growth – Light Vehicles

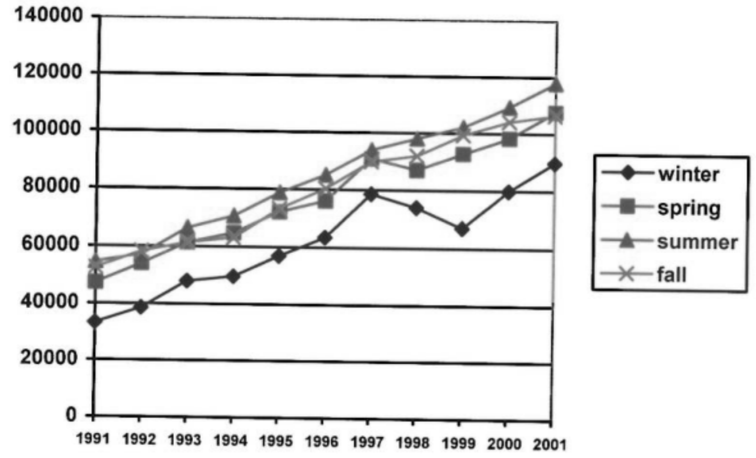


Figure 4.5: Seasonal Traffic Growth – Heavy Vehicles

4.3 Historic Traffic Growth in the Corridor

Figure 4.6 below charts historic traffic growth on Highway 1 West of Hope, the Coquihalla, Highway 1 North of Hope and Highway 3 East of Hope.

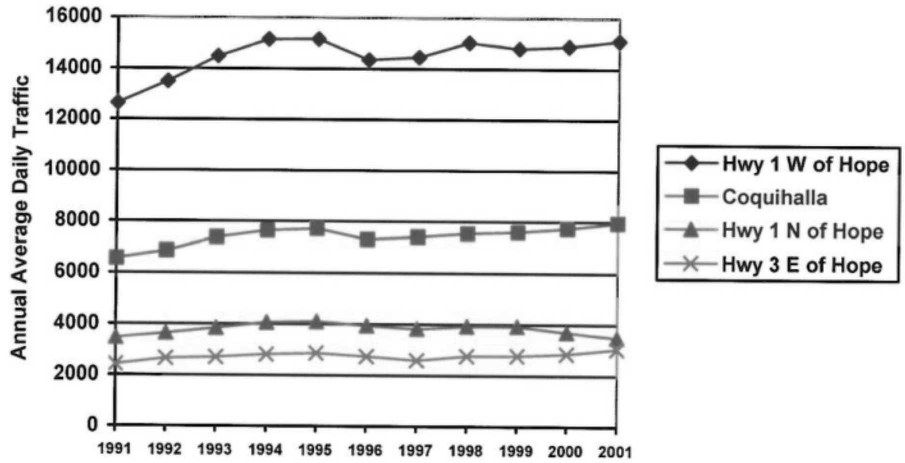


Figure 4.6: Corridor Traffic Growth

The graph shows that traffic on Highway 1 to the West of Hope has followed a similar pattern to traffic on the Coquihalla, although the fluctuations in traffic have tended to be more pronounced. Traffic on Highway 1 to the North of Hope rose slightly between 1991 and 1995 and then declined between 1995 and 2001. Traffic volumes on this route were virtually the same in 2001 as they were in 1991. Traffic volumes on Highway 3 have risen steadily during the same period. The conclusion to be drawn from this graph is that traffic growth in the corridor since 1991 has largely been captured on the Coquihalla Highway, and to a lesser extent, Highway 3.

4.4 Explanation of Light Vehicle Traffic Growth

The change in selected key socio-economic variables between 1991 and 2001 is plotted in Figure 4.7 below.

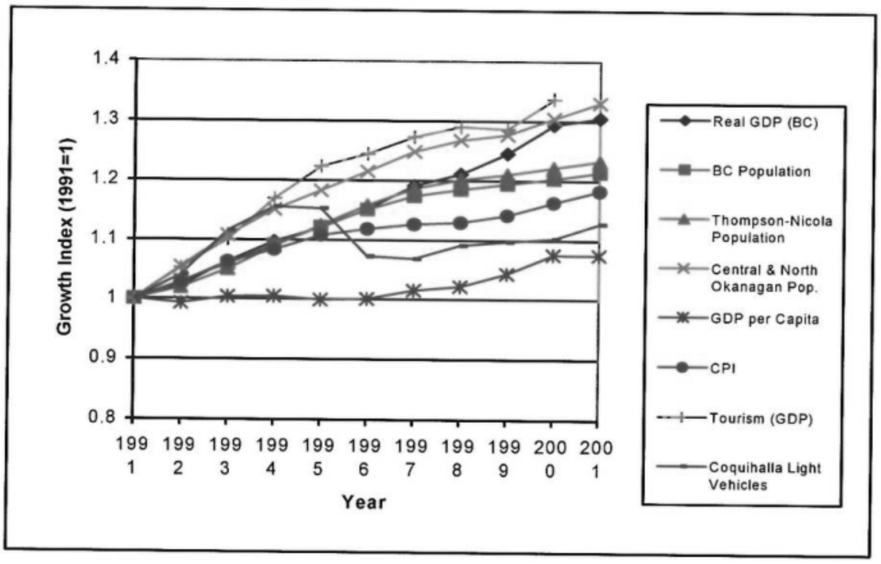


Figure 4.7: Growth of Socio-Economic Variables

Also shown in the graph is light vehicle traffic on the Coquihalla, again indexed against 1991 volumes. Figure 4.7 shows that whilst light vehicle volumes follow the general trend in most variables until 1994, none of the socio-economic variables can explain the sharp drop in traffic between 1994 and 1996. A multitude of other analyses were undertaken including the separate analyses of each arm of the Coquihalla Highway (Okanagan population versus traffic on the Connector for example). Unfortunately, no single variable, or combination of variables could adequately explain the historic traffic pattern.

The historic growth pattern in light vehicles between 1992 and 1996 can either be put down to abnormally high traffic volumes in 1993-1994 or a sharp drop between 1994 and 1996. It is difficult to explain the phenomenon in terms of unexpectedly high growth, especially when the high volumes are seen only in a limited number of months; July, September, October and December.

4.4.1 *Modal Competition*

The introduction of new low-cost air services in the region by WestJet in 1996 could partly explain the sharp drop in light vehicles in that year. However this does not explain why

a) traffic began to fall in 1995 before the entry of WestJet into the market

b) the traffic fall is actually less pronounced on the Okanagan Connector compared to other routes in the area when it would be expected otherwise due to the Vancouver-Kelowna service

Furthermore there are questions as to whether the airlines and the highway would serve the same markets – would vacationers need their vehicles whilst they are vacationing for example? Experience of low-cost operations elsewhere suggests that the majority of passengers are extracted from existing air services or are completely new trips that would not be otherwise undertaken. So, whilst some WestJet passengers may well have previously driven on the Coquihalla, this effect alone cannot explain the traffic patterns observed between 1994 and 1996. It is likely that the traffic patterns were due in part to other highly variable factors such as weather conditions. Indeed, because of the relatively low absolute volumes of traffic on the Coquihalla Highway, special events and occurrences can have a much larger impact on traffic figures that would be the case on a more heavily trafficked route.

4.5 *Explanation of Heavy Vehicle Traffic Growth*

Growth in Coquihalla truck traffic is plotted against growth in real GDP and CPI in Figure 4.8.

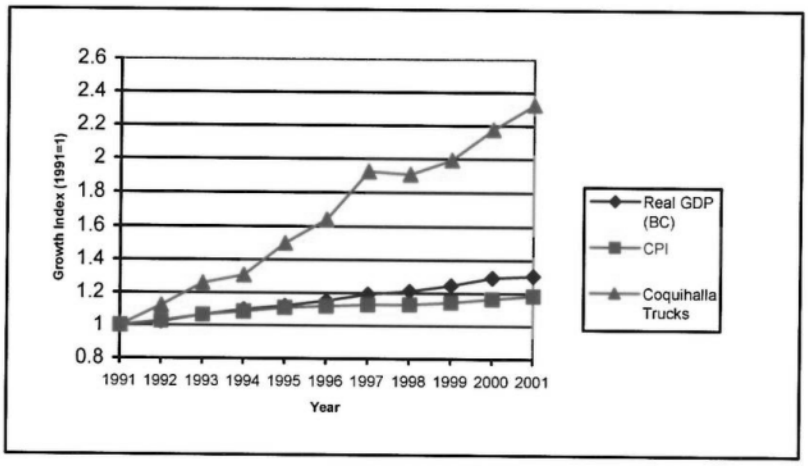


Figure 4.8: Truck Growth versus Real GDP and CPI

Truck traffic growth on the Coquihalla has far exceeded economic growth over the past ten years. Undoubtedly this is partly due to increased diversion from other routes, especially Highway 1. These two factors alone however cannot explain the rapid growth in truck traffic. Unfortunately, very little historic truck traffic data are available for other highways in the corridor (MoT classifying count stations were only introduced in mid-1999). Two-day truck traffic counts were undertaken on a number of routes in the summer of 1989 however and these illustrate both an increased diversion rate from Highway 1 to the Coquihalla since then, and a strong growth in truck traffic in the corridor as a whole.

4.5.1 *Growth Due to Increased Capture Rate on the Coquihalla Highway*

Tolls on the Coquihalla Highway have not increased since 1990. In real terms therefore they have fallen in value by 28% (1990 – 2002). This reduction in the real value of toll has increased the attractiveness of the Coquihalla markedly for truck drivers, especially when it is widely understood that truck power and performance levels have increased substantially over the same period, and the trucking industry has become more competitive making time savings more important. Analysing truck counts in the corridor from 1989 to 2002, it is estimated that the capture rate for the Coquihalla Highway compared to Highway 1 has increased from less than 50% in 1991 to around 70% in 2001. It is estimated that the corresponding car capture rate has risen from 75% to around 80% over the same period.

4.6 *Alternative Traffic Forecasting Approach*

Given the difficulties encountered in relating traffic growth to year on year growth in various socio-economic variables, a simpler approach was adopted looking at average growth in traffic and key variables between 1991 and 2001, including growth due to increased diversion. Traffic growth in the corridor and on the Coquihalla Highway is compared to the change in key variables in Table 4.1.

	Total Growth 1991-2001	Average Annual Growth
Coquihalla Truck Traffic Growth	130%	8.8%
Corridor Truck Traffic Growth	60%	4.8%
Estimated Growth Due to Increased Diversion	70%	5.0%
Coquihalla Light Vehicle Traffic	13%	1.2%
Corridor Light Vehicle Traffic Growth	8%	0.8%
Estimated Growth Due to Increased Diversion	5%	0.4%
Real GDP (BC)	29%	2.6%

BC Population	22%	2.0%
GDP/Capita	7%	0.7%
Disposable Income	0%	0%
CPI	18%	1.7%
Alberta GDP	52%	4.3%

Figure 4.1: Traffic Growth and Key Variables 1991-2001

4.6.1 *Truck Traffic Forecasting Recommendations*

Removing the diversion elements of the truck traffic growth on the Coquihalla, background traffic growth has been in the region of 4.8% per annum. This compares to growth of the BC economy of around 2.6% per annum. The difference between the two is probably due to external factors such as the higher economic growth in Alberta (around 40% of Coquihalla truck traffic has an origin or destination in Alberta) and other reasons. In the future, it is unlikely that the historically high truck traffic growth rates can be sustained. It is the opinion of the traffic forecasting team therefore that future background truck traffic growth rates will be close to the growth in real GDP of British Columbia.

According to the latest Conference Board of Canada economic forecasts, average annual growth rates for real GDP in BC will be around 2.8% per annum between 2002 and 2010 and around 2.6% per annum between 2010 and 2020. It is therefore predicted that future truck traffic growth rates on the Coquihalla will slow to these levels.

4.6.2 *Light Vehicle Traffic Forecasting Recommendations*

Removing the diversion elements of the light vehicle traffic growth on the Coquihalla, background traffic growth was in the region of 0.7% per annum between 1991 and 2001. This is abnormally low traffic growth by any standard. At the same time, the economy of BC grew at an average of 2.6% per annum. Since traffic growth is normally closely linked to economic growth, how can the differences be explained? The traffic forecasting team believe that the differences can be explained by examining GDP per capita statistics rather than gross GDP figures. As previously stated, the economy of BC over that period grew at an average of 2.6% per annum. The population of BC over the same period however grew at an average of 2.0% per annum, largely as a result of in-migration. Most of the economic growth therefore was "consumed" by population growth, and the real wealth of British Columbians grew very little. In fact, average disposable incomes in BC did not grow at all between 1991 and 2001. When it is considered that the majority of light vehicle traffic on the Coquihalla is made up of domestic vacation related trips, which are inherently sensitive to changes in wealth and income, it is perhaps less surprising that light vehicle traffic growth has been so low on the Coquihalla. Looking at the growth in GDP per capita over the period 1991-2001, it can be seen that this figures averages at 0.7% per annum. This compares to average background growth in Coquihalla traffic of 0.8% per annum. The traffic forecasting team therefore recommends that GDP per capita be adopted as the key forecasting variable for light vehicle traffic on the Coquihalla Highway.

According to the latest Conference Board of Canada economic and population forecasts, average annual growth rates for real GDP per capita in BC will be around 1.5% per annum between 2002 and 2010 and around 1.3% per annum between 2010 and 2020. It is therefore predicted that future light vehicle traffic growth rates on the Coquihalla will be similar to these levels, showing a small increase over historic growth rates observed between 1991 and 2001.

5 Traffic Forecasts

5.1 *Overview*

Traffic and revenue forecasts for 28 alternative tolling strategies were produced between December 2002 and July 2003. These scenarios are listed, together with the location of the results files, in Table 8.1 at the rear of this report. The traffic and revenue forecasts for the Base Case and three key scenarios are summarised in the following sections. Full year on year traffic and revenue forecasts for the Base Case for each toll category can be found in Appendix A.

For each scenario central, low and high growth forecasts are presented. All revenues shown are in **current year** prices. The scenarios definitions are as follows:

- Base Case — All tolls as now, remaining fixed over the concession period.

  No discounts available

- Scenario 1 — Category 1 tolls remain the same as today, rising annually in-line with inflation after 2004.

  Category 2-6 tolls remain the same as today, rising annually in-line with inflation after 2004.

  No discounts available

- Scenario 2 — Category 1 toll increased to $13 in 2004, rising annually in-line with inflation thereafter.

  Category 2-6 tolls remain the same as today, rising annually in-line with inflation after 2004.

  No discounts available

- Scenario 3 — Category 1 toll increased to $13 in 2004, rising annually in-line with inflation thereafter.

  Category 2-6 tolls remain the same as today, rising annually in-line with inflation after 2004.

A frequent traveller pass will be available to all Category 1 vehicles. This pass would cost $10 and cover a three-month period. The first 4 trips on the Coquihalla Highway would be charged at $10 per trip. All subsequent trips during that 3-month period would be free of charge.

Likely take-up rates for the frequent traveller pass (FTP) were derived from the results of the surveys undertaken in May 2003. From these surveys, it is estimated that around 20% of Category 1 vehicles passing through the toll booths would possess a frequent traveller pass, and that the average cost per trip for those possessing FTP would be around $5.

5.2 *Base Case Forecasts*

Traffic and revenue forecasts for the Base Case are summarised in Table 5.1 below. Full year on year traffic and revenue forecasts for each toll category can be found in Appendix A.

Forecast Year	2004		2014		2024		2034	
Growth Scenario	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)
Low	8,500	46.2	9,900	56.2	11,400	66.7	12,600	73.7
Central	8,600	47.1	11,100	63.2	14,100	82.7	15,900	96.1
High	8,800	48.1	12,500	71.0	17,500	102.4	21,700	131.1

Table 5.1: Base Case Traffic and Revenue Summary

5.3 **_Scenario 1 Forecasts_**

Traffic and revenue forecasts for the Scenario 1 are summarised in Table 5.2 below.

Forecast Year	2004		2014		2024		2034	
Growth Scenario	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)
Low	8,500	46.2	9,400	64.1	10,500	88.0	11,600	118.5
Central	8,600	47.1	10,100	69.8	11,600	101.4	13,000	143.6
High	8,800	48.1	11,400	78.4	14,300	125.7	17,800	196.3

Table 5.2: Scenario 1 Traffic and Revenue Summary

5.4 **_Scenario 2 Forecasts_**

Traffic and revenue forecasts for the Scenario 2 are summarised in Table 5.3 below.

Forecast Year	2004		2014		2024		2034	
Growth Scenario	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)
Low	7,600	50.2	8,500	69.4	9,500	95.2	10,500	128.2
Central	7,800	51.2	9,200	75.5	10,500	109.2	11,900	154.1
High	8,000	52.2	10,300	84.8	13,000	135.3	16,200	210.6

Table 5.3: Scenario 2 Traffic and Revenue Summary

5.5 *Scenario 3 Forecasts*

Traffic and revenue forecasts for the Scenario 3 are summarised in Table 5.3 below.

Forecast Year	2004		2014		2024		2034	
Growth Scenario	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)	Annual Average Daily Traffic	Annual Revenue ($million)
Low	8,000	47.1	9,000	65.2	10,000	89.5	11,000	120.5
Central	8,200	48.0	9,600	71.0	11,000	103.1	12,400	145.8
High	8,400	48.9	10,800	79.8	13,700	127.8	17,000	199.3

Table 5.3: Scenario 3 Traffic and Revenue Summary

5.6 *Comparison of Revenue Forecasts*

For comparison purposes only, the Present Value of predicted 2004 to 2034 revenues for each scenario and each growth assumption was calculated using a discount rate of 8%. The results are presented in Table 5.5 below, compared to the Base Case value, which has been given an index of 100.

	Growth Assumption		
Scenario	Low	Central	High
Base Case	89	100	114
Scenario 1	103	113	130
Scenario 2	112	122	140
Scenario 3	105	115	132

Table 5.5: Revenue Comparison of Main Scenarios

6 Tolling Systems & Technology

6.1 *Introduction*

The purpose of this chapter is to provide a review of tolling system and technologies applicable to the Coquihalla Highway – within the context of this Investment Grade Study.

Currently, there is a single Toll Plaza along the Coquihalla Highway. This plaza is located 60 km southwest of Merritt and 55 km northeast of Hope. Figure 6.1 provides an overview of the corridor and the location of the toll plaza. Tolls are charged on a per vehicle basis (i.e., passengers are not charged), in accordance to the following classifications:

- $5 Motorcycles
- $10 Car, light truck with trailer or camper, all recreational vehicles with or without a vehicle in tow.
- $20 2 axle vehicles 6,000 kg or more with or without a trailer
- $20 2 axle truck tractor with or without a trailer
- $30 Vehicles or combinations with 3 axles
- $40 Vehicles or combinations with 4 to 5 axles
- $50 Vehicles or combinations with more than 5 axles

Toll transactions are processed manually at the plaza, and include cash, credit card, and debit.

This review is intended to identify potential technology applications for enhancing the existing toll system, and supporting additional toll collection points between Merrit and Hope, and Merrit and Kelowna. Accordingly, this review covers the following:

- Review of Toll System Concepts
- Potential Applications/Improvements for the Coquihalla
- System Requirements
- System Wide Implications

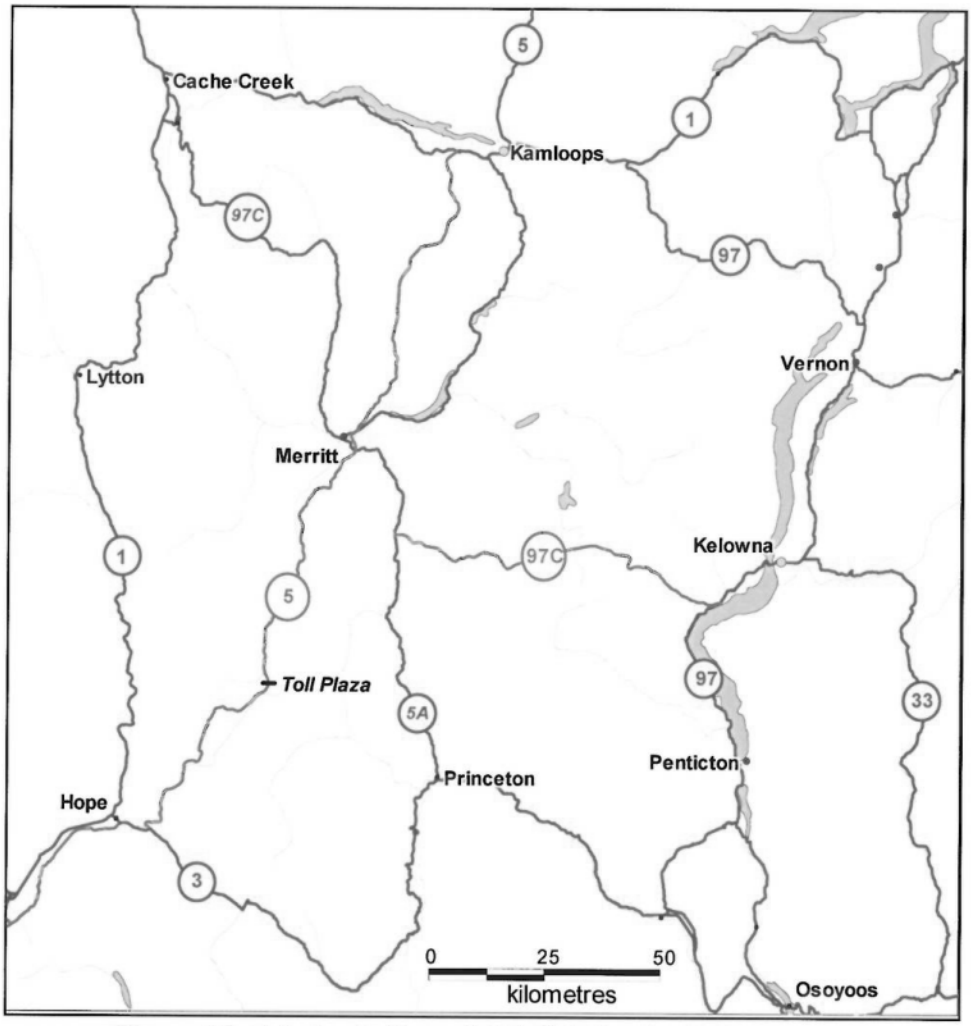


Figure 6.1: Existing & Potential Toll Collection Points

6.2 *Overview of Tolling System Concepts*

6.2.1 *Toll Collection Strategies*

Tolls can be collected using one or a combination of two basic strategies:

Mainline toll collection points involve one or more points of payment located independently from other toll collection points, whereby users pay a flat fee associated with that particular toll collection point. This strategy is also sometimes referred to as an "open system" implying that the toll collection point could be bypassed if other routes are available.

Entry and exit toll collection points involve multiple points of assessment strategically located to collect payment from all users based on the distance travelled between the point of entry and point of exit. This strategy is also sometimes referred to as a "closed system" implying that toll assessment points are located at all points of entry and exit.

6.2.2 Toll System Configurations

Different toll system configurations can be applied to collect payment at a given toll collection point regardless of whether they are part of an isolated "open system" or entry/exit "closed" system.

There are two basic toll system configurations that can be used for the collection of tolls:

Plazas Toll Collection requires motorists to stop or slow down to participate in a payment transaction. The actual method of payment can vary and include combinations of manual cash transactions, automatic coin transactions, or automatic smart-card or transponder based transactions.

Electronic Toll Collection (ETC) permits motorists to pass the toll collection point(s) at free flow speeds while the toll payment transaction is processed automatically. The actual technology automating the payment transaction can be based on the use of transponders or automatic photo tracking of license plates for vehicle identification.

There are a number of technical, operational, institutional, and financial issues associated with the above two toll system infrastructure options. A summary of these issues is tabulated in Figure 6.2. Issues specific to the potential applications to the Coquihalla Highway toll system are discussed in Section 6.3.

PLAZA TOLL COLLECTION	ELECTRONIC TOLL COLLECTION
Technological Issues ▪ Technological risks are minimal with these types of systems. They have been operating for considerable periods of time ▪ Mixed systems (i.e. cash, automatic coin, and gated ETC) would have to be over designed to minimize impacts of failure. ▪ The size of the plaza can become large. ▪ Provides less redundancy than full ETC **Institutional Issues** ▪ Environmental impacts (noise and emission) ▪ Negative Public perception of additional stop for toll payment on top of existing signals. ▪ Needs proper legal framework for pursuing violators/non-payers **Financial Issues** ▪ Revenue risk/loss • Through bypassing of the barrier toll plazas • Through fraud in connection with cash handling • Through fraud at automatic machines ▪ Additional Land/property acquisition ▪ Higher capital costs due to greater land requirements ▪ Engineering challenges for plaza location due to difficult topography ▪ High operating costs **Operational Issues** ▪ Higher level of staffing ▪ Security for staff & cash handling ▪ Reliability of equipment and effect of failure/maintenance of equipment on capacity, throughput, and need to over design or provide redundancy. ▪ Safety of higher-speed ETC users next to stop-and-go manual payment users ▪ Safety for booth attendants near ETC lanes, or having to cross them for access to booths.	**Technological Issues** ▪ These systems have been in operation long enough, with considerable operating experience, that the technical risk is low. ▪ Accuracy of better than 99.5% to identify vehicles (but not collection of tolls). ▪ Rapid evolution of transponder standards between the present and downstream implementation time-frames. ▪ Migration towards micro-chip embedded license plates, more of a political issue than a technical one. ▪ Migration towards smart-card based transponders in multi-application systems, otherwise higher cost and more bulky equipment ▪ Evolution of smart card standards for other electronic payment for transportation services such as transit, parking, ferries, etc. ▪ Compatibility with evolving standards associated with AVI for CVO safety assurance and credentials administration ▪ Expansion of the Coquihalla toll system as one element in one integrated toll system framework in BC **Institutional Issues** ▪ Public perception of privacy violation ▪ Users need to easily perceive or "feel" the benefits to accept ▪ Need to detect non-ETC-equipped users by video systems or other means ▪ Easier to market with increasing number of similar applications ▪ Reciprocal agreements required with other agencies for out of province users ▪ Operating agency will require a recourse for collection of unpaid tolls, such as denying vehicle insurance or registration etc. ▪ Vehicle registration and insurance data bases to be current for toll billing ▪ Difficulty of enforcement, both technological and legal **Financial Issues** ▪ Difficulty to collect from out-of-province users ▪ Can trucks be required to carry transponders? ▪ Need to classify and recognize toll-exempt vehicles ▪ Implementation through a public-private partnership and related issues **Operational Issues** ▪ Need extensive Revenue Management System, ▪ Need Enforcement and billing system ▪ Need access to and checking of vehicle registration and/or insurance records for accurate billing ▪ Need good video license plate imaging to reduce the video exception processing requirements and cost ▪ Need Customer Service Centre, essential for good service relations but challenging to achieve operational objectives at an acceptable costs

Figure 6.2: Toll System Configuration Issues

6.3 *Potential Applications for the Coquihalla*

The two strategies and the two toll system technologies described in section 6.2 can be combined into 4 different basic tolling options. However, not all of these options are relevant to the Coquihalla Highway. In order to identify potential applications to the Coquihalla Highway, an understanding of the current and potential needs of the Coquihalla Highway toll system is required. These needs can be summarised as follows:

- Enhancing the efficiency of the toll plaza through the implementation of self-serve and/or automated lanes
- Supporting the capability to provide local and/or frequent users with discounted tolls
- Supporting potential new toll collection points (such as Merritt-Kamloops and Merritt-Kelowna sections)
- Ensuring downstream inter-operability with other e-payment, commercial vehicle and ITS applications in the region

In order to keep the discussion of potential toll system applications focused to the needs of the Coquihalla, the matrix presented in Table 6.3 has ben prepared to summarise/shortlist applicable toll system options.

Toll Collection Strategies & System Configurations	Mainline Toll Collection	Entry/Exit Toll Collection
Plaza Toll Collection	The existing configuration of the Coquihalla toll system is a "mainline toll plaza". Opportunities exist to enhance toll processing capabilities at the plaza through the introduction automated lanes (i.e., incorporating smart-cards or transponders). The "enhanced" mainline plaza concept is also ***applicable*** in context of the addition of toll collection points between Merritt and Kamloops, and Merritt and Kelowna, and the potential need to distinguish local and/or frequent users.	The Entry/Exit toll collection strategy is ***not applicable*** to the Coquihalla Highway corridor. Entry/Exit systems are applicable along roadways where traffic leakage may affect revenues – thus requiring all points of entry and exit to be toll assessment points to create a "closed" system. Even with the addition

Electronic Toll Collection	In context of the Coquihalla Highway alone, ETC capabilities are not considered relevant due to the high percentage of infrequent users. However, ETC capabilities *may be applicable in the future*, when other ETC systems in the region have generated a significant enough population of vehicles equipped with transponders. At that time, the mainline plazas can be modified to include one or two full ETC lanes allowing vehicles to bypass the plaza, safely, at free-flow speeds.	system. Even with the addition of toll collection points between Merritt and Kamloops, and Merritt and Kelowna, Entry/Exit toll collection will not be required due to limited opportunities for leakage.

Figure 6.3: Matrix of Toll System Options

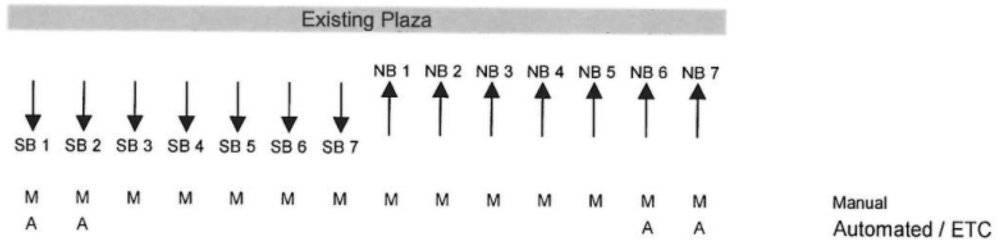
Based on the above, the most applicable toll system concept for enhancing the existing facility, supporting discounted tolls for local and/or frequent users, and for potentially adding new toll collection points between Merritt and Kamloops, and Merritt and Kelowna, is the mainline toll plaza concept with self-serve and/or automated capabilities. The following provides additional considerations with respect to this concept.

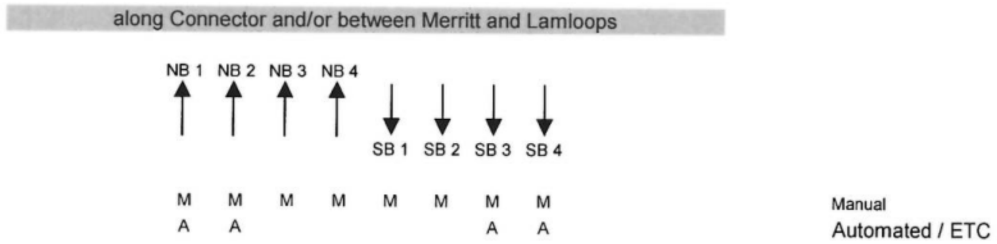
As noted earlier, the existing toll facility along the Coquihalla is a single mainline toll plaza located approximately halfway between Hope and Merritt; however, toll collection at this plaza is currently limited to manual transactions involving cash, credit, and debit. The addition of self-serve/automated capabilities will require the use of either smart cards or transponders as the mechanism for electronic payment (i.e., both can be used to identify vehicles and deduct the appropriate charges from the vehicle owners' tolling accounts). Operationally however, smart card users will have to come to a complete stop in order to "swipe" the card by the corresponding reader, while transponder users can go through a "rolling" stop as they pass by the corresponding reader.

Issues that should be considered for the introduction of self-serve/automated lanes for the Coquihalla Highway include the following:

- "Throughput" calculations should be taken into account by comparing peak demands, against the combined throughput of manual and automated lanes – taking into account the potential percentage of users that would use the automated lanes versus the manual lanes. Based on the projected peak demands of 1600 vehicles per hour per direction along the existing tolled stretch, and 800 vehicles per hour per direction for the other two potential sites (i.e., along the Connector, as well as between

Merritt and Kamloops), the following lane assignments were estimated for adding in automated Smart Card or ETC capabilities. Even with assuming that the automated lanes would attract 15% of the peak demands, only one automated lane was identified to be adequate; however, as illustrated below, two automated lanes have been assigned in each direction to provide redundancy. Also, manual capabilities are retained along those lanes.





- Based on the throughput calculation, it can be determined whether some of the existing toll plaza lanes can be 'converted' to automated lanes, or whether additional lanes are required. Due to adjacent topography, widening of the plaza may be costly, unless the northbound and southbound toll booths/lanes can be offset.

- Since the toll plaza would be supporting both manual and automated lanes, the toll plaza will have to support a combination of payment methods within the toll collection lanes in order to ensure that a level of redundancy is provided during equipment failures and maintenance.

Depending on the vehicle/toll pricing structure, the selected Automatic Vehicle Identification technology, and the overall configuration and architecture of the system, the toll lanes equipped with electronic payment capabilities may need to be complemented by an Automatic Vehicle Classification (AVC) system to determine the correct toll amount that is to be deducted from the user's account – based on vehicle classification (currently, vehicle classifications are carried out visually by the toll booth attendant).

The toll lanes equipped with electronic payment capabilities may also need to be complemented by a Vehicle Enforcement System to prevent unauthorized users from using the automated lanes. In a plaza environment, enforcement can involve a range of options from traditional gates through to image capture systems that can photograph a vehicle's licence plate.

It should also be noted that the self-serve/ automated lane concepts discussed herein are aimed at both enhancing efficiency, and at using the vehicle identification technology as a potential mechanism for supporting discounted tolls for local and/or frequent users. Other discounting mechanisms however, can also be adopted without necessarily automating any toll plaza lanes. For example, a frequent traveller loyalty program can be accommodated using vehicle license plates as the identifier for keeping track of the number of trips undertaken and an associated pass or smart card that is handled by a toll booth attendant to confirm past frequency of trips and the applicable toll rate.

High-level cost estimates for upgrading the existing toll system to accommodate automated/ self-serve lanes could range between $1.5 million for a fairly simple magnetic trip card concept to $10 million for an ETC type solution.

These costs include building, back-office, and lane equipment costs, along with 30% for design and 30% for contingency. It should be noted that the back office costs (ranging around $1-2M for Smart Cards and $3-5M for Transponder based) are difficult to estimate if there are no other regional systems/services with which those cards or transponders are shared with. The back office cost estimates presented here are relatively high when one considers the size of the target audience, but on the low side if compared to larger systems/coverage areas. Accordingly, the operating costs are also difficult to estimate – because they are tied into the back-office operations, and are highly dependent on the smart card/transponder sales, service, distribution mechanisms which can be high when there is a low level of market penetration.

6.4 *Toll System Technology Components*

As noted above, the components required to add automated toll lanes to the Coquihalla Toll System include:

Electronic Payment System (EPS)

Automatic Vehicle Classification (AVC)

Vehicle Enforcement System (VES)

The following sections provide an overview of current, relevant technologies associated with the above.

6.4.1 *Electronic Payment (EPS)*

Automating the payment process in tolling applications requires a means of identifying vehicles for the purpose of collecting a toll from its owner. In context of the Coquihalla Highway toll system, the ability to electronically identify vehicles for billing purposes also provides the additional capability of distinguishing local users from other users.

The two mechanisms considered herein are smart cards and transponders, as discussed below.

6.4.2 *Smart Cards*

A smart card is a type of plastic card embedded with a computer chip that stores and transacts data between users. This data is associated with either value or information or both and is stored and processed within the card's chip, either a memory or microprocessor chip. The card data is transacted via a reader that is part of a central computing system. Smart cards improve the convenience and security of transactions, and storage of user and account identities.

There are two basic categories of smart cards:

Contact smart cards are the size of a conventional credit or debit card with a single embedded integrated circuit chip that contains just memory or memory plus a microprocessor. Contact smart cards must be inserted into a card acceptor device where pins attached to the reader make "contact" with pads on the surface of the card to read and store information in the chip. Contact smart cards are the size of a conventional credit or debit card with a single embedded integrated circuit chip that contains just memory or memory plus a microprocessor.

Contactless smart cards have all the features and functions found in contact smart cards, plus an embedded antenna (instead of contact pads attached to the chip) for reading and writing information contained in the chip's memory. Contactless cards do not have to be inserted into a card acceptor device. Instead, they need only be passed within range of a radio frequency acceptor to read and store information in the chip. Contactless smart cards are used in many of the same applications as contact smart cards, especially where the added convenience and speed of not having to insert the card into a reader is desirable.

6.4.3 Transponders

RF transponders are currently the most popular Automatic Vehicle Identification (AVI) technology for toll applications in North America, and are at the center of an evolutionary industry struggle towards standardization. There are currently three types of RF tags available on the market:

Type I **–** transponders have been around for a long time, and are small plastic credit card sized devices that store permanent information (such as vehicle/patron identification data for tolling). These transponders are placed on vehicle windshields or bumper or roof; every time the vehicle passes below a transponder reader, the unique vehicle identification data is correlated with location and time data, and transmitted to a central system for billing purposes.

Type II **–** transponders operate exactly the same as Type I transponders with the added benefit of supporting both read and write functions. That is, the data stored on the vehicle transponder can be dynamically updated. For tolling purposes, application of this added functionality can include providing status information to the driver regarding pre-paid accounts; for example, when a vehicle passes a reader/antenna at a toll assessment point and the transponder is read to identify the patron and the status of the prepaid, the transponder can then be encoded with a 'low" or "empty" code which triggers the transponder's LED indicator to yellow or red respectively.

Type III **–** transponders, also referred to as smart tags, have two classes that are typically referred to as Type III Smart Tag and the Smart Card with Type III Smart Tag. The Type III Smart Tags are similar to the Type II tags except they have more memory and a microprocessor that can interface with other systems and exchange data. The Smart Card with a Type III Smart Tag is comprised of an RF transponder with an interface to a smart card via a serial connection; these smart cards are integrated circuit (IC) devices with their own microprocessor and memory for storing account information.

While the technological evolution of transponders is progressing, providing increased processing power, memory, and interfaces to other systems and devices, the biggest and most critical issue hindering the potential benefits that could be derived from these "smart tags" is the lack of standardization regarding the communications protocols that the transponders use with the roadside reader. The main technology issue affecting interoperability between AVI systems relates to the communications protocols that different manufacturers of toll transponders and transponder readers use for the exchange of information between the transponder and the roadside transponder reader.

Most of the differing proprietary protocols used by transponder manufacturers are based on two general operating principles for Dedicated Short Range Communications (DSRC):

Passive (also referred to as backscatter): With this type of protocol, the tag rests "passively" until an RF pulse is beamed at it, the tag then reflects a modified signal. The modified signal is encoded with data from the tag.

Active: protocols require the tag to transmit an RF signal to a roadside reader

The selection of the appropriate AVI technology has significant implications towards compatibility with other AVI systems (both for tolling and other purposes).

6.4.4 *Automatic Vehicle Classification (AVC)*

The application of AVC technologies in tolling is intended to automate the process of determining the classification of vehicles for the purpose of charging the appropriate amount of toll. The three key determinants for vehicle classification are:

Number of axles

Number of tires

Dimensions (height, length, wheelbase, etc.)

Table 6.1 below provides a tabulation of various vehicle classification technologies relative to the three determinants referenced above.

Vehicle Classification Technologies	Axle Detection	Tire Detection	Dimension / Weight Detection
Loops – Magnetic Induction, Piezoelectric tube	✔		
Treadles – Electromechanical, rubber, piezoelectric	✔	✔	
Scanning Devices			
▪ Light Curtains	✔		✔
▪ Laser Scanner	✔		✔
▪ Ultrasonic Scanner			✔
▪ Infrared Scanner			✔
▪ Acoustic			✔
Weigh in Motion – Bending plates, Capacity strip, piezoelectric sensor	✔	✔	✔
Video Image Processing			✔

Table 6.1: Vehicle classification technologies

As illustrated above, most of the technologies identified for vehicle classification are geared towards one or two of the classification determinants; for example, loops and treadle technologies are effective in detecting the number of axles and tires, while scanning technologies are effective in establishing 2 or 3 dimensional vehicle profiles. Emergence of smart loops are permitting the classification of up to 23 classes of vehicles based on vehicle signature recognition.

Therefore the key issue in selecting a technology for vehicle classification is to ensure its accuracy relative to the type of classifying that is required. Specifically if the established toll rates require:

Classification by weight, then loop and treadle-based technologies can be used. Typically, using the number of axles for classifying by weight "category" is acceptable (even though over-weight vehicles can not be singled out).

Classification by size and dimension, then the emerging technology of choice (as used for the Highway 407 ETC system) is 3 dimensional laser based scanning systems. The primary advantage of these systems is the relative accuracy at high speed / volume combinations; the size and mounting requirements of the equipment is similar to, and can be integrated with, AVI and VES components; and, the equipment is non-evasive to the roadway pavement thus minimizing installation and maintenance costs.

6.4.5 Vehicle Enforcement System (VES)

Historically, toll collection enforcement has been accomplished using gated toll booths, toll attendants, and police patrols. In more recent times, advances in video image processing has enabled the automatic capturing of information about violators, such as license plate numbers, for enforcement purposes or for billing purposes.

One of the benefits of a manual collection and enforcement system using a physical plaza is a low violation rate. However, this benefit is outweighed by many negative attributes associated with a toll plaza, such as low vehicle throughput, higher capital and operating costs for additional traffic lanes on the plaza approaches, cash handling, manual enforcement, etc.

Recent advances in vehicle identification and license plate recognition have addressed many of these issues, and are able to identify and validate vehicles electronically, at normal highway speeds, eliminating the need for additional toll plaza lanes. The systems identify the vehicle, determine whether the vehicle has a transponder on board, and if not, captures an image of the vehicle license plate.

Once captured, the license plate image is converted to an actual license plate number, with associated jurisdiction information, to permit the automatic searching of the jurisdiction's motor vehicle records to determine the registered owner of the vehicle and mail out a violation fine or bill notice. The method of converting the license plate image into data can be manual, or based on Optical Character Recognition (OCR) technologies, or a combination.

<u>Technologies</u>

Image Capture Technologies:

Photograph / Video Based – Early systems employed the use of cameras for taking photographs, or cameras with video recorders for capturing images of violators. Generally, the operation of these technologies for enforcement has proven to be extremely labour intensive due to the level of effort required to manage the equipment, exchanging of films/video tapes, storage of pictures/video tapes, as well as the effort required for manual image processing (discussed below).

Digital Imaging – Most current applications employ digital imaging as part of their violation enforcement system, which involve video based monitoring that are based on digital image capture and storage. Digital imaging facilitates the electronic storage and transmission of images efficiently.

Image Processing Technologies:

Manual – Review of images manually is a labour intensive process that requires the viewing of individual images, and the keying in of license plate data into a central computer for subsequent automated look-up in the appropriate jurisdiction's motor vehicle records for sending out a violation fine or bill.

Optical Character Recognition (OCR) – With the emergence of digital imaging for the capturing of violator license plate images, OCR technologies are also improving and allow the automatic recognition of license plate data for the purposes of extracting the license plate number and issuing jurisdiction. The current state-of-the-art OCR applications for automatic recognition of license plates does not have 100% accuracy, and requires manual intervention for the processing of those images that the system cannot process. Application of OCR on the Highway 407 toll system in Toronto currently achieves "hit-rate" of approximately 80% of images for automatic processing, resulting in the manual processing of the remaining 20%. The manual processing effort is however more streamlined as most OCR systems display, to the viewer, the closest matches that the system was able to find but not confirm.

Issues

In the planning of a VES for toll applications, the following issues need to be considered.

Image content is an important issue to consider in system design; on one hand the camera field of view must be large enough and at an acceptable resolution to provide the required license plate data, while on the other hand, too large an image may pose privacy issues if driver or passengers are visibly in the image.

Image accuracy and quality must be taken into account, and system design must address issues associated with illumination / weather and shutter speed, front versus rear license plates, and the number / sequence of images required (of the same vehicle) to ensure data capture.

Image management generally covers issues associated with compression, storage, management, and archiving of the images both before and after processing.

Image processing is the main issue affecting the efficiency and economics of a VES for toll applications. Depending on the level of manual intervention required, appropriate resources both in terms of staff and computer processing power need to be allocated for the processing of license plate data. In a fully manual system, it is estimated that 75 images could be processed by one person in one hour, this translates to viewing/entering data for approximately 1.25 images per minute. Comparatively, based on experience from Highway 407, this manual processing rate can double to approximately 150 images per hour (or 2.5 images per minute) when OCR is used – since the manual intervention is only required to check or confirm those that the system could not match at the required confidence level. Depending on the number of potential vehicles that may need to be processed manually, the above processing rates can be used to establish required resources and associated costs.

Jurisdictional and institutional issues also need to be considered. Specifically, the accommodation of license pates from other provinces and states, access to information from motor vehicle departments of other provinces/states, and local legislation to collect tolls via this type of technology, and assess and collect associated fees.

6.5 System Wide Implications

The preceding sections have provided a description of the technologies and issues associated with the components required to implement automated tolling capabilities for the Coquihalla Highway toll system. Although the scope of this project is limited to the Coquihalla Highway, the use of smart cards and/or transponders for tolling purposes have implications that go beyond the Coquihalla Highway toll system.

The British Columbia Provincial ITS Vision and Strategic Plan (completed in November of 2001), includes a provincial ITS architecture that illustrates the linkages between tolling and other electronic payment systems, thus highlighting the critical links for future interoperability etc. Figures 6.4 and 6.5 illustrate the relevant ITS architectures developed for BC.

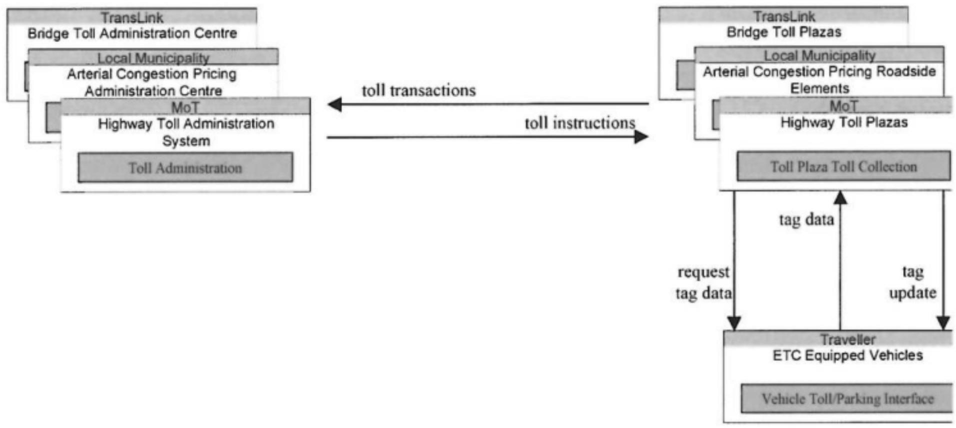


Figure 6.4: Provincial ITS Architecture for Tolling

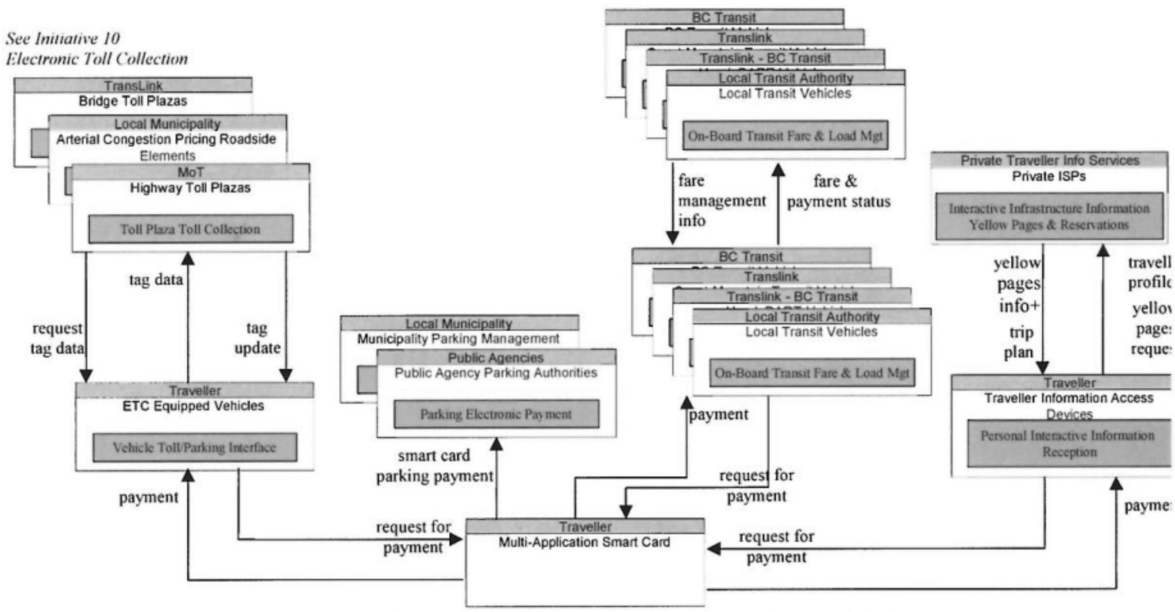


Figure 6.5: Provincial ITS Architecture for Smart Cards

Technology decisions associated with the AVI component of the toll system has the biggest implications to future toll applications, as well as other ITS applications incorporating DSRC.

6.5.1 *Interoperability With Other Toll Systems in Region*

This represents the first level of interoperability required for electronic tolling on a region wide basis. This would permit users to use and pay for the transportation system using a single transponder (or other vehicle identifier); and, will allow the integration and streamlining of the billing process to a regional or provincial level. Ensuring interoperability with other toll systems in the region will require the regional/provincial adoption of a DSRC standard.

6.5.2 Interoperability With AVI Applications FOR CVO

This represents the next level of interoperability, and will permit commercial vehicle operators who use transponders for other purposes to use those same transponders for toll payment. The commercial vehicle industry has been dealing with interoperability issues through the Commercial Vehicle Information Systems and Networks (CVISN) program.

CVISN is the collection of information systems and communication networks that support commercial vehicle operations (CVO). It is not a new information system, but rather a way for existing and newly-designed systems to exchange information through the use of standards and available communications infrastructure. CVISN includes information systems owned and operated by federal and state governments, motor carriers, and other stakeholders. CVISN will enable government agencies, the motor carrier industry, and other parties engaged in CVO safety and regulation to exchange information and conduct business transactions electronically.

Currently CVISN focuses on the following areas of ITS/CVO: Credential Administration which facilitates electronic application, processing, fee collection, and issuance and distribution of CVO credentials, and supports base state agreements and CVO tax filing and auditing; Safety Information Exchange which facilitates automated collection of information on safety performance and credentials status, improved access to carrier, vehicle and driver safety and credentials information, and pro active updates of carrier, vehicle and driver snapshot data; and Roadside Electronic Screening which facilitates screening of vehicles that pass roadside check stations. Screening applications may be based on identifiers read from the transponder, and correlated with snapshot safety/credential information or manual identifiers linked to credential or safety information, which aid in determining whether further inspection or verification of credentials is required. Screening applications may also include weigh-in- motion (WIM) and automatic vehicle classification (AVC) systems that flag vehicles for static weight or credential checks.

Currently CVISN has adopted the ASTM Draft 6 DSRC specifications, and supports the ASTM draft 7 for the future.

6.5.3 *Tolling Of Out-Of-Province Vehicles*

DSRC decisions associated with AVI based tolling of out of province vehicles must be driven by well-defined policies at a national level. Decisions need to take into account the evolution of the Canadian Architecture for ITS, provincial ITS plans, and recommendations from the Canadian Working Group on ITS standards.

6.5.4 *Interoperability With Other Electronic Payment Systems*

Interoperability issues for integrating e-payment for other transportation services need to be based on regional needs, with justification for multiple applications that can benefit from integrated electronic payment devices. Provincial and regional ITS plans can support these decisions.

Strategic and policy decisions will also need to be made with respect to the management, purchasing, distribution, and sale of transponders (or depending on the technology used, other devices/services that users may need to purchase/subscribe to). Public and private partnerships may need to be fostered for the efficient distribution and sales of such devices/services.

6.5.5 *Policy Issues*

Two key policy decisions that will have implications on future toll system technologies include:

Cash Acceptance: The requirement to maintain cash acceptance as an option eliminates the opportunity to pursue fully open ETC systems (whereby all vehicles are permitted to go through the toll assessment point at free-flow speeds).

Definition of Legitimate Users: The requirement to classify all users of a toll facility as "legitimate users" eliminates the opportunity to force users to get transponders, with others considered as violators. Instead, vehicles without transponders are detected and charged using their licence plat – without any onboard devices require. The Highway 407 ETC system operates on this basis.

7 Alternative Tolling Strategies

7.1 *Introduction*

This section looks at the potential revenue impacts of selected alternative tolling strategies including extra tollbooths and varying toll rates by time of the year and day of the week.

7.2 *Location of Toll Booths*

Currently there is a single tollbooth on the Coquihalla Highway located on the Hope-Merritt section. Owing to the limited number of entries and exits on the system, it was not thought worthwhile to consider a "closed" tolling system, with tollbooths at each entry and exit point. The possibility of introducing tollbooths on the Okanagan Connector and the Merritt-Kamloops section was examined however.

Our analysis shows that the number of trucks currently travelling on the Connector or the Merritt-Kamloops section and **not** currently passing through the tollbooth is negligible. The subsequent analysis is thus restricted to car traffic only. The diversion model predicts that revenue maximising toll on both the Connector and the Merritt-Kamloops section is around $3 per car, with a corresponding reduction in toll at the existing tollbooth. Thus whilst the revenue maximising toll in the single (existing) tollbooth scenario is $15-16, the revenue maximising structure in the three tollbooth scenario is $13-$3-$3. This scenario would yield a further 2-3% in overall revenues (all categories) compared to the single tollbooth option. The reason for this "skewing" towards the single tollbooth option, is that traffic has viable alternative routes to the Connector and Merritt-Kamloops section such as Highway 5A for trips between Merritt and Kamloops, and Highway 97/1 for traffic between the Okanagan Valley and Kamloops. Raising tolls above three dollars on the two "new" tollbooths therefore would lead to too much diversion to these alternative routes and thus reduced revenues.

7.3 *Discounts*

The effect of offering discounts to frequent users has already been presented in Chapter 5. More generally, our analysis shows that offering discounts can only reduce revenues. This is because it is physically difficult to segregate those market segments that have a lower average value of time, and therefore may generate more revenue if tolls are lowered from the revenue maximising toll for *all* vehicles for example. Thus it would be practically difficult to separate out the "car other" and "car long vacation" market segments and offer discounts to them, and not to other car drivers.

Conversely, those types of trips for which it would be possible to segregate from other market segments, do not have a value of time lower than the average for all users. Frequent users, for example, feature a strong component of work-related trips, which have the highest values of time of all car drivers. Offering discounts to frequent users therefore, whilst perhaps politically desirable, can only reduce revenues.

7.4 *Temporal Variation of Tolls*

Varying toll rates by time of day, day of week or by season is common practice for many types of transport operation. These variations however are often used in response to varying demand and capacity issues. Thus if demand exceeds supply for a facility at a given price at a certain time, then the price may be raised at that time to dampen demand and increase revenues. In the case of the Coquihalla Highway however, it is unlikely that the demand for the facility will outstrip supply in the foreseeable future, so this mechanism cannot be used. Current traffic volumes are very low for a freeway standard road, and even in the busiest periods (summer holiday weekends), one-way daily traffic volumes reach only 14,000 vehicles.

The mix of traffic does vary by the time of year and day of week however and there may be opportunities to exploit this. For example our analysis shows that the vast majority of car traffic on the Coquihalla Highway during summer weekends is made up of the market segments with the highest values of time – namely "car short vacation" and "car business". For this reason it is estimated that the revenue maximising toll would be closer to $18 per trip during the following days:

Days	Months
Fridays & Sundays	June, July, August, September
Thursday, Friday, Saturday, Sunday, Monday	July & August

Our analysis shows that car traffic on these days of the year constitutes around 30% of the total annual car traffic. Increasing the toll rates on these days therefore could generate an extra 3% in overall annual revenues (all categories).

8 Sensitivity Tests

8.1 *Introduction*

This final section shows the results of sensitivity tests carried out on the key variables and assumptions in the forecasting model. For comparison purposes only, the results are presented in terms of the overall effect on revenues expressed as the net present value of total revenues from 2004-2034 using a discount rate of 8%. The central forecast revenue is shown as an index of 100.

8.2 *Sensitivity Test 1: Low and High Growth Assumptions*

Assumptions:

Low Forecast	=	Central annual growth rates minus 1% (bottomed to 1% minimum where necessary)
High Forecast	=	Central annual growth rates plus 1%

The results for this test are shown for all four main scenarios.

	Growth Assumption		
Scenario	Low	Central	High
Base Case	89	100	114
Scenario 1	103	113	130
Scenario 2	112	122	140
Scenario 3	105	115	132

8.3 ***Sensitivity Test 2: Toll Sensitivity***

Assumptions:

Low Forecast = Toll sensitivity increased by 50%

High Forecast = Toll sensitivity reduced by 50%

The results for this test are shown for Scenario 3

	Toll Sensitivity Forecast		
Scenario	Low	Central	High
Scenario 1	95	100	103

8.4 ***Sensitivity Test 3: Frequent Traveller Pass Take-Up Rate***

Assumptions:

Low Forecast = Take-up rate of 31%

Central Forecast = Take-up rate of 21%

High Forecast = Take-up rate of 11%

The results for this test are shown for Scenario 3

	Frequent User Discount Take-Up Rate		
Scenario	Low	Central	High
Scenario 1	97	100	103

8.5 *Scenarios Tests*

Traffic and revenue forecasts for a total of 28 alternative scenarios were produced between December 2002 and July 2003, covering a variety of possible tolling strategies. The results of these scenarios tests, together with a brief description of each test and the location of the results file can be found in Table 8.1.

Table 8.1: Scenario Test List

Scenario	2004 Car Tariff ($)	Frequency Discount Qualifiers	Frequency Discount Rate ($)	Frequency Discount TakeUp %	Local Discount Qualifiers	Local Discount Rate	Local Discount TakeUp %	Tolls rising Post 2004?	NPV Revenue Central	File	Date Released
1	13	12 per annum	9	7		0	1	yes	$857	'Scenario Traffic Forecasts 12th December.xls'	12/12/2002
2	14	12 per annum	9	7		0	1	yes	$868	'Scenario Traffic Forecasts 12th December.xls'	12/12/2002
3	13	12 per annum	9	7				yes	$862	'Scenario Traffic Forecasts 12th December.xls'	12/12/2002
4	13					0	8	yes	$830	'Scenario Traffic Forecasts 12th December.xls'	12/12/2002
5	13	12 per annum	9	7		0	8	yes	$821	'Scenario Traffic Forecasts 12th December.xls'	12/12/2002
6	13	5 per annum	9	15				yes	$855	'Scenario Traffic Forecasts 17th December.xls'	17/12/2002
7	13	5 per annum	9	15		0	1	yes	$849	'Scenario Traffic Forecasts 17th December.xls'	17/12/2002
8	10							yes	$804	'Further Scenario Tests 9 Jan.xls'	09/01/2003
9	11							yes	$830	'Further Scenario Tests 9 Jan.xls'	09/01/2003
10	12							yes	$852	'Further Scenario Tests 9 Jan.xls'	09/01/2003
11	13							yes	$869	'Further Scenario Tests 9 Jan.xls'	09/01/2003
12	14							yes	$881	'Further Scenario Tests 9 Jan.xls'	09/01/2003
13	15							yes	$889	'Further Scenario Tests 9 Jan.xls'	09/01/2003
14	10					0	8	no	$681	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
15	10					0	8	yes	$770	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
16	11					0	8	yes	$794	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
17	12					0	8	yes	$814	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
18*	13					0	8	yes	$830	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
19	14					0	8	yes	$841	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
20	15					0	8	yes	$848	'Scenario Traffic Forecasts 23rd January.xls'	23/01/2003
* Scenario 18 is the same as Scenario 4											
					Spread of pass applicability						
					Concentrated (Summer)	Annual	Rationality				
21	13	3 month passes	7.85	43.6	60%	40%	100%	yes	$805	'March 6 Frequency Option Traffic Forecast.xls'	08/03/2003
22	13	3 month passes	7.07	28.4	60%	40%	50-100%	yes	$817	Scenario 22.xls'	09/03/2003
23	13	3 month passes	7.33	23.8	60%	40%	50%	yes	$828	Scenario 23.xls'	09/03/2003
24	13	3 month passes	7.98	54.8	80%	20%	100%	yes	$790	Scenario 24.xls'	09/03/2003
25	13	3 month passes	7.61	32.6	40%	60%	100%	yes	$817	Scenario 25.xls'	09/03/2003
26	13	3 month passes	5.16	21.4	as per May survey results			yes	$818	Scenario 26.xls'	11/06/2003
Revised Base Case for July 2003 Final Report											
27	10							no	$711	'Revised Base Case for July Final Report.xls'	23/06/2003
Revised Case with shadow tolls for trucks beyond 2021											
28	10							yes	$580	Scenario 28 – Full Worksheet – Shadow Tolls 2022.xls	10/07/2003

Appendix A

Base Case Traffic & Revenue Forecasts

Coquihalla Highway Traffic & Revenue Forecasts
SCENARIO: **BASE CASE - Tolls as now. No increase in tolls after 2004**

Central Forecast

Average Daily Traffic (excluding exempt vehicles)
Full Toll Paying Vehicles

	Current Toll ($)	2004 Toll ($)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Annual Growth (cars)					2.83	2.63	2.17	2.34	2.48	2.73	2.60	2.46	2.42	2.30	2.26	2.32	2.39
Passenger Vehicles	10	10	6,693	6,861	7,055	7,240	7,397	7,570	7,758	7,969	8,177	8,377	8,580	8,777	8,975	9,184	9,403
Trucks (2axles)	20	20	72	73	76	79	82	85	88	91	95	98	102	106	109	113	118
Trucks (3axles)	30	30	80	80	83	87	90	93	96	100	104	108	112	116	120	124	129
Trucks (4 or 5 axles)	40	40	590	608	632	657	679	704	731	760	789	818	848	879	910	943	977
Trucks (6 axles or more)	50	50	479	484	503	523	541	561	582	605	628	652	676	700	725	751	778
Motorcycles	5	5	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Total:			7,948	8,159	8,382	8,618	8,822	9,045	9,287	9,558	9,825	10,086	10,351	10,611	10,872	11,147	11,437
Annual Growth (trucks)					3.95	3.90	3.45	3.66	3.74	3.98	3.86	3.72	3.69	3.59	3.53	3.59	3.65

Average Daily Traffic (excluding exempt vehicles)
Vehicles Receiving Discount

	Current Toll ($)	2004 Toll ($)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Passenger Vehicles	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (2axles)	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (3axles)	30	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (4 or 5 axles)	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (6 axles or more)	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total:			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Average Daily Traffic (Free Access to Local Vehicles)
Vehicles Passing Free

	Current Toll ($)	2004 Toll ($)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Passenger Vehicles	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (2axles)	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (3axles)	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (4 or 5 axles)	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trucks (6 axles or more)	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total:			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annual Revenue ($ 000's current)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Compound Toll Inflator				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Passenger Vehicles	24,431	25,041	25,750	26,427	27,000	27,630	28,316	29,088	29,844	30,576	31,317	32,093	32,761	33,521	34,320
Trucks (2axles)	524	534	555	577	597	618	642	667	693	719	745	772	799	828	858
Trucks (3axles)	879	879	913	949	982	1,018	1,056	1,098	1,140	1,183	1,226	1,270	1,315	1,362	1,412
Trucks (4 or 5 axles)	8,618	8,877	9,227	9,587	9,916	10,281	10,665	11,090	11,518	11,947	12,388	12,832	13,285	13,762	14,265
Trucks (6 axles or more)	8,747	8,835	9,184	9,541	9,871	10,233	10,615	11,038	11,464	11,891	12,329	12,771	13,222	13,697	14,198
Motorcycles	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Total:	43,258	44,225	45,689	47,141	48,427	49,841	51,354	53,041	54,720	56,376	58,066	59,743	61,442	63,230	65,113

NPV of 2004-2034 Revenues @	8.000%	$710,608