GOING THE DISTANCE
Franchir le fil d'arrivée

Canadian Transportation Research Forum

Le Groupe de Recherches sur les Transports au Canada

PROCEEDINGS of the 29th Annual Meeting

ACTES de la 29ième Conférence annuelle

Victoria
B. C. / C.-B.
May 15-18,
15 au 18 mai,
1994

Lions Gate Bridge - Vancouver
Toll Revenue and Traffic Impact Study

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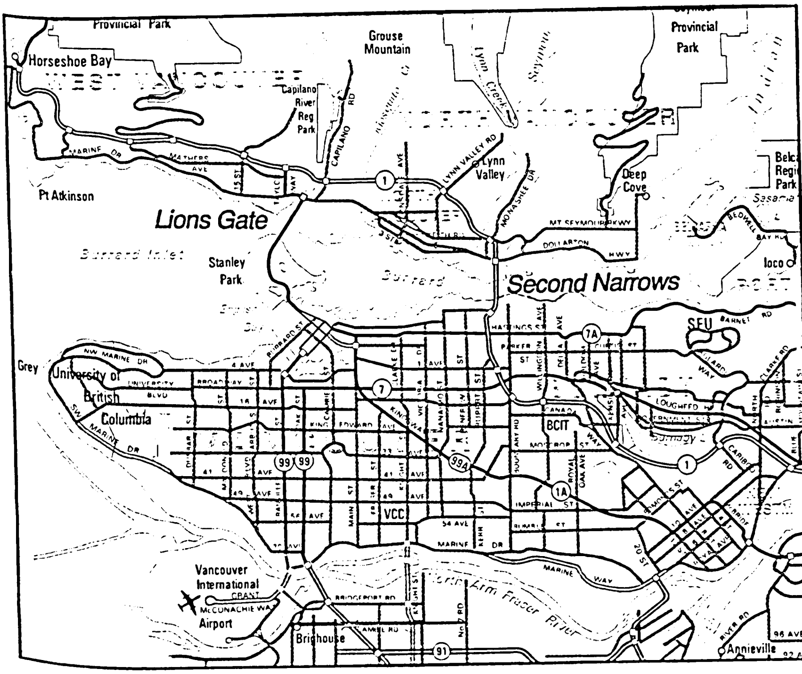
Introduction

The Lions Gate Bridge and the Second Narrows Bridge are the two major links carrying 70,000 and 100,000 vehicles/day respectively across the Burrard Inlet between North Vancouver and Vancouver (exhibit 1). The Lions Gate Bridge is now 56 years old and is approaching the end of its physical and functional life. Several improvement alternatives are being studied and tolls are being considered as a means to finance future capital works. The objectives of this study are to analyze the impact on traffic patterns of introducing tolls on the Lions Gate and Second Narrows Bridges and to assess the potential toll revenues.

The analysis assumes the Lions Gate Bridge is replaced or improved to provide four full standard lane widths replacing the existing three substandard width lanes.

Traffic demands and traffic forecasts on the improved system were developed under different toll rates and schemes using the Transportation Model developed by the Greater Vancouver Regional District (GVRD). The GVRD Transportation Model is implemented using the EMME/2 transportation modelling package.

Exhibit 1
The Study Area



GVRD Transportation Model

The GVRD Transportation Planning Model is a strategic planning tool that can be used to estimate morning peak hour travel demand for current and future years. The model is comprised of three main components:

- **traffic zone system** - The region is divided up into 445 traffic zones. Each zone contains detailed demographic information for current and future years.
- **road and transit network** - a digital road and transit network provides coverage for the entire region. The road network consists of 1,900 nodes (intersections) and 7,000 links (roadway segments). Each roadway link

contains information on the number of lanes, posted speed limit, capacity and turning restrictions. The transit network which utilizes the road network (with the exception of Skytrain and SeaBus), contains information on 180 transit lines totalling 8,000 transit line segments.

- **modelling procedure** - predicts the number of auto and transit trips made in the morning peak hour (7:30-8:30 am)

The modelling procedure is based on the classic four step transportation forecasting methodology:

- **Trip generation** - estimates the number of person trips produced and attracted by each traffic zone based on zonal demographics (e.g. population, labour force, employment). This stage produces a set of production and attraction vectors for four trip purposes: work, post-secondary school, grade school and other.

- **Trip distribution** - a gravity model that allocates trips between origin and destination based on the impedances (auto and transit travel costs - including perceived time costs, operating costs, parking costs etc.) between zones. This stage produces origin/destination tables for the four trip purposes.

- **Mode split** - a logit model that determines how many trips go by auto or transit, based on the impedances between zones. This stage produces origin destination tables by mode and trip purpose. These tables are aggregated by purpose to produce an auto driver and transit passenger trip table.

- **Trip Assignment** - utilizes the EMME/2 equilibrium assignment algorithm to load the auto trips onto the digital network, and through an iterative process, estimates the routes taken by each trip. The transit table is assigned to the network using a multipath assignment algorithm to determine transit routing. A multitude of statistics are available from the assignments that include: link volumes (auto and transit), link speeds, origin destination travel times, transit loading factors etc.

The current model was calibrated using survey data collected from 1985 (Greater Vancouver Travel Survey). It has since been validated for 1992 travel conditions using demographic estimates and vehicle and transit screenline data.

Modelling Road Tolls

The application of road tolls could potentially affect travel demand and patterns for each step of the modelling process - trip generation, trip distribution, mode split and trip assignment. The current GVRD Transportation Model together with the EMME/2 transportation modelling package are capable of simulating changes in trip distribution, mode split and trip assignment as a result of road tolls. The effects of road tolls on the four step modelling process are discussed in the following sections.

Most of the trips made during the morning peak hour are obligatory trips (work and school trips)and tend to be inelastic with respect to the cost of travel. In another word, many of these trips have to be made for work or school purposes, therefore, the impact of road tolls on morning peak hour trip generation would be minor or negligible. However the impact of road tolls on discretionary trips (e.g. leisure family, recreation and shopping trips) might be greater due to the elastic nature of these trips. Most discretionary trips usually occur during afternoon and off-peak periods.

The added cost of road tolls would also result in changes in trip distribution similar to traffic congestion. In general the impacts of road tolls on trip distribution would be more gradual and longer term because the majority of trip makers could not change their residential or employment locations immediately after the imposition of road tolls. The study only considered a ten year time frame and their impacts on trip distribution was considered to be negligible.

Road tolls would have immediate impacts on mode choices. The additional costs would shift some of the auto users to higher occupancy vehicles and public transit. The simulation of mode shifts was performed using the GVRD Logit Mode Choice Model by including road tolls in the generalized travel time impedances measured in units of time. Different road toll schemes were tested by increasing the time impedances on a link by the time equivalent of the proposed tolls. The time equivalent of a toll is the amount of the toll divided by the value of travel time.

$$\text{Travel Impedance (minutes)} = \frac{\text{Toll Rate (\$)} \times 60}{\text{Time Value (\$/hr)}}$$

The time equivalent of a given toll would also vary by aggregated income level and by vehicle occupancy.

A road toll would also have an immediate impact on route choice in the transportation network. The trip assignment was performed using the EMME/2 equilibrium assignment algorithm. The auto assignment program considers travel time, vehicle operating cost based on distance travelled, and road tolls in the computing network paths for each iteration of the assignment. Typically 15 to 30 iterations are required to achieve network equilibrium depending on the level of traffic congestion and the value of the toll. Exhibit 2 depicts the shift in network traffic as the toll on the Lions Gate Bridge increases.

Study Assumptions

A base case and two proposed scenarios were tested. The base case assumes no tolls are in place and the Lions Gate link is a 4 lane link. The proposed cases simulate:

1. Tolls on Lions Gate Bridge only
2. Tolls on both Lions Gate and Second Narrows Bridges

The two scenarios simulate traffic diversions which would occur between the two bridges over a range of equivalent toll impedances from 10 to 40 minutes.The analysis assumes:

- No change in trip generation or distribution from the base case
- Constant number of person trips across Burrard Inlet

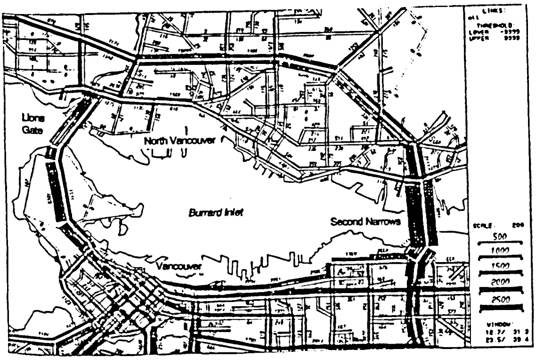
The values of time used were:

Commuter Trips	$6 to $9/hr
Business/work trips	$18/hr
Other Trips	$2 to $3/hr

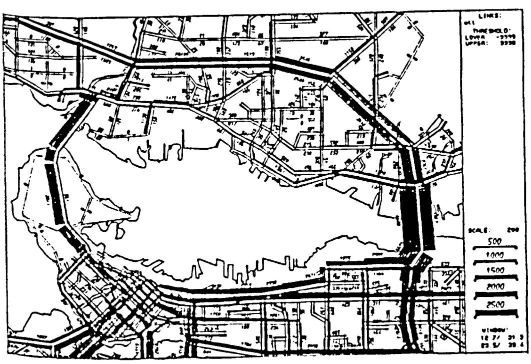
Analysis

In scenario 1, a range of tolls from $1 to $7 are applied to the Lions Gate bridge only, to establish the pattern of traffic diversion away from the bridge. Exhibit 3 shows the percentage of daily traffic which diverts as the toll level is increased. The diverted traffic includes traffic shifting to the Second Narrows Bridge (a toll free alternative) and from private auto to transit. The initial effect of a $1 toll in each direction results in about 23% of Lions Gate traffic diverting to Second Narrows or to transit. As the Lions Gate toll is increased further the rate of diversion declines due to the increasing congestion on the Second Narrows Bridge.

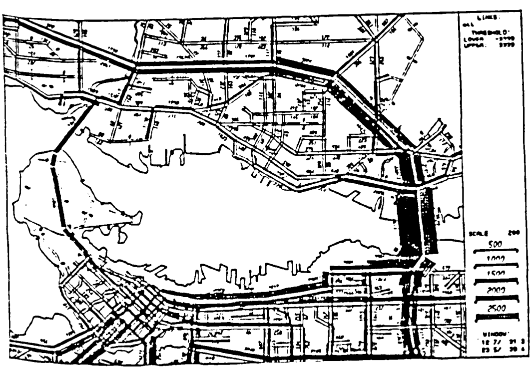
Exhibit 2
Traffic Shift to Second Narrows with Tolls on Lions Gate Bridge



No Toll

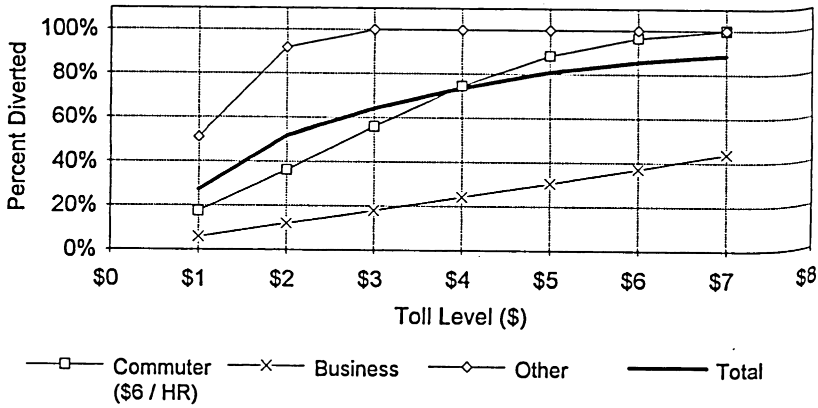


$2 Toll



$7 Toll

Exhibit 3
Two Way Tolls on the Lions Gate Bridge Only
Diversion to Second Narrows Bridge and Transit



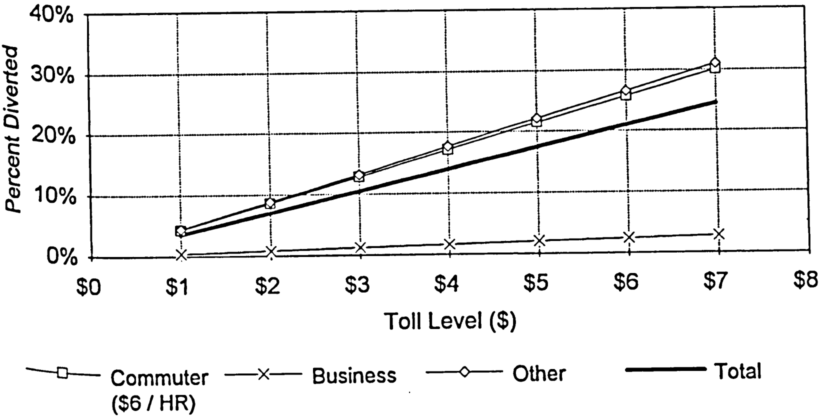
In scenario 2, the tolls are increased on both bridges simultaneously. The increasing toll level results in a shift to transit but very little diversion between the two bridges. Exhibit 4 plots the results for this scenario and shows that the diversion to transit is a linear function of toll with about %3.5 diversion for each $1 increase in the toll.

Calculating the daily toll revenues cannot be done directly from the link volumes provided by the GVRD Regional Transportation Model since the model is designed to predict volumes for the a.m. peak period only. The a.m. peak hour volumes were factored up to daily volumes based on the weekday hourly traffic profile from permanent count stations (PCS) on the approaches to each bridge.

Annual toll revenues were similarly factored up using PCS data for the entire year. The day which was modelled was a typical October weekday. Annual traffic is then calculated, knowing the ratio between the typical October weekday volume and the annual weekday volume.

In addition to toll level, the rate of traffic diversion is also influenced by other travel factors which vary over the course of the day. Ideally these factors would be incorporated in further runs of the regional model representing the p.m. peak and off-peak periods. At present, the regional model does not have these capabilities and, for the purpose of this study, a series of extrapolations were made outside the modelled a.m. peak period.

Exhibit 4
One-Way Toll (SB) on Both the Lions Gate and Second Narrows Bridges - Diversion to Transit



Trip purpose data during peak and off peak periods was taken from 1985 GVRD travel surveys to provide approximate proportions of commuter, business and other trip purpose for different periods of the day. As the trip purpose varies, the aggregate value of time will also vary. If the average value of time increases during off-peak periods, due to a higher component of business travel, then there will be increased acceptance of a specific toll as compared with the specific modelled a.m. peak period. This results in a lower proportion of diversion to other routes and modes.

For a given trip purpose and toll at Lions Gate, the proportion of traffic diverted to Second Narrows will also vary depending upon general volume and travel time conditions throughout the network. During off-peak periods for example, travel times throughout the network joining North Vancouver and Vancouver are substantially less than those experienced in the morning peak period. During these periods the reduced travel times mean that the catchment area of trips which divert to the Second Narrows Bridge will be much larger for a given toll.

In using the regional model a.m. peak projections with mode split changes incorporated, consideration had to be given to estimating transfers to transit during the rest of the day. For different periods of the day, estimates of the existing percentages of trips by transit to and from North Vancouver (excluding internal

North Vancouver trips) were taken from the 1985 GVRD travel Survey. Overall transit ridership levels have been fairly constant over recent years.

The rate of transit ridership in the a.m. peak period and direction is about three times greater than off-peak rates. To account for this variation over the day, a series of factors were established for other time periods to reflect the changes in transit ridership rate (by direction) relative to the modelled a.m. period. An allowance was also made for trip purpose, since commuter travel is more likely to use transit when compared to business and personal travel.

Based on the travel factors outlined above, a spreadsheet analysis was developed to maintain separated journey purposes by direction and time of day for diversion analysis. An example of this worksheet is illustrated in exhibit 5.

The left hand column in exhibit 5 (6-9 a.m.) presents the traffic diversions based on the model runs, and the remaining column show the extrapolations for the rest of the day. At the bottom of the spreadsheet the summary includes the estimate of diverted traffic and distribution of toll revenue.

These worksheets were completed for each combination of toll charge, bridge and direction and used to determine the diversion rates in exhibits 3 and 4 and toll revenues in exhibits 6 and 7.

Summary of Results

Exhibit 6 shows the impact of increasing toll level on total toll revenues in scenario 1 where the toll is applied only to the Lions Gate Bridge. The graph shows total revenue increasing up to a toll level of $3. As the toll increases beyond $3, total revenues begin to decline again as the revenue lost to diverting traffic begins to exceed the revenue gained from the higher toll level. At a toll level of $3, there is an estimated 60% diversion including diversion from private auto to transit or to the Second Narrows Bridge.

The estimated diversion is about 20% for each $1 of toll implemented on the Lions Gate Bridge.

Exhibit 7 shows the impact of toll levels on total revenue for scenario 2 where tolls are applied equally to both bridges. Total revenues increase almost linearly with toll level since traffic cannot divert to a non-tolled route. The estimated diversion from private auto to transit is about 3% for each $1 of toll implemented on the two bridges.

Exhibit 5 TOLL REVENUE WORKSHEET – WEEKDAY AUTOMOBILE TRAVEL

BRIDGE: LIONS GATE (NO TOLL ON SECOND NARROWS)
DIRECTION: SOUTH BOUND
TOLL: $2.00

	TIME PERIOD	1	2	3	4	5	6	7	8	9
		6–9 A.M.	9–12	12–3 P.M.	3–6	6–9	9–12	12–3 A.M.	3–6	24 HR
	TRAFFIC DATA (1992 VOLUMES)									
A.	TRAFFIC VOLUMES	9300	6900	5100	4600	3800	2200	400	400	32699.5
B.	VOLUME FACTOR	1.00	0.74	0.55	0.49	0.41	0.24	0.04	0.04	3.52
C.	VOLUME FOR DIVERSION	9300	6900	5100	4600	3800	2200	2000	2000	–
C1.	OVERALL USAGE FACTOR	1.00	0.40	0.30	0.39	0.30	0.20	0.10	0.00	
C2.	COMMUTER TRANSIT FACTOR	1.10	0.55	0.45	0.54	0.42	0.28	0.14	0.00	
C3.	BUSINESS TRANSIT FACTOR	0.40	0.20	0.16	0.20	0.15	0.10	0.05	0.00	
C4.	OTHER TRANSIT FACTOR	0.80	0.40	0.32	0.39	0.31	0.20	0.10	0.00	
C5.	COMMUTER TRANSIT DIVERSION	10.4%	10.4%	10.4%	10.4%	10.4%	10.4%	10.4%	10.4%	
C6.	BUSINESS TRANSIT DIVERSION	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	
C7.	OTHER TRANSIT DIVERSION	43.8%	43.8%	43.8%	43.8%	43.8%	43.8%	43.8%	43.8%	
	TRIP INFORMATION									
D.	COMMUTER %	80%	40%	20%	40%	20%	10%	10%	10%	43%
E.	COMMUTER VOLUME	7440	2760	1020	1840	760	220	40	40	14120
F.	COMMUTER AUTO OCC.	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	
G.	BUSINESS %	10%	30%	30%	30%	20%	10%	10%	10%	21%
H.	BUSINESS VOLUME	930	2070	1530	1380	760	220	40	40	6970
I.	BUSINESS AUTO OCC.	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	
J.	OTHER %	10%	30%	50%	30%	60%	80%	80%	80%	36%
K.	OTHER VOLUME	930	2070	2550	1380	2280	1760	320	320	11610
L.	OTHER AUTO OCC.	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	
	TIME VALUE INFORMATION									
M.	COMMUTER TIME VALUE ($/HR)	$9	$9	$9	$9	$9	$9	$9	$9	$9
N.	BUSINESS TIME VALUE ($/HR)	$18	$18	$18	$18	$18	$18	$18	$18	$18
O.	OTHER TIME VALUE ($/HR)	$3	$3	$3	$3	$3	$3	$3	$3	$3
P.	TOLL ($)	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
	DIVERSION CALCULATION									
Q.	COMMUTER IMPEDANCE (MIN)	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	
R1.	COMMUTER % DIVERTED TO TRANSIT	11.4%	5.7%	4.7%	5.6%	4.4%	2.9%	1.5%	0.0%	8%
R2.	COMMUTER % DIVERTED TO 2ND NARROWS	1.6%	14.1%	23.5%	25.9%	30.4%	39.3%	40.9%	41.5%	11%
R.	COMMUTER % DIVERTED	13.1%	19.8%	28.2%	31.5%	34.7%	42.2%	42.4%	41.5%	20%
S.	COMMUTER VOLUME DIVERTED	973	545	288	579	264	93	17	17	2775
T.	BUSINESS IMPEDANCE (MIN)	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	
U1.	BUSINESS% DIVERTED TO TRANSIT	2.0%	1.0%	0.7%	0.9%	0.8%	0.5%	0.2%	−0.0%	1%
U2.	BUSINESS% DIVERTED TO 2ND NARROWS	0.4%	7.7%	13.2%	14.7%	17.1%	22.0%	22.7%	22.8%	11%
U.	BUSINESS % DIVERTED	2.4%	8.7%	13.9%	15.6%	17.9%	22.5%	22.9%	22.8%	12%
V.	BUSINESS VOLUME DIVERTED	22	179	213	216	136	50	9	9	834
W.	OTHER% IMPEDANCE (MIN)	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	
X1.	OTHER% DIVERTED TO TRANSIT	35.1%	17.5%	14.0%	17.1%	13.6%	8.8%	4.4%	0.0%	15%
X2.	OTHER% DIVERTED TO 2ND NARROWS	10.2%	35.2%	54.1%	56.8%	66.9%	87.1%	93.4%	97.7%	57%
X.	OTHER % DIVERTED	45.3%	52.7%	68.1%	73.9%	80.5%	95.8%	97.8%	97.7%	72%
Y.	OTHER VOLUME DIVERTED	421	1092	1736	1020	1836	1687	313	313	8417
	SUMMARY									
Z.	TOTAL DIVERTED	1416	1816	2237	1814	2236	1829	339	338	12026
AA.	TOTAL % DIVERTED	15.2%	26.3%	43.9%	39.4%	58.8%	83.1%	84.8%	84.6%	36.8%
BB.	TRAFFIC REMAINING	7884	5084	2863	2786	1564	371	61	62	20674
DD.	% 24 HOUR TOLL REVENUE	38.1%	24.6%	13.8%	13.5%	7.6%	1.8%	0.3%	0.3%	100.0%

Exhibit 6
Two Way Toll on the Lions Gate Bridge Only - Daily Toll Revenues

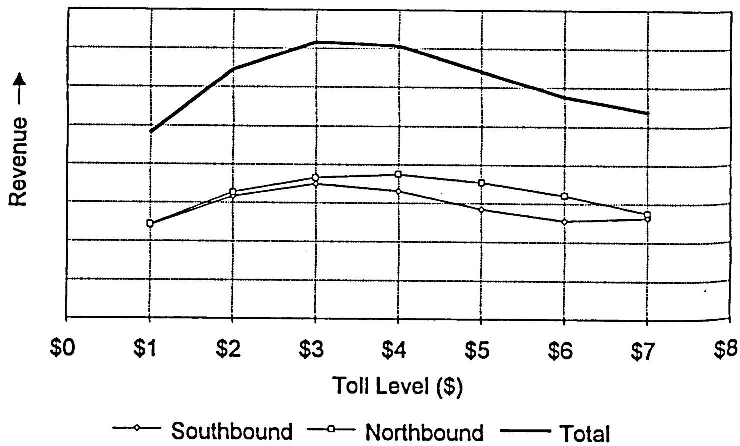
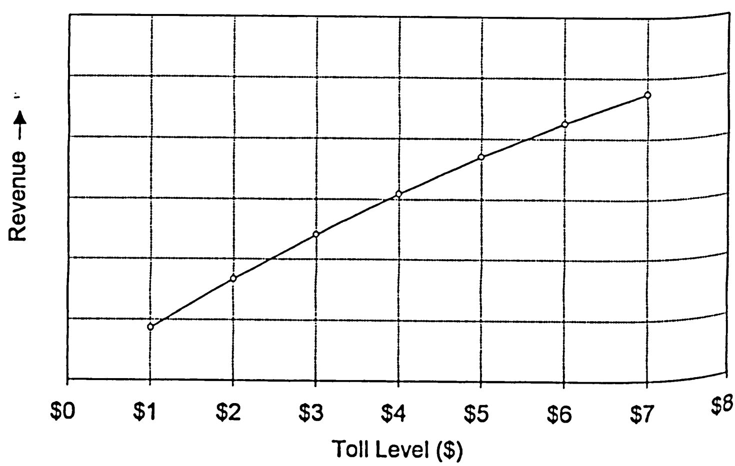


Exhibit 7
One-Way Toll (SB) on Both the Lions Gate and Second Narrows Daily Toll Revenues



Conclusions

- The study procedures were successful in meeting the Ministry of Transportation and Highways objective to produce a comprehensive set of traffic diversion and revenue projections for a range of possible toll levels on Lions Gate only or both Lions Gate and Second Narrows Bridges.

- The Regional Transportation Model using time impedances to represent tolls, provided outputs for the a.m. peak period that were rational and reasonable in terms of changes in traffic patterns. Valuable information was also provided regarding ranges in peak period traffic congestion levels resulting from traffic diversions.

- Considerable judgement and some ingenuity were required to extrapolate a.m. peak period results to daily totals. The extrapolation calculations, based on limited data, were quite different for the two directions of travel but produced very similar results for overall daily traffic diversions and toll revenues in each direction. These results supported our confidence in the process used.

- For further work in this area, use of the Regional Transportation Model would be enhanced by extension of the model into the off-peak and p.m. peak hour of the day. Model development and calibration for these other periods of the day is a substantive project, which is under consideration by the GVRD.

- More research is required into behavioral travel forecasts that can be shown to be directly applicable to areas such as Greater Vancouver, dealing with perceived values of time relative to the toll charges and covering the variability of trip purpose and travel conditions throughout the day. These factors are crucial to the actual decisions made by the travelling public in changing their mode of travel or route choice in response to tolls or other road system user charges.

Disclaimer

The findings, interpretations and conclusions expressed in this study are the results of research supported by the British Columbia Ministry of Transportation and Highways, but they are entirely those of the authors and should not be attributed in any manner to the Ministry.