BRITISH COLUMBIA FERRY SERVICES, INC.
REVENUE YIELD FOR SELECTED ROUTES

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TECHNICAL REPORT

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1 INTRODUCTION

Since its privatization in April 2003, BC Ferry Services Inc. has faced a series of financial, economic, and institutional issues that have significantly impacted its pricing structure and levels of fares and tariffs. These impacts include the need for BC Ferry Services to implement fuel surcharges as the price of oil has changed; the need for fares and tariffs to remain competitive with other modes; and the requirements of the Regulator with respect to the cap on fare levels.

To ensure that it is effectively evaluating and assessing the impact of these factors, BC Ferry Services Inc. would like to update the traffic and revenue models previously developed by TEMS for BC Ferry Services Inc. The analysis should eventually provide updated tariff, and revenue information for all the BC Ferry routes and assess the variation in elasticities by key factors such as trip purpose, time of day, level of service etc. The market data used in the Revenue models for BC Ferry Services Inc. were last updated several years ago. The Major Routes were last updated in 2003 and the Minor Routes were last updated in 1998 except for routes 17, 18 and 7, which were updated in 2005 as part of a route service study, and the Northern Routes were never addressed.

To begin the update, BC Ferry Services Inc. has asked TEMS to review the existing database, models, forecasts and elasticities for seven specific routes that will provide a guide to how each type of route will respond, and to prepare a proposal outlining the work required to bring the analysis to a 2006 basis.

1.1 PURPOSE AND OUTLINE OF THIS STUDY

This update study is designed to provide BC Ferry Services Inc. with a revised set of fare elasticities that consider the potential fares, tariffs and revenues for the three pricing periods each year considered by BC Ferry Services Inc. (*i.e.*, peak season, shoulder and off peak), as well as by trip type (business, commuter, social, tourist and commercial. The analysis should evaluate the impact of overall charges (*e.g.*, fuel charge, reservations) and the popularity of different sailings across the day.

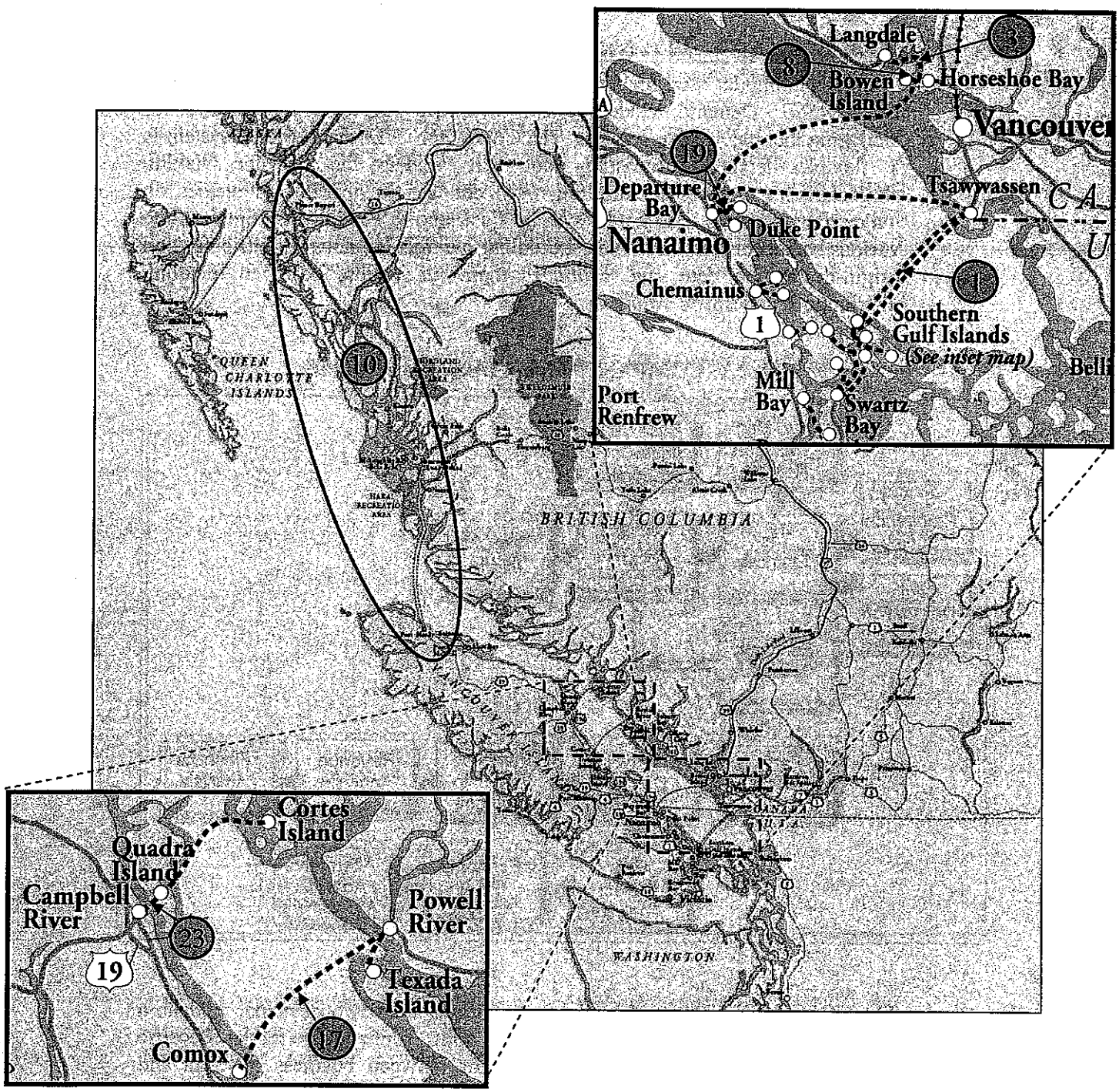
By evaluating each specific segment of the market, the analysis can provide input into the pricing policy and strategy of BC Ferry Services Inc., while remaining within the overall fare caps set by the Regulator.

The specific Routes BC Ferries asked TEMS to assess were the following:

- Route 1 - Georgia Strait South: Swartz Bay to Tsawwassen
- Route 3 - Howe Sound: Langdale to Horseshoe Bay
- Route 8 - Queen Charlotte Channel: Horseshoe Bay to Bowen Island
- Route 10 - Inside Passage: Port Hardy to Prince Rupert
- Route 17 - Georgia Strait North: Powell River to Comox
- Route 19 - Northumberland Channel: Nanaimo Harbour to Gabriola Island
- Route 23 - Seymour Narrows: Campbell River to Quadra Island

A map of the service routes is shown in Exhibit 1.1.

Exhibit 1.1: Map of the routes selected for analysis

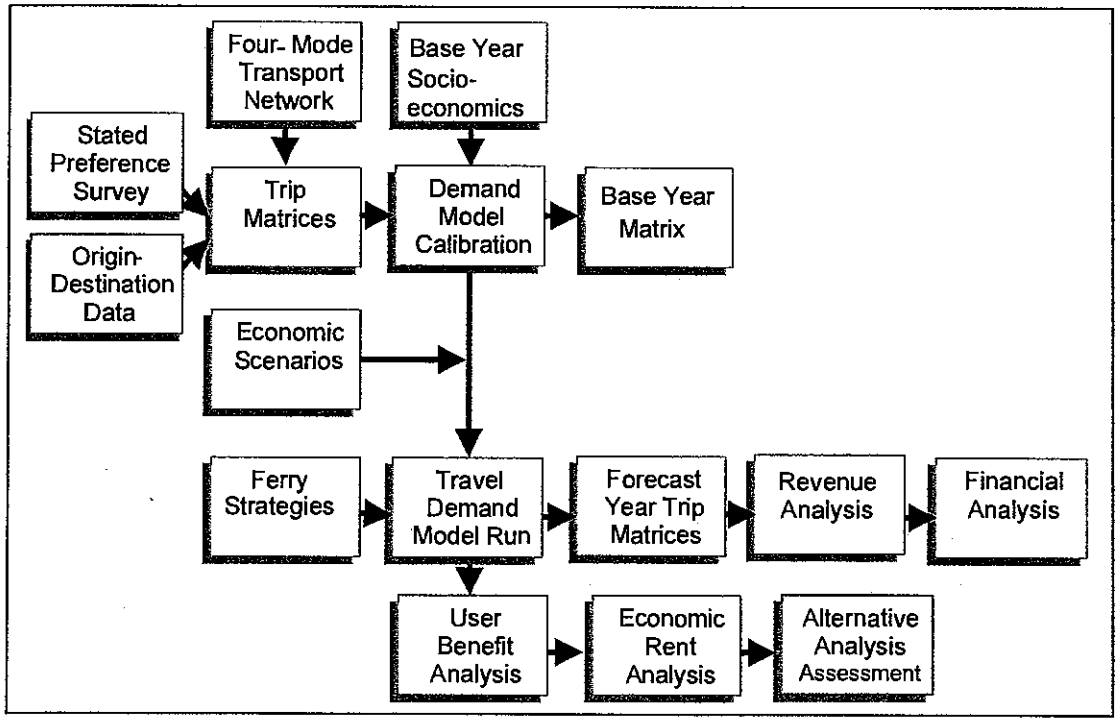


2 METHODOLOGY

2.1 *COMPASS*™ MODEL

The demand model used for forecasting ridership for the BCFS is based on the *COMPASS*™ Demand Model system that was developed specifically for analyzing the major route services. The *COMPASS*™ Demand Model system is a flexible demand forecasting tool that models the decision making characteristics of travelers resulting from changes in operating strategies on major route services. The model system illustrated in Exhibit 2.1 combines the various socioeconomic variables, attitudinal parameters, network attributes and origin-destination data, and calibrates them all against observed traveling distributions and traffic volumes.

Exhibit 2.1: COMPASS™ Model Database Structure



The COMPASS™ Demand Model is structured upon two principal models: a total demand model and a hierarchal modal split / route choice model. Because of significant differences in travel behavior between business travelers and leisure travelers within each season, a separate set of models was calibrated for each market segment. The recalibration process utilized previous databases that were designed specifically to capture the average effect across all categories. As a result, only slight changes to the original coefficients are made across the

different market type segments. Details of the modeling techniques are left to Appendix A.

2.2 TRIP GENERATION

The demand model forecasts the total travel demand of all modes in the forecast year based on two factors: socioeconomic interaction and the quality of service in the designated market area. The quality of service measures transportation accessibility while the socioeconomic term measures the strength of the socioeconomic interaction between the origin and destination zones and the projected growth within these zones over time. The hypothesis is that the greater the population, income or employment in any two zones, the more travel interaction there will be between the zones at any given level of transportation service.

Socioeconomic Factors

In terms of the generation of ferry traffic, three factors have been found to be critical: population, employment, and income. For business travel, employment and income are the dominant factors in generating business trips. This reflects the fact that business trips are made to employment centers and that income is highly correlated with the level of economic activity. For social travel, the key factors are population and income. This reflects the fact that the larger the population and the greater its disposable income, the more trips this population segment will be inclined to make. In modeling trip generation, a series of different relationships are used. The relationship for business used in COMPASS™ is a function of employment in the origin and destination zones, and the income is each zone.

Travel Access Factors

Trip generation is also impacted by the ease of access between any two locations. As the travel times and costs are improved between any two locations the level of trip making increases. In COMPASS™, this relationship is estimated by comparing the ease of travel in the base or current situation with that in any proposed set of transport improvements. The elasticity with respect to travel access across British Columbia is very significant and is lower for business trips and higher for social and tourist travel.

3 DATA COLLECTION

3.1 ZONE SYSTEM

A zone system including the whole extension of British Columbia plus the Province of Alberta and Washington State in the U.S. as external zones has been formed. The total number of zones in this system is 108, and a list of zone names plus the geographical location of the respective centroids is given in the Appendix B.

3.2 SOCIOECONOMIC DATA

The socioeconomic data is used in the total demand model to derive the volume of travel between two zones. The variables used in the description and calibration process are –

- Population
- Employment
- Median household income

Population data, as well as Median household income data is available at the Census, for the years 1996, 2001 and 2006. Employment data comes from BC Stats, Ministry of Management Services. The table in Exhibit 3.1 shows the population projections for some selected super-zones (i.e., aggregation of zones) in the region.

Exhibit 3.1: Population Projections for British Columbia

Population (in thousands)	2006	2011	2016	2021	2026	2031
Lower Vancouver Island and Southern Gulf Islands	584	613	647	677	704	726
Upper Vancouver Island and Northern Gulf Islands	114	122	128	136	142	147
Greater Vancouver	2090	2230	2382	2526	2656	2771
Sunshine Coast	322	355	394	431	467	501
Skeena-Prince Rupert	17	17	18	19	19	19

3.3 TRANSPORTATION NETWORK

The COMPASS™ Demand Model requires a complete description of all relevant attributes that affect travel behavior within the three major route corridors for each mode of travel. The network data assembled and updated for the study included:

- Average vehicle charges
- Average passenger charges
- On-board traveling times
- Frequency of ferry service
- Terminal wait times
- Access and egress times
- Vehicle operating costs for the access and egress
- Average vehicle occupancy
- Passenger charges
- On-board traveling times
- Frequency of ferry service
- Average terminal wait times
- Access and egress times and costs

The network data used to update the model was obtained from highway network databases, and BC Ferries time and fare schedules. The update of the model required that the differentiations between the seasonal fares and traveling characteristics be captured. The full fare scenarios were input into the network files. Exhibit 3.2 demonstrates the extension of the spatial network used in the analysis, where the geographic road and ferry network of British Columbia can be noticed. A zoom-in showing the extent of Vancouver Island is shown in Exhibit 3.3.

Access times were based on typical driving times at posted road speeds with the exception of the Greater Vancouver Area where speeds were reduced by 10 to 20km/h to reflect the higher level of average congestion here.

Exhibit 3.2: British Columbia Travel Network, as coded in COMPASS™

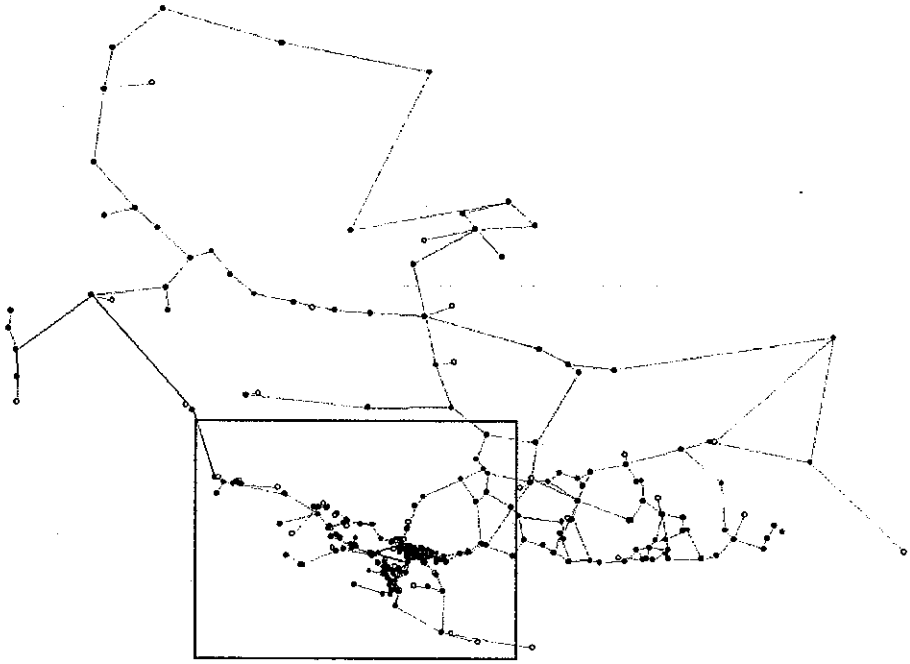
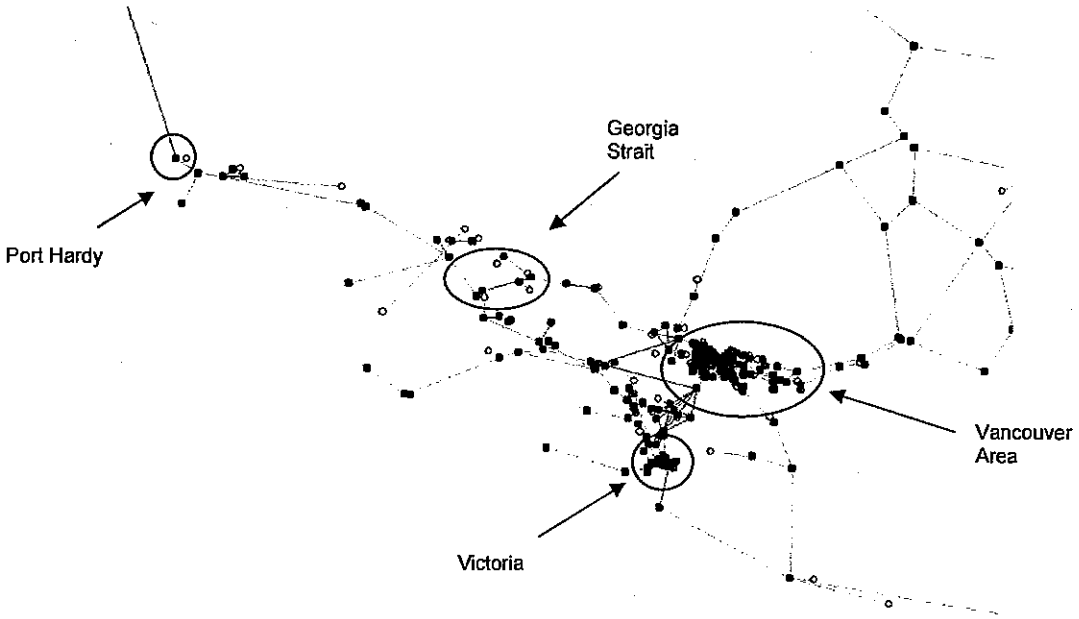


Exhibit 3.3: Vancouver Island, zoom-in from Exhibit 3.2

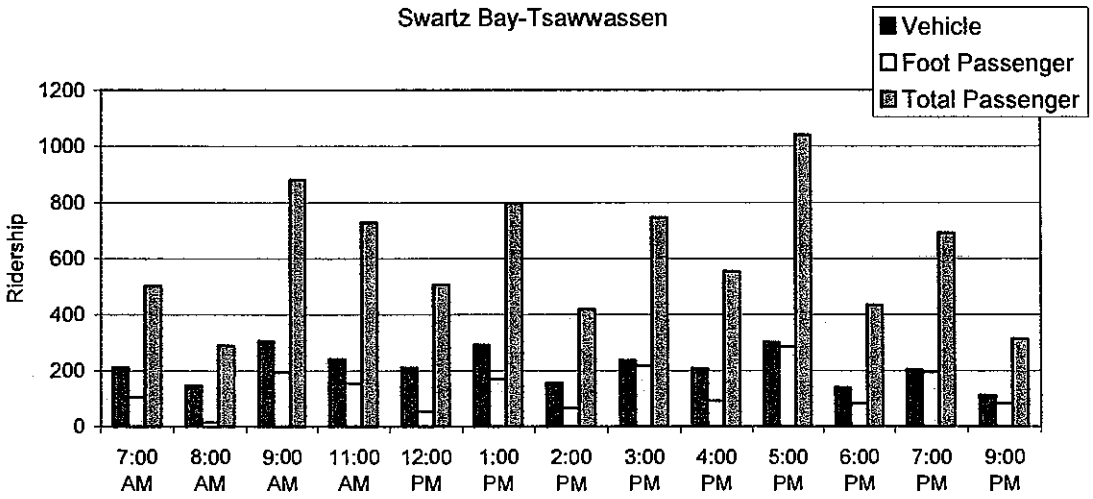


There is a well-demonstrated difference between the real costs and the perceived costs of operating an automobile [Metcalf, et al, 1977]. The real costs of a car journey include not only marginal costs such as fuel and maintenance but also fixed costs such as depreciation, insurance and interest. A number of studies (e.g., [Quarmby, 1966]) have shown that many users perceive only fuel and possibly maintenance costs as part of the total cost. For this study, business travelers were assumed to perceive full costs because of their legal accountability while all other travelers were assumed to perceive only fuel costs.

3.4 FERRY TRAFFIC DATA

Traffic data per sailing was made available by BC Ferries to TEMS for the purpose of this study. We show traffic data from March 2006 only, the month during which the Stated Preference Survey took place. The average data is done per sailing and it is related to March 2006 only (except for Route 10). In all charts, the red column shows the average number of vehicles (not "vehicle passengers") on board each sailing, the yellow column shows the average number of foot passengers, and the clue column shows the average number of total passengers.

Exhibit 3.4: Route 1 ridership, March 2006



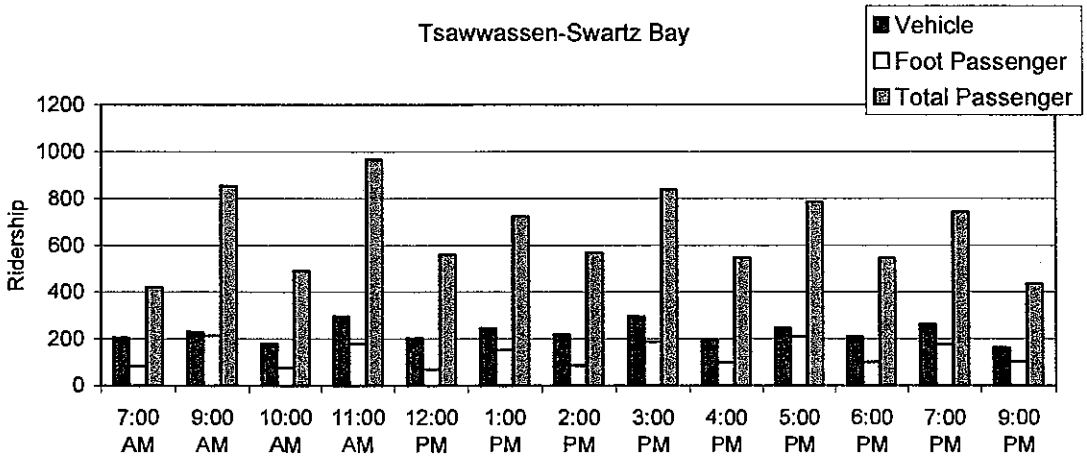
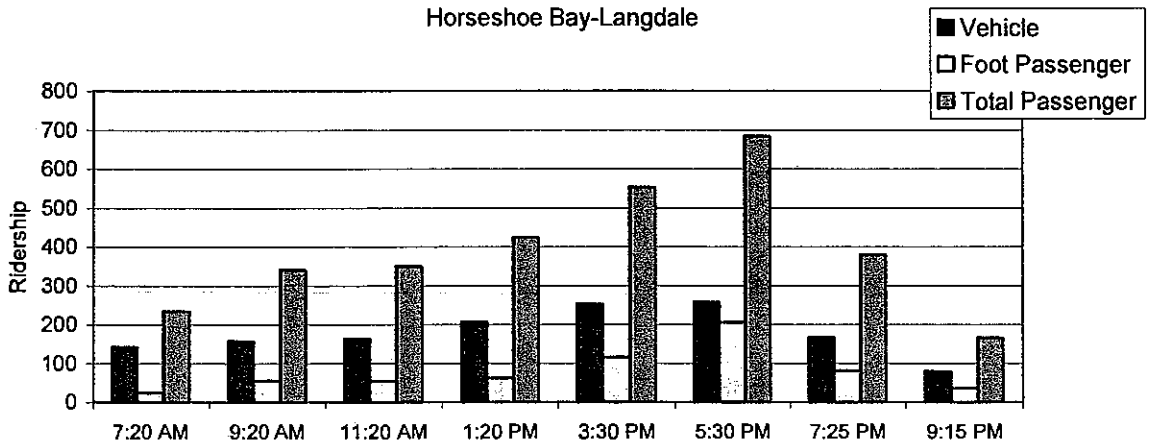


Exhibit 3.5: Route 3 ridership, March 2006



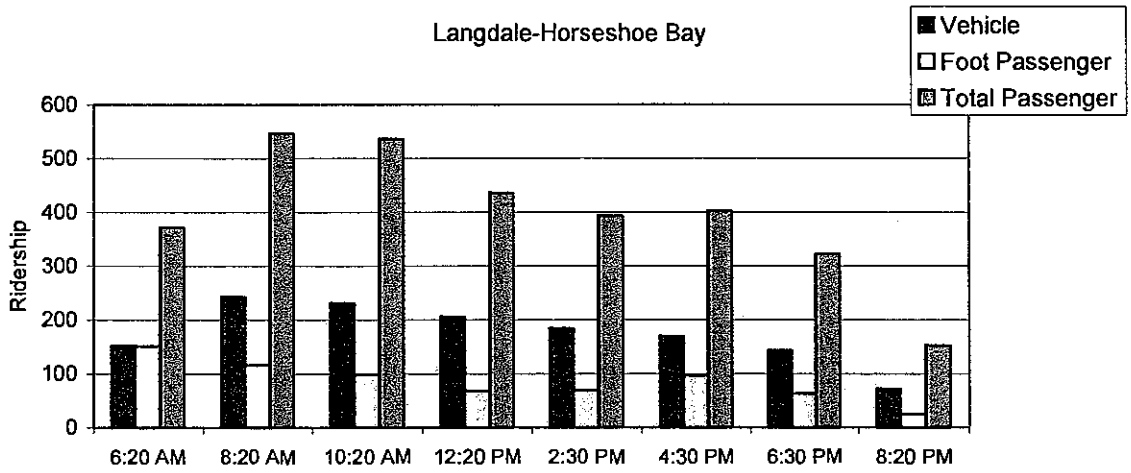
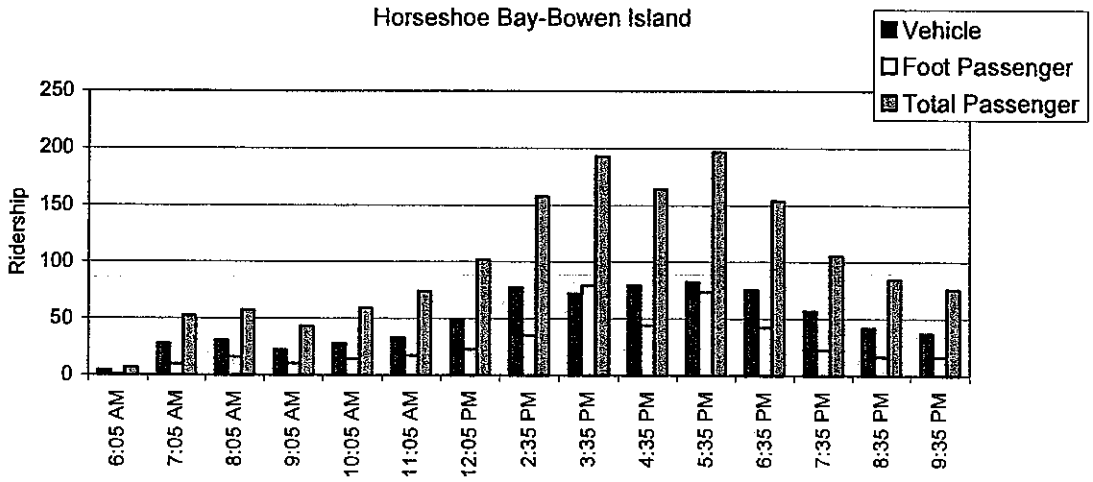
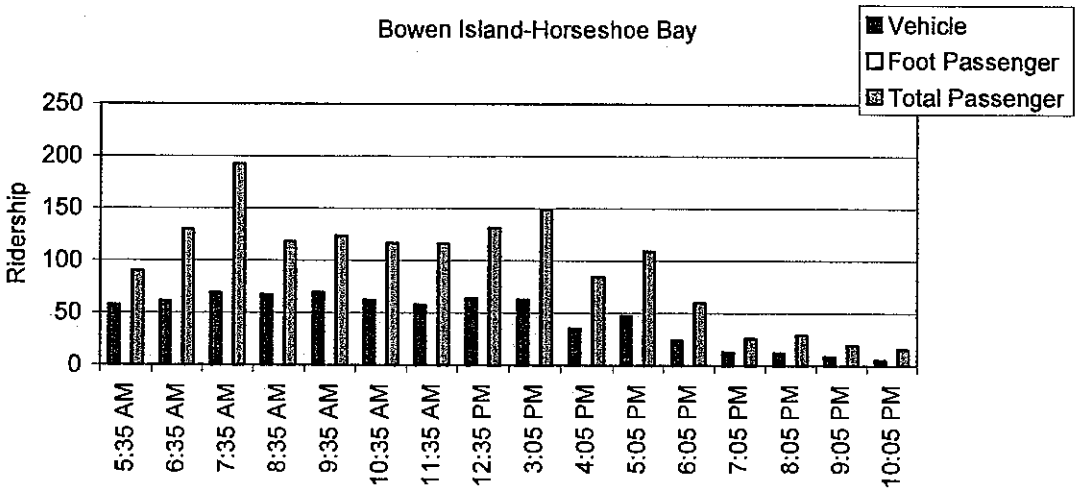


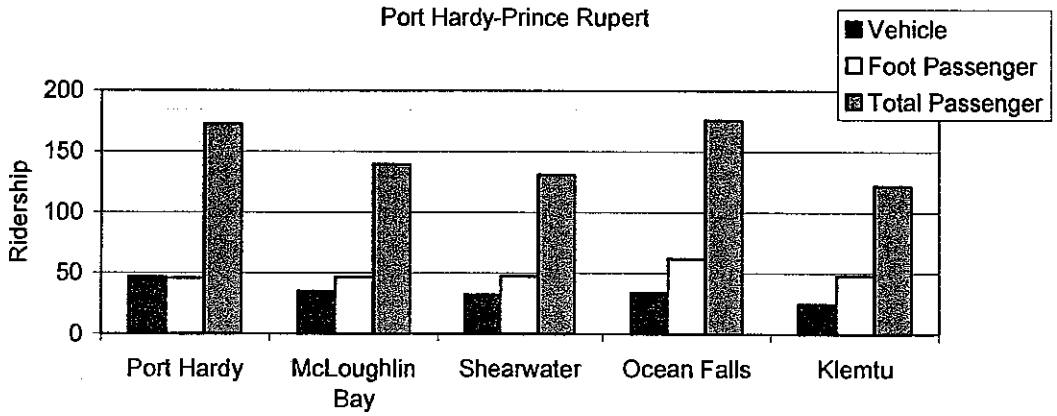
Exhibit 3.6: Route 8 ridership, March 2006





All averages shown for Route 10 have been computed for March 2005, since the March 2006 data is influenced by the accident to the Queen of North on March 22, 2006 that disrupted the service for the remainder of the month.

Exhibit 3.7: Route 10 ridership, March 2005



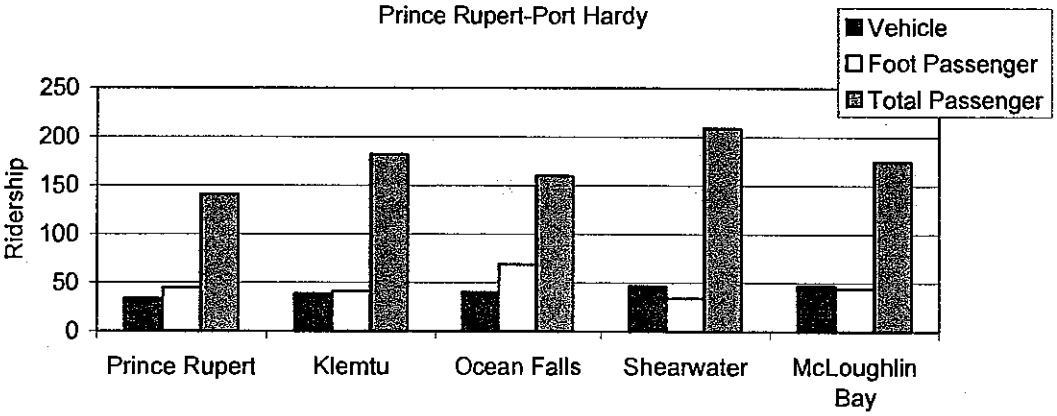
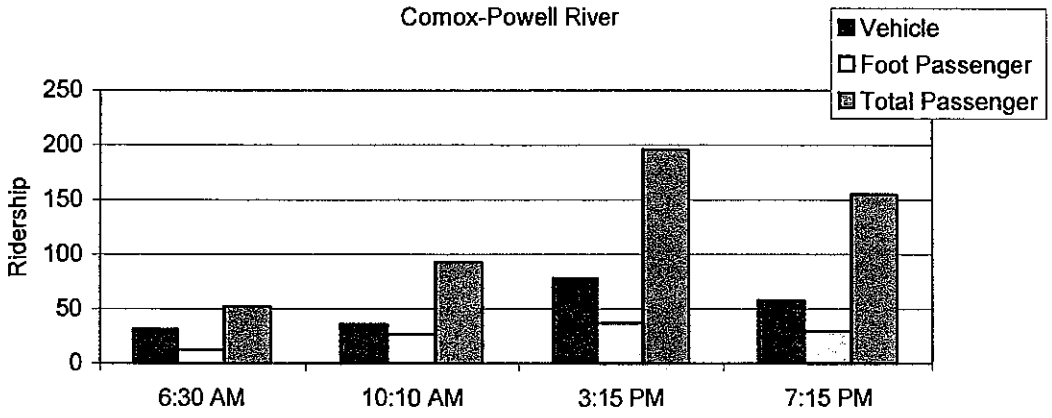


Exhibit 3.8: Route 17 ridership, March 2006



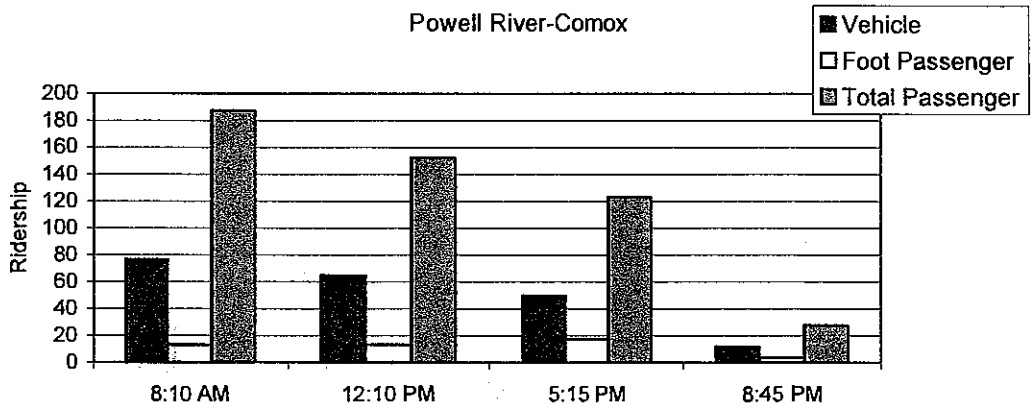
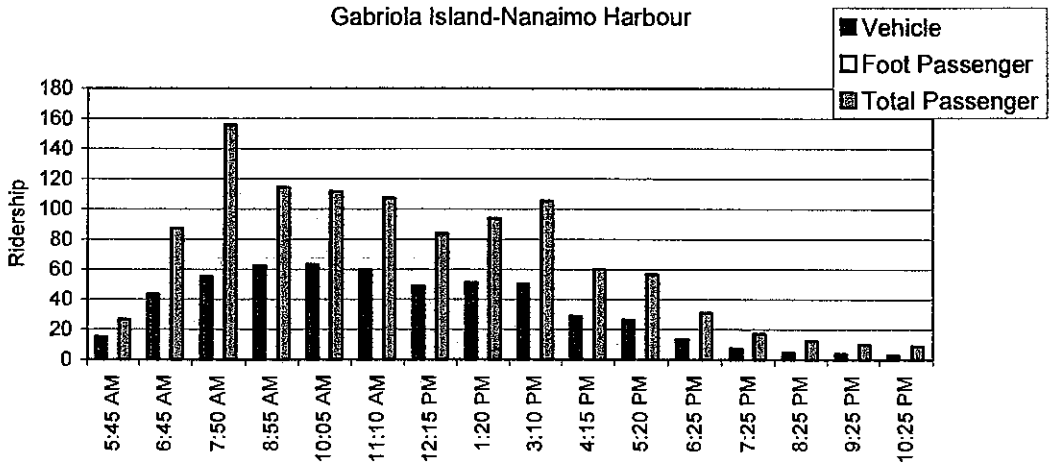


Exhibit 3.9: Route 19 ridership, March 2006



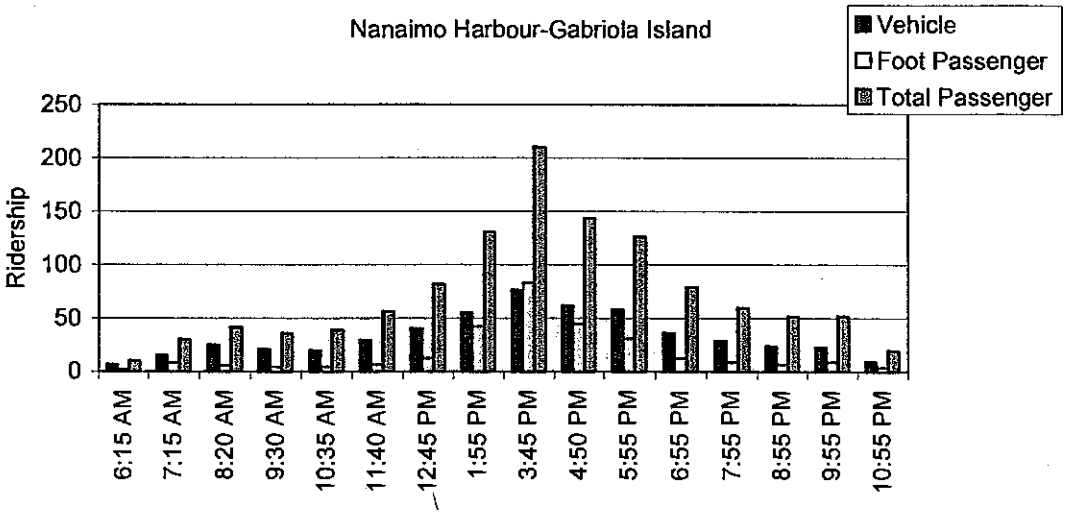
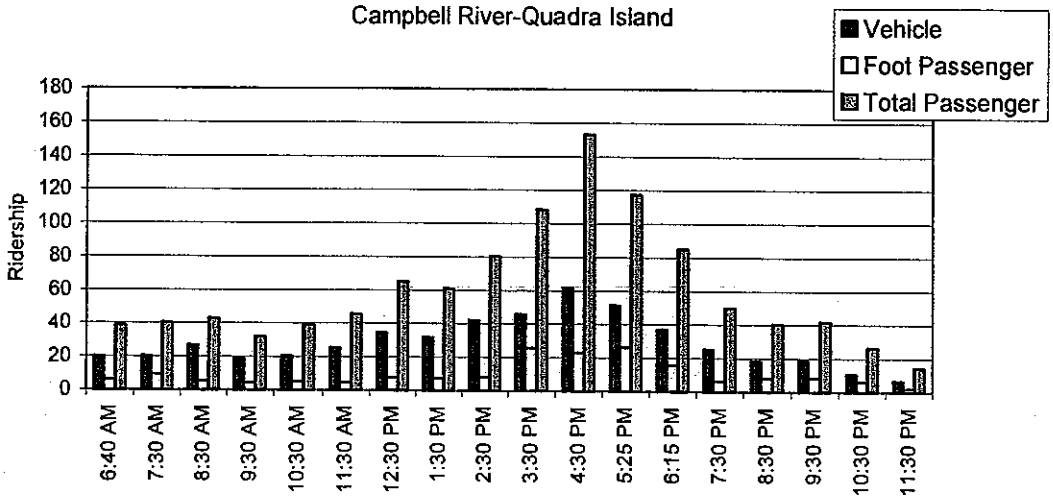
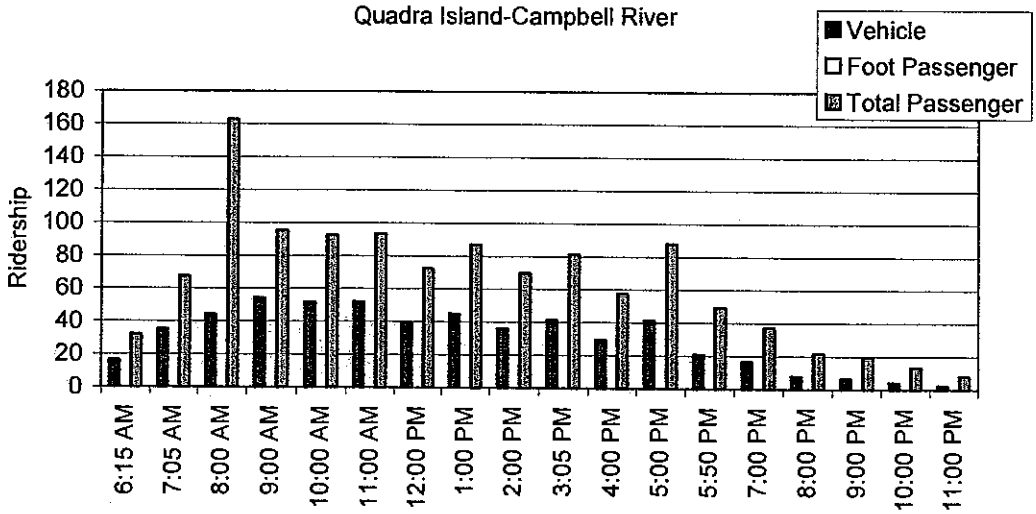


Exhibit 3.10: Route 23 ridership, March 2006





4 STATED PREFERENCE SURVEY

Surveys can be carried out in several ways, depending on the nature of the information the surveyor wishes to determine, and the type of hypothetical scenarios he/she wishes to test. To this aim, the technical literature now abounds of treatises on Stated Preference (SP) and Revealed Preference (RP) surveys. Among the available technical literature on this issue, for more information the reader can consult [Louviere et al., 2000], for example. Additionally, the whole volume 22, Issue 1 of the respected Journal of Transport Economics & Policy (JTEP) is dedicated to the theory and practice of SP surveys [JTEP, 1998].

Revealed-preference data relate to people's actual choices in real-world situations, while stated-preference data are collected in experimental or survey situations where respondents are presented with hypothetical choice situations. Revealed-preference data have the advantage of reflecting actual choices, however such data are limited to choice situations that must exist, or have existed historically. On the contrary, stated-preference data can be used to examine situations that do not currently exist, or when variation in a high number of factors is examined.

4.1 SURVEY ORGANIZATION AND DESIGN

A Stated Preference (SP) Survey was carried out in the period March 11 until March 21. The schedule of the survey work is:

- 3/11 (pilot): Routes 17 & 23;
- 3/12: Route 19;
- 3/13: Route 8;
- 3/14: Routes 1 & 3;
- 3/15: Route 17;
- 3/16: Route 23;
- 3/17—3/21: Route 10.

TEMS' personnel carried out the interviews on board of the respective vessels. In total, 18 survey forms have been designed for the survey of the 7 routes. Each survey form will have four pages. The first page is a general questionnaire, followed by a three-page trade-off questionnaire aimed to retrieve information on the value of time (VOT), the value of frequency (VOF), the value of access (VOA) and the value of reliability (VOR). Routes are classified as short, medium or long, based on trip time. The following exhibit shows the classification of the 7 routes.

Exhibit 4.1: Classification of the routes

Classification Name	Routes included
Short Routes (S)	3, 8, 19, 23
Medium Routes (M)	1, 17
Long Route (L)	10

The next two exhibits provide a brief description of the 18 survey forms. The trade-off questionnaires for each survey form are passenger specific. For instance, the Set 1 trade-off questionnaire for S-A1 is not the same as the Set 1 trade-off questionnaire for S-C1. All sets labeled "1" contain a page with general questions about the trip, plus tradeoff questions on VOT, VOF and VOA. All sets labeled "2" have a tradeoff question on VOR in lieu of the VOA. Forms of both types "1" and "2" for a specific route were handed over randomly in order to have approximately equal amounts of VOA and VOR answers.

Exhibit 4.2: Legend for Short Routes

Form	Description	Set Number
S-A1	Short Route – Auto Driver /Passenger	SET 1
S-A2	Short Route – Auto Driver/Passenger	SET 2
S-C1	Short Route – Commercial Vehicle Driver	SET 1
S-C2	Short Route – Commercial Vehicle Driver	SET 2
S-W1	Short Route – Transit/Walker/Drop off	SET 1
S-W2	Short Route – Transit/Walker/ Drop off	SET 2

Exhibit 4.3: Legend for Medium Routes

Form	Description	Set Number
M-A1	Medium Route – Auto Driver /Passenger	SET 1
M-A2	Medium Route – Auto Driver /Passenger	SET 2
M-C1	Medium Route – Commercial Vehicle Driver	SET 1
M-C2	Medium Route – Commercial Vehicle Driver	SET 2
M-W1	Medium Route – Transit/Walker/Drop off	SET 1
M-W2	Medium Route – Transit/Walker/ Drop off	SET 2

Exhibit 4.4: Legend for Long Route

Form	Description	Set Number
L-A1	Long Route – Auto Driver /Passenger	SET 1
L-A2	Long Route – Auto Driver /Passenger	SET 2
L-C1	Long Route – Commercial Vehicle Driver	SET 1
L-C2	Long Route – Commercial Vehicle Driver	SET 2
L-W1	Long Route – Transit/Walker/Drop off	SET 1
L-W2	Long Route – Transit/Walker/ Drop off	SET 2

The survey forms are shown in Appendix.

4.2 RESULTS

Exhibit 4.5: Survey forms completed

Routes	1	3	8	10	17	19	23	All
A1	133	102	81	88	113	80	101	698
A2	108	106	53	73	103	73	136	652
W1	66	66	89	88	42	52	41	444
W2	77	30	90	54	52	77	53	433
C1	3	15	33	0	7	13	13	84
C2	14	11	8	0	2	13	15	63
Total	**401**	**330**	**354**	**303**	**319**	**308**	**359**	**2,374**

4.2.1 ROUTE 1: TSAWWASSEN – SWARTZ BAY

Exhibit 4.6: Purpose breakdown of Survey form

	Purpose	Quantity
Vehicle	Business	88
	Commuter	9
	Tourism	53
	Social	91
Foot	Business	17
	Commuter	11
	Tourism	33
	Social	82
Commercial	Full-time	17
	Part-time	0
Total		**401**

Exhibit 4.7: Behavioral variables (all quantities in $/hr)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	27.50	21.79	21.32	14.50
	Commuter	22.00	24.00	22.00	21.50
	Tourism	28.90	26.43	17.29	14.50
	Social	24.12	22.77	21.56	12.00
Foot	Business	11.40	8.10	11.00	8.00
	Commuter	7.50	6.00	9.00	8.00
	Tourism	9.17	12.86	11.20	6.25
	Social	8.01	9.77	14.60	13.75
Commercial	Full-time	45	50	45	10
	Part-time	n/a	n/a	n/a	n/a

Business and Seasonal Tourism values of time are higher than the respective values for Commuter and Social travel. A similar trend emerges for the other behavioral variables, with the exception of the value of reliability. The data for commuters has a higher variation, due to the lower number of observations. No part-time commercial drivers were found on board.

4.2.2 Route 3: Horseshoe Bay – Langdale

Exhibit 4.8: Purpose breakdown of Survey forms

	Purpose	Quantity
Vehicle	Business	44
	Commuter	30
	Tourism	49
	Social	85
Foot	Business	21
	Commuter	20
	Tourism	17
	Social	38
Commercial	Full-time	23
	Part-time	3
Total		**330**

Exhibit 4.9: Behavioral variables (all quantities in $/hr)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	24.76	19.44	17.20	15.70
	Commuter	11.77	5.20	16.03	14.14
	Tourism	17.45	25.24	20.21	10.15
	Social	13.80	7.07	8.57	14.66
Foot	Business	17.21	8.30	8.00	8.36
	Commuter	11.41	6.50	7.90	7.12
	Tourism	11.72	9.33	7.46	5.00
	Social	10.72	8.82	9.84	10.11
Commercial	Full-time	42.96	40	40	40
	Part-time	n/a	n/a	n/a	n/a

Contrarily to other short routes, VOTs for foot passengers are generally higher. Also, contrarily to other routes, VOTs for (seasonal) tourism is lower, a likely product of the fact that most tourism on this route appears to be local (i.e., mostly originated from the Vancouver area). Very few part-time commercial drivers were found on board, to make an extrapolation significant.

4.2.3 Route 8: Horseshoe Bay Bowen Island

Exhibit 4.10: Purpose breakdown of Survey forms

	Purpose	Quantity
Vehicle	Business	35
	Commuter	35
	Tourism	23
	Social	39
Foot	Business	61
	Commuter	53
	Tourism	29
	Social	35
Commercial	Full-time	20
	Part-time	24
Total		**354**

Exhibit 4.11: Behavioral variables (all quantities in $/hr)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	15.76	17.00	17.28	23.70
	Commuter	12.71	15.50	13.50	9.90
	Tourism	19.33	12.17	14.17	10.10
	Social	17.39	15.57	21.04	12.00
Foot	Business	9.96	11.86	7.50	14.83
	Commuter	9.26	8.82	6.67	21.04
	Tourism	13.33	12.00	n/a	n/a
	Social	15.20	15.33	15.10	14.81
Commercial	Full-time	50.62	42.30	27.00	n/a
	Part-time	35.10	32.00	27.00	n/a

As in the case of Route 3, VOTs for tourism is lower, given that most tourism on this route appears to be local (from the Vancouver area).

4.2.4 Route 10: Port Hardy – Prince Rupert

Exhibit 4.12: Purpose breakdown of Survey forms

	Purpose	Quantity
Vehicle	Business	19
	Commuter	0
	Tourism	45
	Social	107
Foot	Business	26
	Commuter	0
	Tourism	29
	Social	77
Commercial	Full-time	0
	Part-time	0
Total		**303**

Exhibit 4.13: Behavioral variables (all quantities in $/hr except VOF which is measured in $/day)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	17.50	35.12	18.50	14.00
	Commuter	n/a	n/a	n/a	n/a
	Tourism	19.95	24.00	26.50	12.00
	Social	14.62	35.86	21.80	14.56
Foot	Business	8.75	28.57	16.00	6.75
	Commuter	n/a	n/a	n/a	n/a
	Tourism	10.25	12.50	5.50	n/a
	Social	10.31	7.77	20.33	7.50
Commercial	Full-time	n/a	n/a	n/a	n/a
	Part-time	n/a	n/a	n/a	n/a

With respect to the journey length (24 hours), all VOTs and VORs are rather low, while the VOF is very high. No data for commercial drivers was collected, since Route 10 uses drop-off container at the terminal, hence no drivers could be found on board. Questionnaires from drivers found on the terminal were not used, because their answers reflect their journeys to/from terminal, but not on board.

4.2.5 ROUTE 17: COMOX – POWELL RIVER

Exhibit 4.14: Purpose breakdown of Survey forms

	Purpose	Quantity
Vehicle	Business	68
	Commuter	22
	Tourism	30
	Social	96
Foot	Business	10
	Commuter	5
	Tourism	22
	Social	57
Commercial	Full-time	7
	Part-time	2
Total		**319**

Exhibit 4.15: Behavioral variables (all quantities in $/hr)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	28.66	23.85	20.20	17.17
	Commuter	16.55	15.00	18.50	16.10
	Tourism	31.36	34.14	23.12	11.50
	Social	14.57	7.10	6.67	20.14
Foot	Business	11.60	10.13	12.00	9.00
	Commuter	8.43	7.50	9.50	8.22
	Tourism	10.27	14.83	7.55	5.50
	Social	8.26	9.88	11.14	13.04
Commercial	Full-time	55	35	35	35
	Part-time	n/a			

Business and Seasonal Tourism values of time are higher than the respective values for Commuter and Social travel. A similar trend emerges for the other behavioral variables, with the exception of the value of reliability. Very few part-time commercial drivers were found on board, to make an extrapolation significant.

4.2.6 ROUTE 19: NANAIMO – GABRIOLA ISLAND

Exhibit 4.16: Purpose breakdown of Survey forms

	Purpose	Quantity
Vehicle	Business	42
	Commuter	23
	Tourism	23
	Social	65
Foot	Business	34
	Commuter	17
	Tourism	11
	Social	65
Commercial	Full-time	29
	Part-time	4
Total		**308**

Exhibit 4.17: Behavioral variables (all quantities in $/hr)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	17.27	15.50	15.20	19.20
	Commuter	10.82	11.83	11.87	8.05
	Tourism	15.93	12.17	12.37	12.66
	Social	11.65	12.19	13.88	10.14
Foot	Business	9.80	9.38	8.50	19.05
	Commuter	7.64	8.75	9.00	21.20
	Tourism	12.90	13.90	13.67	16.50
	Social	8.23	11.29	9.33	17.50
Commercial	Full-time	53.46	30.40	31.40	52.20
	Part-time	n/a	n/a	n/a	n/a

Very few part-time commercial drivers, were found on board, to make an extrapolation significant

4.2.7 Route 23: Campbell River – Quadra Island

Exhibit 4.18: Purpose breakdown of Survey forms

	Purpose	Quantity
Vehicle	Business	58
	Commuter	24
	Tourism	31
	Social	124
Foot	Business	24
	Commuter	11
	Tourism	3
	Social	55
Commercial	Full-time	25
	Part-time	4
Total		**359**

Exhibit 4.19: Behavioral variables (all quantities in $/hr)

	Purpose	VOT	VOF	VOA	VOR
Vehicle	Business	19.75	14.06	18.75	18.00
	Commuter	9.19	8.81	10.77	7.20
	Tourism	15.04	13.58	12.15	11.16
	Social	10.07	11.61	9.72	11.31
Foot	Business	9.50	9.55	9.02	16.64
	Commuter	7.11	7.75	7.22	25.52
	Tourism	n/a	n/a	n/a	n/a
	Social	8.11	10.79	10.30	12.22
Commercial	Full-time	60.00	40.00	34.50	60.00
	Part-time	n/a	n/a	n/a	n/a

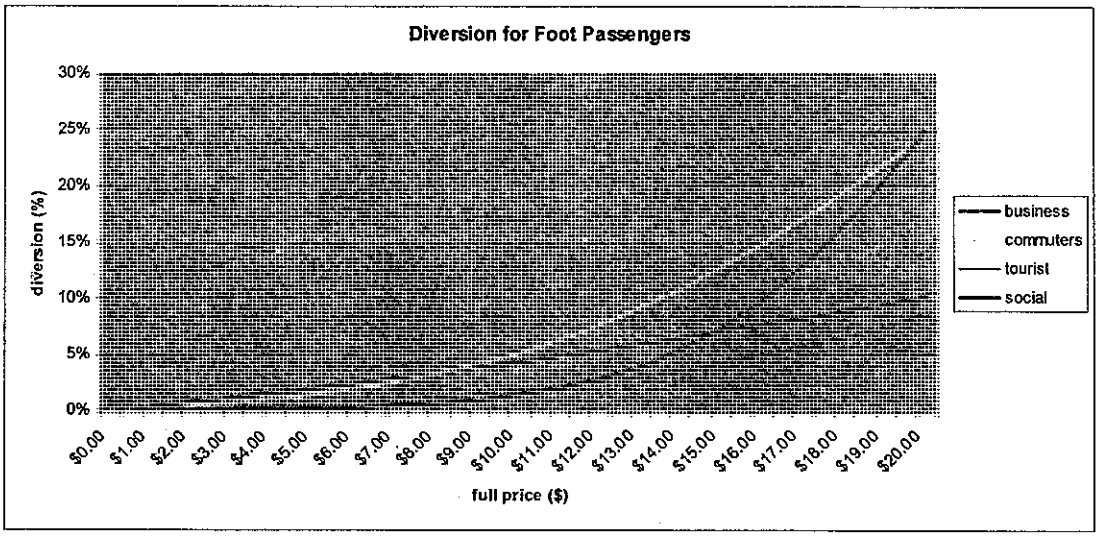
Very few tourist foot passengers, and part-time commercial drivers, were found on board, to make an extrapolation significant.

5 REVENUE YIELD MODELS

In the following charts, we outline the variations in demand for the routes considered in this study. For each route we present the diversion rate and the corresponding revenue yield curve as a function of price for the route. Both sets of charts are given for foot passengers and vehicle passengers, and differentiated by purpose of travel.

5.1 ROUTE 1: TSAWWASSEN – SWARTZ BAY

Exhibit 5.1: Route 1 Diversion



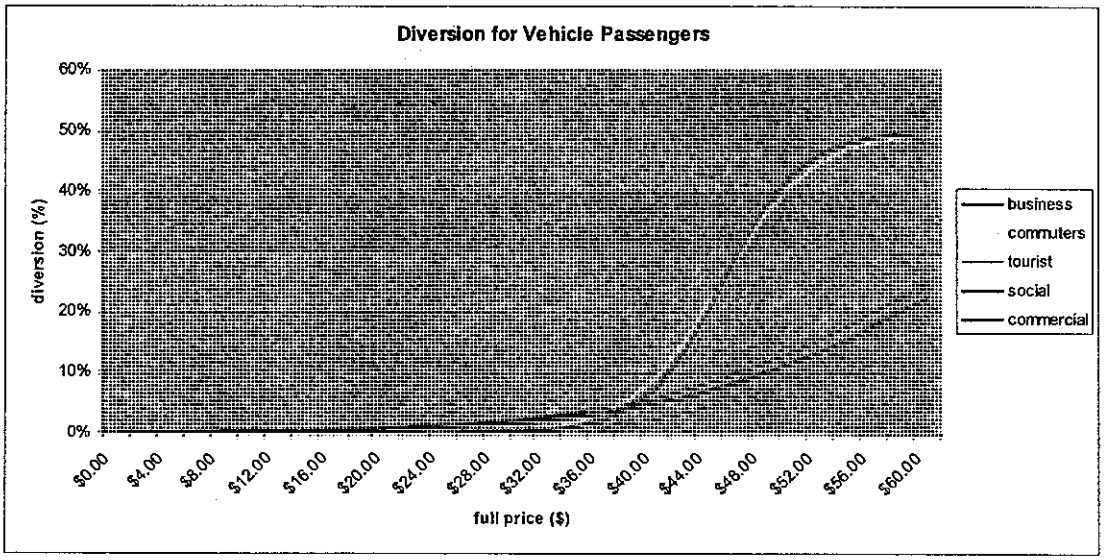
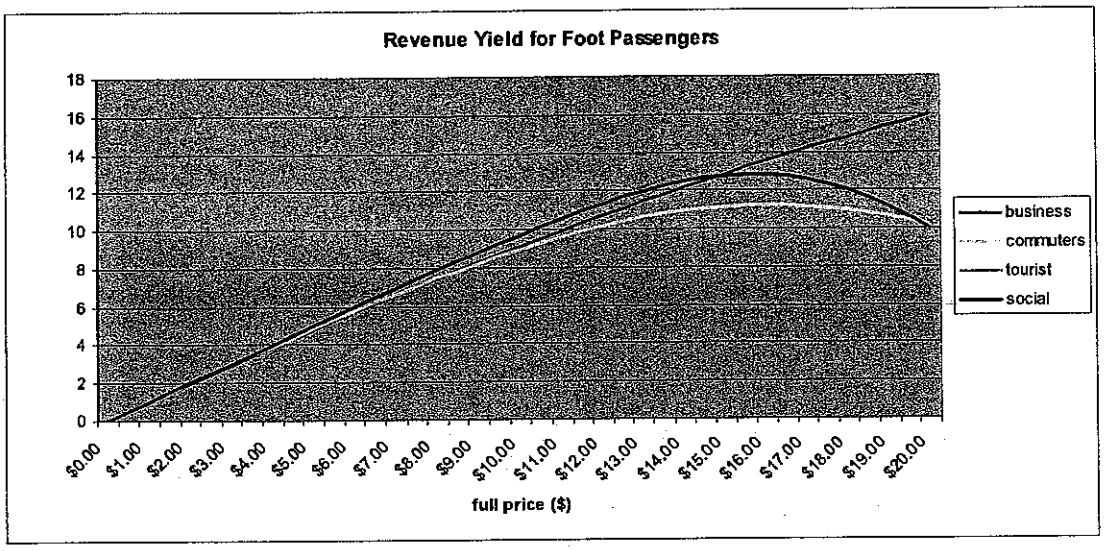
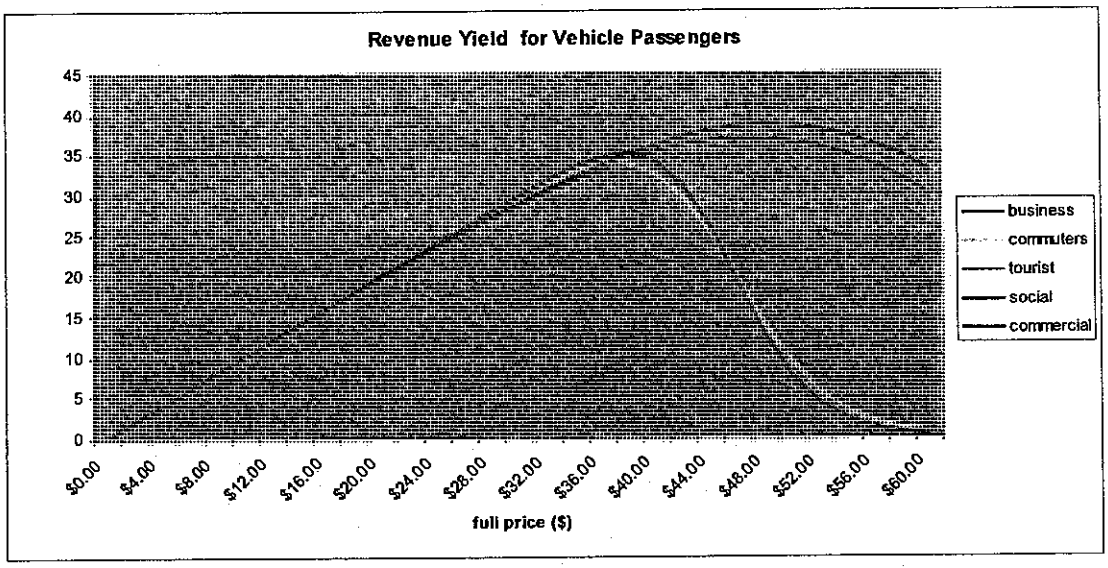


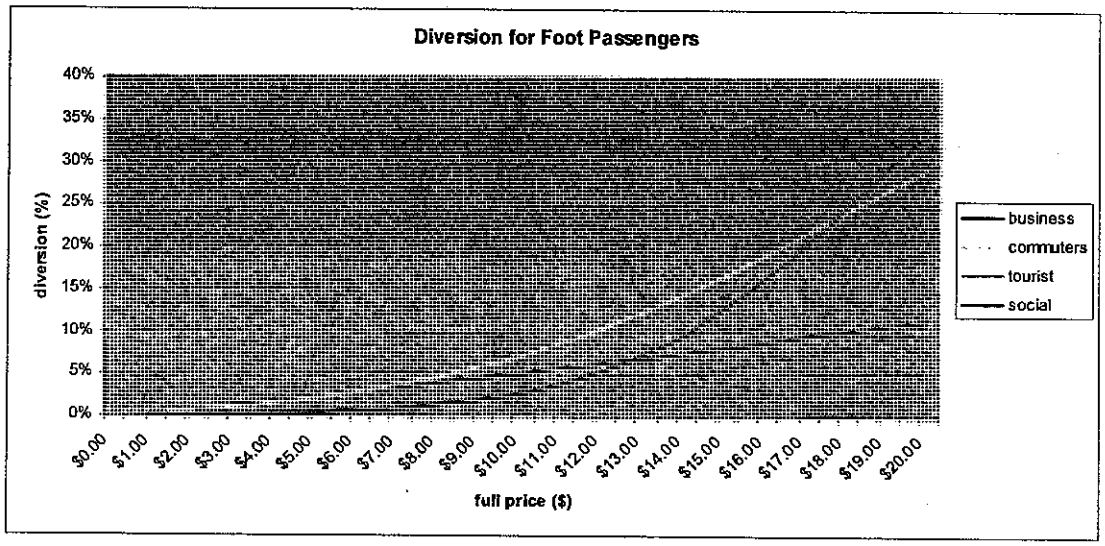
Exhibit 5.2: Route 1 Revenue Yield





5.2 ROUTE 3: HORSESHOE BAY – LANGDALE

Exhibit 5.3: Route 3 Diversion



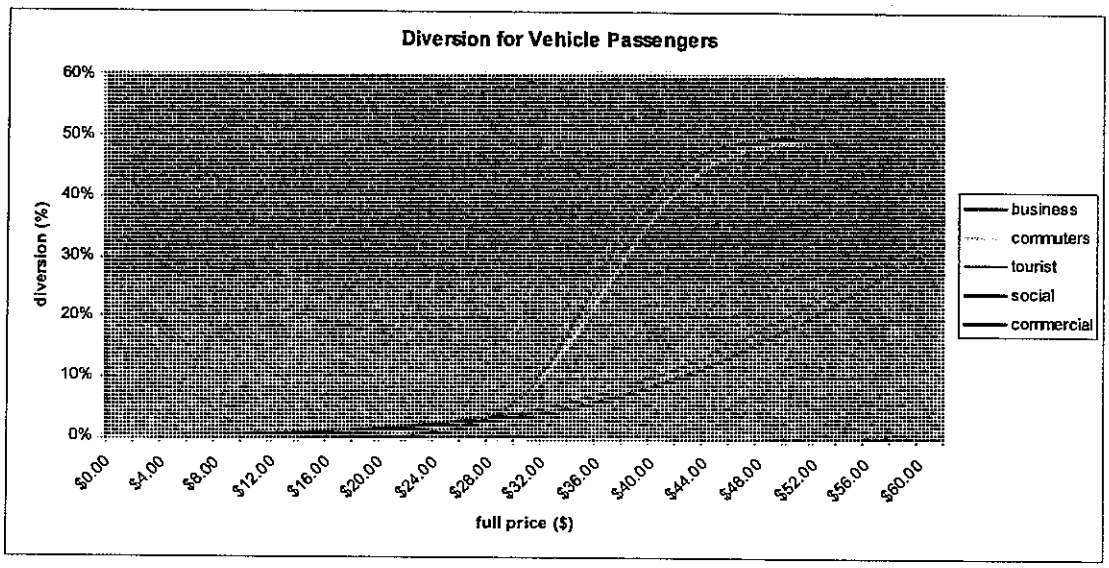
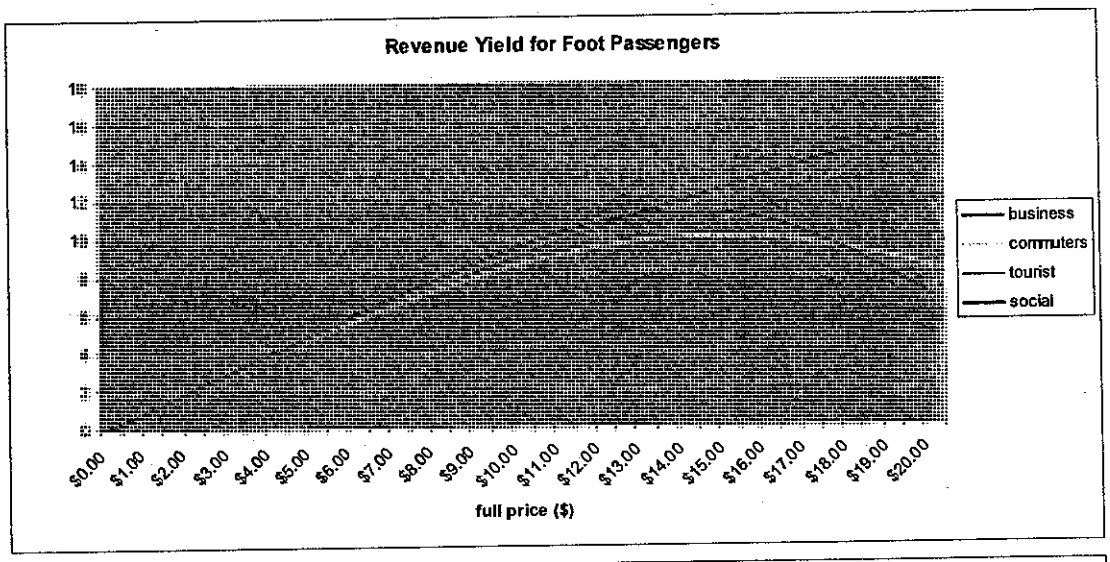
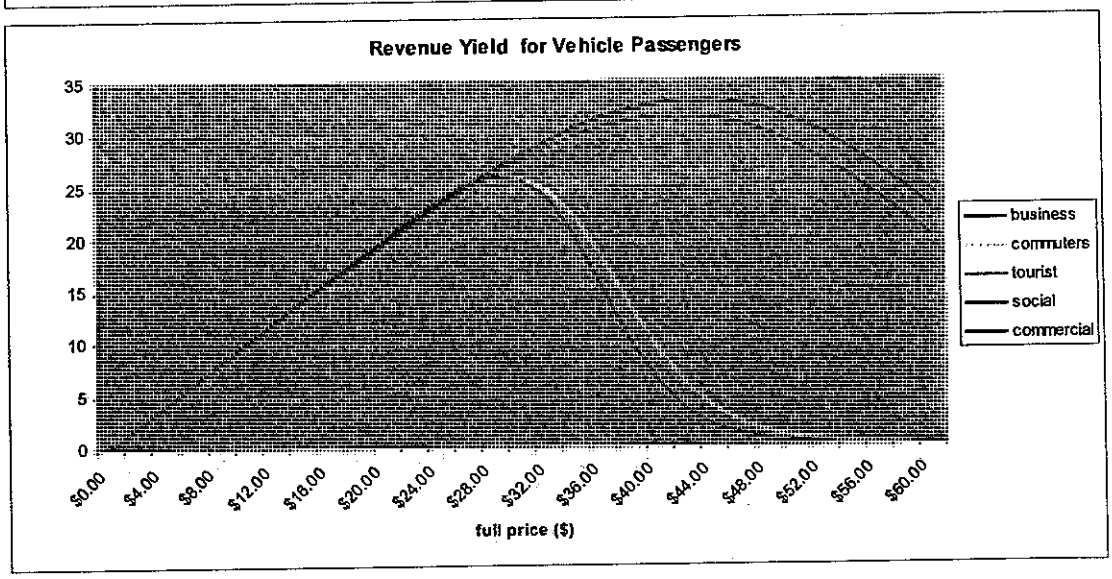


Exhibit 5.4: Route 3 Revenue Yield

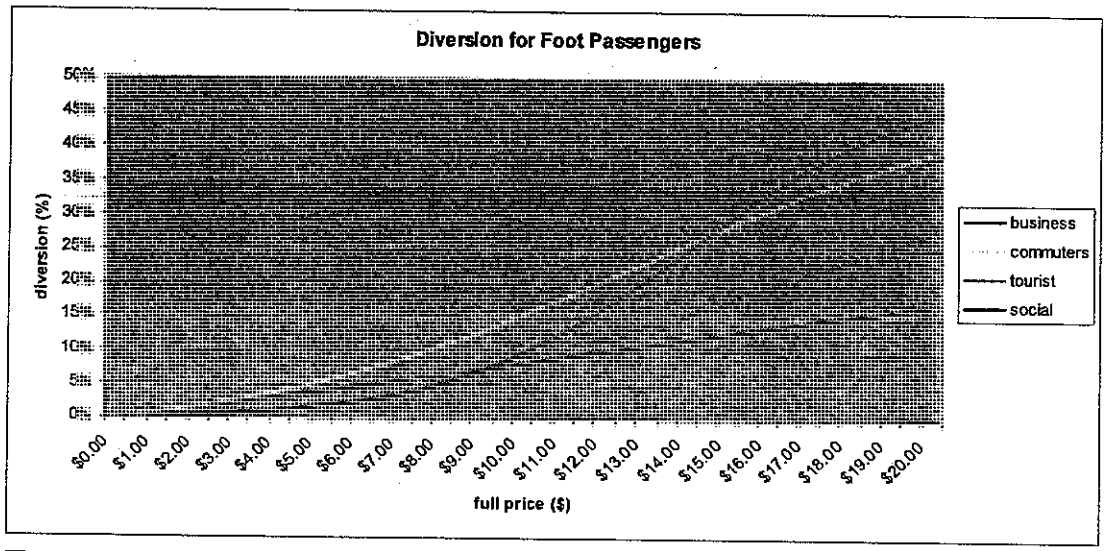




Revenue Yield for Route 3 shows similar features to the other short routes analyzed in this study. The major source of difference is in the behavior of the tourist segment. The Survey has shown that tourist VOTs are relatively lower (with respect to business VOTs) than for other routes, which is likely byproduct of the fact that most tourists surveyed on this route were local, originating from the Vancouver area, therefore, most likely not on an extended vacation.

5.3 ROUTE 8: HORSESHOE BAY – BOWEN ISLAND

Exhibit 5.5: Route 8 Diversion



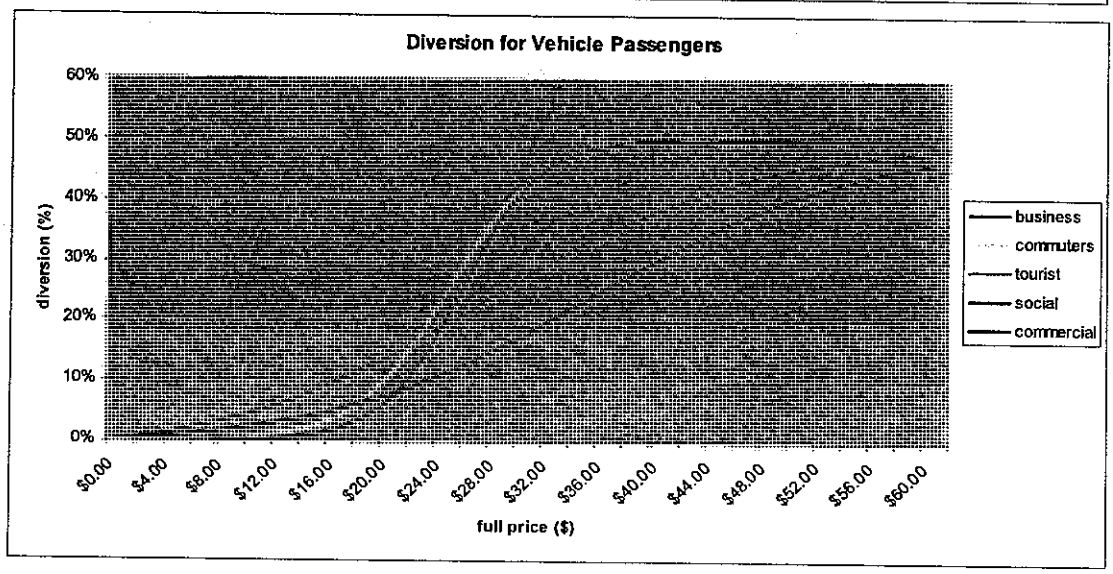
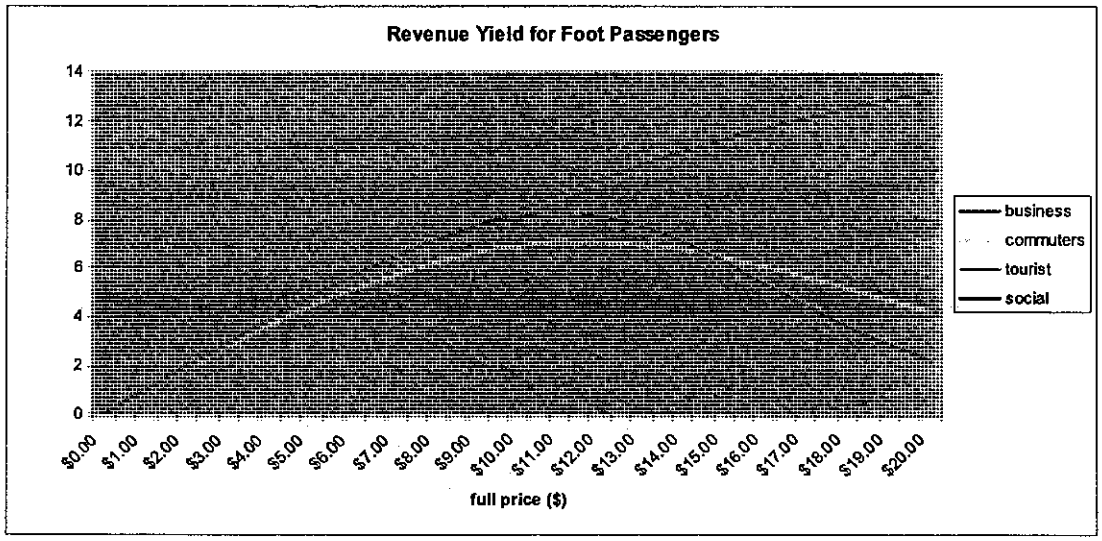
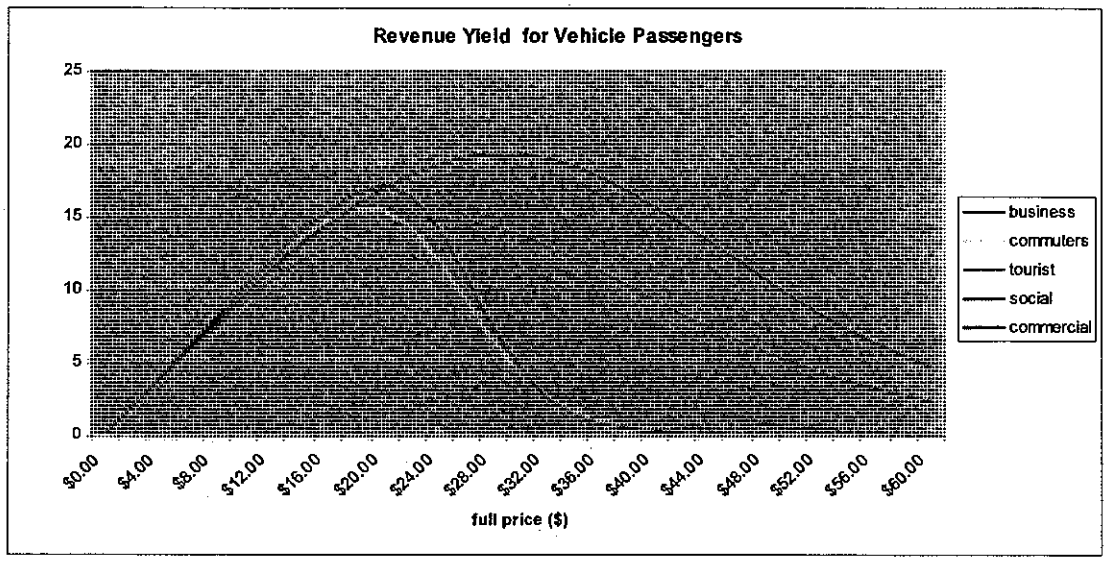


Exhibit 5.6: Route 8 Revenue Yield

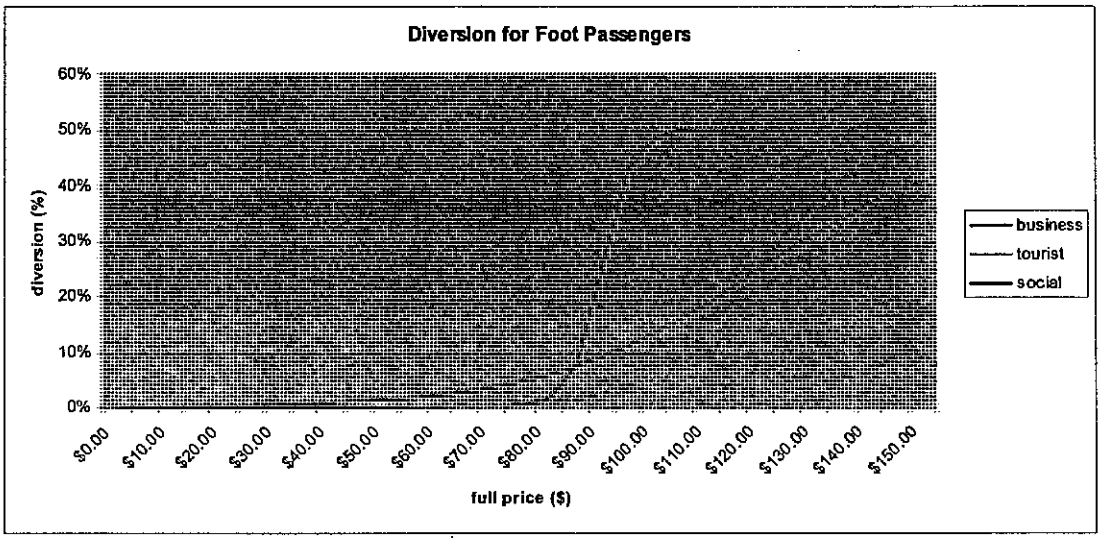




Route 8 has in common with routes 19 and 23 the fact that they both serve island communities, hence revenue yield profiles for these three routes are similar. The peak of revenue yield for Route 8, however, is slightly higher than for the other two cases, to reflect the higher incomes for the residents in Bowen Island.

5.4 ROUTE 10: PORT HARDY – PRINCE RUPERT

Exhibit 5.7: Route 10 Diversion



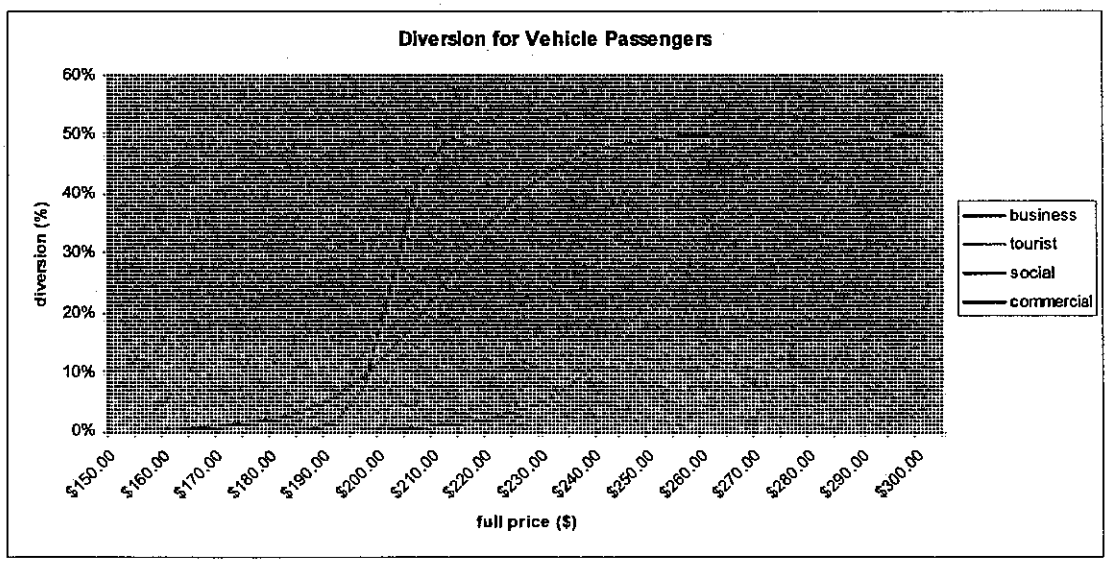
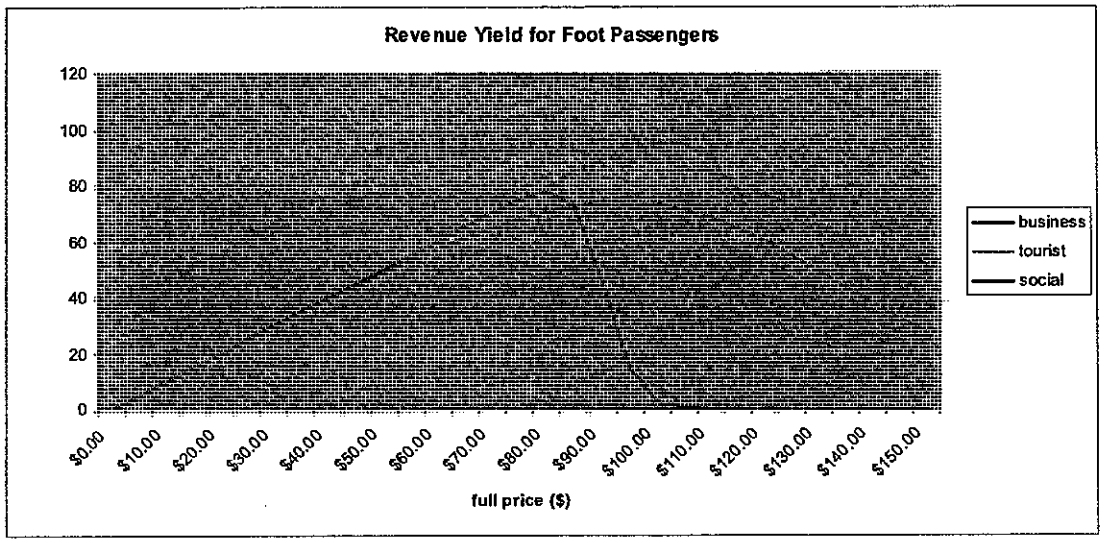
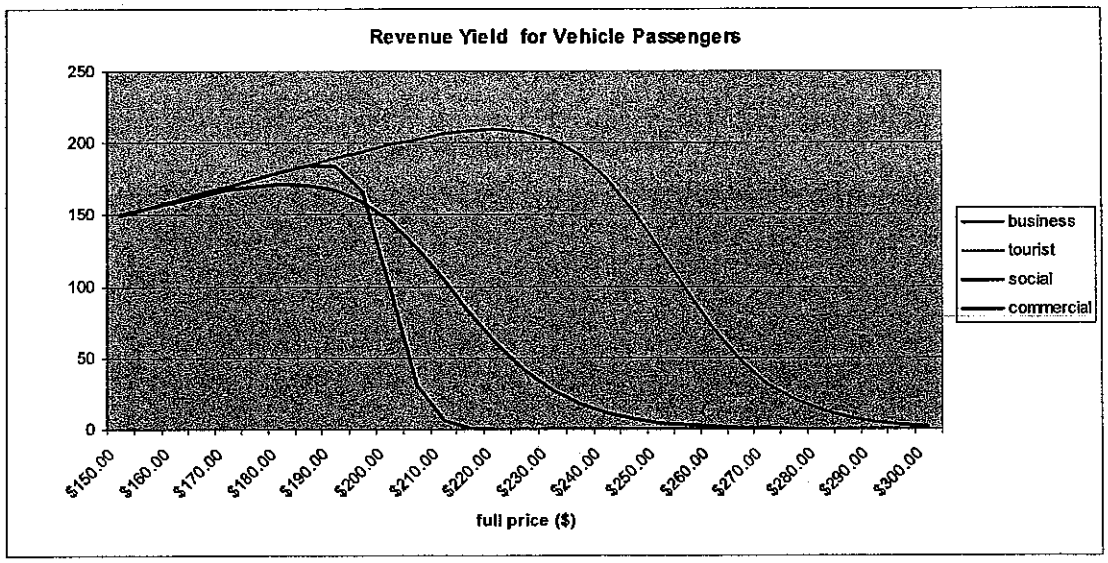


Exhibit 5.8: Route 10 Revenue Yield

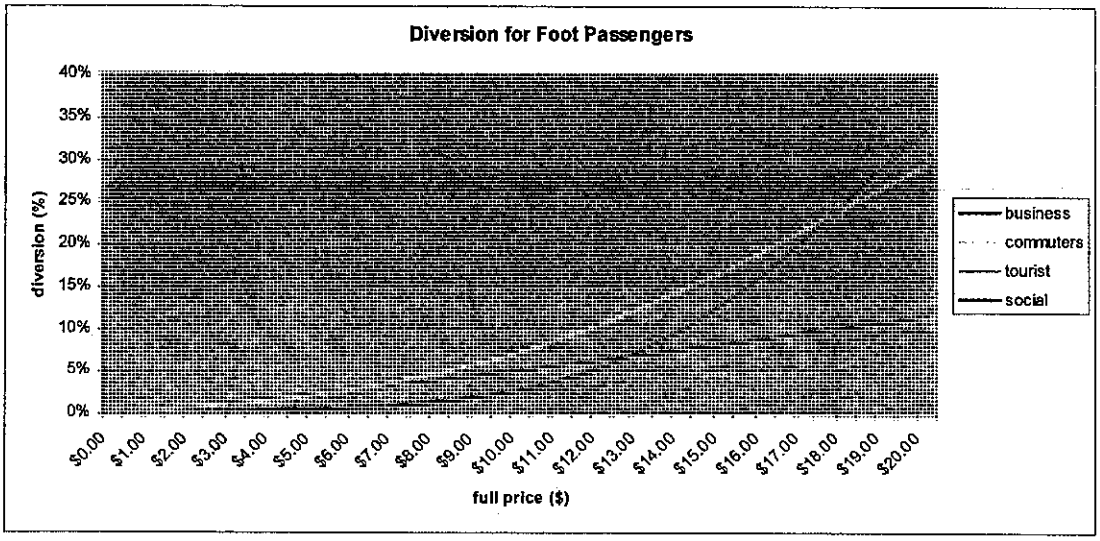




For Route 10, no sizable commuting population was present at the time of the survey, which is likely for a sailing that is approximately 24 hours long.

5.5 Route 17: Comox – Powell River

Exhibit 5.9: Route 17 Diversion



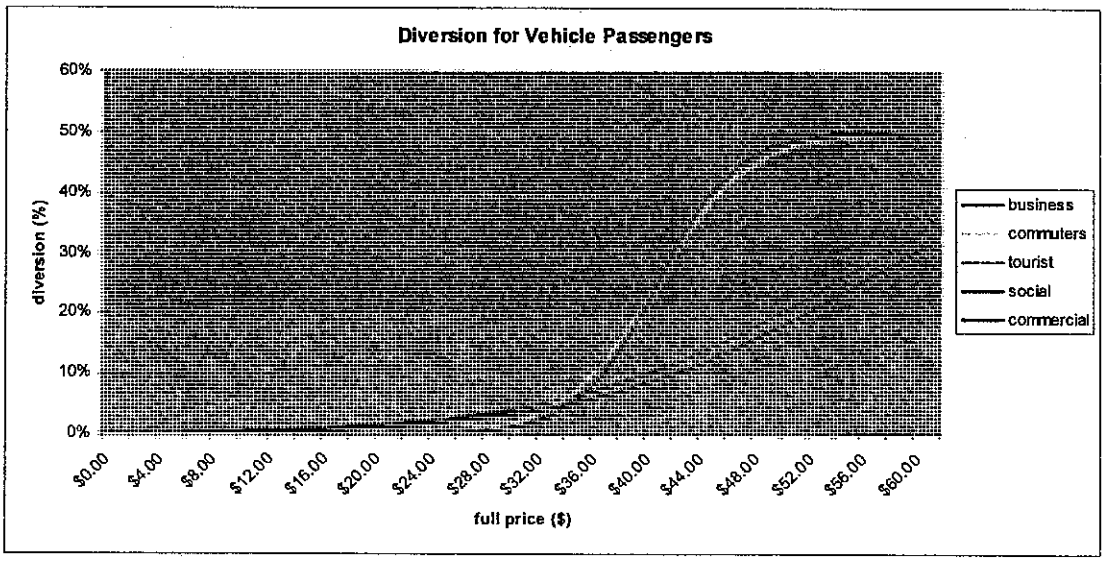
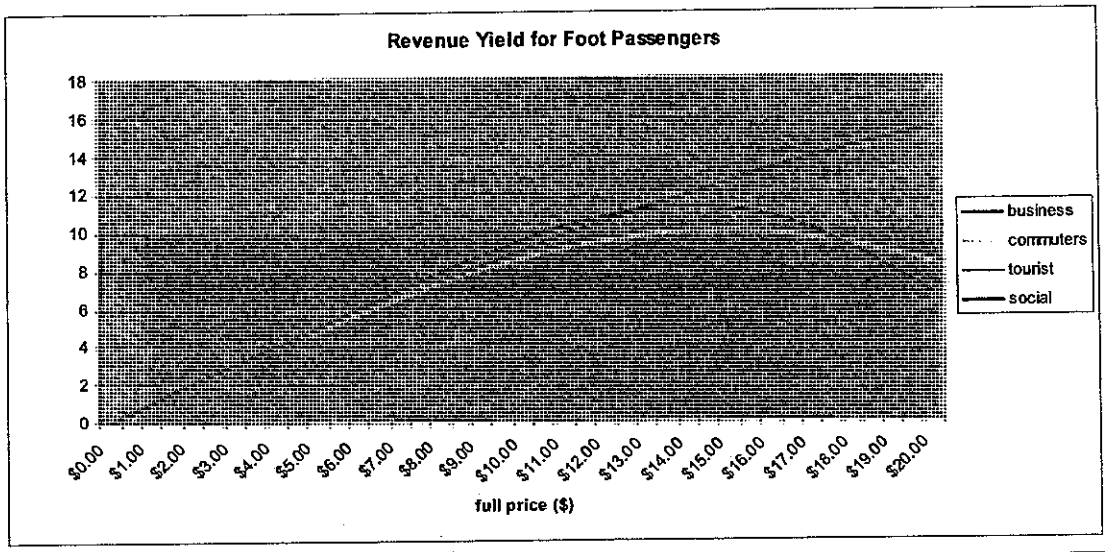
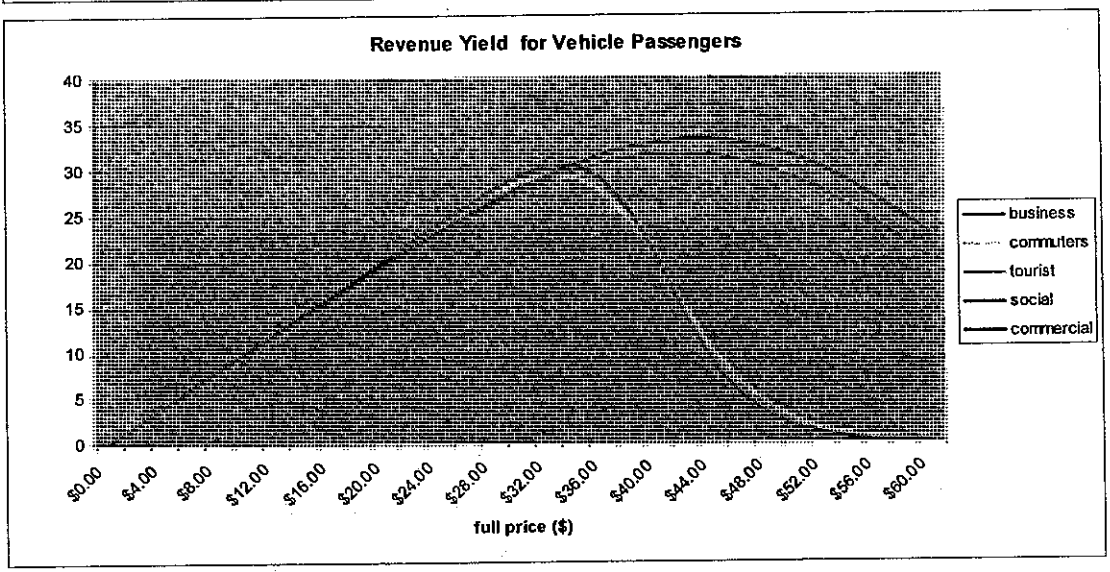


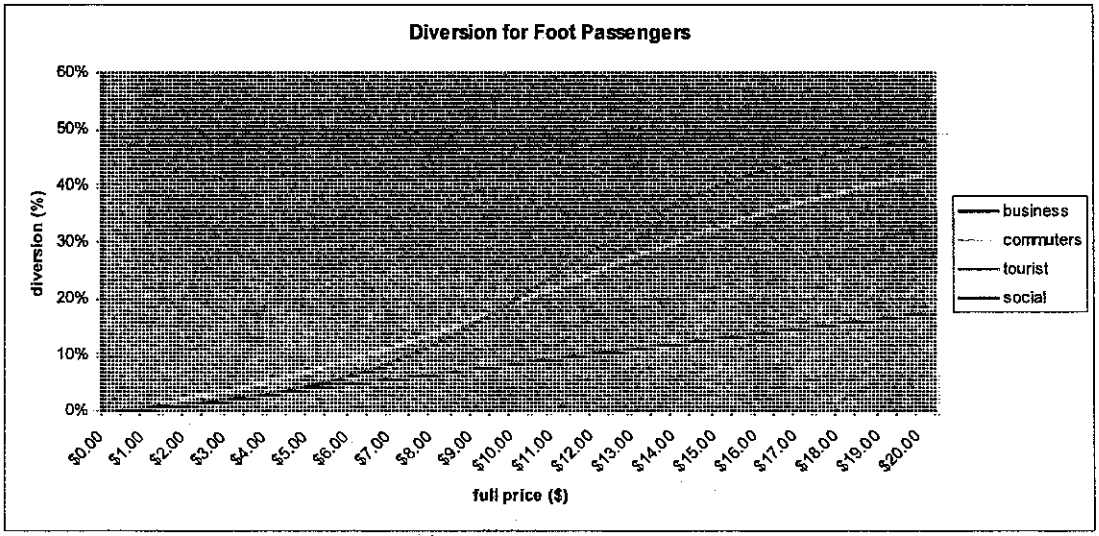
Exhibit 5.10: Route 17 Revenue Yield





5.6 ROUTE 19: NANAIMO – GABRIOLA ISLAND

Exhibit 5.11: Route 19 Diversion



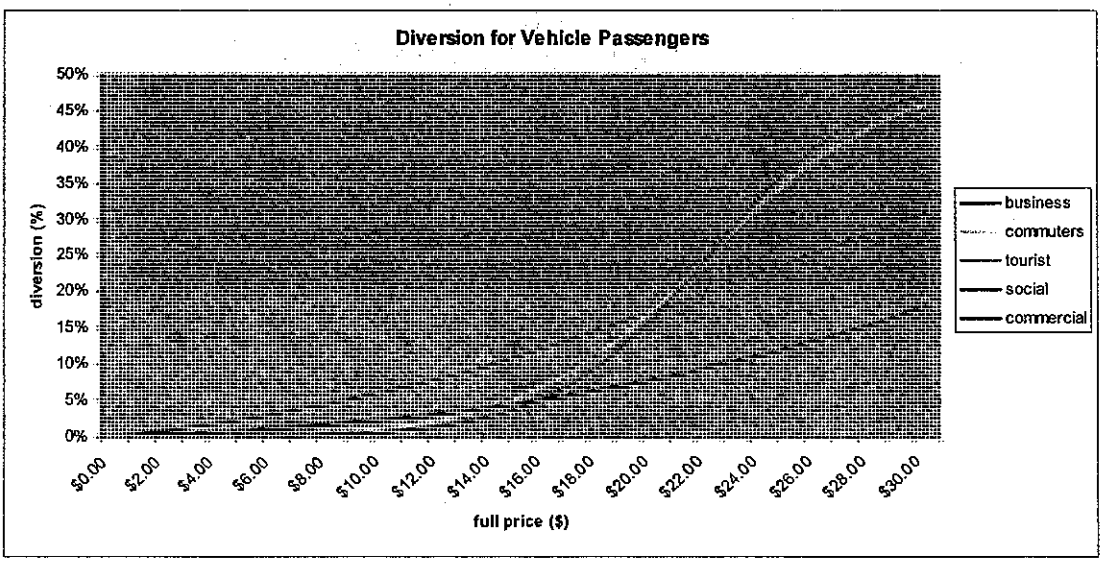
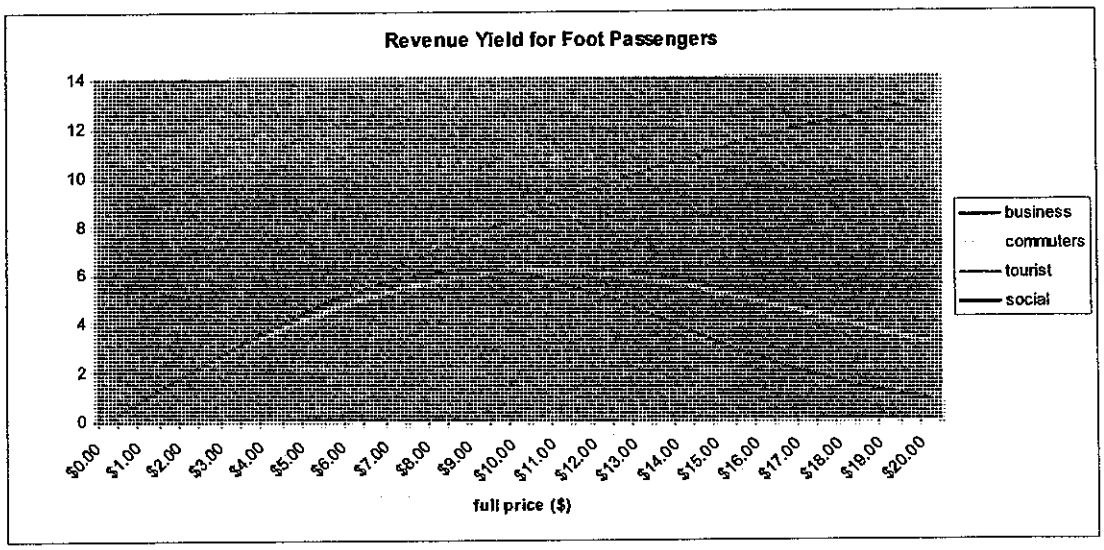
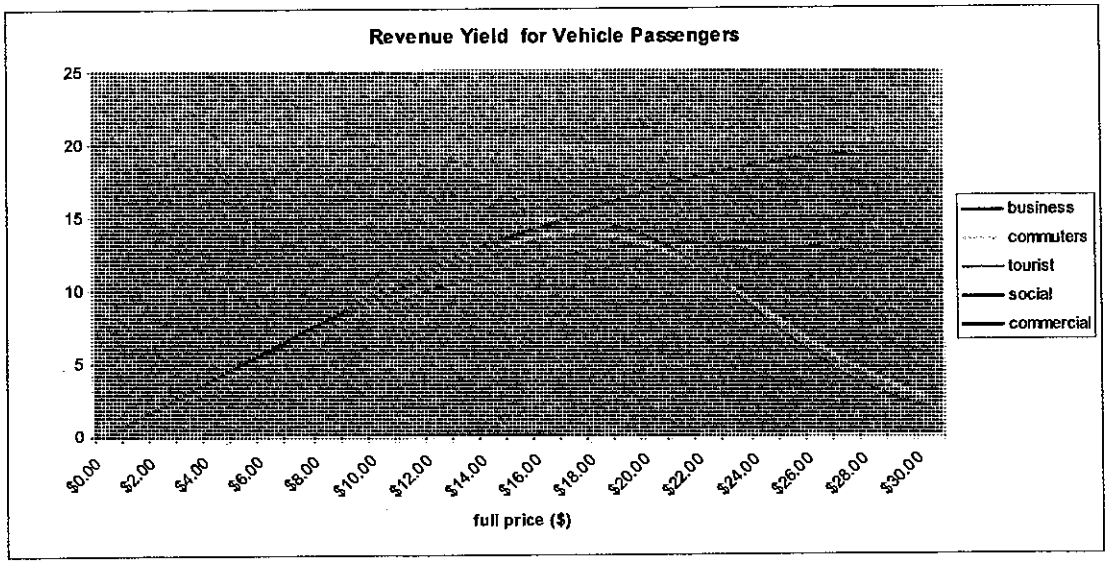


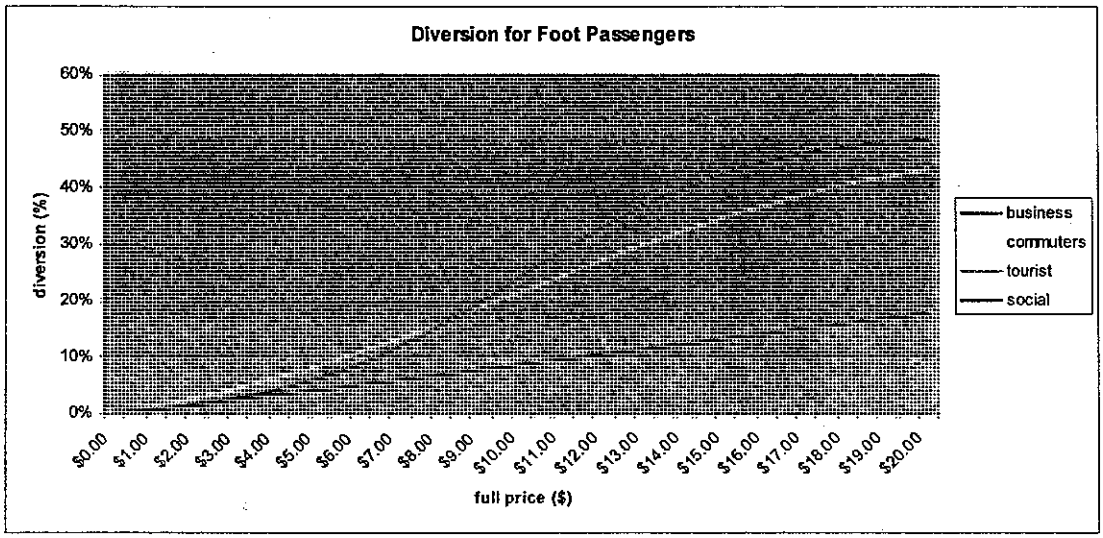
Exhibit 5.12: Route 19 Revenue Yield





5.7 ROUTE 23: CAMPBELL RIVER – QUADRA ISLAND

Exhibit 5.13: Route 23 Diversion



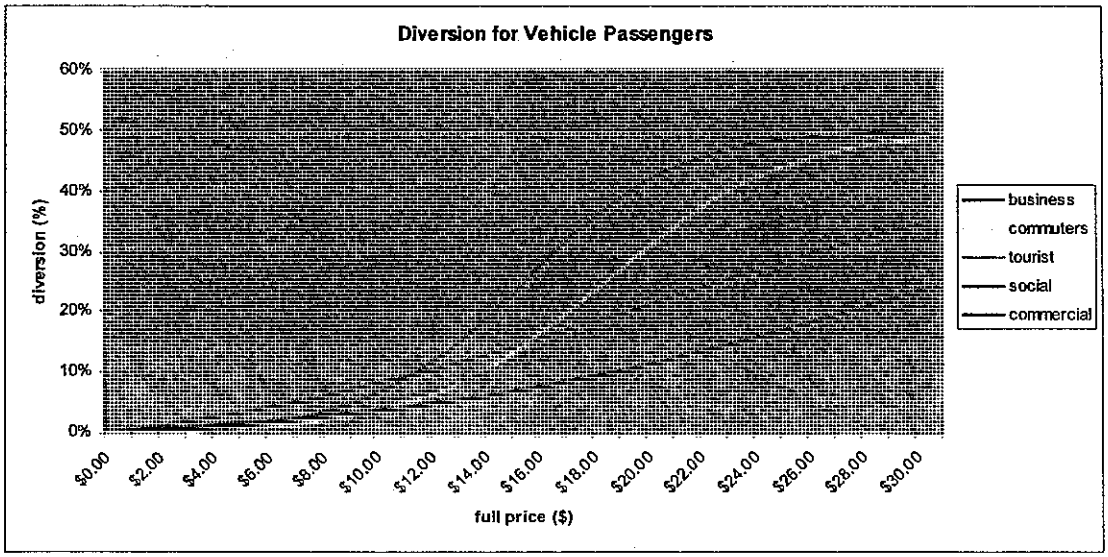
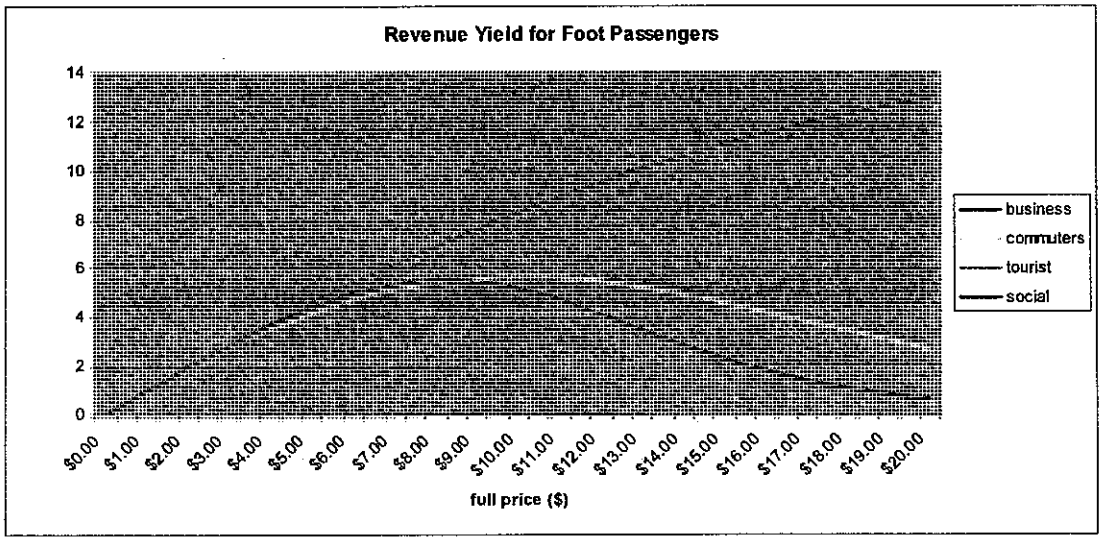
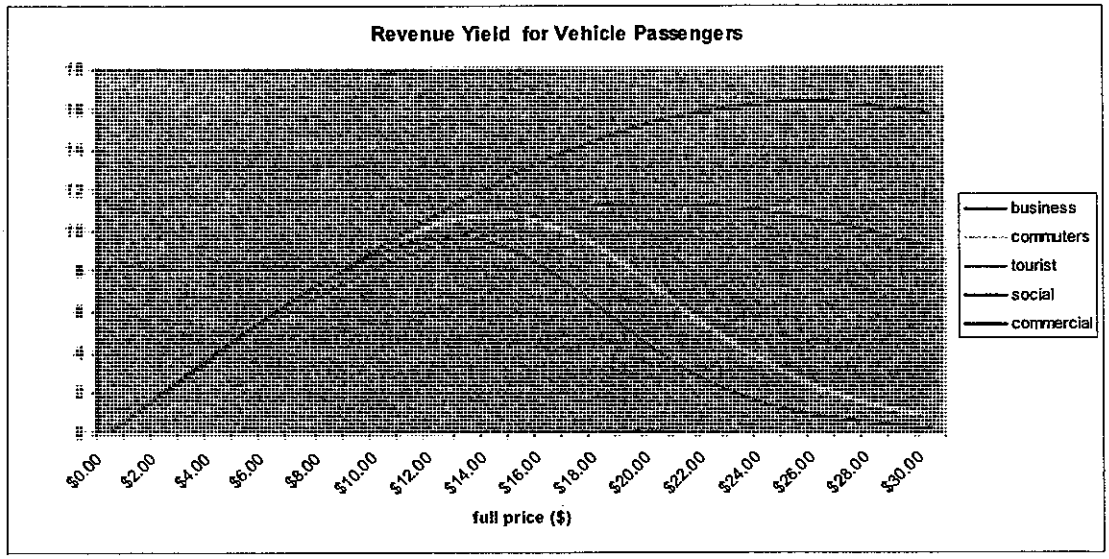


Exhibit 5.14: Route 23 Revenue Yield

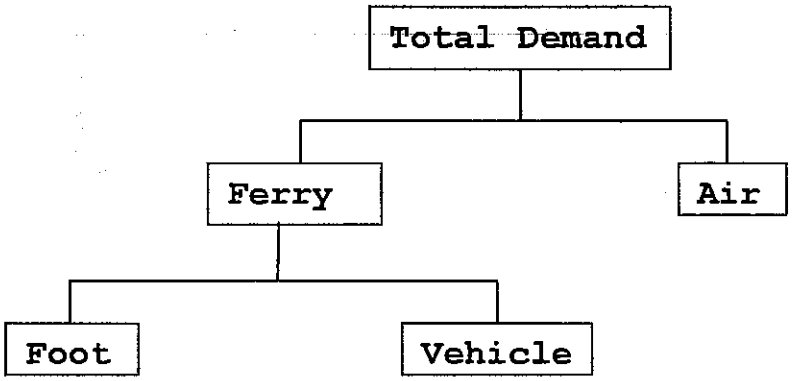




6 MODEL CALIBRATION & FORECASTS

Every route considered is unique for geographical setting and availability of diversion choices; hence a separate calibration was performed for each one of them. A common hierarchy was produced for all them, which is shown in Exhibit 6.1.

Exhibit 6.1: Modal Choice Hierarchy



In most circumstances, competition with Air traffic was negligible, hence it could be safely excluded from the modeling; the only routes for which Air competition was included in the computations were Route 1 (competing with the air service Vancouver – Victoria), and Route 10 (competing with the air service Prince Rupert – Vancouver). The analytic form of the demand equations to calibrate is given in Appendix A.2, equations (2) and (3). The results for the significant coefficients for the calibration of the demand model are shown in the Exhibit 6.2 below:

Exhibit 6.2: Calibration of the Total Demand Model

Demand	Socio	Utility
Island Routes	0.45 (business)	0.9 (business)
(Routes 8,17,23)	0.35 (all other)	1.1 (all other)
Mainland Routes	0.4-0.7 (tourist)	1.34 (social)
(Routes 3,17)	0.4-0.5 (all other)	0.7-0.9 (all other)
Route 1	0.68 (tourist)	0.6 (business)
	0.4 (all other)	0.9 (all other)
Route 10	0.5 (business)	1.5 (social)
	0.4 (all other)	0.6 (all other)

6.1 NATURAL GROWTH

Based on the calibrated variation of the demand as a function of demographic and utility,

Exhibit 6.3: Unconstrained Natural Revenue Growth

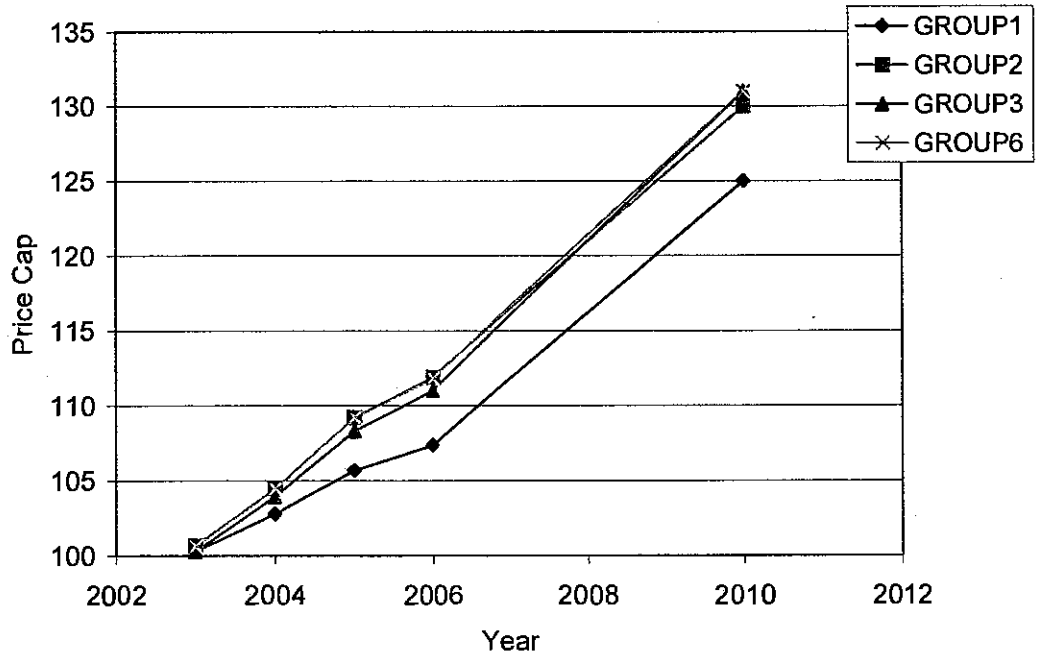
Unconstrained Natural Revenue Growth (2006 – 2010) (in thousands of 2007 $)			
Route	**2006**	**2010**	**%**
1	134,666	143,543	+6.5%
3	25,943	28,783	+11%
10	9,233	9,650	+4.5%
8	5,491	5,892	+7%
17	6,886	7,300	+6%
19	3,309	3,467	+5%
23	3,267	3,284	+0.5%

Route 3 is forecasted to have the highest rate of increase in the 3-year period considered.

6.2 PRICE CAP

In order to produce an estimate of a constrained revenue optimization, we need an estimate of the price cap for the year 2010. In the Exhibit 6.4 below we plot the historic price cap (from [BCF, 2006]) and an estimation of the 2010 price cap given the present trend. The price cap does not include the fuel surcharge.

Exhibit 6.4: Historic and projected Price Cap for selected Groups of Routes



The price cap shown in the Exhibit is given for the groups 1 (Major Routes), 2 (Route 3),

3 (Northern Routes) and 6 (Minor Routes).

6.3 RIDERSHIP CURVES

Once the Compass Model is calibrated it is possible to analyze any set of premium or discount fares at a disaggregate level. However, for illustrative purposes, in the analysis that follows, we have adopted two structures in order to illustrate the working of the analysis, and to provide guidance on the pricing options.

1. Business, commercial and out of province tourist travelers are classified together as "premium fare" group, while commuters and social travelers, being mostly locals, are classified together as "discounted fare" group. The base fare level considered is March 2007, unless otherwise noted.
2. The fare is varied with a "fare factor" for each of the two fare groups (premium or discount). This works by defining a new price as (1+ fare factor)*current price. In other words, a fare factor of zero means no change, a fare factor of 1 indicates an increase of 100% in fares, while a fare factor of –0.5 indicates a decrease of fares of 50%.

These two structures allow us to produce results in three dimensions, *i.e.*, premium fare, discounted fare and revenues.

The following Exhibits (6.5-6.11) we show the behavior of the total foot and vehicle passenger traffic as a function of the fare factor. In most circumstances, a drastic reductions in vehicle passengers generates a modest increase in foot passengers due to diversion. The forecast year used is, again, 2010.

Exhibit 6.5: Route 1 traffic in 2010 as a function of the fare factor

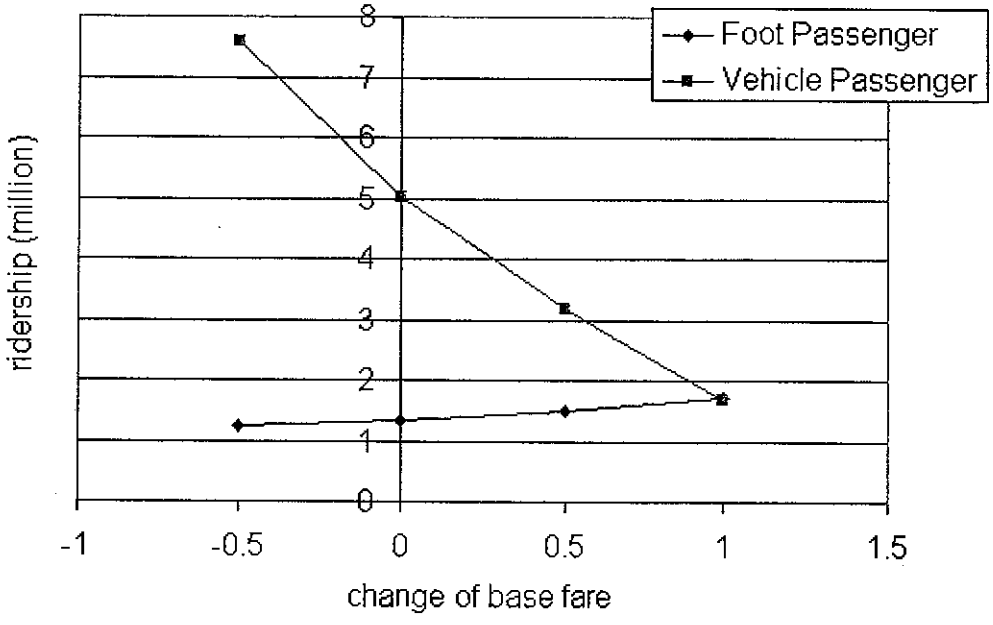


Exhibit 6.6: Route 3 traffic in 2010 as a function of the fare factor

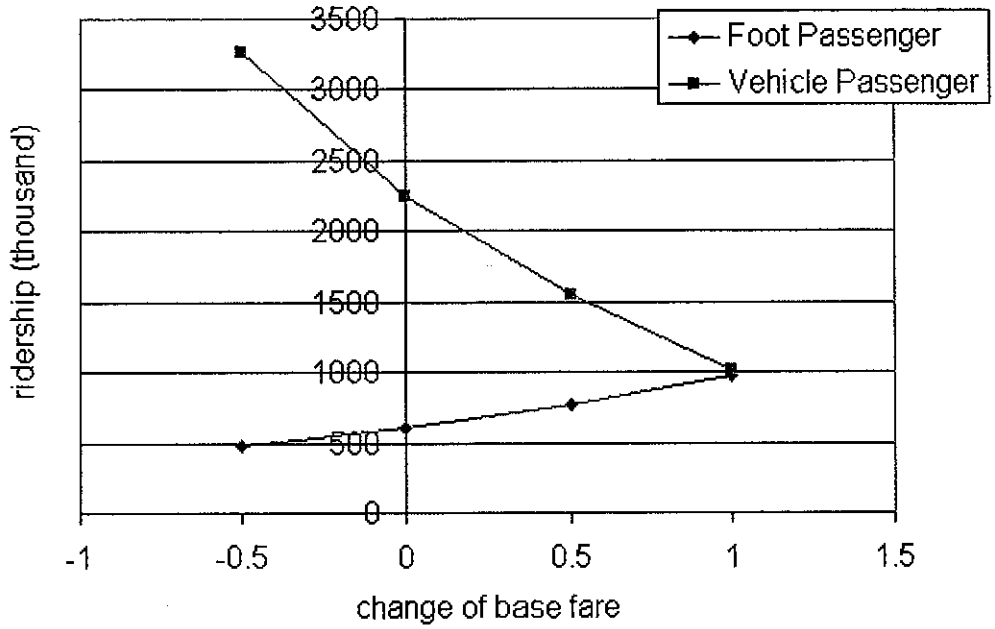


Exhibit 6.7: Route 10 traffic in 2010 as a function of the fare factor

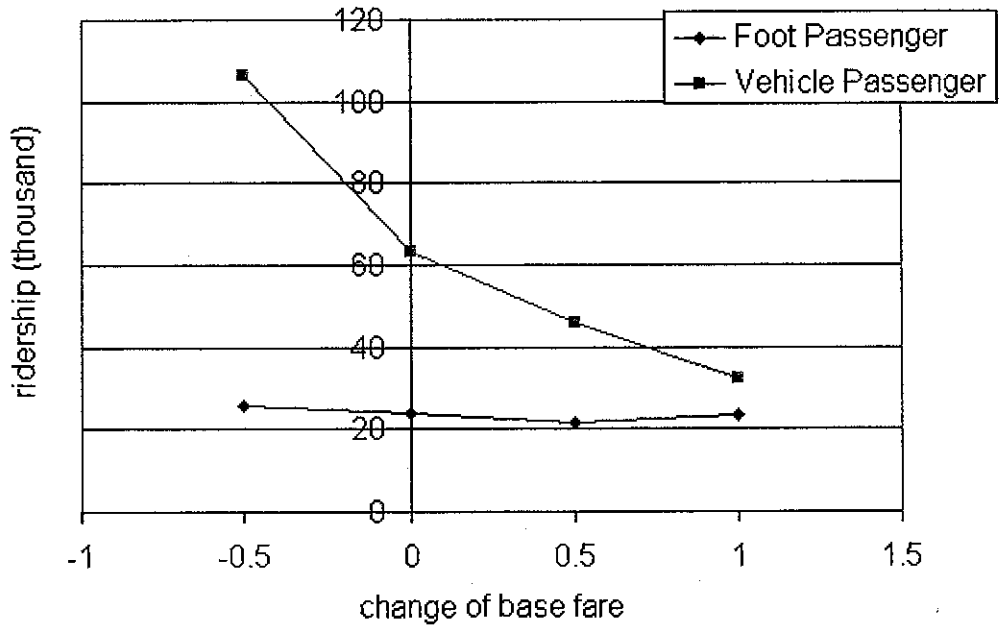


Exhibit 6.8: Route 8 traffic in 2010 as a function of the fare factor

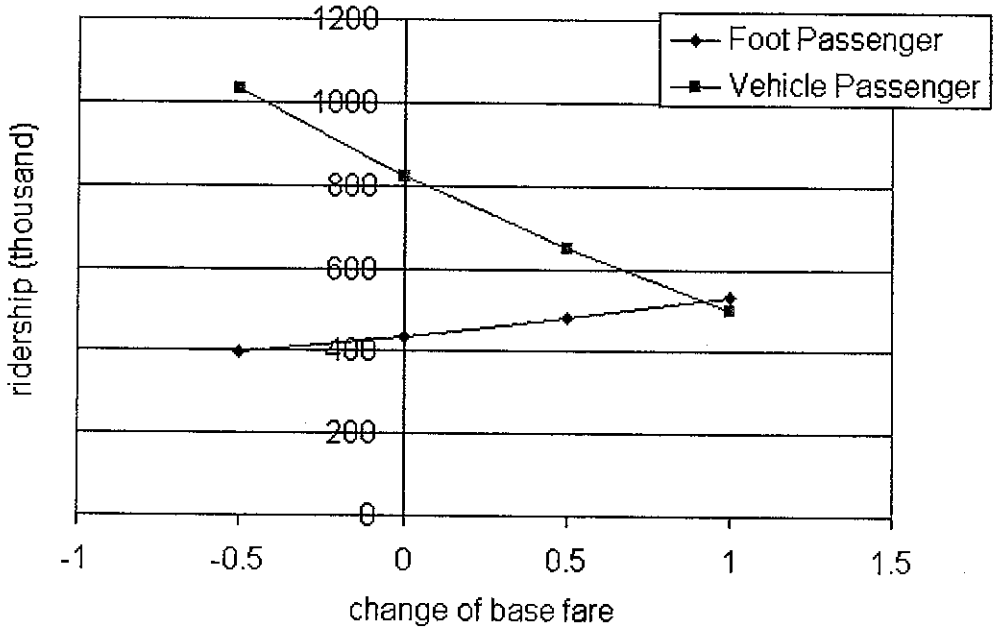


Exhibit 6.9: Route 17 traffic in 2010 as a fnnction of the fare factor

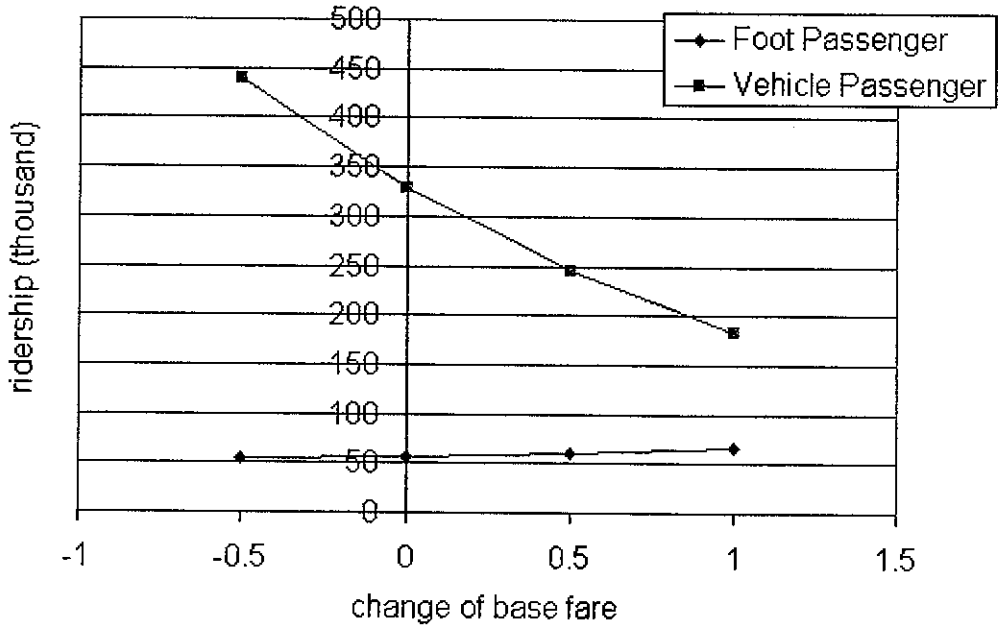


Exhibit 6.10: Route 19 traffic in 2010 as a function of the fare factor

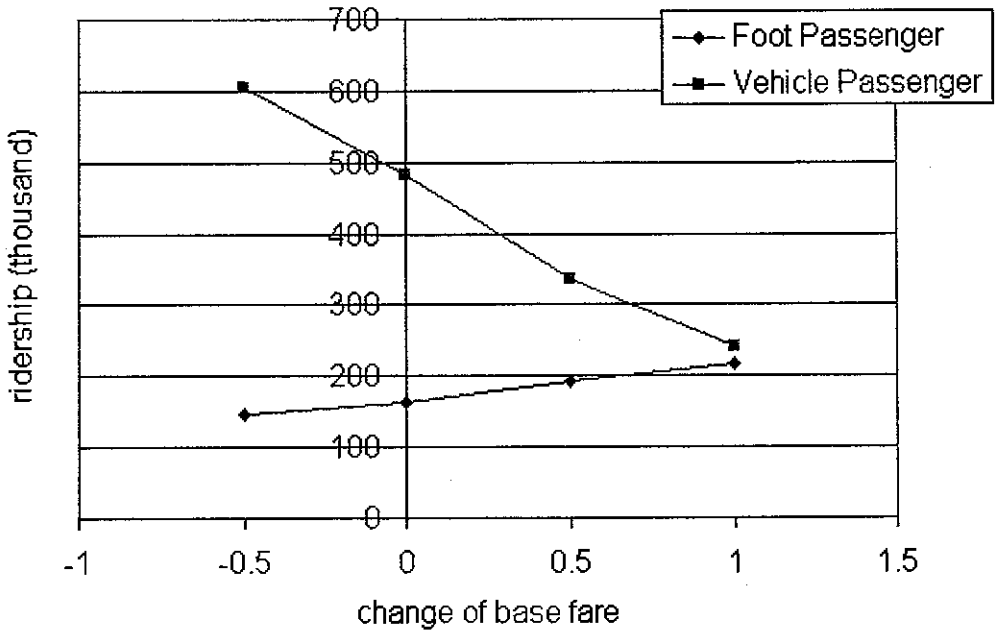
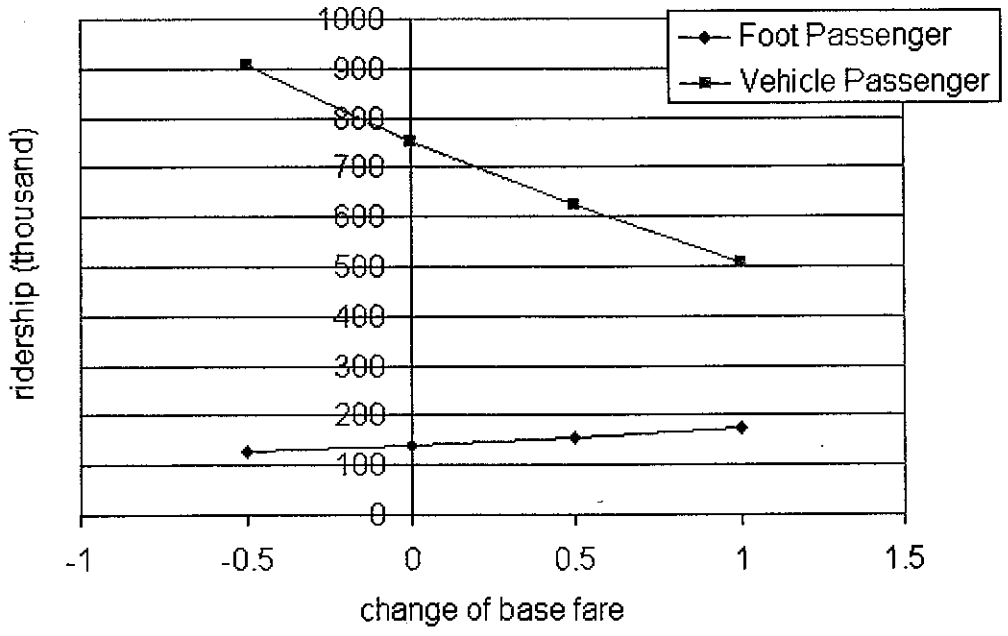


Exhibit 6.11: Route 23 traffic in 2010 as a function of the fare factor



6.4 REVENUE SURFACES

By varying two types of fares (discount and premium) independently, we are able to produce "revenue surfaces", *i.e.*, an surface showing the behavior of the revenue for all combinations of premium and discounted fare, for each route (Exhibits 6.12-6.18).

Exhibit 6.12: Route 1 Revenue Surface as a function of the fare factor

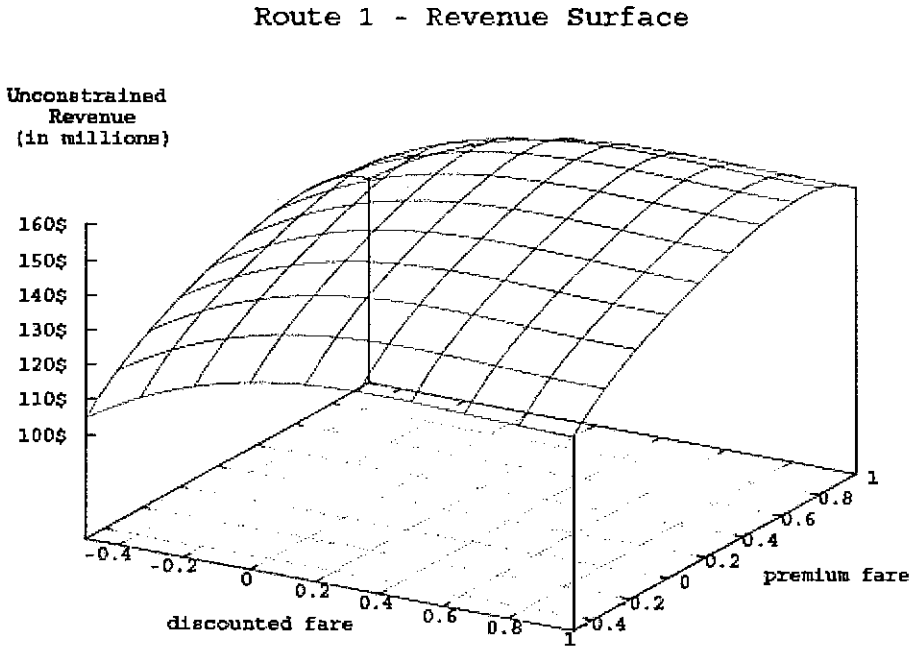


Exhibit 6.13: Route 3 Revenue Surface as a function of the fare factor

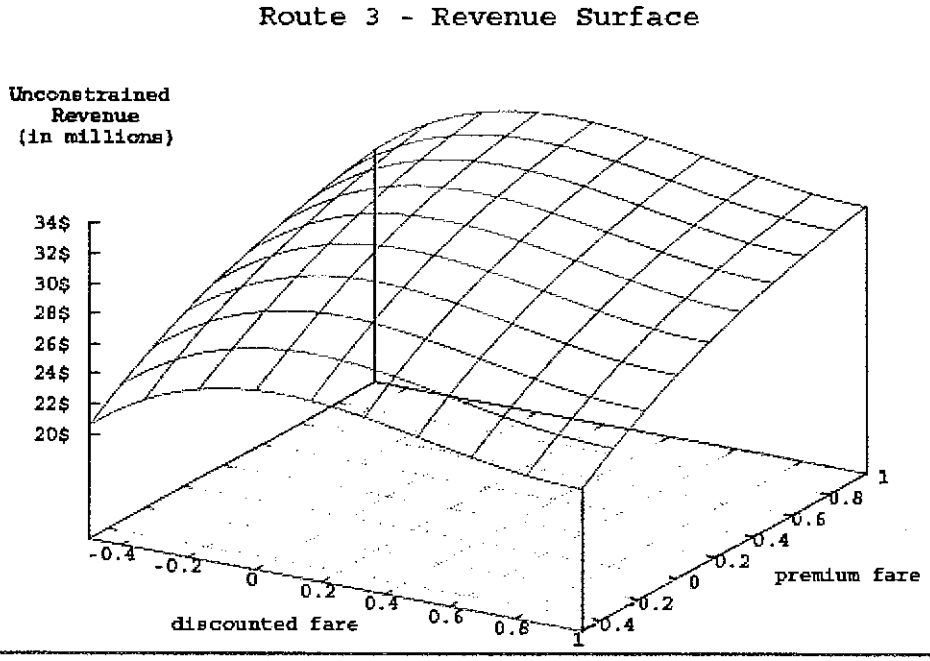


Exhibit 6.14: Route 10 Revenue Surface as a function of the fare factor

Route 10 - Revenue Surface

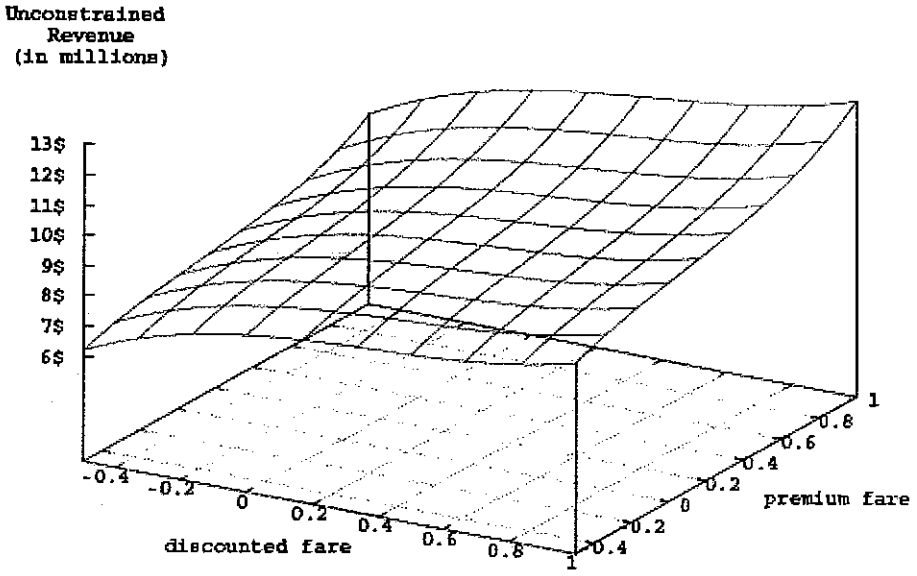


Exhibit 6.15: Route 8 Revenue Surface as a function of the fare factor

Route 8 - Revenue Surface

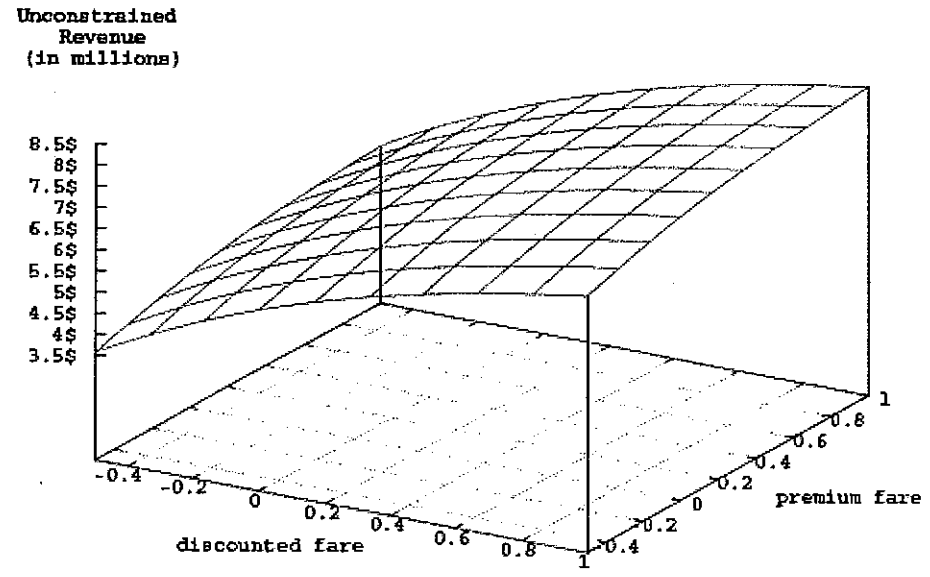


Exhibit 6.16: Route 17 Revenue Surface as a function of the fare factor

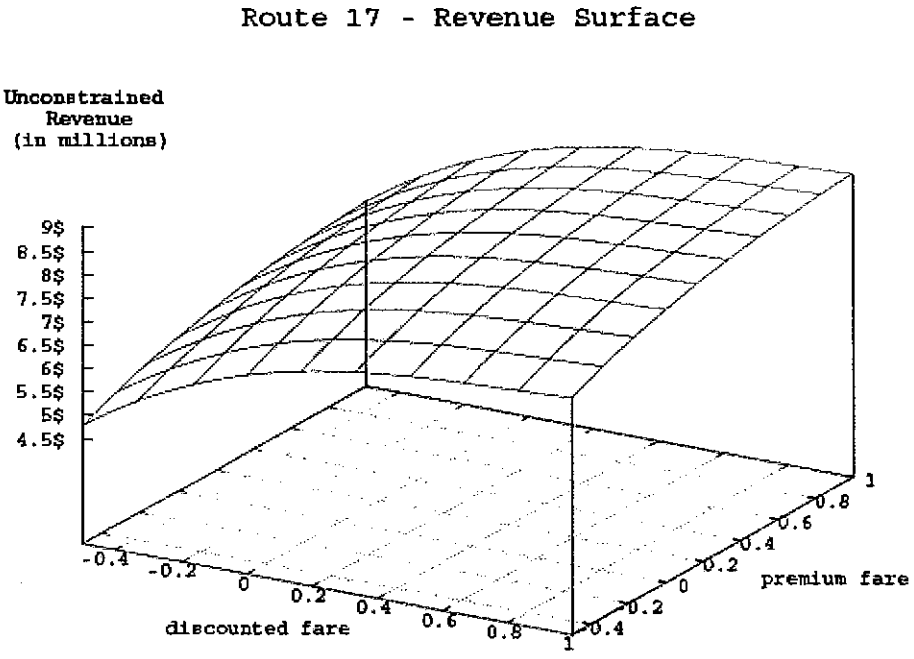


Exhibit 6.17: Route 19 Revenue Surface as a function of the fare factor

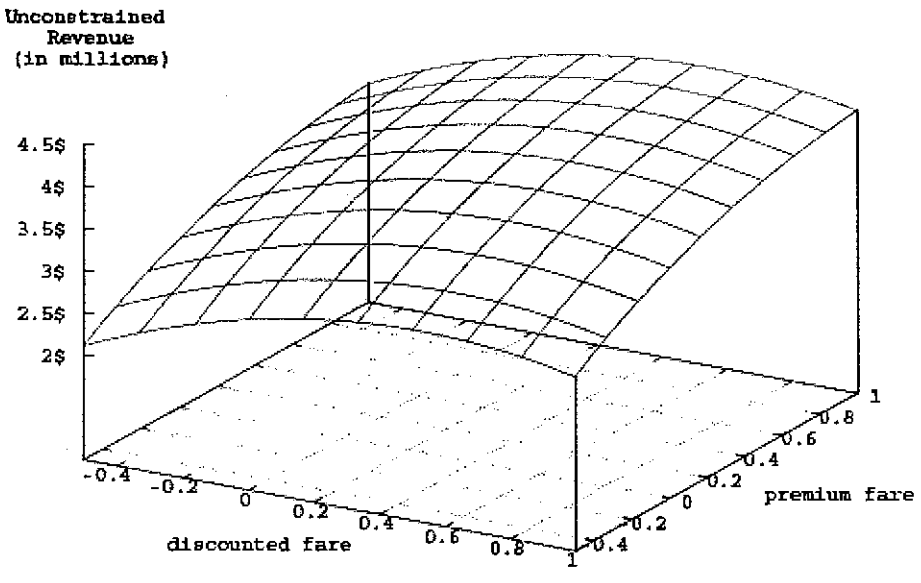
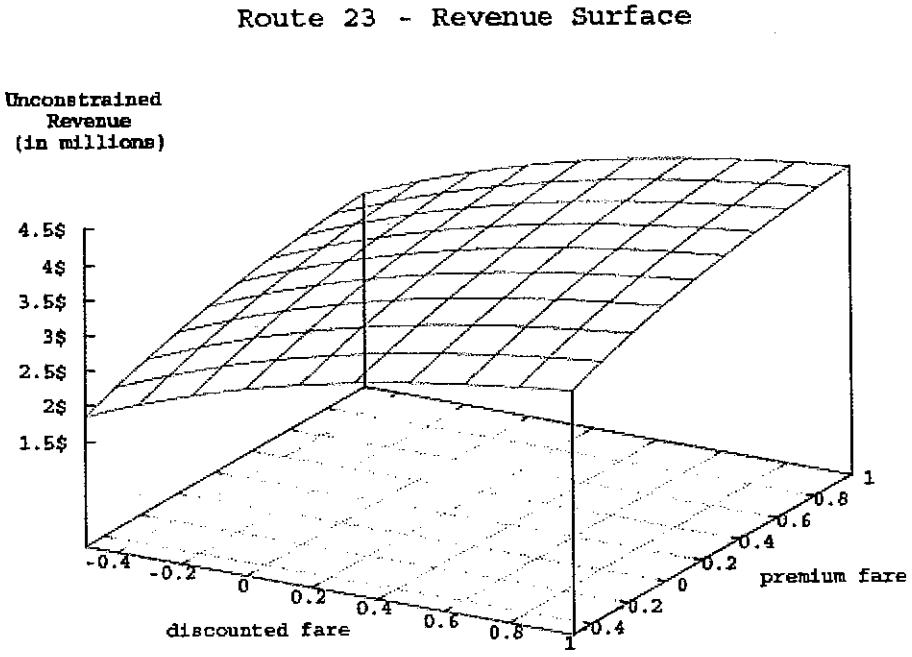


Exhibit 6.18: Route 23 Revenue Surface as a function of the fare factor



6.5 CONSTRAINED REVENUE OPTIMIZATION

The development of the revenue surface information provides the ability to estimate the optimum revenue for any pricing policy. However, to identify the most effective option for BC Ferries we must also consider the Price Cap set by the regulator. As such, we need to complete a Constrained Revenue Optimization process, *i.e.*, an analysis that allows us to maximize revenues while keeping the average fare below a pre-specified level. The average fare is calculated according to the Paasche Index for values of the premium and discounted fares in the same range as the revenue surface, *i.e.*, [-0.5,1.0]. Once the Price Cap is superimposed on the contour lines of the revenue surfaces (*i.e.*, lines in the plane premium fare / discounted fare at constant revenue), it is possible to visually identify those combinations of fares that will optimize revenues still maintaining an average fare below the Price Cap.

Exhibit 6.19 shows the results of the Constrained Revenue Optimization, by route, for the forecast year 2010. In all circumstances it is possible to improve the revenue stream by price differentiation, still satisfying the restrictions imposed by the Regulator. Exhibits 6.20-6.26 show the revenue optimization analysis by superimposing revenue contour lines, average fare lines by the Paasche Index and the Price Cap in the plane premium fare / discounted fare. This analysis on a per-route basis produces the overall results that are reported in Exhibit 6.19 below.

Exhibit 6.19: Constrained 2010 Revenue Optimization

Constrained 2010 Revenue Optimization (in millions of 2007 $)			
Route	**2010**	**Potential**	**%**
1	143	154	+7%
3	29	34	+17%
10	9.7	13	+35%
8	5.9	6.8	+15%
17	7.3	8.1	+11%
19	3.5	3.9	+11%
23	3.3	3.7	+12%

6.5.1 PRICING POLICY OPTIONS

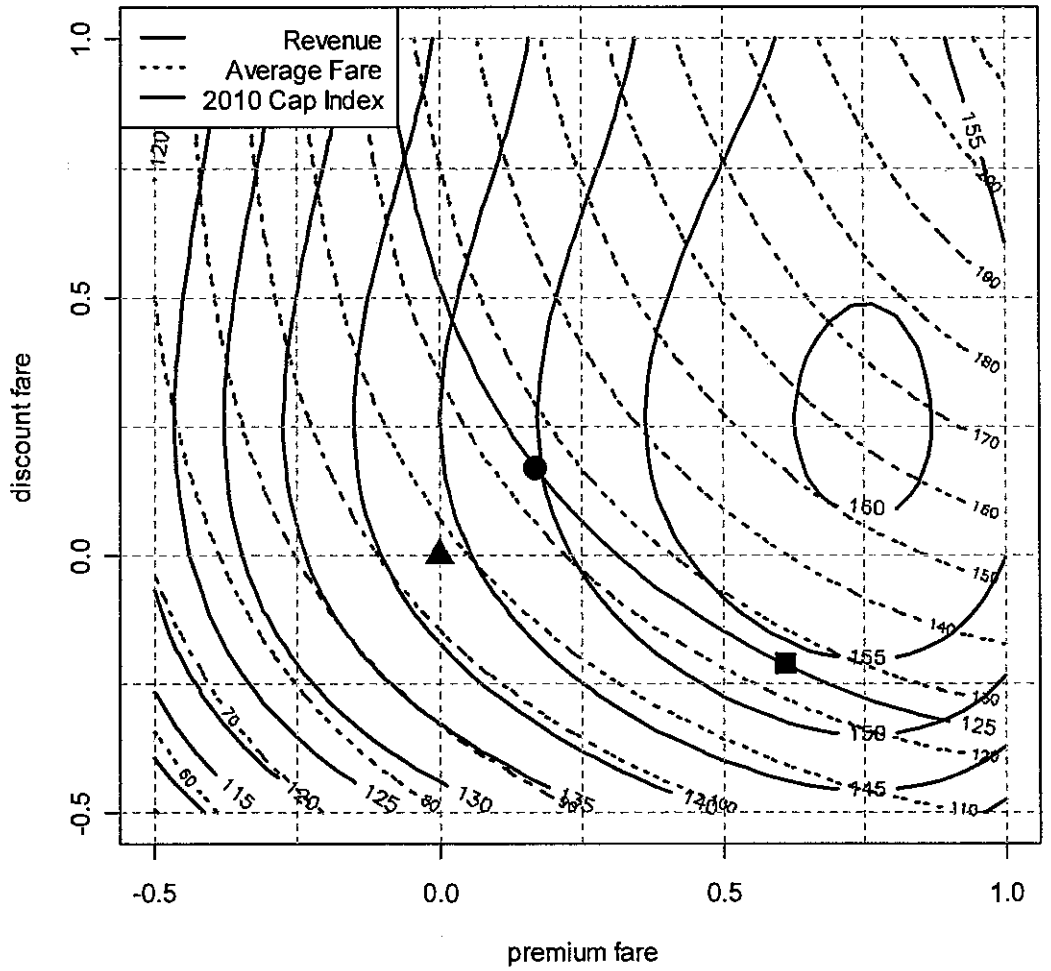
By visual inspection of the Exhibits 6.20-6.26, we can evaluate the pricing options open to BC Ferries. Using Exhibit 6.20 (related to Route 1) we can assess the impact of a wide variety of pricing options.

The two axis of the chart show the premium fare and the discounted fare, both in the range [-0.5,1.0] for Route 1. The blue solid lines are the contour lines of the Revenue Surface for Route 1, previously shown in Exhibit 6.12, and the respective revenue amount is superimposed on the lines themselves. It can be easily seen that the *unconstrained* maximum of the revenue lies approximately at a 75% increase in the premium fare combined to a 25% increase in the discounted fare, which yields a revenue in the order of 160 millions (of 2007 $).The red dotted lines are contour lines for the average fare, calculated using the Paasche Index. For example, the average fare in the neighborhood of (0,0) is a little less than 110. One special line of average fare is the Price Cap forecasted for 2010, which is plotted using a solid green line, and for Route 1 this is set at 117.

Three symbols are present in the picture to illustrate the change from the base revenue to the optimum revenue. The solid black triangle is always located at (0,0), hence it represent the Base Revenue, the revenue that is forecasted based on socioeconomic growth if no changes in the fare structure happen. The solid black circle shows what happens with the Price Cap revenue and assumes the same price increase for all types of travelers on a route. The solid black square shows the Optimum Revenue, *i.e.*, the approximate location of the point on the Price Cap curve that produce the optimum revenue stream. As shown in the chart, different points along the Price Cap curve are associated with different revenue levels. For example, the point (0,0.25), corresponding to an increase in the discounted fare of 25%, yields a revenue of $145 million, while the point (0.5,-0.25), corresponding to an increase of the premium fare of 50% combined to a decrease of the discounted fare of 25%, produces a revenue of approximately $150 million.

Exhibit 6.20: Route 1 Constrained Revenue Optimization Analysis

Route 1: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



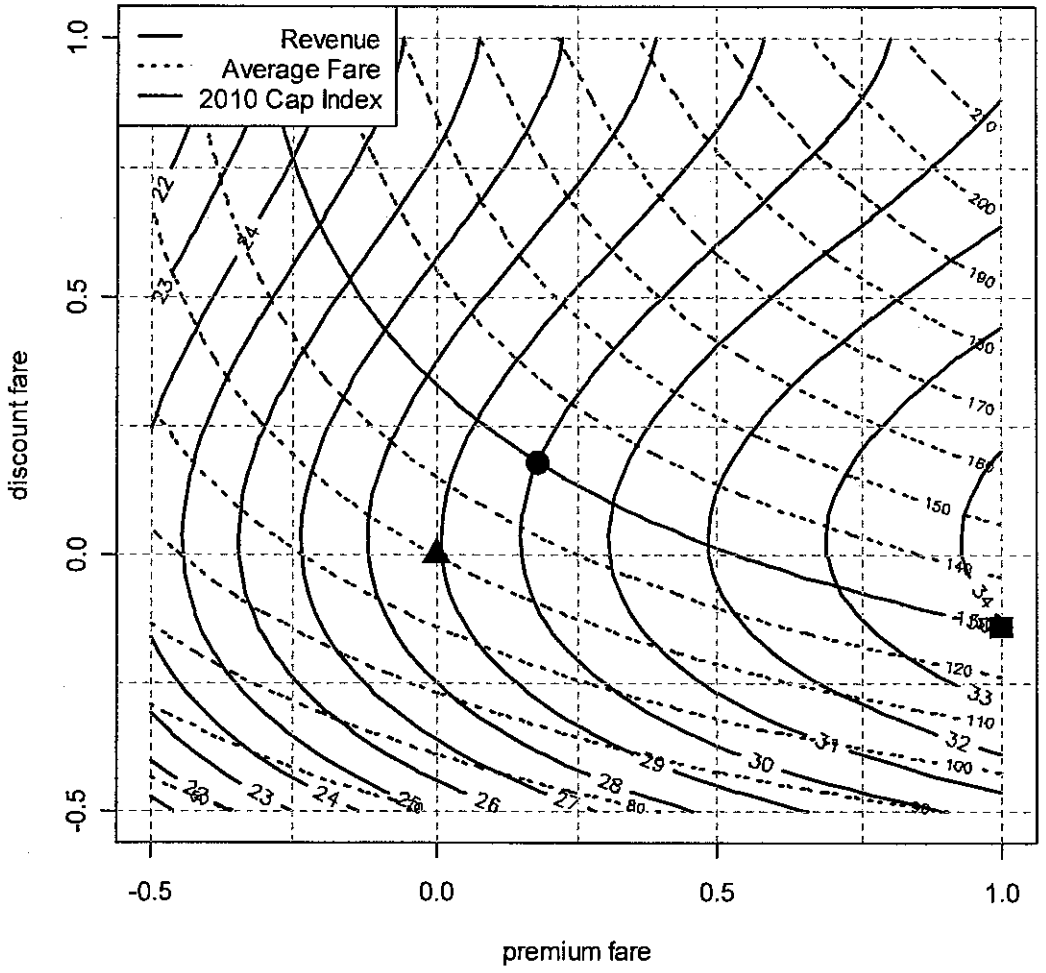
KEY:

▲ Base Revenue-$143.3 million
● Price Cap Revenue-$149.7 million
■ Optimum Revenue-$153.8 million

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Million)	Vehicle (Million)	Revenue (Million)	Passenger (Million)	Vehicle (Million)	Revenue (Million)	Passenger (Million)	Vehicle (Million)	Revenue (Million)
6.3	2.0	143.3	5.7	1.8	149.7	5.9	1.8	153.8

Exhibit 6.21: Route 3 Constrained Revenue Optimization Analysis

Route 3: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



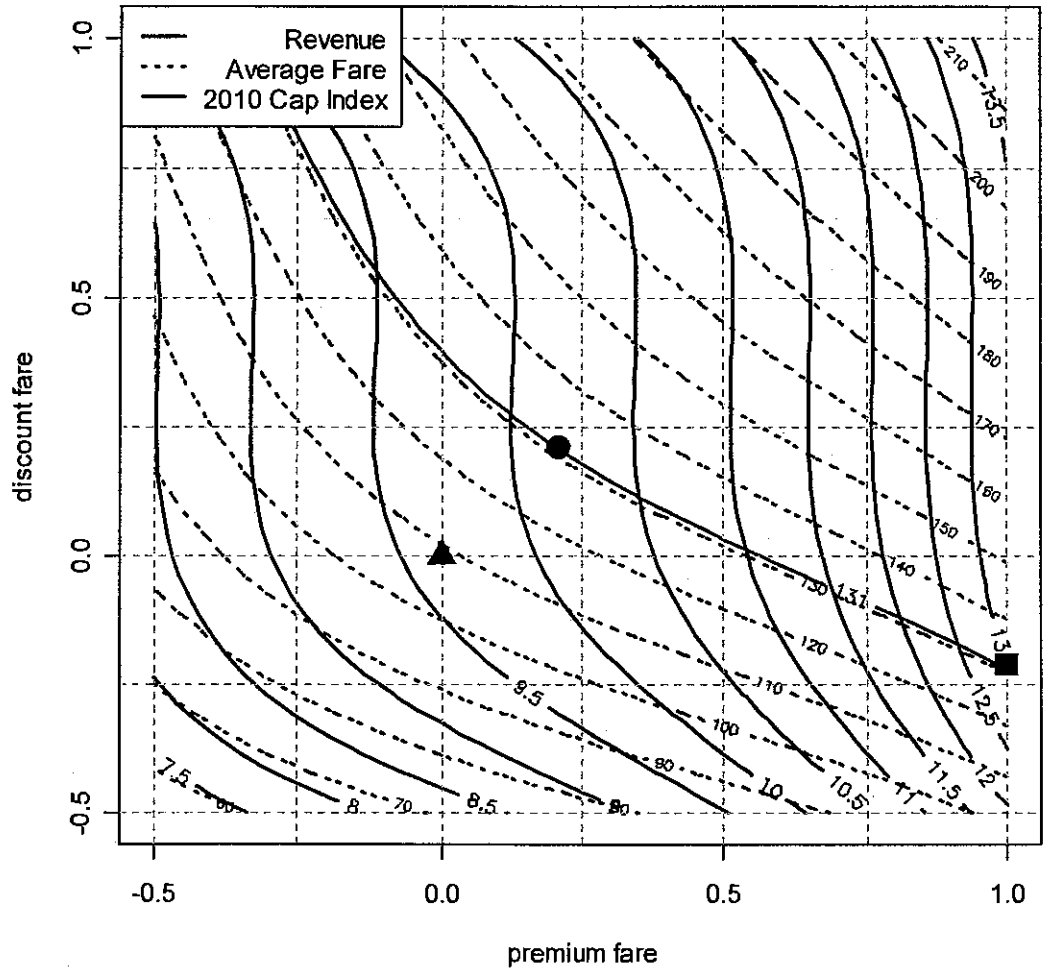
KEY:

▲ Base Revenue-$28.9 million
● Price Cap Revenue-$30.0 million
■ Optimum Revenue-$33.9 million

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Million)	Vehicle (Million)	Revenue (Million)	Passenger (Million)	Vehicle (Million)	Revenue (Million)	Passenger (Million)	Vehicle (Million)	Revenue (Million)
2.8	1.3	28.9	2.6	1.1	30.0	2.8	1.3	33.9

Exhibit 6.22: Route 10 Constrained Revenue Optimization Analysis

Route 10: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



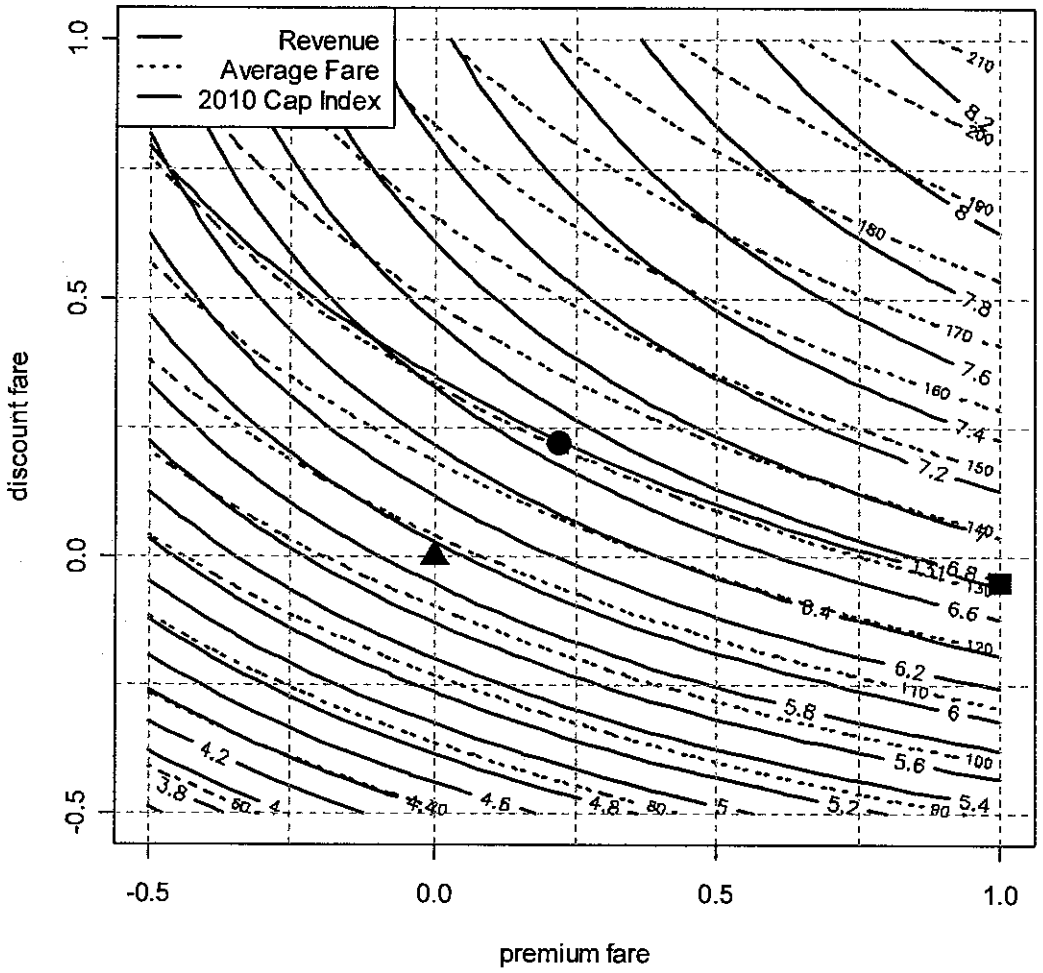
KEY:

▲ Base Revenue-$9.6 million
● Price Cap Revenue-$10.2 million
■ Optimum Revenue-$13.0 million

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)
87.1	18.6	9.6	78.2	15.2	10.2	98.7	19.7	13.0

Exhibit 6.23: Route 8 Constrained Revenue Optimization Analysis

Route 8: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



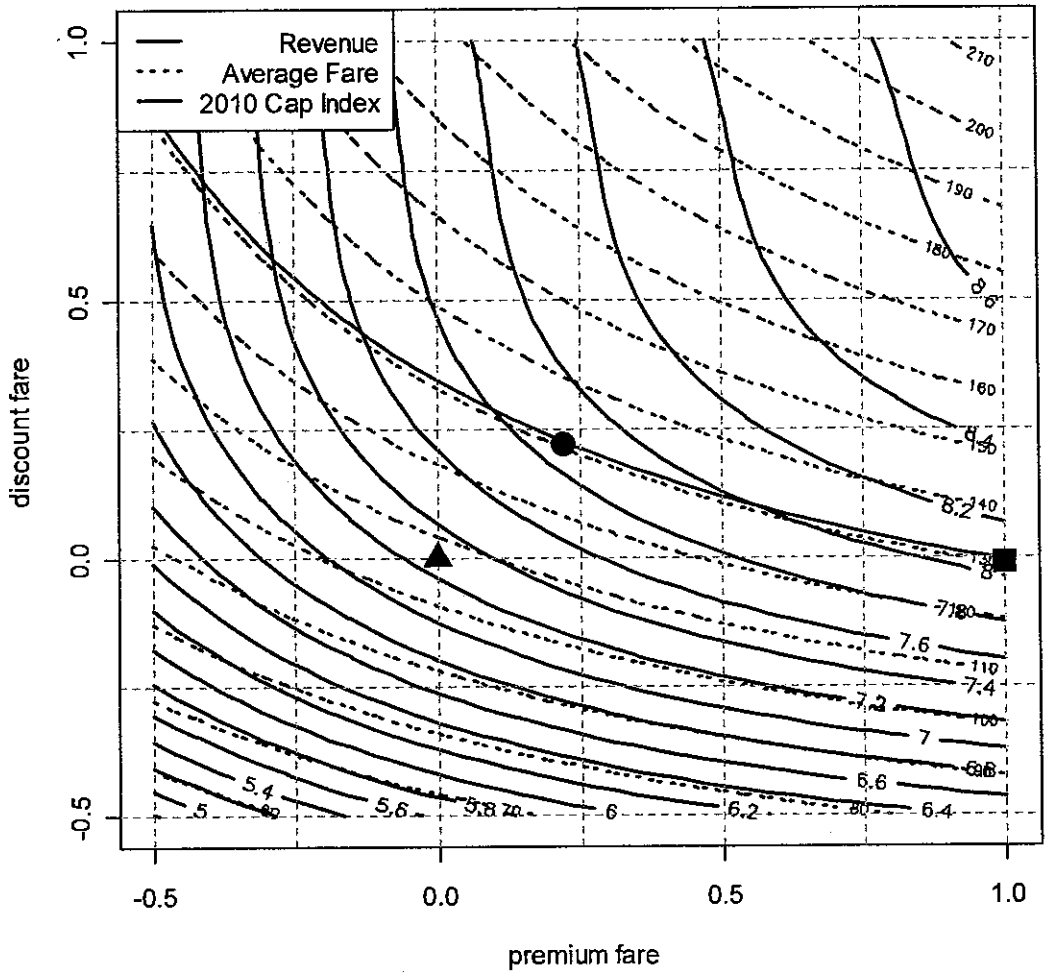
KEY:

▲ **Base Revenue-$5.9 million**
● **Price Cap Revenue-$6.7 million**
■ **Optimum Revenue-$6.8 million**

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Million)	Vehicle (Million)	Revenue (Million)	Passenger (Million)	Vehicle (Million)	Revenue (Million)	Passenger (Million)	Vehicle (Million)	Revenue (Million)
1.3	0.6	5.9	1.2	0.5	6.7	1.2	0.5	6.8

Exhibit 6.24: Route 17 Constrained Revenue Optimization Analysis

Route 17: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



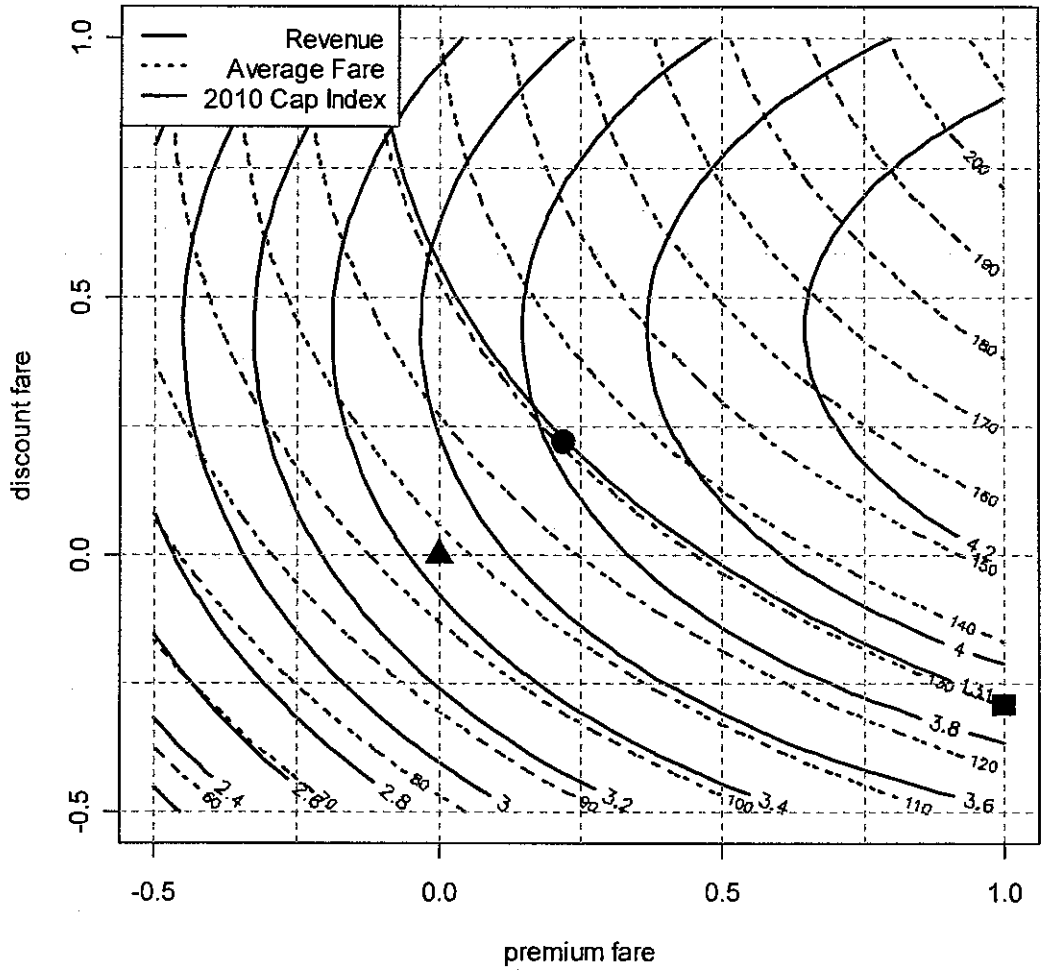
KEY:

▲ **Base Revenue-$7.3 million**
● **Price Cap Revenue-$7.9 million**
■ **Optimum Revenue-$8.1 million**

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)
362.8	161.5	7.3	326.3	141.2	7.9	334.7	147.3	8.1

Exhibit 6.25: Route 19 Constrained Revenue Optimization Analysis

Route 19: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



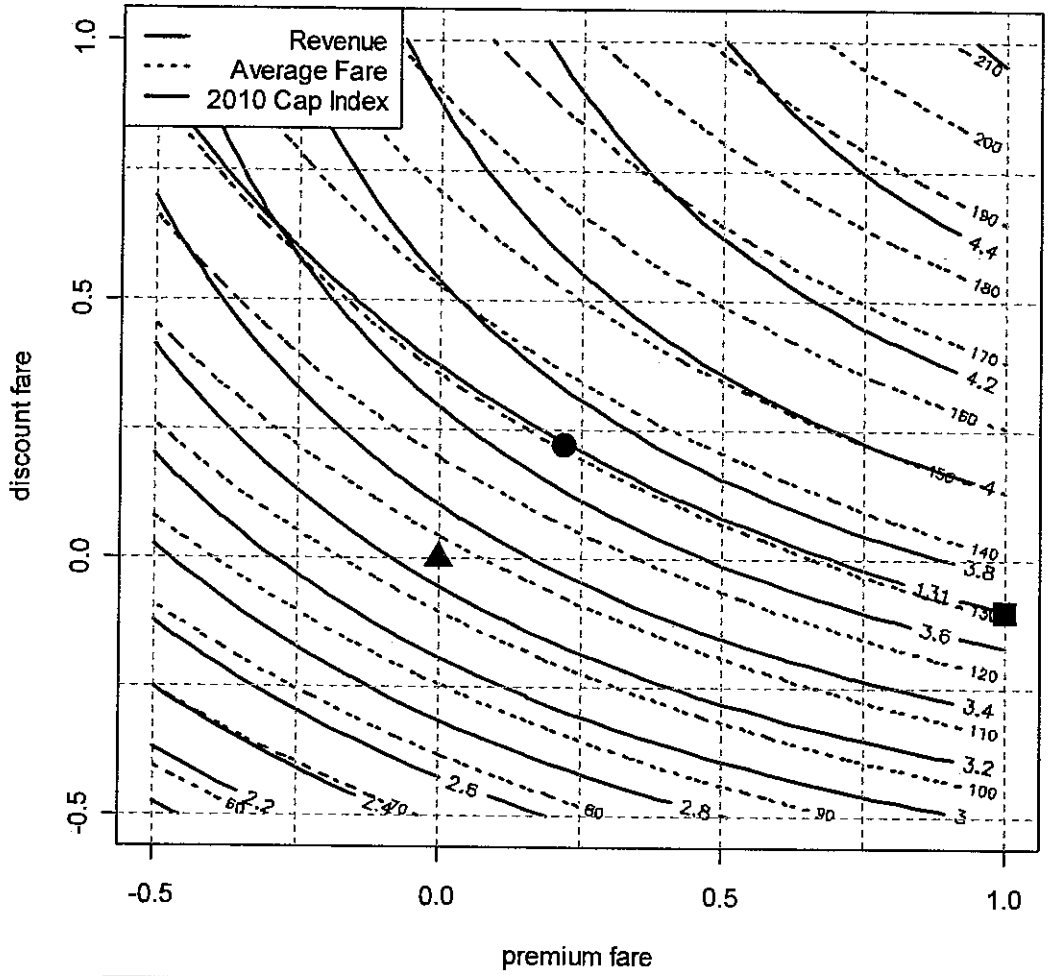
KEY:

▲ Base Revenue-$3.5 million
● Price Cap Revenue-$3.8 million
■ Optimum Revenue-$3.9 million

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)
644.6	427.8	3.5	599.1	378.9	3.8	632.3	416.1	3.9

Exhibit 6.26: Route 23 Constrained Revenue Optimization Analysis

Route 23: 2010 Revenue (in millions of 2007 $) and Price Cap Index Contour Lines



KEY:

▲ **Base Revenue-$3.3 million**
● **Price Cap Revenue-$3.7 million**
■ **Optimum Revenue-$3.7 million**

Base			Cap constraint No Price optimization			Cap constraint Price optimization		
Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)	Passenger (Thousand)	Vehicle (Thousand)	Revenue (Million)
855.0	405.5	3.3	800.9	370.5	3.7	822.0	387.3	3.7

7 CONCLUSIONS

- The elasticities derived in this study show that there is significant pricing flexibility and that by using time of day, route, trip purpose pricing the overall revenues of BC Ferries can be increased under the caps set by the regulator. BC Ferries is clearly in a position to begin to increase revenues by using a flexible pricing policy.
- The overall potential revenue gain for the seven routes studied from using a flexible pricing system is $21.8 million or an increase of 10.8% over the existing fare structure in 2010.
- Results by Route are as follows:

Revenue Increase by Route	
Route	**Potential %**
Route 1	+7%
Route 3	+17%
Route 10	+35%
Route 8	+15%
Route 17	+11%
Route 19	+11%
Route 23	+12%

Work Required: Four final elements of Phase II work are needed to complete the study, and provide BC Ferries with a price flexibility analysis system:

- Develop additional data on Summer Tourists; Stated Preference Survey proposed. This is essential as summer tourists have the highest elasticities, and are critical to the major and northern route results.
- Develop additional data on Southern Gulf Islands which were unrepresented in initial surveys; a Stated Preference (SP) Survey is proposed
- Generalize results to all BC Ferry routes using the initial SP Survey and additional data collected in Phase II. This will show total revenue potential gains by route and proposed fare systems.
- Work with BC Ferries to develop practical and realistic flexible fare structures.

Study Risk: Results indicate positive opportunity to introduce a flexible pricing system that offers higher fares in congested periods and lower fares for uncongested periods. In addition, the system will offer significant discounts for regular users, and more market based fares for tourists and business travelers.

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APPENDIX

A. DEMAND ESTIMATION

Demand modeling involves a series of mathematical models that aim to simulate travel behavior based on the status of a transportation network and some measure of people's capability to travel.

The demand model forecasts the total travel demand of all modes in the forecast year based on two factors: socioeconomic interaction and the quality of service in the designated market area. The quality of service measures transportation accessibility while the socioeconomic term measures the strength of the socioeconomic interaction between the origin and destination zones and the projected growth within these zones over time. The hypothesis is that the greater the population, income or employment in any two zones, the more travel interaction there will be between the zones at any given level of transportation service.

A.1 GENERALIZED COST AND UTILITY

The generalized cost of travel is typically defined in terms of travel time rather than dollars because trip times are usually more intuitive than automobile operating costs. All attributes are converted to time by applying appropriate conversion factors, as shown in Equation (1) below. Because the same value of time is used for all observations of the same purpose and modal grouping, the generalized costs can be easily converted to dollars by multiplying by the value of time for that grouping. The generalized cost of travel between zones i and j for mode m and trip purpose p is calculated as follows

$$GC_{ijmp} = TT_{ijm} + \frac{TC_{ijmp}}{VOT_{mp}} + \frac{VOF_{mp} \times OH}{VOT_{mp} \times F_{ijm}} \qquad (1)$$

where the various terms in Equation (1) are as follows:

TT_{ijm} = Travel time between zones i and j for mode m (in-vehicle time + delay time + connection wait times + access/egress time + interchange penalty), with delay, connect and access/egress time multiplied by factors (usually approximately 2) to account for the additional disutility felt by travelers for these activities

TC_{ijmp} = Travel cost between zones i and j for mode m and trip purpose p (fare + access/egress cost and operating costs for auto)

VOT_{mp} = Value of Time for mode m and trip purpose p

VOF_{mp} = Value of Frequency for mode m and trip purpose p

F_{ijm} = Frequency in departures per week between zones i and j for mode m

OH = Operating hours per week

Value of Time (VOT) can be interpreted as the opportunity cost of time. For example, a VOT of $25 per hour means that the traveler values each extra hour of travel as a lost opportunity of $25. Original surveys showed that the variation in values of time across the different time periods were not statistically significant such that the average values of time for all time period assumptions was carried forward in this analysis.

Value of Frequency (VOF) usually measures the trade-off between the frequency of service and the fare charged for that service. This parameter represents the potential of passengers being prevented from boarding the ferry of their choice because of capacity constraints. This problem is especially acute during peak summer days when demand is higher for the ferry service.

The VOF is typically measured in dollars-per-hour of expected waiting time and is obtained from the surveys to represent the trade-off between service frequency and capacity concerns. The magnitude of this parameter was found to be similar to that of the VOTs for ferry travel, which is considered relatively higher than normal (VOFs obtained in other studies were typically 60 to 80 percent of the corresponding VOT). These relatively high VOFs for vehicle passengers on BC Ferries were attributable to an "uncertainty" premium that exists as a direct consequence of ferry users' anxiety associated with waiting for the next available ferry during capacity constraint periods.

The utility function is then derived from the generalized costs as

$$U_{ijp} = F(GC_{ijp}) \qquad (2)$$

where F is a decreasing function of the generalized cost, and depending also on the modes of travel. Understandably, if a passenger perceives that Trip A has a higher generalized cost than Trip B, he/she will assign a lower utility to such trip. The main point behind the genesis and formulation of the generalized cost is that it quantifies travel cost not according to how much money and time is actually spent, but according to how much money and time the traveler perceives he/she is spending.

In deriving the total utility term, a special "logsum" approach is used in which utilities are built up from individual modes in a recursive fashion. Further details are provided later in this report. The exact form for the mode utility function is determined from the calibration process for the modal split models.

A.2 DEMAND MODEL EQUATIONS

The total demand model structure is shown in Equation (3)

$$T_{ijp} = \beta_{0p}(SE_{ijp})^{\beta_{1p}} \exp(\beta_{2p}U_{ijp}) \quad (3)$$

where

T_{ijp} = Volume of trips between zones i and j for purpose trip p
SE_{ijp} = Socioeconomic variables for zones i and j for purpose trip p
U_{ijp} = Total Utility of the transportation system for zone i to j

and where β_{0p}, β_{1p} and β_{2p}, are coefficients for purpose trip p to be evaluated. Their evaluation is simpler when Equation (3) is rewritten in logarithmic form

$$\log T_{ijp} = \log \beta_{0p} + \beta_{1p} \log(SE_{ijp}) + \beta_{2p}U_{ijp} \quad (4)$$

so that the coefficients β_{0p}, β_{1p} and β_{2p} can be calibrated using a linear fit. They depend on the purpose trip p, because different groups of travelers behave differently, and their characteristics are better described by different models.

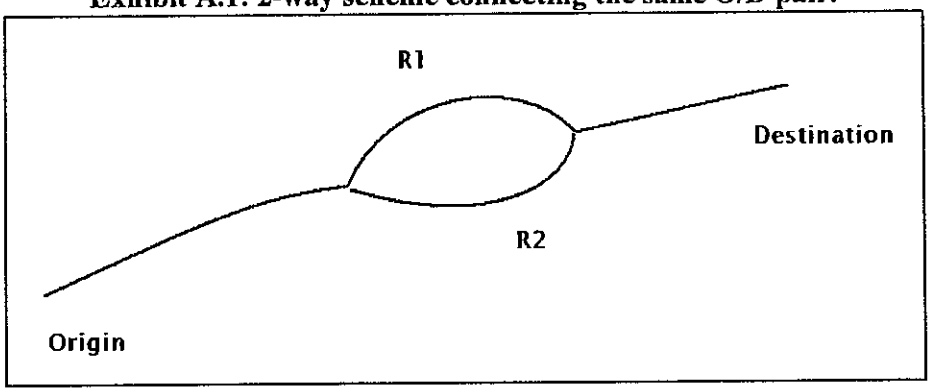
A.3 LOGIT MODELS FOR DIVERSION

The theory of discrete choice models is based on the concept of random utility. A user will take a decision based on observed factors x, such as cost of fuel, tolls, vehicle operating costs, etc., but also on other factors that are cannot easily be observed, let alone be described, by the researcher. These "unobservable" factors, denoted with ε, are considered to be random with probability density function $f(\varepsilon)$. If we denote the outcome of a decision with y, the outcome is related to observable and unobservable factors through some function h called the "behavioral process", i.e., $y=h(x,\varepsilon)$. For a more detailed discussion on the theory of discrete choice models, we refer the reader to [Train, 2003], for example. Additionally, an interesting account on the development of the theory of logit-type formulas is given in Daniel McFadden's 2000 Nobel Prize Lecture [McFadden, 2000].

Given the presence of random terms, the user's choice cannot be exactly predicted. Instead, the probability that the user will make a specific choice will be derived. The probability that the user will then make a specific choice is now given by the probability distribution of the random terms.

Consider the scheme in Exhibit A.1 below.

Exhibit A.1: 2-way scheme connecting the same O/D pair.



In the scheme above origin and a destination are linked by two possible ways (roads) R_1 and R_2. Let GC_1 and GC_2 be the generalized costs associated to journeys on R_1 and R_2, respectively. Let us suppose that the user will make a specific choice based on the generalized cost of travel only. In other words, the user will make a choice if it yields to him the largest utility. Let us suppose that the utility of choosing the road $i=1,2$ is given by

$$U_i = -\beta GC_i + \varepsilon_i . \tag{A.1}$$

The user will therefore choose R_1 if

$$U_1 > U_2; \quad \textit{i.e.,} \quad \varepsilon_1 - \varepsilon_2 > \beta(GC_1 - GC_2) . \tag{A.2}$$

This condition has to be averaged over the whole range of possible values for the difference $\varepsilon = \varepsilon_1 - \varepsilon_2$. If we assume that ε is distributed logistically, i.e.,

$$f(\varepsilon) = \frac{e^{-\varepsilon}}{(1+e^{-\varepsilon})^2} \tag{A.3}$$

with cumulative distribution

$$F(\varepsilon) = \frac{1}{1+e^{-\varepsilon}} \tag{A.4}$$

then the probability of the person choosing R_1 is

$$P(R1) = \int_{\beta(GC_1-GC_2)}^{\infty} f(\varepsilon)d\varepsilon = 1 - F[\beta(GC_1 - GC_2)] = \frac{e^{-\beta(GC_1-GC_2)}}{1+e^{-\beta(GC_1-GC_2)}} \tag{A.5}$$

Since $P(R_2)=1-P(R_1)$, it follows that

$$\frac{P(R1)}{P(R2)} = e^{-\beta(GC_1-GC_2)} \quad (A.6)$$

The assumption we use now is that the choice probabilities do represent actual road choices, so that the formulation of the Logit Route Choice Model is

$$\log\frac{T_1}{T_2} = -\beta(GC_1 - GC_2) \quad (A.7)$$

The model above uses the assumption that none of the alternatives have "intangibles", i.e., scenic views or acute congestion that would affect travel behavior. Based on this assumption, there is also no additive constant term, which implies no bias. Additionally, we used a single coefficient β for both generalized costs, because the choice is made only in terms of difference in generalized costs only.

A.3.1 FARE VARIATIONS

Let us now assume that we apply the fare increase c_T to R_1. Our aim is to estimate the percentage of traffic that is diverted from R_1 to R_2 as a result of this increase, a function, which we denote with $\lambda(c_T)$. The total traffic across R_1 to R_2 will then change to T'_1 and T'_2.

We consider the following simplifying assumptions:

- No traffic is deduced from the system, i.e., $T_1+T_2=T'_1+T'_2$. In other words, we deal with diverted traffic only.
- Increasing the cost along R_1 will not change the generalized cost GC2 of R_2.
- Generalized cost is linear in cost, i.e.,

$$GC=cost+VOT\times time+other\ terms. \quad (A.8)$$

- Increasing fare to one alternative simply increases its GC of the extra fare amount.

As explained above, $\lambda(c_T)$ represents the fraction (or percentage) of traffic T_1 that diverts on R_2 depending on the amount c_T. Hence, we have

$$T'_1 = [1 - \lambda(c_T)]T_1$$
$$T'_2 = T_2 + \lambda(c_T)T_1 \qquad \text{(A.9)}$$

since all traffic diverted from R_1 ends in R_2. At equilibrium, we assume that the route choice model still applies, so that the traffic is diverted to an amount depending on the difference between the new generalized costs. Hence, we also have

$$\log\frac{T'_1}{T'_2} = -\beta(GC_1 + c_T - GC_2) \qquad \text{(A.11)}$$

from which we derive

$$\log\frac{[1 - \lambda(c_T)]T_1}{T_2 + \lambda(c_T)T_1} = -\beta c_T + \log\frac{T_1}{T_2} \qquad \text{(A.12)}$$

that can be rearranged as

$$[1 - \lambda(c_T)]\exp(\beta c_T) = 1 + \lambda(c_T)\frac{T_1}{T_2} \qquad \text{(A.13)}$$

This relationship between $\lambda(c_T)$ and c_T, can be solved explicitly in terms of the ratio between T_1 and T_2, which in turn can be expressed as the difference between the original generalized costs, as in the original route choice equation. We then derive the solution

$$\lambda(c_T) = \frac{\exp(\beta c_T) - 1}{\exp(\beta c_T) + \exp(\beta\delta)} \qquad \text{(A.14)}$$

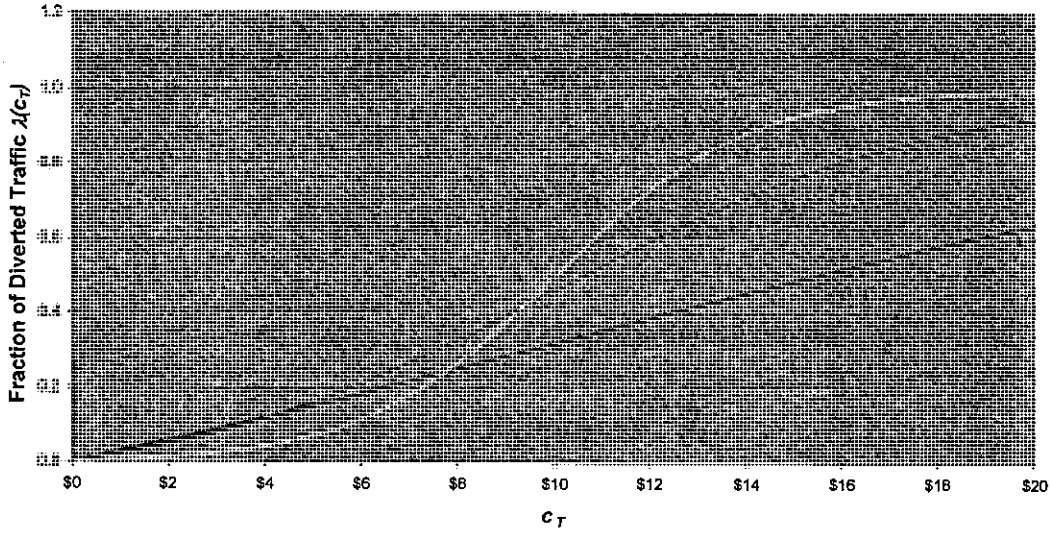
where we defined $\delta = GC_2 - GC_1$, i.e., the original difference between the generalized costs.

A.3.2 DIVERSION CURVES

We can now examine in detail the behavior of the family of curves $\lambda(c_T)$. The function is increasing, bounded between 0 and 1, and depending on the parameters β, the elasticity coefficient of the route choice model, and δ, the difference in generalized cost between R_2, that receives traffic diverted from R_1, and R_1.

The parameter β represents the response rate of a selected category of users to the increase in generalized cost due to the fare increase. Users with low values of β will show an inelastic response, while users with high values of β will begin diverting to alternative ways. Exhibit A.2 shows four curves $\lambda(c_T)$ for four different values of β, and for fixed $\delta=GC_2-GC_1$, kept constant at \$10 (assuming it measured in currency rather than in minutes).

Exhibit A.2: Example of Diversion Functions



A.3.3 USER HETEROGENEITY

The first generalization of this result is a diversification of the values of time for selected groups of users. In most applications, we do not take into account an actual probability distribution of VOTs, rather, we assign average VOTs to selected user groups. All business travelers will have the same average VOT, different than the average VOT assigned to all commuters, etc. So, the problem of computing diverted traffic for a heterogeneous sample of drivers is now broken into computing response functions for the individual categories of travelers.

More precisely, following the syntax previously used, if we define with $p=1,2,...,$n a set of different purposes of travel (we will consider $n=2$, e.g., business and non-business), then we can similarly denote with T_{11} and T_{21} the volumes of traffic on the portion R_1 of the network for purposes of travel p_1 and p_2 respectively. Given that two categories of users that differ for the purpose of travel will have different VOTs and subsequently different elasticity coefficients β, we can define separate functions $\lambda_1(c_T)$ and $\lambda_2(c_T)$ that describe the percentage of traffic diverted from R_1 to R_2

because of the amount c_T imposed on R_1, for purposes p_1 and p_2 separately.

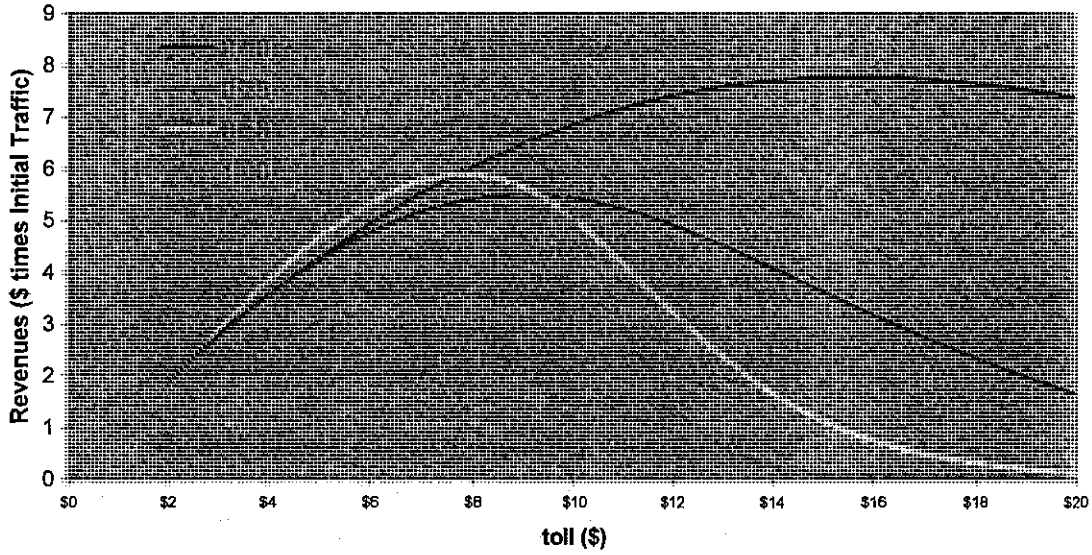
A.3.4 REVENUE YIELD ANALYSIS

The predation function can be used to derive the Revenue Yield curve for R_1 as depicted in Exhibit A.3. The revenue curve as a function of the fare increase is simply calculated as $R(c_T) = Tc_T\,[1-\lambda(c_T)]$, where the T in front of the equation represents the total traffic in the zero toll situation, i.e.,

$$R(c_T) = Tc_T\left(1 - \frac{\exp(\beta c_T) - 1}{\exp(\beta c_T) + \exp(\beta\delta)}\right). \qquad \text{(A.15)}$$

Four curves for $R(c_T)/T$ are shown in Exhibit A.3 for the same values of β as in the previous Exhibit.

Exhibit A.3: Examples of Revenue Yield Curves from Equation (A15)



B. ZONE SYSTEM

Zone	Longitude	Latitude	Description
1	-123.4980	48.8312	Saltspring Island
2	-123.4550	48.9302	Galiano Island
3	-123.3590	48.8517	Mayne Island
4	-123.1790	48.7901	Saturna Island
5	-123.2850	48.7875	Pender Island
6	-123.4550	48.6166	North & Central Saanich
7	-123.3860	48.4905	Saanich
8	-123.3030	48.4571	Oak Bay
9	-123.3620	48.4251	Victoria
10	-123.3660	48.4242	Downtown Victoria
11	-123.3940	48.4320	Esquimalt
12	-123.4440	48.4684	View Rohlands/Colwood
13	-123.4960	48.4333	Mechosin/Sooke
14	-123.6070	48.6801	South Cowichan Valley
15	-123.6990	48.7836	North Cowichan
16	-123.8210	48.9915	Ladysmith
17	-124.0460	48.8355	Lake Cowichan
18	-123.6920	49.0073	Thetis Island
19	-123.4690	48.4397	Kuper Island
20	-123.6580	49.0634	Valdes
21	-123.9810	49.1488	Nanaimo City
22	-124.3260	49.3205	Parksville - Qualicum Beach
23	-123.8230	49.1943	Gabriola Is.
24	-123.9810	49.1488	Nanaimo RD (other)
25	-124.8880	49.2800	Alberni-Clayoquot
26	-124.6980	49.5169	Hornby Island
27	-124.8010	49.5440	Denman Island
28	-124.9320	49.6827	Buckley Bay & Environs
29	-124.9290	49.6834	Courtenay / Comox
30	-125.2260	49.9836	Campbell River/Strathcona
31	-125.2260	50.1092	Quadra Island
32	-124.9790	50.1252	Cortes Island
33	-125.0940	50.1923	Read & Other Islands
34	-126.0560	49.7809	Gold River & Environs
35	-125.9190	50.3624	Sayward & Environs
36	-127.0950	50.5846	Port McNeill & Environs

37	-127.4170	50.7108	Port Hardy & Environs
38	-126.9590	50.6437	Malcolm Island
39	-126.9190	50.5845	Alert Island
40	-123.3770	49.3708	Bowen Island
41	-123.2350	49.4591	Lions Bay
42	-123.1590	49.3371	West Vancouver
43	-123.0750	49.3466	North Vancouver District
44	-123.0690	49.3194	North Vancouver City
45	-123.1230	49.2826	Vancouver - Downtown
46	-123.2190	49.2585	UBC / UEL
47	-123.1250	49.2833	Vancouver West side
48	-123.1250	49.2833	Vancouver - northeast
49	-123.1250	49.2833	Vancouver - southeast
50	-123.1820	49.1935	Sea Island - YVR
51	-123.0930	49.1773	Richmond
52	-122.9770	49.2557	Burnaby
53	-122.9070	49.2120	New Westminster
54	-123.0760	49.0908	Ladner & Tsawwassen
55	-122.9240	49.1499	North Delta
56	-122.8370	49.2001	North Surrey
57	-122.8360	49.1702	Central Surrey
58	-122.8360	49.1503	South Surrey
59	-122.7990	49.0224	White Rock
60	-122.6570	49.1038	Langley District
61	-122.6570	49.1038	Langley City
62	-122.8450	49.2901	Port Moody
63	-122.8570	49.2380	Coquitlam
64	-122.7670	49.2590	Port Coquitlam
65	-122.6830	49.2500	Pitt Meadows
66	-122.6170	49.2224	Maple Ridge
67	-122.6190	49.2255	Dewdney-Alouette
68	-122.2960	49.0505	Central Fraser Valley
69	-121.7710	49.2048	Fraser-Cheam
70	-123.1310	49.8227	Squamish-Lillooet
71	-123.3910	49.4830	Gambier Island
72	-123.4570	49.3999	Keats Island
73	-123.5060	49.4077	Gibson's & Environs
74	-123.7540	49.4817	Sechelt & Environs
75	-123.9520	49.7600	Egmont & Environs
76	-124.5540	49.8641	Powell River
77	-124.8170	49.9370	Lund & Savary Island

78	-124.6410	49.7360	Texada Island
79	-124.3500	49.4914	Lasqueti Island
80	-120.5960	50.4985	Thompson-Nicola
81	-122.0840	53.0300	Cariboo
82	-118.2100	51.1960	Columbia-Shuswap
83	-119.2760	50.2583	Okanagan-Similkameen
84	-119.4930	49.9010	Central Okanagan
85	-120.3270	50.6932	North Okanagan
86	-118.3610	49.1128	Kootenay-Boundary
87	-117.4670	50.3139	Central Kootenay
88	-115.5370	49.9852	East Kootenay
89	-125.7830	49.5680	Comox - Strathcona
90	-126.1100	50.5100	Mt. Waddington
91	-126.5500	52.3880	Central Coast
92	-129.8330	54.2502	Skeena-Prince Rupert
93	-132.0080	53.2434	Skidegate
94	-131.9790	53.2045	Alliford Bay
95	-128.5490	54.0491	Kitimat-Stikine
96	-125.3640	54.1340	Bulkley-Nechako
97	-122.1220	54.1701	Fraser-Fort George
98	-128.9390	58.5961	Stikine
99	-122.7830	55.4690	Peace River
100	-126.0250	59.4000	Fort Nelson-Liard
101	-116.1980	51.4330	Alberta
102	-111.9400	49.2600	Rest of Canada
103	-122.5240	48.7939	Bellingham & Environs
104	-123.0160	48.5360	San Juan Islands
105	-122.1560	47.5790	Seattle & Environs
106	-123.4360	48.1140	Port Angeles
107	-121.5390	47.3990	Eastern Washington
108	-120.2960	47.2870	Rest of USA

C. SURVEY FORMS

- SHORT DISTANCE SP FORM (S-A1)
- MEDIUM DISTANCE SP FORM (M-W2)
- LONG DISTANCE SP FORM (L-W1)

BC Ferries Stated Preference Survey/Questionnaire

Departure Date:_____ Route # : _____
Departure Time:_____ Surveyor: _____

Dear Respondent: This survey is part of a transportation study being conducted by BC Ferries in order to better understand and serve the travel needs of the Province of British Columbia. Please take a few minutes to answer the questions on this form and return it to our representative. The information you provide will be kept strictly confidential. Thank you for your cooperation.

1. What is the origin and destination of your trip?

Origin City _____ Postal code _____

Destination City _____ Postal code _____

What is the city and province/state of your primary residence? _____

2. What is the purpose of your trip? (Check one box)

- ☐ Business (travel for work)
- ☐ Commuter (travel to/from work)
- ☐ Recreation/Vacation
- ☐ Visit friends or relatives
- ☐ Shopping
- ☐ Attend school/college
- ☐ Attend special social event
- ☐ Other _____

3. How many people are traveling in your vehicle today? _____

4. Are you a holder of a prepaid ticket?

☐ Yes ☐ No

5. How often do you use this route? (Check one box)

- ☐ 3 times or more per week
- ☐ Once a week
- ☐ Twice a month
- ☐ Once a month
- ☐ Less than once a month

6. Did you make a reservation for this trip?

☐ Yes ☐ No

7. How long was your wait time at the terminal today? _____

8. What is your employment status?

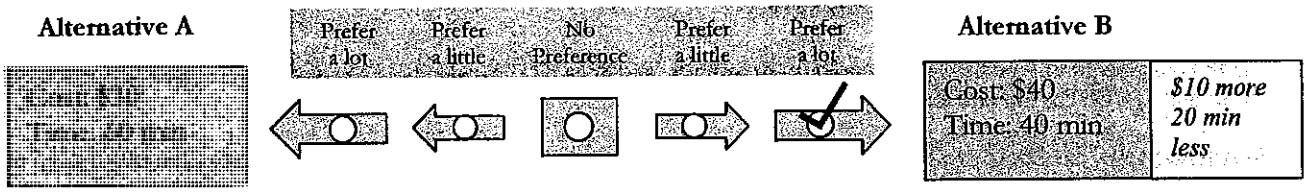
☐ Employed full-time ☐ Employed part-time ☐ Retired Other: _____

9. What is the combined annual income of everyone in your household?

☐ Less than $30,000 ☐ $30,000 to $59,999 ☐ $60,000 to $99,999 ☐ $100,000 or more

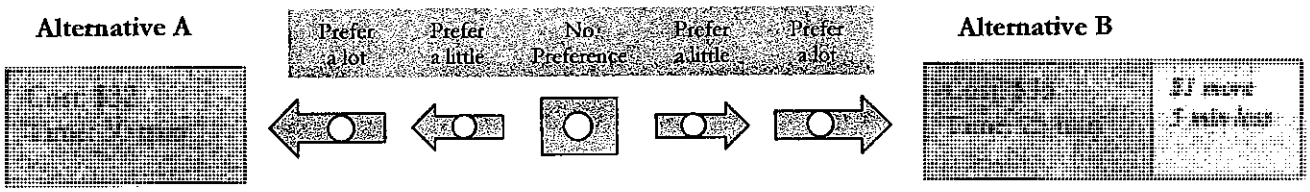
How to answer this questionnaire....

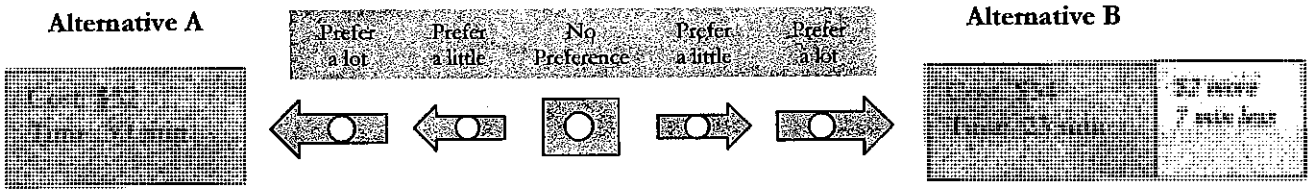
Indicate, as shown in the example below, the degree to which you prefer Alternative A or Alternative B. All times and costs are hypothetical and may not be the same as your trip today. In this example, the traveller strongly preferred Alternative B and is very willing to spend $10 more to save 20 minutes in travel time.

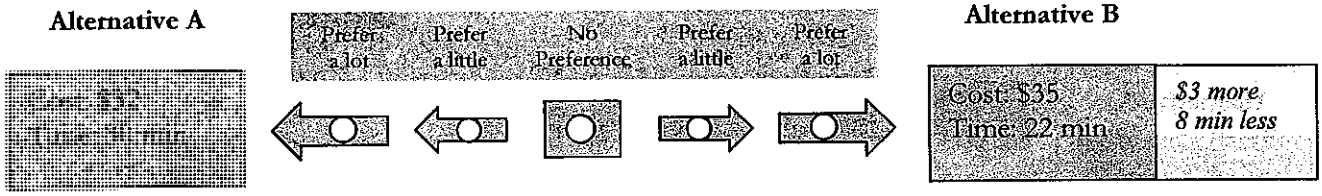


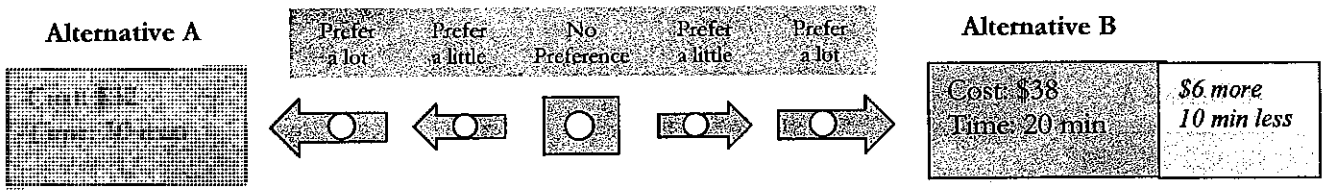
How much do you value your time when travelling?

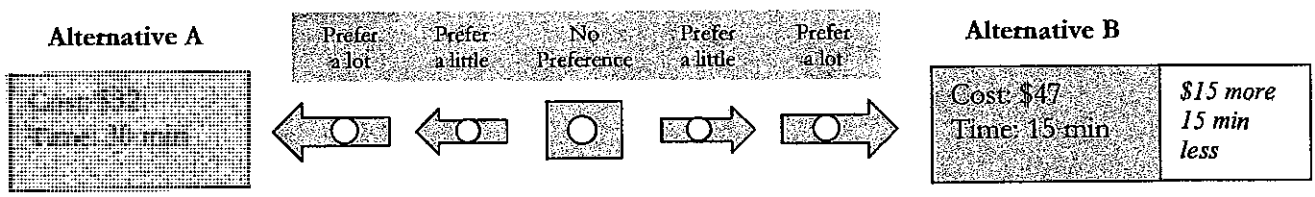
Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST. TIME is the actual time you spend on the ferry for a one-way trip and does NOT include time spent at the ferry terminal or travelling to the terminal. COST is the fare for a ONE-WAY ticket. In Alternative B, the COST of a one-way ticket varies depending on the amount of TIME spent on the ferry. Put a checkmark on your level of preference for EACH of the five choices given below.









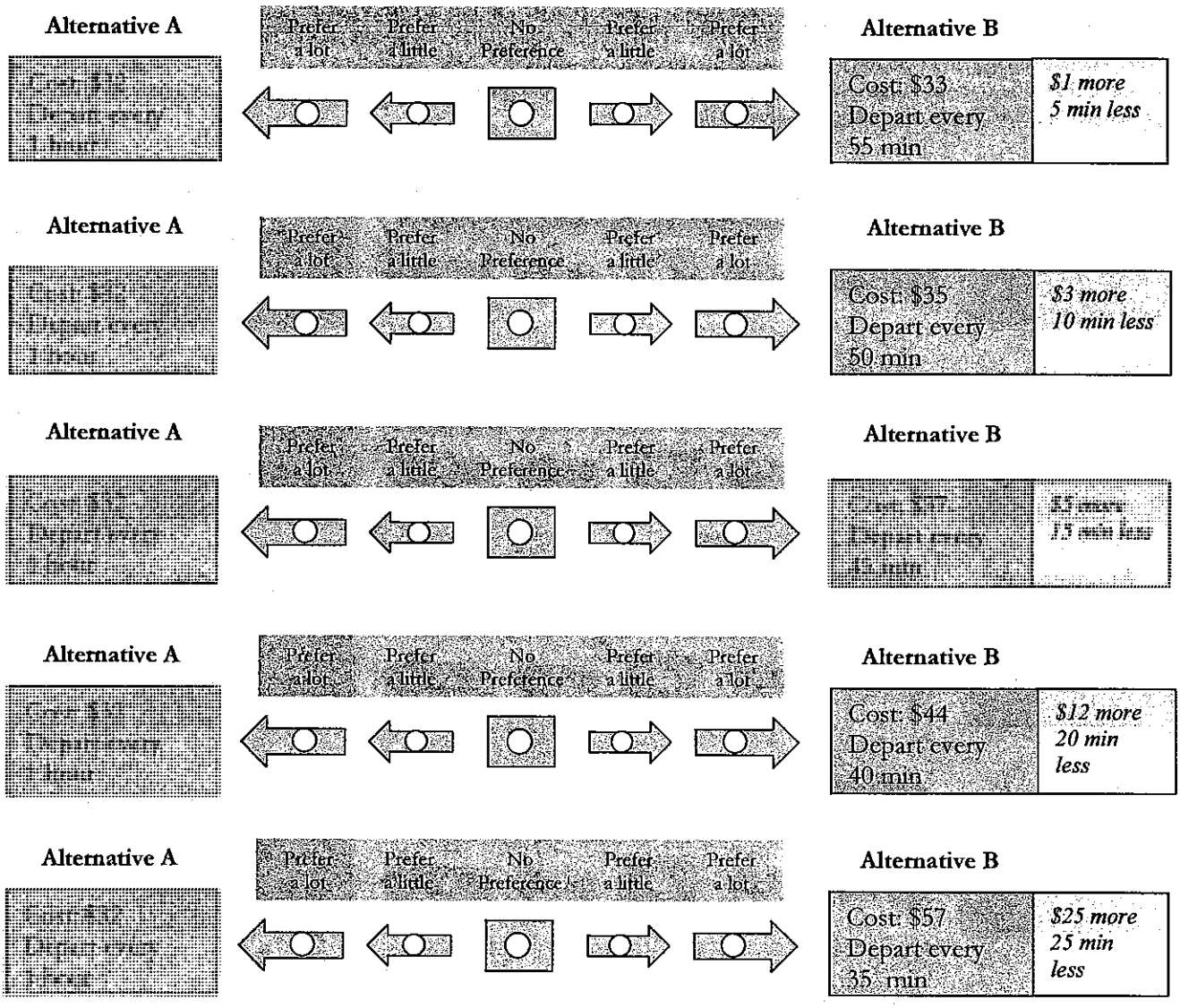


How do you value frequency of service?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST.

TIME is the length of time between actual ferry departures, and does NOT include time spent at the ferry terminal or travelling to the terminal. COST is the fare for a ONE-WAY ticket.

In Alternative B, the COST of a one-way ticket varies depending on the frequency of service or how often the ferry runs. Put a checkmark on your level of preference for EACH of the five choices given below.

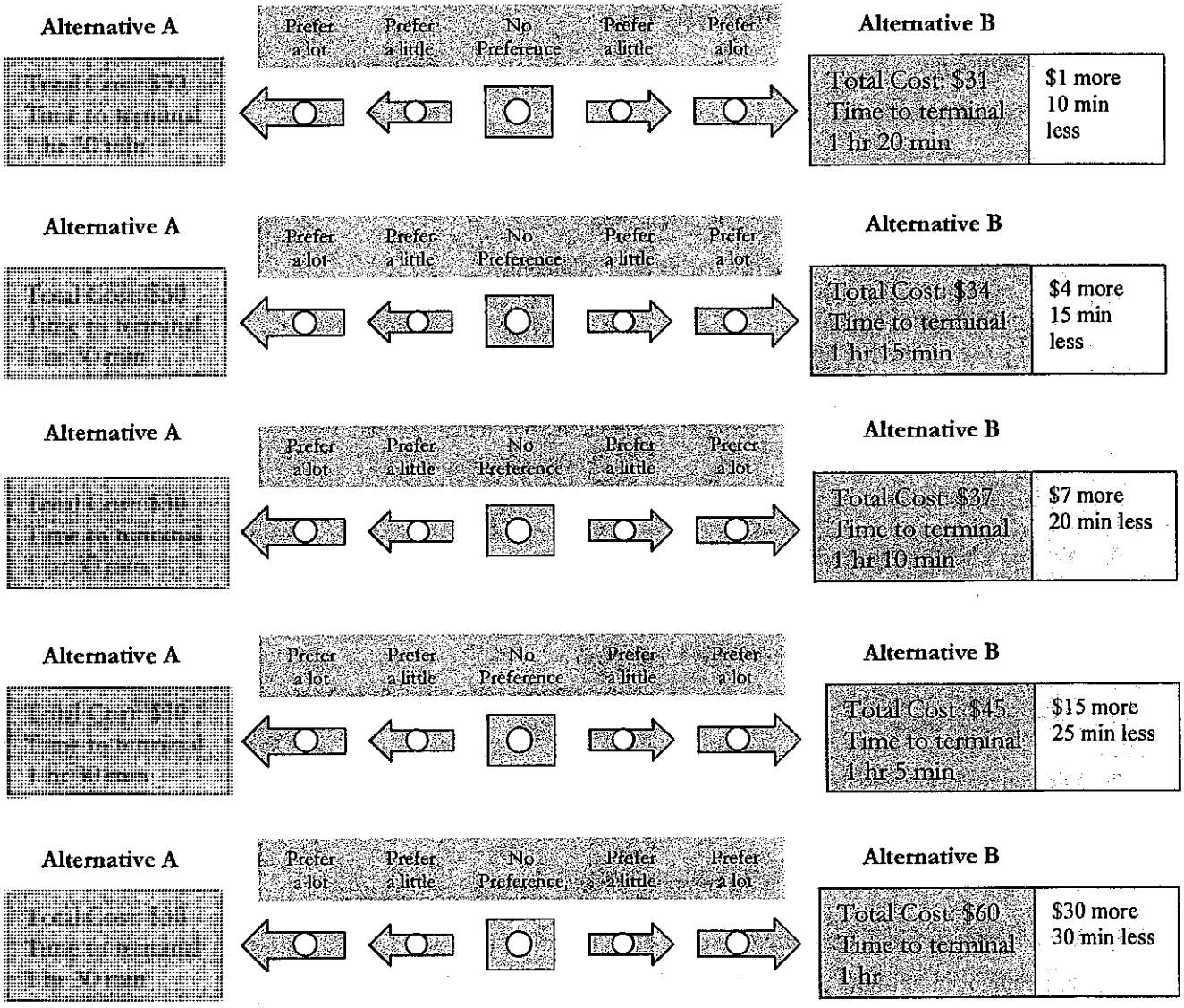


How do you value the time and money you spend to travel to the ferry terminal?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST.

TIME is the length of time it takes you to travel to the ferry terminal, and does NOT include time spent at the terminal or travelling on the ferry. COST is the TOTAL it costs you to travel to the terminal and includes (but is not limited to) auto operating costs, tolls, parking fees, and taxi fares. COST does NOT include the fare for your ticket.

In Alternative B, the COST of travelling to the terminal varies depending on how long it takes you to travel to the terminal. Put a checkmark on your level of preference for EACH of the five choices given below.



BC Ferries Stated Preference Survey/Questionnaire

Departure Date:_____ Route # : _____
Departure Time:_____ Surveyor: _____

Dear Respondent: This survey is part of a transportation study being conducted by BC Ferries in order to better understand and serve the travel needs of the Province of British Columbia. Please take a few minutes to answer the questions on this form and return it to our representative. The information you provide will be kept strictly confidential. Thank you for your cooperation.

1. How did you travel from your actual trip origin to the BC Ferries terminal?

☐ Transit ☐ Walk
☐ Drop-off ☐ Drive and park the car

2. What is the origin and destination of your trip?

Origin City _____ Postal code _____

Destination City _____ Postal code _____

What is the city and province/state of your primary residence? _____

3. What is the purpose of your trip? (Check one box)

☐ Business (travel for work) ☐ Shopping
☐ Commuter (travel to/from work) ☐ Attend school/college
☐ Recreation/Vacation ☐ Attend special social event
☐ Visit friends or relatives ☐ Other _____

4. How will you travel from the destination terminal to your actual destination?

☐ Auto ☐ Transit/Walk
☐ Pick-up ☐ Other _____

5. Are you a holder of a prepaid ticket?

☐ Yes ☐ No

6. How often do you use this route? (Check one box)

☐ 3 times or more per week ☐ Twice a month ☐ Less than once a month
☐ Once a week ☐ Once a month

7. Did you make a reservation for this trip?

☐ Yes ☐ No

8. How long was your wait time at the terminal today? _____

9. What is your employment status?

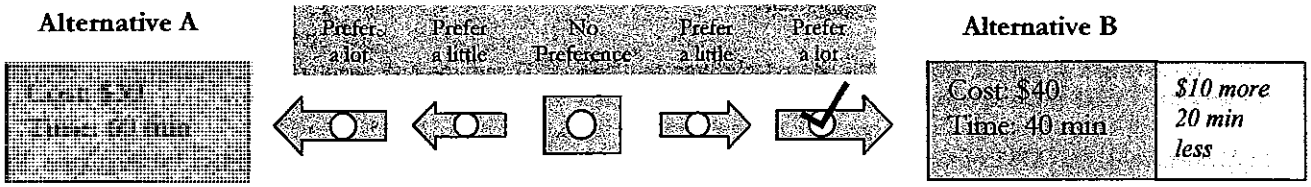
☐ Employed full-time ☐ Employed part-time ☐ Retired Other: _____

10. What is the combined annual income of everyone in your household?

☐ Less than $30,000 ☐ $30,000 to $59,999 ☐ $60,000 to $99,999 ☐ $100,000 or more

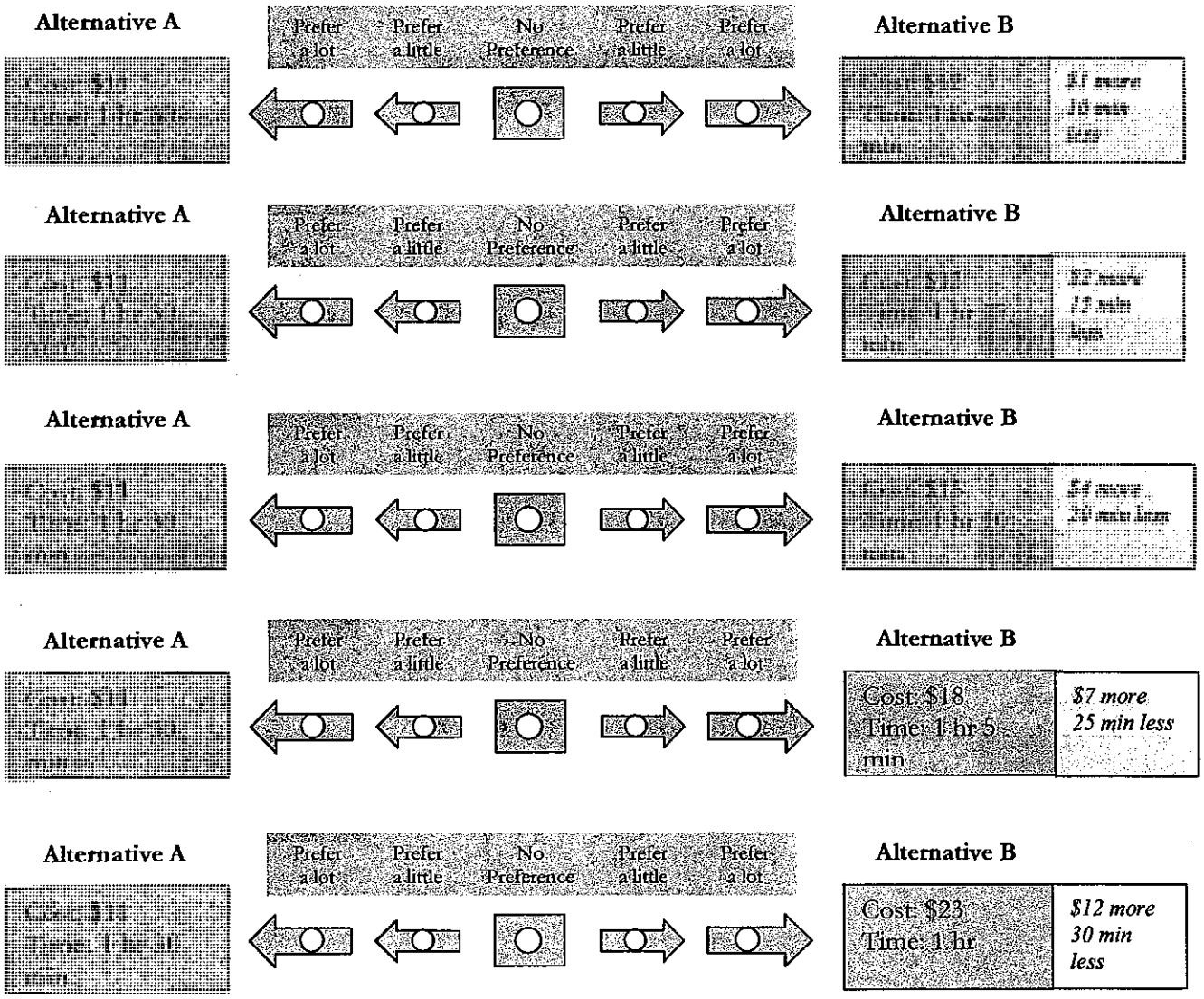
How to answer this questionnaire....

Indicate, as shown in the example below, the degree to which you prefer Alternative A or Alternative B. All times and costs are hypothetical and may not be the same as your trip today. In this example, the traveller strongly preferred Alternative B and is very willing to spend $10 more to save 20 minutes in travel time.



How much do you value your time when travelling?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST. TIME is the actual time you spend on the ferry for a one-way trip and does NOT include time spent at the ferry terminal or travelling to the terminal. COST is the fare for a ONE-WAY ticket. In Alternative B, the COST of a one-way ticket varies depending on the amount of TIME spent on the ferry. Put a checkmark on your level of preference for EACH of the five choices given below.

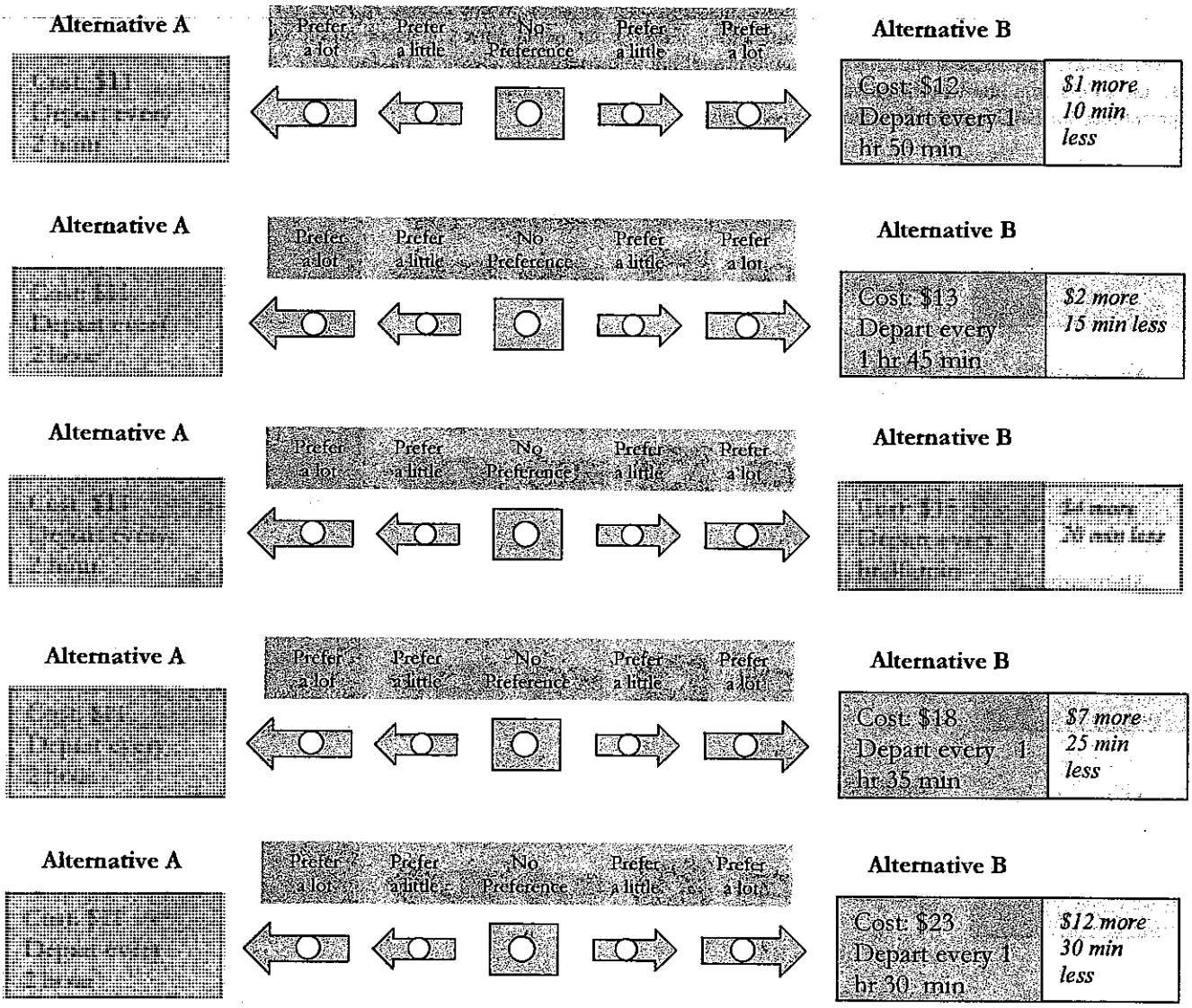


How do you value frequency of service?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST.

TIME is the length of time between actual ferry departures, and does NOT include time spent at the ferry terminal or travelling to the terminal. COST is the fare for a ONE-WAY ticket.

In Alternative B, the COST of a one-way ticket varies depending on the frequency of service or how often the ferry runs. Put a checkmark on your level of preference for EACH of the five choices given below.



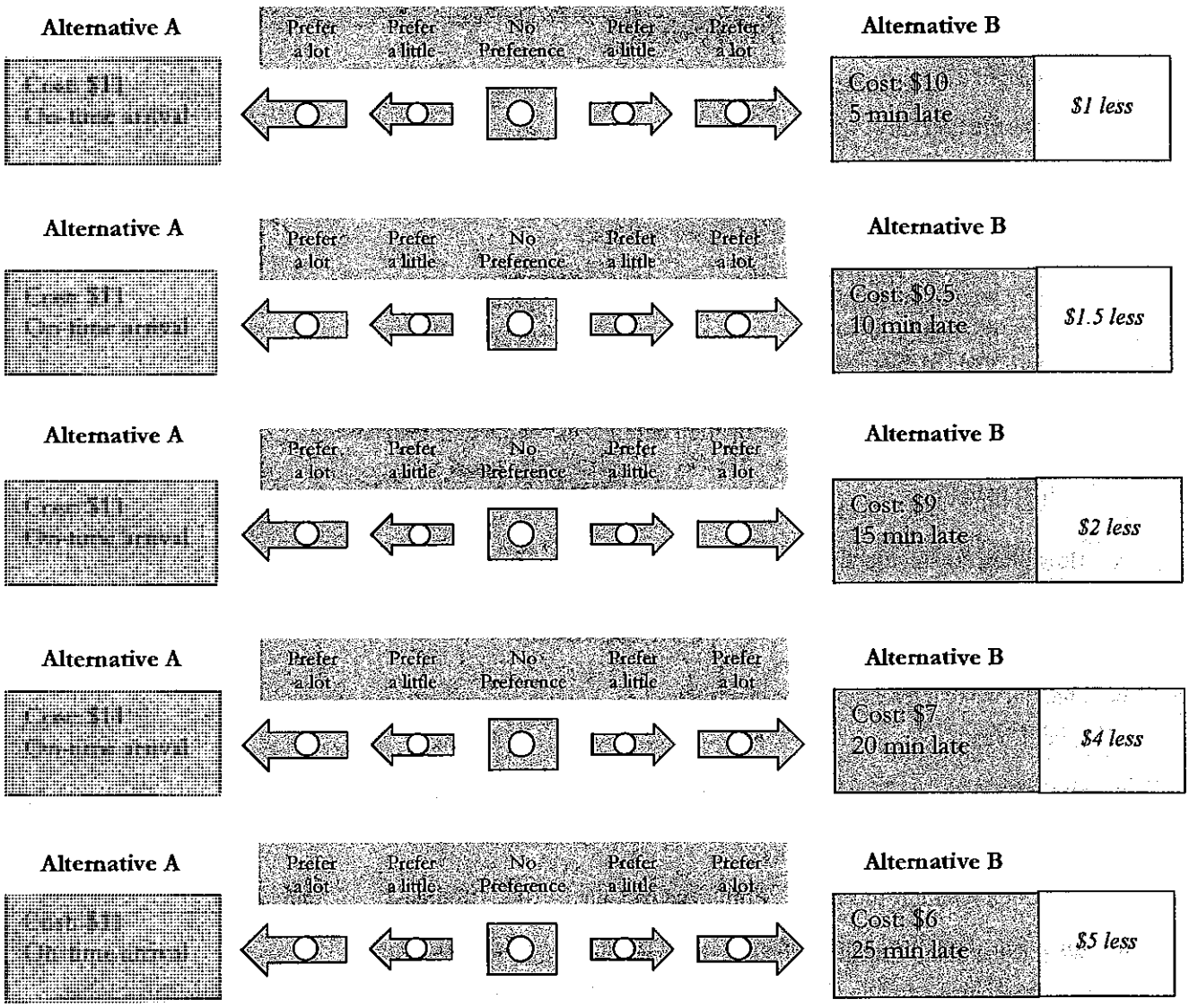
M-W2

How do you value the reliability of the ferry service?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST. Also imagine there is a ferry departing EVERY THREE DAYS.

TIME in this case is how late the ferry arrives at the destination. COST is the fare for a ONE-WAY ticket.

In Alternative B, the COST of a one-way ticket varies depending on the on-time performance of the ferry or how many minutes late the ferry arrives at the destination. Put a checkmark on your level of preference for EACH of the five choices given below.



BC Ferries Stated Preference Survey/Questionnaire

Departure Date:_____ Route # : _____
Departure Time:_____ Surveyor: _____

Dear Respondent: This survey is part of a transportation study being conducted by BC Ferries in order to better understand and serve the travel needs of the Province of British Columbia. Please take a few minutes to answer the questions on this form and return it to our representative. The information you provide will be kept strictly confidential. Thank you for your cooperation.

1. How did you travel from your actual trip origin to the BC Ferries terminal?

☐ Transit ☐ Walk
☐ Drop-off ☐ Drive and park the car

2. What is the origin and destination of your trip?

Origin City _____ Postal code _____

Destination City _____ Postal code _____

What is the city and province/state of your primary residence? _____

3. What is the purpose of your trip? (Check one box)

☐ Business (travel for work) ☐ Shopping
☐ Commuter (travel to/from work) ☐ Attend school/college
☐ Recreation/Vacation ☐ Attend special social event
☐ Visit friends or relatives ☐ Other _____

4. How will you travel from the destination terminal to your actual destination?

☐ Auto ☐ Transit/Walk
☐ Pick-up ☐ Other _____

5. How often do you use this route? (Check one box)

☐ 3 times or more per week ☐ Twice a month ☐ Less than once a month
☐ Once a week ☐ Once a month

6. Did you make a reservation for this trip?

☐ Yes ☐ No

7. How long was your wait time at the terminal today? _____

8. What is your employment status?

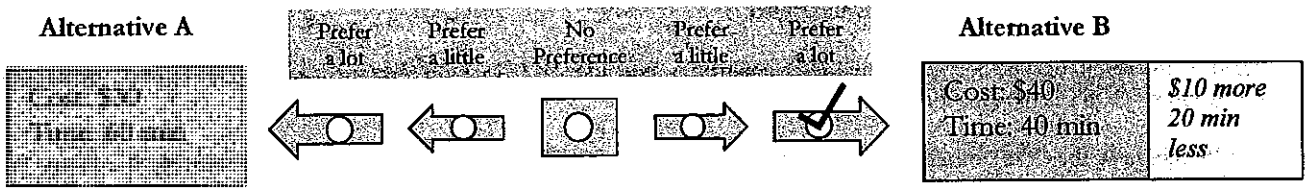
☐ Employed full-time ☐ Employed part-time ☐ Retired Other: _____

9. What is the combined annual income of everyone in your household?

☐ Less than $30,000 ☐ $30,000 to $59,999 ☐ $60,000 to $99,999 ☐ $100,000 or more

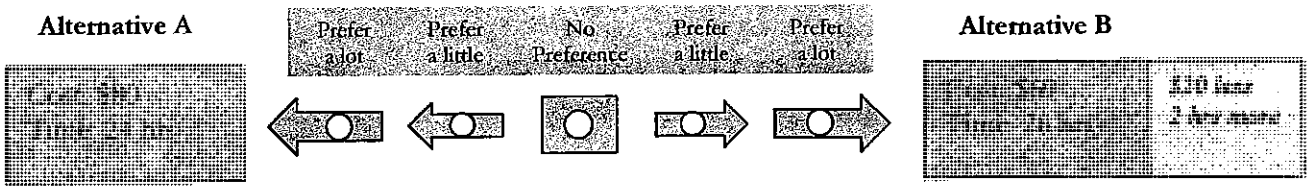
How to answer this questionnaire....

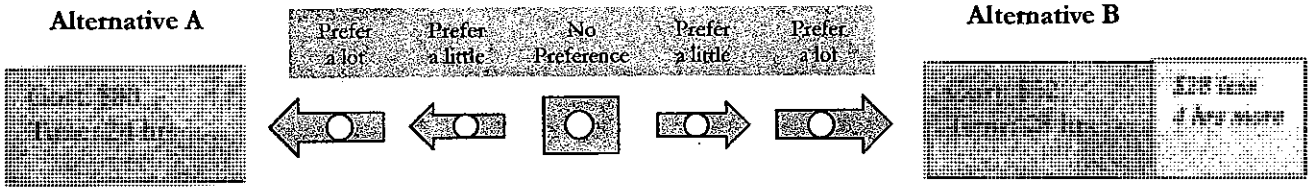
Indicate, as shown in the example below, the degree to which you prefer Alternative A or Alternative B. All times and costs are hypothetical and may not be the same as your trip today. In this example, the traveller strongly preferred Alternative B and is very willing to spend $10 more to save 20 minutes in travel time.

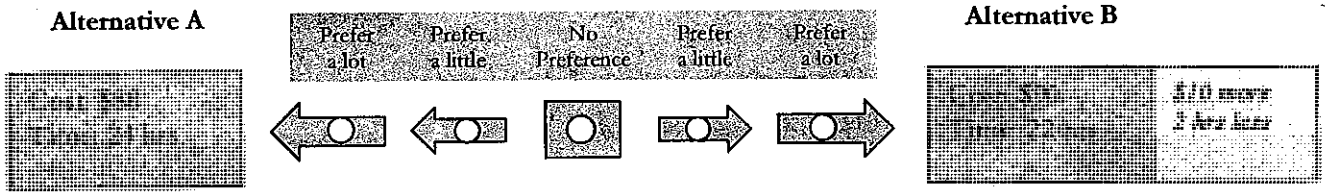


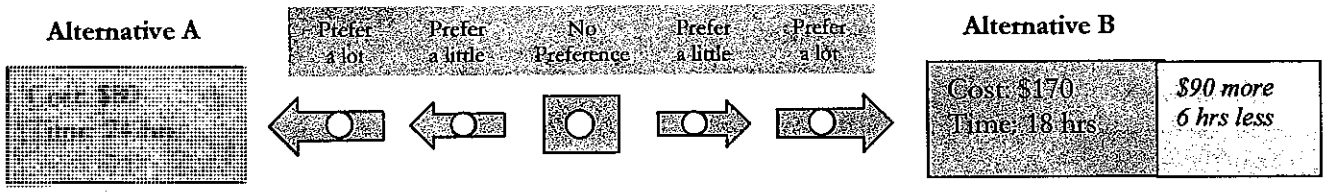
How much do you value your time when travelling?

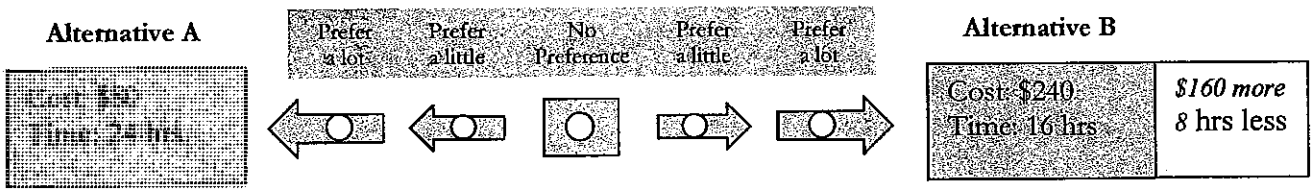
Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST. TIME is the actual time you spend on the ferry for a one-way trip and does NOT include time spent at the ferry terminal or travelling to the terminal. COST is the fare for a ONE-WAY ticket. In Alternative B, the COST of a one-way ticket varies depending on the amount of TIME spent on the ferry. Put a checkmark on your level of preference for EACH of the five choices given below.











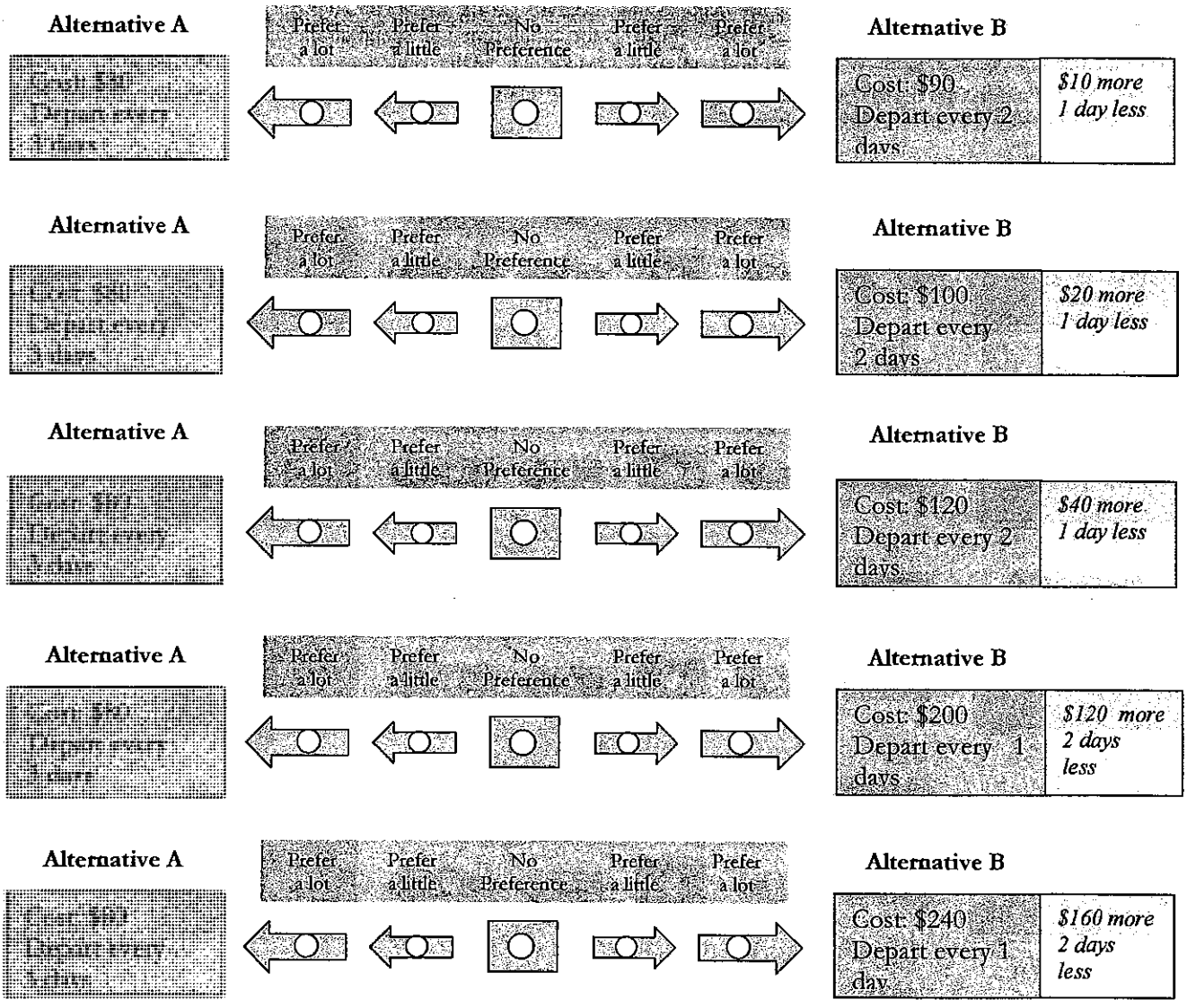
L-W1

How do you value frequency of service?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST.

TIME is the length of time between actual ferry departures, and does NOT include time spent at the ferry terminal or travelling to the terminal. COST is the fare for a ONE-WAY ticket.

In Alternative B, the COST of a one-way ticket varies depending on the frequency of service or how often the ferry runs. Put a checkmark on your level of preference for EACH of the five choices given below.



L-W1

How do you value the time and money you spend to travel to the ferry terminal?

Imagine you are making the same trip you are making today AGAIN, to the SAME PLACE for the SAME PURPOSE and are given a series of choices between TIME and COST.

TIME is the length of time it takes you to travel to the ferry terminal, and does NOT include time spent at the terminal or travelling on the ferry. COST is the TOTAL it costs you to travel to the terminal and includes (but is not limited to) auto operating costs, tolls, parking fees, and taxi fares. COST does NOT include the fare for your ticket.

In Alternative B, the COST of travelling to the terminal varies depending on how long it takes you to travel to the terminal. Put a checkmark on your level of preference for EACH of the five choices given below.