**HIGH OCCUPANCY VEHICLE MONITORING
AND EVALUATION FRAMEWORK**

by

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ABSTRACT

This thesis describes a framework for monitoring and evaluating the effectiveness of a high occupancy vehicle (HOV) facility based on a set of quantifiable objectives. The framework is developed specifically to evaluate the effectiveness of the arterial and freeway HOV facilities within the Greater Vancouver area of British Columbia. However, it should be applicable to other jurisdictions as well.

As a contribution to existing HOV evaluation procedures, the HOV evaluation objectives are categorized into three groups by their relationship to the goals of an HOV program: primary, supporting, and operational. Primary objectives directly relate to the HOV goals of improving the person throughput and encouraging higher occupancy. Characteristics of an HOV facility that contribute to the attainment of the HOV goals are evaluated as supporting evaluation objectives. Attributes that protect the performance of the HOV facility (and therefore its attractiveness to users) are evaluated as operational objectives. Quantifiable measures of effectiveness (MOEs) are selected to determine if an objective is met. The data required to evaluate each of the MOEs is summarized. In addition, a data collection methodology and comprehensive procedures for analyzing and presenting the MOEs are described. To enhance current practices of evaluating HOV facilities, the framework includes a procedure to calculate the statistical reliability and relative uncertainty of the data collected. Finally, a multi-criteria evaluation procedure to evaluate the cost-effectiveness of an HOV facility is presented. Only the quantifiable benefits and costs of an HOV facility are considered in performing a benefit-cost analysis.

The framework is applied to evaluate the effectiveness of the HOV facility on the Barnet/Hastings corridor. A multi-criteria evaluation is performed and the results are presented. The objectives of the framework that are considered to be effective include: 'Person Throughput', 'Travel Time Savings', and 'Impact on GP Lanes'. The travel speed standard deviations of the HOV lane are less than the GP lane. However, it was determined that the HOV lane is not providing a statistically significant more reliable trip at the 95% confidence level. The Ministry of Transportation and Highways desired compliance rate of 85% is not presently being attained on the Barnet/Hastings corridor. No public opinion survey data relating to the operation of the HOV facility is available for the application and the safety results are not conclusive. Finally, a preliminary analysis indicated that the HOV facility on the Barnet/Hastings corridor is cost-effective.

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1. INTRODUCTION

1.1 BACKGROUND

In the South Coast Region of British Columbia, a high occupancy vehicle (HOV) network is being implemented by the Ministry of Transportation and Highways. As part of the implementation, HOV facilities are being developed on identified arterials and freeways within the Greater Vancouver area. The goals of the HOV network are to improve the person throughput and encourage higher occupancy on selected corridors. HOV facilities are anticipated to provide incentives such as travel time savings and reliability. It is expected that these HOV incentives will encourage drivers to shift modes from single occupant vehicles (SOVs) into high occupancy vehicles (HOVs) such as carpools, vanpools, and buses.

The first section of the HOV network was completed in the Fall of 1996 on the Barnet/Hastings HOV corridor (Route 7A), from Renfrew Street in Vancouver to Ioco Road in Port Moody. The HOV facility on the Barnet/Hastings corridor is comprised of both arterial and freeway sections. The curbside lane of the facility is a part-time HOV lane. The HOV lane is in operation (Monday to Friday) during the peak periods with an occupancy requirement of 2 or more people. The second section of the HOV network is currently under construction on Highway 1, between the Grandview and Cape Horn interchanges. The anticipated completion of the HOV facility is the Fall of 1998. An exclusive median HOV lane will operate throughout the day in each direction of travel. The occupancy requirement of the freeway HOV lane is scheduled to be 3 or more people.

A framework was developed for the monitoring and evaluation of these initial and any other future HOV facilities. The purpose of developing the framework, the scope of the framework, and the application of the framework to the HOV facility on the Barnet/Hastings corridor are presented in this thesis.

1.2 PURPOSE OF THESIS

In general, there is agreement among transportation professionals that "before-and-after" evaluations and ongoing monitoring be performed on HOV facilities. HOV facilities are to be evaluated in an unbiased, consistent manner that clearly evaluates the attainment of an HOV project's objectives. In British Columbia, however, there is no consistent methodology for evaluating its present and future HOV corridors.

Nonetheless, the performance of the HOV facility on the Barnet/Hastings corridor was evaluated based on certain criteria such as travel time savings and the average vehicle occupancy (AVO) of vehicles using the corridor. The facility's baseline information collected prior to the HOV lane construction was compared with data collected after its opening. The results of the "before-and-after" evaluation were documented in the *"Barnet/Hastings People Moving Project Monitoring and Evaluation Program After-Implementation Interim Report"* (MoTH¹, 1997). It is foreseen that a similar "before-and-after" evaluation will be performed on the future Highway 1 HOV corridor upon its completion. Therefore, extensive baseline information was collected on Highway 1 in the Fall of 1997, prior to any construction activity.

To properly measure the effectiveness of these HOV facilities, it was determined that a HOV monitoring and evaluation framework be developed. Firstly, a comprehensive literature review of current North American HOV evaluation practice was performed to assist in developing the framework. The value of reviewing existing HOV evaluation procedures is that it gives transportation agencies a strong foundation for creating policy to properly monitor and evaluate HOV facilities.

The review of the North American HOV literature indicated that there exists considerable differences between the evaluation practices among jurisdictions. In fact, a standard methodology for the evaluation of HOV facilities does not currently exist. Therefore, there is a need to develop an HOV monitoring and evaluation framework to directly consider the goals of the South Coast Region HOV program. By developing this framework, a set of evaluation objectives tailored to the evaluation needs of the South Coast Region could be selected. The HOV monitoring and evaluation framework is based on the HOV evaluation procedures that currently exist.

1.3 SCOPE OF THESIS

The HOV framework is a procedure to monitor and evaluate an HOV facility. The process of measuring the effectiveness of an HOV facility is based on evaluating a set of quantifiable objectives. As a contribution to existing HOV evaluation procedures, the set of evaluation objectives are categorized by their relationship to the goals of the South Coast Region HOV program. They are categorized as either primary, supporting, or operational objectives.

The primary evaluation objective of the framework is directly related to the HOV network goals of improving the person throughput and increasing the use of HOVs on selected facilities. Characteristics of an HOV facility that contribute to the attainment of the HOV goals are evaluated as supporting evaluation objectives. Travel time savings is an example of a supporting objective. Attributes that ensure the protection of the HOV goals are evaluated as operational evaluation objectives. Safety is an example of an operational objective.

Each of the primary, supporting and operational objectives are described. Quantifiable measures of effectiveness (MOEs) are selected to determine if an objective is met. For example, one aspect of the primary evaluation objective is to examine if adding an HOV lane to a corridor encourages people to shift modes to an HOV. An MOE used to assist in determining if the objective was met is the average vehicle occupancy (AVO).

The data required to evaluate each of the MOEs is summarized. To enhance current practices of evaluating HOV facilities, the framework includes a procedure to calculate the statistical reliability of the data collected. Statistical procedures were often mentioned in HOV evaluations but little was reported on statistically examining the reliability of the data collection. In addition to the data requirements, a data collection methodology and comprehensive procedure for analyzing and presenting the MOEs are described.

Furthermore, the relative uncertainty of an MOE is quantified as part of the framework, where applicable. The literature review indicated that variances (or standard deviations) were examined in evaluating the travel time reliability of an HOV facility. However, the

proposed framework in this thesis examines the statistical reliability of other MOEs such as the AVO.

Besides examining the statistical reliability, the framework describes the testing of the difference between two MOEs for statistical significance. It is important to understand if the difference between two values can be considered to be statistically significant or can be expected by chance.

Finally, a multi-criteria evaluation of an HOV facility is outlined in the framework. Only the quantifiable benefits and costs of an HOV facility are considered in a benefit-cost analysis. In addition, a sensitivity analysis methodology is described.

To obtain a clear understanding of the HOV monitoring and evaluation framework, an application was performed on the HOV facility of the Barnet/Hastings corridor. Data related to the implementation of the Barnet/Hastings HOV lane was analyzed in accordance with the framework. The numerical results of the data analysis are summarized in this thesis. As well, this thesis discusses the results on the effectiveness of the Barnet/Hastings HOV corridor with respect to the framework's quantifiable objectives (wherever data is available).

1.4 ORGANIZATION OF THESIS

This thesis is divided into seven chapters. Following this introductory chapter, Chapter Two discusses the findings of an extensive literature review on HOV evaluation practices in North America. Chapter Three outlines the objectives and the evaluation

procedures of the HOV monitoring and evaluation framework. Chapter Four summarizes the framework's evaluation objectives' measures of effectiveness, data requirements and data collection methodology as well as a statistical method for analyzing such data. Chapter Five describes the procedure for conducting a multi-criteria HOV evaluation. Chapter Six summarizes the application of the framework to the Barnet/Hastings HOV corridor. Finally, a concluding chapter summarizes the findings of the thesis and suggestions for further HOV evaluation research.

1.5 SUMMARY

A monitoring and evaluation framework is required to evaluate the HOV facilities of British Columbia's South Coast Region's HOV network. Building upon the experiences of other North American cities' evaluations, a framework suitable to the area was designed to evaluate the region's HOV corridors. The framework consists of a set of quantifiable objectives and measures of effectiveness that are typically included in HOV evaluations.

It expands on current practice by categorizing the evaluation objectives and by including comprehensive procedures for statistically analyzing the reliability and significance of the results. A multi-criteria methodology is presented and the application of the framework to an existing corridor is discussed. The proposed monitoring and evaluation framework is directly applicable for an HOV facility within British Columbia and can also easily be adapted for application in other jurisdictions.

2. LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1 The Evaluation of HOV Facilities

An extensive literature review of current North American HOV evaluation practice was performed. The review of North American literature indicated that there is no standard practice across Canada and the United States in evaluating HOV facilities. Different HOV projects have their own set of evaluation objectives which reflect the reasons for implementing their respective HOV facility (see for example: Brown and Jacobson, 1996; Pint et al., 1995; RSMI¹, 1997).

Although each HOV evaluation has been unique in its approach to a certain extent, there appear to be some common steps taken in the evaluation process. Most studies identified a set of objectives and some measures of effectiveness (MOEs) to evaluate these objectives. Some studies identified expected target values for the MOEs (Pint et al., 1995) whereas others did not (Brown and Jacobson, 1996).

The information needs of an HOV evaluation were usually identified and the data collected accordingly. However, "before" data collected prior to the opening of an HOV facility was not always available. In other cases, "before" data was available but was not adequate to make statistically meaningful conclusions when compared to "after" data (Turnbull et al., 1991).

An example of a comprehensive examination of HOV lane projects is the evaluation carried out by the Texas Transportation Institute (TTI) which is published in several

reports. The TTI studies (see for example: Turnbull^{1,2}, 1992) examined several cities with freeway HOV facilities in detail. The common elements of evaluating freeway HOV facilities were highlighted and a general list of the most effective and representative HOV evaluation objectives was proposed.

One particular TTI study (Turnbull et al., 1991) recommended a specific HOV evaluation procedure as a guideline to measure the effectiveness of a freeway HOV facility. The study encouraged that this suggested procedure be tailored to meet the specific set of objectives of different agencies in implementing their HOV facilities. The TTI studies, however, do not discuss the evaluation of arterial HOV facilities. In fact, very little was found from the North American literature on evaluating arterial HOV facilities, especially when compared to the number of HOV freeway evaluation reports.

2.1.2 Evaluation Objectives

Defining clear and measurable objectives was often stated as one of the most important and often neglected steps in the HOV evaluation process. If these objectives are not clearly defined, evaluating an HOV facility becomes more difficult because evaluators cannot identify what they are trying to assess (Turnbull et al., 1991). Many of the objectives reviewed were merely qualitative in nature and as simple as a brief statement.

Identifying objectives that relate well to an HOV project's objectives appeared to be a difficult task. Some HOV evaluation procedures separated objectives into primary and secondary categories (RSMI¹, 1997). However, most HOV evaluations simply stated the objectives and did not attempt to imply their relative importance.

A wide range of objectives have been adopted to become the standard set of HOV evaluation objectives for any specific HOV project. Table 2.1 summarizes all of the objectives identified in the literature review into twelve broad representative categories. Some objectives are similar but have been reported under various names. For example, one study examines the air quality due to the introduction of an HOV lane as the environmental objective (Turnbull et al., 1991). Each of the HOV evaluation studies reviewed in the literature examined the HOV objectives of people moving efficiency, travel time savings, safety and compliance. These four out of twelve objectives could therefore be considered the core group of objectives to be evaluated for any HOV facility.

Table 2-1: HOV Evaluation Objectives Identified in the Literature Review

<i>People Moving Efficiency*</i>	<i>Impact of HOV on GP Lanes**</i>	<i>Public Support</i>
<i>Travel Time Savings*</i>	<i>Impact of HOV on Parallel Routes</i>	<i>Cost-Effectiveness</i>
<i>Safety*</i>	<i>Overall Corridor Efficiency</i>	<i>Transit Efficiency</i>
<i>Compliance*</i>	<i>Air Quality/Environmental</i>	<i>Travel Time Reliability</i>

NOTES: * indicates an objective that was evaluated in each report reviewed
 ** GP = general purpose

2.1.3 Thresholds and Measures of Effectiveness

The literature review indicated that there is no consensus on the level of improvement necessary for an HOV facility to be considered as a successful and effective transportation improvement (Turnbull et al., 1991). This is likely because thresholds and target values are influenced by local and corridor specific conditions such as the level of congestion and delay. In general, few studies in the literature identified improvement thresholds. The thresholds suggested were influenced by the type of HOV facility being evaluated and by the anticipated improvement the HOV facility is expected to have (Turnbull et al., 1991). Where no thresholds were established, terms like "increase" and

“reduce” were used to indicate at least the expected direction the HOV facility should achieve in relation to a certain objective.

HOV evaluation objectives are evaluated by measures of effectiveness (MOEs). The literature review identified some key characteristics of MOEs. For example, MOEs should be meaningful and quantifiable and accurately relate to the HOV project's objectives. MOEs should be realistically quantified within a project's budget and time constraints. Some of the MOEs should evaluate the operational impact of the adjacent general purpose (GP) lanes and parallel routes.

Table 2.2 is a list of the MOEs identified in the literature by several HOV evaluation reports. Because each report's MOEs are particular to its set of objectives, the MOEs were categorized under the twelve broad representative HOV evaluation objectives previously mentioned. For example, the TTI study (Turnbull et al., 1991) examines the average vehicle occupancy (AVO) as an MOE to evaluate its objective of 'People Moving Capacity' while another HOV evaluation study (Pint et al., 1995) examines the AVO to evaluate its objective of 'Increase the Peak Hour Carpool/Vanpool Modal Split'. Therefore, for comparative purposes, similar MOEs for different studies are categorized under the same HOV evaluation objective. For the case of the AVO, the MOE is categorized under the 'People Moving Efficiency' objective.

There are some interesting things to note about Table 2.2. Firstly, it is evident that no two list of MOEs for any HOV project were exactly the same. Secondly, although each HOV procedure reviewed and evaluated the core group of objectives mentioned previously, the same MOEs were not always selected to evaluate them. For example, to

evaluate the 'People Moving Efficiency' objective, one study selected "percent of transit use" (RSMI¹, 1997) as an MOE while another selected "percentage increase in transit ridership" (Pint et al., 1995). These differences further reinforce the absence of a standard practice in evaluating HOV facilities and that each evaluation has been customized to reflect a specific HOV project's objectives.

2.2 OBJECTIVES

The following sections of this chapter discuss in detail each of the twelve HOV evaluation objectives and their related MOEs. Each section summarizes the most common applicable MOEs identified in the literature for each respective HOV evaluation objective.

2.2.1 People Moving Efficiency

The 'People Moving Efficiency' objective reflects the goal that the addition of an HOV lane to a facility should increase the people moving efficiency of a corridor. Alternatively, this objective can be restated as the 'People Moving Capacity' objective (Turnbull et al., 1991) or as the 'Increase Carpool/Vanpool Usage' objective (Pint et al., 1995). The 'People Moving Efficiency' objective best represents the overall goal that an HOV lane should encourage an increase in the number of people that choose to commute in HOVs in general (i.e., carpools, vanpools, buses, etc.). Therefore, it is not surprising to have noted that the 'People Moving Efficiency' objective was stated to be the primary objective of some reports reviewed (RSMI¹, 1997; Turnbull et al., 1991). Increases in the number of carpools or bus riders are usually represented by increases in the MOEs for this objective.

Table 2-2: Summary of Measures of Effectiveness (MOEs)

	HOV Implementation Project, Vancouver (RSM^{2,3}, 1997)	Suggested Procedures for Evaluating the Effectiveness of Freeway HOV facilities (Turnbull et al., 1991)	Shirley Highway HOV Lanes, Northern Virginia (Turnbull et al., 1991)	San Bernardino Freeway Busway, Los Angeles (Turnbull et al., 1991)
People Moving Efficiency*	AVO % transit use	AVO # carpools/vanpools # bus riders	AVO person-trips modal share vehicle & person-miles	persons/peak hour transit ridership
Travel Time Savings*	travel times	travel times	travel times perceived travel times	travel times
Safety*	accident rates traffic conflicts	accident rates # accidents	accident rates # accidents	# accidents
Compliance*	compliance rates enforcement level	violation rates	violation rates	violation rates enforcement level
Impact on GP Lanes	travel times	LOS of GP lanes	-	-
Impact on Parallel Route	-	✓	-	travel times volumes
Overall Corridor Efficiency	-	person-movement per-lane efficiency	person throughput LOS of facility vehicular speeds	-
Air Quality/ Environmental	-	emissions fuel consumption vehicles-miles vehicle-hours	auto emissions gasoline consumption	air pollutant emissions gallons of gasoline
Public Support	public awareness level	perception of utilization & whether good improvement	general perceptions	perception of facility
Cost- Effectiveness	-	B/C ratio	-	value of time savings user cost savings accidents savings
Transit Efficiency	schedule adherence bus travel speeds	vehicle productivity schedule adherence bus travel speeds	schedule adherence	bus travel times
Travel Time Reliability	travel time variance	travel time reliability	-	-
Target Values	yes	yes	no	no

* shading indicates a core objective that was evaluated in each study

✓ indicates mentioned but MOEs not explicitly discussed

Table 2-2: Summary of Measures of Effectiveness (continued)

	<i>I-394 Phase III Evaluation Interim Report, Minnesota (SRF, 1993) (Pint et al., 1995)</i>	<i>HOV Evaluation and Monitoring Phase III, Seattle (Brown and Jacobson, 1996)</i>	<i>An Evaluation of High-Occupancy Vehicle Lanes in Texas, 1994 (Henk et al., 1995) (Turnbull et al., 1991)</i>	<i>Toronto Arterial HOV Lanes: Effectiveness, Operational Safety, and Enforcement (Bacque & Bahar, 1996)</i>
People Moving Efficiency*	auto occupancy rates # carpools/vanpools transit ridership person-trips modal split	ACO bus ridership	AVO # carpools/vanpools bus ridership	AVO modal shift
Travel Time Savings*	travel times peak hour speed	travel times	travel times perceived travel times	travel times
Safety*	accident rates	perception of safety accident rates accident patterns	accident rates	# accidents accident frequencies
Compliance*	compliance rates	violation rates violation outcomes perception of compliance	violation rates	violation rates
Impact on GP Lanes	travel times peak hour speed	-	travel speeds	-
Impact on Parallel Route	-	-	AVO carpool volumes % carpools diverted	-
Overall Corridor Efficiency	LOS queue lengths	-	person-movement per-lane vehicle volume per-lane efficiency	person-movement
Air Quality/ Environmental	-	-	fuel consumption kg of emissions	vehicular stops/starts air quality records
Public Support	level of satisfaction	support for HOV lanes	perception of whether good improvement	support for HOV lanes
Cost- Effectiveness	✓	-	B/C ratio	-
Transit Efficiency	bus travel times bus travel speeds	-	bus travel speeds schedule adherence	bus travel times perceived travel times
Travel Time Reliability	speed variability	90 th percentile speed	speed variability	travel time variation
Target Values	yes	no	yes	no

* shading indicates a core objective that was evaluated in each study

✓ indicates mentioned but MOEs not explicitly discussed

The evaluation of the effectiveness of this HOV evaluation objective is affected by the proportion of existing HOVs on the facility. To attain the 'People Moving Efficiency' objective, a significant amount of new carpools may need to be created. It was identified in the literature that is difficult to measure the amount of new carpools to a facility. Oftentimes, the carpools perceived as new are actually existing carpools diverted from parallel routes taking advantage of the travel time savings being provided for HOVs on the facility (see 'Impact of HOV on Parallel Routes' objective for further discussion).

The MOEs used to evaluate the 'People Moving Efficiency' objective are listed in Table 2.3. The AVO was selected as an MOE for each freeway HOV evaluation procedure reviewed. In addition, most studies examined the actual or percentage increase in the number of carpools/vanpools or bus ridership as supplementary 'People Moving Efficiency' MOEs. Other commonly used MOEs includes modal share, modal split, or modal shift.

Table 2-3: 'People Moving Efficiency' Objective MOEs

Most Common MOEs	Similar MOEs
average vehicle occupancy bus/transit ridership modal split person-trips percent transit use number of carpools/vanpools vehicle & person-miles	auto occupancy rates number of bus riders modal share, modal shift persons/peak hour

2.2.2 Travel Time Savings

The 'Travel Time Savings' objective addresses the main incentive for commuters to switch to a higher occupancy mode. The HOV lane should be providing a relative travel time savings advantage to the occupants of HOVs. Fuhs (1993) indicates that the HOV

lane's ability to provide such a travel time savings as being one of its most reliable predictors of effectiveness. Fuhs (1993) also indicated that commuters who benefit the most from the travel time savings (i.e., long distance commuters) would most likely be encouraged to switch to a higher occupancy mode.

A threshold of at least 1 minute per mile is commonly accepted to be the minimum travel time savings necessary for a freeway HOV lane to be effective (see for example: Brown and Jacobson, 1996; RSMI¹, 1997; Turnbull et al., 1991; Henk et al., 1995). This threshold is based on the "*Freeway High-Occupancy Vehicle Lanes and Ramp Metering Evaluation Study*" (D. Baugh and Associates, 1979)* and no supportive explanations for this threshold was presented in the literature.

The 'Travel Time Savings' objective was generally evaluated with either the travel times or travel speeds MOEs. A couple of studies identified the perceived travel time of commuters as an additional MOE. Table 2.4 is a list of the travel time savings MOEs.

Table 2-4: 'Travel Time Savings' Objective MOEs

Most Common MOEs	Similar MOEs
travel times perceived travel times	travel speeds

* NOTE: as reported by Henk et al. (1995)

2.2.3 Safety

The 'Safety' objective assesses whether adding an HOV lane to a facility is a safe transportation improvement. The TTI studies (Turnbull^{1,2}, 1992) suggest that the implementation of an HOV lane should not decrease the level of safety of a facility nor should the accident rate on the HOV lane be greater than that of the GP lanes.

However, it is often the case that current accident reporting practice does not include referencing the accident to either the HOV or GP lane specifically (see for example: SRF, 1993; RSMI³, 1997).

An example of a comprehensive evaluation of the safety conditions associated with HOV lanes was performed by the Institute of Transportation Studies at the University of California (Golob and Recker, 1988). Two freeway HOV lane's safety impacts in the greater Los Angeles area were evaluated. It was concluded in the paper that there was *"no adverse effect on safety conditions"* due to HOV operation on one of these HOV facilities. A slight increase in the number of accidents was observed on the second HOV facility. However, it was concluded that the increase was *"no greater than 2 percent over and above the level that would be expected from mixed-flow operation of the lane"*.

The accident patterns and locations of the Los Angeles HOV facilities were also summarized in the University of California paper (Golob and Recker, 1988). The exposure to accidents migrated downstream to the traffic bottlenecks of both HOV facilities. The particular bottlenecks described were categorized as *"severe"* and it was mentioned that in other jurisdictions where *"the downstream bottlenecks are less severe, overall safety improvements can be expected"*.

Often, information on the total number, severity, and type of accidents was not available for a "before-and-after" comparison. One study recommended that a minimum of 3 years of "before" data be collected to perform a statistically meaningful "before-and-after" analysis (RSMI², 1997). Other studies also suggested that the safety of a representative group be monitored to determine the "after" changes in accident rates

that are common to the region (see for example: Turnbull et al., 1991; Sayed¹, 1996). A control facility is presently being monitored as part of the on-going evaluation of the safety conditions of the Houston HOV project (Turnbull et al., 1991).

Traffic conflicts at the merging points of HOV and GP traffic and at the terminus points of HOV facilities were occasionally observed (Turnbull², 1992). A direct assessment of the traffic conflicts at intersections and/or terminal points is useful when evaluating the safety of HOV facilities to complement insufficient or inconclusive accident data (RSMI², 1997).

Table 2.5 is a complete list of MOEs used to evaluate the 'Safety' objective. The primary MOEs are accident rates and the number of accidents. Other safety MOEs include accident frequencies, patterns and locations as well as vehicle breakdown rates (Henk et al., 1995). One HOV evaluation reviewed in the literature included an MOE based on the public's opinion of the safety of the HOV lane (Brown and Jacobson, 1996).

Table 2-5: 'Safety' Objective MOEs

Most Common MOEs	Similar MOEs
accident rates number of accidents accident locations traffic conflicts perception of safety	accident frequencies accident patterns

2.2.4 Compliance

The 'Compliance' objective protects the HOV operation by evaluating if violators of the HOV lane are being sufficiently discouraged by the level of enforcement. It is important

to remain within an accepted range of compliance to protect the travel time savings and reliability benefits for HOV commuters.

The violation rate of an HOV lane is calculated by dividing the total number of violators of the occupancy requirement by the total number of cars in the HOV lane, expressed as a percentage. Similarly, the compliance rate is the percentage of vehicles in the HOV lane who meet the occupancy requirement and is equal to 100% minus the violation rate. The violation or compliance rates are determined from either vehicle classification and occupancy surveys or from the violation data of local enforcement agencies. Different desired thresholds for compliance were observed in the literature. A compliance rate between 85% and 90% was most frequently stated as acceptable for freeway HOV operations.

The compliance rate observed is dependent on numerous factors. The number of officers dedicated to enforcing the HOV occupancy requirement and the availability of adequate locations for enforcement are most likely the two most important. Supporting programs such as the institution of a region-wide HERO program (Brown and Jacobson, 1996), adequate penalties (Ulberg and Jacobson, 1993), and proper geometric design of the HOV lane (Turnbull², 1992) were all identified to be secondary but still very important factors.

A study from Washington State Transportation Center (TRAC) examined in detail HOV enforcement and the objective of compliance (Ulberg and Jacobson, 1993). It was concluded that each of the three types of enforcement techniques implemented on their regional HOV network had a positive effect on the compliance rate and none was

considered to be more effective than the others. The three types of enforcement techniques included: intensive enforcement, once a week saturation enforcement, and once a week stationary enforcement. The Washington State TRAC study also complimented its violation rate data with a public opinion survey. Amongst other questions, respondents were asked if they support the concept of HOV lanes as well as admit if they had ever violated the HOV occupancy requirement.

Enforcement fines and strategies were often discussed in the literature. In California, an increase in the HOV violation fine to \$271 (US\$) for the first offence and public awareness concerning the magnitude of the fine decreased its violation rate by about 65% (Fuhs, 1993). Other proposed enforcement strategies were to penalize second and third time HOV violators greater than first time offenders and to ticket by mail to maximize the allocated resource time of local enforcement agencies (Ulberg and Jacobson, 1993). The Washington State Department of Transportation is currently researching the outcomes of its HOV violations as a compliance follow-up strategy (Brown and Jacobson, 1996).

It is strongly recommended that the level of enforcement (the enforcement details: # of officers, shifts and hours) be kept in records and correlated to either the compliance rate on the corridor or the number of citations being issued (RSMI³, 1997). It is perhaps the most effective way of evaluating the performance of enforcement versus compliance but has yet to be fully researched and documented.

The violation rates and compliance rates are the MOEs most frequently used to evaluate the 'Compliance' objective. Table 2.6 summarizes the 'Compliance' objective MOEs.

Table 2-6: 'Compliance' Objective MOEs

Most Common MOEs	Similar MOEs
violation rate perception of compliance outcomes of HOV violation tickets	compliance rate

2.2.5 Impact of HOV on GP Lanes

The 'Impact of HOV on GP Lanes' objective examines the operational impact of adding an HOV lane on its adjacent general purpose (GP) lanes. The addition of an HOV lane to an existing facility should not adversely affect the operation of the GP lanes. In other words, the operating speed and level of service (LOS) being provided on the GP lanes should not be degraded due to the addition of the HOV lane (Turnbull et al., 1991). The 'Impact of HOV on GP Lanes' objective was rarely quantified in the review of HOV evaluations. When evaluated, travel times or speeds of the GP lanes were often compared to on a "before-and-after" basis as an MOE. However, the comparison was often made as part of the evaluation of the 'Travel Time Savings' objective as opposed to a separate 'Impact of HOV on GP Lanes' objective. A comparison of the "before-and-after" LOS on the GP lanes was another MOE identified in the literature (Turnbull et al., 1991). Table 2.7 summarizes the 'Impact of HOV on GP Lanes' objective MOEs.

Table 2-7: 'Impact of HOV on GP Lanes' Objective MOEs

Most Common MOEs	Similar MOEs
travel times LOS of GP lanes	travel speeds

2.2.6 Impact of HOV on Parallel Routes

The 'Impact of HOV on Parallel Routes' objective addresses the operational impact of adding an HOV lane on its alternative parallel routes. The most significant impact the

HOV corridor may have on its parallel routes is its tendency to attract and divert HOVs onto the HOV lane to benefit from the travel time savings being provided. It is assumed that some HOVs from parallel routes will change their commuting patterns to make use of an adjacent HOV facility.

The 'Impact of HOV on Parallel Routes' objective is related to the 'People Moving Efficiency' objective. An increase in a facility's people moving efficiency is proportional to the increase in a facility's number of carpools. The increase in the number of carpools may be doubly counting benefits as existing HOVs are diverted from alternative parallel routes. To understand the net increase in the number of carpools, diverted HOVs should be taken out of the estimate of the benefits.

Information necessary to evaluate this objective is the "before-and-after" percentage of HOVs on the parallel routes. The percentage difference can be used to approximate the number of vehicles diverted from parallel routes. However, it should be made clear that the suggested amount of diversion is difficult to measure. It is only possible to determine a more accurate number with an extensive survey and data collection effort. Network efforts are most difficult to assess because they are affected by many other factors. Few HOV evaluation studies discussed the 'Impact of HOV on Parallel Routes' objective. However, Henk et al. (1995) presented results of a survey that estimated the percentage of carpoolers who were diverted from a parallel route as well as the AVO of the parallel routes. The MOEs identified from the literature for the 'Impact of HOV on Parallel Routes' objective are summarized in Table 2.8.

Table 2-8: 'Impact of HOV on Parallel Routes' Objective MOEs

Most Common MOEs	Similar MOEs
percent of mainline carpoolers diverted AVO of parallel routes travel times of parallel routes	carpool volume counts

2.2.7 Overall Corridor Efficiency

The 'Overall Corridor Efficiency' objective focuses on the operational impact of adding on HOV lane on the entire HOV facility, GP lanes included. The person-movement MOE is typically used as an MOE for this objective. It is suggested that the percentage increase in the total (GP plus HOV) person volume should be greater than the percentage increase in the amount of directional lanes added to a facility (Henk et al., 1995). The "before-and-after" level of service (LOS) of the entire HOV facility was also presented frequently as an MOE to evaluate the 'Overall Corridor Efficiency' objective.

Another approach for evaluating this objective is suggested by the TTI studies. A per-lane efficiency MOE that is equal to the total person volume of the facility multiplied by the average vehicle operating speed is suggested (Turnbull et al., 1991). It is expected that the per-lane efficiency of a facility should increase with the implementation of an HOV lane. Other MOEs mentioned in the literature were person throughput (Turnbull et al., 1991) and queue lengths (SRF, 1993). The person throughput MOE was expressed in person-miles of travel per hour and the queue lengths were expressed in number of vehicles. Table 2.9 summarizes the MOEs for the 'Overall Corridor Efficiency' objective.

Table 2-9: 'Overall Corridor Efficiency' Objective MOEs

Most Common MOEs	Similar MOEs
person movement LOS of facility per-lane efficiency queue lengths	person throughput operating speeds per-lane vehicle volume

2.2.8 Air Quality/Environmental

The 'Air Quality/Environmental' objective reflects the attitude that adding an HOV lane should have more favourable impacts on the environment than the "do nothing" or "add a GP lane" alternatives (Turnbull et al., 1991). Few detailed analyses were performed regarding this objective.

Neither a decrease in vehicular volumes nor reduction in emissions is expected with the implementation of an HOV lane. Therefore, simplistic computer models were sometimes used to estimate and compare the environmental impacts of three alternatives: do nothing, add a GP lane, and add an HOV lane (Henk et al., 1995). The modelling was performed by keeping the demand constant and adjusting the AVO appropriately for all three alternatives. The 'Air Quality/Environmental' objective was evaluated by comparing the differences in the environmental impact outputs of the computer simulation. These outputs (kg of emissions, fuel consumption) are the most frequently used MOEs.

One particular study examined vehicular starts and stops and air quality records as alternative MOEs (Bacque and Bahar, 1996). The complete list of 'Air Quality/Environmental' objective MOEs is summarized in Table 2.10.

Table 2-10: 'Air Quality/Environmental' Objective MOEs

Most Common MOEs	Similar MOEs
fuel consumption kg of emissions vehicle-miles vehicular starts/stops air quality records	gasoline consumption auto emissions vehicle-hours

2.2.9 Public Support

The 'Public Support' objective recognizes that public support of the concept and operation of HOV lanes is important and should therefore be evaluated. The TTI studies indicated that the majority of the public should perceive HOV lanes as being adequately utilized and as a good transportation improvement (Turnbull¹, 1992).

Telephone or mail out surveys are most frequently used to evaluate the public support of HOV facilities. They are generally conducted to measure the overall attitudes and level of satisfaction of all commuters: carpoolers, bus riders, and those who drive alone (see for example: SRF, 1993; Brown and Jacobson, 1996). The preferred method of a public opinion survey is a mail out survey that is sent to actual users of an HOV facility whose license plates are observed and addresses retrieved.

The percentage of people surveyed who support the concept and/or operation of the HOV lanes are the most frequently observed MOEs for this objective. The public awareness level of the HOV lane was also suggested as a similar MOE (RSMI², 1997). The 'Public Support' MOEs are summarized in Table 2.11.

The violation rate is often used to complement public opinion survey MOEs. High violation rates suggest that users of the HOV facility do not support or respect the concept and/or operation of the HOV lane. However, as discussed earlier, violation rates are influenced by more than just public support. All phone calls, letters, and press releases concerning the operation of the HOV facility were sometimes monitored and reviewed as alternative MOEs for this objective (Turnbull², 1992).

Table 2-11: 'Public Support' Objective MOEs

Most Common MOEs	Similar MOEs
support for HOV lanes public awareness level violation rates phone calls	perception of HOV lane as a good improvement perception of HOV lane utilization compliance rates letters, press releases

2.2.10 Transit Efficiency

The 'Transit Efficiency' objective evaluates any improved performance of the transit system in general. Most reports reviewed examined either the schedule adherence or the travel times of buses as MOEs for this objective. However, HOV projects did not often evaluate the 'Transit Efficiency' objective as its own separate category. Transit system impacts were usually examined as part of the general 'People Moving Efficiency' objective.

The data needed to evaluate the 'Transit Efficiency' MOEs is dependent on a significant amount of co-operation with the in-place transit system agency. Therefore, it is often not possible to quantify the transit MOEs without the help of a transit agency's resources which is the main reason why the objective is not exclusively evaluated.

The complete list of MOEs used to evaluate the 'Transit Efficiency' objective are listed in Table 2.12. One particular study evaluated the actual as well as the perceived bus travel times as MOEs for this objective (Bacque and Bahar, 1996). The TTI study was the only report reviewed that suggested evaluating the vehicle productivity (operating cost per vehicle-mile, passenger, and passenger-mile) as an MOE in addition to schedule adherence or bus travel speeds (Turnbull et al., 1991).

Table 2-12: 'Transit Efficiency' Objective MOEs

Most Common MOEs	Similar MOEs
schedule adherence bus travel speeds perceived bus travel times vehicle productivity	on-time performance bus travel times

2.2.11 Travel Time Reliability

The 'Travel Time Reliability' objective examines the variability of the travel times or speeds of the HOV lane in comparison to its adjacent GP lane(s). It was often mentioned as an objective in the literature yet was rarely quantified (Turner et al., 1994). To measure the travel time variability of both the HOV and GP lanes, continual sampling over an extended period of time is required.

The MOEs used most frequently to evaluate the 'Travel Time Reliability' objective are the variance or standard deviations of either the travel times or travel speeds. However, a paper written specifically on travel time reliability stated that travel speeds provide better estimates of travel time reliability because speed distributions are less skewed (more normal) than travel time distributions (Turner et al., 1994). The paper also presented the use of statistical tests to analyze the differences in the HOV and GP travel speed results. Table 2.13 summarizes the 'Travel Time Reliability' MOEs.

MOEs used to evaluate the travel time reliability particular to Washington State are the speed range observed and the 90th percentile speed (Brown and Jacobson, 1996). These MOEs are used to evaluate the Washington State Freeway HOV System Policy that *"HOV lane vehicles should maintain or exceed an average speed of 45 mph or*

greater at least 90% of the times they use that lane during the peak hour (measure for a six-month period)" (Brown and Jacobson, 1996).

Table 2-13: 'Travel Time Reliability' Objective MOEs

Most Common MOEs	Similar MOEs
travel time variance travel speed standard deviations 90 th percentile speed	travel speed variance speed range observed

2.2.12 Cost-Effectiveness

The 'Cost-Effectiveness' objective examines if the implementation of an HOV lane is a transportation improvement whose benefits outweigh its costs. To determine an HOV project's cost-effectiveness, a benefit/cost analysis is usually performed. The cost-effectiveness MOE most frequently quantified is the benefit/cost ratio. However, the marginal benefit/cost ratio and marginal net present value (NPV) are two other MOEs that have been used to evaluate the cost-effectiveness of an HOV project (Ulberg and Jacobson, 1988). The 'Cost-Effectiveness' MOEs are summarized in Table 2.14.

To calculate the benefit/cost ratio, many assumptions are made regarding an appropriate discount rate, salvage value of the project, and the dollar value of travel time savings. Each component of the ratio, whether benefit or cost, is either annualized or converted to a net present value. The benefits such as the travel time saved are related to the users of the HOV facility. The costs are related to the transportation agencies responsible for the operation of the HOV lane. The costs typically include the following: construction costs (including right-of-way), maintenance costs, operation costs, and enforcement costs.

It is recommended in the literature that only the travel time savings benefits of the users of the HOV the facility be quantified in the benefit/cost ratio (see for example: Henk et al., 1991; Turnbull², 1992). By not including other benefits such as congestion savings, vehicle operating cost savings, and improved trip reliability, a more conservative benefit-cost ratio is produced. One particular paper compared the cost-effectiveness of existing HOV lanes in Seattle with the "do nothing" and "add a GP lane" alternatives (Ulberg and Jacobson, 1988). A sensitivity analysis that included worst case, best case, and base values for the benefits and costs was performed for each alternative.

In another HOV evaluation paper, the minimum mode shift or amount of travel time savings required for the HOV lane to be cost-effective was quantified (Henk et al., 1991). It was presented that a minimum travel time savings of 0.8 minutes per mile is required for a Houston HOV lane to be cost-effective. Alternatively, the paper suggested that a HOV lane's annual total value of travel time savings be equal to or greater than 10 percent of its total construction costs to be cost-effective.

Table 2-14: 'Cost-Effectiveness' Objective MOEs

Most Common MOEs	Similar MOEs
benefit/cost ratio	marginal benefit/cost ratio
net present value	marginal net present value

2.3 DATA COLLECTION

2.3.1 Data Collection Techniques

After objectives and appropriate MOEs are established as part of an HOV evaluation and monitoring program, the information needs are identified. The frequency of conducting data collection is dependent on the available resources, the type of HOV

facility being evaluated (arterial vs. freeway), and the maturity of the system (newer facilities require higher frequency) (Turnbull et al., 1991). Data is often collected for the purpose of HOV evaluation as part of other data collection efforts to maximize the available resources (Turnbull et al., 1991). The variety of potential data collection surveys is summarized in Table 2.15.

Table 2-15: Summary Of Data Collection Surveys

travel time runs enforcement level violations	classification & occupancy surveys transit information/scheduling volume counts	public opinion survey accident records traffic conflict survey
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Many surveys are conducted on both the HOV mainline as well as its parallel routes. The tendency to collect excessive data is balanced against obtaining too little data for any statistically meaningful results. Therefore, sample sizes are selected on a project specific basis to ensure that representative conclusions on the effectiveness of the HOV lane are made from the data collection surveys. Some of the more common types of data collection surveys are: travel time runs, vehicle classification and occupancy counts, and public opinion surveys.

2.3.2 Travel Time Runs

Two alternative methods are used to collect data for travel time runs: the 'average' (or 'floating') car technique and the license plate method (Turnbull et al., 1991). The results of the travel time runs are dependent on the individual driver's style (Brown and Jacobson, 1996). The 'average' car technique is used to help identify problem areas such as bottlenecks or excessively long delays at intersections along a corridor. However, a limited number of travel time runs are performed such that each run is considered to be statistically independent of one another. A minimum interval spacing of

15 minutes between trips is recommended (Turnbull et al., 1991). The license plate method is capable of producing a more accurate representation of the total trip time over a range of volume conditions but is much more costly (Brown and Jacobson, 1996). The license plate method to collect travel time runs has been used in Seattle. However, they have but recently switched to the 'average' car technique (Brown and Jacobson, 1996). To assist in collecting the large sample size of travel time runs required for the 'travel time reliability' objective, regular commuters or transit agencies were suggested as possible sources to perform travel time runs (RSMI³, 1997).

2.3.3 Vehicle Classification and Occupancy Counts

To determine the number of manual occupancy counts an agency needs to collect on a specific corridor, the regional variance in occupancy rates should be determined (Turnbull et al., 1991). Occupancy counts should be collected on the HOV mainline as well as on parallel routes if the data collection budget permits.

The number of riders on a bus or in a vanpool are only coarsely estimated during vehicle classification and occupancy surveys. Because of the higher degree of uncertainty associated with these estimates, buses and vanpools exhibit a higher variance in their AVOs than regular automobiles (Turnbull et al., 1991). Therefore, TTI strongly recommends using a stratified random sampling technique as opposed to a simple random sampling technique (Turnbull et al., 1991). With stratified random sampling, the number of bus and vanpool occupancy counts is maximized and a more significant estimate of the AVOs is achieved.

2.3.4 Public Opinion Surveys

Many types of public opinion surveys for the purpose of HOV evaluation were reviewed in the literature (see for example: Turnbull et al., 1991; Brown and Jacobson, 1996; and SRF, 1993). Each of the surveys reviewed a included a section for comments at the end of the survey. Some of the questions asked of the respondents that were common to all of the surveys are highlighted below:

- ◆ What is your usual present mode of travel ?
- ◆ How often do you make this commute ?
- ◆ How many people (and/or family members) do you regularly commute with ?
- ◆ Prior to the HOV lane, what was your usual mode of travel ?
- ◆ Why do you choose to carpool (or not to) ?
- ◆ What is your home zip code (or city) ?
- ◆ What is the destination of your trip ?
- ◆ Do you feel that the HOV lane is adequately utilized ?
- ◆ What is your age and gender ?
- ◆ What is the highest level of education you have completed ?

3. H.O.V. MONITORING AND EVALUATION FRAMEWORK

3.1 INTRODUCTION

As previously mentioned in Chapter One, a region-wide high occupancy vehicle (HOV) network is being implemented in the South Coast Region of British Columbia. An important step in the implementation of a regional HOV network is to evaluate the effectiveness of its existing HOV facilities. Accordingly, an HOV framework was developed for the monitoring and evaluation of British Columbia's HOV facilities. The framework is based on the HOV evaluation experience of other North American jurisdictions.

The HOV monitoring and evaluation framework is comprised of three sections: an evaluation framework, a monitoring framework, and a multi-criteria evaluation. The first two sections are described in this chapter. The multi-criteria evaluation is presented in Chapter Five of this thesis.

3.2 THE H.O.V. EVALUATION FRAMEWORK

The evaluation framework described herein is based on existing HOV evaluation practices. It was developed specifically for application in the Greater Vancouver area of British Columbia. It is also applicable to HOV projects in other jurisdictions. This section of the chapter is the framework procedure to evaluate an HOV corridor based on a set of quantifiable objectives. The general evaluation methodology of the framework is summarized in Table 3.1.

Firstly, a description of the objective being evaluated and its relation to goals of implementing an HOV corridor is presented. Secondly, the measures of effectiveness (MOEs) that were selected to assist in determining the attainment of the objective are described. The data requirements to evaluate each objective are listed as well as a data collection methodology. The data is analyzed according to the type of HOV facility (arterial vs. freeway). Data collected on the mainline as well as routes parallel to an HOV facility are examined. The statistical reliability of the data is investigated and the differences between two MOEs are tested for statistical significance. Finally, a discussion of the results is introduced.

Table 3-1: Evaluation Framework Methodology

OBJECTIVE
Measures of Effectiveness
Data Requirements
Data Collection Methodology
Data Analysis
Arterial vs. Freeway Analysis
Parallel Routes Analysis
Statistical Reliability
Statistical Significance
Discussion of Results

3.2.1 Objectives

The set of objectives selected for the HOV evaluation framework are its foundation. The objectives of the framework were selected to strongly reflect the HOV network goals. Table 3.2 lists the set of objectives selected for the HOV monitoring and evaluation framework. The objectives have been categorized as either primary, supporting, or operational objectives based on their relationship to the HOV network goals.

Table 3-2: Evaluation Framework Objectives

PRIMARY OBJECTIVE	SUPPORTING OBJECTIVES	OPERATIONAL OBJECTIVES
Person Throughput	Travel Time Savings Travel Time Reliability Public Support	Compliance Safety Impact on GP Lanes

The 'Person Throughput' objective is directly related to the HOV network goals of improving the person throughput and encouraging higher occupancy. Therefore, the 'Person Throughput' objective is the primary objective of the evaluation framework.

Some characteristics of an HOV facility contribute to the attainment of the HOV network goals. For example, a travel time savings benefit for HOVs encourages people to shift modes to an HOV. As a result, it is anticipated that the person throughput would increase as well as the HOV share of the commuting traffic. Therefore, a noticeable travel time savings benefit helps to support the attainment of the HOV network goals. The evaluation framework measures the effectiveness of these characteristics as supporting objectives. They include 'Travel Time Savings', 'Travel Time Reliability', and 'Public Support'.

Other characteristics of a newly constructed HOV facility may not contribute to the success of the HOV project goals, however, they may inherently protect them. For example, a low violation rate will most likely not have an effect on the primary objective of person throughput. However, a high number of violators in the HOV lane could potentially negatively affect the travel time savings and reliability benefits for HOVs. Therefore, operational objectives such as 'Compliance' are also assessed as part of the

evaluation framework. Other examples of operational objectives include 'Safety', and 'Impact on GP Lanes'.

The evaluation framework set seven objectives is very similar to the twelve broad categories described in the literature review. However, the HOV evaluation framework excludes the following three objectives: 'Transit Efficiency', 'Impact of HOV on Parallel Routes', and 'Air Quality'. The 'Cost-Effectiveness' objective is described in the HOV monitoring and evaluation framework as part of the multi-criteria evaluation and neither a primary, supporting, nor operational objective.

The 'Transit Efficiency' objective was determined to be redundant and unnecessary to evaluate as a separate objective. The objective's MOEs directly relate to the productivity and efficiency of the transit fleet service. The operation of the transit fleet in the Greater Vancouver area is under the direction of BC Transit. Nevertheless, the number of transit passengers and bus operating speeds are still significant variables that should be examined when evaluating an HOV lane's effectiveness. Therefore, these variables are taken into account when evaluating the preferred set of seven objectives.

Similar to the 'Transit Efficiency' objective, it was determined to be nonessential to evaluate air quality as part of the HOV evaluation framework. The effect the construction of an HOV facility will have on the region's air quality is an important environmental aspect. However, improving air quality is neither a primary nor supporting objective for building an HOV lane. It may also be difficult to quantify the air quality of a corridor. Nevertheless, it is anticipated that the addition of an HOV lane to a facility would be less obtrusive on air quality than other alternatives.

Regarding the 'Impact of HOV on Parallel Routes', the literature review recommended that such an operational impact be evaluated as a separate objective. It is a very important aspect that must be accounted as part of the HOV evaluation. In the framework, the impact an HOV lane will have on its adjacent routes is evaluated as part of each of the preferred set of objectives, if relevant. Therefore, it was not required to evaluate the impact on parallel routes as a separate objective.

3.2.2 Measures of Effectiveness

Each of the framework's primary, supporting, and operational objectives are evaluated by mean of measures of effectiveness (MOEs). These MOEs are selected such that they directly relate to the preferred set of objectives. An MOE selected for the evaluation of an objective is used to determine the effectiveness of that objective. Therefore, MOEs are usually quantifiable numerical units representative of the effectiveness of the respective objective being evaluated. An MOE's absolute value, magnitude, and trend over time are used to help determine and interpret the effectiveness of an HOV lane.

For example, the average vehicle occupancy (AVO) is an MOE used to determine if the 'Person Throughput' objective has been met. AVO is calculated by dividing the total number of passenger occupants by the total number of passenger cars. Significant increases in the AVO are indicative that an HOV facility has been effective in increasing the average number of occupants per car along the corridor. This type of trend in the AVO indicates that people are shifting to a higher occupancy mode since the introduction of the HOV lane, buses excluded. If people are shifting to HOVs along a

corridor, the person throughput will most likely improve. Therefore, AVO is a quantifiable and representative MOE for the 'Person Throughput' objective.

The specific MOEs for each of the framework's seven objectives are summarized in Table 3.3. The detailed description of the MOEs are found in Chapter Four of this report.

Table 3-3: Objectives and Their MOEs

CATEGORY	OBJECTIVE	MOE
Primary	Person Throughput	Per-Lane Efficiency AVO HOV Market Share
Supporting	Travel Time Savings	Travel Time Difference
	Travel Time Reliability	Travel Speed Standard Deviation
	Public Support	Support for HOV Lane
Operational	Compliance	Compliance Rate
	Safety	Accident Rate
	Impact on GP Lanes	GP Travel Speed

3.2.3 Data Requirements

The MOEs of the objectives are calculated from data collected on the HOV facility. Therefore, the next step of the HOV evaluation framework is to determine the type of data that is required to evaluate the effectiveness of the objectives. The data requirements are often the same for more than one of the objectives. For example, vehicle classification and occupancy data is required for evaluating both the 'Person Throughput' and 'Compliance' objectives. The data requirements of the HOV evaluation framework are outlined below. They are explained in detail in Chapter Four of this report.

- ◆ vehicle classification & occupancy counts
- ◆ travel time surveys

- ◆ public opinion survey
- ◆ accident statistics
- ◆ traffic volumes

3.2.4 Data Collection Methodology

Based on the data requirements of the objectives, a data collection methodology is established. Collecting data with the purpose of evaluating an HOV facility is similar to collecting data for the evaluation of any other “before-and-after” transportation improvement. It is necessary to ascertain that there is an adequate amount of data collected such that statistically reliable conclusions can be made from the results. Information that is uniquely characteristic to the data collection methodology of evaluating an HOV facility is emphasized in the framework.

3.2.5 Data Analysis

Before evaluating the effectiveness of the HOV facility, the data should be converted into a presentable format that is studied in finer detail so that conclusions can be made. The first step of the data analysis is to calculate the MOEs based on the samples of data collected. An MOE is calculated for each sample of data. The average of these values is presented as the mean MOE of the HOV facility. However, this mean MOE (based on samples) is only an estimate of the true population mean. In previous HOV evaluations, these MOE sample mean estimates were presented as absolute values with no uncertainty associated with them. In other words, it was assumed that the mean MOE estimate (calculated from only a sample of data) was in fact the mean of the population.

However, the mean MOE estimate is not always representative of the true population mean. Therefore, it is insightful to understand how close the mean MOE estimate is to the actual population mean. For this purpose, confidence limits of a MOE are calculated, where applicable. A confidence limit is the interval that has a specific probability of capturing the true population mean. Generally, the probability of capturing the true mean is selected as close to unity as possible. Therefore, a 95% level of confidence was selected for constructing confidence limits for HOV evaluation purposes. In other words, an evaluator is confident that a calculated MOE will be somewhere in between the upper and lower bounds of the confidence limits 19 out of 20 times. The methodology for calculating a confidence limit is found in Appendix A - Statistical Analysis.

The upper and lower bounds of an MOE's confidence limits are also important as input into the multi-criteria section of the HOV evaluation framework. The net present value (NPV) of an HOV facility is firstly determined with the mean MOE estimates to produce the most likely value. The NPV is then recalculated for the both the upper and lower bounds of the MOEs as part of a sensitivity analysis to produce the worst and best case scenario values.

The second step of the data analysis is to present the MOEs of the framework in an appropriate format. The presentation of the MOEs as either actual numbers in contrast to percent increases or in tables as opposed to graphs is important, depending upon the audience the report is addressing. The most suitable presentation format of the MOEs is outlined in the data analysis section.

3.2.6 Arterial vs. Freeway Analysis

The HOV evaluation framework is a flexible procedure that can be applied to evaluate the effectiveness of either an arterial or freeway HOV facility. Realistically, however, it is sometimes preferred to slightly modify or tailor the application of the evaluation framework to the specific type of HOV facility being evaluated. For example, the HOV facility on the Barnet/Hastings corridor is comprised of three very characteristic sections. After applying the HOV evaluation framework to the corridor, it was determined that each section be examined on its own for many of the objectives. The initial application of the HOV evaluation framework to the Barnet/Hastings corridor was tailored to gain a better insight on the effectiveness of its HOV lane.

However, there are some general characteristics of an arterial HOV facility that are unlike that of a freeway HOV facility. Where applicable, any concerns and lessons learned between the application of the HOV evaluation framework to arterial and freeway HOV facilities is highlighted.

3.2.7 Parallel Routes Analysis

As mentioned in the discussion of the HOV evaluation framework's objectives, the operational impact the addition of an HOV lane has on its parallel routes is a very important aspect that should be accounted for. However, it is not recommended that all of the MOEs be calculated for the parallel routes. There is a trade-off between the cost of collecting data on adjacent routes and the need for such data to gain further insight into the effectiveness of an HOV facility. Therefore, it is important to spend time

deciding which, if any, of the MOEs need to be quantified for the parallel routes as well as the HOV facility.

3.2.8 Statistical Reliability

The data collected are samples of an entire population. The statistical reliability of these samples should be investigated as part of the HOV evaluation framework. The adequacy of data collected is determined based on its sample size, mean, and variance. For the travel time runs, the statistical reliability of a sample of data is tested at the specified permitted error for “before-and-after” studies as recommended in the *‘ITE Transportation and Traffic Engineering Handbook’* (ITE, 1992). For AVO data, the margin of error associated with the samples of vehicle classification and occupancy counts is derived. The AVO margins of error are presented as percentages of the mean.

3.2.9 Statistical Significance

A methodology for evaluating the statistical significance of an MOE is described within the HOV evaluation framework. The statistical significance of an MOE is tested to determine if the difference between two values can be explained by random chance. The type of statistical test used is dependent on the method the data was collected and analysed. The results are tested at the 95th percentile. Examples of the framework’s suggested statistical tests are found in Appendix A - Statistical Analysis.

3.2.10 Discussion of Results

A discussion should be conducted on the results of the MOEs of the objectives. Particular emphasis should be placed in the comparison of the peak hour and peak

period results. Likewise, the results of the HOV mainline and its parallel routes should be compared. Any trends over time should be discussed if the evaluation conducted is part of the ongoing HOV monitoring and evaluation program.

3.3 THE H.O.V. MONITORING FRAMEWORK

The HOV evaluation framework is a procedure to assess the effectiveness of an HOV lane. The evaluation of an HOV facility is performed at particular times throughout the lifetime of an HOV project. The frequency of such evaluations is determined as part of an on-going HOV monitoring and evaluation program. The HOV monitoring framework is a guideline that discusses how often and when the effectiveness of an HOV facility should be determined.

Firstly, prior to the construction of an HOV facility, it is recommended to establish the baseline conditions of a corridor as part of an anticipated HOV monitoring program. Statistically reliable baseline data is necessary to perform meaningful “before-and-after” HOV evaluations. The data required to establish the baseline conditions of a corridor is the same as that summarized in the HOV evaluation framework. Similarly, the procedures for collecting, analyzing, and presenting the baseline data are also outlined in the HOV evaluation framework.

The literature review identified that it is significant to regularly evaluate an HOV facility in its first few years of operation. Once an HOV facility is stable in its operation, the frequency of evaluations is of less importance. Consequently, there is no specific time period warranted in between successive evaluations of an HOV facility. However, it is invariably important to collect data that is statistically reliable for each HOV evaluation.

Otherwise, it is impractical to make conclusions and interpretations from the data collected. It is preferred to wait longer in between successive HOV evaluations than to collect data that is statistically unreliable.

In an HOV monitoring program, the seasonal timing of an HOV facility evaluation is as important as the frequency of evaluation. It is preferred to repeatedly conduct an annual HOV evaluation at the same time of each year.

4. OBJECTIVES AND EVALUATION PROCEDURES

4.1 INTRODUCTION

As discussed in Chapter One, seven objectives are evaluated as part of the HOV monitoring and evaluation framework. The objectives are categorized according to their relationship with the HOV network goals as either a primary, supporting, or operational objective. The general evaluation methodology of the HOV evaluation framework was summarized in Chapter Three. The evaluation procedure is repeated to measure the effectiveness of each objective of the framework. The remaining sections of this chapter describe the specific evaluation methodology for each of the primary, supporting, and operational objectives in the following order:

- ◆ Person Throughput
- ◆ Travel Time Savings
- ◆ Travel Time Reliability
- ◆ Public Support
- ◆ Compliance
- ◆ Safety
- ◆ Impact on GP Lanes

4.2 PERSON THROUGHPUT

The main purpose for performing an evaluation on an HOV facility is to measure its effectiveness at achieving the HOV project's goals. As described in Chapter One, the goals of the HOV network are to improve the person throughput and encourage higher occupancy on selected corridors. As a result, the framework's primary evaluation

objective is to measure an HOV facility's effectiveness at attaining these regional HOV goals. Accordingly, the primary objective is referred to as the 'Person Throughput' throughout the framework.

4.2.1 Measures of Effectiveness

The 'Person Throughput' objective is evaluated with the following three MOEs: Per-Lane Efficiency, AVO, and HOV Market Share.

PER-LANE EFFICIENCY

The efficiency of an arterial or freeway lane is calculated by multiplying the lane's average operating speed by the total number of persons on the lane over a period of time. The efficiency of a lane is expressed in 1,000 person-km/h per hour.

$$\text{Efficiency} = \frac{\text{average speed} \times \text{total number of persons/time}}{1,000}$$

The per-lane efficiency of a facility is calculated by taking an average of the facility's respective lane efficiencies. For example, the efficiency of an HOV facility is a per-lane weighted average of the GP lane efficiency and the HOV lane efficiency. It is desired that the per-lane efficiency of a facility increases with the introduction of an HOV lane. Increases in this MOE indicate that the person throughput of the overall facility has improved from the pre-HOV lane condition.

AVO

The average vehicle occupancy (AVO) of a facility is calculated by dividing the total number of passenger car occupants by the total number of passenger cars.

$$\text{AVO} = \frac{\text{\# of passenger car occupants}}{\text{\# of passenger cars}}$$

The AVO is a measure of the average number of persons on a facility on a per car basis. An increase in this MOE indicates that the average number of persons per car has increased. In other words, an increase in the AVO indicates that people are shifting to a higher occupancy mode, buses excluded.

HOV MARKET SHARE

The HOV Market Share is calculated by dividing the total number of persons that make their trip on an HOV (carpool, vanpool, or bus) by the total number of person trips.

$$\text{HOV Market Share} = \frac{\text{\# of HOV person trips}}{\text{\# of total person trips}}$$

The HOV Market Share is a measure of the number of persons that commute by the means of an HOV, buses included. It is an MOE of the 'Person Throughput' objective because it is directly related to evaluating the effectiveness of the regional goal of encouraging higher occupancy. Increases in the HOV Market Share indicate that a greater percentage of the commuting traffic is travelling in HOVs, buses included.

4.2.2 Data Requirements

To determine the 'Person Throughput' objective, vehicle classification and occupancy counts as well as travel time data are required. The vehicle classification and occupancy counts are necessary for the calculation of all three primary objective MOEs.

Conversely, the travel time data is only required for the calculation of the HOV facility's per-lane efficiency.

4.2.3 Data Collection Methodology

The following issues concerning the desired data collection methodology for the 'Person Throughput' objective should be considered:

- ◆ The vehicle classification and occupancy counts are to be performed for the entire peak period. This reflects the fact that the MOE results of an HOV facility may significantly differ in the peak hour and the peak period. It is recommended that this effort be continued until it is determined that the HOV facility is mature. At such time, the pattern of the peak period could be predicted based on its peak hour of operation.
- ◆ The vehicle classification and occupancy counts are to be conducted at representative locations along an HOV corridor.
- ◆ The vehicle classification and occupancy data is combined directly with the travel time data in the determination of the per-lane efficiency MOE. Therefore, it is preferred to coordinate the two types of surveys at the same time (i.e., same week of calendar year).

4.2.4 Data Analysis

For all three of the 'Person Throughput' MOEs, the peak hour of operation is defined to be the hour that GP traffic experienced their longest travel times along the HOV corridor. Therefore, the analysis of the peak hour is consistent between surveys (see 'Travel Time Savings' objective for further explanation).

PER-LANE EFFICIENCY

The per-lane efficiency is calculated for the peak direction of traffic. For the purpose of HOV evaluation, it is not necessary to evaluate this MOE for both the peak period and peak hour of operation. Therefore, it is recommended that only the peak hour per-lane efficiency be calculated.

Example:

Sample calculation of the peak hour per-lane efficiency

(Source of data: Appendix B - Efficiency Data)

TYPE OF LANE	# OF LANES	PERSON VOLUME	TIME (hrs)	SPEED (km/h)	PER-LANE EFFICIENCY
GP	2	1505	1.0	30	23
HOV	1	2188	1.0	36	79
HOV FACILITY					41

AVO

The AVO is calculated in 15-minute interval samples for each location of a vehicle classification and occupancy survey. The mean, standard deviation, and 95% confidence limits of these 15-minute interval samples is determined at each location for both the peak period and peak hour of operation.

Example:

Sample calculation of the mean peak hour AVO, standard deviation, and 95% confidence limits

(Source of data: Appendix C - AVO Data)

TIME	AVO
7:30-7:45	1.24
7:45-8:00	1.30
8:00-8:15	1.38
8:15-8:30	1.37

AVO = 1.32

Standard Deviation = 0.07

95% Confidence Limits = 1.21 to 1.43

The peak hour and peak period AVO and 95% confidence limits of the overall HOV corridor are calculated similar to the example above and presented as part of the results of the data analysis.

HOV MARKET SHARE

Unlike the AVO results, the HOV Market Share results are not presented in 15-minute interval samples. They are calculated as absolute numbers for each location of a vehicle classification and occupancy survey for the peak period of HOV operation.

Example:

Sample calculation of the peak period HOV Market Share

(Source of data: Appendix D - HOV Market Share Data)

TYPE	VOLUME	% OF TOTAL VOLUME
SOVs	3868	53 %
HOVs	2365	32 %
BUS	1047	15 %
TOTAL	7280	100 %
HOV MARKET SHARE	3412	47 %

Similar to the AVO, HOV Market Share is also calculated for the overall HOV corridor as part of the data analysis. The peak period corridor MOE is computed from all representative survey locations.

4.2.5 Parallel Routes Analysis

To examine the HOV lane's impact on its parallel routes, it is recommended that the AVO and HOV Market Share be determined on these routes. The trends in the AVO of the mainline and its parallel routes should be examined together to develop a better understanding of the HOV facility's 'Person Throughput' effectiveness.

4.2.6 Statistical Reliability

As mentioned in Chapter Three, the statistical reliability of the mean AVO results are investigated by quantifying the margins of error associated with the AVO samples of data. The margins of error are presented as percentages of the mean AVO results. Both the mainline and parallel routes (if available) AVO results are examined.

4.2.7 Statistical Significance

The difference between the baseline or “before” AVO and any “after” AVO results are tested for statistical significance. The differences in the AVO results are tested using a two sample *t*-test. An example of a two sample *t*-test is presented in Appendix A - Statistical Analysis. Minimum “after” AVOs are also calculated using an average AVO standard deviation and sample size. The minimum “after” AVOs are estimates of the lowest AVO that would produce statistically significant differences in the “before” AVOs.

4.3 TRAVEL TIME SAVINGS

Travel time savings is evaluated as a supporting objective because it contributes to the attainment of the HOV network goals. A travel time savings benefit for HOVs is the main incentive that encourages single occupant commuters to shift to a higher occupancy mode. The evaluation of the ‘Travel Time Savings’ objective examines the effectiveness of the HOV lane at providing a relative travel time advantage to the occupants of HOVs.

4.3.1 Measures of Effectiveness

The ‘Travel Time Savings’ objective is evaluated with the travel time difference MOE:

TRAVEL TIME DIFFERENCE

The travel time difference is calculated by subtracting the HOV travel time from the general purpose (GP) travel time for a pair of HOV and GP travel time runs that began at the same time. The MOE is expressed in minutes.

$$\text{Travel Time Difference} = \text{GP travel time} - \text{HOV travel time}$$

It is anticipated that the HOV travel times will be less than the GP travel times. Therefore, travel time difference is the relative measure of the number of minutes an HOV occupant saves as compared to a GP occupant. The larger the travel time difference being provided, the larger the incentive for commuters to shift to a higher occupancy mode.

4.3.2 Data Requirements

Travel time survey data on both the HOV and GP lanes is required to determine the effectiveness of the HOV lane at providing a relative travel time savings advantage. The travel time survey should be conducted for the entire peak period of HOV operation on representative weekdays, preferably Tuesday through Thursday.

4.3.3 Data Collection Methodology

To calculate the travel time difference, two simultaneous travel time runs should be conducted. One test vehicle should drive in the GP lane(s) and another vehicle in the HOV lane. Both test vehicles should depart at the same time from the beginning of the HOV facility.

4.3.4 Data Analysis

The travel time difference is calculated from the HOV and GP travel time survey data. The mean, standard deviation, and 95% confidence limits of the travel time differences should be presented as part of the data analysis. The results should be determined for both the peak period and peak hour of HOV operation.

To be consistent between travel time surveys, the peak hour should be defined to be the hour where GP traffic experienced their longest delays along the corridor. The incentive for GP traffic to take advantage of the HOV travel time savings is most likely to occur during this period of time. If the GP travel times are relatively similar throughout the entire peak period, the hour with the largest traffic volume should be defined as the peak hour.

Example:

Sample calculation of the peak hour travel time difference, standard deviation, and 95% confidence limits

(Source of data: Appendix E - Travel Time Savings Data)

<i>TIME</i>	<i>GP travel time (minutes)</i>	<i>HOV travel time (minutes)</i>	<i>Travel Time Difference (minutes)</i>
7:15	25.5	23.0	2.5
7:30	28.0	24.1	3.9
7:45	28.6	25.1	3.5
8:00	26.1	22.2	3.9

TRAVEL TIME DIFFERENCE = 3.5 minutes

Standard Deviation = 0.7 minutes

95% Confidence Limits = 2.4 to 3.6 minutes

In addition to travel time differences, a distance versus time plot could be used to summarize the travel time survey data. The plot would be beneficial in identifying an HOV corridor's "hot spots" and gaining further insight into the effectiveness and operation of the HOV lane versus the GP lane(s).

4.3.5 Arterial vs. Freeway Analysis

For either an arterial or freeway HOV facility with distinct operational segments, the travel time differences should be calculated for each segment as well as the entire corridor. The HOV lane may be providing a range of travel time savings for different segments. Therefore, the effectiveness and operation of each segment should be examined separately.

4.3.6 Statistical Reliability

As mentioned in Chapter Three, the statistical reliability of both the HOV and GP travel time survey data should be investigated. The samples of data should be tested at the minimum specified error of ± 5 km/h for “before-and-after” studies as recommended in the *‘ITE Transportation and Traffic Engineering Handbook’* (ITE, 1982).

4.3.7 Statistical Significance

The mean travel time differences between the HOV and GP lanes are tested for statistical significance using a paired sample *t*-test. An example of a paired sample *t*-test is found in Appendix A - Statistical Analysis.

4.4 TRAVEL TIME RELIABILITY

An HOV facility should provide HOVs with a more reliable trip relative to other commuters in the GP lane. By providing a more reliable trip, the HOV facility offers another motive for commuters to switch to a higher occupancy mode. The ‘Travel Time Reliability’ objective examines the effectiveness of an HOV facility at providing a more

reliable trip to HOV drivers and their occupants. It is also evaluated as a supporting objective because providing HOVs with a more reliable trip contributes to the attainment of the HOV network goals.

4.4.1 Measures Of Effectiveness

The 'Travel Time Reliability' objective is evaluated by quantifying and comparing the standard deviation of the travel speeds associated both the HOV and GP lanes. It is expressed in kilometers per hour. The standard deviation of the travel speed of a given lane is a measure of the travel time variability that a commuter will experience travelling on that lane over a period of time. The larger the standard deviation, the less reliable the trip on that lane. It is anticipated that the users of the HOV lane will experience a more reliable trip over time as compared to the users of the GP lanes. In other words, the travel speed standard deviation of vehicles travelling on the HOV lane should be less than the travel speed standard deviation of vehicles travelling on the adjacent GP lanes.

4.4.2 Data Requirements

To evaluate the 'Travel Time Reliability' objective, a travel time survey is required in addition to the one previously described for the 'Travel Time Savings' objective. The additional travel time survey should be conducted on both the HOV and GP lanes over an extended period of time on consecutive weekdays.

4.4.3 Data Collection Methodology

The following issues concerning the desired data collection methodology for the 'Travel Time Reliability' objective should be considered:

- ◆ The travel time survey should be conducted daily, Monday through Friday.

- ◆ Departure times within the peak period of HOV operation should be selected ahead of time. More than one departure time may be selected. However, at least one departure time should be selected within the peak hour.
- ◆ For each selected departure time, a pair of HOV and GP test vehicles should depart together from the beginning of the HOV facility.

4.4.4 Data Analysis

The HOV and GP travel speed standard deviations are calculated from the travel time survey data. As mentioned in the literature review, travel speeds provide better estimates of travel time reliability than travel time distributions (Turner et al., 1994). Therefore, the travel time survey data is firstly converted into travel speeds. Secondly, the travel speed standard deviations of both the HOV and GP lanes is calculated for each departure time of the survey. The standard deviations should be presented as absolute values (in km/h) as well as percentages of the mean travel speed.

Example:

*Sample calculation of the peak hour travel speed standard deviation of a lane
(Source of data: Appendix F - Travel Time Reliability Data)*

DATE	SPEED (km/h)	DATE	SPEED (km/h)
October 16	42	October 24	43
October 17	43	October 27	45
October 20	42	October 28	39
October 21	39	October 29	36
October 22	43	October 30	37
October 23	35	October 31	39

TRAVEL SPEED = 40.2 km/h

Standard Deviation (km/h) = 3.3 km/h

Standard Deviation (% of the mean) = 8.2 %

For each departure time, a comparison of the HOV and GP travel speed standard deviations should be made. Once again, the peak hour of operation is defined to be the hour that GP traffic experienced their longest travel times along the corridor. In addition, the travel time reliability of both the HOV and GP lanes can be analyzed through the use of a frequency versus travel speed plot. The plots may be of use to graphically assist in demonstrating the smaller variability (or range) of travel speeds experienced on the HOV lane when compared to the adjacent GP lanes.

4.4.5 Arterial vs. Freeway Analysis

No additional insight is gained in re-calculating the travel speed standard deviations for the distinct operational segments of either an arterial or freeway HOV corridor because it is the overall travel time reliability that is being evaluated.

4.4.6 Statistical Reliability

Similar to the 'Travel Time Savings' objective, the statistical reliability of the travel time survey data should be tested at the minimum specified permitted error of $\pm 5\text{km/h}$ as recommended in the *'ITE Transportation and Traffic Engineering Handbook'* (ITE, 1982).

4.4.7 Statistical Significance

The difference between the travel speed standard deviations of the HOV and GP lanes is tested for statistical significance using an F-test. The difference is analyzed at the 95th percentile. An example of an F-test is found in Appendix A - Statistical Analysis.

4.5 PUBLIC SUPPORT

The public's perception of the operation and effectiveness of HOV lanes is important to the success of an HOV network. The level of satisfaction and attitude of commuters can positively or negatively contribute to the attainment of the HOV network goals. Therefore, the public's support (or lack of) is evaluated in the framework as a supporting objective.

A public opinion survey is used to evaluate the attitudes and travel preferences of all types of commuters on the HOV facilities including bus riders, carpoolers, vanpoolers, and those who drive alone. The results of the public opinion survey can provide insight into the target areas and level of effort necessary to improve marketing and public education. Therefore, the purpose of the survey is to establish commuter perceptions on a variety of HOV topics such as: travel time savings, travel time reliability, HOV enforcement, overall HOV network issues, and carpool incentives.

4.5.1 Measures of Effectiveness

The 'Public Support' objective is evaluated with the support for HOV lane measure of effectiveness.

SUPPORT FOR HOV LANE

The support for HOV lane MOE is calculated by dividing the number of people who support the use of HOV lanes by the total number of people surveyed. The MOE is expressed as a percentage.

$$\text{Support for HOV Lane (\%)} = \frac{\text{number of people who support HOV lanes}}{\text{number of people surveyed}}$$

It is most likely that the responses of many survey questions could be used to determine the percent support for HOV lanes. For example, commuter's answers to the following three survey questions may all be used to determine this MOE:

- ◆ *Are the HOV lanes a good idea ?*
- ◆ *Are the HOV lanes being well-used ?*
- ◆ *Are the HOV lanes convenient to use ?*

4.5.2 Data Requirements

To evaluate the 'Public Support' objective, either a mail-out or telephone survey is required. However, it is recommended that the license plates of actual users of the HOV facility be recorded and matched to addresses from the driver's license database and a mail-out survey be used.

4.5.3 Data Collection Methodology

When conducting a public opinion survey, it is important that a statistically significant sample of HOV users be obtained. The sample size required is highly dependent on the anticipated response rate of those being surveyed. Therefore, the survey data collection methodology should be established after selecting the type of public opinion survey to be conducted.

4.5.4 Data Analysis

The analysis of the public opinion survey data is dependent on the content of the survey and the types of questions asked of the respondents. A sample mail-out public opinion survey is, therefore, presented as part of the evaluation framework. The survey is based

on the HOV public opinion surveys of other jurisdictions and is tailored to the needs of the South Coast Region HOV program. It is comprised of two sections: 'Part 1: Your Commute Trip' and 'Part 2: Your Opinion' (see Figures 4.1 and 4.2). The survey format was reviewed by the Region's Communications section as well as the BCTFA. In addition to the two sections, it is necessary to include an introductory letter explaining the purpose and scope of the survey as well as a section for the respondents' written comments.

4.5.5 Statistical Reliability

The statistical reliability of the public opinion survey data should be quantified as the margin of error associated with the sample size obtained. The margin of error should be expressed as a percentage and obtained for the 95% confidence level.

4.6 COMPLIANCE

A high degree of compliance inherently protects HOV operation and the attainment of the HOV network goals. Therefore, compliance is evaluated as an operational objective. HOV facilities with a low degree of compliance indicate a higher than desirable proportion of violators, thereby compromising the effectiveness of the HOV lane. It is important that the degree of compliance remain within an acceptable range to protect the travel time savings and reliability benefits for HOV commuters.

4.6.1 Measures of Effectiveness

The 'Compliance' objective is evaluated with the compliance rate MOE.

1. How many times per week (Monday through Friday) do you usually commute on either the Barnet Highway or Hastings St. (or both) ?
☐ once a week or less ☐ 2 to 4 times per week ☐ Monday through Friday
2. What is your PRESENT usual mode of travel between 6:00-8:30 AM and 3:30-6:00 PM ?
(pick only one please)
☐ drive alone ☐ carpool with one other person
☐ bus ☐ carpool with two or more people
☐ vanpool ☐ other _____
3. Prior to the introduction of the Barnet/Hastings HOV lane in September 1996, what was your usual mode of travel? (pick only one please)
☐ drive alone ☐ carpool with one other person
☐ bus ☐ carpool with two or more people
☐ vanpool ☐ other _____
4. Prior to the introduction of the Barnet/Hastings HOV lane in September 1996, did you commute on a different route ?
☐ YES ☐ NO
5. Have you regularly made use of the Barnet/Hastings HOV lane since it has been introduced ?
☐ YES ... ☐ on St.Johns and/or Clarke St. ☐ on the Barnet Highway
 ☐ on Hastings Street
☐ NO
6. Have you ever NOT used the Barnet/Hastings HOV lane even though you had enough people to qualify for it ?
☐ YES ... if yes, why? _____
☐ NO
7. Have you formed a new carpool in order to be able to use the newly constructed HOV lane ?
☐ YES
☐ NO ... if no, why not ? _____
8. How many minutes, if any, do you believe you save by using the HOV lane instead of the regular lanes ?
_____ minutes in the morning _____ minutes in the evening

Chapter 4: Objectives and Evaluation Procedures

PART 2: YOUR OPINION

Please indicate whether you agree, disagree or are neutral about the following statements.

PERCEPTION OF THE BARNET/HASTINGS HOV LANE

The HOV lane is being well-used	☐ agree	☐ neutral	☐
<i>disagree</i>			
The HOV lane is faster than the regular lanes	☐ agree	☐ neutral	☐ disagree
The HOV lane is more reliable than the regular lanes	☐ agree	☐ neutral	☐ disagree
The HOV lane has helped <u>all</u> commuters to save time	☐ agree	☐ neutral	☐ disagree

THE OPERATION OF THE BARNET/HASTINGS HOV LANE

The HOV lane is convenient to use	☐ agree	☐ neutral	☐ disagree
The HOV lane is safe	☐ agree	☐ neutral	☐ disagree
There are too many buses in the HOV lane	☐ agree	☐ neutral	☐ disagree
Many cars weave in and out of the HOV lane	☐ agree	☐ neutral	☐ disagree

ENFORCEMENT ON THE BARNET/HASTINGS HOV LANE

HOV violators are seldom caught	☐ agree	☐ neutral	☐ disagree
There are a lot of violators in the HOV lane	☐ agree	☐ neutral	☐ disagree
Cameras should be used to help enforce the HOV lane	☐ agree	☐ neutral	☐ disagree
There should be higher penalties for HOV violators	☐ agree	☐ neutral	☐ disagree

OVERALL HOV NETWORK ISSUES

HOV lanes are a good idea	☐ agree	☐ neutral	☐ disagree
HOV lanes need to be more widespread	☐ agree	☐ neutral	☐ disagree
HOV lanes are unfair to those who need to drive alone	☐ agree	☐ neutral	☐ disagree
HOV lanes should be eliminated	☐ agree	☐ neutral	☐ disagree
HOV lanes should be in operation 24 hours a day	☐ agree	☐ neutral	☐ disagree
HOV lanes should all be 2 or more people occupancy	☐ agree	☐ neutral	☐ disagree
HOV lanes should all be 3 or more people occupancy	☐ agree	☐ neutral	☐ disagree
HOV lanes are good investments of tax payers money	☐ agree	☐ neutral	☐ disagree

CARPOOL INCENTIVES

I would be encouraged or motivated to carpool if...			
... carpooling was easy to arrange	☐ agree	☐ neutral	☐ disagree
... HOV lanes saved time	☐ agree	☐ neutral	☐ disagree
... there were more HOV lanes	☐ agree	☐ neutral	☐ disagree
... HOV lanes were more reliable than the regular lanes	☐ agree	☐ neutral	☐ disagree
Nothing would motivate me to carpool	☐ agree	☐ neutral	☐ disagree

Figure 4-2: Sample Public Opinion Survey - Part 2

COMPLIANCE RATE

The compliance rate is calculated by dividing the total number of cars in the HOV lane that meet the occupancy requirement by the total number of cars in the HOV lane. The MOE is expressed as a percentage.

$$\text{Compliance Rate (\%)} = \frac{\text{number of cars that meet the occupancy requirement}}{\text{total number of cars in the HOV lane}}$$

The desired rate of compliance on an HOV facility was determined by MoTH to be 85%. However, MoTH recognizes that achieving this target rate is dependent on the resource allocated by local enforcement agencies for conducting HOV enforcement which are presently limited.

4.6.2 Data Requirements

Only vehicle classification and occupancy counts for the HOV lane are required to determine the 'Compliance' objective. The vehicle classification and occupancy counts should be conducted for the entire peak period of HOV operation on randomly selected weekdays.

4.6.3 Data Collection Methodology

The vehicle classification and occupancy counts are to be conducted at representative locations along an HOV corridor. To maximize the accuracy of the data collected, it is preferred to conduct compliance counts at locations with good visibility and low vehicular speeds.

It should be made clear that observing the compliance of high speed vehicles in poor daylight conditions is not an easy task. For example, four out of ten cars in the HOV lane identified as violators by a Port Moody police officer turned out to be legitimate HOVs when pulled over (as observed in an actual police ride-along). Children in the back seat, passengers reclining in their seat, and tinted windows are some of the examples that may be perceived as HOV violators when performing compliance counts.

4.6.4 Data Analysis

The compliance rates are calculated from the vehicle classification and occupancy counts. The compliance rate for each location should be presented as well as a corridor average. When calculating the corridor average, only locations that are representative of the typical compliance rate observed are to be included. For example, the compliance rate is sometimes obtained at certain locations for operational purposes only to assist in identifying problem areas. These compliance rates should not be included in the calculation of the corridor average.

Example:

*Sample calculation of the peak period compliance rate of a corridor
(Source of data: Appendix G - Compliance Data)*

<i>Location</i>	<i># of cars that meet the occupancy requirement</i>	<i>Total # of cars in the HOV lane</i>	<i>Compliance Rate</i>
<i>Williams</i>	<i>495</i>	<i>563</i>	<i>88.0 %</i>
<i>Clark</i>	<i>724</i>	<i>829</i>	<i>87.3 %</i>
<i>Reed</i>	<i>820</i>	<i>953</i>	<i>86.0 %</i>
<i>Bayview</i>	<i>807</i>	<i>927</i>	<i>87.0 %</i>
<i>Willingdon</i>	<i>851</i>	<i>958</i>	<i>88.8 %</i>
<i>Esmond</i>	<i>873</i>	<i>1015</i>	<i>86.0 %</i>
COMPLIANCE RATE = 87.2 %			

In addition to compliance rates, the number of HOV violation tickets issued could be obtained. If records are kept on the level of enforcement, these should be correlated to either the compliance rates or the number of HOV violation tickets being issued (RSMI³, 1997).

4.6.5 Arterial vs. Freeway Analysis

For either an arterial or freeway HOV facility with distinct operational segments, the compliance rates should also be calculated for each segment as well as the entire corridor. The compliance rate should be examined separately to identify the segments where special HOV enforcement should be allocated.

4.7 SAFETY

'Safety' is an operational objective which evaluates an HOV facility's "before-and-after" level of safety. Intersections and road sections are examined separately to determine if the implementation of the HOV facility has adversely affected the level of safety being provided on the corridor.

4.7.1 Measures of Effectiveness

The 'Safety' objective is evaluated with the accident rate measure of effectiveness. The accident rates for intersections and sections are quantified and compared separately.

ACCIDENT RATE

The accident rate of an intersection is calculated for a given period of time by dividing the number of accidents at the intersection by the number of vehicles entering the intersection from all approaches. The MOE is expressed in accidents

per million-entering-vehicles (acc/MEV). Similarly, the accident rate of a road section is calculated by dividing the number of accidents by the number of vehicle-kilometers, expressed as accident per million-vehicle-kilometers (acc/MVK).

$$\text{Intersection Accident Rate} = \frac{N \times 1,000,000}{\text{AADT} \times t \times 365}$$

$$\text{Section Accident Rate} = \frac{N \times 1,000,000}{L \times \text{AADT} \times t \times 365}$$

where N = number of accidents observed during a period t
 L = length of segment (km)
 AADT = average annual daily traffic volume (veh/day)
 t = observation period (years)

It is anticipated that the accident rates of a corridor will not increase with the implementation of an HOV facility. Increases in the accident rates indicate that the safety of the corridor has been somewhat compromised as a result of the HOV lane.

4.7.2 Data Requirements

“Before-and-after” accident data on both the HOV and GP lanes is required to determine the effectiveness of the HOV lane at providing safe operations. Usually, at least three years of “before” accident data and at least one year of “after” accident data should be obtained for the safety analysis. In addition, “before-and-after” traffic volume data is also required.

4.7.3 Data Collection Methodology

The following issues concerning the desired data collection methodology for the ‘Safety’ objective should be considered:

- ◆ AADT data should be obtained from a minimum of one representative location along the HOV facility.
- ◆ Any changes in the accident reporting procedure of the local enforcement agencies should be documented to assist in interpreting the results of the “before-and-after” safety analysis.
- ◆ If possible, the lane in which an accident occurs in (either HOV or GP) should be reported as part of the accident reporting and compiling procedure.

4.7.4 Data Analysis

The “before-and-after” intersection and section accident rates of the HOV facility should be calculated from the accident and traffic volume data.

Example:

*Sample calculation of the “before” intersection accident rate at a location
(Source of data: Appendix H - Safety Data)*

N = 30 accidents over 4 years
AADT = 33,400 (veh/day)
t = 4 years

$$\begin{aligned} \text{Intersection Accident Rate} &= \frac{30 \times 1,000,000}{33,400 \times 4 \times 365} \\ &= 0.62 \text{ acc/MEV} \end{aligned}$$

In addition, if the accident data is categorized under the type of lane in which the accident occurred in, the “after” accident rates of both the HOV and GP lane should also be quantified and compared with one another. It is anticipated that the “after” HOV accident rates would be equal to or less than the “after” accident rates in the GP lane.

4.7.5 Statistical Significance

A simple comparison between the mean “before-and-after” intersection and section accident rates should be performed. This simple “before-and-after” comparison method assumes that the mean accident rates would not have changed if the HOV lane had not been implemented on the facility. The differences between the mean “before-and-after” accident rates are tested for statistical significance using a paired sample *t*-test. An example of how to perform a paired sample *t*-test is found in Appendix A -Statistical Analysis. It should be made clear that a simple “before-and-after” comparison method does not account for the inclusion of unrelated effects nor the regression to the mean (RTM) effect. As previously mentioned in the literature review, it is suggested that the “after” changes in accident rates common to the region also be determined (see for example: Turnbull et al., 1991; Sayed¹, 1996).

To account for unrelated effects, it is suggested that the accident rates of a set of “control group” locations similar to the HOV facility be observed. To account for the regression to the mean effect, it is suggested an Empirical Bayes approach be used. The suggested approach differs from most traditional statistical methods of examining safety records in that it requires the use of a reference group. The reference group represents a similar corridor as that of the HOV facility that is being examined and eliminates the bias in traditional safety improvement evaluations. The Empirical Bayes approach provides “*a formal mechanism for combining information drawn from different sources in a single analysis*” (Sayed¹, 1996). The Empirical Bayes approach is presently being used by the Insurance Corporation of British Columbia (ICBC) in their safety analyses.

4.8 IMPACT ON GP LANES

The 'Impact on GP Lanes' objective evaluates the operational impact of the HOV lane on its adjacent general purpose (GP) lanes. It is anticipated that the implementation of an HOV facility will not adversely affect the operation of the GP lanes. However, it should be noted that with other network factors such as latent demand and regional growth, it is probable that the level-of-service being provided to GP users will decrease over time even with the addition of an HOV lane. Therefore, the effectiveness of the 'Impact on GP Lanes' objective is only evaluated on a short term basis.

4.8.1 Measures of Effectiveness

The "Impact on GP Lanes" objective is evaluated with the GP travel speed MOE.

GP TRAVEL SPEED

The GP travel speed MOE is determined by quantifying and comparing the "before-and-after" GP travel speeds. The MOE is expressed in kilometers per hour.

$\text{GP Travel Speed} = \text{"before" GP travel speed vs. "after" GP travel speed}$
--

It is anticipated that the "before" GP travel speed will be less than the "after" GP travel speed, at least in the short term. The HOV facility is considered to be effective at not adversely affecting the operation of the GP lanes as long as the "before" vs. "after" GP travel speed difference remains positive. The larger the difference, the more effective the HOV facility has been at attaining this objective.

4.8.2 Data Requirements and Data Collection Methodology

"Before-and-after" travel time survey data on the GP lanes is required to determine the effectiveness of the 'Impact on GP Lanes' objective. Similar to the 'Travel Time Savings' objective, "before-and-after" travel time surveys should be conducted for the entire peak period of HOV operation on representative weekdays, preferably Tuesday through Thursday. The travel time data collected on the GP lanes for the 'Travel Time Savings' objective can also be used as the "after" travel time data required for the evaluation of this objective.

4.8.3 Data Analysis

Mean GP travel speeds are calculated from the GP travel time survey data. Similar to the per-lane efficiency, it is not necessary to evaluate this MOE for both the peak period and peak hour of HOV operation. Therefore, it is recommended that only the peak hour GP travel speeds be calculated. As previously mentioned, the peak hour should be defined to be the hour where GP traffic experienced their longest delays along the corridor.

Example:

*Sample calculation of the mean peak hour GP travel speed
(Source of data: Appendix I - GP Travel Speed Data)*

TIME	OCTOBER 22, 1996	OCTOBER 24, 1996
7:15	42 km/h	41 km/h
7:30	38 km/h	38 km/h
7:45	38 km/h	41 km/h
8:00	41 km/h	40 km/h
GP TRAVEL SPEED = 40 km/h		

In addition, if vehicle classification and occupancy data is also available, a more insightful analysis of the GP travel speeds should be performed. The vehicular volumes in the GP lanes should be quantified and compared to the GP travel speeds. It is anticipated that the "after" GP travel speeds will decrease over time as the "after" GP vehicular volumes increase. Only the volumes at locations where the HOV lane has been added to an existing facility should be compared to on a "before-and-after" basis. In other words, the "before-and-after" GP volumes should not be compared to locations where a GP lane has been converted into an HOV lane.

Example:

Sample comparison of the "before-and-after" peak hour GP travel speeds and GP vehicular volumes at a location

(Source of data: Appendix I - GP Travel Speed Data)

TIME	DATE	GP TRAVEL SPEED (km/h)	GP VEHICULAR VOLUME
Before	March, 1996	18	2060
After	October, 1996	45	1898
	October, 1997	42	2063

4.8.4 Arterial vs. Freeway Analysis

For either an arterial or freeway HOV facility with distinct operational segments, the GP travel speeds should be calculated for each segment as well as the entire corridor. The HOV lane may be providing a range of GP travel speeds for the different segments. Therefore, the effectiveness of the 'Impact on GP Lanes' objective should be examined separately for each segment.

5. MULTI-CRITERIA EVALUATION

5.1 INTRODUCTION

The multi-criteria evaluation is a procedure for evaluating if the cost-effectiveness of the HOV facility. During these times of limited available funds, it is important that the limited financial resources for various transportation improvements are efficiently utilized (Sayed¹,1996). Therefore, an economic analysis should be performed to examine the cost-effectiveness of implementing an HOV facility.

In a benefit-cost analysis, the present value of the benefits and costs of a project are determined and compared. It is recommended that only the quantifiable criteria of an HOV facility be used as inputs into the benefit-cost analysis. However, intangible criteria such as travel time reliability that cannot be readily quantified should still be considered in the economic justification of an HOV facility. For example, an HOV project may be deemed to be more desirable if it links separate HOV corridors into a network. The multi-criteria evaluation procedure of an HOV facility and sensitivity analysis are presented in this chapter.

5.1.1 The Multi-Criteria Evaluation Procedure

The first step of the multi-criteria evaluation is to identify the quantifiable benefits and costs of the HOV facility. For example, travel time savings is an example of a quantifiable benefit. The travel time saved can be converted into a dollar value. Secondly, the parameters necessary to calculate the quantifiable benefits and costs are identified. For example, travel time differences, person-volumes, vehicle classification

counts, average wage rates, and the value of travel time are the parameters required to calculate the travel time savings benefit. In addition, other parameters such as the discount rate and the expected number of years of the HOV project also need to be identified. For each parameter identified, a most likely, worst case, and best case value is determined, where applicable. For example, discount rates are not fixed but variable. Presently, a discount rate of 8% is being used by MoTH to economically evaluate its roadway projects. However, other Canadian roadway jurisdictions are using discount rates ranging between 6% and 12% (MoTH, 1993). Therefore, the most likely discount rate for evaluating the cost-effectiveness of HOV facilities is determined to be 8%. The worst case and best case discount rates are determined to be 12% and 6% respectively.

The cost-effectiveness of the HOV facility is usually evaluated with either the benefit/cost (B/C) ratio or the net present value (NPV) MOEs. In quantifying these MOEs, the most likely values of the parameters are assumed. Finally, a sensitivity analysis is performed by re-calculating the cost-effectiveness MOEs for the worst case and best case values of the parameters. A summary of the steps of the multi-criteria evaluation procedure is presented below:

- ◆ Identify benefits and costs
- ◆ Select quantifiable benefits and costs
- ◆ Determine the types of parameters for each benefit and cost
- ◆ Select the most likely, worst case, and best case values for each parameter
- ◆ Determine the cost-effectiveness
- ◆ Perform sensitivity analysis

5.2 BENEFITS AND COSTS

Travel time savings is the main quantifiable benefit of implementing an HOV facility. Other quantifiable benefits of an HOV facility include: vehicle operating cost savings, air quality savings, and safety savings. The main quantifiable cost of an HOV facility is its construction. Other examples of quantifiable costs include: maintenance, enforcement, and marketing. Table 5.1 summarizes the quantifiable benefits and costs of the multi-criteria evaluation.

Table 5-1: Multiple-Criteria Evaluation Benefits and Costs

BENEFITS	COSTS
<i>Travel Time Savings</i>	<i>Construction Costs</i>
<i>Vehicle Operating Cost Savings</i>	<i>Maintenance Costs</i>
<i>Air Quality Savings</i>	<i>Enforcement Costs</i>
<i>Safety Savings</i>	<i>Marketing Costs</i>

5.2.1 Travel Time Savings

The value of travel time savings experienced by HOV, GP, and bus users is calculated based on the following parameters:

VARIABLE PARAMETERS

- ♦ travel time differences
- ♦ value of travel time

FIXED PARAMETERS

- ♦ average wage rate
- ♦ person-volumes
- ♦ vehicle classification counts

The travel time differences between the “add an HOV lane” alternative and the “do nothing” alternative for HOV, GP, and bus users are multiplied by their respective person-volumes to determine the total amount of travel time saved. The mean travel time differences represent the most likely values. The upper and lower bounds (95%

confidence limits) of the travel time differences represent the best and worst case values respectively.

The travel time saved is quantified in terms of number of wage hours saved based on the following "value of travel time" guidelines (Waters, 1992). For example, one hour of travel time saved for an automobile driver is equal to 0.5 wage hours saved:

- ◆ Automobile driver's value of travel time = 50% of wage rate
- ◆ Automobile occupant's value of travel time = 35% of wage rate
- ◆ Bus occupant's value of travel time = 35% of wage rate
- ◆ Commercial driver's value of travel time = 120% of wage rate

The total number of wage hours saved is converted into travel time savings by multiplying the number of wage hours by the average wage rate. The most likely value of the wage rate for the Greater Vancouver area is \$18 per hour (MoTH, 1993). It is recommended that the value of travel time range plus 30 or minus 20 percentage points for a sensitivity analysis (Waters, 1992). Therefore, the best case and worst case values are taken to be \$23 per hour and \$14 per hour, respectively.

5.2.2 Vehicle Operating Cost Savings and Air Quality Savings

The annual value of vehicle operating cost savings and air quality savings are based on the following parameters:

VARIABLE PARAMETERS

- ◆ unit costs
- ◆ AVO

FIXED PARAMETERS

- ◆ person-volumes
- ◆ length of HOV facility

Quantifying the value of vehicle operating cost savings and air quality savings depends on calculating the number of vehicle-kilometers saved due to the implementation of the HOV facility. Firstly, the number of vehicles required to move the same person-volume is determined with both the “before” AVO and the “after” AVO. The mean AVO is used to calculate the most likely values and the AVO’s 95% confidence limits are used to calculate worst and best case values.

For example, 1000 vehicles are required to move 1200 persons with a mean “before” AVO of 1.20. However, only 960 vehicles are required to move the same number of people with a mean “after” AVO of 1.25. Due to an increase in the AVO, 40 less vehicles are required to move the same number of people.

The difference in the number of vehicles required to move the same person-volume is multiplied by the length of the facility to determine the number of vehicle-kilometers saved. The value of vehicle operating cost savings and air quality savings are calculated by multiplying the number of vehicle-kilometers saved by a unit cost (\$/km). The range of vehicle operating unit costs (\$/km) were selected as follows: worst case, 0.08; most likely, 0.09; and best case, 0.12 (CAA, 1997). Similarly, the range of air pollutant unit costs (\$/km) used to calculate the air quality savings are as follows: worst case, 0.02; most likely, 0.04; and best case, 0.08 (Bein, 1994).

5.2.3 Safety Savings

The annual value of safety savings is based on the following parameters:

VARIABLE PARAMETERS

- ◆ accident frequency
- ◆ accident costs

Safety savings are represented by the estimated reduction in the number and/or severity of accidents following the implementation of the HOV facility. The reduction in accidents between the “before-and-after” accident frequencies are multiplied by the respective accident cost per accident type (fatality, injury, or PDO) to determine the safety savings.

There are several methods to calculate the reduction in accidents. The easiest method is the simple “before-and-after” comparison which assumes that the frequency of accidents would have remained the same if the HOV lane had not been implemented. However, there are several deficiencies with the simple “before-and-after” comparison method (Sayed¹, 1996):

- ◆ the inclusion of unrelated effects
- ◆ the normal distribution assumption
- ◆ the regression to the mean (RTM) effect
- ◆ the traffic exposure effect

A simple “before-and-after” comparison of accident rates addresses the traffic exposure effect. However, to account for each deficiency of the simple “before-and-after” comparison method, an Empirical Bayes approach is suggested. The Empirical Bayes approach was previously discussed in the evaluation procedure of the ‘Safety’ objective (see section 4.7).

There is little agreement in the literature regarding the value assigned to the different accident types. The disagreement on what constitutes the direct and indirect accident costs to society has led to several accident cost models. MoTH's Highway Safety Branch suggests that the discount future earnings (DFE) model represents "*the most reasonable and acceptable value for costing exercises*" (MoTH, 1995). The accident costs of the DFE model are the most likely values of the accident costs. ICBC's real costs are used as the lower bound values and the willingness to pay (WTP) model accident costs are used as the upper bound values. Table 5.2 summarizes the range of accident costs for the sensitivity analysis.

Table 5-2: Accident Costs

ACCIDENT TYPE	ICBC (MoTH, 1995)	DFE (MoTH, 1995)	WTP (Sayed ² , 1996)
FATAL	\$ 100,000	\$ 1,222,000	\$ 2,900,000
INJURY	\$ 17,500	\$ 29,500	\$ 100,000
P.D.O.	\$ 2,300	\$5,000*	\$ 6,000

NOTES: - all accident costs are reported in Canadian dollars (CDN\$)
 - DFE P.D.O. accident cost modified from \$9,000 to be in between upper and lower bounds

5.2.4 Costs

The costs of the HOV facility are dependent on the following parameters:

VARIABLE PARAMETERS

- ◆ maintenance unit cost
- ◆ enforcement costs
- ◆ marketing costs

FIXED PARAMETERS

- ◆ construction costs
- ◆ length of HOV facility

The total construction cost of the HOV facility includes capital costs, project management costs, design costs, and right-of-way acquisition costs. The annual maintenance cost is calculated by multiplying the maintenance unit cost (\$/lane-km per

year) by the number of lane-kilometers of the HOV facility. The most likely maintenance unit cost should be based on MoTH's most recent maintenance services contract. Over the life of the project, the maintenance, enforcement, and marketing costs will fluctuate from year to year. The lowest reported costs should be used as the lower bound values and the highest reported costs as the upper bound values.

5.3 COST- EFFECTIVENESS

To determine the cost-effectiveness, either the benefit/cost (B/C) ratio or the net present value (NPV) is usually used. Both MOEs provide a good measure of the cost-effectiveness of an HOV facility and inherently have their own advantages and disadvantages. However, it was identified in the literature review that the B/C ratio is the most frequently used cost-effectiveness MOE.

The B/C ratio is the ratio between the present value of the benefits and the present value of the costs. An HOV project that has a ratio B/C ratio greater than one is considered to be cost-effective.

$$\text{Benefit/Cost Ratio} = \Sigma \text{ benefits} / \Sigma \text{ costs}$$

The NPV of an HOV project is calculated by subtracting the present value of the costs from the present value of the benefits. The present value of the benefits and costs should be based on the most likely values of the parameters.

$$\text{NPV of HOV facility} = \Sigma \text{ benefits} - \Sigma \text{ costs}$$

It is recommended that the B/C ratio or NPV of the HOV facility be calculated for the base year in which the HOV lane was implemented. In other words, all of the costs accrued prior to the implementation of the HOV lane and all of the benefits and costs anticipated in the future are discounted to the base year. The present value of a known future amount occurring N years from the base year is calculated with the following formula:

$$PV = \frac{F}{(1 + i)^N}$$

where *PV* = present value of amount
F = future value of amount
i = discount rate
N = number of years

Similarly, the present value of a known past amount from N years ago is calculated with the following formula:

$$PV = P \times (1 + i)^N$$

where *PV* = present value of amount
P = past value of amount
i = discount rate
N = number of years

5.3.1 Sensitivity Analysis

A sensitivity analysis of the cost-effectiveness MOEs is performed as a decision making tool to indicate the sensitivity of the results to the different parameters and the uncertainty associated with the most likely values. The desirability and relative priority of a program of HOV projects is dependent on how changes in the parameters affects the outcome of the cost-effectiveness MOEs. For example, if an HOV project's B/C ratio is calculated to be 2.0 for the most likely values of the parameters, the HOV project is

considered to be cost-effective. However, if the B/C ratios of the lower and upper bounds of the parameters are calculated to be 0.5 and 5.0 respectively, the cost-effectiveness of the HOV project is sensitive to the different parameters of the benefits and costs. The sensitivity analysis is performed by firstly calculating the cost-effectiveness MOEs with the most likely values of the parameters. Secondly, the MOEs are re-calculated using the lower bound (or worst case) values as well as the upper bound (best case) values. A comparison of all three scenarios is performed and the sensitivity of the results is discussed.

6. APPLICATION OF THE FRAMEWORK

6.1 INTRODUCTION

An application of the evaluation framework was performed to evaluate the effectiveness of the HOV facility on the Barnet/Hastings corridor. The purpose of performing the application was to clearly demonstrate the suggested procedure of the evaluation framework. The Barnet/Hastings HOV corridor was selected for the application because it is the only regional HOV facility currently in operation. In other words, it is the only local HOV facility where "before-and-after" data is available.

6.1.1 Data Collection Summary

For the purpose of the application, "before-and-after" vehicle classification and occupancy counts, travel time runs, and accident records were retrieved. In addition, "after" compliance data was also obtained as well as "before-and-after" 24-hour traffic counts on a parallel route. No public support data relating to the operation of the Barnet/Hastings HOV corridor was available at the time of the application. The "before-and-after" data was obtained through numerous agencies. The sources and dates of the Barnet/Hastings HOV corridor data collection surveys and records are summarized in Table 6.1.

6.1.2 Description of the HOV Facility

The HOV facility on the Barnet/Hastings corridor, otherwise known as Route 7A, is the first HOV corridor constructed by British Columbia's Ministry of Transportation and Highways (see Figure 6.1). The curb-lane of the corridor operates as an HOV lane in the peak direction of travel. The Barnet/Hastings HOV lane was constructed along certain

sections by simply upgrading the curb-lane of the facility. In other sections, the facility was widened to accommodate an additional HOV lane.

The three distinct arterial and freeway sections of the Barnet/Hastings HOV corridor were previously categorized by MoTH as Hastings Street, Barnet Highway, and St. Johns Street (MoTH¹, 1997). The westbound HOV lane was constructed in all three sections. Therefore, the length of the westbound HOV lane is 18 kilometers, the approximate length of the HOV facility. However, no HOV lane was constructed eastbound along the St. Johns Street section. Consequently, the length of the eastbound HOV lane is only 15 kilometers. Curtis Street (or Parker Street) was identified as a parallel route along the Hastings Street section of the HOV facility.

Table 6-1: Summary of the Data Collection Surveys and Records

TYPE OF DATA	SOURCE OF DATA	"BEFORE" DATES	"AFTER" DATES
Vehicle Classification & Occupancy	Transtech Data Services	Mar.'96	Oct.'96 Mar.'97 Oct.'97
Travel Time	Transtech Data Services	Mar.'96	
	The University of British Columbia		Oct.'96 Oct.'97
Compliance	Transtech Data Services		Oct.'96 Mar.'97 Oct.'97
	ICBC		Sept.'96 - Sept.'97
Accident	MoTH	Jan.'92 - Dec.'95	Sept.'96 - Jun.'97
	City of Burnaby	Jun.'92 - Dec.'95	Sept.'96 - Oct.'97
	City of Vancouver	Jan.'92 - Dec.'95	Sept.'96 - Dec.'97
Parallel Routes Data	City of Burnaby	Feb.'96 - Mar.'96	Nov.'96

The HOV lane is in operation part-time (Monday to Friday) during the peak periods with an occupancy requirement of 2 or more people. The peak period in the morning is westbound between 6:00 and 8:30 AM (2.5 hours). Similarly, the eastbound afternoon peak period is between 3:30 and 6:00 PM (2.5 hours).

As mentioned in Chapter Four, the peak hour of operation is defined to be the hour that GP traffic experienced their longest travel times along the HOV facility. Accordingly, the Barnet/Hastings' westbound peak hour is between 7:30 and 8:30 AM, the last hour of the morning peak period. Likewise, the last hour of the afternoon peak period (5:00 to 6:00 PM) is the corridor's eastbound peak hour.

NOTES:

- Westbound HOV lane starts at loco Rd. in Port Moody and runs along St. John Street, turns onto Clarke St. at Moody St. and continues along Barnet Highway and Hastings St. and terminates at Renfrew St. in Vancouver.
- Eastbound HOV lane starts at Renfrew St. on Hastings and terminates just north of Clarke Street on Barnet Highway
- Curtis Street parallel route turns into Parker Street parallel route at Holdom Avenue

Figure 6-1: The Barnet/Hastings HOV Corridor

(MoTH¹, 1997)

6.1.3 Data Analysis

In accordance with framework, the effectiveness of the HOV facility on the Barnet/Hastings corridor was analyzed using the available “before-and-after” data. The data was used to calculate the respective MOEs of the primary, supporting, and operational evaluation objectives of the framework. The results of the evaluation of the effectiveness of the Barnet/Hastings HOV corridor are presented in the following sections of this chapter.

Firstly, the primary evaluation objective of ‘Person Throughput’ is examined. Secondly, the supporting evaluation objectives are evaluated. The results of the ‘Travel Time Savings’ and ‘Travel Time Reliability’ objectives are presented. However, as mentioned previously, no public opinion survey data was available for the application. Therefore, no ‘Public Support’ results are presented. Finally, the effectiveness of the operational objectives of ‘Compliance’, ‘Safety’ and ‘Impact on GP Lanes’ are assessed. In summary, the objectives are evaluated in the following order:

- ◆ Person Throughput
- ◆ Travel Time Savings
- ◆ Travel Time Reliability
- ◆ Compliance
- ◆ Safety
- ◆ Impact on GP Lanes

In addition, a multi-criteria evaluation to measure the cost-effectiveness of the HOV facility is performed and the results are presented in the last section of this chapter.

6.2 PERSON THROUGHPUT

As specified in Chapter Three, 'Person Throughput' is the primary evaluation objective of the HOV evaluation framework. Accordingly, the 'Person Throughput' effectiveness of the Barnet/Hastings HOV corridor is examined in this section.

As shown in Table 6.1, "before-and-after" vehicle classification and occupancy counts as well as travel time data were obtained for the application. Therefore, all three of the 'Person Throughput' objective measures of effectiveness (MOEs) were quantified and analyzed as described in the HOV evaluation framework. The results and discussions of each of the 'Person Throughput' MOEs are presented in the following order:

- ◆ Per-Lane Efficiency
- ◆ Average Vehicle Occupancy (AVO)
- ◆ HOV Market Share

The only data relating to the operation of the parallel routes of the HOV corridor were some "before-and-after" 24-hour traffic volume counts conducted by the City of Burnaby. The results of the counts are summarized in Table 6.2. The decreases in the "before-and-after" traffic volumes ranged from a low of 12% to a high of 44%.

Table 6-2: Parker/Curtis Street 24-Hour Traffic Volume Counts

LOCATION	BEFORE	AFTER	% DECREASE
<i>Carleton to Madison</i>	13956	12298	12 %
<i>Delta to Springer</i>	20178	15704	22 %
<i>Springer to Howard</i>	17703	14740	17 %
<i>Holdom to Fell</i>	17835	13454	25 %
<i>Kensington to Grove</i>	16312	10873	33 %
<i>Sperling to Duncan</i>	17579	9823	44 %

NOTES: - "before" counts conducted on either Feb.2-'96 or Mar.3-'96
- "after" counts conducted on either Nov.14-'96 or Nov.26-'96

6.2.1 Per-Lane Efficiency

Figure 6.2 shows the “before-and-after” peak hour per-lane efficiencies of the HOV facility on the Barnet/Hastings corridor. The peak hour per-lane efficiencies were calculated for each section of the corridor. The “after” results are an average of two surveys: October, 1996, and October, 1997.

Figure 6-2: Peak Hour Per-Lane Efficiencies

The westbound per-lane efficiency has more than doubled on the St. Johns St. section of the Barnet/Hastings HOV corridor. Meanwhile, the westbound per-lane efficiency has increased on the Barnet Highway section and slightly decreased on Hastings St. section. As well, the eastbound per-lane efficiencies of both the Barnet Highway and the Hastings St. sections have increased quite significantly.

Discussion of Results

Overall, the HOV lane has been effective in increasing the per-lane efficiency of the corridor. With the exception of the westbound Hastings St. section, the Barnet/Hastings' peak hour per-lane efficiencies have increased since the introduction of the HOV lane.

6.2.2 Average Vehicle Occupancy

Westbound

Figures 6.3 and 6.4 show the Barnet/Hastings HOV corridor's westbound "before-and-after" AVOs for both the peak hour and peak period of operation.

Figure 6-3: Westbound Peak Hour AVO

Figure 6-4: Westbound Peak Period AVO

The westbound peak hour AVO has increased from 1.25 to an average of 1.31 over the three "after" periods of evaluation. However, the "after" peak hour AVO has decreased slightly from 1.32 to 1.30 since the first evaluation in October, 1996 to the most recent evaluation in October, 1997. Similarly, the westbound peak period AVO has increased from 1.23 to an average of 1.28 over the first full year of operation of the HOV lane. There has also been a slight decrease in the westbound "after" peak period AVO.

Table 6.3 shows the 95% confidence limits and margins of error of the westbound "before-and-after" AVOs for both the peak hour and peak period of HOV operation. The margins of error of the AVO results were calculated as a percentage of the mean. The margins of error of the westbound AVO results were determined to be adequately small at 2% or less.

Table 6-3: Westbound AVO 95% Confidence Limits and Margins of Error

	BEFORE	AFTER		
	(March, 1996)	(October, 1996)	(March, 1997)	(October, 1997)
<i>Peak Hour AVO</i>	1.25	1.32	1.31	1.30
<i>95% Confidence Limits</i>	1.22 to 1.28	1.30 to 1.34	1.29 to 1.34	1.28 to 1.32
<i>% Margin of Error</i>	2%	2%	2%	2%
<i>Peak Period AVO</i>	1.23	1.29	1.29	1.27
<i>95% Confidence Limits</i>	1.22 to 1.24	1.27 to 1.31	1.27 to 1.31	1.25 to 1.29
<i>% Margin of Error</i>	1%	1%	1%	1%

The increases in the westbound peak hour and peak period AVOs along the Barnet/Hastings HOV corridor were each determined to be statistically significant for all three “after” evaluations. The differences between each of the “after” AVOs and the “before” AVO were statistically tested at the 95th percentile for both the peak period and peak hour of HOV operation. A two sample *t*-test was used as explained in the HOV evaluation framework.

Figure 6.5 shows the westbound “before-and-after” AVOs as well as the estimates of the minimum acceptable “after” AVOs to achieve a statistically significant improvement. Both the average “after” peak hour AVO of 1.31 and the average “after” peak period AVO of 1.28 are greater than the minimum AVOs of 1.28 and 1.25, respectively. Therefore, the average increases in the westbound AVOs are also determined to be statistically significant at the 95% confidence level.

NOTES:: - After results are an average of three "after" surveys
 - Minimum based on an average AVO standard deviation and sample size

Figure 6-5: Westbound "Before-and-After" and Minimum AVOs

Eastbound

Figures 6.6 and 6.7 show the Barnet/Hastings HOV corridor's eastbound "before-and-after" AVOs for both the peak hour and peak period of operation.

Figure 6-6: Eastbound Peak Hour AVO

Figure 6-7: Eastbound Peak Period AVO

The eastbound "before" peak hour AVO has increased from 1.32 to a high of 1.37 in March of 1997. The average eastbound "after" peak hour AVO is 1.35 for the three "after" periods of evaluation. The eastbound peak period AVO has increased from 1.29 to an "after" average of 1.33 with no decrease in the AVO over time.

Table 6.4 shows the eastbound “before-and-after” AVO 95% confidence limits as well as the AVO margins of error as a percentage of the mean. Similar to the westbound results, the eastbound margins of error were adequately small at 3% or less.

Table 6-4: Eastbound AVO 95% Confidence Limits and Margins of Error

	BEFORE	AFTER		
	(March, 1996)	(October, 1996)	(March, 1997)	(October, 1997)
<i>Peak Hour AVO</i>	1.32	1.33	1.37	1.35
<i>95% Confidence Limits</i>	1.29 to 1.35	1.29 to 1.36	1.33 to 1.40	1.33 to 1.38
<i>% Margin of Error</i>	2%	3%	3%	2%

<i>Peak Period AVO</i>	1.29	1.32	1.33	1.33
<i>95% Confidence Limits</i>	1.27 to 1.31	1.30 to 1.34	1.31 to 1.35	1.32 to 1.34
<i>% Margin of Error</i>	1%	2%	1%	1%

Figure 6.8 shows the eastbound “before-and-after” AVOs as well as the estimates of the minimum acceptable “after” AVOs. The average eastbound “after” peak hour AVO is exactly equal to the minimum acceptable AVO of 1.35. Therefore, the increase in the eastbound AVO was determined to be statistically significant. However, in October of 1996, the eastbound “after” peak hour AVO of 1.33 was less than the minimum acceptable AVO of 1.35. Therefore, it was not found to be statistically different than the “before” AVO of 1.32. The other two “after” peak hour AVOs of 1.37 and 1.35 in 1997 were both greater than (or equal to) the minimum and produced statistically significant AVO differences.

The average eastbound “after” peak period AVO of 1.33 is greater than the minimum of 1.31 and is determined to be statistically significant at the 95% confidence level. All three “after” peak period AVOs produced statistically significant AVO differences from the “before” AVO of 1.29. In other words, each “after” peak period AVO was greater than the minimum acceptable AVO of 1.31.

NOTES:: - After results are an average of three "after" surveys
 - Minimum based on an average AVO standard deviation and sample size

Figure 6-8: Eastbound "Before-and-After" and Minimum AVOs

Discussion of Results

Overall, the HOV facility on the Barnet/Hastings corridor has been effective at increasing the average number of persons per car on the facility. The HOV corridor has generally been able to maintain a statistically significant increase in its AVO for its full year of operation for both the peak hour and peak period. However, there seems a downward trend in the westbound AVO. If this trend continues it may lead to a statistically insignificant AVO difference.

6.2.3 HOV Market Share

As described in the HOV evaluation framework, the HOV Market Share is a measure of the number of persons that commute by means of an HOV (carpool, vanpool or bus). Figures 6.9 through 6.12 show the "before-and-after" peak period HOV Market Share percentages as well the exact percentage breakdown of single occupancy vehicle (SOV), high occupancy vehicle (carpool or vanpool), and bus person-trips.

The westbound HOV Market Share has improved slightly from 48% to an average of 51%. This net 3% growth is attributable to an 8% growth in the percentage of people commuting in a carpool or vanpool and a 5% drop in the percentage of people commuting by bus.

Westbound

HOV MARKET SHARE = 48%

Figure 6-9: WB - "Before" Market Share

HOV MARKET SHARE = 51%

Figure 6-10: WB - "After" Market Share

Eastbound

The eastbound "before" HOV Market Share has improved by one percent to 53%. Similar to the westbound results, there has been a 5% drop in the percentage of people commuting by bus. The percentage of people commuting eastbound in a carpool or vanpool has grown from 32 to 38%.

HOV MARKET SHARE = 52%

Figure 6-11: EB - "Before" Market Share

HOV MARKET SHARE = 53%

Figure 6-12: EB - "After" Market Share

Discussion of Results

The HOV Market Share has slightly increased since the introduction of the HOV lane to the Barnet/Hastings corridor. However, there has been an interesting shift in the distribution of person-trips. The percentage of bus commuters has decreased 5% in both directions while the percentage of carpooling and vanpooling traffic has increased 8% and 6% in the westbound and eastbound directions respectively.

6.2.4 Person Throughput Summary

The Barnet/Hastings HOV lane has been effective at improving the 'Person Throughput' of the corridor. With the exception of the westbound Hastings St. section, the HOV corridor's per-lane efficiencies have all increased and are continuing to grow. The AVOs were determined to have increased by statistically significant amounts and the HOV Market Share of the corridor has also increased in both directions of travel since the introduction of the HOV lane.

6.3 TRAVEL TIME SAVINGS

The effectiveness of the HOV facility on the Barnet/Hastings corridor in providing a relative travel time savings benefit to the occupants of HOVs is evaluated in this section. Travel time savings data from October of 1996 and 1997 were obtained for the application. The travel time difference MOE is quantified according to the framework and the results are discussed.

6.3.1 Travel Time Difference

Westbound

Figure 6.13 shows the westbound peak hour and peak period travel time differences of the HOV facility of the Barnet/Hastings corridor. The westbound peak hour is between 7:30 and 8:30 AM and the westbound peak period is between 6:00 and 8:30 AM.

Figure 6-13: Westbound Travel Time Differences

Table 6.5 presents the westbound travel time difference 95% confidence limits. The westbound travel time differences were all determined to be statistically significant at the 95% confidence level. Over one year, the peak hour travel time difference almost doubled from 4.3 minutes to 8.1 minutes. As well, the peak period travel time difference has more than doubled from 2.2 minutes in 1996 to 4.6 minutes in 1997.

Table 6-5: Westbound Travel Time Difference 95% Confidence Limits

	AFTER	
	(October, 1996)	(October, 1997)
Peak Hour Travel Time Difference 95 % Confidence Limits	4.3 minutes 3.3 to 5.3 minutes	8.1 minutes 6.2 to 9.9 minutes
Peak Period Travel Time Difference 95 % Confidence Limits	2.2 minutes 0.9 to 3.5 minutes	4.6 minutes 3.0 to 6.2 minutes

Table 6.6 shows the individual section peak hour travel time differences. The St. Johns St. section is experiencing a negative benefit for the occupants of HOVs. However, this negative benefit is decreasing and less than or equal to half a minute. The Barnet Highway peak hour travel time difference has doubled from 2.6 to 5.2 minutes. Finally, the Hastings St. section experienced a slight increase in its peak hour travel time difference from 2.2 to 2.9 minutes.

Table 6-6: Westbound Peak Hour Travel Time Differences by Section

	AFTER	
	(October, 1996)	(October, 1997)
<i>St. Johns Street</i>	<i>-0.5 minutes</i>	<i>-0.1 minutes</i>
<i>Barnet Highway</i>	<i>2.6 minutes</i>	<i>5.2 minutes</i>
<i>Hastings Street</i>	<i>2.2 minutes</i>	<i>2.9 minutes</i>
TOTAL	4.3 minutes	8.1 minutes

Table 6.7 shows the travel speed margins of error for both the GP and the HOV travel time runs expressed in km/h as well as in percentages of the mean travel speed. The westbound travel speed margins of error ranged from a minimum of 1.5 km/h to a maximum of 4.4 km/h, all below the minimum specified error of 5 km/h. Therefore, the travel time data obtained is considered to be statistically reliable.

Table 6-7 Westbound Travel Speed Margins of Error

	AFTER			
	(October, 1996)		(October, 1997)	
	GP	HOV	GP	HOV
<i>Peak Hour Margin of Error (km/h)</i>	<i>1.5 km/h</i>	<i>3.1 km/h</i>	<i>1.8 km/h</i>	<i>1.7 km/h</i>
<i>Margin of Error (% of the mean)</i>	<i>4 %</i>	<i>6 %</i>	<i>6 %</i>	<i>4 %</i>
<i>Peak Period Margin of Error (km/h)</i>	<i>3.8 km/h</i>	<i>3.2 km/h</i>	<i>4.4 km/h</i>	<i>3.1 km/h</i>
<i>Margin of Error (% of the mean)</i>	<i>8 %</i>	<i>6 %</i>	<i>11 %</i>	<i>6 %</i>

Eastbound

Figure 6.14 shows the eastbound peak hour and peak period travel time differences of the HOV facility of the Barnet/Hastings corridor. The eastbound peak hour is between 5:00 and 6:00 PM and the eastbound peak period is between 3:30 and 6:00 PM.

Figure 6-14: Eastbound Travel Time Differences

Table 6.8 presents the eastbound travel time difference 95% confidence limits. Similar to the westbound direction, each eastbound travel time difference was determined to be statistically significant at the 95% confidence level. Both the peak hour and peak period eastbound travel time differences have slightly increased from 1996 to 1997.

Table 6-8: Eastbound Travel Time Difference 95% Confidence Limits

	AFTER	
	(October, 1996)	(October, 1997)
Peak Hour Travel Time Difference 95% Confidence Limits	2.4 minutes 1.5 to 3.3 minutes	2.8 minutes 1.2 to 4.5 minutes
Peak Period Travel Time Difference 95% Confidence Limits	1.7 minutes 1.0 to 2.4 minutes	2.5 minutes 1.7 to 3.4 minutes

Table 6.9 shows the individual section eastbound peak hour travel time differences. Both the Hastings St. section and the Barnet Highway peak hour travel time differences have slightly increased by 0.3 minutes and 0.1 minutes respectively.

Table 6-9: Eastbound Peak Hour Travel Time Differences by Section

	AFTER	
	(October, 1996)	(October, 1997)
<i>Hastings Street</i>	<i>1.7 minutes</i>	<i>2.0 minutes</i>
<i>Barnet Highway</i>	<i>0.7 minutes</i>	<i>0.8 minutes</i>
TOTAL	2.4 minutes	2.8 minutes

Table 6.10 shows the eastbound travel speed margins of error for both the GP and HOV travel time runs expressed in km/h as well as in percentages of the mean travel speed. The eastbound travel speed margins of error are all well below the minimum specified error of 5 km/h. The maximum eastbound travel speed margin of error was 3.4 km/h (or 8% of the mean travel speed). Similar to the westbound direction, the eastbound travel time data is determined to be statistically reliable.

Table 6-10: Eastbound Travel Speed Margins of Error

	AFTER			
	(October, 1996)		(October, 1997)	
	GP	HOV	GP	HOV
<i>Peak Hour Margin of Error (km/h)</i>	<i>2.1 km/h</i>	<i>3.3 km/h</i>	<i>3.4 km/h</i>	<i>2.0 km/h</i>
<i>Margin of Error (% of the mean)</i>	<i>5 %</i>	<i>8 %</i>	<i>8 %</i>	<i>5 %</i>
<i>Peak Period Margin of Error (km/h)</i>	<i>1.6 km/h</i>	<i>1.7 km/h</i>	<i>2.0 km/h</i>	<i>1.8 km/h</i>
<i>Margin of Error (% of the mean)</i>	<i>4 %</i>	<i>4 %</i>	<i>5 %</i>	<i>4 %</i>

6.3.2 Travel Time Savings Summary

Overall, the HOV facility on the Barnet/Hastings corridor has been effective at providing a statistically significant travel time savings benefit (at the 95% level) to the occupants of

HOVs. The peak hour and peak period travel time differences have increased in both directions of travel from 1996 to 1997.

The westbound travel time differences are significantly higher than the eastbound's. For example, the 1997 westbound peak hour travel time difference was 8.1 minutes. Comparatively, the 1997 eastbound peak hour travel time difference was only 2.8 minutes. However, it should be noted that the westbound HOV lane is longer in length than the eastbound by an additional 2.9 kilometers.

6.4 TRAVEL TIME RELIABILITY

The effectiveness of the HOV facility at providing a more reliable trip to HOV drivers and their occupants is evaluated using travel time data obtained in October, 1997.

6.4.1 Travel Speed Standard Deviation

Westbound

Figure 6.15 shows the westbound travel speed standard deviations of the HOV and GP lanes for the departure times of 7:00 AM and 8:00 AM respectively. Both departure times are within the westbound peak period (6:00 to 8:30 AM) and the latter is within the peak hour of HOV operation (7:30 to 8:30 AM).

Figure 6-15: Westbound Travel Speed Standard Deviations

Table 6.11 presents the westbound travel speed standard deviations expressed in kilometers per hour as well as the results of the statistical tests performed on the differences between the HOV and GP standard deviations using the F-test as explained earlier.

Table 6-11: Westbound Travel Speed Standard Deviations

DEPARTURE TIME	GP LANE	HOV LANE	SIGNIFICANT DIFFERENCE ?
7:00 AM	3.3 km/h	3.9 km/h	No
8:00 AM	5.2 km/h	3.0 km/h	YES

It was determined that there is no statistically significant difference between the HOV and GP travel speed standard deviations at either the 95% or the 90% confidence level for the 7:00 AM departure time. As an absolute value, the GP travel speed standard deviation of 3.3 km/h was actually less than the HOV lane (3.9 km/h). However, the HOV lane is providing a more reliable trip at 8:00 AM. The HOV lane's travel speed standard deviation is statistically significantly less than that of the GP lane at the 95% confidence level.

Table 6.12 shows the westbound travel speed margins of error for both the GP and HOV travel time runs expressed in kilometers per hour as well as in percentages of the mean travel speed. The margins of error are all very low (less than 3.3 km/h) indicating that the travel time data is statistically reliable.

Table 6-12: Westbound Travel Speed Margins of Error

	DEPARTURE TIME			
	7:00 AM		8:00 AM	
	GP	HOV	GP	HOV
Margin of Error (km/h)	2.1 km/h	2.5 km/h	3.3 km/h	1.9 km/h
Margin of Error (% of the mean)	5 %	5 %	8 %	4 %

Eastbound

Figure 6.16 shows the eastbound travel speed standard deviations of the HOV and GP lanes for the departure times of 4:30 PM and 5:30 PM respectively. Both departure times are within the eastbound peak period (3:30 to 6:00 PM) and the latter is within the peak hour of HOV operation (5:00 to 6:00 PM).

Figure 6-16: Eastbound Travel Speed Standard Deviations

Table 6.13 presents the eastbound travel speed standard deviations expressed in kilometers per hour as well as the results of the statistical tests performed on the differences between the HOV and GP standard deviations.

Table 6-13: Eastbound Travel Speed Standard Deviations

DEPARTURE TIME	GP LANE	HOV LANE	SIGNIFICANT DIFFERENCE ?
4:30 PM	4.2 km/h	3.5 km/h	No
5:30 PM	3.2 km/h	2.5 km/h	No

For both departure times, the differences in the eastbound travel speed standard deviations were not determined to be statistically significant at either the 95% or 90% confidence levels. Therefore, even though the eastbound GP lane's standard deviations are greater than the HOV lane, the differences are not adequate enough to conclude that the HOV lane is providing a more reliable trip.

Table 6.14 shows the eastbound travel speed margins of error for both the GP and HOV travel time runs expressed in kilometers per hour as well as in percentages of the mean travel speed. The travel speed margins of error ranged from a minimum of 2.5 km/h to a maximum of 4.2 km/h, all below the minimum specified error of 5km/h. Therefore, the eastbound travel time data is also considered to be statistically reliable.

Table 6-14: Eastbound Travel Speed Margins of Error

	DEPARTURE TIME			
	4:30 PM		5:30 PM	
	GP	HOV	GP	HOV
<i>Margin of Error (km/h)</i>	4.2 km/h	3.5 km/h	3.2 km/h	2.5 km/h
<i>Margin of Error (% of the mean)</i>	9 %	7 %	7 %	5 %

6.4.2 Travel Time Reliability Summary

Overall, the HOV facility on the Barnet/Hastings corridor has not provided a statistically significant more reliable trip. It was determined that there is no statistically significant difference between the eastbound HOV and GP travel speed standard deviations. The HOV lane was determined to be more reliable than the adjacent GP lanes only during the morning peak hour of HOV operation (departure time of 8:00 AM).

6.5 COMPLIANCE

The compliance rates of the HOV facility on the Barnet/Hastings corridor are determined according to the HOV evaluation framework in this section. The effectiveness of the HOV facility at achieving MoTH's desired compliance rate of 85% is evaluated and the results are discussed. The compliance rates were calculated based on vehicle classification and occupancy counts obtained in the following months: October, 1996; March, 1997; and October, 1997. In addition, the results of a search of HOV violation tickets are presented as well as a summary of the HOV enforcement activity of the Burnaby Royal Canadian Mounted Police (RCMP) Detachment.

6.5.1 Compliance Rates

The compliance rates of each location of the vehicle classification and occupancy surveys were calculated for each 15-minute interval of the peak period. It was observed that the compliance rates of the first and last 15-minute intervals of the peak period were consistently lower than the remaining 15-minute intervals. The following compliance data obtained from a location along the St. Johns Street section of the Barnet/Hastings HOV corridor illustrates this point.

Example:

*Compliance data from Williams location of St. Johns St. section, March 1997
(Source of data: Appendix G - Compliance Data)*

<i>TIME</i>	<i>COMPLIANCE RATE</i>
6:00 - 6:15	69.6 %
6:15 - 6:30	80.6 %
6:30 - 6:45	86.6 %
6:45 - 7:00	84.7 %
7:00 - 7:15	87.9 %
7:15 - 7:30	88.7 %
7:30 - 7:45	88.3 %
7:45 - 8:00	89.4 %
8:00 - 8:15	88.2 %
8:15 - 8:30	70.3 %
Average = 83 % (including first & last interval)	
Average = 87 % (excluding first & last interval)	

The compliance rate of the location is only 83% when the first and last 15-minute intervals are included. If these intervals are excluded, the compliance rate is 87% and the desired rate of 85% is achieved.

Based on interviews with the local enforcement agencies, it was determined that the compliance rates of the first and last 15-minute intervals are consistently lower than the average because the start and end times of the HOV operation are subjective. The local enforcement agencies usually allow a ten-minute period of grace during these times. In this specific example, police officers would most likely not have been ticketing HOV violators between 6:00 to 6:10 AM and between 8:20 to 8:30 AM. The compliance rate excluding the first and last 15-minute intervals is more representative of the compliance during routine HOV operation. Therefore, all of the compliance rates of the HOV facility on the Barnet/Hastings corridor were determined in this manner.

Westbound

Figure 6.17 shows the compliance rates for the three westbound sections of the HOV facility on the Barnet/Hastings corridor for each compliance survey conducted. The westbound compliance rates in October, 1996, were all above the desired rate of 85%. By March of 1997, the compliance rates on the Barnet/Hastings HOV corridor were decreasing. The Barnet Highway section was already experiencing a less than desired rate of 81%. Each of the section's compliance rates were determined to be below 85% by October, 1997. Overall, the average westbound compliance rates of each section are 84%, 80%, and 83% respectively.

Figure 6-17 : Westbound Compliance Rates by Section

Table 6.15 summarizes the westbound compliance rates by location as well the westbound corridor averages for each compliance survey. The average compliance rates for the corridor in October, 1996, and in March, 1997, were equal to or greater than the desired rate of 85%. However, similar to the section averages shown in Figure

6.17, the average compliance rates for the corridor decreased below 85% in October, 1997.

Table 6-15: Westbound Compliance Rates by Location

SECTION	LOCATION	OCT-96	MAR-97	OCT-97
<i>St. Johns Street</i>	<i>Williams</i>	88 %	87 %	83 %
	<i>Clark</i>	87 %	89 %	70 %
<i>Barnet Highway</i>	<i>Reed</i>	86 %	76 %	78 %
	<i>Bayview</i>	87 %	85 %	69 %
<i>Hastings Street</i>	<i>Willingdon</i>	89 %	89 %	78 %
	<i>Esmond</i>	86 %	82 %	74 %
	<i>Lillooet*</i>	77 %	74 %	33 %
	AVERAGE*	87 %	85 %	75 %

* Lillooet location not included in average

The Lillooet compliance rates are not considered to be representative of the routine compliance along the corridor because they were obtained at the end of the HOV facility. Therefore, the Lillooet compliance rates were not included in the calculation of either the westbound Hastings Street section or westbound corridor averages.

Eastbound

Figure 6.18 shows the compliance rates for the two eastbound sections of the HOV facility on the Barnet/Hastings corridor for each compliance survey conducted. Eastbound section averages are also presented. Similar to the westbound direction, the eastbound compliance rates were all above the desired rate of 85% in October, 1996, decreasing by March, 1997, and below 85% by October, 1997. Overall, the average eastbound compliance rate on the Hastings Street section was determined to be 79%. However, the average eastbound compliance rate on the Barnet Highway section was determined to be equal to the desired rate of 85%.

Figure 6-18: Eastbound Compliance Rates by Section

Table 6.16 summarizes the eastbound compliance rates by location as well the eastbound corridor averages for each compliance survey.

Table 6-16: Eastbound Compliance Rates by Location

SECTION	LOCATION	OCT-96	MAR-97	OCT-97
Hastings Street	Lillooet*	65 %	64 %	55 %
	Cassiar	82 %	68 %	73 %
	Kootenay	86 %	75 %	80 %
	Carleton	87 %	80 %	76 %
	Willingdon	85 %	74 %	79 %
	Howard	84 %	81 %	78 %
Barnet Highway	Bayview	89 %	95 %	89 %
	Union	87 %	80 %	69 %
AVERAGE*		86 %	80 %	78 %

* Lillooet location not included in average

The HOV facility on the Barnet/Hastings corridor achieved its desired rate of compliance in the eastbound direction for the surveys conducted in October, 1996, and March, 1997. However, the eastbound corridor compliance rate of 78% in October of 1997 is

7% short of the desired rate of 85%. Once again, the Lillooet compliance rates were not included in the calculation of either the eastbound compliance averages.

6.5.2 Violation Data

A search for traffic violation ticket information concerning HOV lanes was requested and performed by the Research Services of ICBC. Traffic violations related to the HOV lane were retrieved based on the section numbers of offences in the Motor Vehicle Act (MVA). For example, the offence related to HOV lanes is presently described in section number 152 of the MVA as follows:

"If a laned roadway has a high occupancy vehicle lane, a person must not drive a motor vehicle or other device in that lane unless permitted by the regulations."

(Source: MVA, Section Number 152: High Occupancy Vehicle Lane, page 94)

The following violation data was retrieved from ICBC for the period of September 1, 1996 to October 24, 1997:

- ◆ Date of Violation
- ◆ Location of Violation
- ◆ Section of Motor Vehicle Act
- ◆ Count of the number of HOV violations

Table 6.17 summarizes the number of violations identified from the ICBC search on a per month basis for the first full year of HOV operation (September, 1996 to August, 1997). The results of the ICBC search, however, are not conclusive on the total number of HOV violation tickets that have been issued for the following reasons:

- ◆ The section number of the HOV offence was 155.1 prior to April 1, 1997 and section number 152 thereafter. Violation data may have not been reported

under the correct section number during the transition period. For example, the search produced no count of the number of violation tickets issued for the month of April, 1997.

- ◆ The MVA section numbers are not consistently entered into ICBC's Contravention System. For example, some counts were retrieved from a search of section number "155.1" and others were retrieved from a search of "155/1".
- ◆ It was identified that some of the local enforcement agencies have the choice of issuing either a MVA ticket or a Bylaw ticket for an HOV offence. No statistics on Bylaw tickets by section or location were available.
- ◆ Many HOV violation warnings were issued in the first year of HOV operation. Warnings would not have appeared as HOV violation tickets in the search.

Table 6-17: ICBC HOV Violation Ticket Information

MONTH	NUMBER OF HOV TICKETS
<i>September, 1996</i>	<i>38</i>
<i>October, 1996</i>	<i>19</i>
<i>November, 1996</i>	<i>11</i>
<i>December, 1996</i>	<i>14</i>
<i>January, 1997</i>	<i>91</i>
<i>February, 1997</i>	<i>16</i>
<i>March, 1997</i>	<i>76</i>
<i>April, 1997</i>	<i>-</i>
<i>May, 1997</i>	<i>62</i>
<i>June, 1997</i>	<i>20</i>
<i>July, 1997</i>	<i>96</i>
<i>August, 1997</i>	<i>44</i>

6.5.3 Enforcement Data

A search was also performed by the Burnaby RCMP Detachment on their level of enforcement activity on the HOV facility of the Burnet/Hastings corridor. The purpose of the search was to determine an order of magnitude estimate on how many man-hours

have been invested in enforcing the HOV lane in the city of Burnaby thus far. The search was conducted for the period between September, 1996, and December, 1997.

MoTH funded special enforcement on the HOV facility for the first six weeks of HOV operation. Table 6.18 shows an estimate of the number of man-hours invested in the special enforcement for the Burnaby RCMP Detachment. It should be noted that MoTH also funded special enforcement with the Vancouver Police and the Port Moody Police during this time.

Table 6-18: Burnaby RCMP Special Enforcement Man-Hours

MONTH	MAN-HOURS
<i>September, 1996</i>	<i>95</i>
<i>October, 1996</i>	<i>45</i>

Table 6.19 shows the routine HOV enforcement activity of the Burnaby RCMP Detachment in man-hours on a per month basis for the first full year of HOV operation. The estimate of the number of man-hours ranged from a low of 4 per month (December, 1996) to a high of 32 per month (August, 1997).

It is interesting to note that the months with the highest number of invested man-hours (Jan.=29, Mar.=29, and Aug.=32) correspond directly with the months with the highest number of HOV violation tickets (Jan.=91, Mar.=76, and Aug.=96) indicating that the violation and enforcement data are somewhat consistent with each other. Unfortunately, it is not possible to correlate the number of invested man-hours with the compliance rate due to the lack of extensive compliance rate data.

Table 6-19: Burnaby RCMP Routine Enforcement Man-Hours

MONTH	MAN-HOURS
<i>September, 1996</i>	<i>20</i>
<i>October, 1996</i>	<i>10</i>
<i>November, 1996</i>	<i>25</i>
<i>December, 1996</i>	<i>4</i>
<i>January, 1997</i>	<i>29</i>
<i>February, 1997</i>	<i>14</i>
<i>March, 1997</i>	<i>29</i>
<i>April, 1997</i>	<i>27</i>
<i>May, 1997</i>	<i>21</i>
<i>June, 1997</i>	<i>11</i>
<i>July, 1997</i>	<i>32</i>
<i>August, 1997</i>	<i>17</i>

6.5.4 Compliance Summary

The average compliance rate for any given section or direction ranged from 79% to 84%. Similarly, the average corridor compliance rate for any given compliance survey ranged from 75% to 87% in the westbound direction and from 78% to 86% in the eastbound direction. Overall, the HOV facility on the Barnet/Hastings corridor has not achieved its desired rate of compliance of 85% but has maintained an effective rate of no less than 75% on any given section or direction for any given survey. However, it should be noted that the compliance rate has been decreasing since the opening of the HOV lane in the Fall of 1996.

In addition to the compliance rates, estimates of the total number of HOV violation tickets issued along the corridor and the level of enforcement activity along the Burnaby section of the HOV facility were presented. While not conclusive, the violation and enforcement data results are useful in developing an understanding of the level of enforcement that occurred during the HOV facility's first full year of operation.

6.6 SAFETY

The 'Safety' objective is evaluated in this section for the HOV facility on the Burnet/Hastings corridor. Four years of "before" accident data (Jan.'92 - Dec.'95) and ten months of "after" accident data (Sept.'96 - Jun.'97) from MoTH's accident database were analyzed according to the framework. In addition, raw accident data was also obtained from the City of Burnaby and the City of Vancouver. However, the accident data was determined to be inconsistent and, therefore, inaccurate. The results of the three sources contradict each other. Therefore, only MoTH's accident data was analyzed as part of the application. The accident data of the City of Burnaby and the City of Vancouver can be found in Appendix H - Safety Data.

The "before-and-after" accident data from MoTH did not include any accident statistics on the most western part of the Hastings St. section of the HOV facility. The safety of the last few kilometers of the HOV facility, west of Boundary Road to Renfrew Street, is the responsibility of the City of Vancouver (see Figure 6.1). Therefore, the safety analysis was performed from Boundary Road in Vancouver to Ioco Road in Port Moody. The corridor was divided up into major intersections and short road sections comprised of minor intersections and road segments. Table 6.20 summarizes the intersections as well as the sections and their respective lengths.

To calculate the accident rates, many assumptions had to be made. For example, no "after" AADT data was available so it was assumed to have remained constant. Therefore, no conclusions or interpretations were made from the analysis of the safety data.

Table 6-20: Summary of Intersections and Sections

INTERSECTION	LKI	SECTION	LKI (start)	LKI (finish)	LENGTH (kms)
Boundary	0.0	Boundary to Gilmore	0.0	0.7	0.7
Gilmore	0.7	Gilmore to Willingdon	0.7	1.5	0.8
Willingdon	1.5	Willingdon to Springer	1.5	2.7	1.2
Springer	2.7	Springer to Ellensmere	2.7	3.0	0.3
Ellensmere	3.0	Ellensmere to Holdom	3.0	3.2	0.2
Holdom	3.2	Holdom to Sperling	3.2	4.3	1.1
Sperling	4.3	Sperling to Malibu	4.3	5.5	1.2
		Malibu to Texaco	5.5	7.3	1.8
		Texaco to PetroCan	7.3	10.2	2.9
		PetroCan to Reed	10.2	11.4	1.2
		Reed to Gore	11.4	12.8	1.4
Gore	12.8	Gore to St. Johns	12.8	13.5	0.7
St. Johns	13.5	St. Johns to Queens	13.5	14.1	0.6
Queens	14.1	Queens to Moody	14.1	14.7	0.6
Moody	14.7	Moody to Hugh	14.7	14.9	0.2
Hugh	14.9	Hugh to Dewdney	14.9	16.3	1.4
Dewdney	16.3				
loco	16.4				

However, the accident rates were still calculated as part of the application as an example for future HOV evaluations. Information concerning the calculation of the accident rates and any assumptions that were made are described in the following list:

- ♦ The "before" AADT volume DATA for the road sections was obtained from a short count location at Holdom Ave. on Hastings St. in the city of Burnaby (see Table 6.21). The average AADT for the 4 years between 1992 and 1995 was determined to be 33,400 vehicles per day. It was assumed that the AADT was constant for the entire corridor.

Table 6-21: Holdom Avenue Traffic Volume Data (1992 -1995)

(Source: Traffic Information Management System, MoTH)

YEAR	1992	1993	1994	1995	AVERAGE
AADT	30,725	34,671	33,012	35,101	33,400

- ◆ No “after” AADT volume data for the sections was available for the application.
Therefore, an assumption was made that the “after” AADT volume data for sections had remained constant at 33,400 vehicles per day.
- ◆ No “before-and-after” AADT volume data was available for the intersections.
Therefore, intersections were assumed to have the same “before-and-after” AADT volume data as the road sections (33,400 veh/day).
- ◆ Only ten months of “after” data were available at the time of the application. It was assumed that this was a representative amount of time post-construction of the HOV lane.
- ◆ The lengths of the sections were assumed to be equal to the exact distance in between two major intersections. In other words, the length of the intersections themselves was assumed to be negligible.
- ◆ Since the opening of the HOV facility, there have been changes made by the local enforcement agencies in the reporting procedure of accidents. Therefore, it is possible that the “after” accident data was not reported under the same criteria as the “before” data. It is generally conceived that less accidents are being reported since these changes were made.

6.6.1 Accident Rates

Intersections

Figure 6.19 summarizes the “before-and-after” accident rates of the intersections of the HOV facility on the Barnet/Hastings corridor. Ten out of the fourteen intersections (71%) experienced a decrease in their “before-and-after” accident rates. The four intersections

whose accident rates have increased since the implementation of the HOV lane are as follows:

- ◆ Ellensmere Avenue (Hastings St.)
- ◆ Gore Street (Barnet Highway)
- ◆ Queens Street (St. Johns St.)
- ◆ Hugh Street (St. Johns St.)

The mean "before" intersection accident was calculated to be 0.74 acc/MEV as compared to the mean "after" intersection accident rate of 0.58 acc/MEV. The difference between the "before-and-after" mean intersection accident rates was tested for statistical significance. It was determined that even though the mean accident rate for intersections along the Barnet/Hastings corridor has decreased since prior to the HOV lane, the difference between the two means was not statistically significant at the 95% or 90% confidence levels.

Sections

Figure 6.20 summarizes the "before-and-after" accident rates of the sections of the HOV facility on the Barnet/Hastings corridor. Thirteen out of the sixteen road sections (81%) experienced an increase in their "before-and-after" accident rates. The intersections whose accident rates have decreased since the implementation of the HOV lane are:

- ◆ Reed Point to Gore Street (Barnet Highway)
- ◆ St. Johns St. to Queens Street (St. Johns St.)
- ◆ Hugh Street to Dewdney Trunk Road (St. Johns St.)

The difference between the mean "before-and-after" accident rates of the section was determined to be statistically significant at the 95% confidence level. The mean "before" section accident rate was calculated to be 0.83 acc/MVK and the mean "after" section accident rate was calculated to be 1.63 acc/MVK.

6.6.2 Safety Summary

The accident and traffic volume data obtained for the application of the framework to evaluate the 'Safety' objective was incomplete and inconsistent. It was not possible to perform a meaningful "before-and-after" safety analysis where representative conclusions could be made. However, the application of the safety objective was still performed with the data obtained as an example for future HOV evaluations.

6.7 IMPACT ON GP LANES

The effect of the HOV facility on the Barnet/Hastings corridor on the operation of the general purpose (GP) lanes was evaluated in this section. As noted previously, the HOV lane should not adversely affect the GP lane. Travel time survey and vehicle classification and occupancy data were obtained for the application.

"Before" data was obtained in March, 1996 and "after" was obtained in both October, 1997 and October, 1997. The GP travel speeds of the entire corridor were quantified as well as the GP vehicular volumes for each section of the HOV facility.

Figure 6.19 : "Before-and-After" Intersection Accident Rates

Figure 6.20 : "Before-and-After" Section Accident Rates

6.7.1 GP Travel Speeds

Figures 6.21 and 6.22 show the mean peak hour “before-and-after” GP travel speeds of the corridor. The westbound GP travel speed of the corridor has increased from 30 km/h to an average of 36 km/h since the introduction of the HOV lane. In the eastbound direction, the GP travel speed has also increased from 28 km/h to 39 km/h.

Figure 6-21: Westbound GP Travel Speeds

Figure 6-22: Eastbound GP Travel Speeds

6.7.2 GP Vehicular Volumes

Westbound

Table 6.25 summarizes the westbound peak hour “before” and most recent “after GP travel speeds and GP vehicular volumes of specific locations along the Barnet/Hastings corridor where the HOV lane was added to the existing facility. Along St. Johns St., the GP travel speed has more than doubled from 18 km/h to 42 km/h as the vehicular volume has remained the same. The GP travel speed along the Barnet Highway has slightly decreased from 44 km/h to 40 km/h. However, the GP volumes have increased at both the Reed and Bayview locations. Finally, the Hastings St. GP travel speed has slightly decreased as its GP vehicular volume has remained approximately the same.

Table 6-22: Westbound "Before-and-After" GP Vehicular Volumes

LOCATION	TYPE OF GP DATA	Mar-1996	Oct-1997
Williams (St. Johns St.)	travel speed (km/h)	18	42
	vehicular volume	2060	2060
Reed (Barnet Hwy)	travel speed (km/h)	44	40
	vehicular volume	1360	1500
Bayview (Barnet Hwy)	travel speed (km/h)	44	40
	vehicular volume	1390	1400
Willingdon (Hastings St.)	travel speed (km/h)	28	24
	vehicular volume	1910	1890

Eastbound

Table 6.26 summarizes the eastbound peak hour "before" and most recent "after" GP travel speeds and GP vehicular volumes of specific locations along the HOV facility on the Barnet/Hastings corridor.

Table 6-23: Eastbound "Before-and-After" GP Vehicular Volumes

LOCATION	TYPE OF GP DATA	Mar-1996	Oct-1997
Willingdon (Hastings St.)	travel speed (km/h)	23	28
	vehicular volume	1830	2070
Bayview (Barnet Hwy)	travel speed (km/h)	35	59
	vehicular volume	1380	1640
Union (Barnet Hwy)	travel speed (km/h)	35	59
	vehicular volume	1430	1820

Along Hastings St., the GP travel speed has increased from 23 km/h to 28 km/h as the vehicular volume has increased from 1830 to 2070. The GP travel speed along the Barnet Highway has increased significantly from 35 km/h to 59 km/h. At the same time, the GP volumes have also increased significantly at both the Bayview and Union locations.

6.7.3 Impact on GP Lanes Summary

Overall, the HOV lane has not adversely affected the operation of the GP lanes. There has been an increase in the peak hour corridor GP travel speed in both directions of travel: 6 km/h westbound and 11 km/h eastbound. On an aggregate level, the GP travel speed has increased on one out of the three westbound sections and on all of the eastbound sections while the GP vehicular volume has increased or remained the same.

6.8 MULTI-CRITERIA EVALUATION

A multi-criteria evaluation was performed on the HOV facility of the Barnet/Hastings HOV corridor. This section summarizes the results of the evaluation and sensitivity analysis. It was not possible to calculate the present value of the travel time saved because the Greater Vancouver Regional District (GVRD) EMME/2 model was under calibration at the time of the application. Therefore, it was not possible to quantify the cost-effectiveness MOEs as described in the framework. However, for illustration purposes only, the EMME/2 model was used to obtain an understanding of the magnitude of the travel time savings.

No enforcement or marketing costs were accrued or anticipated in the future for the HOV facility. Therefore, the present values of these cost were not quantified. However, the present value of the following benefits and costs were determined:

- ◆ Vehicle operating cost savings
- ◆ Air quality savings
- ◆ Construction costs
- ◆ Maintenance costs

6.8.1 Project Parameters

It was assumed that the most likely value of the life of the HOV facility on the Barnet/Hastings corridor is 20 years, as recommended in MoTH's Economic Analysis Guidebook (MoTH, 1993). A typical year is comprised of 250 working days. As previously mentioned, the range of discount rates to be used in the multi-criteria evaluation is between 6% to 12% with a most likely value of 8%. However, it is common practice to assume a discount rate of 0% to 4% for environmental benefits and costs (Bein et al., 1994). Therefore, a conservative fixed discount rate of 4% was selected to calculate the air quality savings of the facility. Actual person-volumes were obtained from vehicle classification and occupancy counts for 1996 and 1997. It is assumed that the traffic volume on the HOV facility will increase over time. Therefore, the person-volumes of future years were based on the 1997 figures and a most likely growth rate of 2%.

6.8.2 Travel Time Savings

The westbound travel time savings was quantified from the base year of 1996 to 2006, half of the life of the project. Peak hour 2006 travel time differences were obtained from the EMME/2 model. Peak hour travel time differences for 1996 were obtained from actual travel time survey data. The peak hour travel time differences of the years between 1996 and 2006 were obtained through interpolation. Table 6.28 summarizes the 1996 and 2006 peak hour travel time differences.

Table 6-24: Peak Hour Travel Time Differences

LANE	YEAR	St.Johns St.	Barnet Hwy.	Hastings St.	TOTAL
GP	1996	5.8	1.9	0.8	8.5
	2006	6.4	6.9	19.6	32.9
HOV	1996	5.4	4.5	3.0	12.9
	2006	7.5	7.6	20.2	35.3

NOTES: - 1996 values based on "before" travel times (Mar-96) and "after" travel times (Oct-96) : APPENDIX E
- 2006 values based on EMME/2 model output : APPENDIX J

The most likely present value of the westbound peak hour travel time savings was estimated to be \$22,530,000 for half of the life of the project. The total amount of travel time savings in the westbound direction was calculated by multiplying the present value of the westbound peak hour travel time savings by a factor of 1.97. The factor was determined based on the travel time savings values reported in the '*Benefit/Cost Evaluation of Barnet/Hastings Project*' (MoTH, 1993). The determination of the westbound and eastbound factors is found in Appendix J - Multi-Criteria Evaluation. Therefore, the most likely present value of the total westbound travel time savings was estimated to be \$44,380,000 (for 1996 to 2006). The results of the sensitivity analysis performed on the total westbound travel time savings are summarized in Table 6.29.

Table 6-25: Westbound Travel Time Savings Sensitivity Analysis

CRITERIA	WORST CASE	MOST LIKELY	BEST CASE
<i>Discount Rate</i>	12%	8%	6%
<i>Average Wage Rate</i>	\$14/hr	\$18/hr	\$23/hr
<i>Growth Rate</i>	0%	2%	5%
TOTAL PV	\$26,090,000	\$44,380,000	\$72,710,000

NOTES: - calculated for the years 1996 to 2006 only
 - Total PV = output of sensitivity x 1.97 (APPENDIX J)

6.8.3 Vehicle Operating Cost Savings

The most likely present value of the vehicle operating cost savings was determined to be \$1,590,000. The vehicle operating cost savings was calculated for the westbound and eastbound peak periods based on the mean and 95% confidence limits of the 1997 data (see Appendix C - AVO Data). Table 6.30 summarizes the results of the sensitivity analysis on the vehicle operating cost savings.

Table 6-26: Vehicle Operating Cost Savings Sensitivity Analysis

CRITERIA	WORST CASE	MOST LIKELY	BEST CASE
<i>Discount Rate</i>	12%	8%	6%
<i>AVO - Westbound</i>	1.25	1.27	1.29
<i>AVO - Eastbound</i>	1.32	1.33	1.34
<i>Unit Cost</i>	\$0.08/km	\$0.09/km	\$0.12/km
<i>Growth Rate</i>	0%	2%	5%
TOTAL PV	\$660,000	\$1,590,000	\$4,150,000

6.8.4 Air Quality Savings

The most likely present value of the air quality savings was determined to be \$960,000. Similar to the vehicle operating cost savings, the air quality savings was calculated from 1997 AVO data for the peak periods of HOV operation only. Table 6.31 summarizes the results of the sensitivity analysis on the air quality savings.

Table 6-27: Air Quality Savings Sensitivity Analysis

CRITERIA	WORST CASE	MOST LIKELY	BEST CASE
<i>AVO - Westbound</i>	1.25	1.27	1.29
<i>AVO - Eastbound</i>	1.32	1.33	1.34
<i>Unit Cost</i>	\$0.02/km	\$0.04/km	\$0.08/km
<i>Growth Rate</i>	0%	2%	5%
TOTAL PV	\$270,000	\$960,000	\$3,320,000

NOTES: - a fixed discount rate of 4% was used to calculate each air quality savings PV

6.8.5 Construction Costs

The actual construction costs of the HOV facility on the Barnet/Hastings HOV corridor were obtained from the 'Barnet/Hastings People Moving Project Completion Report' (MoTH², 1997). The most likely total present value of the construction costs was calculated to be \$127,330,000. The worst case construction cost (discount rate of 12%) was determined to be \$140,340,000 and the best case construction cost (discount rate of 6%) was determined to be \$121,340,000.

6.8.6 Maintenance Costs

The total number of lane-kilometers of the HOV facility was calculated to be 82.75 kilometers. The total maintenance cost per year for the HOV facility was obtained from MoTH's 'Service Area #6 Year 2 Maintenance Services Contract' (MoTH³, 1997). A yearly rate of \$6326.83/lane-km was reported for Class 1A highways such as the Barnet/Hastings corridor. The yearly rate was increased and decreased by 10% for the sensitivity analysis. A total present value of \$5,550,000 was determined for the maintenance costs. Table 6.32 summarizes the results of the sensitivity analysis on the maintenance costs.

Table 6-28: Maintenance Costs Sensitivity Analysis

CRITERIA	WORST CASE	MOST LIKELY	BEST CASE
<i>Maintenance Cost</i>	\$5694/lane-km	\$6327/lane-km	\$6960/lane-km
<i>Discount Rate</i>	6%	8%	12%
TOTAL PV	\$7,000,000	\$5,551,000	\$3,940,000

6.8.7 Summary

The following benefits and costs of the HOV facility on the Barnet/Hastings corridor were quantified as part of the multi-criteria evaluation:

- ◆ Construction costs \$127,330,000 (PV)
- ◆ Maintenance costs \$5,550,000 (PV)
- ◆ Vehicle operating cost savings \$1,590,000 (PV)
- ◆ Air quality savings \$960,000 (PV)

In addition, the present value of the westbound travel time savings for half of the life of the project was determined to be \$44,380,000. Based on these estimates, it is clear that the HOV travel time savings alone will greatly exceed the construction and maintenance costs of the HOV facility. Therefore, it is estimated that the Barnet/Hastings HOV facility is cost-effective.

7. CONCLUSION

An HOV monitoring and evaluation framework was developed to evaluate the effectiveness of either arterial or freeway HOV facility. An extensive literature review on HOV evaluation practices in North America was performed and the framework was designed based on these HOV evaluation procedures that currently exist.

The HOV monitoring and evaluation framework is a procedure to evaluate an HOV facility based on a set of quantifiable objectives. As a contribution to existing HOV evaluation procedures, the evaluation objectives are selected and categorized into three groups by their relationship to the goals of the HOV network: primary, supporting, and operational. Measures of effectiveness (MOEs) that directly relate to the set of objectives are selected to determine the effectiveness of each objective. The data requirements to evaluate each of the MOEs is summarized. In addition, a data collection methodology and comprehensive procedures for analyzing and presenting the MOEs are described in the framework. To enhance current practices of evaluating HOV facilities, the framework describes procedures to calculate the statistical reliability and relative uncertainty of the data collected as well the testing of the difference between two MOEs for statistical significance. A multi-criteria HOV evaluation and sensitivity analysis methodology is presented for evaluating the cost-effectiveness of an HOV facility.

An application of the proposed HOV monitoring and evaluation framework was performed to evaluate the effectiveness of the HOV facility on the Barnet/Hastings corridor. "Before-and-after" data was retrieved through numerous agencies and used to calculate the respective MOEs of the primary, supporting, and operational objectives of

the framework. The objectives of the framework that are considered to be effective include: 'Person Throughput', 'Travel Time Savings', and 'Impact on GP Lanes'. The travel speed standard deviations of the HOV lane are less than the GP lane. However, it was determined the HOV lane is not providing a statistically significant more reliable trip at the 95% confidence level. The Ministry of Transportation and Highways desired compliance rate of 85% is not presently being attained on the Barnet/Hastings corridor. No public opinion survey data relating to the operation of the HOV facility is available for the application and the safety results are not conclusive. Finally, a preliminary analysis indicated that the HOV facility on the Barnet/Hastings corridor is cost-effective.

In applying the framework, deficiencies in the availability of applicable data were noted as well as suggestions for further HOV evaluation research. The following is a list of the deficiencies and/or recommendations presented in the thesis:

- ◆ Extensive baseline information should always be collected on a corridor prior to the construction of an HOV facility. The HOV facility should be regularly evaluated in its first few years of operation.
- ◆ Parallel routes adjacent to an HOV facility should be identified in advance and appropriate "before-and-after" data collected accordingly.
- ◆ AADT volume data should be collected yearly at a minimum of one representative location along an HOV facility.
- ◆ Travel time and vehicle classification data should be collected at approximately the same time of year for HOV evaluation purposes, preferably the same week of a calendar year.

- ◆ A public opinion survey should be conducted on the HOV facility to establish the public's perception of the operation and effectiveness of the HOV lane.
- ◆ The level of enforcement activity of local enforcement agencies should be kept in records and correlated to the compliance rate to enhance the evaluation of the compliance objective.
- ◆ The safety of the HOV lane should be compared to that of the GP lanes. However, current accident reporting practice does not include referencing to either the HOV or GP lane specifically. In addition, the current accident reporting procedures should be improved so that meaningful "before-and-after" safety evaluations can be performed on the facility.
- ◆ A "before-and-after" safety comparison method such as the Empirical Bayes approach which makes use of a reference group to account for the randomness inherent in the accident occurrence process should be used to determine the reduction in accidents on an HOV facility.
- ◆ Only the quantifiable benefits and costs should be considered in the benefit-cost analysis. However, criteria that is difficult to quantify should still be considered in the economic justification of an HOV facility.
- ◆ A probabilistic economic evaluation which accounts for the uncertainty of the cost-effectiveness of an HOV facility should be performed, if possible.

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APPENDIX A - STATISTICAL ANALYSIS

INTRODUCTION

This appendix outlines the statistical procedures for collecting and analysing the data as described in the HOV monitoring and evaluation framework. The following statistical tests or methodologies are presented:

- ◆ Sample size estimation
- ◆ Statistical reliability
- ◆ 95% confidence limits
- ◆ Two sample *t*-test
- ◆ Paired sample *t*-test
- ◆ F-test

SAMPLE SIZE ESTIMATION

Travel time runs should be performed using the 'average' car technique as described in the '*ITE Transportation and Traffic Engineering Handbook*' (ITE, 1982). The travel times of test vehicles as they pass through the middle of designated intersections and at the beginning and terminal points of the HOV facility should be recorded. In addition, traffic conditions and critical events that should also be recorded include: weather conditions; locations and time of incidents; stalled or parked vehicles; etc..

To determine an estimate of the sample size required for a travel time survey, the level of confidence is firstly selected. As presented in the framework, a 95% level of confidence is recommended for all HOV monitoring and evaluation purposes. The desired level of accuracy of the travel time runs is then selected. For before-and-after studies, the '*ITE Transportation and Traffic Engineering Handbook*' (ITE, 1982) suggests a range of specified permitted errors between ± 2 km/h to ± 5 km/h. Finally, an estimate of the standard deviation of the travel time runs to be performed is selected. The standard deviation should be estimated based on the most recent available travel time data.

When all of the assumptions have been made, the following equation is used to determine an estimate of the required sample size:

$$\text{estimate of the sample size required} = \left[\frac{Z_{\alpha/2} \sigma}{d} \right]^2$$

where

$Z_{\alpha/2}$ = standard normal statistic corresponding to the $1-\alpha$ level of confidence
= 1.96 for a 95% level of confidence

d = acceptable margin of error of mean value (km/h)
= 2.0 to 5.0 km/h

σ = estimate of the standard deviation (km/h)

EXAMPLE:

$$\begin{aligned}Z_{\alpha/2} &= 1.96 \\d &= 2.0 \text{ to } 5.0 \text{ km/h} \\\sigma &= 7.7 \text{ km/h}\end{aligned}$$

<u>Acceptable Margin of Error</u>	<u>Estimate of Required Sample Size</u>
2.0 km/h	57
3.5 km/h	19
5.0 km/h	10

It should be noted that the number of travel time runs required is a function of the estimate of standard deviation estimate (7.7 km/h in the example). To understand the importance of selecting a meaningful and representative standard deviation, a sensitivity analysis on the estimate of the required sample size is performed by varying the standard deviation.

<u>Standard Deviation</u>	<u>Acceptable Margin of Error</u>		
<u>km/h</u>	<u>2.0 km/h</u>	<u>3.5 km/h</u>	<u>5.0 km/h</u>
5.0	25	8	4
6.0	36	12	6
7.0	48	16	8
8.0	62	21	10
9.0	78	26	13
10.0	97	32	16

The sensitivity analysis shows that the estimate of the required sample size increases as:

- ♦ the estimate of the standard deviation increases
- ♦ the acceptable margin of error decreases

Therefore, a conservative acceptable margin of error of 5km/h per hour is recommended to estimate the required sample size of a travel time survey.

STATISTICAL RELIABILITY

The statistical reliability of a sample of data is determined by quantifying the sample's margin of error as follows:

$$\text{margin of error} = \frac{s * t_{\alpha/2}}{\sqrt{n}}$$

where

- $t_{\alpha/2}$ = test-statistic at the 95% confidence level ($t_{0.025}$ or $z_{0.025}$)
- n = number of travel times runs performed
- s = the standard deviation of the travel speeds (km/h)

The test-statistic is obtained from either the z-distribution ($n > 30$) or the t-distribution ($n < 30$), depending on the sample size. In addition, it is recommended that the margin of error be presented as a percentage of the mean as follows:

$$\text{margin of error} = \left(\frac{s * t_{\alpha/2}}{\sqrt{n}} \right) \times 100\%$$

mean

Travel Time Data

For travel time data, the margin of error should be less than the specified permitted error of 5 km/h as recommended in the 'ITE Transportation and Traffic Engineering Handbook' (ITE, 1982). Travel time data with margins of error less than 5km/h are considered to be statistically reliable.

EXAMPLE:

$t_{\alpha/2}$	= 2.110	margin of error	= 3.8 km/h
n	= 18		= 8% of the mean
s	= 7.7 km/h		
mean	= 47.2 km/h		

Therefore, because the margin of error is less than 5.0 km/h, the sample of travel time data is considered to be statistically reliable.

AVO Data

For AVO data, only the margin of error expressed as a percentage of the mean is calculated and discussed.

EXAMPLE:

$z_{\alpha/2}$	= 1.96	margin of error	= 1% of the mean
n	= 50		
s	= 0.049		
mean	= 1.230		

95% CONFIDENCE LIMITS

95% confidence limits are determined with the following formula:

$$\bar{x} \pm t_{\alpha/2} * \frac{s_x}{\sqrt{n}}$$

where

$\bar{x}$	= sample mean
$t_{\alpha/2}$	= test-statistic at the 95% confidence level ($t_{0.025}$ or $z_{0.025}$)
s_x	= standard deviation of the sample

n = sample size

The test-statistic is obtained from either the z-distribution ($n > 30$) or the t-distribution ($n < 30$), depending on the sample size.

Large Samples ($n > 30$)

Samples sizes greater than 30 are assumed to have a distribution that is approximately normal and a population standard deviation that is known and fixed. Therefore, the z-distribution is used to establish the 95% confidence limits for sample sizes greater than 30.

EXAMPLE:

The mean peak period AVO was calculated to be 1.230 with a standard deviation of 0.049. The sample size was 50.

$$\begin{aligned}\bar{x} &= 1.230 \\ z_{\alpha/2} &= 1.96 \\ s_x &= 0.049 \\ n &= 50\end{aligned}$$

Therefore, the 95% confidence interval of the mean peak period AVO is:

$$\begin{aligned}1.23 \pm 0.01 \\ 1.22 \text{ to } 1.24\end{aligned}$$

Small Samples ($n < 30$)

To determine the 95% confidence limits for samples less than 30 in size, it is necessary to assume that the sample is approximately normally distributed. However, the population mean is unknown and the sampling distribution is, therefore, based on the sample's standard deviation as opposed to the population's. Therefore, the t-distribution with $n-1$ degrees of freedom is used to establish the 95% confidence limits for sample sizes of less than 30.

EXAMPLE:

The mean peak hour travel time savings was calculated to be 4.31 minutes with a standard deviation of 1.19 minutes. The sample size was 8.

$$\begin{aligned}\bar{x} &= 4.31 \text{ minutes} \\ t_{\alpha/2} &= t_{0.025} \text{ for a 95\% confidence level and 7 degrees of freedom} \\ &= 2.365 \\ s_x &= 1.19 \text{ minutes} \\ n &= 8\end{aligned}$$

Therefore, the 95% confidence interval of the mean peak hour travel time savings is:

$$\begin{aligned}4.31 \text{ minutes} \pm 1.0 \text{ minutes} \\ 3.31 \text{ to } 5.31 \text{ minutes}\end{aligned}$$

STATISTICAL SIGNIFICANCE

Statistical hypothesis testing is used to determine the statistical significance of a measure of effectiveness (MOE). The construction of a hypothesis test requires the formation of a null hypothesis, H_0 , and an alternative hypothesis, H_A . The null hypothesis should always be defined as the hypothesis which, it is hoped, will be rejected. The alternative hypothesis can be defined in a number of ways. The following examples illustrate the use of hypothesis testing to determine the statistical significance of MOEs. For HOV evaluations, all of the hypothesis testing is performed at the 95% confidence level.

Two Sample t-test (large samples)

$$\text{z-statistic} = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{\sigma_A^2}{n_A} + \frac{\sigma_B^2}{n_B}}}$$

where

- $\bar{X}_A$ = mean of sample A
- $\bar{X}_B$ = mean of sample B
- σ_A = standard deviation of sample A
- σ_B = standard deviation of sample B
- n_A = sample size of A
- n_B = sample size of B

Null Hypothesis

$$H_0 : \mu_A - \mu_B = 0$$

Alternative Hypothesis

- $H_A : \mu_A - \mu_B \neq 0$
- $H_A : \mu_A - \mu_B > 0$
- $H_A : \mu_A - \mu_B < 0$

Rejection Region

- $|z\text{-statistic}| > z_{\alpha/2}$
- $z\text{-statistic} > z_{\alpha}$
- $z\text{-statistic} < z_{\alpha}$

EXAMPLE:

The difference between two mean AVOs is tested using the two-sample t-test and the hypothesis that the "after" AVO is greater than the "before" AVO ($H_A : \mu_A - \mu_B > 0$). The "before" AVO was 1.230 with a standard deviation of 0.049 and a sample size of 50. The "after" AVO was 1.293 with a standard deviation of 0.065 and a sample size of 50.

The z-statistic is calculated to be 5.5 and the z_{α} is 1.645. Therefore, the difference in the "before-and-after" AVOs is considered to be statistically significant.

Two Sample t-test (small samples)

Before we can compute the t-statistic for the difference in means for small samples, a pooled estimate of the population standard deviation (s_p) is required:

$$s_p^2 = \frac{(n_A - 1)s_A^2 + (n_B - 1)s_B^2}{n_A + n_B - 2}$$

where

s_A = standard deviation of sample A

s_B = standard deviation of sample B

n_A = sample size of A

n_B = sample size of B

$$\text{t-statistic} = \frac{\bar{X}_A - \bar{X}_B}{s_p \sqrt{\frac{1}{n_A} + \frac{1}{n_B}}}$$

($n_A + n_B - 2$) degrees of freedom

where

$\bar{X}_A$ = mean of sample A

$\bar{X}_B$ = mean of sample B

s_p = pooled standard deviation

n_A = sample size of A

n_B = sample size of B

Null Hypothesis

$$H_0 : \mu_A - \mu_B = 0$$

Alternative Hypothesis

$$H_A : \mu_A - \mu_B \neq 0$$

$$H_A : \mu_A - \mu_B > 0$$

$$H_A : \mu_A - \mu_B < 0$$

Rejection Region

$$|\text{t-statistic}| > t_{\alpha/2}$$

$$\text{t-statistic} > t_{\alpha}$$

$$\text{t-statistic} < t_{\alpha}$$

EXAMPLE:

The difference between two mean AVOs is tested using the two-sample t-test and the hypothesis that the "after" AVO is greater than the "before" AVO ($H_A : \mu_A - \mu_B > 0$). The "before" AVO was 1.248 with a standard deviation of 0.060 and a sample size of 20. The "after" AVO was 1.323 with a standard deviation of 0.046 and a sample size of 20.

The pooled variance is calculated to be 0.053. The t-statistic is calculated to be 4.4 and the t_{α} is 1.645 for 38 degrees of freedom. Therefore, the difference in the "before-and-after" AVOs is considered to be statistically significant.

Paired Sample t-test

A paired sample *t*-test is performed when sample data has been collected in pairs. The mean difference between two samples is determined to be statistically significant if the *t*-statistic obtained is greater than a *t*-critical for a 95% level of confidence and *n*-1 degrees of freedom.

$$t\text{-statistic} = \frac{\bar{D}}{S_D / \sqrt{n}}$$

(*n*-1) degrees of freedom

where

$\bar{D}$ = mean of the differences ($X_A - X_B$)

S_D = standard deviation of the differences

n = sample size (number of paired samples or differences)

Null Hypothesis

$$H_0 : u_d = 0$$

Alternative Hypothesis

$$H_A : u_d \neq 0$$

$$H_A : u_d > 0$$

$$H_A : u_d < 0$$

Rejection Region

$$|t\text{-statistic}| > t_{\alpha/2}$$

$$t\text{-statistic} > t_{\alpha}$$

$$t\text{-statistic} < t_{\alpha}$$

EXAMPLE (Travel Time Difference Data):

The mean of the peak hour travel time differences was calculated to be 4.31 minutes with a standard deviation of 1.19 minutes. The sample size was 8.

$$\begin{array}{ll} \bar{D} &= 4.31 \text{ minutes} \\ S_D &= 1.19 \text{ minutes} \\ n &= 8 \end{array} \quad \begin{array}{ll} t\text{-statistic} &= 10.244 \end{array}$$

$$\begin{array}{ll} H_A : u_d > 0 & t\text{-statistic} > t_{\alpha} \\ & > t_{0.05} @ 95\% \text{ with } 7 \text{ d.o.f.} \\ & > 1.895 \end{array}$$

Therefore, because the *t*-statistic is greater than the *t*-critical, the travel time difference between travelling in the GP and HOV lanes is significant at the 95% confidence level.

EXAMPLE ("Before-and-after" Safety Data):

The difference between the mean "before" accident rate and mean "after" accident rate is also determined with a paired sample test. However, a pooled standard deviation is used as follows:

$$S_D^2 = S_B^2 + S_A^2 - 2 \left[\frac{\sum (X_B - X_{B(\text{mean})})(X_A - X_{A(\text{mean})})}{n-1} \right]$$

F-test

An F-test is performed to compare two sample standard deviations. The difference in the two sample standard deviations is determined by examining the ratio of sample variances (the F-statistic). If the F-statistic is greater than an F-critical for a 95 % level of confidence and respective degrees of freedom, then the difference in the standard deviation is considered to be significant. F-statistics in statistical tables are always greater than one in value, therefore, the sample standard deviation of A should be greater than sample B's for performing such a test.

$$F\text{-statistic} = \frac{\sigma_A^2}{\sigma_B^2}$$

($n_A - 1$) degrees of freedom in the numerator
($n_B - 1$) degrees of freedom in the denominator

where

σ_A = standard deviation of sample A
 σ_B = standard deviation of sample B
 n_A = sample size of A
 n_B = sample size of B

Null Hypothesis

$$H_0 : \sigma_A^2 = \sigma_B^2$$

Alternative Hypothesis

$$H_A : \sigma_A^2 > \sigma_B^2$$

Rejection Region

$$F\text{-statistic} > F_\alpha (n_A - 1, n_B - 1)$$

EXAMPLE:

The standard deviation of the HOV lane was calculated to be 2.95 km/h while that of the adjacent GP lane was calculated to be 5.17 km/h. The sample size of the travel time reliability survey was 12 for both lanes.

σ_A = 5.17 km/h
 σ_B = 2.95 km/h
 n_A = 12
 n_B = 12

F-statistic = 3.06

$$H_A : \sigma_A^2 > \sigma_B^2$$

F-statistic > $F_\alpha (n_A - 1, n_B - 1)$
> $F_{0.05} (11, 11)$
> 2.82

Therefore, because the F-statistic is greater than the F-critical, the difference in the standard deviations is considered to be statistically significant at the 95% confidence level. In other words, the HOV lane is more reliable than the GP lane.

PER-LANE EFFICIENCY

MARCH, 1996

WESTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	St. Johns Street	Barnet Highway		Hastings Street	
<i>Location</i>	Williams	Reed	Bayview	Willingdon	Lilloet
<i>Total # of lanes</i>	3	1	1	2	3
<i>Total Person Volume</i>	3294	1814	1939	3278	4592
<i>time (hrs)</i>	1	1	1	1	1
GP					
<i># of lanes</i>	3	1	1	2	3
<i>person volume</i>	3294	1814	1939	3278	4592
<i>speed (km/h)</i>	18	44	44	28	28
<i>Per-Lane Efficiency</i>	20	80	85	46	43
HOV					
<i># of lanes</i>					
<i>person volume</i>					
<i>speed (km/h)</i>					
<i>Per-Lane Efficiency</i>					

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location</i> <i>Per-Lane</i> <i>Efficiency</i>	20	80	85	46	43
<i>Section</i> <i>Per-Lane</i> <i>Efficiency</i>	20	83	44		

PER-LANE EFFICIENCY
OCTOBER, 1996
WESTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	St. Johns Street	Barnet Highway		Hastings Street	
<i>Location</i>	Williams	Reed	Bayview	Willingdon	Lillooet*
<i>Total # of lanes</i>	3	2	2	3	
<i>Total Person Volume</i>	3519	3091	2826	3693	
<i>time (hrs)</i>	1	1	1	1	
<i>GP</i>					
<i># of lanes</i>	2	1	1	2	
<i>person volume</i>	2507	1941	1826	1505	
<i>speed (km/h)</i>	45	53	53	30	
<i>Per-Lane Efficiency</i>	56	103	97	23	
<i>HOV</i>					
<i># of lanes</i>	1	1	1	1	
<i>person volume</i>	1012	1150	1000	2188	
<i>speed (km/h)</i>	40	75	75	35	
<i>Per-Lane Efficiency</i>	40	86	75	77	

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location Per-Lane Efficiency</i>	51	95	86	41	
<i>Section Per-Lane Efficiency</i>	51	90	41		

NOTES:

1. Volumes at Lillooet not included due to an accident on day of survey

PER-LANE EFFICIENCY**OCTOBER, 1997****WESTBOUND**

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	St. Johns Street	Barnet Highway		Hastings Street	
<i>Location</i>	Williams	Reed	Bayview	Willingdon	Lilloet
<i>Total # of lanes</i>	3	2	2	3	3
<i>Total Person Volume</i>	3862	3117	3312	4028	4397
<i>time (hrs)</i>	1	1	1	1	1
GP					
<i># of lanes</i>	2	1	1	2	2
<i>person volume</i>	2642	1527	1468	2086	2266
<i>speed (km/h)</i>	42	40	40	24	24
<i>Per-Lane Efficiency</i>	55	61	59	25	27
HOV					
<i># of lanes</i>	1	1	1	1	1
<i>person volume</i>	1220	1590	1844	1942	2131
<i>speed (km/h)</i>	41	72	72	29	29
<i>Per-Lane Efficiency</i>	50	114	133	56	62

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location</i> <i>Per-Lane</i> <i>Efficiency</i>	54	88	96	35	39
<i>Section</i> <i>Per-Lane</i> <i>Efficiency</i>	54	92	37		

PER-LANE EFFICIENCY**MARCH, 1996****EASTBOUND**

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton*	Willingdon	Bayview	Union
<i>Total # of lanes</i>	3		2	1	1
<i>Total Person Volume</i>	4140		2889	2112	1995
<i>time (hrs)</i>	1		1	1	1
GP					
<i># of lanes</i>	3		2	1	1
<i>person volume</i>	4140		2889	2112	1995
<i>speed (km/h)</i>	23		23	35	35
<i>Per-Lane Efficiency</i>	32		33	74	70
HOV					
<i># of lanes</i>					
<i>person volume</i>					
<i>speed (km/h)</i>					
<i>Per-Lane Efficiency</i>					

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location</i> <i>Per-Lane</i> <i>Efficiency</i>	32		33	74	70
<i>Section</i> <i>Per-Lane</i> <i>Efficiency</i>	32			72	

NOTES:*1. no data collected at Carleton in March, 1996*

PER-LANE EFFICIENCY
OCTOBER, 1996
EASTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton*	Willingdon	Bayview	Union
<i>Total # of lanes</i>	3		3	2	2
<i>Total Person Volume</i>	4306		3910	2739	2868
<i>time (hrs)</i>	1		1	1	1
GP					
<i># of lanes</i>	2		2	1	1
<i>person volume</i>	2508		2392	1648	1932
<i>speed (km/h)</i>	27		27	63	63
<i>Per-Lane Efficiency</i>	34		32	104	122
HOV					
<i># of lanes</i>	1		1	1	1
<i>person volume</i>	1798		1518	1091	936
<i>speed (km/h)</i>	31		31	70	70
<i>Per-Lane Efficiency</i>	56		47	76	66

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location</i> <i>Per-Lane</i> <i>Efficiency</i>	41		37	90	94
<i>Section</i> <i>Per-Lane</i> <i>Efficiency</i>	39			92	

NOTES:

1. no data collected at Carleton in October, 1996

PER-LANE EFFICIENCY
OCTOBER, 1997
EASTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton	Willingdon	Bayview	Union
<i>Total # of lanes</i>	3	3	3	2	2
<i>Total Person Volume</i>	3989	4602	4504	3196	3356
<i>time (hrs)</i>	1	1	1	1	1
GP					
<i># of lanes</i>	2	2	2	1	1
<i>person volume</i>	2025	2448	2475	1984	2084
<i>speed (km/h)</i>	28	28	28	59	59
<i>Per-Lane Efficiency</i>	28	34	35	117	123
HOV					
<i># of lanes</i>	1	1	1	1	1
<i>person volume</i>	1964	2154	2029	1212	1272
<i>speed (km/h)</i>	33	33	33	67	67
<i>Per-Lane Efficiency</i>	65	71	67	81	85

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location</i> <i>Per-Lane</i> <i>Efficiency</i>	41	47	45	99	104
<i>Section</i> <i>Per-Lane</i> <i>Efficiency</i>	44			102	

AVERAGE VEHICLE OCCUPANCY (AVO)**MARCH, 1996****WESTBOUND**

<i>Corridor</i>	Barnet/Hastings HOV Corridor					
<i>Section</i>	St. Johns Street		Barnet Highway		Hastings Street	
<i>Location</i>	Williams	Clark	Reed	Bayview	Willingdon	Lilloet
6:00-6:15	1.229		1.185	1.188	1.195	1.203
6:15-6:30	1.134		1.185	1.202	1.183	1.208
6:30-6:45	1.223		1.205	1.181	1.171	1.233
6:45-7:00	1.229		1.240	1.216	1.198	1.197
7:00-7:15	1.233		1.261	1.275	1.288	1.293
7:15-7:30	1.246		1.236	1.231	1.234	1.253
7:30-7:45	1.237		1.176	1.241	1.279	1.267
7:45-8:00	1.297		1.178	1.190	1.236	1.284
8:00-8:15	1.375		1.217	1.183	1.291	1.280
8:15-8:30	1.367		1.171	1.175	1.256	1.260

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location Mean</i>	1.257		1.205	1.208	1.233	1.248
<i>SD</i>	0.072		0.032	0.032	0.045	0.035
<i>Section Mean</i>	1.257		1.207		1.240	
<i>SD</i>	0.072		0.031		0.040	
<i>Corridor Mean</i>	1.230					
<i>SD</i>	0.049					

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location Mean</i>	1.319		1.186	1.197	1.266	1.273
<i>SD</i>	0.065		0.021	0.030	0.024	0.011
<i>Section Mean</i>	1.319		1.191		1.269	
<i>SD</i>	0.065		0.025		0.018	
<i>Corridor Mean</i>	1.248					
<i>SD</i>	0.060					

NOTES:

1. no data collected at Carleton in March, 1996
2. SD = Standard Deviation

AVERAGE VEHICLE OCCUPANCY (AVO)
OCTOBER, 1996
WESTBOUND

Corridor	Barnet/Hastings HOV Corridor					
Section	St. Johns Street		Barnet Highway		Hastings Street	
Location	Williams	Clark	Reed	Bayview	Willingdon	Lilloet
6:00-6:15	1.220	1.476	1.368	1.190	1.211	1.245
6:15-6:30	1.145	1.394	1.348	1.288	1.290	1.229
6:30-6:45	1.198	1.388	1.336	1.288	1.229	1.240
6:45-7:00	1.194	1.371	1.413	1.270	1.266	1.244
7:00-7:15	1.206	1.455	1.386	1.351	1.265	1.281
7:15-7:30	1.233	1.541	1.401	1.340	1.259	1.255
7:30-7:45	1.258	1.457	1.383	1.341	1.377	1.279
7:45-8:00	1.284	1.399	1.372	1.283	1.314	1.303
8:00-8:15	1.367	1.380	1.335	1.298	1.370	1.260
8:15-8:30	1.329	1.311	1.385	1.256	1.382	1.289

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location Mean</i>	1.243	1.417	1.373	1.291	1.296	1.263
<i>SD</i>	0.067	0.065	0.026	0.048	0.062	0.024
<i>Section Mean</i>	1.243		1.332		1.279	
<i>SD</i>	0.067		0.056		0.049	
<i>Corridor Mean</i>	1.293					
<i>SD</i>	0.065					

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location Mean</i>	1.310	1.387	1.369	1.295	1.361	1.283
<i>SD</i>	0.048	0.060	0.023	0.036	0.032	0.018
<i>Section Mean</i>	1.310		1.332		1.322	
<i>SD</i>	0.048		0.048		0.048	
<i>Corridor Mean</i>	1.323					
<i>SD</i>	0.046					

NOTES:

1. Clarke St. not included in averages because separate from most of GP traffic

AVERAGE VEHICLE OCCUPANCY (AVO)**MARCH, 1997****WESTBOUND**

<i>Corridor</i>	Barnet/Hastings HOV Corridor					
<i>Section</i>	St. Johns Street		Barnet Highway		Hastings Street	
<i>Location</i>	Williams	Clark	Reed	Bayview	Willingdon	Lilloet
6:00-6:15	1.224	1.373	1.171	1.312	1.304	1.164
6:15-6:30	1.209	1.425	1.201	1.356	1.344	1.281
6:30-6:45	1.202	1.426	1.238	1.270	1.287	1.274
6:45-7:00	1.233	1.454	1.263	1.295	1.326	1.237
7:00-7:15	1.228	1.482	1.223	1.343	1.363	1.281
7:15-7:30	1.274	1.447	1.299	1.356	1.376	1.372
7:30-7:45	1.259	1.473	1.225	1.371	1.377	1.341
7:45-8:00	1.287	1.466	1.243	1.339	1.362	1.311
8:00-8:15	1.336	1.486	1.235	1.323	1.359	1.298
8:15-8:30	1.380	1.473	1.231	1.301	1.352	1.314

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location Mean</i>	1.263	1.451	1.233	1.327	1.345	1.287
<i>SD</i>	0.058	0.035	0.034	0.032	0.030	0.057
<i>Section Mean</i>	1.263		1.280		1.316	
<i>SD</i>	0.058		0.058		0.053	
<i>Corridor Mean</i>	1.291					
<i>SD</i>	0.059					

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location Mean</i>	1.316	1.475	1.234	1.334	1.363	1.316
<i>SD</i>	0.053	0.008	0.008	0.029	0.011	0.018
<i>Section Mean</i>	1.316		1.284		1.339	
<i>SD</i>	0.053		0.057		0.028	
<i>Corridor Mean</i>	1.312					
<i>SD</i>	0.051					

NOTES:

1. Clarke St. not included in averages because separate from most of GP traffic

AVERAGE VEHICLE OCCUPANCY (AVO)
OCTOBER, 1997
WESTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor					
<i>Section</i>	St. Johns Street		Barnet Highway		Hastings Street	
<i>Location</i>	Williams	Clark	Reed	Bayview	Willingdon	Lilloet
6:00-6:15	1.267	1.362	1.271	1.365	1.173	1.290
6:15-6:30	1.176	1.296	1.194	1.361	1.237	1.190
6:30-6:45	1.169	1.326	1.262	1.283	1.197	1.184
6:45-7:00	1.216	1.393	1.252	1.290	1.174	1.197
7:00-7:15	1.249	1.508	1.271	1.270	1.193	1.233
7:15-7:30	1.286	1.426	1.323	1.390	1.289	1.207
7:30-7:45	1.313	1.493	1.379	1.384	1.312	1.257
7:45-8:00	1.283	1.520	1.296	1.355	1.265	1.251
8:00-8:15	1.411	1.498	1.255	1.335	1.257	1.261
8:15-8:30	1.319	1.352	1.219	1.267	1.285	1.288

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location Mean</i>	1.269	1.417	1.272	1.330	1.238	1.236
<i>SD</i>	0.072	0.083	0.052	0.048	0.051	0.040
<i>Section Mean</i>	1.269		1.301		1.237	
<i>SD</i>	0.072		0.057		0.044	
<i>Corridor Mean</i>	1.269					
<i>SD</i>	0.062					

PEAK HOUR (7:30 TO 8:30 AM)

<i>Location Mean</i>	1.332	1.466	1.287	1.335	1.280	1.264
<i>SD</i>	0.055	0.077	0.069	0.050	0.025	0.016
<i>Section Mean</i>	1.332		1.311		1.272	
<i>SD</i>	0.055		0.061		0.021	
<i>Corridor Mean</i>	1.300					
<i>SD</i>	0.051					

NOTES:

1. Clarke St. not included in averages because separate from most of GP traffic

AVERAGE VEHICLE OCCUPANCY (AVO)**MARCH, 1996****EASTBOUND**

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton	Willingdon	Bayview	Union
3:30-3:45	1.360		1.260	1.199	1.257
3:45-4:00	1.293		1.232	1.292	1.284
4:00-4:15	1.316		1.273	1.235	1.239
4:15-4:30	1.306		1.215	1.248	1.280
4:30-4:45	1.344		1.226	1.210	1.225
4:45-5:00	1.386		1.288	1.254	1.268
5:00-5:15	1.365		1.309	1.308	1.203
5:15-5:30	1.380		1.327	1.285	1.309
5:30-5:45	1.385		1.398	1.299	1.209
5:45-6:00	1.340		1.345	1.341	1.264

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location Mean</i>	1.348		1.287	1.267	1.254
<i>SD</i>	0.034		0.058	0.045	0.034
<i>Section Mean</i>	1.317			1.260	
<i>SD</i>	0.056			0.040	
<i>Corridor Mean</i>	1.289				
<i>SD</i>	0.056				

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location Mean</i>	1.368		1.345	1.308	1.246
<i>SD</i>	0.020		0.038	0.024	0.050
<i>Section Mean</i>	1.356			1.277	
<i>SD</i>	0.031			0.049	
<i>Corridor Mean</i>	1.317				
<i>SD</i>	0.057				

NOTES:

1. no data collected at Carleton in March, 1996
2. SD = Standard Deviation

AVERAGE VEHICLE OCCUPANCY (AVO)
OCTOBER, 1996
EASTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton	Willingdon	Bayview	Union
3:30-3:45	1.447		1.310	1.260	1.249
3:45-4:00	1.399		1.320	1.222	1.240
4:00-4:15	1.445		1.301	1.259	1.237
4:15-4:30	1.337		1.311	1.266	1.300
4:30-4:45	1.431		1.315	1.324	1.287
4:45-5:00	1.441		1.307	1.291	1.268
5:00-5:15	1.423		1.353	1.298	1.271
5:15-5:30	1.434		1.321	1.268	1.302
5:30-5:45	1.413		1.375	1.239	1.283
5:45-6:00	1.438		1.290	1.271	1.274

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location Mean</i>	1.421	1.320	1.270	1.271
<i>SD</i>	0.033	0.025	0.029	0.023
<i>Section Mean</i>	1.371		1.270	
<i>SD</i>	0.059		0.026	
<i>Corridor Mean</i>	1.321			
<i>SD</i>	0.068			

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location Mean</i>	1.427		1.335	1.269	1.283
<i>SD</i>	0.011		0.037	0.024	0.014
<i>Section Mean</i>	1.381			1.276	
<i>SD</i>	0.055			0.020	
<i>Corridor Mean</i>	1.328				
<i>SD</i>	0.068				

NOTES:

1. no data collected at Carleton in October, 1996
2. SD = Standard Deviation

AVERAGE VEHICLE OCCUPANCY (AVO)**MARCH, 1997****EASTBOUND**

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton	Willingdon	Bayview	Union
3:30-3:45	1.299		1.283	1.343	1.285
3:45-4:00	1.356		1.300	1.329	1.272
4:00-4:15	1.289		1.266	1.324	1.277
4:15-4:30	1.318		1.231	1.356	1.284
4:30-4:45	1.283		1.324	1.389	1.306
4:45-5:00	1.301		1.299	1.373	1.293
5:00-5:15	1.388		1.285	1.430	1.297
5:15-5:30	1.417		1.317	1.434	1.301
5:30-5:45	1.367		1.280	1.477	1.327
5:45-6:00	1.404		1.333	1.507	1.272

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location Mean</i>	1.342		1.292	1.396	1.291
<i>SD</i>	0.050		0.030	0.063	0.017
<i>Section Mean</i>	1.317			1.344	
<i>SD</i>	0.048			0.070	
<i>Corridor Mean</i>	1.330				
<i>SD</i>	0.061				

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location Mean</i>	1.394		1.304	1.462	1.299
<i>SD</i>	0.022		0.025	0.037	0.023
<i>Section Mean</i>	1.349			1.381	
<i>SD</i>	0.053			0.091	
<i>Corridor Mean</i>	1.365				
<i>SD</i>	0.074				

NOTES:

1. no data collected at Carleton in March, 1997
2. SD = Standard Deviation

AVERAGE VEHICLE OCCUPANCY (AVO)
OCTOBER, 1997
EASTBOUND

<i>Corridor</i>	Barnet/Hastings HOV Corridor				
<i>Section</i>	Hastings Street			Barnet Highway	
<i>Location</i>	Lillooet	Carleton	Willingdon	Bayview	Union
3:30-3:45	1.311	1.352	1.317	1.260	1.295
3:45-4:00	1.314	1.346	1.307	1.283	1.257
4:00-4:15	1.293	1.347	1.299	1.277	1.255
4:15-4:30	1.311	1.360	1.328	1.328	1.266
4:30-4:45	1.338	1.383	1.329	1.273	1.302
4:45-5:00	1.374	1.425	1.361	1.283	1.256
5:00-5:15	1.364	1.474	1.368	1.300	1.343
5:15-5:30	1.383	1.430	1.338	1.282	1.287
5:30-5:45	1.390	1.450	1.379	1.290	1.264
5:45-6:00	1.367	1.380	1.362	1.323	1.290

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location Mean</i>	1.345	1.395	1.339	1.290	1.282
<i>SD</i>	0.035	0.047	0.027	0.021	0.028
<i>Section Mean</i>	1.359			1.286	
<i>SD</i>	0.044			0.025	
<i>Corridor Mean</i>	1.330				
<i>SD</i>	0.052				

PEAK HOUR (5:00 TO 6:00 PM)

<i>Location Mean</i>	1.376	1.434	1.362	1.299	1.296
<i>SD</i>	0.013	0.040	0.017	0.018	0.033
<i>Section Mean</i>	1.390			1.297	
<i>SD</i>	0.040			0.025	
<i>Corridor Mean</i>	1.353				
<i>SD</i>	0.058				

NOTES:

1. SD = Standard Deviation

AVERAGE VEHICLE OCCUPANCY (AVO) CONFIDENCE INTERVALS
MARCH, 1996 TO OCTOBER, 1997

WESTBOUND

PEAK PERIOD (6:00 TO 8:30 AM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{0.025})	CONFIDENCE INTERVALS		
March, 1996	1.230	0.049	50	1.960	1.23 +/- 0.01	1.22	to 1.24
October, 1996	1.293	0.065	50	1.960	1.29 +/- 0.02	1.27	to 1.31
March, 1997	1.291	0.059	50	1.960	1.29 +/- 0.02	1.27	to 1.31
October, 1997	1.269	0.062	50	1.960	1.27 +/- 0.02	1.25	to 1.29

PEAK HOUR (7:30 TO 8:30 AM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{0.025})	CONFIDENCE INTERVALS		
March, 1996	1.248	0.060	20	2.093	1.25 +/- 0.03	1.22	to 1.28
October, 1996	1.323	0.046	20	2.093	1.32 +/- 0.02	1.30	to 1.34
March, 1997	1.312	0.051	20	2.093	1.31 +/- 0.02	1.29	to 1.34
October, 1997	1.300	0.051	20	2.093	1.30 +/- 0.02	1.28	to 1.32

EASTBOUND

PEAK PERIOD (3:30 to 6:00 PM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{0.025})	CONFIDENCE INTERVALS		
March, 1996	1.289	0.056	40	1.960	1.29 +/- 0.02	1.27	to 1.31
October, 1996	1.321	0.068	40	1.960	1.32 +/- 0.02	1.30	to 1.34
March, 1997	1.330	0.061	40	1.960	1.33 +/- 0.02	1.31	to 1.35
October, 1997	1.330	0.052	50	1.960	1.33 +/- 0.01	1.32	to 1.34

PEAK HOUR (5:00 to 6:00 PM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{0.025})	CONFIDENCE INTERVALS		
March, 1996	1.317	0.057	16	2.131	1.32 +/- 0.03	1.29	to 1.35
October, 1996	1.328	0.068	16	2.131	1.33 +/- 0.04	1.29	to 1.36
March, 1997	1.365	0.074	16	2.131	1.37 +/- 0.04	1.33	to 1.40
October, 1997	1.353	0.058	20	2.093	1.35 +/- 0.03	1.33	to 1.38

AVERAGE VEHICLE OCCUPANCY (AVO) MARGIN OF ERRORS
MARCH, 1996 TO OCTOBER, 1997

WESTBOUND

PEAK PERIOD (6:00 TO 8:30 AM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})	MARGIN OF ERROR	MARGIN OF ERROR AS A % OF THE MEAN
<i>March, 1996</i>	1.230	0.049	50	1.960	0.01	1%
<i>October, 1996</i>	1.293	0.065	50	1.960	0.02	1%
<i>March, 1997</i>	1.291	0.059	50	1.960	0.02	1%
<i>October, 1997</i>	1.269	0.062	50	1.960	0.02	1%

PEAK HOUR (7:30 TO 8:30 AM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})	MARGIN OF ERROR	MARGIN OF ERROR AS A % OF THE MEAN
<i>March, 1996</i>	1.248	0.060	20	2.093	0.03	2%
<i>October, 1996</i>	1.323	0.046	20	2.093	0.02	2%
<i>March, 1997</i>	1.312	0.051	20	2.093	0.02	2%
<i>October, 1997</i>	1.300	0.051	20	2.093	0.02	2%

EASTBOUND

PEAK PERIOD (3:30 to 6:00 PM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})	MARGIN OF ERROR	MARGIN OF ERROR AS A % OF THE MEAN
<i>March, 1996</i>	1.289	0.056	40	1.960	0.02	1%
<i>October, 1996</i>	1.321	0.068	40	1.960	0.02	2%
<i>March, 1997</i>	1.330	0.061	40	1.960	0.02	1%
<i>October, 1997</i>	1.330	0.052	50	1.960	0.01	1%

PEAK HOUR (5:00 to 6:00 PM)

	AVO (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})	MARGIN OF ERROR	MARGIN OF ERROR AS A % OF THE MEAN
<i>March, 1996</i>	1.317	0.057	16	2.131	0.03	2%
<i>October, 1996</i>	1.328	0.068	16	2.131	0.04	3%
<i>March, 1997</i>	1.365	0.074	16	2.131	0.04	3%
<i>October, 1997</i>	1.353	0.058	20	2.093	0.03	2%

AVERAGE VEHICLE OCCUPANCY (AVO) STATISTICAL SIGNIFICANCE

MARCH, 1996 TO OCTOBER, 1997

WESTBOUND

PEAK PERIOD (6:00 TO 8:30 AM)

	AVO (Mean)	Standard Deviation	Sample Size	test statistic A	t-critical (t _{.05}) B	STATISTICALLY SIGNIFICANT A>B ?
March, 1996	1.230	0.049	50			
October, 1996	1.293	0.065	50	5.5	1.645	yes
March, 1997	1.291	0.059	50	5.6	1.645	yes
October, 1997	1.269	0.062	50	3.5	1.645	yes
MINIMUM*	1.25	0.06	50	1.7	1.645	

PEAK HOUR (7:30 TO 8:30 AM)

	AVO (Mean)	Standard Deviation	Sample Size	Pooled Variance	test statistic A	t-critical (t _{.05}) B	STATISTICALLY SIGNIFICANT A>B ?
March, 1996	1.248	0.060	20				
October, 1996	1.323	0.046	20	0.053	4.4	1.645	yes
March, 1997	1.312	0.051	20	0.056	3.6	1.645	yes
October, 1997	1.300	0.051	20	0.056	3.0	1.645	yes
MINIMUM*	1.28	0.05	20	0.056	1.7	1.645	

NOTES:

1. MINIMUM based on an average standard deviation & sample size

AVERAGE VEHICLE OCCUPANCY (AVO) STATISTICAL SIGNIFICANCE
MARCH, 1996 TO OCTOBER, 1997
EASTBOUND

PEAK PERIOD (3:30 to 6:00 PM)

	AVO (Mean)	Standard Deviation	Sample Size	test statistic A	t-critical (t _{.05}) B	STATISTICALLY SIGNIFICANT A>B ?
<i>March, 1996</i>	1.289	0.056	40			
<i>October, 1996</i>	1.321	0.068	40	2.3	1.645	yes
<i>March, 1997</i>	1.330	0.061	40	3.1	1.645	yes
<i>October, 1997</i>	1.330	0.052	50	3.6	1.645	yes
MINIMUM*	1.31	0.06	43	1.7	1.645	

PEAK HOUR (5:00 to 6:00 PM)

	AVO (Mean)	Standard Deviation	Sample Size	Pooled Variance	test statistic A	t-critical (t _{.05}) B	STATISTICALLY SIGNIFICANT A>B ?
<i>March, 1996</i>	1.317	0.057	16				
<i>October, 1996</i>	1.328	0.068	16	0.063	0.5	1.645	NO
<i>March, 1997</i>	1.365	0.074	16	0.066	2.1	1.645	yes
<i>October, 1997</i>	1.353	0.058	20	0.058	1.9	1.645	yes
MINIMUM*	1.35	0.06	17	0.061	1.7	1.645	

NOTES:

1. MINIMUM based on an average standard deviation & sample size

HOV SHARE OF TOTAL TRIPS MADE
MARCH, 1996
WESTBOUND

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location</i>	Williams	Clarke*	Reed	Bayview	Willingdon	Lillooet
<i>SOVs</i>	3868		2933	2877	3546	3685
<i>HOVs</i>	2365		1370	1381	1976	2189
<i>BUS</i>	1047		490	585	1809	3469
<i>TOTAL</i>	7280		4793	4843	7331	9343
<i>SOVs %</i>	53%		61%	59%	48%	39%
<i>HOVs %</i>	32%		29%	29%	27%	23%
<i>BUS %</i>	14%		10%	12%	25%	37%
<i>HOV SHARE</i>	47%		39%	41%	52%	61%

<i>Section</i>	St. Johns Street	Barnet Highway	Hastings Street
<i>SOVs %</i>	53%	60%	44%
<i>HOVs %</i>	32%	29%	25%
<i>BUS %</i>	14%	11%	31%
<i>HOV SHARE</i>	47%	40%	56%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	52%
<i>HOVs %</i>	28%
<i>BUS %</i>	20%
<i>HOV SHARE</i>	48%

NOTES:

1. no data collected at Clarke in March, 1996
2. HOV SHARE = % of HOVs + % of Bus

HOV SHARE OF TOTAL TRIPS MADE
OCTOBER, 1996
WESTBOUND

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location</i>	Williams	Clarke*	Reed	Bayview	Willingdon	Lillooet*
<i>SOVs</i>	4212	1350	3514	3718	3650	3296
<i>HOVs</i>	2451	1761	3689	2824	2739	2128
<i>BUS</i>	1053	585	665	541	2362	1971
<i>TOTAL</i>	7716	3696	7868	7083	8751	7395
<i>SOVs %</i>	55%	37%	45%	52%	42%	45%
<i>HOVs %</i>	32%	48%	47%	40%	31%	29%
<i>BUS %</i>	14%	16%	8%	8%	27%	27%
<i>HOV SHARE</i>	45%	63%	55%	48%	58%	55%

<i>Section</i>	St. Johns Street	Barnet Highway	Hastings Street
<i>SOVs %</i>	55%	49%	43%
<i>HOVs %</i>	32%	43%	30%
<i>BUS %</i>	14%	8%	27%
<i>HOV SHARE</i>	45%	51%	57%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	48%
<i>HOVs %</i>	36%
<i>BUS %</i>	16%
<i>HOV SHARE</i>	52%

NOTES:

1. Volumes at Lillooet are low due to an accident
2. HOV SHARE = % of HOVs + % of Bus
3. Clarke location separate from most of GP traffic, therefore, not included as part of averages

HOV SHARE OF TOTAL TRIPS MADE
MARCH, 1997
WESTBOUND

PEAK PERIOD (6:00 TO 8:30 AM)

<i>Location</i>	Williams	Clarke*	Reed	Bayview	Willingdon	Lillooet
<i>SOVs</i>	4311	1503	3962	4145	4125	3837
<i>HOVs</i>	2796	2162	2299	3506	3980	2840
<i>BUS</i>	727	760	660	555	1140	2979
<i>TOTAL</i>	7834	4425	6921	8206	9245	9656
<i>SOVs %</i>	55%	34%	57%	51%	45%	40%
<i>HOVs %</i>	36%	49%	33%	43%	43%	29%
<i>BUS %</i>	9%	17%	10%	7%	12%	31%
<i>HOV SHARE</i>	45%	66%	43%	49%	55%	60%

<i>Section</i>	St. Johns Street	Barnet Highway	Hastings Street
<i>SOVs %</i>	55%	54%	42%
<i>HOVs %</i>	36%	38%	36%
<i>BUS %</i>	9%	8%	22%
<i>HOV SHARE</i>	45%	46%	58%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	49%
<i>HOVs %</i>	37%
<i>BUS %</i>	14%
<i>HOV SHARE</i>	51%

NOTES:

1. Clarke location separate from most of GP traffic, therefore, not included as part of averages
2. $HOV\ SHARE = \% \text{ of } HOVs + \% \text{ of } Bus$

HOV SHARE OF TOTAL TRIPS MADE**OCTOBER, 1997****WESTBOUND****PEAK PERIOD (6:00 TO 8:30 AM)**

<i>Location</i>	Williams	Clarke*	Reed	Bayview	Willington	Lillooet
<i>SOVs</i>	4630	1628	4430	3932	4590	3993
<i>HOVs</i>	3012	2059	3040	3365	2660	2260
<i>BUS</i>	1053	475	742	615	1729	2678
<i>TOTAL</i>	8695	4162	8212	7912	8979	8931
<i>SOVs %</i>	53%	39%	54%	50%	51%	45%
<i>HOVs %</i>	35%	49%	37%	43%	30%	25%
<i>BUS %</i>	12%	11%	9%	8%	19%	30%
<i>HOV SHARE</i>	47%	61%	46%	50%	49%	55%

<i>Section</i>	St. Johns Street	Barnet Highway	Hastings Street
<i>SOVs %</i>	53%	52%	48%
<i>HOVs %</i>	35%	40%	27%
<i>BUS %</i>	12%	8%	25%
<i>HOV SHARE</i>	47%	48%	52%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	50%
<i>HOVs %</i>	34%
<i>BUS %</i>	16%
<i>HOV SHARE</i>	49%

NOTES:

1. Clarke location separate from most of GP traffic, therefore, not included as part of averages
2. HOV SHARE = % of HOVs + % of Bus

HOV SHARE OF TOTAL TRIPS MADE
MARCH, 1996
EASTBOUND

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location</i>	Lillooet	Carleton*	Willingdon	Bayview	Union
<i>SOVs</i>	3327		3475	2829	2778
<i>HOVs</i>	2924		2381	1725	1592
<i>BUS</i>	3491		1502	655	575
<i>TOTAL</i>	9742		7358	5209	4945
<i>SOVs %</i>	34%		47%	54%	56%
<i>HOVs %</i>	30%		32%	33%	32%
<i>BUS %</i>	36%		20%	13%	12%
<i>HOV SHARE</i>	66%		53%	46%	44%

<i>Section</i>	St. Johns Street	Barnet Highway
<i>SOVs %</i>	41%	55%
<i>HOVs %</i>	31%	33%
<i>BUS %</i>	28%	12%
<i>HOV SHARE</i>	59%	45%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	48%
<i>HOVs %</i>	32%
<i>BUS %</i>	20%
<i>HOV SHARE</i>	52%

NOTES:

1. no data collected at Carleton in March, 1996
2. $HOV\ SHARE = \% \text{ of } HOVs + \% \text{ of } Bus$

HOV SHARE OF TOTAL TRIPS MADE
OCTOBER, 1996
EASTBOUND

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location</i>	Lillooet	Carleton*	Willingdon	Bayview	Union
<i>SOVs</i>	3272		4597	3640	3622
<i>HOVs</i>	3885		3792	2442	2395
<i>BUS</i>	3003		1252	691	545
<i>TOTAL</i>	10160		9641	6773	6562
<i>SOVs %</i>	32%		48%	54%	55%
<i>HOVs %</i>	38%		39%	36%	36%
<i>BUS %</i>	30%		13%	10%	8%
<i>HOV SHARE</i>	68%		52%	46%	45%

<i>Section</i>	St. Johns Street	Barnet Highway
<i>SOVs %</i>	40%	54%
<i>HOVs %</i>	39%	36%
<i>BUS %</i>	21%	9%
<i>HOV SHARE</i>	60%	46%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	47%
<i>HOVs %</i>	38%
<i>BUS %</i>	15%
<i>HOV SHARE</i>	53%

NOTES:

1. no data collected at Carleton in October, 1996
2. $HOV\ SHARE = \% \text{ of } HOVs + \% \text{ of } Bus$

HOV SHARE OF TOTAL TRIPS MADE
MARCH, 1997
EASTBOUND

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location</i>	Lillooet	Carleton*	Willingdon	Bayview	Union
<i>SOVs</i>	3244		4373	3737	3683
<i>HOVs</i>	2983		3247	3858	2579
<i>BUS</i>	2461		755	661	420
<i>TOTAL</i>	8688		8375	8256	6682
<i>SOVs %</i>	37%		52%	45%	55%
<i>HOVs %</i>	34%		39%	47%	39%
<i>BUS %</i>	28%		9%	8%	6%
<i>HOV SHARE</i>	63%		48%	55%	45%

<i>Section</i>	St. Johns Street	Barnet Highway
<i>SOVs %</i>	45%	50%
<i>HOVs %</i>	37%	43%
<i>BUS %</i>	19%	7%
<i>HOV SHARE</i>	55%	50%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	47%
<i>HOVs %</i>	40%
<i>BUS %</i>	13%
<i>HOV SHARE</i>	53%

NOTES:

1. no data collected at Carleton in March, 1997
2. $HOV\ SHARE = \% \text{ of } HOVs + \% \text{ of } Bus$

HOV SHARE OF TOTAL TRIPS MADE
OCTOBER, 1997
EASTBOUND

PEAK PERIOD (3:30 TO 6:00 PM)

<i>Location</i>	Lillooet	Carleton*	Willingdon	Bayview	Union
<i>SOVs</i>	3643	3800	4718	3998	4192
<i>HOVs</i>	3203	4149	4077	2872	2825
<i>BUS</i>	2431	2533	2056	532	459
<i>TOTAL</i>	9277	10482	10851	7402	7476
<i>SOVs %</i>	39%	36%	43%	54%	56%
<i>HOVs %</i>	35%	40%	38%	39%	38%
<i>BUS %</i>	26%	24%	19%	7%	6%
<i>HOV SHARE</i>	61%	64%	57%	46%	44%

<i>Section</i>	St. Johns Street	Barnet Highway
<i>SOVs %</i>	40%	55%
<i>HOVs %</i>	37%	38%
<i>BUS %</i>	23%	7%
<i>HOV SHARE</i>	60%	45%

<i>Corridor</i>	Barnet/Hastings HOV Corridor
<i>SOVs %</i>	46%
<i>HOVs %</i>	38%
<i>BUS %</i>	17%
<i>HOV SHARE</i>	54%

NOTES:

1. *HOV SHARE* = % of *HOVs* + % of *Bus*

TRAVEL TIME AND SPEEDS

MARCH, 1996

WESTBOUND

PEAK HOUR (7:30 AM TO 8:30 AM)

<i>Section</i>	St. Johns St.	Barnet Hwy	Hastings St.	HOV Corridor
<i>Distance (kms)</i>	3.02	7.81	7.02	17.85
GP				
<i>Travel Time (minutes)</i>	9.9	10.7	14.9	35.5
<i>Travel Speed (km/h)</i>	18	44	28	30
HOV				
<i>Travel Time (minutes)</i>				
<i>Travel Speed (km/h)</i>				

TRAVEL TIME AND SPEEDS
OCTOBER, 1996
WESTBOUND

PEAK HOUR (7:30 AM TO 8:30 AM)

Section	St. Johns St.	Barnet Hwy	Hastings St.	HOV Corridor
Distance (kms)	3.02	7.81	7.02	17.85
GP				
Travel Time (minutes)	4.1	8.8	14.1	27.0
Travel Speed (km/h)	45	53	30	40
HOV				
Travel Time (minutes)	4.5	6.2	11.9	22.7
Travel Speed (km/h)	40	75	35	47
TRAVEL TIME DIFFERENCE	-0.5	2.6	2.2	4.3
TRAVEL TIME DIFFERENCE PER KM				0.24

PEAK PERIOD (6:00 AM TO 8:30 AM)

Section	St. Johns St.	Barnet Hwy	Hastings St.	HOV Corridor
Distance (kms)	3.02	7.81	7.02	17.85
GP				
Travel Time (minutes)	3.8	7.6	11.8	23.3
Travel Speed (km/h)	48	61	36	46
HOV				
Travel Time (minutes)	4.3	6.2	10.5	21.1
Travel Speed (km/h)	42	75	40	51
TRAVEL TIME SAVINGS	-0.5	1.4	1.3	2.2
TRAVEL TIME DIFFERENCE PER KM				0.12

TRAVEL TIME AND SPEEDS**OCTOBER, 1997****WESTBOUND****PEAK HOUR (7:30 AM TO 8:30 AM)**

Section	St. Johns St.	Barnet Hwy	Hastings St.	HOV Corridor
Distance (kms)	3.02	7.81	7.02	17.85
GP				
Travel Time (minutes)	4.3	11.7	17.6	33.7
Travel Speed (km/h)	42	40	24	32
HOV				
Travel Time (minutes)	4.4	6.5	14.7	25.7
Travel Speed (km/h)	41	72	29	42
TRAVEL TIME DIFFERENCE	-0.1	5.2	2.9	8.0
TRAVEL TIME DIFFERENCE PER KM				0.45

PEAK PERIOD (6:00 AM TO 8:30 AM)

Section	St. Johns St.	Barnet Hwy	Hastings St.	HOV Corridor
Distance (kms)	3.02	7.81	7.02	17.85
GP				
Travel Time (minutes)	4.0	9.3	13.9	27.1
Travel Speed (km/h)	46	51	30	39
HOV				
Travel Time (minutes)	4.3	6.4	12.0	22.6
Travel Speed (km/h)	43	74	35	47
TRAVEL TIME SAVINGS	-0.3	2.9	1.9	4.6
TRAVEL TIME DIFFERENCE PER KM				0.25

TRAVEL TIME AND SPEEDS

MARCH, 1996

EASTBOUND

PEAK HOUR (5:00 PM TO 6:00 PM)

<i>Section</i>	Hastings St.	Barnet Hwy	HOV Corridor
<i>Distance (kms)</i>	7.05	7.93	14.97
GP			
<i>Travel Time (minutes)</i>	18.7	13.5	32.2
<i>Travel Speed (km/h)</i>	23	35	28
HOV			
<i>Travel Time (minutes)</i>			
<i>Travel Speed (km/h)</i>			

TRAVEL TIME AND SPEEDS
OCTOBER, 1996
EASTBOUND

PEAK HOUR (5:00 PM TO 6:00 PM)

Section	Hastings St.	Barnet Hwy	HOV Corridor
Distance (kms)	7.05	7.93	14.97
GP			
Travel Time (minutes)	15.6	7.6	23.2
Travel Speed (km/h)	27	63	39
HOV			
Travel Time (minutes)	13.9	6.9	20.8
Travel Speed (km/h)	30	69	43
TRAVEL TIME DIFFERENCE	1.7	0.7	2.4
TRAVEL TIME DIFFERENCE PER KM			0.16

PEAK PERIOD (3:30 PM TO 6:00 PM)

Section	Hastings St.	Barnet Hwy	HOV Corridor
Distance (kms)	7.05	7.93	14.97
GP			
Travel Time (minutes)	14.5	7.4	21.8
Travel Speed (km/h)	29	65	41
HOV			
Travel Time (minutes)	13.2	6.9	20.1
Travel Speed (km/h)	32	69	45
TRAVEL TIME DIFFERENCE	1.2	0.5	1.7
TRAVEL TIME DIFFERENCE PER KM			0.11

TRAVEL TIME AND SPEEDS
OCTOBER, 1997
EASTBOUND

PEAK HOUR (5:00 PM TO 6:00 PM)

<i>Section</i>	Hastings St.	Barnet Hwy	HOV Corridor
<i>Distance (kms)</i>	7.05	7.93	14.97
GP			
<i>Travel Time (minutes)</i>	15.0	8.0	23.0
<i>Travel Speed (km/h)</i>	28	59	39
HOV			
<i>Travel Time (minutes)</i>	13.0	7.2	20.1
<i>Travel Speed (km/h)</i>	33	67	45
TRAVEL TIME DIFFERENCE	2.0	0.8	2.8
TRAVEL TIME DIFFERENCE PER KM			0.19

PEAK PERIOD (3:30 PM TO 6:00 PM)

<i>Section</i>	Hastings St.	Barnet Hwy	HOV Corridor
<i>Distance (kms)</i>	7.05	7.93	14.97
GP			
<i>Travel Time (minutes)</i>	14.1	7.5	21.7
<i>Travel Speed (km/h)</i>	30	63	41
HOV			
<i>Travel Time (minutes)</i>	12.2	7.0	19.1
<i>Travel Speed (km/h)</i>	35	68	47
TRAVEL TIME DIFFERENCE	2.0	0.6	2.5
TRAVEL TIME DIFFERENCE PER KM			0.17

TRAVEL TIME DIFFERENCE CONFIDENCE INTERVALS
OCTOBER, 1996 TO OCTOBER, 1997

WESTBOUND

PEAK PERIOD (6:00 AM TO 8:30 AM)

	Travel Time				CONFIDENCE INTERVALS			
	Difference (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})				
<i>October, 1996</i>	2.16	2.64	18	2.110	2.16 +/- 1.31	0.85	to	3.47
<i>October, 1997</i>	4.59	3.86	25	2.064	4.59 +/- 1.59	3.00	to	6.18

PEAK HOUR (7:30 AM TO 8:30 AM)

	Travel Time				CONFIDENCE INTERVALS			
	Difference (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})				
<i>October, 1996</i>	4.31	1.19	8	2.365	4.31 +/- 1.00	3.31	to	5.31
<i>October, 1997</i>	8.05	2.76	11	2.228	8.05 +/- 1.85	6.20	to	9.90

EASTBOUND

PEAK PERIOD (3:30 PM TO 6:00 PM)

	Travel Time				CONFIDENCE INTERVALS			
	Difference (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})				
<i>October, 1996</i>	1.71	1.66	27	2.056	1.71 +/- 0.66	1.05	to	2.37
<i>October, 1997</i>	2.54	2.10	27	2.056	2.54 +/- 0.83	1.71	to	3.37

PEAK HOUR (5:00 PM TO 6:00 PM)

	Travel Time				CONFIDENCE INTERVALS			
	Difference (Mean)	Standard Deviation	Sample Size	t-critical (t _{.025})				
<i>October, 1996</i>	2.41	1.44	12	2.201	2.41 +/- 0.91	1.50	to	3.32
<i>October, 1997</i>	2.83	2.57	12	2.201	2.83 +/- 1.63	1.20	to	4.46

TRAVEL SPEED MARGIN OF ERRORS
OCTOBER, 1996 TO OCTOBER, 1997

WESTBOUND

PEAK PERIOD (6:00 AM TO 8:30 AM)

	Travel Speed (Mean)	Standard Deviation	Sample Size	t-critical ($t_{0.025}$)	MARGIN OF ERROR (km/h)	MARGIN OF ERROR (as a % of the mean)
GP						
October, 1996	47.2	7.72	18	2.110	3.8	8%
October, 1997	41.9	10.74	25	2.064	4.4	11%
HOV						
October, 1996	51.5	6.34	18	2.110	3.2	6%
October, 1997	48.5	7.39	25	2.064	3.1	6%

PEAK HOUR (7:30 AM TO 8:30 AM)

	Travel Speed (Mean)	Standard Deviation	Sample Size	t-critical ($t_{0.025}$)	MARGIN OF ERROR (km/h)	MARGIN OF ERROR (as a % of the mean)
GP						
October, 1996	39.8	1.75	8	2.365	1.5	4%
October, 1997	32.0	2.73	11	2.228	1.8	6%
HOV						
October, 1996	47.5	3.66	8	2.365	3.1	6%
October, 1997	41.9	2.49	11	2.228	1.7	4%

EASTBOUND

PEAK PERIOD (3:30 PM TO 6:00 PM)

	Travel Speed (Mean)	Standard Deviation	Sample Size	t-critical ($t_{0.025}$)	MARGIN OF ERROR (km/h)	MARGIN OF ERROR (as a % of the mean)
GP						
October, 1996	41.6	4.08	27	2.056	1.6	4%
October, 1997	42.1	4.95	27	2.056	2.0	5%
HOV						
October, 1996	45.1	4.41	27	2.056	1.7	4%
October, 1997	47.4	4.48	27	2.056	1.8	4%

PEAK HOUR (5:00 PM TO 6:00 PM)

	Travel Speed (Mean)	Standard Deviation	Sample Size	t-critical ($t_{0.025}$)	MARGIN OF ERROR (km/h)	MARGIN OF ERROR (as a % of the mean)
GP						
October, 1996	39.0	3.34	12	2.201	2.1	5%
October, 1997	39.8	5.31	12	2.201	3.4	8%
HOV						
October, 1996	43.8	5.23	12	2.201	3.3	8%
October, 1997	44.9	3.19	12	2.201	2.0	5%

TRAVEL TIME DIFFERENCE STATISTICAL SIGNIFICANCE
OCTOBER, 1996 TO OCTOBER, 1997

WESTBOUND

PEAK PERIOD (6:00 AM TO 8:30 AM)

	Travel Time			test statistic	t-critical (t ₀₅)	STATISTICALLY SIGNIFICANT A>B ?
	Difference	Standard	Sample			
	(Mean)	Deviation	Size			
October, 1996	2.16	2.64	18	3.47	1.740	yes
October, 1997	4.59	3.86	25	5.95	1.711	yes
MINIMUM*	1.21	3.25	22	1.73	1.721	

PEAK HOUR (7:30 AM TO 8:30 AM)

	Travel Time			test statistic	t-critical (t ₀₅)	STATISTICALLY SIGNIFICANT A>B ?
	Difference	Standard	Sample			
	(Mean)	Deviation	Size			
October, 1996	4.31	1.19	8	10.24	1.895	yes
October, 1997	8.05	2.76	11	9.67	1.812	yes
MINIMUM*	1.18	1.98	10	1.84	1.833	

EASTBOUND

PEAK PERIOD (3:30 PM TO 6:00 PM)

	Travel Time			test statistic	t-critical (t ₀₅)	STATISTICALLY SIGNIFICANT A>B ?
	Difference	Standard	Sample			
	(Mean)	Deviation	Size			
October, 1996	1.71	1.66	27	5.35	1.706	yes
October, 1997	2.54	2.10	27	6.28	1.706	yes
MINIMUM*	0.62	1.88	27	1.71	1.706	

PEAK HOUR (5:00 PM TO 6:00 PM)

	Travel Time			test statistic	t-critical (t ₀₅)	STATISTICALLY SIGNIFICANT A>B ?
	Difference	Standard	Sample			
	(Mean)	Deviation	Size			
October, 1996	2.41	1.44	12	5.80	1.796	yes
October, 1997	2.83	2.57	12	3.81	1.796	yes
MINIMUM*	1.04	2.01	12	1.80	1.796	

NOTES:

1. MINIMUM based on an average standard deviation & sample size

TRAVEL TIME AND SPEEDS
OCTOBER, 1997
WESTBOUND

	7:00 AM		8:00 AM	
	GP LANE	HOV LANE	GP LANE	HOV LANE
16-Oct	42.00	47.75	32.59	47.22
17-Oct	42.99	52.21	43.02	45.32
20-Oct	42.11	47.85	40.02	46.34
21-Oct	39.21	47.14	35.82	44.21
22-Oct	42.65	50.84	31.06	43.28
23-Oct	34.74	39.72	35.62	39.92
24-Oct	42.84	51.09	47.71	51.33
27-Oct	45.35	50.45	42.17	46.14
28-Oct	39.40	49.67	37.72	45.71
29-Oct	35.53	47.26	36.15	44.29
30-Oct	37.21	50.41	38.32	45.48
31-Oct	38.53	56.23	46.40	49.90
Mean Travel Speed	40.21	49.22	38.88	45.76
Standard Deviation	3.29	3.93	5.17	2.95
Standard Deviation as a % of the mean	8.2%	8.0%	13.3%	6.5%
F-statistic	A	0.70	3.06	
F-critical ($F_{0.05}$)	B	2.82	2.82	
Statistically Significant?	A > B	NO	yes	
Sample Size	12	12	12	12
t-critical ($t_{0.025}$)	2.201	2.201	2.201	2.201
Margin of Error (km/h)	2.09	2.50	3.28	1.88
Margin of Error as a % of the mean	5.2%	5.1%	8.4%	4.1%

TRAVEL TIME AND SPEEDS
OCTOBER, 1997
EASTBOUND

	4:30 PM		5:30 PM	
	GP LANE	HOV LANE	GP LANE	HOV LANE
16-Oct	55.12	59.34	39.97	50.84
17-Oct	48.91	54.93	51.13	55.88
20-Oct	48.87	54.88	47.26	53.78
21-Oct	52.89	57.69	49.7	51.66
22-Oct	49.17	58.96	46.71	55.69
23-Oct	45.55	53.2	38.25	49.51
24-Oct	50.41	56.37	40.83	43.42
27-Oct	56.37	56.87	51.58	47.08
28-Oct	42.70	43.99	40.29	50.29
29-Oct	45.45	56.62	47.46	48.32
30-Oct	42.96	51.25	52.33	54.23
31-Oct	31.53	42.48	42.45	46.17
Mean Travel Speed	47.49	53.88	45.66	50.57
Standard Deviation	6.66	5.48	5.07	3.91
Standard Deviation as a % of the mean	14.0%	10.2%	11.1%	7.7%
F-statistic	A	1.48	1.68	
F-critical ($F_{0.05}$)	B	2.82	2.82	
Statistically Significant?	A > B	NO	NO	
Sample Size	12	12	12	12
t-critical ($t_{0.025}$)	2.201	2.201	2.201	2.201
Margin of Error (km/h)	4.23	3.48	3.22	2.49
Margin of Error as a % of the mean	8.9%	6.5%	7.1%	4.9%

COMPLIANCE RATES
WESTBOUND

Corridor	Barnet/Hastings HOV Corridor								
Section	St. Johns Street		Barnet Highway			Hastings Street			
Location	Williams	Clark	Reed	Bayview		Willingdon	Esmond	Lillooet	

OCTOBER, 1996

PEAK PERIOD (6:15 TO 8:15 AM)

Location Mean	88%	87%	86%	87%	89%	86%	77%
Section Mean	88%		87%		87%		
Corridor Mean	87%						

PEAK HOUR (7:30 TO 8:30 AM)

Location Mean	85%	77%	82%	87%	88%	83%	70%
Section Mean	81%		85%		80%		
Corridor Mean	82%						

MARCH, 1997

PEAK PERIOD (6:15 TO 8:15 AM)

Location Mean	87%	89%	76%	85%	89%	82%	74%
Section Mean	88%		81%		85%		
Corridor Mean	85%						

PEAK HOUR (7:30 TO 8:30 AM)

Location Mean	84%	90%	73%	82%	89%	83%	76%
Section Mean	87%		78%		83%		
Corridor Mean	85%						

OCTOBER, 1997

PEAK PERIOD (6:15 TO 8:15 AM)

Location Mean	83%	70%	78%	69%	78%	74%	33%
Section Mean	76%		73%		76%		
Corridor Mean	75%						

PEAK HOUR (7:30 TO 8:30 AM)

Location Mean	78%	74%	79%	73%	79%	79%	44%
Section Mean	76%		76%		67%		
Corridor Mean	72%						

NOTES: Lillooet rates not included in averages

COMPLIANCE RATES
EASTBOUND

Corridor	Barnet/Hastings HOV Corridor							
Section	Hastings Street						Barnet Highway	
Location	Lillooet	Cassiar	Kootenay	Carleton	Willingdon	Howard	Bayview	Union

OCTOBER, 1996

PEAK PERIOD (3:45 TO 5:45 PM)

Location Mean	65%	82%	86%	87%	85%	84%	89%	87%
Section Mean	85%						88%	
Corridor Mean	86%							

PEAK HOUR (5:00 TO 6:00 PM)

Location Mean	63%	80%	82%	86%	82%	81%	88%	82%
Section Mean	79%						85%	
Corridor Mean	80%							

MARCH, 1997

PEAK PERIOD (3:45 TO 5:45 PM)

Location Mean	64%	68%	75%	80%	74%	81%	95%	84%
Section Mean	76%						89%	
Corridor Mean	80%							

PEAK HOUR (5:00 TO 6:00 PM)

Location Mean	64%	75%	80%	83%	76%	84%	96%	86%
Section Mean	77%						91%	
Corridor Mean	80%							

OCTOBER, 1997

PEAK PERIOD (3:45 TO 5:45 PM)

Location Mean	55%	73%	80%	76%	79%	78%	89%	69%
Section Mean	77%						79%	
Corridor Mean	78%							

PEAK HOUR (5:00 TO 6:00 PM)

Location Mean	45%	72%	84%	73%	76%	80%	86%	66%
Section Mean	72%						76%	
Corridor Mean	73%							

NOTES: Lillooet rates not included in averages

BEFORE ACCIDENT RATES

LKI	LKI	CUMULATIVE		TOT		F I PDO		F I PDO		TOT	acc	YRS	ACCIDENT	AADT		MEV	MVK	INTERSECTION	SECTION
Start	Finish	Length		F	I	PDO	TOT	F	I	PDO	(acc)	(yr)	(acc/yr)	AADT				RATE	RATE
Boundary	0.0	0.7	0.7	1	13	16	30	1	13	16	30	4	8	33400		48.76	33.65	0.62	0.56
Boundary to Gilmore	0.0	0.7	0.7	1	23	25	49	0	10	9	19	4	5	33400		48.76	33.65	0.21	
Gilmore	0.7	1.5	0.8	2	24	33	59	1	1	8	10	4	3	33400		48.76	39.01		0.49
Gilmore to Willingdon	0.7	1.5	0.8	2	32	44	78	0	8	11	19	4	5	33400		48.76	39.01	0.76	
Willingdon	1.5	2.7	1.2	2	48	65	115	0	16	21	37	4	9	33400		48.76	56.57		0.28
Willingdon to Springe	1.5	2.7	1.2	3	54	74	131	1	6	9	16	4	4	33400		48.76	56.57	0.14	
Springe	2.7	3.0	0.4	4	57	77	138	1	3	3	7	4	2	33400		48.76	18.53		0.00
Springe to Ellensmere	2.7	3.0	0.4	4	57	77	138	0	0	0	0	4	0	33400		48.76	18.53	0.02	
Ellensmere	3.0	3.2	0.1	4	57	78	139	0	0	1	1	4	0	33400		48.76	5.85	0.45	1.20
Ellensmere to Holdom	3.0	3.2	0.1	4	59	83	146	0	2	5	7	4	2	33400		48.76	5.85	0.37	0.29
Holdom	3.2	4.3	1.2	4	68	96	168	0	9	13	22	4	6	33400		48.76	58.03		
Holdom to Spierling	3.2	4.3	1.2	4	73	108	185	0	5	12	17	4	4	33400		48.76	58.03		
Spierling	4.3	5.5	1.1	4	80	119	203	0	7	11	18	4	5	33400		48.76	55.59	0.04	0.07
Spierling to Malibu	4.3	5.5	1.1	4	81	122	207	0	1	3	4	4	1	33400		48.76	55.59	1.99	0.09
Malibu to Texaco	5.5	7.3	1.8	6	85	124	215	2	4	2	8	4	2	33400		48.76	86.31		0.12
Texaco to PetroCan	7.3	10.2	3.0	7	91	134	232	1	6	10	17	4	4	33400		48.76	144.34		0.23
PetroCan to Reed	10.2	11.4	1.2	7	98	141	246	0	7	7	14	4	4	33400		48.76	59.98		0.31
Reed to Gore	11.4	12.8	1.3	7	110	149	266	0	12	8	20	4	5	33400		48.76	64.86	0.04	1.07
Gore	12.8	13.5	0.8	7	112	149	268	0	2	0	2	4	1	33400		48.76	36.57		
Gore to St Johns	12.8	13.5	0.8	7	135	165	307	0	23	16	39	4	10	33400		48.76	36.57	1.99	2.97
St Johns (7A)	13.5	14.1	0.6	7	174	223	404	0	39	58	97	4	24	33400		48.76	29.26	0.68	2.22
St Johns to Queens	13.5	14.1	0.6	7	222	262	491	0	48	39	87	4	22	33400		48.76	29.26	0.92	1.64
Queens	14.1	14.7	0.6	7	235	282	524	0	13	20	33	4	8	33400		48.76	29.75	0.55	1.70
Queens to Moody	14.1	14.7	0.6	7	267	316	590	0	32	34	66	4	17	33400		48.76	29.75	1.97	
Moody	14.7	14.9	0.2	7	290	338	635	0	23	22	45	4	11	33400		48.76	7.31		
Moody to Hugh	14.7	14.9	0.2	7	300	340	647	0	10	2	12	4	3	33400		48.76	7.31	0.55	1.70
Hugh	14.9	16.3	1.4	8	312	354	674	1	12	14	27	4	7	33400		48.76	67.78	1.70	
Hugh to Dewdney	14.9	16.3	1.4	8	381	400	789	0	69	46	115	4	29	33400		48.76	67.78		
Dewdney	16.3	16.4		8	428	449	885	0	47	49	96	4	24	33400		48.76	67.78	1.70	
Two	16.4			8	476	484	968	0	48	35	83	4	21	33400		48.76	67.78	1.70	
				8	476	484	968						242						
			16.27																

LKI	LKI	Length		CUMULATIVE				TOT		TOT		FREQ		MEV	MVK	SECTION	
		Start	Finish	F	I	PDO	TOT	F	I	PDO	(acc)	(yr)	(acc/yr)			INTERSECTION RATE	RATE
Boundary	0.0	0.7	0.7	0	0	4	4	0	0	4	4	0.83	5	33400	10.16	0.39	1.43
Boundary to Gilmore	0.0	0.7	0.7	0	5	9	14	0	5	5	10	0.83	12	33400	10.16	0.20	1.72
Gilmore	0.7	1.5	0.8	0	6	10	16	0	1	1	2	0.83	2	33400	10.16		
Gilmore to Willingdo	0.7	1.5	0.8	0	12	18	30	0	6	8	14	0.83	17	33400	10.16		
Willingdo	1.5	2.7	1.2	0	15	20	35	0	3	2	5	0.83	6	33400	10.16	0.49	0.85
Willingdo to Sprin	1.5	2.7	1.2	1	19	25	45	1	4	5	10	0.83	12	33400	10.16	0.00	0.78
Springer	2.7	3.0	0.4	1	19	25	45	0	0	0	0	0.83	4	33400	10.16	1.18	1.64
Springer to Ellensmer	2.7	3.0	0.4	1	20	27	48	0	1	2	3	0.83	4	33400	10.16	0.30	1.99
Ellensmer	3.0	3.2	0.1	2	24	34	60	1	4	7	12	0.83	14	33400	10.16	0.30	1.47
Ellensmer to Holdom	3.0	3.2	0.1	2	25	35	62	0	1	1	2	0.83	2	33400	10.16		0.61
Holdom	3.2	4.3	1.2	2	25	38	65	0	0	3	3	0.83	4	33400	10.16		0.57
Holdom to Sperling	3.2	4.3	1.2	2	30	57	89	0	5	19	24	0.83	29	33400	10.16		1.04
Sperling	4.3	5.5	1.1	2	30	60	92	0	0	3	3	0.83	4	33400	10.16	0.49	0.07
Sperling to Malibu	4.3	5.5	1.1	2	35	72	109	0	5	12	17	0.83	20	33400	10.16		1.18
Malibu to Texaco	5.5	7.3	1.8	2	39	79	120	0	4	7	11	0.83	13	33400	10.16	0.20	1.31
Texaco to PetroCan	7.3	10.2	3.0	2	46	89	137	0	7	10	17	0.83	20	33400	10.16	0.69	3.23
PetroCan to Reed	10.2	11.4	1.2	2	50	98	150	0	4	9	13	0.83	16	33400	10.16	0.59	6.56
Reed to Gore	11.4	12.8	1.3	2	50	99	151	0	0	1	1	0.83	1	33400	10.16	1.08	1.56
Gore	12.8	13.5	0.8	2	51	103	156	0	1	4	5	0.83	6	33400	10.16	1.48	
Gore to St Johns	12.8	13.5	0.8	2	56	107	165	0	5	4	9	0.83	11	33400	10.16		
St Johns (TA)	13.5	14.1	0.6	2	58	107	167	0	2	0	2	0.83	2	33400	10.16		
St Johns to Queens	13.5	14.1	0.6	2	61	112	175	0	3	5	8	0.83	10	33400	10.16		
Queens	14.1	14.7	0.6	2	62	118	182	0	1	6	7	0.83	8	33400	10.16		
Queens to Moody	14.1	14.7	0.6	2	71	129	202	0	9	11	20	0.83	24	33400	10.16		
Moody	14.7	14.9	0.2	2	73	133	208	0	2	4	6	0.83	7	33400	10.16		
Moody to Hugh	14.7	14.9	0.2	3	79	136	218	1	6	3	10	0.83	12	33400	10.16		
Hugh	14.9	16.3	1.4	3	83	140	226	0	4	4	8	0.83	10	33400	10.16		
Hugh to Dewdney	14.9	16.3	1.4	3	95	150	248	0	12	10	22</						

ACCIDENT RATES BEFORE & AFTER

INTERSECTION	"Before" X_{Bi}	"After" X_{Ai}	SECTION	"Before" X_{Bi}	"After" X_{Ai}
Boundary	0.62	0.39	Boundary to Gilmore	0.56	1.43
Gilmore	0.21	0.20	Gilmore to Willingdon	0.49	1.72
Willingdon	0.76	0.49	Willingdon to Springer	0.28	0.85
Springer	0.14	0.00	Springer to Ellensmere	0.00	0.78
Ellensmere	0.02	1.18	Ellensmere to Holdom	1.20	1.64
Holdom	0.45	0.30	Holdom to Sperling	0.29	1.99
Sperling	0.37	0.30	Sperling to Malibu	0.07	1.47
Gore	0.04	0.49	Malibu to Texaco	0.09	0.61
St Johns (7A)	1.99	0.20	Texaco to PetroCan	0.12	0.57
Queens	0.68	0.69	PetroCan to Reed	0.23	1.04
Moody	0.92	0.59	Reed to Gore	0.31	0.07
Hugh	0.55	0.79	Gore to St. Johns	1.07	1.18
Dewdney	1.97	1.08	St Johns (7A) to Queens	2.97	1.31
Ioco	1.70	1.48	Queens to Moody	2.22	3.23
			Moody To Hugh	1.64	6.56
			Hugh to Dewdney	1.70	1.56
MEAN	0.74	0.58	MEAN	0.83	1.63
ST.DEV.	0.68	0.42	ST.DEV.	0.89	1.50
VARIANCE	0.46	0.18	VARIANCE	0.79	2.24
N	14	14	N	16	16
N-1	13	13	N-1	15	15
SUM of $(X_{Bi}-X_{Bavg})(X_{Ai}-X_{Aavg})$	1.346	1.346	SUM of $(X_{Bi}-X_{Bavg})(X_{Ai}-X_{Aavg})$	8.626	8.626
VARIANCE _{Difference}	0.429	0.429	VARIANCE _{Difference}	1.883	1.883
ST.DEV _{Difference}	0.655	0.655	ST.DEV _{Difference}	1.372	1.372
t-statistic	0.914	0.914	t-statistic	2.326	2.326
$t_{0.05}$ @ 95% with 13 d.o.f.	1.771	1.771	$t_{0.05}$ @ 95% with 15 d.o.f.	1.753	1.753
$t_{0.05}$ @ 90% with 13 d.o.f.	1.350	1.350	$t_{0.05}$ @ 90% with 15 d.o.f.	1.341	1.341
STATISTICALLY SIGNIFICANT ?	NO	NO	STATISTICALLY SIGNIFICANT ?	Yes	Yes

BURNABY ACCIDENT REPORT

Before (3 years, 7 months) After (1 year, 2 months)

Intersection	TOTAL	OTAL/YR	TOTAL	TOTAL/YR
Hastings and Boundary	66	18	9	8
Hastings and Esmond	8	2	9	8
Hastings and Ingleton	14	4	5	4
Hastings and Macdonald	17	5	2	2
Hastings and Gilmore	42	12	17	15
Hastings and Carleton	15	4	4	3
Hastings and Madison	19	5	7	6
Hastings and Rosser	29	8	11	9
Hastings and Willingdon	82	23	12	10
Hastings and Alpha	34	9	8	7
Hastings and Beta	10	3	4	3
Hastings and Gamma	38	11	3	3
Hastings and Hythe	5	1	4	3
Hastings and Springer	12	3	3	3
Hastings and Howard	10	3	8	7
Hastings and Ellesmere	6	2	3	3
Hastings and Warwick	7	2	1	1
Hastings and Holdom	69	19	5	4
Hastings and Fell	17	5	7	6
Hastings and Kensington	31	9	10	9
Hastings and Grove	7	2	1	1
Hastings and Sperling	46	13	9	8
Hastings and Clare	7	2	1	1
Hastings and Duncan	12	3	1	1
Hastings and Ellerslie	2	1	0	0
Hastings and Cliff	4	1	2	2
Hastings and Inlet	14	4	2	2
	623	174	148	127

VANCOUVER ACCIDENT REPORT

	Before (4 years)			After (4 months)		
Intersection	Fatalities	Injuries	PDOs	Fatalities	Injuries	PDOs
Hastings and Renfrew	1	37	86	0	1	6
	0	16	23	0	0	3
Hastings and Lilloet	0	6	8	0	0	1
	0	7	11	1	0	1
Hastings and Windermere	0	10	14	0	1	1
	0	10	19	0	0	0
Hastings and Rupert	0	0	1	0	0	0
	0	3	14	0	0	0
Hastings and Cassiar	0	20	37	0	1	3
	0	12	29	0	0	2
Hastings and Skeena	0	17	42	0	0	5
	0	8	40	0	0	0
Hastings and Kootenay	0	11	19	0	0	0
	0	9	34	0	0	0
Hastings and Boundary	1	17	47	0	2	4
TOTAL @ INTERSECTION	2	118	254	0	5	20
TOTAL @ MID-BLOCK	0	65	170	1	0	6
TOTAL	2	183	424	1	5	26
TOTAL/YR	1	46	106	3	15	78

IMPACT ON GP LANES
WESTBOUND

Corridor	Barnet/Hastings HOV Corridor				
Section	St. Johns Street	Barnet Highway		Hastings Street	
Location	Williams	Reed	Bayview	Willingdon	Lilloet
MARCH,1996					
GP Volume	2060	1363	1392	1909	2191
Section GP Volume	2060	1378		2050	
Section Travel Speed	18	44		28	
Corridor Travel Speed	30				
OCTOBER,1996					
GP Volume	1898	1574	1606	1352	
Section GP Volume	1898	1590		1352	
Section Travel Speed	45	53		30	
Corridor Travel Speed	40				
OCTOBER,1997					
GP Volume	2063	1499	1401	1889	1818
Section GP Volume	2063	1450		1854	
Section Travel Speed	42	40		24	
Corridor Travel Speed	32				

IMPACT ON GP LANES
EASTBOUND

Corridor

Barnet/Hastings HOV Corridor

Section

Hastings Street

Barnet Highway

Location

Lillooet

Carleton

Willingdon

Bayview

Union

MARCH, 1996

GP Volume

1927

1832

1380

1431

Section GP Volume

1880

1406

Section Travel Speed

23

35

Corridor Travel Speed

28

OCTOBER, 1996

GP Volume

1478

2029

1523

1678

Section GP Volume

1754

1601

Section Travel Speed

27

63

Corridor Travel Speed

39

OCTOBER, 1997

GP Volume

1493

1837

2071

1644

1819

Section GP Volume

1800

1732

Section Travel Speed

28

59

Corridor Travel Speed

39

EMME/2 2006 MODELING OUTPUT
WESTBOUND

	<u>Travel Times</u>			<u>Travel Time Differences</u>	
	<i>"Do nothing"</i>	<i>"Add HOV lane"</i>		<i>GP</i>	<i>HOV</i>
		<i>GP</i>	<i>HOV</i>		
<i>St. Johns Street</i>	2.32	1.30	1.11		
	4.93	2.36	1.78		
	1.62	0.95	0.91		
	0.95	0.67	0.48		
	0.58	0.55	1.19		
	3.45	1.70	0.44		
	0.22	0.12	0.62		
<i>Section Total</i>	14.07	7.65	6.53	6.4	7.5
<i>Barnet Highway</i>	1.58	0.77	0.59		
	0.80	0.39	0.36		
	1.00	0.49	0.51		
	0.56	0.27	0.23		
	0.92	0.45	0.39		
	1.08	0.52	0.46		
	1.68	0.82	0.72		
	5.12	2.48	2.19		
	1.12	1.08	1.08		
	0.61	0.59	0.62		
	0.93	0.69	0.67		
<i>Section Total</i>	15.40	8.55	7.82	6.9	7.6
<i>Hastings Street</i>	2.96	1.09	0.80		
	1.35	0.79	0.77		
	0.31	0.30	0.31		
	3.30	1.04	0.88		
	0.61	0.59	0.71		
	3.89	0.79	0.60		
	1.58	0.57	0.58		
	2.89	1.06	1.01		
	0.48	0.47	0.58		
	2.82	0.87	0.80		
	3.08	1.13	1.10		
	2.91	1.07	1.04		
	3.37	0.83	0.93		
	1.56	0.91	0.81		
<i>Section Total</i>	31.11	11.51	10.92	19.6	20.2
<i>Corridor Total</i>	60.58	27.71	25.27	32.9	35.3

PERSON-VOLUMES
1996 & 1997

OCTOBER, 1996

			Drivers	Occupants	Bus	Total
<u>WESTBOUND</u>	<i>St. Johns Street</i>	GP	1886	424	197	2507
		HOV	265	247	500	1012
		Total	2151	671	697	3519
	<i>Barnet Highway</i>	GP	1574	367	0	1941
		HOV	447	378	325	1150
		Total	2021	745	325	3091
	<i>Hastings Street</i>	GP	1353	152	0	1505
		HOV	539	528	1121	2188
		Total	1892	680	1121	3693
<u>EASTBOUND</u>	<i>Hastings Street</i>	GP	2027	365	0	2392
		HOV	560	523	435	1518
		Total	2587	888	435	3910
	<i>Barnet Highway</i>	GP	1523	125	0	1648
		HOV	433	402	256	1091
		Total	1956	527	256	2739

OCTOBER, 1997

		Drivers	Occupants	Bus	Total	
<u>WESTBOUND</u>	<i>St. Johns Street</i>	GP	2057	436	149	2642
		HOV	411	384	425	1220
		Total	2468	820	574	3862
	<i>Barnet Highway</i>	GP	1499	28	0	1527
		HOV	665	604	321	1590
		Total	2164	632	321	3117
	<i>Hastings Street</i>	GP	1888	188	10	2086
		HOV	565	505	872	1942
		Total	2453	693	882	4028
<u>EASTBOUND</u>	<i>Hastings Street</i>	GP	2070	395	10	2475
		HOV	662	593	774	2029
		Total	2732	988	784	4504
	<i>Barnet Highway</i>	GP	1644	340	0	1984
		HOV	656	346	210	1212
		Total	2300	686	210	3196

NOTES: - Westbound locations: St. Johns @ Williams, Barnet @ Reed, Hastings @ Willingdon
- Eastbound locations: Hastings @ Willingdon, Barnet @ Bayview

WAGE HOURS SAVED PER YEAR
WESTBOUND

GP				HOV				TRAVEL TIME SAVED PER DAY (hours)				WAGE HOURS SAVED PER YEAR									
Person Volumes		Travel Time Difference		Person Volumes		Travel Time Difference		Drivers		Occupants		Bus		Drivers		Occupants		Bus		TOTAL	
1996	St. Johns	1886	424	197	5.8	265	411	247	500	206	63	64	27574	5531	5604	38710					68900
	Barnet	1574	367	0	1.9	447	378	325	325	83	40	24	11151	3498	2133	16781					
	Hastings	1353	152	0	0.8	539	528	1121	1121	45	28	56	6017	2487	4904	13409					
1997	St. Johns	2057	436	149	5.86	411	384	425	425	239	78	54	32010	6868	4750	43628					92841
	Barnet	1499	28	0	2.4	665	604	321	321	113	50	26	15150	4335	2252	21736					
	Hastings	1888	188	10	2.68	565	505	872	872	129	48	69	17224	4211	6041	27476					
1998	St. Johns	2057	436	149	5.92	411	384	425	425	243	80	56	32478	7023	4894	44395					110252
	Barnet	1499	28	0	2.9	665	604	321	321	129	53	27	17280	4628	2397	24305					
	Hastings	1888	188	10	4.56	565	505	872	872	204	68	94	27303	5993	8256	41552					
1999	St. Johns	2057	436	149	5.98	411	384	425	425	246	82	58	32945	7179	5037	45161					127662
	Barnet	1499	28	0	3.4	665	604	321	321	145	56	29	19411	4922	2542	26874					
	Hastings	1888	188	10	6.44	565	505	872	872	279	89	120	37381	7775	10471	55627					
2000	St. Johns	2057	436	149	6.04	411	384	425	425	250	84	59	33413	7335	5180	45928					145073
	Barnet	1499	28	0	3.9	665	604	321	321	161	60	31	21541	5215	2687	29443					
	Hastings	1888	188	10	8.32	565	505	872	872	355	109	145	47460	9557	12685	69702					
2001	St. Johns	2057	436	149	6.1	411	384	425	425	253	86	61	33880	7491	5323	46694					162484
	Barnet	1499	28	0	4.4	665	604	321	321	177	63	32	23671	5509	2832	32012					
	Hastings	1888	188	10	10.2	565	505	872	872	430	130	170	57538	11339	14900	83778					
2002	St. Johns	2057	436	149	6.16	411	384	425	425	257	87	62	34348	7646	5466	47461					179895
	Barnet	1499	28	0	4.9	665	604	321	321	193	66	34	25801	5802	2977	34581					
	Hastings	1888	188	10	12.08	565	505	872	872	506	150	196	67617	13122	17115	97853					
2003	St. Johns	2057	436	149	6.22	411	384	425	425	260	89	64	34815	7802	5610	48227					197306
	Barnet	1499	28	0	5.4	665	604	321	321	209	70	36	27932	6096	3122	37150					
	Hastings	1888	188	10	13.96	565	505	872	872	581	170	221	77696	14904	19329	111929					
2004	St. Johns	2057	436	149	6.28	411	384	425	425	264	91	66	35283	7958	5753	48993					214716
	Barnet	1499	28	0	5.9	665	604	321	321	225	73	37	30062	6389	3268	39719					
	Hastings	1888	188	10	15.84	565	505	872	872	656	191	246	87774	16686	21544	126004					
2005	St. Johns	2057	436	149	6.34	411	384	425	425	267	93	67	35750	8114	5896	49760					232127
	Barnet	1499	28	0	6.4	665	604	321	321	241	76	39	32192	6683	3413	42288					
	Hastings	1888	188	10	17.72	565	505	872	872	732	211	272	97853	18468	23759	140080					
2006	St. Johns	2057	436	149	6.4	411	384	425	425	271	95	69	36218	8269	6039	50526					249538
	Barnet	1499	28	0	6.9	665	604	321	321	257	80	41	34323	6976	3558	44857					
	Hastings	1888	188	10	19.6	565	505	872	872	807	231	297	107931	20250	25974	154155					

NOTES: 1. travel time differences between 1996 and 2006 interpolated
2. travel time saved converted to wage hours saved as follows: drivers * 0.535 (5% commercial drivers and 95% regular drivers), occupants * 0.35, bus * 0.35
3. assumed 250 days per year

PEAK HOUR FACTORS

		<u>WESTBOUND</u>		<u>EASTBOUND</u>	
		Percentage of		Percentage of	
		Vehicle Travel	Peak Hour Travel	Vehicle Travel	Peak Hour Travel
Time		Time Savings	Time Savings	Time Savings	Time Savings
from	to	(vehicle-hours)	(%)	(vehicle-hours)	(%)
0:00	1:00				
1:00	2:00				
2:00	3:00				
3:00	4:00				
4:00	5:00				
5:00	6:00	0.15	0.03%		
6:00	7:00	215.4	44.6%	0.05	0.01%
7:00	8:00	483.0	100.0%	0.13	0.03%
8:00	9:00	244.0	50.5%	0.08	0.02%
9:00	10:00	2.60	0.54%	0.04	0.01%
10:00	11:00	0.48	0.10%	0.05	0.01%
11:00	12:00	0.19	0.04%	0.12	0.03%
12:00	13:00	0.18	0.04%	0.23	0.05%
13:00	14:00	0.28	0.06%	0.55	0.12%
14:00	15:00	0.44	0.09%	1.14	0.24%
15:00	16:00	1.13	0.23%	100.0	21.1%
16:00	17:00	0.91	0.19%	473.0	100.0%
17:00	18:00	0.31	0.06%	200.4	42.4%
18:00	19:00	0.30	0.06%	13.29	2.81%
19:00	20:00	0.04	0.01%	0.53	0.11%
20:00	21:00	0.01	0.00%	0.14	0.03%
21:00	22:00	0.01	0.00%	0.12	0.03%
22:00	23:00	0.01	0.00%	0.04	0.01%
23:00	0:00			0.04	0.01%
TOTAL			197%	TOTAL	167%
FACTOR			1.97	FACTOR	1.67

NOTES: vehicle-hours obtained from the "Benefit/Cost Evaluation of Barnet/Hastings Project" (MoTH,1993)

PEAK HOUR TRAVEL TIME SAVINGS
WESTBOUND

INPUT:	Worst Case	Most Likely	Best Case	CHOICE
DISCOUNT RATE	12%	8%	6%	8%
AVERAGE WAGE RATE	14.00	18.00	23.00	18.00
GROWTH RATE	0%	2%	5%	2%

OUTPUT:	
PRESENT VALUE	\$ 13,245,558 \$ 22,532,918 \$ 36,908,539

FROM	TO	PROJECT YEAR	WAGE HOURS SAVED/YEAR	WAGE HOURS WITH GROWTH	TRAVEL TIME SAVED/YEAR	DISCOUNTED TOTALS
1990	1991		0	0	0	0
1991	1992		0	0	0	0
1992	1993		0	0	0	0
1993	1994		0	0	0	0
1994	1995		0	0	0	0
1995	1996		0	0	0	0
1996	1997	1	68,900	68,900	1,240,200	1,240,200
1997	1998	2	92,841	92,841	1,671,138	1,547,350
1998	1999	3	110,252	112,457	2,024,227	1,735,448
1999	2000	4	127,662	132,820	2,390,752	1,897,856
2000	2001	5	145,073	153,953	2,771,147	2,036,876
2001	2002	6	162,484	175,878	3,165,802	2,154,592
2002	2003	7	179,895	198,619	3,575,135	2,252,942
2003	2004	8	197,306	222,199	3,999,575	2,333,714
2004	2005	9	214,716	246,641	4,439,541	2,398,546
2005	2006	10	232,127	271,974	4,895,528	2,448,983
2006	2007	11	249,538	298,221	5,367,978	2,486,413
2007	2008	12			0	0
2008	2009	13			0	0
2009	2010	14			0	0
2010	2011	15			0	0
2011	2012	16			0	0
2012	2013	17			0	0
2013	2014	18			0	0
2014	2015	19			0	0
2015	2016	20			0	0
			1,780,794	1,974,501	\$ 35,541,024	\$ 22,532,918

NUMBER OF KILOMETRES SAVED
OCTOBER, 1996

<u>WESTBOUND PEAK PERIOD</u>					
<u>Location</u>	<u>Person Volume</u>	"BEFORE" AVO "AFTER" AVO		<u>KMS</u>	<u>KMS SAVED</u>
		<u>1.23</u>	<u>1.29</u>		
		<u># of vehicles</u>	<u># of vehicles</u>	<u>Difference</u>	
St. Johns	6663	5417	5165	252	761
Reed Pt.	7203	5856	5584	272	
Bayview	6542	5319	5071	247	
Barnet	6873	5587	5328	260	2030
Willingdon	6389	5194	4953	242	
Lilloet					
Hastings	6389	5194	4953	242	1696
TOTAL KMS				17.85	4487
TOTAL KMS/YEAR					1,121,642

<u>EASTBOUND PEAK PERIOD</u>					
<u>Location</u>	<u>Person Volume</u>	"BEFORE" AVO "AFTER" AVO		<u>KMS</u>	<u>KMS SAVED</u>
		<u>1.29</u>	<u>1.32</u>		
		<u># of vehicles</u>	<u># of vehicles</u>	<u>Difference</u>	
Lilloet	7157	5548	5422	126	
Willingdon	8389	6503	6355	148	
Hastings	7773	6026	5889	137	965
Bayview	6082	4715	4608	107	
Union	6017	4664	4558	106	
Hastings	6050	4690	4583	107	844
TOTAL KMS				14.97	1810
TOTAL KMS/YEAR					452,395
					1,574,036

NOTES: - based on 250 working days per year

NUMBER OF KILOMETRES SAVED
OCTOBER, 1997

<u>WESTBOUND PEAK PERIOD</u>	Location	Person Volume	"BEFORE" AVO "AFTER" AVO			KMS	KMS SAVED
			1.23 # of vehicles	1.29 # of vehicles	Difference		
	St. Johns	7642	6213	5924	289	3.02	873
	Reed Pt.	7470	6073	5791	282		
	Bayview	7297	5933	5657	276		
	Barnet	7384	6003	5724	279	7.81	2181
	Willingdon	7250	5894	5620	274		
	Lilloet	6253	5084	4847	236		
	Hastings	6752	5489	5234	255	7.02	1792
	TOTAL KMS		17.85				4846
	TOTAL KMS/YEAR						1,211,377

<u>EASTBOUND PEAK PERIOD</u>	Location	Person Volume	"BEFORE" AVO "AFTER" AVO			KMS	KMS SAVED
			1.29 # of vehicles	1.34 # of vehicles	Difference		
	Lilloet	6749	5232	5037	195		
	Carleton	7836	6074	5848	227		
	Willingdon	8741	6776	6523	253		
	Hastings	7775	6027	5802	225	7.05	1586
	Bayview	6836	5299	5101	198		
	Union	6981	5412	5210	202		
	Hastings	6909	5355	5156	200	7.92	1583
	TOTAL KMS		14.97				3168
	TOTAL KMS/YEAR						792,053
							2,003,430

NOTES: - based on 250 working days per year

VEHICLE OPERATING COST SAVINGS
WESTBOUND & EASTBOUND

INPUT:		Worst Case	Most Likely	Best Case	CHOICE
DISCOUNT RATE		12%	8%	6%	8%
OPERATING COST RATE		0.08	0.09	0.12	0.09
GROWTH RATE		0%	2%	5%	2%
KMS SAVED/YR		899,146	1,458,709	2,003,430	1,458,709
OUTPUT:					
PRESENT VALUE		\$ 655,756	\$ 1,591,122	\$ 4,151,110	

FROM	TO	PROJECT YEAR	KMS SAVED/YEAR	KMS SAVED WITH GROWTH	VEHICLE OPERATING \$ SAVED/YEAR	DISCOUNTED TOTALS
1990	1991		0	0	0	0
1991	1992		0	0	0	0
1992	1993		0	0	0	0
1993	1994		0	0	0	0
1994	1995		0	0	0	0
1995	1996		0	0	0	0
1996	1997	1	1,574,036	1,574,036	141,663	141,663
1997	1998	2	1,458,709	1,458,709	131,284	121,559
1998	1999	3	1,458,709	1,487,883	133,909	114,806
1999	2000	4	1,458,709	1,517,641	136,588	108,428
2000	2001	5	1,458,709	1,547,994	139,319	102,404
2001	2002	6	1,458,709	1,578,954	142,106	96,715
2002	2003	7	1,458,709	1,610,533	144,948	91,342
2003	2004	8	1,458,709	1,642,743	147,847	86,267
2004	2005	9	1,458,709	1,675,598	150,804	81,475
2005	2006	10	1,458,709	1,709,110	153,820	76,948
2006	2007	11	1,458,709	1,743,292	156,896	72,673
2007	2008	12	1,458,709	1,778,158	160,034	68,636
2008	2009	13	1,458,709	1,813,721	163,235	64,823
2009	2010	14	1,458,709	1,849,996	166,500	61,222
2010	2011	15	1,458,709	1,886,996	169,830	57,820
2011	2012	16	1,458,709	1,924,736	173,226	54,608
2012	2013	17	1,458,709	1,963,230	176,691	51,574
2013	2014	18	1,458,709	2,002,495	180,225	48,709
2014	2015	19	1,458,709	2,042,545	183,829	46,003
2015	2016	20	1,458,709	2,083,396	187,506	43,447
			29,289,507	34,891,764	\$ 3,140,259	\$ 1,591,122

NOTES: - calculated for the peak periods only

AIR QUALITY SAVINGS
WESTBOUND & EASTBOUND

INPUT:	Worst Case	Most Likely	Best Case	CHOICE
DISCOUNT RATE	4%			4%
POLLUTANT COST RATE	0.02	0.04	0.08	0.04
GROWTH RATE	0%	2%	5%	2%
KMS SAVED/YR	899,146	1,458,709	2,003,430	1,458,709
OUTPUT:				
PRESENT VALUE	\$ 267,667	\$ 963,089	\$ 3,321,759	

FROM	TO	PROJECT YEAR	KMS SAVED/YEAR	KMS SAVED WITH GROWTH	POLLUTANTS SAVED/YEAR	DISCOUNTED TOTALS
1990	1991		0	0	0	0
1991	1992		0	0	0	0
1992	1993		0	0	0	0
1993	1994		0	0	0	0
1994	1995		0	0	0	0
1995	1996		0	0	0	0
1996	1997	1	1,574,036	1,574,036	62,961	62,961
1997	1998	2	1,458,709	1,458,709	58,348	56,104
1998	1999	3	1,458,709	1,487,883	59,515	55,025
1999	2000	4	1,458,709	1,517,641	60,706	53,967
2000	2001	5	1,458,709	1,547,994	61,920	52,929
2001	2002	6	1,458,709	1,578,954	63,158	51,911
2002	2003	7	1,458,709	1,610,533	64,421	50,913
2003	2004	8	1,458,709	1,642,743	65,710	49,934
2004	2005	9	1,458,709	1,675,598	67,024	48,974
2005	2006	10	1,458,709	1,709,110	68,364	48,032
2006	2007	11	1,458,709	1,743,292	69,732	47,108
2007	2008	12	1,458,709	1,778,158	71,126	46,202
2008	2009	13	1,458,709	1,813,721	72,549	45,314
2009	2010	14	1,458,709	1,849,996	74,000	44,442
2010	2011	15	1,458,709	1,886,996	75,480	43,588
2011	2012	16	1,458,709	1,924,736	76,989	42,749
2012	2013	17	1,458,709	1,963,230	78,529	41,927
2013	2014	18	1,458,709	2,002,495	80,100	41,121
2014	2015	19	1,458,709	2,042,545	81,702	40,330
2015	2016	20	1,458,709	2,083,396	83,336	39,555
			29,289,507	34,891,764	\$ 1,395,671	\$ 963,089

NOTES: - calculated for the peak periods only

CONSTRUCTION COSTS

INPUT:		Worst Case	Most Likely	Best Case	CHOICE
	DISCOUNT RATE	12%	8%	6%	12%
OUTPUT:	PRESENT VALUE	\$ 140,343,482	\$ 127,327,070	\$ 121,335,938	

FROM	TO	PROJECT YEAR	CONSTRUCTION COSTS	DISCOUNTED TOTALS
1990	1991		7,718,000	15,233,963
1991	1992		11,062,000	19,495,024
1992	1993		8,590,000	13,516,531
1993	1994		13,920,000	19,556,598
1994	1995		20,811,400	26,105,820
1995	1996		27,940,500	31,293,360
1996	1997	1	14,825,400	14,825,400
1997	1998	2	354,800	316,786
1998	1999	3		0
1999	2000	4		0
2000	2001	5		0
2001	2002	6		0
2002	2003	7		0
2003	2004	8		0
2004	2005	9		0
2005	2006	10		0
2006	2007	11		0
2007	2008	12		0
2008	2009	13		0
2009	2010	14		0
2010	2011	15		0
2011	2012	16		0
2012	2013	17		0
2013	2014	18		0
2014	2015	19		0
2015	2016	20		0
2016	2017	21		0
2017	2018	22		0
2018	2019	23		0
2019	2020	24		0
2020	2021	25		0
			\$ 105,222,100	\$140,343,482

MAINTENANCE COSTS

INPUT:		Worst Case	Most Likely	Best Case	CHOICE
DISCOUNT RATE		6%	8%	12%	8%
MAINTENANCE /YR		575,900	523,545	471,191	523,545
OUTPUT:					
PRESENT VALUE		\$ 7,001,853	\$ 5,551,461	\$ 3,941,875	

FROM	TO	PROJECT YEAR	MAINTENANCE COSTS	DISCOUNTED TOTALS
1990	1991		0	0
1991	1992		0	0
1992	1993		0	0
1993	1994		0	0
1994	1995		0	0
1995	1996		0	0
1996	1997	1	523,545	523,545
1997	1998	2	523,545	484,764
1998	1999	3	523,545	448,855
1999	2000	4	523,545	415,607
2000	2001	5	523,545	384,821
2001	2002	6	523,545	356,316
2002	2003	7	523,545	329,922
2003	2004	8	523,545	305,483
2004	2005	9	523,545	282,855
2005	2006	10	523,545	261,903
2006	2007	11	523,545	242,503
2007	2008	12	523,545	224,539
2008	2009	13	523,545	207,907
2009	2010	14	523,545	192,506
2010	2011	15	523,545	178,247
2011	2012	16	523,545	165,043
2012	2013	17	523,545	152,818
2013	2014	18	523,545	141,498
2014	2015	19	523,545	131,017
2015	2016	20	523,545	121,312
			\$ 10,470,900	\$ 5,551,461

NUMBER OF LANE-KILOMETRES

		# of lanes	kms	lane-kms
St. Johns	W/B	3	3.02	9.06
Barnet	W/B	2	7.81	15.62
Hastings	W/B	3	7.02	21.06
Hastings	E/B	3	7.05	21.15
Barnet	E/B	2	7.93	15.86
			TOTAL	82.75
			COST/KM	\$ 6,326.83
			COST/YR	\$ 523,545