Ministry of Transportation and Highways
Province of British Columbia

Trans Canada Highway HOV-TMP Monitoring and Evaluation Program *"Before" Implementation Study*

APPENDICES FINAL DRAFT – January 1998

EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

In order to alleviate congestion in the Highway 1 corridor and to encourage the modal shift to higher occupancy vehicles explicit in GVRD's Transport 2021 Plan, the Ministry of Transportation and Highways (MoTH), together with the BC Transportation Financing Authority (BCTFA), are initiating two major highway improvement projects in the Highway 1 corridor through the Lower Mainland. The first project, which commenced construction in September 1997 and is to open in the Fall, 1998, is the widening of Highway 1 from 4 lanes to 6 lanes between Grandview Highway and Cape Horn, to provide a high occupancy vehicle (HOV) lane in each direction. The second major project will involve implementation of the Traffic Management Program (TMP) on a longer, 30 km section of the highway, extending from Lynn Valley Road in North Vancouver to 160 Street in Surrey. The Traffic Management Program is a multi-phase program of traffic monitoring, incident management and traveller information, commencing with introduction of emergency patrols in conjunction with opening of HOV lanes, followed by implementation of automatic incident detection and traveller information, expected to be operational by late 2002.

Since these two projects involve substantial investments by the province, approximately $65 million for the HOV Project and $35 million for the TMP Project, MoTH and TFA wish to evaluate the impacts of these projects in terms of traveller benefits, and the extent to which they achieve the objectives of the Livable Region Strategy. In this first phase of the evaluation program, objectives were defined, measures of effectiveness were established for each of the objectives and the baseline traveller data were collected along the length of the corridor during August and September 1997.

This Phase I traffic data will be the baseline for measuring the benefits of the HOV Project. Phase II traffic data, to be collected after opening of the HOV facility, will provide the "after" benefits of the HOV Project, as well as the "before" traffic conditions for the TMP Project. Phase III, to be conducted after implementation of the TMP Project, will provide the "after" benefits of the TMP Project relative to both the Phase I and Phase II travel patterns.

This report describes the first phase of the evaluation program and recommends scope and procedures for undertaking the Phase II and Phase III evaluation programs.

HOV PROJECT

As shown in the following exhibit, the HOV Project will involve development of exclusive HOV lanes on Highway 1 between Grandview Highway on the west and Cape Horn interchange on the east, to be operational by approximately the end of September, 1998. The improvement project has a capital budget of $65 million. The HOV facility will be in operation throughout the day and will be restricted to high occupant vehicles, including carpools, vanpools and buses, as well as motorcycles.

By providing higher travel speed and lower travel time variability, the HOV facility is expected to encourage a modal shift to higher occupancy vehicles, resulting in an increase in the person carrying throughput of the highway, increase in travel speed, more reliable travel times and a reduction in energy consumption and vehicle emissions due to reduced delays and congestion.

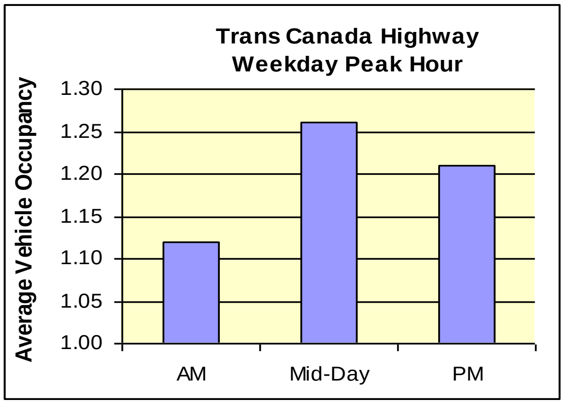
In order to evaluate the benefits of this HOV Project, seven objectives were defined:

1. **increase person movement throughput;**
2. **provide travel time savings;**
3. **improve trip travel time reliability;**
4. **increase per-lane efficiency;**
5. **ensure general purpose (GP) lane operations are not adversely affected;**
6. **ensure safety;**
7. **improve environmental conditions.**

For each of these objectives, measures of effectiveness (MOEs) were defined. These dictated the travel data to be collected to measure the degree of achievement of each of the objectives. Each of the HOV Project objectives and its measures of effectiveness are described in the following sections.

HOV Objective 1 - Increase Person Movement Throughput

This objective focuses on increasing the number of persons per vehicle travelling in the corridor, including both private vehicles and public transit vehicles. In order to measure the vehicle occupancy, all vehicles were counted and classified by type. The numbers of occupants crossing 5 screenlines strategically defined along the length of Highway 1 and including parallel routes that may be impacted by the HOV facility were recorded. The counts were undertaken on selected weekdays, a typical weekend and the Labour Day weekend, during the morning, mid-day and evening peak periods. The average vehicle occupancy varied by time of day, but was consistent within the peak periods across the screenlines and by direction. The average vehicle occupancies are as follows:



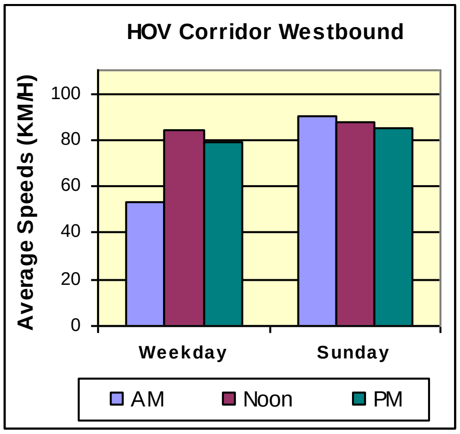
A statistical analysis of the vehicle occupancy counts indicated that the variance within the time periods and across adjacent screenlines is not significant, implying that fewer counts are required in the future program. This finding is incorporated in the Phase II and III program requirements presented later.

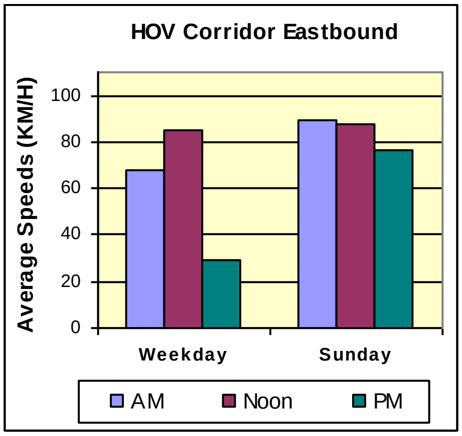
HOV Objective 2 - Provide Travel Time Savings

HOV facilities are intended to provide travel time savings for users of the facility relative to travelling in the general purpose lanes, and relative to the pre-HOV operations.

In order to measure the travel time savings, travel time surveys were undertaken during three weekdays and on a typical weekend over the entire length of the facility. Travel times and speeds were recorded during the morning, midday and evening peak periods for each of 20 sections of the highway, to isolate possible operational issues that may need to be addressed.

The average speeds by direction are shown below for two segments in the HOV facility:





The travel times and speeds indicated the following:

- mid-day travel speeds range between 80 and 90 km per hour, very close to free flow operations;
- PM peak travel speeds are lower than AM peak travel speeds, due to higher traffic levels and congestion;
- the speeds in the peak direction are much lower than in the off peak direction, again due to the higher volumes and congestion in the peak direction;
- Sunday travel speeds are higher than weekday speeds at all times of the day.

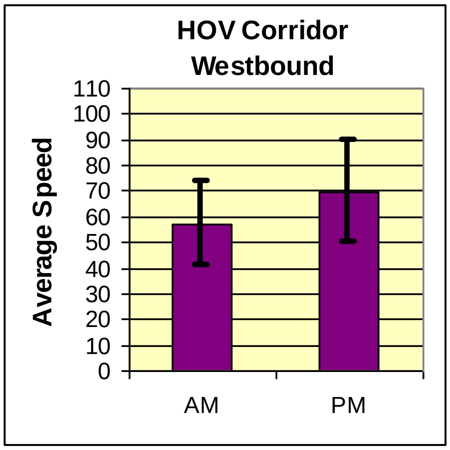
An analysis of variance indicated that the margin of error in the peak period ranges between 5 and 7.5 km per hour, implying that in order for future speeds to be significantly different, variations will need to be greater than these values.

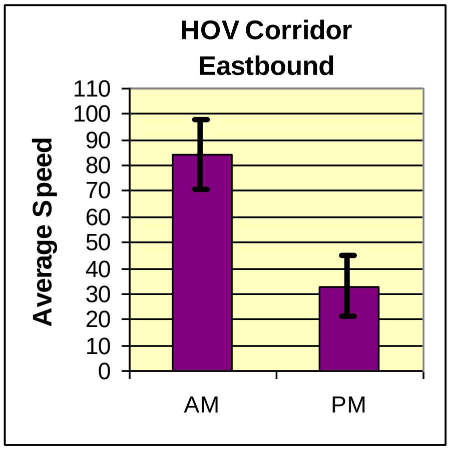
HOV Objective 3 - Improve Trip Travel Time Reliability

The intent of this objective is to provide eligible HOVs with improved travel time reliability on the HOV facility, thus making the HOV usage more attractive and encouraging a shift to high occupancy vehicle travel.

Trip travel time reliability was measured over 20 weekdays during both the morning and evening peak periods. Travel time and average speeds were recorded over each of four sections of the entire facility from Lynn Valley Road to 176th Street, which included the two segments within the HOV section. Two travel time runs were made in each direction during each period.

The travel times and average speeds obtained from this survey over 20 weekdays were statistically similar to the average travel times and speeds obtained from the more detailed travel time surveys described above under Objective 2. As shown in the chart below, the standard deviation of the average speeds by direction and time period varied between 12 and 16 km per hour, with the exception of the variance during the PM peak period in the off-peak direction where a standard deviation of 20 km per hour was obtained.





Note: I = Standard Deviation

The margin of error is estimated to range between 4 and 6km per hour, compared to the ITE suggested margin of error of 5km per hour. It was observed that the first run in each of the periods achieved higher speeds than the second run, due to heavier congestion in the latter part of the peak period. Stratification of these runs would reduce the margin of error. Also grouping observations during similar weather conditions and separating those that encountered an incident reduced the variability.

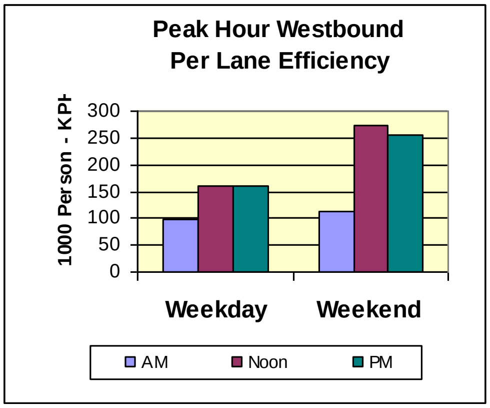
For Phases II and III, it is recommended that a similar program of travel time reliability surveys be undertaken during the same time periods and that results be stratified by weather, with weekends and holidays excluded.

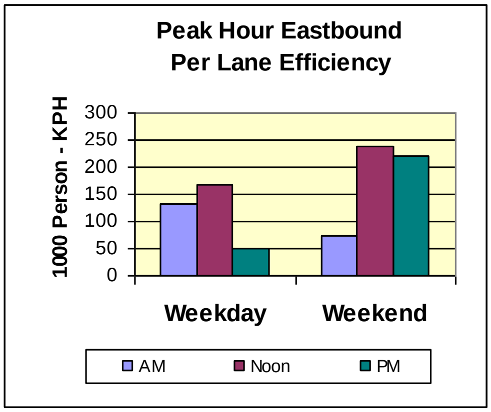
HOV Objective 4 - Increase Per-Lane Efficiency

The intent of this objective is to increase the per-lane efficiency of the highway, expressed in terms of person-kilometres per hour.

This objective was measured in terms of average person volumes per lane multiplied by the average travel speeds. Thus, either an improvement in average travel speed or an increase in vehicle occupancy, or both, with the introduction of HOV facility will increase the per-lane efficiency of the corridor.

The Phase I per-lane efficiency as observed west of the Cariboo Interchange is shown in the following chart.





The per-lane efficiency results are presented in thousand-person kilometres per hour. Clearly the combination of high occupants and average higher speeds during the mid-day period and the weekend provide the highest per-lane efficiency, followed by the AM and PM off-peak directions. The lowest per-lane efficiency is during the peak period in the peak direction, particularly during the PM peak when speeds are much lower than other times.

In the future, the per-lane efficiency will be affected by the level of car occupancy permitted in the HOV lane. A 2+ regulation could result in a higher number of HOV vehicles in the HOV lane, compared to 3+ persons per vehicle regulation, and therefore higher passenger volumes. On the other hand, average speeds may be lower in the HOV lanes due to higher vehicle volumes with 2+ regulations compared to 3+ regulations.

HOV Objective 5 - Ensure GP Lane Operations Not Adversely Affected

The intent of this objective is to ensure that the introduction of HOV operations does not lower the capacity and operating speeds of the adjacent general purpose lanes. This objective addresses the potential concern that the HOV facility will induce more weaving between the GP lanes and the HOV lane, thus affecting capacity.

In order to examine this objective, vehicle counts and average speeds were analyzed to estimate level of service by road segment prior to introduction of the HOV facility.

In both the eastbound and westbound direction, highway segments within the HOV corridor operate at a level of service (LOS) E or worse during the morning and afternoon peak hours.

Traffic and queue lengths on the ramps at each interchange were also observed and recorded from an aircraft and analyses were undertaken to determine levels of service. The eastbound on-ramp from Grandview Highway and the eastbound on-ramp from Lougheed Highway in both the morning and afternoon peak periods were observed to be operating at LOS E or worse.

In Phase II, traffic operations at the entrance and exit of the HOV facility should be observed, particularly weaving, to determine possible impacts of the HOV facility on the general purpose lanes, in addition to the level of service analysis.

HOV Objective 6 - Ensure Safety

The intent of this objective is to ensure that the HOV facility provides safe operations and that the safety of the GP lanes is not compromised or worsened as a result of the introduction of the HOV lanes. The measurement of this objective is the number of accidents before and after implementation of the HOV lanes.

Highway 1 collision data, covering a 5-year period (1992 - 1996) was analyzed. During this time period there were 2,800 reported collisions for the HOV segment. However, due to changes in police reporting in 1996, the accident levels reduced dramatically compared to previous years. Future accident monitoring must determine the criteria for reporting accidents, whether they are similar to 1996 reporting criteria or earlier criteria.

The accident analysis revealed that:

- collision frequency was highest on Fridays, at approximately 16%, and compared well to the 1995 provincial average of 17%;
- hourly collision frequency was found to have distinct peaks in the morning and afternoon peak periods (16% and 23% respectively), significantly higher than the 1995 provincial averages (10% and 20%);
- approximately 59% of collisions were classified as property damage, while 41% were classified as injury;
- the most frequent collision type is rear-end, accounting for 61% of reported collisions, while 18% were recorded as off road collisions;
- approximately 24% of collisions occur during rainy weather;
- approximately 58% of collisions involved 2 vehicles;
- the interchanges and segments with the highest collision rate are:
  - eastbound lanes at Grandview and Willingdon Avenues;
  - eastbound and westbound lanes at the Lougheed/Cape Horn interchange;
  - eastbound lanes between Brunette and Lougheed/Cape Horn interchange;
  - eastbound lanes at the Cariboo interchange.

HOV Objective 7 - Improve Environmental Conditions

The intent of this objective is to improve air quality conditions by lowering vehicle emissions per person travelling in the corridor. These benefits will be achieved when HOVs encounter less stop-and-go conditions, and travel at optimum traffic flow conditions.

An environmental assessment model was utilized to measure levels of emissions resulting from traffic volumes and operating speeds observed during the baseline survey. In addition, the GVRD Environmental Assessment Branch carried out air quality measurements over a 15 day period along Highway 1 between the Cape Horn and Brunette interchanges.

Estimates of the levels of emissions as obtained from the environmental assessment model for the length of the HOV corridor are shown below:

- Nitrogen Oxides

  < 5.7 to 9.1 grams per person (in each direction during the peak hour)

- Carbon Monoxide

  < 6.5 to 11.3 grams per person (in each direction during the peak hour)

In terms of the individual segments considered, the area surrounding the Cariboo Interchange is estimated to have the highest levels of emissions of nitrogen oxide and carbon monoxide.

The air quality data obtained by the GVRD Environmental Assessment Branch will be retained for comparison with air quality data obtained during Phase II to provide another estimate of the environmental impact of the HOV facility.

TMP PROJECT

The section of the Trans Canada Highway, between Lynn Valley Road in North Vancouver and 176th Street in Surrey is the corridor examined in this project. This section encompasses the “pilot corridor” for the first phase of the TMP which extends between Lynn Valley Road and 160th Street. The service applications to be implemented along this pilot corridor include Incident Management (Automatic Incident Detection, CCTV Monitoring, Emergency Patrols, *4444 Incident Reporting System) and Traveller Information (Changeable Message Signs, Media and Internet dissemination, Highway Advisory Radio). The system will be integrated through a Traffic Management Centre supported by a SONET backbone fiber-optic telecommunication system. The system is planned to be operational by the year 2002.

As a pilot corridor, the evaluation of system benefits will form a key consideration in the justification and approval of future phases of the TMP. In order to evaluate benefits, five measurable objectives were identified in this study:

1. **reduce non-recurrent congestion;**
2. **reduce recurrent congestion;**
3. **improve safety;**
4. **efficient use of capacity;**
5. **environmental benefits.**

These objectives are described below in terms of their purpose, MOEs, data requirements, baseline data obtained, and future requirements.

TMP Objective 1 - Reduce Non-recurrent Congestion

The intent of this objective is to use incident management strategies and technologies to reduce the impacts of traffic incidents. The primary impacts of traffic incidents are non-recurrent congestion, vehicular delays, and risk of secondary accidents due to lane blockage.

The MOEs identified for this objective are incident duration and vehicular delays due to incidents. Use of these MOEs requires “before” and “after” incident data related to response times, clearance times, and impacts. To collect the baseline data, traffic incidents were observed and logged over a three week period, and along a total of 20km of the 34km corridor.

A total of 76 incidents were logged, two-thirds of which comprised vehicle stoppages on the shoulder of the roadway, requiring no response. Data for 24 "responded" incidents were reviewed. It was observed that 75% of the responded incidents were vehicle breakdowns requiring only a response from tow trucks. It was further observed that 75% of the incidents occurred in the PM peak period, with the location and direction of the incidents evenly distributed throughout the corridor. The following was noted:

- average incident duration was 42 minutes;
- average occurrence to response time was 23 minutes;
- average response to clearance time was 19 minutes.

Statistical analysis of the data has shown that the standard deviations of the above times is as large as the actual times. However, this is found to be consistent with other studies (such as the evaluation of the COMPASS system in Toronto where average incident durations were observed to be 86 minutes with a standard deviation of 88 minutes).

The total vehicle and person delay, and the associated cost to the consumers was estimated for a typical incident. The "cost" of a 30 minute incident on the Port Mann Bridge was estimated to be 450 vehicle-hours, or 540 person-hours. This delay equates to a social cost of $6,500 (at an approximate time value of $12 per hour). Thus, improvements which reduce incident duration yield a benefit of $216 per minute saved per incident.

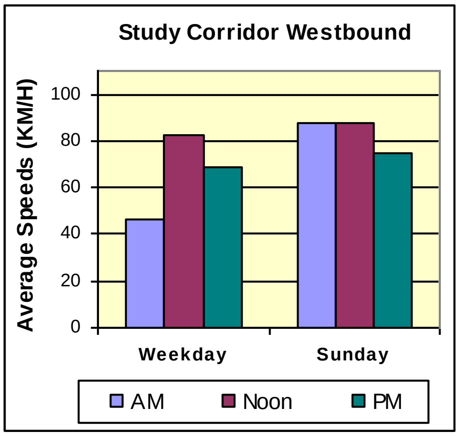
In comparing "before" and "after" incident duration data, the sample size must be large enough so that any measured reduction in incident duration is statistically significant. Furthermore, to compute delays resulting from incidents, the data must include a significant sample of incidents with lane blockages.

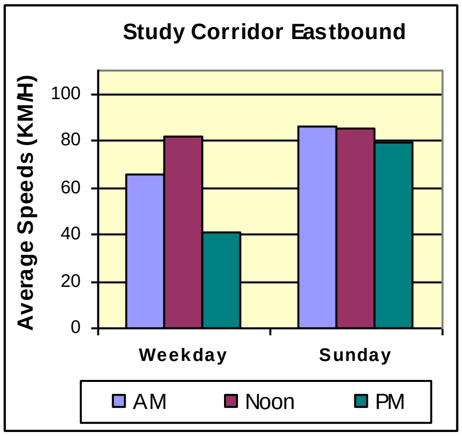
Accordingly, it is recommended that "before" data from Phase I be supplemented to increase the sample size by collecting additional incident data in Phase II, after the opening of the HOV lanes, and before full implementation of the TMP. Based on the review of current/planned incident management procedures, the collection of Phase II incident data may be enhanced through the use of the temporary monitoring facility set-up for HOV lane construction traffic management, and by more refined information exchange and flows between the Region 1 Communications Centre and supporting road maintenance contractors.

TMP Objective 2 - Reduce Recurrent Congestion

The intent of this objective is to use the capabilities of real-time traffic monitoring and traveller information system to better manage recurring congestion. The primary quantifiable benefit of this objective is an increase in average speeds and a decrease in total travel times.

To measure the "before" data for these indicators, the travel time surveys undertaken for *HOV Objective 2* were extended to encompass the TMP corridor as well. The average weekday speeds by direction are shown below in terms of the four segments in the TMP corridor:





The observed speeds are very similar to the patterns of the HOV segments. However, speeds are lower on the North Shore section because of the delays resulting from peak period congestion experienced on the Second Narrows Bridge approaches.

TMP Objective 3 - Improve Safety

The intent of this objective is to improve the safety of the corridor through reduction of non-recurrent and recurrent congestion.

The overall safety benefit of TMP is derived from the integrated operation of all its capabilities (i.e. incident management, automatic incident detection, and en-route traveller information). The primary measure of this objective is collision rates along the TMP corridor.

Highway 1 collision data collected over the last 5 years was analyzed to establish baseline conditions. During this time period there were 4,740 reported collisions along the TMP corridor. Approximately 60% of these collisions are those analyzed for the HOV segment. In this regard, collision characteristics for the whole TMP corridor were found to be quite similar to the HOV segments alone. In addition to the HOV corridor interchanges and segments with high collision rates, the eastbound lanes between Fern Street and the Second Narrows Bridge were also identified as having a high collision rate. The impact of the changes in police reporting in 1996 also persist in the TMP baseline data.

A specific benefit of automatic incident detection and traveller information, through Changeable Message Signs (CMSs), is the reduction of secondary accidents. The incident data obtained in the survey did not include any secondary accidents. In order to quantify this benefit, the supplemental incident data recommended for collection under Phase II is intended to also obtain a sample of secondary accidents.

TMP Objective 4 - Efficient Use of Capacity

The intent of this objective is to make use of all available road capacity in the corridor, including parallel routes. While the management of recurrent congestion will provide travel time benefits along the mainline, it will also allow for more efficient use of available capacity along the mainline and parallel routes at a network level. In this regard, real-time traffic monitoring complemented with traveller information can balance traffic demand and capacity between a congested facility and a parallel facility.

It was determined that there is little or no spare capacity on the parallel routes available during the peak periods, indicating that it may not be possible to achieve greater efficient use of capacity. It also indicates that there will be limited opportunity to divert traffic from the mainline to the parallel facilities in the peak periods. However, due to lower volumes and therefore available spare capacity at non-peak times, the opportunities exist to achieve efficient use of capacity in the mid-day period and on weekends.

Consequently, in Phase II when additional “before” TMP traffic data is collected, traffic counts on both the mainline and parallel routes should be monitored simultaneously to determine the extent of traffic diversion between routes during congested periods; thus, achieving efficient use of capacity.

TMP Objective 5 – Environmental Benefit

The intent of this objective is to achieve improved air quality conditions, through the reduction of recurring and non-recurring congestion, and therefore reducing vehicle emissions. These benefits will result from TMP congestion management strategies.

The environmental assessment model used for the HOV corridor was also utilized to measure levels of emissions, and fuel consumption resulting from traffic volumes and operating speeds observed along the TMP corridor. Estimates of the levels of emissions are shown below for the length of the TMP corridor:

- Nitrogen Oxides

  < 6.3 to 7.8 grams per person (in each direction during the peak hour)

- Carbon Monoxide

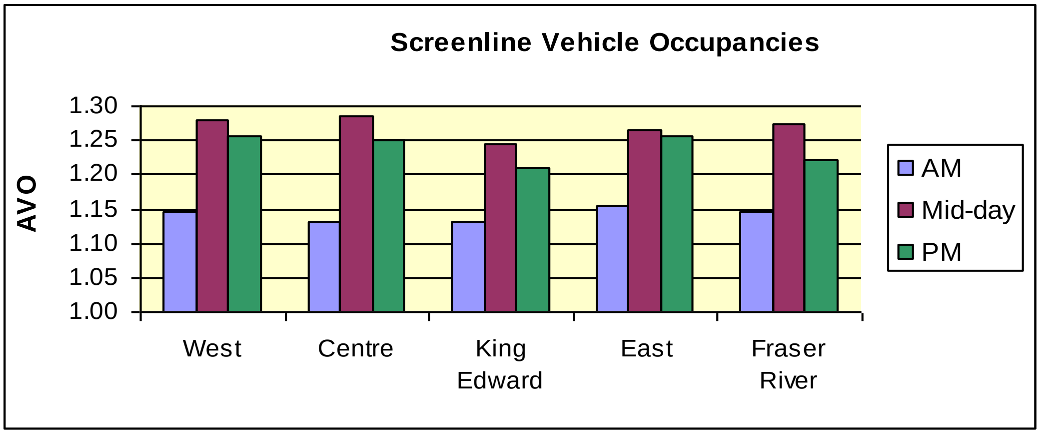
  < 7.1 to 9.5 grams per person (in each direction during the peak hour)

These levels of emissions will be estimated again in Phases II and III using the model to evaluate the impacts of the TMP project.

NETWORK IMPACTS

Impacts on the road network adjacent to the TCH corridor were analyzed in order to be able to differentiate between actual mode shifts to the HOV facility, rather than diversion of existing HOVs from routes parallel to the HOV facility. As a consequence, the data collection program undertaken in this study was extended to include the routes parallel to the TCH, as well as the mainline, thus accounting for existing HOV traffic diverted from the parallel routes to the mainline.

The AVOs on the TCH mainline and the parallel routes across the five screenlines along the corridor were as follows:



Intersection turning movement and 24-hour counts were also collected at key intersections along the parallel routes. Capacity analysis indicates that the majority of the intersections along the parallel routes are operating near or at capacity during the weekday peak periods – thus limiting the potential of absorbing diversions from the TCH mainline to off-peak periods.

In order to ensure that the network impacts of HOV and TMP projects are considered within the appropriate corridor of influences, the following is recommended:

- confirmation of the corridor of influence using the GVRD EMME/2 model;
- evaluation of environmental impacts and benefits, with the determined corridor of influence, using emissions and air quality modeling;
- simulation of model effects of the HOV facility and the TMP system to enhance the actual "after" data.

FUTURE REQUIREMENTS

Based on the study methodology adopted for the Phase I data collection, the analysis of the actual data collected, the lessons learned, and current understanding of future requirements, a preliminary Work Program was developed for the future phases of this study. The Work Program is comprised of the following major activities:

- **Phase II Project Initiation:** The first step of Phase II efforts will be to confirm objectives, refine MOEs, and finalize data requirements as identified under this study. The output of this activity will be the Phase II data collection program.

- **Phase II Data Collection:** This activity will consist of the actual data collection efforts. These efforts will be very similar to the Phase I efforts, but will include the recommended improvements to the data collection program outlined herein, the enhanced incident observation and logging, as well as public opinion surveys of the HOV facility.

- **Phase II Evaluation:** Under this activity, all of the Phase I and Phase II data will be compiled and analyzed in terms of “before” and “after” evaluation of each MOE, along with the documentation of additional “after” data such as public response. The output of this activity will be three reports: HOV Evaluation Report, TMP Interim Evaluation Report, and TMP Baseline Conditions Report.

- **Phase III Project Initiation:** Under this activity, all related works from Phases I and II will be reviewed, and the TMP timelines, strategies, operations, and technologies will be confirmed. Based on this update, system objectives and MOEs will be confirmed, and the baseline data will be compiled to properly form the “before” TMP data.

- **Phase III Data Collection:** Efforts under this activity will be different from the previous phases, as the TMP technologies will provide a large portion of the required “after” data. Specifically, the vehicle detector stations and the automatic incident detection data processing will provide volume and speed data, while the CCTV monitoring will provide continuous incident logging.

- **Phase III Evaluation:** Under this activity, the Phase II and Phase III data will be analyzed and a TMP evaluation report will be prepared for the pilot implementation. The data and analysis will also be used to provide an update on the HOV operations.

Phase II efforts will be carried out during 1999, between six months and one year after the opening of the HOV lanes in September of 1998. Subsequent monitoring efforts should be carried out on an annual basis until the Phase III study in late 2002 and early 2003. Ongoing monitoring of both projects will be required for proper evaluation and documentation of benefits. For HOV facilities especially, much of the significant impacts of successful implementations elsewhere have been observed to occur up to two to four years after opening. For the TMP project, the benefits of some components will be measurable immediately, such as Incident Management, while other benefits such as public response to pre-trip and enroute traveller information will require absorption periods (6 months to 1 year).

Future (post Phase III) monitoring efforts need not be as extensive as the Phase I - III evaluation project, and can be focused on a set of alternating key indicators to be more cost effective. The long term perspective of a monitoring program is nevertheless an essential requirement for the proper evaluation and documentation of the benefits that will result from these two projects.

1.0 INTRODUCTION

1.1 BACKGROUND

The South Coast Region of British Columbia is one of the fastest growing and economically vibrant regions in Canada and North America. Unfortunately, with growth comes traffic congestion and accidents. Although the Greater Vancouver Regional District's (GVRD) Transport 2021 document provides a long-term vision for the region's transportation needs, trip lengths will increase and the automobile will likely continue to be one of the major modes of transportation. Traffic congestion, accidents and air pollution will continue to increase.

In an attempt to better manage traffic growth in the face of limited capital resources, and to meet the reduction in single occupancy vehicles (SOVs) explicit in the Transport 2021 Plan, the Ministry of Transportation and Highways (MoTH) is about to implement two comprehensive projects to enhance the person carrying capacity and to reduce traffic congestion, accidents and air pollution along the Highway 1 (Trans Canada Highway) corridor. These two major initiatives are:

- Widening of Highway 1 between the Grandview Highway and the Port Mann Bridge to 6 lanes, accommodating high occupancy vehicles (HOVs) in the two new lanes.

- Implementing the first two functions, incident management and traveller information, of the Traffic Management Program (TMP), in the section of Highway 1 between Lynn Valley Road in North Vancouver and 160th Street in Surrey.

The South Coast Region HOV Network Study (July 1995), undertaken by IBI Group in association with Parsons Brinckerhoff, identified a phased program of implementation of HOV systems improvements, including the construction of HOV lanes on Highway 1. Construction commenced in September 1997 and is to be completed in late September 1998. Once completed, the project will significantly change travel patterns in the corridor. In anticipation of this, MoTH wishes to determine the extent of changes in travel behavior in the corridor and has therefore initiated this project to establish the baseline traffic patterns before implementation of the HOV. Post-HOV studies will be undertaken after opening of the HOV lanes to complete the evaluation of the impact of the new facility.

The second component of the highway improvement program in the Trans Canada Highway corridor is the Traffic Management Program, outlined in the TMP Master Plan dated 1994. The TMP Master Plan identifies a large number of improvements, incorporating Intelligent Transportation System (ITS) applications, to better manage traffic in the South Coast Region. The TMP identifies a number of short-term, "early winners", including incident management and traveller information in the Highway 1 corridor.

In support of the TMP project, communication conduits and related underground infrastructure are being installed as part of the HOV widening project. Other civil work associated with the TMP project will be installed during the HOV construction, following which the TMP systems and field devices will be installed and a Traffic Management Centre (TMC) constructed in 1999 with full TMC operation by 2002.

Similar to the HOV Project, MoTH wishes to evaluate the impact of the TMP project by establishing a pre-TMP traffic baseline, for comparison with the post-TMP traffic patterns in the corridor. Since the majority of the TMP service applications will likely be implemented some time after the opening of the HOV lanes, the TMP evaluation will include the presence of the HOV lanes in much of its baseline data. The true pre-TMP/post-HOV baseline will be established, after opening of the HOV lanes. The demonstration of the effectiveness and benefits of the TMP along the Highway 1 pilot corridor will be an important part of ensuring that the TMP is expanded to other future corridors.

The Ministry of Transportation and Highways has initiated this data collection project to establish a monitoring and evaluation program and obtain the “before” traffic data in the corridor, to be used as the baseline for evaluating improvements for the HOV Project, and to be one of the baselines for the evaluation of the TMP project. MoTH has developed Terms of Reference dated June 25, 1997 outlining the required project.

IBI Group, in association with Hamilton Associates, was retained by MoTH to undertake this first phase project. **Exhibit 1.1** provides the project team structure.

The primary objectives of Phase I, as defined in the Terms of Reference, are as follows:

1. Identify HOV and TMP measures of effectiveness (MOE’s) and develop a methodology for a quantitative evaluation of the MOE’s for both “before” and “after” surveys.

2. Coordinate and conduct data collection activities for the “before” survey only, and document the baseline traffic information in the corridor prior to the HOV 6-lane construction.

3. Define the monitoring and data collection program for the “after” surveys, namely the Phase II post-HOV/pre-TMP project, and Phase III, the post-TMP project.

The study area is the 34 km section of Trans Canada Highway between Lynn Valley Road overpass in North Vancouver and the 176th Street overpass in Surrey. This corridor encompasses both the HOV and TMP pilot corridors. The corridor includes parallel arterial roads which may provide alternate routes for TCH traffic, and includes Canada Way, Lougheed Highway, as well as Mary Hill Bypass and Barnet Highway. **Exhibit 1.2** illustrates the coverage of the study area.

1.2 STUDY METHODOLOGY

The following steps summarize the methodology used to carry out the “before” data collection and to establish baseline conditions. This methodology is also illustrated in **Exhibit 1.3**.

1. **Establish Project Objectives:** The first step in developing the evaluation program was to clearly define measurable objectives and goals that the HOV and TMP projects are intended to accomplish.
2. **Identify Measures of Effectiveness:** For each objective, appropriate measure(s) of effectiveness (MOEs) were defined. Threshold levels or ranges of change (i.e. typical benefits) that may be used to determine if objectives have been met were also identified.
3. **Establish Data Requirements:** The specific “before” and “after” data needs of each MOE were defined. The identification of data requirements also included definition of the methodology for data collection and supporting data analysis. As it is possible for different MOEs to have common data requirements, it was important to ensure that the data collection met the needs of the various MOEs.
4. **Develop Study Design:** Completion of the above three steps led to the development of a Data Collection Program which was compiled into a study design for carrying out the “before” data collection. This document entitled TCH-HOV-TMP Monitoring and Evaluation Program - “Before” Implementation Study Methodology & Work Program (August 1997) established the framework for this Phase I study.
5. **Conduct Data Collection:** Based on the HOV and TMP objectives, MOEs, and data requirements identified for “before” and “after” evaluation, the “before” data collection program was finalized and conducted. The program included the following types of surveys and data collection:

    - Short counts (mainline and parallel routes)
    - Vehicle occupancy and classification surveys (mainline & parallel routes)
    - Manual intersection counts (parallel routes)
    - Travel time, speed, and delay surveys
    - Trip time reliability surveys
    - Incident observation and logging
    - Highway approach queue surveys
    - Collision data
    - Emissions modeling and air quality monitoring

    Transtech Data Services assisted the project team in conducting the surveys. The detailed results of these surveys and data collection efforts are documented in the appendix to this report.

6. **Analysis:** The raw data was analyzed and “packaged” to suit the data requirements for each MOE. In order to establish the variability and reliability of collected data, statistical analysis was conducted for each of the major data sets (excluding intersection counts). The mean and

variance values were calculated and these values were used to establish the acceptable limits of error for the collected samples.

7. **Reporting:** The results of Phase I are documented in this final report and supported by the detailed appendix to the report. The report reviews in detail each of the objectives defined for the HOV and TMP projects, and presents the baseline data in terms of each MOE and its data requirements. The report then presents an analysis of the parallel routes and outlines a work program for Phases II and III of the monitoring and evaluation program.

2.0 HOV MONITORING & EVALUATION

Research has shown that development of high-occupancy vehicle (HOV) facilities has been one of the most effective techniques to manage traffic growth and its related affects, such as vehicle delay and congestion, accidents, and environmental impacts such as fuel consumption and air pollution. The benefits of HOV facilities are realized by a shift to higher-occupancy vehicles, such as car pools, van pools and buses, resulting in an increase in vehicle occupancy and person carrying throughput of the highway corridor, an increase in average travel speeds, more reliable trip travel times, and a reduction in energy consumption and vehicle emissions.

In order to evaluate the Highway 1 HOV widening project relative to these benefits, a number of objectives and measures of effectiveness were developed expressing these benefits. The draft *HOV Operations Implementation Manual* for the Trans Canada Highway HOV facility developed for MoTH was used as a reference for the objectives and the measures of effectiveness. Other literature and research was also reviewed including the Texas Transportation Institute document entitled An Assessment of High Occupancy Vehicle Facilities in North America. The objectives proposed for this evaluation are:

1. increase person movement throughput;
2. provide travel time savings and trip time reliability;
3. improve trip travel time reliability;
4. increase per-lane efficiency;
5. ensure GP lane operations not adversely affected;
6. ensure safety;
7. improve environmental conditions.

The objectives listed above are considered to be measurable through “before” and “after” surveys. Some additional objectives, such as degree of public support and degree of compliance, cannot be measured until the improvements are implemented. These are addressed in section 5.0 Future Requirements.

In this report, the “before” baseline travel and traffic data is presented. Following implementation of the HOV facility, the “after” traffic data will be recorded and compared to the “before” baseline data to evaluate the benefits of the HOV Project relative to each of the objectives.

Each of the objectives identified for evaluation is discussed in terms of the following sections:

1. **primary focus;**
2. **recommended MOEs for evaluation;**
3. **data requirements;**
4. **description of the baseline data and analysis;**
5. **recommendations regarding future travel and traffic surveys for Phase II and Phase III evaluations.**

2.1 INCREASE PERSON MOVEMENT THROUGHPUT

2.1.1 Objective Description

The focus of this objective is to increase the movement throughput of a congested roadway in terms of the number of people, rather than the number of vehicles. This objective is achieved when the Average Vehicle Occupancy (AVO) level of a roadway increases. This increase should be a function of attracting new transit riders, vanpools, and carpools, and not the result of attraction/diversion of existing high occupant vehicles from adjacent lanes or routes.

2.1.2 MOEs

Specific MOEs which were selected to evaluate the achievement of this objective are:

- increase in AVO;
- increase in the number of vanpools and carpools;
- increase in bus ridership.

2.1.3 Data Requirements

In order to measure the MOEs identified above, the "before" and "after" data collection must include:

- vehicle counts;
- vehicle occupancy counts;
- vehicle classifications (vanpool, carpool and buses).

These MOEs must be measured on all roadways in the corridor, including Highway 1 and the parallel routes on Canada Way and Lougheed Highway, in order to distinguish between induced HOV usage and diverted HOVs from parallel routes.

2.1.4 Baseline Data

All of the data requirements for the MOEs identified above have been obtained with the vehicle occupancy and classification count surveys (documented in Appendix A-2). This information has been compiled and analyzed to establish the baseline conditions for each MOE.

Increase In AVO

To facilitate the measurement of an increase in AVOs, collected occupancy data has been summarized into the following exhibits:

- **Exhibit 2.1.1** presents the weekday and Sunday AVOs, for the AM, noon, and PM peak hours, at all 6 stations along the mainline (corridor averages are provided in the table below);

Average Peak Hour AVO	Weekday		Sunday	
	EB	WB	EB	WB
AM Peak	1.12	1.12	1.40	1.52
Mid-day	1.25	1.26	1.69	1.77
PM Peak	1.20	1.22	1.66	1.82

- **Exhibit 2.1.2** presents the weekday AVOs, for the AM, noon, and PM peak hours, at all 8 stations along the parallel routes;
- **Exhibits 2.1.3, 2.1.4, and 2.1.5** present the weekday AVOs, on a screenline basis (combining mainline and parallel route AVOs), for the AM, noon, and PM peak hours respectively.

Weekday vehicle occupancies are observed to be lowest during the AM period which comprises largely work trips, highest during the mid-day period which comprises the least proportion of work trips, and between the two extremes for the PM period which comprises a combination of work and non-work trips. Weekend occupancies are much higher than average on Sundays, as they comprise mostly social / recreational trips.

Future data can be plotted adjacent to the existing “before” data in order to measure changes in AVO. While the first two exhibits allow such comparisons to be carried out for the mainline and parallel routes independently, the latter three exhibits, which consider AVOs on a screenline basis, are the recommended approach for using this MOE. In this regard, consideration of changes in AVO on a screenline basis will allow the evaluation to distinguish between the attraction of new high occupant vehicles, as opposed to the diversion of existing high occupant vehicles from the parallel routes.

Increase in the Number of Vanpools and Carpools

Measuring an increase in the number of carpools and vanpools also serves as a useful indicator for this objective – allowing for the evaluation of the HOV facility in terms of encouraging a change towards high occupant commute modes.

For establishing baseline conditions herein, the vehicle classification and occupancy data can be used to generate various “carpool” categories. **Exhibits 2.1.6, 2.1.7, and 2.1.8** provide the vehicle occupancy data for mainline weekday, mainline Sunday, and parallel routes weekday - peak hour conditions respectively. The tabulations provide vehicle occupancy categories ranging from 1 to 4+, and a van pool category which assumes 6 occupants; here, the number of vehicles in each category are tabulated along with a percentage relative to total vehicles.

Exhibits 2.1.9, 2.1.10, and 2.1.11 tabulate the peak hour vehicle classification data for mainline weekday, mainline Sunday, and parallel routes weekday - peak hour conditions respectively.

Truck traffic tends to be relatively constant throughout the day, but represents a higher proportion of total vehicles during the mid-day as a result of the lower number of car trips. The proportion of truck traffic along the parallel routes is much higher than on the mainline.

Increase in Bus Ridership

Similar to encouraging the generation of new carpools, an effective HOV facility should lead to an increase in bus ridership where applicable. As indicated in the terms of reference for this study, the estimation of BC Transit bus occupancies does not apply to the baseline data collection program, as there are currently no transit buses operating along the length of the mainline corridor. The data collected did nevertheless separately classify other types of "buses" (i.e. tour, etc.).

Since the vehicle classification component of the surveys did include a general bus category, an attempt was made to estimate occupancies for other types of buses (tour, etc.). However, caution must be used in the analysis and interpretation of these numbers, due to the difficulty of counting large numbers of transit passengers on the buses and the likely high margin of error. In general, bus occupancy data should be based on actual ridership information obtained from BC Transit, and not on observed occupancy estimates. For the purposes of this MOE, use of "before" data is not applicable along the mainline, while "after" data can be obtained from BC Transit in Phase II of this project.

As part of the stakeholder liaisons undertaken in this study, BC Transit was contacted to determine availability of transit ridership data along the parallel routes considered. It was found that Lougheed Highway and Highway 1 formed two of four corridors considered by BC Transit in an internal strategic planning study focusing on the potential transit use of HOV facilities. The BC transit ridership data compiled under this study, will be available for the Phase II analysis of this project upon internal compilation by BC Transit.

2.1.5 Phase II - Post-HOV "After" Evaluation

Data collection for measuring increases in AVO and carpools must be of similar detail to those obtained for baseline conditions, while taking into account the comments, lessons learned, and recommendations provided in Appendix A-2.

Data related to measuring an increase in the number of new carpools can be supplemented through the survey of car-poolers in order to identify those formed primarily as a result of the introduction of HOV lanes along Highway 1. In general, the survey of car-poolers in the "after" conditions present an excellent means of collecting supplemental information for the evaluation of other objectives presented in this report (i.e. on travel time savings and trip reliability – discussed in subsequent sections).

Regarding future bus ridership data, BC Transit does have a regular monitoring program which focuses on hot spots, or specific areas of study. Future data collection efforts in this regard must ensure sufficient timing is available for BC Transit to incorporate the mainline and parallel routes into their monitoring program.

The extent to which this data will be required for Phase II evaluation purposes will largely depend on the effectiveness of the HOV facility to attract buses. Discussions with BC Transit have indicated that current strategies do not include the addition of many buses along the mainline, despite the implementation of HOV lanes. Use of Highway 1 by BC Transit buses is anticipated to be only for short “on and off” sections.

2.1.6 Phase III (Post-TMP) Ongoing Monitoring

The extent to which this objective can be monitored in subsequent phases will depend primarily on the results of the evaluation under Phase II. As the achievement of this objective could range from a negligible increase in person movement throughput to the use of the HOV lane “at” capacity, the focus of the monitoring efforts should include documenting the continued increase in person-volumes, so that appropriate actions can be taken prior to the HOV lanes reaching their capacity.

2.2 PROVIDE TRAVEL TIME SAVINGS

2.2.1 Objective Description

The focus of this objective is to provide eligible HOVs with travel time savings over the length of the HOV facility to encourage greater HOV use. Achievement of this objective is critical to the success of an HOV facility, since travel time savings is one of the key incentives for commuters to switch to a high occupancy mode.

2.2.2 MOEs

Specific MOEs which were selected to evaluate the achievement of the objective are:

- lower travel time along the HOV lanes in comparison to the post-HOV GP lanes;
- lower travel time along the HOV lanes in comparison to the pre-HOV GP lanes.

2.2.3 Data Requirements

In order to measure the MOEs identified above, data collection must include:

- “before” vehicle average speeds in the general purpose lanes;
- “after” vehicle average speeds in both the HOV and GP lanes.

2.2.4 Baseline Data

The MOEs identified for this objective are lower travel times along the HOV lanes when compared against the GP lanes (both pre and post HOV lane construction). As detailed in Appendix A-4, baseline travel time data has been obtained for weekday and weekend conditions, and summarized in terms of both average travel times and speeds.

Baseline travel times were obtained along the full length of the study corridor, and grouped in terms of North Shore, Burnaby, Coquitlam, and Surrey. However, only the Burnaby and Coquitlam sections apply to the evaluation of this HOV objective (while travel times associated with the full length of the corridor are presented later in the context of the TMP corridor and objectives.) **Exhibit 2.2.1** provides a graphical summary of the data in terms of average speeds.

Exhibit 2.2.2 tabulates the travel time data obtained for the HOV corridor, along with the calculated average speeds, and the delay experienced when compared to free-flow conditions. Average travel speeds and delay have been calculated for both weekday and weekend conditions, and in terms of AM, noon, and PM peak periods.

The results indicate that HOV lane travel time benefits will be most desirable and measurable during the eastbound weekday PM period, when average speeds between 25 and 35 km per hour were recorded; and, followed by the westbound weekday AM period, when average speeds between 50 and 65 km per hour were recorded.

The “before” and “after” comparisons of average speeds can be used to measure the achievement of this objective. However, breakdown of this benefit to a unit of time (delay reduction) to which a value can be attributed provides a unique indicator for estimating benefits. Upon collection of the “after” HOV travel time data, a dollar value of travel time per person hour can be applied to the observed “before” and “after” differences to further document benefits resulting from delay reduction. For baseline conditions herein, the delay estimates are based on the comparison of current travel times against free flow travel times at 80 km per hour.

2.2.5 Phase II - Post-HOV “After” Evaluation

Collection of post-HOV travel time data should be based on a similar approach to the baseline surveys, but must distinguish between the HOV lanes and GP lanes present in the “after” condition. Therefore, efforts in this regard will require twice the person-hours used for the baseline data collection. If the required occupancy in the HOV lane is 3 persons, special markings may be required on the survey vehicle to ensure that it is not stopped due to non-compliance of minimum occupancy requirements. Future average travel speeds (for both the HOV and GP lanes) can be plotted adjacent to the existing “before” data in order to document the recorded changes and anticipated benefits.

It should be noted that although the evaluation of this objective requires average travel times to be obtained only at the end points of the two segments considered (i.e. Burnaby and Coquitlam), the intermediate landmarks used in the surveys allow for qualitative analysis of the corridor in terms of recurring “hot-spots” (such as Highway 1 at Cariboo Road, Second Narrows Bridge, and 160 Street as identified in the travel speed figures in A4-1 to A4-12 in Appendix A-4) affecting average speeds. Therefore, a similar breakdown of intermediate checkpoints should be used in the post-HOV travel time surveys.

2.2.6 Phase III (Post-TMP) Ongoing Monitoring

Ongoing monitoring of available travel time benefits associated with the HOV lane, as opposed to the GP lanes, can generally be carried out using similar methodology.

Since the evaluation of TMP objectives will require travel time data, this information could also be used for the subsequent monitoring of HOV travel time benefits as well. Subsequently however, consideration could be given to additional means of collecting travel time data, whereby TMP technologies can be used to collect larger samples of travel time data more cost-effectively. For example:

- In the medium term of TMP implementation, a program could be set-up for selected commuters to report travel times at corridor end points via cellular phones. This effort could be coordinated through the TMC.

- In the longer term, the CCTV system, complemented by emerging video image processing technologies, could be used to collect travel time data based on computerized license plate matching at designated corridor checkpoints. Alternately, if electronic tolling is introduced elsewhere in the Lower Mainland, it may be possible to poll on-board electronic tags to track travel speeds of vehicles using the facility.

2.3 IMPROVE TRIP TRAVEL TIME RELIABILITY

2.3.1 Objective Description

The focus of this objective is to provide eligible HOVs with improved travel time reliability along the HOV facility. Achievement of this objective, in addition to the travel time advantage over the GP lanes, is also critical to HOV usage, since travel time reliability is also a key incentive for commuters to switch to a high-occupancy mode.

2.3.2 MOEs

Specific MOEs which were selected to evaluate the achievement of this objective are:

- lower variance in travel times along the HOV lanes in comparison to the pre-HOV GP lanes;
- lower variance in travel times along the HOV lanes in comparison to the post-HOV GP lanes;

2.3.3 Data Requirements

In order to measure the MOEs identified above, the data collection program included:

- "before" variance in average speeds in the GP lanes over the length of the HOV facility.

The post implementation (Phase II) survey should also include:

- "after" variance in average vehicle speeds in both the HOV and GP lanes over the length of the facility.

2.3.4 Baseline Data

This objective builds on the benefits of the travel time savings objective by providing HOV lane users with a more reliable trip time in comparison to the GP lane users. The MOE for this objective has been identified as a reduction in the variance of average travel speeds along the length of the HOV lanes, when compared against the variance of travel speeds along the "before" or "after" GP lanes.

As presented in Appendix A-5, the travel times obtained for this objective were designed specifically for the purpose of evaluating trip reliability. In this regard, surveys were carried out along the length of the study corridor, with the HOV corridor terminus points being the only intermediate checkpoints. Travel times were collected over a 20 day period, during the morning and evening peak periods.

Exhibit 2.3.1 presents average speeds and standard deviations, by direction and period, for the HOV corridor, and the full length of the corridor as reference. For the purposes of this objective, the critical values for the HOV corridor can be summarized as follows:

Trip Travel Time Reliability	**AM**		**PM**	
	Average Speed	**Standard Deviation**	**Average Speed**	**Standard Deviation**
Eastbound	84 kph	14	33 kph	12
Westbound	57 kph	16	70 kph	20

The average speed data obtained from the trip reliability surveys are consistent with those obtained in the travel time surveys when the standard deviations are taken into account. For the PM period, the standard deviations are observed to be higher in the off-peak directions when compared to the peak; this is expected since the peak direction traffic has been observed to be considerably congested and average speeds are consistently lower.

2.3.5 Phase II (Post-HOV) “After” Evaluation

Following the opening of the HOV lanes, “after” data collection efforts must provide travel times between the terminus points of the HOV facility, for both the HOV lanes and the GP lanes. As was found in this study, data collection can be very cost-effective if intermediate landmarks are not incorporated. Furthermore, it has been found that programs such as the Jack Bell Foundation vanpools provide additional low-cost sources of travel time data over extended time periods.

Under Phase II, evaluation of this objective should focus on the differences in trip reliability between the HOV lanes and the GP lanes during “after” conditions.

2.3.6 Phase III (Post-TMP) Ongoing Monitoring

Travel time savings and trip reliability provide two of the key incentives to attract users to switch to a higher occupant mode. Therefore, the ongoing monitoring of HOV lane reliability versus the GP lane reliability will be insightful as the HOV lane matures and users adapt.

2.4 INCREASE PER-LANE EFFICIENCY

2.4.1 Objective Description

The focus of this objective is to increase the per-lane efficiency of the highway facility expressed in terms of person-kilometres per hour. Since HOV lanes facilitate the movement of higher person-volumes at higher speeds, the overall efficiency of the highway facility is expected to improve.

2.4.2 MOEs

The MOE selected to evaluate the achievement of this objective is based on a comparison of the per-lane efficiency of the highway prior to the provision of HOV lanes, with the per-lane efficiency of the GP and HOV lanes after the implementation of the HOV facility. Per-lane efficiency is calculated by multiplying the person-volume on the highway with the average highway operating speed. For the “after” conditions, the facility per-lane efficiency is the weighted combination of the per-lane efficiency of the GP lanes with the HOV lanes.

2.4.3 Data Requirements

In order to measure the MOEs identified above, data collection must include:

- “before” and “after” vehicle occupancy counts on a lane basis;
- “before” vehicle average speeds in the general purpose lanes;
- “after” vehicle average speeds in both the HOV and GP lanes.

2.4.4 Baseline Data

As indicated by the data requirements for this MOE, achievement of this objective is essentially a function of the “increase in AVO” and “lower travel time” objectives. For baseline conditions, the formula used for the calculation of per-lane efficiency is:

$$Efficiency = \frac{ppv \times v_{avg}}{1000 \times (n)}$$

where:

Efficiency = Peak Hour Per-lane Efficiency (1,000 Person – Kilometres/ Hour)
ppv = Average Per-lane Peak Hour Person Volume (AVO x Vehicles)
v_{avg} = Average Recorded Speed
n = Number of Lanes

Exhibit 2.4.1 presents graphs of per-lane efficiency for both directions, and for weekday and weekend conditions based on traffic volumes west of the Deer Lake interchange and average corridor AVOs and speeds. The results are also tabulated below.

EASTBOUND	**Weekday**			**Sunday**		
	AM	**Noon**	**PM**	**AM**	**Noon**	**PM**
Traffic Volumes (Deer Lake)	3500	3150	2850	1200	3200	3450
AVO (Corridor Average)	1.12	1.25	1.20	1.40	1.69	1.66
Total Occupants	3920	3938	3420	1680	5408	5727
Average Speeds	68	85	29	89	88	77
PER LANE EFFICIENCY*	**134**	**168**	**50**	**75**	**238**	**219**

WESTBOUND	**Weekday**			**Sunday**		
	AM	**Noon**	**PM**	**AM**	**Noon**	**PM**
Traffic Volumes (Deer Lake)	3300	3000	3350	1650	3500	3300
AVO (Corridor Average)	1.12	1.26	1.22	1.52	1.77	1.82
Total Occupants	3696	3780	4087	2508	6195	6006
Average Speeds	53	84	79	90	88	85
PER LANE EFFICIENCY*	**98**	**159**	**162**	**113**	**272**	**255**

*Values presented in 1,000-person kilometres per hour.

Interpretation of the baseline data is not possible without comparison with the “after” data because the only desired effect is an increase in per-lane efficiency, in the peak periods and directions. A low value for per-lane efficiency in the baseline data does not indicate an inefficient facility, as it could be a function of low person volumes (i.e. during off-peak conditions). However, it is interesting to note that currently per-lane efficiency is highest during weekday off-peak periods and Sundays due to the combination of high occupants and average speeds.

Furthermore, caution must be used in the interpretation of “before” and “after” results, because average speeds are part of the data input, and obtaining representative average speed data requires a reliable sample size.

For discussion purposes, **Exhibit 2.4.2** has been included to illustrate a further correlation between volumes and speeds and to illustrate reduction in vehicle throughput due to demand exceeding capacity. The 24 hour count data taken from a sample eastbound station west of the Cariboo Interchange, has been plotted and overlaid with average speed data obtained from the same vicinity during morning, mid-day and afternoon time periods. As indicated on this exhibit, traffic flow breaks down due to over-saturation around 2:00 PM, and by 6:00 PM reaches a low of 3,000 vehicles travelling at an average speed of 20 kph in the two lanes. As a result of the lower throughput, it can be seen that the time it takes for the actual demand to clear extends beyond the peak period, reflecting traveller delay.

The exhibit is also overlaid with an estimate of what a typical volume profile (for the same total demand) would look like had no breakdown taken place. The area between the actual volume profile and the “typical” volume profile can be interpreted as the delay experienced.

2.4.5 Phase II (Post-HOV) “After” Evaluation

Phase II requirements for this objective will largely be a function of the requirements associated with vehicle occupancy and travel time data. For the purposes of this objective, however, it will be critical to ensure that vehicle occupancy data is obtained near the Cariboo Interchange, and that sufficient travel time data is obtained for both the HOV lane and the GP lanes. Computation of per-lane efficiency in the “after” period is based on a weighted average of the per-lane efficiency of the HOV lane and the per-lane efficiency of the GP lanes.

2.4.6 Phase III (Post-TMP) Ongoing Monitoring

Per-lane efficiency is also a useful measure for ongoing monitoring of an HOV facility. The efficiency of the facility will continue to grow as use of the HOV lane increases.

2.5 ENSURE GP LANE OPERATIONS NOT ADVERSELY AFFECTED

2.5.1 Objective Description

The focus of this objective is to ensure that the provision of HOV lanes in a highway facility does not lower the capacity and operating speeds of the adjacent GP lanes.

2.5.2 MOEs

The MOE which can be used to evaluate the achievement of this objective is a comparison of the level of service and vehicle speeds along the GP lanes "before" and "after" the introduction of HOV lanes. Since introduction of HOV lanes will induce more weaving between the GP lanes and the HOV lanes, there could be capacity impacts on the GP lanes which must be measured.

2.5.3 Data Requirements

In order to establish the MOEs identified above, data collection must include "before" and "after":

- vehicle counts per-lane;
- vehicle average speeds in the general purpose lanes;
- amount of weaving traffic after implementation of HOV lanes.

2.5.4 Baseline Data and Discussion

The level of service for the highway segments between the Boundary Interchange and the Lougheed Highway/Cape Horn Interchange was calculated based on vehicle average speeds collected during September, 1997 and the methods outlined in the 1994 Highway Capacity Manual. The results are summarized in **Exhibit 2.5.1.**

In both the eastbound and westbound direction, highway segments within the HOV section experience a level of service E or worse during the morning and afternoon peak hours. A level of service E or worse, as defined by the HCM, corresponds to an average travel speed between approximately 80 and 85 kilometres per hour, while a level of service F encompasses speeds below 80 kilometres per hour. It should be noted, however, that when Highway 1 within the study area limits is operating at an average travel speed of 80 kilometres per hour, drivers generally perceive the level of service to be satisfactory.

Average vehicle speeds in the general purpose lanes between the Boundary Road Interchange and the Lougheed Highway/Cape Horn Interchange are summarized in **Exhibit 2.5.2**. In general, the morning peak period experiences lower travel speeds in the westbound direction when compared to the eastbound direction. In the afternoon peak period, the eastbound direction experiences lower travel speeds when compared to the westbound direction.

EXHIBIT 2.5.2 AVERAGE VEHICLE TRAVEL SPEEDS ALONG TCH HOV SEGMENT

DIRECTION	MORNING PEAK PERIOD	AFTERNOON PEAK PERIOD
Eastbound	68 kilometres per hour	29 kilometres per hour
Westbound	53 kilometres per hour	79 kilometres per hour

2.5.5 Phase II (Post-HOV) “After” Evaluation

The provision of the HOV lane facility should not unduly impact the operation of the highway GP lanes. The capacity and operating speeds of the adjacent highway GP lanes should not be degraded due to the implementation of the HOV lane facility. This can be measured by a comparison of the level of service on the GP lanes “before” and “after” the implementation of the HOV lane facility. In particular, the performance of the GP lane can be measured by vehicular volumes and travel time runs in the GP lane. The F-test can be used to determine the statistical significance of the difference between the “before” and “after” results of the travel speeds along the HOV segment. The T-test can be used to test the mean.

Although weaving sections were not identified as a concern in the “before” period, this phase should pay particular attention to the traffic operations at the access and egress points of the HOV facility, where weaving between mixed use vehicles is likely to occur. If the weaving maneuvers at these access and egress points are found to be operating poorly, a detailed operational review should be conducted and mitigative measures such as ramp metering may need to be investigated.

2.5.6 Phase III (Post-TMP) Ongoing Monitoring

During this phase, the monitoring of the HOV facility should be continued. The data collection should include:

- traffic volumes;
- vehicle average speeds in the general purpose lanes;
- amount of weaving traffic after implementation of HOV lanes.

This phase should make use of the TMP technology to collect the data in a cost-effective manner, such as by using the CCTV cameras to observe weaving.

2.6 ENSURE SAFETY

2.6.1 Objective Description

The focus of this objective is to ensure that the HOV facility provides safe operations, and that the safety of Highway 1 is not compromised as a result of the introduction of the HOV lanes.

2.6.2 MOEs

Specific MOEs which can be used to evaluate the achievement of this objective are:

- frequency of collisions by time period (year, month, day of week, and time of day),
- severity of collisions,
- type of collision,
- prevailing weather condition at time of collision,
- number of vehicles involved in each collision,
- number of injuries involved in each collision,
- contributing factors to collision,
- spatial collision distributions,
- collision severity ratios, and
- collision rates.

Vehicle conflicts may be used as a surrogate for collisions, since they occur with greater frequency. A vehicle conflict occurs when one vehicle is required to take evasive action such as braking or steering to avoid a collision with another vehicle. A conflict survey was conducted near the Grandview and Willingdon interchanges, and is summarized in Appendix A-10. The chosen site is near the planned beginning of the eastbound HOV lanes, and is where the widest observer coverage is possible. Conflicts were recorded on videotape and are available for analysis and comparison in the post-implementation phase of this study.

2.6.3 Data Requirements

In order to establish the MOEs identified above, the data collection must include:

- collision data spanning a minimum of three years prior to the construction of the HOV facility,
- separate collision data for the HOV and GP lanes over a corresponding period of time (minimum one year) after HOV facility is completed (differentiation of accident data between the HOV lanes and GP lanes may be a challenging task, requiring a new form for accident data logging).

2.6.4 Baseline Data and Discussion

Collision data from 1992 through 1996 for the study section of the Trans Canada Highway (Landmark Kilometre Inventory Segment 0550, 0.5km to16.1km, and Segment 0555, 38.5km to 53.4km) were supplied by the BC Ministry of Transportation and Highways (MoTH). The data set contains complete records of 2,796 collisions for the HOV project segment (comprised of 0.3% Fatals, 40.9% Injuries, and 58.8% PDOs). However, data trends are partially obscured by a change in the police reporting procedure commencing in April 1996 (whereby police are now less likely to attend non-severe accidents) and resulting in an apparent decrease in the number of collisions recorded in 1996.

The collision data have been analyzed to provide a pre-implementation baseline for the future evaluation of the safety performance of the HOV lanes and the TMP. In order to monitor the individual impacts of the HOV lanes and of the proposed TMP applications, collision data characteristics have been compiled separately for the HOV and TMP facilities. Collisions associated with interchanges and highway segments have also been isolated.

Appendix A-8 contains an examination of collision trends, showing frequency or proportion by time period (year, month, day of week, and time of day), severity, type of collision, prevailing weather condition, number of vehicles involved in each collision, number of injuries involved in each collision, and contributing factors. Spatial distributions for the eastbound and westbound travel directions are also presented in **Exhibit 2.6.1**. Collision severity ratios and collision rates for interchanges and segments were determined and are shown in Appendix A-8. The key collision characteristics are summarized below, and are compared with data from collisions on all roads (including municipal streets, provincial highways, and rural roads) in British Columbia.

Temporal Distribution of Collisions: The highest frequency of collisions, approximately 16 percent, occurred on Fridays. This compares closely with a 1995 provincial value of 17 percent. Hourly collision distributions show distinct morning and afternoon peaks. About 16 percent of the collisions occurred in the morning period between 0700 and 1000 hours; this proportion is significantly higher than the 1995 provincial value of 10 percent. Approximately 23 percent of collisions occurred in the afternoon period between 1500 and 1800 hours; this proportion also is significantly higher than the 1995 provincial value of 20 percent.

Collision Severity: In the 1992 to 1996 period, approximately 59 percent of collisions were classified as Property Damage Only (PDO) and approximately 41% were classified as Injury. The proportion of fatalities was 0.3 percent along the HOV project segment. The proportions of Injury and PDO accidents along the HOV segment are significantly different from the 1992-1995 provincial averages of 65 percent PDO collisions and 35 percent Injury collisions, indicating a higher collision severity on the subject section of highway.

Collision Types: The major accident type was rear-end collisions, accounting for 60 percent of the total collisions along the HOV project segment. This proportion is significantly higher than the 1995 provincial value, which was 21 percent.

Weather Conditions: Approximately 75 percent of the collisions along the HOV project segment occurred during clement weather (defined as clear or cloudy). This proportion is similar to the 1995 provincial value of 74 percent.

Number of Vehicles Involved: Approximately 76 percent of the collisions along the HOV project segment involved multiple, while 24 percent involved a single vehicle. This distribution is very similar to the province-wide 1995 distribution of approximately 75 percent multiple vehicle collisions.

Contributing Factors: In approximately 50 percent of reported collisions, police did not identify a specific contributing factor, denoting the factor as unspecified, unknown, other, or not applicable. Driver error or driving without due care were identified as the main contributing factor in 39 percent of collisions, and driver impairment was identified in a further 6 percent of collisions.

Number of Injuries per Collision: Approximately 66 percent of Injury collisions involved a single injury, and approximately 23 percent involved injuries to two persons.

Collision Severity Ratios: As an indication of the combined number and severity of collisions along the study segment, the Collision Severity Ratios for individual segments and interchanges have been calculated. The Collision Severity Ratio for the entire HOV segment was 5.2, compared with a provincial average of 4.6 in 1995.

Identification of Collision Blackspots: A collision blackspot is identified as a road segment or interchange with a collision rate that exceeds the average provincial collision rate for multilane urban freeways. Five year (1992-1996) and three-year (1994-1996) average collision rates were calculated to identify these hazardous interchanges and segments relative to average collision rates on British Columbia multilane urban freeways between 1991 and 1993. Collision data from 1996 is included as the most recent information available, but is affected by changes in the police reporting procedure discussed above. The results of these calculations are summarized in Appendix A-8 and Exhibit A8-2.

2.6.5 Phase II (Post-HOV) "After" Evaluation

Since the HOV and TMP facilities are expected to be introduced in a relatively short time frame, the individual safety impact of each project may be difficult to isolate. A minimum of one year's collision data will be required for a "before" and "after" comparison. Three to five years are preferred to balance annual fluctuations. Collision data collected during the construction of the HOV lanes cannot be used in the post-HOV evaluation, since it will be biased due to changes in traffic characteristics. The impact of the HOV lanes alone is likely to be indistinguishable from that of the combined HOV and TMP projects unless the TMP is implemented beyond a one year post-HOV implementation horizon.

Coordination at a management level between the Ministry and the Port Mann Freeway Patrol is recommended, to ensure that the current level of effort in attending and collecting collision data is maintained. Additional data collection may be requested to identify whether the collision occurred in an HOV or GP lane, or whether it occurred at a merge or diverge area.

The post-implementation compliance rate for vehicle occupancies in the HOV lanes should be considered when compiling safety data (as well as all other performance data) to determine whether the lanes are being used by the vehicles for which they are intended. When violation rates are high, the impact of the HOV facility may not be accurately indicated. Additionally, the safety characteristics of the HOV facility may change if minimum vehicle occupancies change, which may increase or decrease the number of vehicles using the HOV lanes. Changes in both the compliance rate and the occupancy requirements should be noted when compiling post-implementation collision data.

2.6.6 Phase III (Post-TMP) Ongoing Monitoring

Reference to other HOV facility evaluations indicates that typically a number of post-implementation evaluation time frames are identified, ranging from one year to several years. The post-implementation time period should not be so long that background conditions, such as demand levels, change significantly.

To ensure comparability of data, it is important that the same procedures, techniques, and definitions be used in both the “before” and “after” data collection and monitoring activities.

Any future changes to collision reporting procedures should be noted. Changes to the police reporting protocol have already been noted above. Further changes may be anticipated since ICBC has assumed responsibility for compiling collision statistics in the province. Resulting gaps in data acquisition, and differences in data collection and reporting protocols (for example, changes in the use of markers to identify collision locations), may distort data trends.

Independent factors may also affect data trends. For example, changes in law enforcement such as speed or drunk driving enforcement campaigns or use of photo radar may affect collision rates. The presence of these factors should be noted and their impacts considered when examining collision trends. This will require awareness of all programs implemented between the “before” and “after” conditions, along with qualitative correlations (where applicable) with the “after” data.

Due to the random nature of collisions, the collision frequency fluctuates around the mean value from year to year, though fluctuations generally diminish with larger sample sizes. A high occurrence of collisions may be due to the chance factor alone, and therefore a high collision occurrence may regress to the mean in the after-treatment period regardless of the effect of a treatment. This phenomenon, commonly known as regression to the mean (RTM), could lead to an underestimation or overestimation of the effect of HOV lanes on collisions. This bias can be an important cause of errors in safety improvement evaluation.

The technique suggested to account for the RTM bias is the Empirical Bayes.

The main concept behind the Empirical Bayes approach is that each site has a true collision rate with a particular probability distribution and that a group of sites will have the same probability distribution (Gamma distribution) with some mean and variance. The Empirical Bayes approach provides a formal mechanism for combining information drawn from different sources in a single analysis.

A critical requirement that distinguishes the Empirical Bayes approach from conventional statistical methods is the use of a reference group. The reference group represents the prior information regarding the distribution of collision rates across a certain region. The quality and size of the reference group is crucial for the successful application of the Empirical Bayes approach. The approach is achieved by selecting the reference group sites such that they truly represent potential treatment sites. Highway 99, Highway 91, and the Upper Levels Highway are possible reference group sites for the present study. In general, the size of the reference group should be at least four to five times the size of the treatment group. Since the present study examines ten TCH segments, the reference group should contain about 50 segments to be statistically reliable.

2.7 IMPROVE ENVIRONMENTAL CONDITIONS

2.7.1 Objective Description

The focus of this objective is to improve air quality conditions by lowering noxious vehicle emissions per person travelling the corridor. The objective will be measured using volume and travel time data and applying an emissions model to estimate the changes in emissions.

2.7.2 MOEs

Specific MOEs which were selected to evaluate environmental benefits are based on estimates and simulations of the following:

- emissions;
- air quality;
- vehicle-kilometres travelled.

An indication of air quality impacts resulting from traffic flow improvements may be obtained by estimating the “before” and “after” overall traffic emissions. Indicative NOx and CO emissions have been estimated using a speed-dependent emission calculation based on typical vehicle emissions. Emissions estimates indicated the *magnitude* of changes in emissions occurring as a result of changing traffic operations; they are therefore useful to compare emissions *before* the implementation of the TMP/HOV facilities with conditions *after* their implementation.

Comparison of pollution levels with established criteria may also be done using air quality monitoring results. A set of “before” air quality monitoring results from two sites along the TCH has already been obtained by the GVRD (as reported), and a set of “after” measurements may be requested following implementation of the TMP/HOV facilities.

2.7.3 Data Requirements

In order to establish the MOEs identified above, data collection must include “before” and “after”:

- vehicle counts;
- vehicle classifications;
- travel time runs.

In addition to vehicle emissions estimated by modeling, existing pollution levels have been monitored. The GVRD Air Quality Branch monitored air quality on both sides of Highway 1 west of Cape Horn for a 15-day period in September 1997. This data established baseline air quality conditions, which will be used for comparison in a repeat survey undertaken after HOV facilities open. The data obtained from the environmental monitoring program have been provided to MoTH in electronic format and need to be processed by the GVRD to clarify baseline conditions.

2.7.4 Baseline Data and Discussion

Baseline air quality was determined directly through the GVRD program of air quality monitoring, and indirectly through calculation of two air quality indicators, vehicle emissions and vehicle-kilometres traveled.

Emissions Modeling: An indication of air quality impacts resulting from traffic flow improvements may be obtained by estimating the "before" and "after" overall emissions. The main influences on emissions are the composition of the vehicle fleet by age, the use of gasoline or diesel engines, the use of catalytic converters, vehicle speeds, road gradients, altitude, and ambient temperatures. In this study, indicative emission rates have been calculated using a speed-dependent equation, and converted to a "grams per person" unit based on segment volume and occupancy data. Details of the analysis are provided in Appendix A9, a summary of the results is provided in **Exhibits 2.7.1, 2.7.2,** and below:

- Nitrogen and oxygen in the air react in vehicle engines to form various nitrogen oxides, collectively known as NO_x. NO_x is a precursor of smog and contributes to the formation of acid rain. Exhaust emissions are primarily in the form of nitric oxide (NO), which oxidizes to NO_2, a criterion pollutant. Calculated peak hourly emissions of NO_x along the HOV section of the Trans Canada Highway are approximately 5.7 to 9.1 grams per person, in each direction and during peak hours.

- Carbon monoxide (CO) is a product of incomplete fuel combustion. Its formation is enhanced at low air-to-fuel ratios (typical of "cold" or poorly tuned engines) when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide (CO_2). CO is a criterion pollutant that is directly harmful to humans. Calculated peak hourly emissions of CO along the HOV section of the Trans Canada Highway are approximately 6.5 to 11.3 grams per person, in each direction and during peak hours.

- Emissions of CO and NO_x are particularly sensitive to speed, ambient temperature, and the ratio of air to fuel. Assumptions concerning temperature and the air-to-fuel ratio were excluded from the present study. With regard to speed, the calculated NO_x and CO emissions have varying sensitivities. At the speed ranges encountered along the subject segment of the Trans Canada Highway, NO_x emissions are more sensitive to speed than CO emissions.

Vehicle-Kilometres Traveled: The 1997 peak hour traffic along the HOV project segment of the Trans Canada Highway reaches 48,000 to 49,000 vehicle-kilometres, and is about 3.6 percent higher in the afternoon peak hour than in the morning peak hour.

GVRD Air Quality Monitoring: Hourly air quality monitoring of criterion pollutants was conducted at two sites in Coquitlam by the GVRD in September 1997. Concurrently with the hourly pollution monitoring, hourly meteorological data were obtained. The monitoring program has produced a total of 651 hours of matched pollution and meteorological data. The data is expected to be available in summarized form from the GVRD by the time of the post-implementation studies.

It should be noted that the results of emission modeling cannot be easily related to the results of the air quality monitoring program. Emission modeling estimates the quantity of pollutants generated by traffic on the HOV section, but does not consider the dispersion of these pollutants. The air quality monitoring program measures the concentration of dispersed pollutants, as they have been diluted by dispersion mechanisms such as wind, atmospheric stability, and local topography. Thus, emissions modeling examines the quantity of pollutants at their source, while air quality monitoring examines the quantity of pollutants at a distance from their source.

2.7.5 Phase II (Post-HOV) “After” Evaluation

It is recommended that the “after” data be compared against the following scenarios:

1. actual “before” data (as obtained under Phase I);
2. do-nothing (estimate of what conditions would be like in Phase II had no improvements taken place);
3. add GP lane (estimate of what conditions would be like if a new GP lane was added instead of the HOV lane);
4. add HOV lane (estimate of the “after” data to be obtained under Phase II).

A significant contributor to the volume of vehicle emissions is the amount of “stop and go” travel. Introduction of the HOV lanes will reduce the amount of “stop and go” travel, as well as reduce emissions per person. However, “stop and go” traffic was not measured explicitly in Phase I, rather, average speeds were obtained, which do not specifically identify the “stop and go” portion of travel. Accordingly, it is proposed that “stop and go” traffic and travel time be measured in Phase II and that a correlation be developed between average speed and “stop and go” travel for input into each of the above scenarios.

In order to obtain volumes and speeds for input into the emissions model for the “do-nothing” and “add GP lane” scenarios, it is proposed that the EMME/2 traffic model be applied. The EMME/2 model should also be applied to the “before” and “after” HOV lane scenarios in order to compare simulated volumes and speeds to observed volumes obtained in Phase I and Phase II.

Since the emissions model used in Phase I did not take into account the effects of “stop and go” conditions, the emissions model to be used in Phase II should be more sensitive to speeds over the full range, in order to account for “stop and go” conditions. For example, the Ministry should investigate the use of the MOBILE Highway Vehicle Emission Factor Model, recommended by the BC Ministry of Environment, and used by the Environmental Protection Agency in the United States. The Phase I estimates may require updating to reflect the “stop and go” conditions.

2.7.6 Phase III (Post-TMP) Ongoing Monitoring

To ensure comparability of data, it is important that the same procedures, techniques, and definitions be used in both the “before” and “after” data collection and monitoring activities. The Phase III ongoing monitoring will measure the collective impact of both the HOV and TMP projects.

3.0 TMP - MONITORING & EVALUATION PROGRAM

The first phase of the Traffic Management Program is to be implemented on Highway 1, stretching between 160 Street in Surrey to Lynn Valley Road in North Vancouver, a distance of approximately 30km. This implementation is referred to as the “pilot corridor”. This corridor is approximately 10km longer and extends on both sides of the first phase of the HOV Project. Data collection efforts common to the MOEs and evaluation of the two projects covered the full study corridor up to 176 Street.

Although the overall objectives of the HOV and TMP projects are intended to serve common transportation goals, the evaluation of these projects differ in timing. Where the evaluation of an HOV facility is based on the introduction of HOV lanes alone, the “before” and “after” evaluation of TMP is based on a number of different – yet mutually supportive – service applications implemented over time.

The TMP pilot corridor will incorporate the deployment of two user service applications: Incident Management and Traveller Information to be operational in 5 years. These user service applications involve the provision of the following systems and procedures:

- Incident Management:
    - Emergency Patrols & #4444 Incident Reporting System
    - Automatic Incident Detection system
    - CCTV cameras
- Traveller Information:
    - Changeable Message Signs
    - Media (radio/TV) dissemination
    - Highway Advisory Radio

The operation of the above requires a communications system as a backbone linking all services to an integrated Traffic Management Centre. Therefore, for the purpose of identifying objectives for “before” and “after” evaluation, it is assumed that the initial implementation of TMP will incorporate the above, and operate as an integrated system.

In order to evaluate the TMP pilot implementation, 5 objectives were defined along with their measures of effectiveness and data requirements. The objectives proposed for this evaluation are:

1. **Reduce non-recurrent congestion;**
2. **Reduce recurrent congestion;**
3. **Improve safety;**
4. **Efficient use of capacity;**
5. **Improve environmental conditions.**

It is also recognized that the initial implementation of TMP will be in place after the opening of the HOV facility. Therefore, the true “before” implementation data for evaluating TMP will be obtained at the same time that the “after” HOV implementation data is collected. The data collected as part of this “before” implementation study is, however, of reference value for TMP evaluation especially since the Emergency Patrols and Incident Reporting System may be in operation shortly after the completion of the HOV lanes. Further, experience gained under this project can be used to improve the “before” TMP data collection efforts carried out in conjunction with the “after” HOV data collection.

Each of the objectives identified for evaluation is discussed in terms of the following sections:

- primary focus;
- recommended MOEs for evaluation;
- data requirements;
- description of the baseline data for analysis;
- recommendations regarding the Phase II data collection for a true TMP baseline which includes the presence of HOV lanes.

3.1 REDUCE NON-RECURRENT CONGESTION

3.1.1 Objective Description

The focus of this objective is to reduce the impacts associated with non-recurrent congestion (i.e. congestion resulting from incidents). Major impacts of non-recurrent congestion includes vehicular delay and accident risk resulting from lane blockage or other traffic impedance. The provision of Automatic Incident Detection (AID), improved incident response and clearance times, incident management, and up-to-date traveller information, will reduce these impacts.

3.1.2 MOEs

The specific MOEs selected to evaluate the achievement of this objective are:

- reduction in incident duration;

  Incident duration is the time between the occurrence of an incident and the clearance of the incident to remove lane blockage or other impedance. This time period is comprised of three intervals: occurrence to detection, detection to response, and response to clearance of the incident, each of which is measured separately.

- reduction in vehicular delay.

  Vehicular delay due to non-recurrent congestion is calculated as a function of incident duration and the number of lanes blocked. Here, the number of lanes blocked can be used to estimate queue lengths; furthermore, the AVO data can be used to estimate person delay.

3.1.3 Data Requirements

In order to measure the MOEs identified above, “before” and “after” data collection must include:

- incident observations and logging times to record separately the occurrence time, response time and clearance times;

- frequency of secondary accidents (not for this objective but for the safety objective).

3.1.4 Baseline Data

The two MOEs identified for this objective are incident duration and vehicular delay. Delay resulting from non-recurrent congestion is typically related to the occurrence of incidents, their duration, and lane blockage.

Baseline data for estimating average incident durations was obtained through the manual observation and logging of incident related data (detailed in Appendix A-6), with the intention of also using the data to estimate baseline delays resulting from incidents. Approximately 20 kilometres out of the total study corridor length of 34 kilometres (which encompasses the TMP corridor) were monitored for incidents. The availability of adequate observation posts limited the opportunity of monitoring the remainder of the corridor.

Exhibit 3.1.1 presents a summary of the incidents logged, in terms of location, direction, type and approximate duration. Here, each bar represents one of the 24 incidents responded to. The bars are justified to the approximate location of the incidents; the colours represent the incident type; the arrows indicate the direction in which the incident occurred; and the length of the bars signify approximate incident duration. The incidents are summarized in terms of type, location, direction, and period in the following tables:

Incident Type

Accident	3	12.5%
Vehicle Breakdown	18	75.0%
Vehicle Stop	3	12.5%
TOTAL	24	100.0%

Direction

EB	14	58.3%
WB	10	41.7%
TOTAL	24	100.0%

Station Location

1. United Blvd.	5	20.8%
2. Cape Horn	4	16.l7%
3. Cariboo	5	20.8%
4. Kensington	5	20.8%
5. Willingdon	5	20.8%
TOTAL	24	100.0%

Occurrence Period

AM	6	25%
PM	18	75%
TOTAL	24	100%

The incident duration data was averaged for all the incidents, and are summarized below:

- average occurrence to response time - 23 minutes;
- average response to clearance time - 19 minutes;
- average incident duration - 43 minutes.

It is observed that the majority of the incidents are “vehicle breakdowns” with only a tow truck response. As a result, minimal impacts were observed on through traffic because vehicles quickly pull over to the shoulder without blocking any lanes; and, because during peak periods the facility is already congested (with the effects of rubber-necking not as visible). It is also observed that the incidents with the greatest impact (i.e. in terms of queue generation) occur on the Port

Mann Bridge where there are no shoulders. These incidents also have the shortest response times due to the proximity of the Mainroad Contracting patrol vehicle.

As indicated in Appendix A-6, “before” and “after” analysis of this type of data requires a large enough sample size so that a measurable reduction can be observed. Statistical review of the baseline data indicates that the standard deviation of the observed times is as high as the time themselves. However, this is found to be consistent with other studies (referenced in Appendix A-6). The key statistical consideration for the “before” and “after” evaluation of the data is the extent of reduction in incident duration between the two comparison periods, and not the variance.

Vehicular delay resulting from incidents is typically calculated as a function of the incident’s lane blockage impacts. For a four lane highway facility (two lanes in each direction), the blockage of a right lane can result in a 50 to 65% reduction in capacity (based on two lanes per direction), while the blockage of a shoulder can result in a 20 to 25% reduction in capacity – merely as a result of through vehicles slowing down (rubber-necking).

An example of traveller delay experienced by lane blockage incident is presented below, based on an incident observed on the Port Mann Bridge. The parameters of the incident are:

- Incident time - 4:40 PM, September 10,1997.
- Location - Westbound on Port Mann Bridge.
- Incident involved accident and materials spill, 2 vehicles.
- Observed queue length more than 25 vehicles.
- Incident cleared at 5:10 PM, i.e. a 30-minute duration.
- Theoretical vehicle capacity - 3,600 vehicles per hour (2 lanes).
- Estimated vehicle demand (based on short count data) - 2,800 vehicles per hour.
- Estimated capacity reduction due to lane blockage - 60%, or vehicle throughput of 1,440 vehicles per hour (the 60% reduction factor is a conservative “thumb-rule” based on the HCM capacity analysis procedures which relate capacity directly to the number of lanes).

Exhibit 3.1.2 following, illustrates how the incident parameters can be used to estimate delay. In context of the incident considered herein, the vehicle delay has been calculated at 450 vehicle-hours (the shaded area in the exhibit).

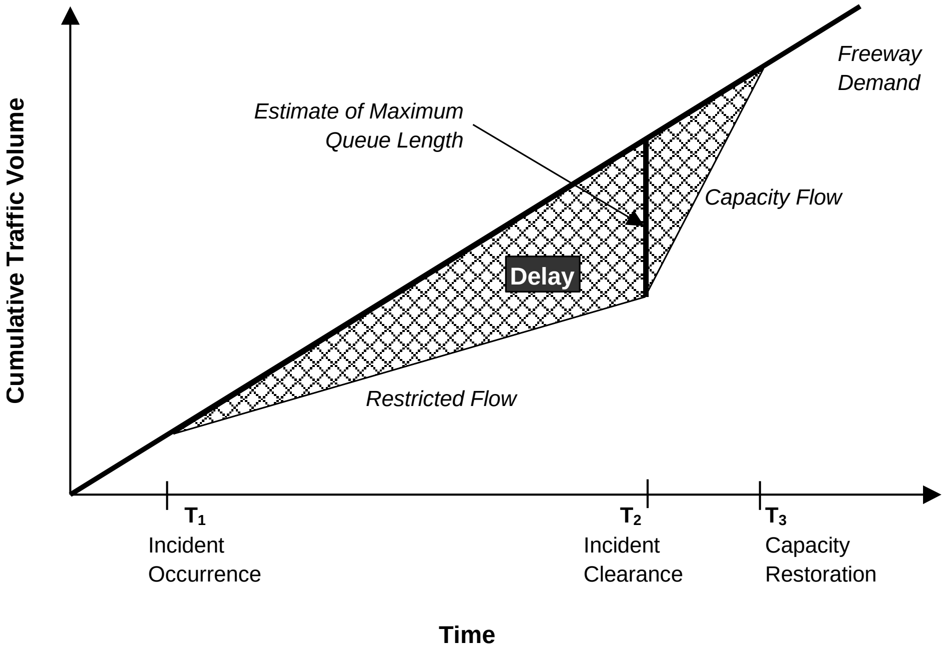
Therefore, using a peak hour AVO of 1.20, the total person-hours of delay resulting from a 30 minute incident is estimated at 540 person-hours. As an example, using the TMP Business Plan (MoTH, 1995), recommended rates of $50 per hour for commercial vehicles (at 6% trucks), $10.50 per hour for auto driver, and $7.50 per hour for passengers, the estimate of the social cost of this delay is $6,500.

Cost = 27 trucks x $50/hr.
+ 423 (drivers) x $10.50/hr.
+ 423 x 0.2 (occupants) x $7.50/hr.
= $6,426 . $6,500

Thus, a reduction in incident duration through rapid incident detection and response could achieve an approximate benefit of $216 per minute of reduction.

The focus of baseline incident data presented herein is the quantification of measurable effects. In addition to reductions in average incident duration, and resulting delay, additional less measurable effects are required to support this objective – such as improved and integrated incident management procedures and operation. Therefore, baseline information on current incident management capabilities need to be established for future comparisons.

EXHIBIT 3.1.2
Delay Due to Incident



Current Incident Management Capabilities

The Ministry's current capability for incident management is facilitated through the Region 1 Communications Centre (RCC). The primary function of the RCC is to act as an emergency response centre for any incidents which "restrict" traffic movement on highways.

The following two-level system is used by the RCC to categorize incidents:

1) Level One
   - Motor Vehicle Accident
   - Slide
   - Spill
2) Level Two
   - Vehicle Stall
   - Debris
   - Dead Animal

With respect to the above categories, the RCC relies on external sources for the detection of incident occurrences. The primary detection sources used by the RCC are:

- “responding contractors” such as Mainroad Contracting Limited or Capilano Highway Services;
- RCMP freeway patrol detachments such as the Port Mann Freeway Patrol;
- media such as radio and television stations with aerial monitoring capabilities;
- general public through the cellular telephone networks.

Once information pertaining to the occurrence of an incident is received by the RCC, related information is entered into a database. The database is primarily used to track an incident until clearance, and subsequently for logging purposes. The database structure allows for most of the input data, related to incident type and location to be entered as “free-form” text, while only automatically filling in the date and time fields associated with the start and end times of an incident. A sample of the data is provided below:

```
1050526     08/28/97     19:36:48     LPM From: R1   To: MR  Src:  LMD
Type:  MVA  MOTOR VEH. ACCIDENT                              Dir:  EB
Rte:  1e    CASSIAR TUNNEL, PORT MANN BRIDGE
RGN:  R1    Loc:         QLen:        IcTime:  0     IcDate:  0
23:05:57    TcDate:  08/28/97
Inc:  MVA EASTBOUND FAST LANE AT CARIBOO
```

Similar to the incident detection sources, the majority of incident responses are provided by sources external to the Ministry (with the exception of mud slides or avalanches – which do not apply to this corridor). For common incidents like motor vehicle accidents and vehicle breakdowns, typical respondents include RCMP Freeway Patrol, emergency services, Mainroad, Capilano Highway Services, and the media (responding through informative broadcasts etc.)

As part of this study, many of these sources were contacted, and met with, to establish current information exchange procedure, and the extent of response coordination between the RCC and other agencies. In terms of information exchange, it was generally found that no standard procedures exist for the flow of information between the responding parties. As a result, incident information is sometimes limited to only the detecting and responding parties – with the RCC uninformed. A recurring example is a Mainroad patrol vehicle discovering and removing a vehicle breakdown without informing the RCC. Improving the information flows between the RCC and supporting parties will benefit the Phase II data collection efforts (discussed in Section 3.1.5).

3.1.5 Phase II (Post-HOV) “True Before” Evaluation

As of December 1997, it is anticipated that specific components of TMP service applications will be implemented in accordance to the following schedule:

- 1998 to 1999
  Roving emergency patrols and *4444 incident reporting system;

- 2000 to 2001
  Traffic Management Centre
- 2001 to 2002
  Incident Management and Traveller Information

Therefore, depending on the opening date of the HOV lanes, and the start-up of the roving emergency patrols/*4444 incident reporting system, the window of obtaining true “before” data for the evaluation of TMP objectives may be very short, or non-existent. This will be critical in designing an incident monitoring and observation program that is not biased by the presence of an incident reporting system or roving emergency patrols.

Nevertheless, an extended incident monitoring and logging program should be undertaken during Phase II. As indicated earlier, and supported in Appendix A-6, the existing sample of incident data is not enough for the quantitative documentation of benefits associated with reducing incident duration and vehicular delays. If the incident reporting system and roving emergency patrols are in place when the Phase II monitoring and logging program is to be undertaken, it may be necessary to select sections of Highway 1 outside the pilot corridor for collecting unbiased data. This data would be supplemented by the baseline incident data collected under this project.

In order to ensure continuous daily coverage in Phase II data collection, temporary cameras could be used at the high elevation locations utilized in this study. This will facilitate the efficient logging of incidents by one-person using multiple monitors , and therefore less person-hours than deploying manual observers at each location. In this regard, consideration should be given to extending the use of the existing CCTV monitoring facility set-up for traffic management during the HOV lane construction. The facility consists of a temporary trailer located at the Cariboo Interchange. A total of 20 CCTV cameras are connected to the facility, providing 80% coverage of the HOV corridor. Observations are made by one person viewing multiple monitors.

The use of the facility could be applicable to Phase II incident observation and logging requirements, and would provide a substantial reduction of the person-hours otherwise required at multiple observation stations. It is recommended that MoTH pursue the transfer and use of the facility after the HOV lane construction period.

Data collection efforts may be enhanced with improved RCC information exchange and data entry. Specifically, the existing user interface used by the RCC for incident logging should be upgraded to eliminate the use of free-form text entries - whereby all location referencing and incident type descriptors are extracted from defined lookup tables using user-friendly pull-down menus.

3.1.6 Phase III (Post-TMP) “After” Evaluation

Data collection for the post-TMP “after” evaluation must be carried out after the provision of Incident Management and Traveller Information service applications (i.e. beyond 2002).

The data collection program for incident data will be facilitated through the TMC. This will be very cost effective as incidents will be detected, confirmed, and logged by the TMC through the incident detection system and CCTV cameras.

A detailed public opinion survey is also recommended under this phase, in order to collect data on the awareness of the road users regarding overall perceived benefit, and more specifically on the usefulness of traveller information media, message content, message usefulness and reliability.

3.2 MANAGE RECURRENT CONGESTION

3.2.1 Objective Description

The focus of this objective is to better manage recurring congestion, using the capabilities of real-time traffic/road monitoring and traveller information. Congestion occurs as traffic volumes approach capacity, which in turn is affected by weather conditions. By monitoring the status of traffic and road conditions on a real-time basis, traveller information mediums can be used to inform motorists of prevailing conditions. Motorists can then make informed decisions to divert to alternate routes, or change their trip time and/or mode.

3.2.2 MOEs

Specific MOEs selected to evaluate the achievement of this objective are:

- increase in average speeds;
- reduction in total travel times.

3.2.3 Data Requirements

In order to measure the MOEs identified above, the “before” and “after” data collection must include:

- vehicle average speeds, as obtained from travel time, speed and delay surveys;

  Since the capacity of Highway 1 will be increased by the introduction of HOV lanes, thus affecting congestion, the “before” conditions for the TMP should be measured post-HOV. However, since travel time data was being collected as part of the HOV evaluation “before” data, the full study corridor (encompassing the TMP corridor) was used. This data will be available for reference in the subsequent phases.

- supplementary queue measurement data.

  Vehicular queue lengths were observed at interchanges along the Highway 1 Study Corridor using aerial photographs and videos. The baseline data is summarized in Appendix A-7. The “before” and “after” comparison of queue lengths at the Highway 1 approaches provides a supplementary means of evaluating the objective of managing recurrent congestion.

3.2.4 Baseline Data

The primary measure of quantifying the benefits of congestion management have been identified as total travel times and average speeds, “before” and “after” the implementation of specific TMP strategies. As a result, the travel time data collection efforts (presented in Appendix A-4, and used for the evaluation of HOV objectives) encompassed the TMP as well as the HOV corridors.

Baseline travel time data was obtained along the full length of the Study Corridor from 176th Street in Surrey to Lynn Valley Road in North Vancouver**.** **Exhibit 3.2.1** presents the computed average travel speeds along the length of the corridor. **Exhibit 3.2.2** presents a tabulated summary of travel times, speeds, and delays broken down into the following four segments: North Shore & Burnaby, Burnaby, Coquitlam, and Surrey. As indicated in Section 2.2.4, estimates of delays are provided with respect to free-flow conditions so that the potential travel time savings are broken down to a unit to which a value can be attributed.

In general, it can be observed that in the peak directions, average speeds are higher for the Study Corridor when compared against similar data for the HOV corridor (presented in section 2.2.4 of this document). This is the result of collecting data over a longer corridor length and the fact that the peak direction and period are in opposing directions east and west of First Avenue (i.e. during the AM period, the peak direction is westbound from 176th Street to First Avenue and eastbound from Lynn Valley Road to First Avenue). Therefore, when comparing average speeds along the Study Corridor for a given time period, peak and off-peak direction data are mixed.

3.2.5 Phase II (Post-HOV) “True Before” Evaluation

In Phase II of the monitoring and evaluation program, travel time and average speed patterns will change as a result of the opening of the HOV lanes. However, the primary benefits of managing recurring congestion will only be realized through traffic monitoring and traveller information functions coordinated through the TMC (while the benefits of managing non-recurrent congestion will be realized through incident detection and management). Therefore, although the TMP emergency patrol and incident reporting systems may be in place in Phase II, benefits of managing recurring congestion will not be present – and true baseline data can be obtained.

Under this phase, travel time data will be obtained for HOV objective evaluation purposes. This data can serve as true baseline travel time and speed data for evaluating this objective under Phase III when traffic monitoring and traveller information functions are in place.

3.2.6 Phase III (Post-TMP) “After” Evaluation

In Phase III of this study, the TMC will be in place and will integrate the traffic monitoring and traveller information functions of the TMP within the pilot corridor. At this time, post-TMP “after” travel time data can be obtained for comparative evaluation against the true “before” travel time data obtained after opening of the HOV lanes.

As indicated in sections 2.2.5 and 2.2.6 of this document, collection of “after” travel time data should be based on the approach used for this study. However, consideration should be given to additional means of collecting travel time data using TMP functions and technologies in place (i.e. CCTV, cellular telephones, etc.)

3.3 IMPROVE SAFETY

3.3.1 Objective Description

The focus of this objective is to improve the overall safety of the highway facility as a result of the provision of traveller information and incident management.

3.3.2 MOEs

Specific MOEs which were selected to evaluate the achievement of this objective are:

- reduction in primary collisions, achieved by improving traffic flow by reducing stop and go conditions;
- reduction in secondary collisions.
- secondary collisions are collisions which result from an incident upstream along the highway and occur after the incident.

  Secondary collisions are caused when vehicles approaching an incident causing lane blockage, or a queue resulting from an earlier incident downstream, are unable to stop in time to safely join the end of the queue or avoid the lane blockage. The TMP is expected to reduce the incident duration time, thus reducing the queue length and collision risk.

Vehicle conflicts may be used as a surrogate for collisions, since they occur with greater frequency. As indicated in Section 2.6, sample data was collected near the Willingdon Interchange. The recorded data can be compared to similar data in Phase II in order to demonstrate the application of this method.

3.3.3 Data Requirements

In order to establish the MOEs identified above, data collection must include “before” and “after”:

- collision data;
- incident observations and logging (including a sample of secondary collisions).

3.3.4 Baseline Data and Discussion

Collision data from 1992 through 1996 for the study section of the Trans Canada Highway (Landmark Kilometre Inventory Segment 0510, 6.3km to 14.4km; Segment 0550, 0.0km to 26.1km; Segment 0555, 29.2km to 55.2km; and Segment 0531, 0.0km to 8.1km) were supplied by the Ministry. The data set contains complete records of 4,740 collisions for the whole study corridor (comprised of 0.4% Fatals, 40.6% Injuries, and 59.0% PDOs). However, data trends are partially obscured by a change in the police reporting procedure commencing in April 1996 and resulting in an apparent decrease in the number of collisions for 1996.

The collision data have been analyzed to provide a pre-implementation baseline for the future evaluation of the TMP. Appendix A8 contains an examination of collision trends, showing the frequency or proportion of collisions by time period (year, month, day of week, and time of day), severity, type of collision, prevailing weather condition, number of vehicles involved in each collision, and contributing factor. Comparison of the collision data for the TMP and HOV segments shows that the proportions of collisions are similar within these parameters. Spatial distributions for the eastbound and westbound directions are also presented in **Exhibit 3.3.1**. Collision Severity Ratios and collision rates for interchanges and segments have been determined.

Temporal Distribution of Collisions: The highest collision frequency occurred on Fridays, when 17 percent of all collisions occurred. This is similar to the 1995 provincial value, which is also 17 percent. The hourly collision distributions show distinct morning and afternoon peaks. About 17 percent of the collisions occurred in the morning peak period (between 0700 and 1000 hours). This is significantly different from the 1995 provincial value of 10 percent. Approximately 23 percent of collisions occurred in the afternoon peak period (between 1500 and 1800 hours), significantly different from the 1995 provincial value of 20 percent.

Collision Severity: Approximately 59 percent of collisions were classified as Property Damage Only (PDO) and approximately 41 percent of collisions were classified as Injury. The fatality rate was 0.4 percent along the TMP project segment. These proportions are significantly different from the 1992-1995 provincial values of 65 percent PDO collisions and 35 percent Injury collisions, indicating that collisions are more severe along the subject section of highway.

Collision Types: The major collision type was rear-end collisions, accounting for 58 percent of the total collisions along the TMP segment. The 1995 provincial value is significantly lower at 21 percent.

Weather Conditions: Approximately 73 percent of the collisions along the TMP segment occurred during clement weather (defined as clear or cloudy), compared to a 1995 provincial value of 75 percent. Approximately 24 percent of collisions along the TMP segment occurred during rainy weather.

Number of Vehicles Involved: Approximately 58 percent of the collisions along the TMP segment involved two vehicles, while 23 percent involved a single vehicle. Province-wide, 26 percent of collisions involved a single vehicle.

Contributing Factors: Police collision reports failed to identify the main contributing factor in 52 percent of collisions. Driver error or driving without due care were identified as the main contributing factor in 38 percent of the collisions, and driver impairment was identified in a further 5 percent of collisions.

Collision Severity Ratios: As an indication of the combined number and severity of collisions along the study segment, the Collision Severity Ratios for individual segments and interchanges have been calculated. The Collision Severity Ratio for the entire TMP segment was 5.0, compared with a provincial average of 4.6 in 1995.

Identification of Collision Blackspots: A collision blackspot is identified as a road segment or interchange with a collision rate that exceeds the average provincial collision rate for multilane urban freeways. Five-year (1992-1996) and three-year (1994-1996) average collision rates were calculated to identify these hazardous interchanges and segments relative to average collision rates between 1991 and 1993. The results are summarized in Appendix A8.

3.3.5 Phase II (Post-HOV) "True Before" Evaluation

The length of the interval between completion of the HOV lanes and the introduction of the TMP system may affect the quality of the Phase II evaluation. If the interval is too brief, the resulting small sample size will affect the validity of the results. In addition, collision rates may be affected by altered traffic flows and movements (particularly lane changes) resulting from the recent introduction of the HOV lanes, and drivers' initial unfamiliarity with these lanes.

Secondary collision data should be collected. The temporary CCTV system that is expected to be installed as part of the traffic management plan during construction of the HOV lane may be useful to identify secondary collisions occurring as a result of a primary incident at the end of a queue or at a blocked lane.

Coordination at management level between the Ministry and the Port Mann Freeway Patrol is recommended, to ensure that the current level of effort in attending and collecting collision data is maintained. Additional data collection may be requested to identify secondary collisions.

3.3.6 Phase III (Post-TMP) "After" Evaluation

Since the HOV and TMP facilities are to be introduced in quick succession, the individual safety impact of each project may be difficult to isolate. Particularly if three- to five-year analysis periods are chosen for the post-implementation study, the impact of the TMP alone is likely to be indistinguishable from that of the combined HOV and TMP facilities.

The safety benefits of traffic management systems in other jurisdictions have been quantified in published sources, and are summarized in the report entitled Review of the Road Safety Benefits of Congestion Management Systems for Freeways by Hamilton Associates (May 1997).

The provision of the TMP may result in reducing secondary collisions caused by driver behavior following a primary incident, and at the arrival end of a queue. A Toronto study of the COMPASS System examined the effect of changeable message signs on secondary collisions. The study concluded that the proportion of secondary collisions resulting from primary collisions dropped from 14 percent to 2 percent following the introduction of the CMS system. The proportion of all secondary collisions relative to all collisions decreased from 17 percent to 5 percent. The analysis conducted showed that this reduction was statistically significant.

A similar study conducted for the TransGuide system in Texas concluded that the number of secondary collisions decreased by 30 percent following the implementation of TransGuide. The Texas study also reviewed the incidence of collisions during clement and inclement weather. After the introduction of the TransGuide system, the number of collisions during rainy weather decreased by 39 percent, and the number of collisions during foggy weather decreased by 57 percent. Over the same sampling period, the number of collisions during clear or dry weather decreased by 28 percent. Overall, a collision reduction of between 15 and 21 percent was reported.

It must be noted however, that the collection of a statistically significant sample of secondary accidents is difficult due to the rareness of their occurrence relative to primary accidents. There were no secondary accidents logged under the Phase I data collected. The use of this MOE will depend on the sample of secondary accidents collected under Phase II. In Phase III, all incident data will be automatically logged by the TMC; therefore, secondary accidents will also be logged continuously.

3.4 EFFICIENT USE OF CAPACITY

3.4.1 Objective Description

The focus of this objective is to utilize available capacity on parallel routes when there is congestion on the mainline.

3.4.2 MOEs

The MOE which can be used to evaluate the achievement of this objective is:

- level of service balancing between a congested facility and a parallel non-congested facility.

This MOE can be used at two levels:

1. A *static* measurement of the throughput (vehicles x occupants x average speed) along the mainline and parallel routes “before” and “after” implementation of TMP. As throughput is a function of level of service, such a measurement could provide a snap-shot of the relative utilization of capacity between two parallel corridors.

2. A *dynamic* measurement of throughput between the mainline and parallel routes after implementation of the TMP - and during congestion/incident conditions – using real-time monitoring along the mainline and parallel route diversion points. The real-time monitoring along the parallel routes sections will need to be similar to the TMP vehicle detection stations capable of counting vehicles and their speeds.

The data requirements and baseline conditions discussed below consider the former static MOE, while the latter MOE is discussed under the sections pertaining to Phase II and Phase III requirements.

3.4.3 Data Requirements

In order to establish the above MOE, the following “before” and “after” data must be obtained:

- vehicle counts;
- vehicle classifications;
- average speeds;
- supplementary queue measurement data.

3.4.4 Baseline Data and Discussion

Since the introduction of HOV lanes along the TCH corridor will impact the throughput of the facility, the baseline data for this objective must be collected in Phase II, during the post-HOV and pre-TMP efforts of Phase II. However, since much of the required data was already collected under this study for the purposes of other MOEs, related baseline analysis, which can be used as a reference in the subsequent phases, has been carried out and is included in this section. Specifically, level of service calculations and sample throughput calculations along the mainline, and intersection analysis along the parallel routes are presented.

The level of service for the highway segments between the Lynn Valley Interchange and the 176 Street Interchange was calculated based on vehicle average speeds collected during September 1997 and the methods outlined in the 1994 Highway Capacity Manual. The results are summarized in **Exhibit 3.4.1.**

In both the eastbound and westbound direction, highway segments within the TMP section experience a level of service E or worse during the morning and afternoon peak hours (with the exception of the highway segment east of the 104th Avenue interchange in the eastbound direction). A level of service E or worse, as defined by the HCM, corresponds to an average travel speed between approximately 80 and 85 kilometres per hour, while a level of F encompasses speeds below 80 kilometres per hour. It should be noted, however, that when Highway 1 within the study area limits is operating at an average travel speed of 80 kilometres per hour, drivers generally perceive the level of service to be satisfactory.

As the intent of the TMP is to optimize the use of existing facilities, while reducing the need to construct new facilities, the measurement of throughput has been identified as a static means of comparing the performance of parallel facilities “before” and “after” introduction of the TMP pilot corridor. Throughput is defined as the product of vehicular volume, travel speed, and occupancy rate, and can be expressed as person-kilometres per hour. (*Calculation of throughput is similar to the Per-lane Efficiency calculation used for HOV evaluation, except that it is not on a per-lane basis).* Increased throughput will indicate more efficient use of the existing available capacity.

Exhibits 3.4.2 to 3.4.5 summarize the existing throughput, as measured by person-kilometres per hour, across six stations along the TCH. These include the 2nd Narrows Bridge, West of Boundary Interchange, Grandview Off-Ramp, West of Cariboo Interchange, Cape Horn Interchange, and the Port Mann Bridge. In the eastbound direction, the throughput ranges from between 109,000 and 367,000 person-kilometres per hour. In the westbound direction, the throughput ranges between 146,000 and 422,000 person-kilometres per hour. With the exception of the West of Boundary I/C station, the eastbound morning throughput was calculated to be higher than the eastbound afternoon throughput. The lower throughput during the eastbound afternoon peak hour may be attributed to low travel speeds due to congestion along the TCH. Similarly, the throughput westbound in the morning peak hour is calculated to be less than the throughput westbound in afternoon peak hour.

Since the parallel routes travel time data is only required for this objective, it can be collected during the post-HOV and pre-TMP conditions of Phase II. The collection of true pre-TMP travel time data along both corridors will be the true baseline, and can be compared against similar data obtained under Phase III.

One of the components of the TMP is to inform travellers to make better decisions regarding travel patterns. For example, information regarding incidents and congestion allow vehicles to reroute onto less congested facilities. **Exhibit 3.4.6** summarizes the intersection level of service along parallel routes of the TCH. The results indicate that the majority of the intersections evaluated along the parallel routes are operating at close to capacity during the weekday peak periods, and the opportunities for redistribution of traffic from the TCH onto the parallel routes may therefore be limited to off-peak periods.

EXHIBIT 3.4.2 THROUGHPUT ACROSS SIX STATIONS ON THE TCH AM PEAK HOUR (0700-0800) EASTBOUND

SCREENLINE	SPEED [km/hr]	OCCUPANCY	VOLUME [veh/hr]	COUNT STATIONS USED	THROUGHPUT [person km/hr]
Second Narrows Bridge	60	1.11	5,515	P15-2, 16-2503, 16-2504, 16-2513	367,300
West of Boundary I/C	65	1.14	3,810	16-095 south	282,320
Grandview Offramp	70	1.13	4,220	16-095 south, 16-1382, 16-1391, 16-0781, 16-1404	333,800
West of Cariboo	80	1.12	3,180	16-0822, 16-1424	284,930
Cape Horn I/C	70	1.13	3,755	P16-2	297,020
Port Mann Bridge	70	1.12	3,755	P16-2	294,390

EXHIBIT 3.4.3 THROUGHPUT ACROSS SIX STATIONS ON THE TCH AM PEAK HOUR (0700-0800) WESTBOUND

SCREENLINE	SPEED [km/hr]	OCCUPANCY	VOLUME [veh/hr]	COUNT STATIONS USED	THROUGHPUT [person km/hr]
Second Narrows Bridge	75	1.11	3,780	P15-2, 16-2502, 16-2501, 16-2512	314,685
West of Boundary I/C	70	1.14	3,170	16-095 north	252,965
Grandview Offramp	75	1.13	3,840	16-095 north ,16-1392	325,440
West of Cariboo	50	1.16	2,520	16-0822, 16-1424	146,160
Cape Horn I/C	75	1.15	3,690	P16-2	318,260
Port Mann Bridge	40	1.13	3,690	P16-2	166,790

EXHIBIT 3.4.4 THROUGHPUT ACROSS SIX STATIONS ON THE TCH PM PEAK HOUR (1600-1700) EASTBOUND

SCREENLINE	SPEED [km/hr]	OCCUPANCY	VOLUME [veh/hr]	COUNT STATIONS USED	THROUGHPUT [person km/hr]
Second Narrows Bridge	65	1.20	4,615	P15-2, 16-2503, 16-2504, 16-2513	359,970
West of Boundary I/C	85	1.21	3,070	16-095 south	315,750
Grandview Offramp	60	1.26	3,360	16-095 south, 16-1382, 16-1391, 16-0781, 16-1404	254,015
West of Cariboo	35	1.25	2,490	16-0822, 16-1424	108,940
Cape Horn I/C	30	1.16	3,875	P16-2	134,850
Port Mann Bridge	55	1.16	3,875	P16-2	247,225

EXHIBIT 3.4.5 THROUGHPUT ACROSS SIX STATIONS ON THE TCH PM PEAK HOUR (1600-1700) WESTBOUND

SCREENLINE	SPEED [km/hr]	OCCUPANCY	VOLUME [veh/hr]	COUNT STATIONS USED	THROUGHPUT [person km/hr]
Second Narrows Bridge	65	1.15	5,260	P15-2, 16-2502, 16-2501, 16-2512	393,185
West of Boundary I/C	75	1.23	3,470	16-095 north	320,110
Grandview Offramp	80	1.24	3,950	16-095 north ,16-1392	391,840
West of Cariboo	85	1.24	2,625	16-0822, 16-1424	276,675
Cape Horn I/C	85	1.27	3,905	P16-2	421,545
Port Mann Bridge	55	1.24	3,905	P16-2	266,320

3.4.5 Phase II (Post HOV) “True Before” Evaluation

With the implementation of the HOV lane facility, the level of service of the highway segments and ramps between the Lynn Valley Interchange and the 176 Street Interchange will need to be re-established to account for expected changes in the ramp and interchange configurations and traffic operation characteristics. Data collection during this phase should include vehicle counts, travel speeds, and vehicle occupancy on both the TCH and parallel routes to measure the level of service and establish the throughput across each screenline including the parallel routes. The total throughput at each screenline can be compared with the data collected in Phase III to quantify any significant increase in throughput due to the introduction of the TMP.

3.4.6 Phase III (Post TMP) “After” Evaluation

Under Phase III, “after” data comprising vehicle counts, travel speeds, and vehicle occupancy on both the TCH and parallel routes can be obtained for comparison against the Phase II data. Throughput between the mainline and parallel routes can not be compared against each other since one facility is a highway, and the other is an arterial/highway with traffic signals. However, a combined throughput on a screen line basis can be computed and compared for "before" and "after" conditions.

As indicated earlier, a more *dynamic* measure of TMP benefits related to the efficient use of capacity can be facilitated by real-time monitoring of parallel corridors during non-recurrent congestion conditions. While real-time monitoring will be present along the TCH during Phase III, similar monitoring will not be available along parallel routes; therefore, there will be cost implications relative to the extent of monitoring required along the parallel routes (or portions of). For example, TMP compatible vehicle detection stations can be used at strategic mainline-to-parallel route diversion points, in order to measure the use of capacity during incident conditions.

The benefits of this objective will be most observable using such a dynamic measure. For example, pre-trip and enroute real-time traveller information will have the ability to divert traffic from a portion of the TCH based on prevailing conditions. The diverted traffic will either delay their trip, or use a parallel facility with available capacity. Therefore, during incident conditions for example, real-time monitoring of traffic volumes/speeds between two parallel corridors is required for the computation of throughput dynamically. Public opinion surveys could also be used to determine the public's perception on the usefulness of traveller information service applications, thus providing an indication on the efficient use of capacity.

3.5 IMPROVE ENVIRONMENTAL CONDITIONS

3.5.1 Objective Description

One of the TMP objectives is to reduce vehicle emissions and improve air quality. The expected benefits will be estimated by measuring vehicle-kilometres traveled and travel speeds, and applying emission models to estimate changes in the emission of criteria pollutants.

3.5.2 MOEs

Specific MOEs which were selected to evaluate environmental benefits are based on estimates/ simulations of the following:

- emissions;
- air quality;
- vehicle-kilometres traveled.

3.5.3 Data Requirements

In order to establish the MOEs identified above, data collection must include “before” and “after”:

- vehicle counts;
- vehicle classifications;
- travel time runs.

3.5.4 Baseline Data and Discussion

Baseline air quality has been determined directly through a program of air quality monitoring, and indirectly through calculation of two air quality indicators, vehicle emissions and vehicle-kilometres traveled.

Emissions Modeling: An indication of air quality impacts resulting from traffic flow improvements may be obtained by estimating the “before” and “after” overall emissions. The main influences on emissions are the composition of the vehicle fleet by age, the use of gasoline or diesel engines, the use of catalytic converters, vehicle speeds, road gradients, altitude, and ambient temperatures. In this study, indicative emission rates have been calculated using a speed-dependent equation to estimate emissions from discrete road segments. Details of the analysis are provided in Appendix A9, and summarized in **Exhibits 3.5.1 and 3.5.2.**

Calculated emissions of NO_x along the subject section of the Trans Canada Highway are approximately 6.3 to 7.8 grams per person in each direction during peak hours. Calculated peak hour emissions of CO along the subject section of the Trans Canada Highway are approximately 7.1 to 9.5 grams per person in each direction during peak hours.

Vehicle-Kilometres Traveled: The 1997 peak hour traffic along the TMP segment of the Trans Canada Highway reaches 103,000 to 105,000 vehicle-kilometres, and is about two percent higher in the afternoon peak hour than in the morning peak hour.

Air Quality Monitoring: Hourly air quality monitoring of criterion pollutants was conducted at two sites in Coquitlam by the GVRD in September 1997. Concurrently with the hourly pollution monitoring, hourly meteorological data were obtained. The monitoring program has produced a total of 651 hours of matched pollution and meteorological data. The data is expected to be available from the GVRD in summarized form by the time of the post-implementation studies.

3.5.5 Phase II (Post-HOV) “True Before” Evaluation

The Phase II “before TMP” condition is equivalent to the Phase II “post-HOV” conditions, described in Section 2.7.5.

3.5.6 Phase III (Post-TMP) “After” Evaluation

The same methodology for measuring vehicle emissions is proposed for the “after TMP” conditions, as the “before TMP” conditions.

4.0 NETWORK IMPACTS

4.1 SCOPE OF CONSIDERATION

The MOE's and the data collection program described in earlier sections were designed to identify, on a network basis, the impacts of either the HOV project or the TMP project. For Phase I, it was assumed that the impacts of the HOV or the TMP projects would be confined to the TCH facility and the following parallel routes:

- Lougheed Highway (Route 7)
- Mary Hill Bypass
- Canada Way
- Barnet Highway
- Pattullo Bridge

Prior to proceeding to Phase II for the HOV and TMP evaluation projects, the areas of influence on the wider network resulting from these projects, needs to be confirmed. A process of confirming these areas of influence and the data collection requirements is discussed in this section.

4.2 EXISTING CONDITIONS

The data collection program included vehicle classification and occupancy surveys along the specified parallel routes at the following stations:

- **West Screenline**
  TCH, Lougheed Highway, and Canada Way - at Willingdon Avenue;
- **Centre Screenline**
  TCH and Lougheed Highway - at Cariboo Road;
- **King Edward Screenline**
  TCH and Lougheed Highway - at King Edward Avenue;
- **East Screenline**
  TCH, Mary Hill Bypass, Lougheed Highway, and Barnet Highway - east of Cape Horn;
- **Fraser River Screenline**
  Patullo Bridge and Port Mann Bridge - along Fraser River.

The location and results of the parallel route occupancy and classification surveys are shown in **Exhibits 4.1 and 4.2**, respectively. Manual peak hour turning movement counts at major intersections along the adjacent parallel routes were collected to evaluate the existing intersection performance, and to determine the availability of any spare capacity at these intersections. In addition, 24 hour traffic volumes were collected at count stations along the parallel routes as summarized **in Exhibit 4.3**. The 24 hour volume distribution of these counts are included in Appendix A1. The parallel route peak hour turning movement intersection counts are summarized in **Exhibit 4.4**.

EXHIBIT 4.3 COUNT STATIONS ALONG PARALLEL ROUTES

DESCRIPTION
Route 7, 0.2 km east of Boundary Road
Route 7, 0.2 km east of North Road
Route 7, 0.2 km east of Colony Farm Road
Route 7A, 0.1 km west of Route 7 at Pine Tree Way
Mary Hill Bypass, 0.8 km east of United Boulevard
Route 7, west of King Edward Street
Canada Way, west of Willingdon Avenue
Pattullo Bridge

The level of service was calculated at major intersections along the adjacent parallel routes. The results are summarized in **Exhibit 4.5**.

The results indicate that the majority of the intersections evaluated along the parallel routes are operating near capacity during the weekday peak periods, and the opportunity for the redistribution of traffic from the TCH onto the parallel routes may therefore be limited during these time periods.

To further understand the network implications of the HOV and TMP projects, all the affected municipalities were contacted and requested to provide a summary of their data collection capabilities and programs. The responses from the municipalities are summarized in Appendix B. MoTH may wish to coordinate with the municipalities to harness future data collection efforts towards evaluating the HOV and TMP projects.

4.3 FUTURE REQUIREMENTS

As mentioned in Section 4.1, the area of influence of the HOV and TMP projects need to be confirmed prior to proceeding to Phase II.

For the evaluation of the HOV project, network level analyses are important in order to properly differentiate between actual modal shifts versus rerouting of existing SOV and HOV traffic across the TCH and parallel routes. For Phase I, the corridor of influence included the two parallel routes: Lougheed Highway - Mary Hill Bypass - Barnet Highway corridor and the Canada Way - Patullo Bridge corridor. The corridor of influence should be confirmed prior to Phase II data collection efforts using the GVRD EMME/2 Regional Transportation Model. Using this model, modal and route diversion effects can be simulated to confirm the selected corridors, or potentially indicate the requirement for additional parallel routes, such as the Fraser Highway in Surrey. If additional parallel routes are identified, then the EMME/2 model will assist in determining the portion of the Phase I traffic that was captured in the parallel routes, and the associated correction factors that must be applied.

For the evaluation of the TMP project, the network impacts are more difficult to detect, such as impacts of improved traveller information; or, are difficult to monitor, such as impacts of incident management programs. Accordingly, it is proposed to define the corridor of influence using the EMME/2 model, as well as using traveller attitude surveys.

The EMME/2 model would be used to simulate the area of influence of some of the specific service applications, such as ramp metering. For assessing the implications of other applications, such as improved driver information, it is proposed to carry out an area-wide survey of travellers to determine their perception of before and after traffic conditions resulting from the TMP project.

For the TMP objective e*fficient use of capacity* (Section 3.4), it is intended to evaluate the impacts at a network level, examining the efficient use of capacity both on the mainline and parallel routes. The parallel routes will need to be determined during the Phase II process. Once the routes are determined, this MOE will require travel time data to be collected along the parallel routes. The data need not be as detailed as the mainline data however, and can be collected and recorded on longer road segments. The travel time data will be required before and after introduction of the full TMP system, and must therefore be obtained during both Phases II and III. Although this MOE will not cover non-average or incident conditions, it will provide a general indication of more efficient corridor balancing resulting from overall improved traffic management and traveller information strategies.

Measurement of the TMP impacts can be improved by monitoring traffic throughput simultaneously along the parallel corridors and the mainline corridor, during diversion conditions. This would require real time monitoring of volumes and speeds along the parallel routes, as well as the mainline route. This will require installation of vehicle detectors at key locations along the parallel routes to detect diversion of traffic. In this regard, the Ministry should investigate the costs associated with implementation of vehicle detector stations at strategic diversion points.

As indicated earlier, public opinion surveys can be a useful way of supplementing the data and determining the public's perception on TMP benefits.

The use of microscopic traffic simulation models was also considered for application in the evaluation of network impacts. However, since such a simulation would need to include both the expected area of impact, as well as the area of non-impact beyond, the extent of the area to be simulated would be excessive and the cost would be prohibitive. It is felt that the EMME/2 model is a much more cost-effective, although not as sensitive, method for determining area-wide traffic impacts.

5.0 PHASES II & III REQUIREMENTS

During Phase II and III, the HOV and TMP monitoring and evaluation programs will document the performance of both the HOV and TMP projects along the Highway 1 corridor. The current anticipated schedule for the start-up of these projects is as follows:

1998	HOV lanes in operation
1998/99	TMP Emergency Patrols and *4444 Incident reporting system
2002	TMP Incident Management, Traveller Information, TMC

These Phases will include:

- Phase II, to be carried out in early 1999, will focus on the “before” and “after” evaluation of the HOV lanes while establishing the true TMP baseline.
- Phase III, to be carried out in late 2002, will focus on the evaluation of the TMP pilot corridor project as well as for additional monitoring of the HOV facility.
- Both Phases II and III must also include the evaluation of network impacts as discussed in Section 4.0.

Exhibit 5.1 illustrates the scheduling of the Phase II and Phase III efforts relative to the HOV and TMP project timelines. The schedule assumes that the HOV lane construction project will be completed on schedule in the fall of 1998.

Phase II data collection is illustrated to start subsequent to opening of the lanes. This data will only be required for sampling purposes of evolving conditions during the first few months of start-up. The actual “after” data collection effort to be undertaken in Phase II should start a *minimum* of six months after opening of the HOV lanes. According to the Texas Transportation Institute technical report <u>An Assessment of High Occupancy Vehicle Facilities in North America</u> (1992), many significant impacts of successful HOV projects appear to occur two to four years after implementation; therefore, a long term perspective is required subsequent to the initial six month period evaluation.

Based on this schedule, data collection along the HOV corridor will take place six months after opening near March of 1999. This will require for the seasonal variation in some of the data to be accounted for. The calibrated data can then be confirmed by the collection of small sample data in September of 1999. On this basis, the Phase II efforts can be completed by October of 1999.

In order to ensure proper data comparability and ease of analysis, it is important that the HOV “before” and “after” evaluation, and the ongoing monitoring efforts, be carried out according to the procedures developed in this Phase I study.

The implementation of the TMP pilot project components are assumed to be according to the following schedule:

- Emergency Patrol and Incident Reporting System starting around September 1998 to April of 1999;

- Traffic Management Centre starting around January of 2000 to January of 2001;

- Incident Management and Traveller Information System starting around January of 2000 and completed by April of 2002.

On this basis, the Phase III TMP "after" data collection can start around September of 2002, and be completed in Spring of 2003. However, as indicated on the schedule, since the HOV monitoring data collection efforts is recommended to be carried out annually between 2000 and 2002, this data can also be used for interim evaluation and monitoring of the implemented Emergency Patrol and Incident Reporting System.

Exhibit 5.2 presents the overall methodology recommended for the future phases of the TCH – HOV – TMP Monitoring and Evaluation Program. The following sections outline a work program for undertaking these efforts.

5.1 PHASE II - PROJECT INITIATION

The purpose of this task will be to prepare the Phase II Study Design, drawing upon the Phase I Study Design (developed under this study) which will define a data collection program for Phase II. Under this task, the following steps should be carried out:

- confirm objectives;
- refine MOEs;
- confirm MOE data requirements;
- prepare data collection program.

The output of this task will be the Phase II Study Design.

5.2 PHASE II - DATA COLLECTION

Data collection efforts will be undertaken according to the Phase II study design. Based on the experience gained during the Phase I data collection program, a number of recommendations have been developed for each of the survey types. These recommendations are presented below.

5.2.1 Short Counts

Although the Phase II short count data collection program will be very similar to the baseline project, the lessons learned under this study can be used to make some recommendations for Phase II.

- A one week sample of short count data, obtained at 15 minute intervals, and over a 24 hour period was found to be adequate for analysis purposes. However, in terms of a scheduling window, it will be important to ensure that a 3 week period is available for data collection in the event of unexpected traffic events or conditions.

- Traffic volumes at many interchanges are comprised of composite counts; therefore, it will be critical to ensure that all count stations are operational prior to the start of the program. In this regard, erroneous data resulting from the malfunctioning of just one station can impact the integrity of data at other stations which rely on it.

- In order to ensure that data summarization and analysis is carried out effectively and efficiently, it will be important to ensure that the data collection contractor is accountable for delivering data timely, and that project timelines are adequate for raw data to be compiled into the Ministry's TIMS format.

Overall, it was found that the early availability of the short count data could have enhanced the design of the data collection program because the information is useful for correlation with other data types and developing sample sizes. Under Phase II, the Phase I short count data can be used for reference, since the actual surveys must be carried out at the same time as other Phase II data collection efforts.

No special Phase III considerations apply to the collection of short count data. However, alternative techniques of data collection should be considered based on TMP technologies in place. Specifically, available permanent vehicle detector stations should be used where possible to provide the required short counts.

5.2.2 Manual Intersection Counts

The collection and analysis of manual intersection turning movement counts for Phases II and II are proposed to be the same as in Phase I.

The scope of the data collection is, however, an important consideration. As discussed in section 4.0 of this document, the extent to which intersections along parallel routes are considered depends on the scope of network impacts being assessed. Phase II and Phase III data collection requirements for intersection turning movement counts must support the analysis of network impacts along the parallel routes under review. Determining the extent of the network to be investigated is one of the early tasks in Phase II.

5.2.3 Vehicle Occupancy and Classification Counts

Collection of vehicle occupancy and classification data is a critical requirement for the evaluation of HOV performance. This data collection effort should be conducted using similar methodology and means as in Phase I. Based on Phase I experience, the following issues should be considered:

- Both peak periods and midday vehicle occupancy data are relevant for usage analysis; therefore, survey efforts should encompass peak and off-peak periods.

- The occupancy data at adjacent screenlines along the corridor were found to be consistent; therefore, potential cost savings may be achieved by undertaking counts at fewer stations, supplemented by sample data collected at the remaining stations for comparison.

- Survey scheduling must allow for data collection survey problems associated with counting occupants during adverse weather, or low daylight conditions (e.g. November to January should be avoided).

- Survey locations must be confirmed with the RCMP Freeway Patrol prior to start-up to ensure that the surveys are not disrupted during the data collection period.

Phase III considerations will likely be similar, but can build on Phase II experience.

5.2.4 Travel Time Surveys

The collection of travel time data under Phase II will serve two purposes, “after” data for the evaluation of the HOV lanes, and as true “before” baseline data for the full evaluation of TMP under Phase III.

It should be noted that the comparative “after” evaluation of travel times between the HOV lanes and GP lanes can be carried out using the Trip Reliability Surveys (Section 5.2.5) since not as many intermediate landmarks are required for the HOV lanes. The detailed travel time surveys can be limited to the GP lanes, in order to assess the “before” and “after” impacts to GP lanes.

Consideration was given to reducing the travel time and surveys to three segments along the length of the TMP corridor in an attempt to reduce the manpower from 2 persons to 1 person per vehicle, but it was concluded that the travel times obtained at the more detailed intervals are useful for identifying congestion “hot-spots” and segment level of service calculations. Accordingly, it is proposed to carry out the detailed travel time surveys logging travel times at some 20 intervals along the corridor.

For detailed travel time data, the methodology for data collection under Phase II will be the same as Phase I.

Phase III considerations will be similar; however, collection methodologies may benefit from implemented TMP technologies, especially in terms of:

- vehicle detector stations and incident detection software (which can provide count and speed data);
- cellular telephone reporting through the TMC;

- CCTV monitoring supplemented with video image processing and license plate matching;
- polling of vehicles equipped with transponders (due to electronic tolling implementation on other facilities).

5.2.5 Trip Reliability Surveys

The primary consideration for trip reliability travel time data collection under Phase II will be to distinguish between the performances of the HOV lanes and the “after” GP lanes. Since trip times between the two lane types will be quite different, it will be important to ensure that the subsequent data analysis of “after” HOV lane versus “after” GP lane travel times compare travel time in the same direction at approximately the same time. Therefore, after completion of one corridor length in a given direction, the HOV lane survey vehicle may have to wait for the GP lane vehicle prior to making the return trip.

Phases II and III data requirements for the trip reliability surveys will be the same as in Phase I, that is AM and PM peak period travel time surveys for 20 weekdays. As in Phase I, two travel time runs should be made in each peak period, to ensure that peak conditions are experienced. This trip reliability survey is very cost-effective, since recording times at 4 points on the route can be carried out by the vehicle driver, avoiding the need for a second person in the vehicle. At this time, RCMP cooperation is assumed, regarding permission for designated/marked test vehicles (SOVs) to use the HOV lanes for this effort. Therefore, large sample sizes can be obtained quite cost-effectively.

The Jack Bell Foundation vanpool program was used as a means of data collection under Phase I. This program provides a valuable source of collecting travel time data along the HOV lanes, and should be utilized in Phases II and III, and particularly in the ongoing annual monitoring of the HOV project.

5.2.6 Incident Observation and Logging

Collection of incident data is required to quantify incident duration (in terms of response and clearance times), while also logging resulting impacts. Experience from Phase I confirms that the methodology and procedures used for data collection were adequate in terms of coverage and details, but the sample size of logged incidents was low. Comparison of the collected sample size against other sources such as the radio (which was monitored during the surveys) and data collected by the RCC, and the HOV lane construction CCTV monitoring facility, confirms that the low sample size was the result of monitoring for only a three week survey period.

In order to collect more incident data during Phase II, the following additional considerations are proposed:

- The traffic management program associated with the current widening of the Trans Canada Highway incorporate temporary CCTV monitoring for incident management purposes during construction. There may be an opportunity to extend the use of the monitoring facility, beyond the completion of construction works, as a means for collecting Phase II incident data.

- The implementation of the Emergency Patrols and the *4444 Incident reporting System will present a valuable source of incident data.

- Depending on the role of the RCC in coordinating the above, their incident logging procedures and software could be enhanced to facilitate better data collection.

During Phase III, the traffic management project will be in place and will, therefore, be the basis for recording incidents.

5.2.7 Highway Approach Queue Surveys

Highway ramp queue lengths provide a measure of recurring congestion on the approaches of the mainline, and can supplement interchange capacity analysis. In general, observation of queue lengths are difficult to observe from ground level or from adjacent overpasses. Aerial photography provides the best means of quantifying queue data. Based on experience from Phase I, it is recommended that efforts focus on the morning and evening peak hours rather than during the midday when queue lengths are minimal, while focusing on interchanges with long queues (as documented in this study).

Although difficult to collect under congested/stop-and-go conditions, queue surveys along the mainline will also be useful, especially in terms of documenting the end-of-queue at bottlenecks and bridges. For example, the same aerial surveys for the approaches can be used to obtain data on the queue end point at the northbound approach to the Port Mann Bridge in the AM peak period.

5.2.8 Collision Data

In Phase I, the source of measure of safety was collision data as compiled by ICBC over the past 5 years. However as noted earlier, the freeway patrol, which has been the source of this information, has reduced the level of coverage, thus affecting the ability to compare accident rates pre and post-1996.

Further, there are additional issues which will need to be considered in Phases II and III:

- isolation of combined safety impacts resulting from implementation of both the HOV and TMP projects on the same facility;
- impacts of changes in reporting protocols as referenced above;
- identification of other roadway improvements that may affect collision rates.

Because accident rates are very infrequent, particularly the ones which are recorded by ICBC, records for at least a year are typically required to obtain sufficient accident information. With the reduction in level of coverage by the freeway patrol, this period is even greater.

Therefore, the following is proposed for future phases:

- Accident information should be recorded by the emergency patrols (when operating) and coordinated with the RCC operation and subsequently transferred to the TMC operation when it comes into affect; (here, it will be important to ensure consistency with RCMP reporting, while preventing the recording of redundant data);

- Location of accidents relative to the HOV lane or GP lane operations need to be recorded by the RCMP, or potentially the Emergency Patrol Vehicles;

- Location of the accidents relative to newly installed TMP components, such as changeable message signs, need to be recorded;

- Location of the accidents relative to other roadway improvements need to be identified by RCMP or potentially the Emergency Patrol Vehicles.

During Phase III, the TMC is expected to be in operation and this facility, along with the E Patrol information, will be the coordinating agency for the accident data.

5.2.9 Air Quality Data

For the Phase I study, the primary method to estimate impacts to the environment was through an emissions model utilizing traffic volumes and speeds to estimate emissions. Input data to the model was for the TCH corridor only.

The GVRD EMME/2 model should also be used to generate do-nothing, add GP lane, and add HOV lane scenarios for comparison with the "after" data.

In addition to the modeling estimates, a set of air quality and meteorological parameters were also monitored west of the Cape Horn interchange by the GVRD Air Quality Program in September of 1997. This information will be made available to the TCH-HOV-TMP monitoring and evaluation project after it is internally documented by GVRD.

For future phases, it is recommended that both of the above data collection programs be repeated to measure air quality conditions on Highway 1.

5.2.10 Public Opinion Surveys

Public opinion surveys provide a valuable and cost effective means of collecting "after" data for the evaluation of objectives and measures which are more qualitative and for which no "before" data exists. The objective here is to determine the public's view of a particular implementation program, and to compare their perception of benefits to actual benefits achieved.

The Phase II data collection program should incorporate public surveys to determine the following:

- the number of existing carpools and vanpools, along other routes, who merely shift to the TCH HOV facility;
- the number of carpools and vanpools formed directly as a result of the HOV lanes;
- perception of travel time savings as a result of using the HOV lanes;
- perception of trip time reliability as a result of using the HOV lanes;
- general support for the HOV Project (by users, non-users, and general public);
- general support for the TMP Emergency Patrols and *4444 Incident Reporting system.

In Phase III, ongoing HOV monitoring of public support can be carried out using similar surveys as in Phase II. In addition, specific surveys will be required for documenting public support and usage of TMP functions.

Driver responses to Changeable Message Signs (CMS) can be used for evaluation of TMP benefits in terms of a number of indicators:

- ease of reading messages;
- ease of understanding messages;
- location of sign versus time for driver to respond;
- the types of messages recalled;
- compliance to messages;
- general usefulness of messages;
- general support for the implementation (i.e. are more CMSs beneficial?).

Public opinion on other TMP traveller information mediums may be evaluated through similar indicators as those identified for CMSs. Depending on the medium technology, actual usage data may also be obtained. For example, if facsimiles are used as a dissemination medium for providing traffic reports to subscribers, the number of subscribers can serve as an indication of usage. Alternatively, if a World Wide Web page is used to provide real-time traveller information along the corridor, the number of "hits" to the Web page can also be an indicator of usage.

5.3 PHASE II EVALUATION

The purpose of this task will be to compile the "before" data from Phase I and the "after" data from Phase II, and carry out the analysis necessary for each MOE.

The output from this task will be the following three independent reports:

- *HOV Evaluation:* The focus of this report will be the “before” and “after” evaluation of the project objectives – in terms of the final selected MOEs, and “after” public opinion surveys. A preliminary evaluation matrix with typical values is provided in **Exhibit 5.3**.

- *Interim TMP Evaluation of Emergency Patrols and *4444 Incident Reporting System*: The focus of this report will be the “before” and “after” evaluation of specific TMP strategies which may be in place by Phase II. Key aspects of the evaluation will be incident duration, public support for the emergency patrols, and “usage” of the incident reporting system.

- *TMP Baseline Conditions (for the Evaluation of Incident Management, Traveller Information, and TMC Functions):* The focus of this report will be the compilation and documentation of data collected under Phase II as baseline data for TMP evaluation. A preliminary evaluation matrix with target values is provided in **Exhibit 5.4**.

5.4 PHASE III PROJECT INITIATION

The purpose of this task will be to prepare for the Phase III “after” evaluation of new TMP functions, and the continuous monitoring/evaluation of HOV operations.

In planning for the TMP “after” evaluation, a number of inputs are required. It is recommended this task commence approximately one year prior to the operation of the Incident Management and Traveller Information functions so that necessary details pertaining to the TMP are available in the planning process.

Key inputs are:

- review Phase I baseline data;
- review Phase II evaluation of TMP Emergency Patrols and *4444 Incident Reporting System;
- review of Phase II baseline data for TMP evaluation;
- confirmation of TMP implementation time-lines;
- confirmation of selected TMP detection technologies;
- confirmation of selected TMP information dissemination mediums and technologies;
- review of TMP Traffic Operations Plan;
- confirmation of previous objectives and MOEs;
- development of additional MOEs applicable only to the “after” TMP conditions (such as public surveys).

5.5 PHASE III DATA COLLECTION

Details of the data collection activities for Phase II and III are discussed in section 5.2. The following list provides a summary of the distinctions to be made between the Phase II and Phase III data collection efforts:

1) Short Count data will be obtained from the TMP vehicle detector stations.
2) Intersection Counts (required for network considerations) will be obtained manually as in Phase II.
3) Vehicle Classification & Occupancy counts) will be obtained manually as in Phase II; however, data collection along the mainline could be complemented by use of the available CCTV system.
4) Travel Time data will be obtained from the TMP vehicle detector stations, and the incident detection software in place.
5) Trip Reliability data will be obtained manually as in Phase II.
6) Incident data will be obtained from the TMC Incident Management data.
7) Highway Approach Queue surveys will be obtained manually as in Phase II, but could however be complemented by future congestion management and queue detection applications.
8) Collision data will be obtained as in Phase II, and supplemented by the TMC Incident Management data.
9) Air Quality data will be obtained/modeled as in Phase II.
10) Public Opinion data will be obtained as recommended for Phase II (personal interviews, WEB page, etc.)

5.6 PHASE III EVALUATION & ONGOING MONITORING

The purpose of this task will be to compile the “before” Phase II data and the “after” Phase III data to carry out the Phase III evaluation of the TMP pilot implementation, and the monitoring of the HOV implementation. The output of this task will be a TMP Evaluation Report, and an HOV Monitoring Update Report.

The ongoing monitoring and evaluation of HOV and TMP performance will essentially be similar to the Phase II and III Study Designs. For monitoring purposes, however, data collection efforts need not be as intensive as for evaluation purposes. The focus of this effort should be the selection of key objectives and MOEs to be used as indicators for ongoing performance. For example, for the monitoring of the HOV facility, data analysis can be limited to vehicle occupancy and travel times in one year, and safety and environmental benefits in the next year.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i

1.0 INTRODUCTION 1
- 1.1 BACKGROUND 1
- 1.2 STUDY METHODOLOGY 3

2.0 HOV MONITORING & EVALUATION 5
- 2.1 INCREASE PERSON MOVEMENT THROUGHPUT 6
- 2.2 PROVIDE TRAVEL TIME SAVINGS 10
- 2.3 IMPROVE TRIP TRAVEL TIME RELIABILITY 13
- 2.4 INCREASE PER-LANE EFFICIENCY 15
- 2.5 ENSURE GP LANE OPERATIONS NOT ADVERSELY AFFECTED 18
- 2.6 ENSURE SAFETY 20

3.0 TMP MONITORING & EVALUATION PROGRAM 29
- 3.1 REDUCE NON-RECURRENT CONGESTION 31
- 3.2 MANAGE RECURRENT CONGESTION 38
- 3.3 IMPROVE SAFETY 41
- 3.4 EFFICIENT USE OF CAPACITY 45
- 3.5 IMPROVE ENVIRONMENTAL CONDITIONS 50

4.0 NETWORK IMPACTS 52
- 4.1 SCOPE OF CONSIDERATION 52
- 4.2 EXISTING CONDITIONS 52
- 4.3 FUTURE REQUIREMENTS 53

5.0 PHASES II & III REQUIREMENTS 55
- 5.1 PHASE II - PROJECT INITIATION 56
- 5.2 PHASE II - DATA COLLECTION 56
- 5.3 PHASE II EVALUATION 62
- 5.4 PHASE III PROJECT INITIATION 63
- 5.5 PHASE III DATA COLLECTION 63
- 5.6 PHASE III EVALUATION & ONGOING MONITORING 64

APPENDICES*
- APPENDIX A - DATA COLLECTION
- APPENDIX B - DATA AVAILABLE AT OTHER MUNICIPALITIES

**separate volume*

LIST OF EXHIBITS

Exhibit No.	Description	Following Page
1.1	Project Team Organization	2
1.2	Study Area	3
1.3	Study Methodology	3
2.1.1	Mainline AVOs	7
2.1.2	Parallel Routes AVOs	7
2.1.3	AM Period Peak Hour AVOs by Screenline	7
2.1.4	Noon Period Peak Hour AVOs by Screenline	7
2.1.5	PM Peak Hour AVOs by Screenline	7
2.1.6	Mainline Vehicle Occupancy - Weekday Peak Hour	7
2.1.7	Mainline Vehicle Occupancy - Sunday Peak Hour	7
2.1.8	Parallel Routes Vehicle Occupancy - Weekday Peak Hour	7
2.1.9	Mainline Vehicle Classification - Weekday Peak Hour	8
2.1.10	Mainline Vehicle Classification - Sunday Peak Hour	8
2.1.11	Parallel Routes Vehicle Classification - Weekday Peak Hour	8
2.2.1	HOV Corridor - Average Travel Speeds	10
2.2.2	HOV Corridor - Travel Time, Speed, and Delay Survey Summary	10
2.3.1	Trip Time Reliability - Average Speeds	14
2.4.1	HOV Corridor - Per-lane Efficiency	16
2.4.2	West of Cariboo Interchange (Eastbound) Traffic Volumes & Speeds	16
2.5.1	HOV Highway Segment Level of Service	18
2.5.2	Average Vehicle Travel Speeds along TCH HOV Segment	19
2.6.1	HOV Highway Segment Collision Frequency	21
2.7.1	HOV Highway Segment Estimated Emissions of Nitrogen Oxides	26
2.7.2	HOV Highway Segment Estimated Emissions of Carbon Monoxide	26
3.1.1	Incident Data Summary	32
3.1.2	Delay Due to an Incident	34
3.2.1	Study Corridor - Average Travel Speeds	39
3.2.2	Study Corridor - Travel Time, Speed, and Delay Survey Summary	39
3.3.1	Study Corridor Collision Frequency	42
3.4.1	Study Corridor Level of Service	46
3.4.2	Throughput Across Six Stations on the TCH - AM Peak Hour Eastbound	46
3.4.3	Throughput Across Six Stations on the TCH - AM Peak Hour Westbound	46
3.4.4	Throughput Across Six Stations on the TCH - PM Peak Hour Eastbound	46
3.4.5	Throughput Across Six Stations on the TCH - PM Peak Hour Westbound	46
3.4.6	Parallel Routes Intersection Level of Service	47
3.5.1	Study Corridor Estimated Emissions of Nitrogen Oxides	50
3.5.2	Study Corridor Estimated Emissions of Carbon Monoxide	50
4.1	Parallel Routes Vehicle Occupancy - Weekday Peak Hour	52
4.2	Parallel Routes Vehicle Classification - Weekday Peak Hour	52
4.3	Count Stations Along parallel Routes	52
4.4	Weekday Peak Hour Parallel Routes Intersection Traffic Volumes	53
4.5	Weekday Peak Hour Parallel Routes Intersection Level of Service	53
5.1	Future Project Schedule	55
5.2	Future Work Program	56
5.3	HOV Objectives, MOEs, Data Requirements and Targets	63
5.4	TMP Objectives, MOEs, Data Requirements and Targets	63