Annexe 1

TRAVEL DEMAND MODEL DEVELOPMENT

FOR TRAFFIC AND REVENUE STUDIES

FOR PUBLIC-PRIVATE PARTNERSHIP HIGHWAY PROJECTS

IN THE MONTREAL REGION

Interim Technical Report
“Evaluation of the Existing Models and Procedures.
Proposal for the Modeling Structure and Estimation”

TABLE OF CONTENTS

1. INTRODUCTION

Decision on the optimal toll structure should be based on a travel demand forecast for the Montreal region that incorporates toll facilities as a part of the regional transportation network. The current report addresses general modeling issues relevant for the demand forecasting procedure proposed for the MTQ Traffic and Revenue Studies project. Forecasting the number of toll-road users will be implemented in a framework of the regional travel-forecasting model that will incorporate a hierarchy of relevant choices (toll road versus non-toll routes in the road network, mode, car occupancy, destination and time-of-day) that can be reconsidered by travelers in the region as a result of introduction of new toll road facilities. For this purpose the current data base and modeling components available from SMST will be used with the necessary additions regarding the choice hierarchy that will include toll road option as an additional travel dimension.

This interim report is intended for discussion of the proposed modeling structure and the approach for the model estimation. In the sections that follow a survey of the state of the art in toll-road traffic and revenue forecasting is presented (section 2), and then the existing modeling procedures and databases developed by SMST are evaluated (section 3). As a result, an enhancement of the mode-choice model is proposed that incorporates toll road as a sub-choice in the general travel choice hierarchy. The proposed model is then analyzed in detail (section 4). An estimation procedure that integrates revealed and stated preference techniques is discussed and the necessary data items are listed (section 5). Finally, the model application procedure is outlined (section 6) and the most important issues are presented in concluding section 7.

2. SURVEY OF THE STATE OF THE ART AND PRACTICE IN MODELING TOLL-ROAD TRAFFIC AND REVENUE

There is a growing body of literature on toll-road use based on both practical evidence from the existing toll facilities and theoretical (or based on stated preference survey technique) research regarding incorporation of tolls in travel demand forecasting models. Majority of the sources refer explicitly or implicitly to estimation of the value-of-time (VOT) as a key parameter in any demand-forecasting model dealing with tolls. We will stratify the literature survey by the following three main modeling aspects relevant to the current project:

- Placement of toll road choice along with the other travel demand dimensions (mode, destination, time of day) in the hierarchical model system,
- Modeling different toll structures,
- Approaches and criteria for choosing the optimal toll structure.

2.1. Toll road choice in the hierarchical model system

Choice models were developed and reported in [*Yan*] based on data from surveys in 1999 on California State Route 91, the US first operational value priced toll facility. Traveler responses to value pricing may have many dimensions. First is the decision of which route to take. This decision is represented as whether to travel in the SR 91 Express (91X) Lanes, the SR 91 free lanes (91F), or the Eastern Toll Road (ETR). Other traveler responses include changing time of day and changing car occupancy (which is termed "mode choice", given the very small shares of bus and rail use in this corridor). Five time periods are distinguished based on the toll schedule. They are before peak (4-5am, 2-3pm), early shoulder (5-7am, 3-5pm), peak (7-8am, 5-6pm), late shoulder (8-9am and 6-7pm), and after peak (9-10am, 7-8pm). Three car occupancy categories are distinguished: driving alone (SOV), two people (HOV2), and three or more people (HOV3+). In addition, as part of the route decision but still distinct from it, the traveler decides whether or not to acquire a transponder in order to pay tolls electronically. Two bi-level nested logit models have been calibrated –see **Figure 1X**. They both have the same lower level of joint choice of route and transponder out of five feasible combinations (three routes with transponder and 91F/ETR without transponder). However, the first model has three mode (car occupancy) alternatives as an upper-level choice while the second model has five time-of-day alternatives as an upper-level choice. It does not appear that modeling time of day and mode simultaneously would reveal much that is new, because these decisions seems to be distinct from decisions whether to get a transponder and what route to take. One of the strongest characteristics increasing the willingness to use a toll road is being female, a finding that confirms earlier studies of the California value pricing projects. Several other factors – high income, middle age, higher education, and travel to or from work – appear to affect toll road use more indirectly, by favoring a willingness to acquire an electronic transponder. The models show implied VOT for commuters in the range of $13-15 per hour, and toll elasticity for Express Lane traffic of 0.7-1.0, depending on the time period involved.

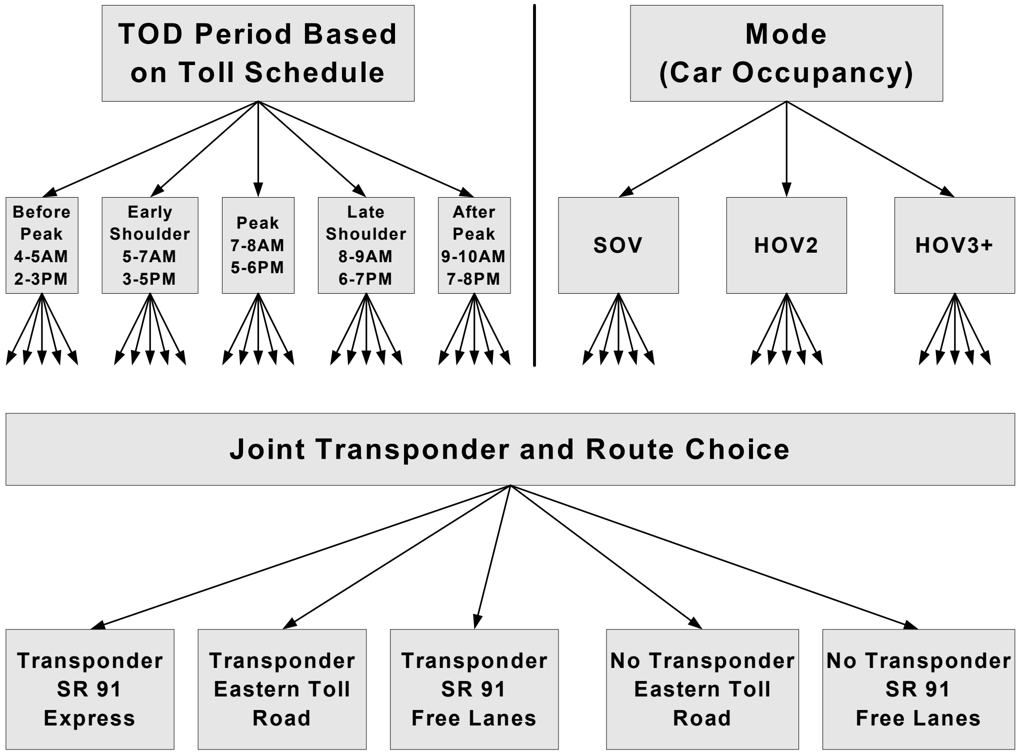

Figure 1X. Choice models developed in [*Yan*]

The research described in [*Mastako 2002*] uses empirical data from a study of SR-91 Express Lanes in Orange County, California to estimate individual choice sets for commuters in this value-priced corridor. In the short term, traveler response to value pricing in the SR-91 corridor occurs along several dimensions including route choice, vehicle occupancy choice, and time-of-day choice. A binary representation is selected for each choice decision in order to keep the number of alternative combinations to a minimum. For route choice the, the decision is represented as one of whether to pay a toll (Paid) or not pay a toll (Free). The two alternatives for vehicle occupancy (or mode) are travel solo (SOV) or share a ride with at least one other person (HOV). Mode choice is equated with vehicle occupancy because the share of bus and rail in this corridor is very small. The two alternatives for time-of-day choice are travel in the middle of the peak (Peak) or travel outside the peak (Off-Peak). The three responses can be represented simultaneously as fully joint decisions giving 2*2*2=8 commute alternatives. More alternatives are generated whenever greater detail is added to any of the choice dimensions. For example, if the route choice decision is represented as a choice between the 91 Free, 91 Express and Eastern Toll Road (ETR) and the mode choice decision is represented as a choice between SOV, HOV2 and HOV3+, then there are 3*3=9 combinations for each time slice that is considered. Over 63% of travelers were identified as having the Paid route alternative in their considered set (however, not necessarily the chosen one). A significant difference between men and women has been revealed. A positive association between income and the size of choice set that traveler consider proved statistically significant.

In recent years, high-occupancy-toll (HOT) lanes have emerged as an increasingly popular alternative to HOV lanes. The study described in [*Li*] examines the determinants of high-occupancy-toll lane use with the first comprehensive survey data on the State Route 91 Express lanes in California and multivariate logistic regressions model. The model is essentially analogous to a binary choice model since the dependent variable in the analysis is a dichotomous variable indicating whether or not the respondent used the SR91 HOT lanes on his/her most recent trip during peak periods. The results show that controlling for other variables, household income, vehicle occupancy, commute trip, and age are important predictors of HOT lane use, but gender, trip length, trip frequency, and other household characteristics make no significant differences in HOT lane use. Moreover, contrary to the conventional wisdom, work-to-home return trips are found to be more likely to use HOT lanes than home-to-work and other trips. These findings have several modeling and policy implications. In particular, explicit modeling of joint household trips from the generation stage may fit better the following HOT lane choice model comparing to the conventional treatment of HOV as a part of mode choice.

The San Diego I-15 Congestion Pricing Project is another demonstration of the policy of selling excessive capacity of HOV lanes to solo drivers by means of HOT lanes [*Ghosh*]. In this research morning and afternoon commute are modeled as a joint decision process. The multinomial logit choice model has been developed for mode (occupancy) choice combination for both commuting legs joint with the pass (transponder) registration (binary) choice. This finally leads to seven choice alternatives: 1) No pass-solo-solo, 2) No pass-carpool-carpool, 3) Pass-solo-solo, 4) Pass-solo-FasTrak (HOT), 5) Pass-FasTrak-Solo, 6) Pass-FasTrak-FasTrak, 7) Pass-Carpool-Carpool. FasTrak use accounts are automatically debited a per-trip fee when they use their transponder. The trip price is adjusted depending on the traffic conditions on the HOT lanes in order to maintain a satisfactory level of services for HOV and can range from $0.50 to $8.00. HOV uses the lanes at no cost. This analysis suggests that high income, female commuters are more likely to own a pass and middle age influences it use. Carpooling is a family affair with larger households and females with children are more likely to carpool. An interesting time-variability variable has been introduced. Morning commuters dislike variability but commuters are more tolerant to variability in afternoon. The VOT estimates are on the high range of estimates derived previously in literature and constitute 50-100% of hourly wage rate depending on the time of travel. VOT for morning commute is substantially higher that for afternoon commute.

The research described in [*Vilain*] addresses the VOT estimation issue in the toll-road context. The empirical measurement of VOT is based on observing subjective VOT, namely the amount of money a user would be willing to pay for a particular time savings in travel while remaining just as well off as previously. The social VOT is a measure of the value of time of an individual to society as a whole. Subjective VOT estimates can produce a biased estimate of social VOT. However, in majority of transportation project appraisals the social VOT is viewed as equal to the subjective VOT. This would be the case for most such travel purposes as commuting and leisure travel, where the decision maker directly bears the cost (and reaps the benefits) of a time saving in transport. In such a case, the VOT of different users is estimated from their observed or stated choices. In particular, with an untolled road and a tolled alternative, empirical estimates of the VOT would be based on the binary choice (logit) model having travel time and cost (vehicle operating and toll) as linear-utility variables. The estimate of VOT is simply a ratio of the time to cost coefficients.

Combination of two simulation tools was used to assess the effect of cordon tolls in eight English towns: SATURN and SATTAX [*Santos*]. SATURN is essentially a simulation and assignment software that estimates the route generalized cost as a sum of both the cost (vehicle operating and toll) and time multiplied by VOT. SATTAX is a batch file procedure that can be added to SATURN. SATTAX has a facility that allows for two kinds of demand responses to changes in trip cost: 1) route choice, 2) transfer off the road. Transfer off the road includes all trips that for one reason or other are dropped from the original trip matrix for the time period under study. The reasons for these trips to be excluded include change of departure time, change of mode, car-pooling and cancellation of the trip. Destination choice represent another potential response, however, it is not easily dealt with in this framework. All transferred off-road users are modeled by a predetermined demand function of generalized cost representing essentially a binary choice (stay vs. transfer).

A similar approach based on fixed-elasticity demand function and tools (SATURN, SATEASY) were used to test different road pricing schemes for the two cities of Cambridge and York, UK [*May*]. The limitations of the adopted modeling approach were mentioned. In particular, there was no disaggregation of the travel demand matrix by VOT or demand elasticity level to take account of different trip purposes and variations in income level. Also, the elasticity approach adopted is extremely simple, because it does not use a separate demand function for each alternative travel choice or incorporate any information about the generalized cost of those alternatives.

The latest SANDAG regional transportation model in combination with the toll-diversion assignment process was use as the base for traffic and revenue analysis for the proposed SR125 South Toll way [*Wilbur Smith*]. The model has a sequential procedure for generating traffic based on eight steps: trip generation, trip distribution, person-to-vehicle trip factoring, external trips integration, preliminary highway assignment, trip distribution (using congested network), mode choice, and final highway traffic assignment. SANDAG provided trip tables and socio-economic data at the traffic zone level for each target year and period of a day (AM, PM, Off-Peak). These tables then were modified based on the revised socio-economic forecast. The last step in the trip table process was to assume some percentage of ETC traffic for the various assignment years. The trip table was then divided into two categories: ETC (electronic toll collection) traffic and cash traffic, before assignment. This allowed for simultaneous assignment of both categories with tolls corresponding to each type of payment. Traffic and revenue on a toll facility is dependent on motorists' willingness to pay a toll for benefits received in using the toll facility. These benefits can include mileage savings, improved quality of travel, safety, and reduced congestion. The motorists' VOT, vehicle operating cost (VOC) and toll charges are the three key elements in determining the cost of making a particular trip and, therefore, the selection of a specific path to travel from the origin to destination of the trip. VOT was derived from median household income by zone. The median household income was divided by the average household worker hours (2,515 per year) and 60 min/hour to calculate the VOT per minute. This cost per minute in each zone was multiplied by a factor that was calculated on the trip purpose distribution of the surveys among work trips, company business trips, and other trips and a perception factor attributed to each of the three purposes. The year 2000 overall average VOT for San Diego County was calculated to be $0.153 per minute ($9,18 per hour) for the peak periods and $0.150 ($9.00 per hour) for the off-peak. VOT for the peak and off-peak periods were increased at 0.5% per year for assumed real income increases for the future-year assignments. VOC was calculated by adding the per mile costs of gasoline and oil, vehicle maintenance, and wear and tear of tires for Southern California drivers ($0,145 per mile). TRANPLAN equilibrium software was used, which has been enhanced to include market share traffic diversion routines, specifically designed to emulate motorists' willingness to pay tolls at varying toll levels and congestion conditions. The trip assignment procedure utilizes a dual minimum path process that builds two sets of paths for each OD zone pair; one using the toll facility (where appropriate) and the other using competing toll-free facilities. A proportion of the total trips moving between the zones is assigned to each network path based on the relative total cost between the paths including VOC multiplied by the distance, travel time multiplied by the average weighted VOT of the two zones (by zonal total productions), and tolls. Diversion traffic assignments were made at alternative toll rates to aid in determining optimum toll levels. Using the multiple "trip purpose" feature of TRANPLAN Equilibrium Assignments, the process involved a simultaneous loading of the nominal ETC and CASH trip tables. Appropriate toll rates and toll structures were used for each of these two categories of vehicles. Separate market share estimates were prepared for the cash and ETC components of total demand. Separate assignments were also prepared for AM peak, PM peak and off-peak conditions. All trip tables and traffic assignments made in this analysis represent typical weekday conditions. Weekend traffic estimates were manually developed as a proportion of the weekday traffic estimates.

The Northwest Parkway traffic model uses a traditional four-step transportation planning procedure [*Vollmer Associates*]. A fifth step, toll diversion, is added to account for the effects of tolls on motorists' choices of trip paths. The model is applied using the MINUTP planning software package. The model estimated for the project is a binary logit model. The model assumes that the driver's decision to choose the toll road over an alternative route is a function of the utility of the toll road for that driver. The utility of the road, in turn, assumed to be a function of the attributes of the toll road (e.g., cost and travel time) and the driver's personal preference (e.g., willingness to pay the toll, value of their time, etc.). Based on results from August and October 1991 stated-preference (SP) surveys conducted in the Denver Area, Cambridge Systematics developed a set of toll diversion models to estimate the market share for the project. SP models were developed for work trips; airport passenger trips; and "other" trips, such as trip to a shopping mall or a trip to a client's office from a driver's work location (i.e., non-home-based trips). A revealed preference (RP) model was developed for shopping and recreational trips (i.e., non-work home-based trips). The latter model was developed from a telephone survey of

Parker area residents and a roadside survey of Parker-area drivers using the newly open first segment of E-470 road and the parallel alternative routes. All four of Cambridge's models produced results that were similar to, but somewhat more conservative than, traditional RP. When the full three segments of E-470 had opened, it was discovered that drivers were more likely to pay tolls than they had expressed in the SP surveys. The toll curves were modified by shifting them upward, but keeping their original shape, to better reflect the RP of Denver area drivers. The revised utility expressions for each of the four purposes includes three components: 1) bias constant; 2) natural logarithm of travel time difference (in minutes) with the coefficients in a range 0.25-0.47; 3) squared toll charge (in dollars) with coefficients in a range 0.03-0.05.

An overview of analytical methods used to develop traffic and revenue forecast for toll roads is presented in [*Dehghani*]. The most common method for conducting toll diversion analysis is through capacity-restrained equilibrium assignment of vehicle trips onto a highway network. It requires the effective time to be calculated for the links where tolls are collected. Effective time is obtained by combining link travel time, delay time due to queuing and service time at toll plazas and a time penalty equivalent to the toll payment (see also [*Mekky, Lin*]). The last component is base on the VOT estimation. Diversion curves represent another method used to prepare toll forecasts. Such curves employ a function, which shows the propensity for using a toll facility (facility share of traffic) versus the relative cost or time of traveling on a toll road as compared with that of a non-tolled competitor. The use of logit functions, which provide S-shaped diversion curve, has become a popular choice. Recent attempts have been made to include toll facility diversion within the mode choice model. This approach provides forecasts of toll facility demand for each category of auto occupancy. The paper also presents a useful assessment of potential pitfalls that must be recognized and coped with by the toll road analyst in order to provide accurate forecasts. The ramp up (public acceptance lag) phenomenon, which can last for several years, can be identified by a significantly higher traffic growth rate than that of other roadways within the corridor. There appear to be significant cultural factors that affect the acceptance and usage of toll facilities. Communities that have never had toll facilities and communities that previously phased out their existing toll facilities take longer to accept them. New toll roads in urban areas have more pronounced peaking characteristics that other facility types. In travel demand models it is often assumed the same peak-to-daily relationship for all facility types. This assumption over-estimates the daily traffic on toll roads. It is important to stratify VOT and the price elasticity of demand by trip purpose, income category and according to the status and personality of trip makers. Another potential pitfall in the forecasting of toll revenues is the model assumption that all vehicles passing through toll plazas will pay tolls. In practice, there is a significant degree of toll evasion at toll plaza facilities.

To summarize the proposed modeling constructs for toll-road traffic forecast the following three basic approaches can be mentioned:

- Application of an equilibrium traffic assignment model with generalized impedance function that incorporates tolls by means of VOT estimations as well as additional delays associated with toll collection [*Santos, May, Dehghani*]. This is a simplest approach that does not require development, estimation and application of choice models. Only VOT estimation is necessary. However, several strong limitations of this approach should be taken into account:

- This approach does not allow for modeling tolled-off (diverted) travelers that may change mode, destination, time of day, car occupancy, etc as a result of imposing a toll. Unrealistic assumption that all travelers stay in the system and may only change the route regardless of any toll policy may lead to significant biases in toll-road traffic forecasts and underestimation of potential sensitivity of toll-road traffic (and consequently revenue) to different toll structures.
- There is much more a complicated interplay of underlying behavioral factors (trip time, cost, variability, etc relative to the person and household characteristics) than is the constant linear relationship captured by VOT estimations. Thus, inherently non-linear choice models with a variety of variables are preferable compared to a simple proportional conversion of a toll to additional impedance measured in minutes.
- All-or-nothing route choice procedure embedded in the deterministic assignment equilibrium algorithm may cause unrealistic abrupt elasticity of toll traffic to the toll structure. While application of stochastic assignment procedure may potentially solve this particular problem, stochastic assignment procedure itself is extremely complicated in real-world networks and requires a long round of calibrations and adjustments. A stochastic assignment is not built-in in the EMME/2 package that is currently adopted by SMST. It would require a complicated iterative procedure to be modeled using the macro language of EMME/2.

- Application of a binary choice model that considers a choice of toll road versus non-toll options in combination with network equilibrium assignment that uses correspondent networks (with and without toll facility) to ensure travel time saving for those who chose paying a toll. Two versions of this approach can be considered:
    - Treatment of tolled-off travelers as non-toll road users assuming that toll-off travelers still stay on the same mode in the same trip time period and do not switch to either transit or higher occupancy vehicle or other time-of-day period [*Wilbur Smith, Vollmer Associates, Dehghani, Li, Vilain*]. While this approach may help in resolving some of the problems mentioned for an assignment procedure with generalized impedance (non-linearity and abrupt sensitivity) it does not refer to the basic problem of behavior of travelers having a variety of alternative options (changing mode, time-of-day, occupancy level etc) rather than a binary choice between two road options.
    - Treatment of toll-of travelers as diverted from the highway mode in this period time [*Santos, May*]. In this case, a binary choice model essentially works as a diversion curve. This is a simplified way to account for all possible alternative choices (switch mode, change time of day, change occupancy) in an aggregate way without explicitly modeling each of them.

However, the reliability of such highly aggregated diversion curve without explicit knowing and modeling alternatives is relatively low. Additionally, a model built on this principle will not be sensitive to alternative mode (transit) improvements.

- Modeling toll-road option as an additional component in the travel demand hierarchy of choices fully accounting for travel behavior across all relevant dimensions [*Yan, Mastako 2002, Ghosh, Dehghani*]. The relevant dimensions that are closely intertwined with toll-road choice include mode and car occupancy. There can be also potentially impact on time of day, destination and trip-frequency choice as well, however these dimensions are considered as less obvious and of second-order dependence. Thus, for the current study of traffic and revenue for MTQ highway projects it is recommended that a comprehensive mode/occupancy/toll choice model be developed that can be applied for each time-of-day period separately with a fixed structure of trip distribution.

2.2. Modeling different toll structures

An extensive survey is presented in [*Small 1998*] for 13 significant road-pricing applications in nine countries, seven of them implemented as of mid-1997. In a subsequent paper [*Small 2001*] more projects that have been subsequently undertaken are analyzed, including an innovative no-cash system using combined electronic and video collection technology on a new expressway near Toronto, Ontario, which opened in October 1997. Yet in only one case (Singapore) has congestion pricing been adopted in something like a first-best form: significant time-of-day variations applying to an entire road network. All other applications are limited, such as toll rings with fixed or nearly fixed tolls (Norway), behavioral experiments (Stuttgart), or pricing on a single facility (France, Ontario, California, Texas, Florida). Increasingly, the favored approach is to adopt small-scale "demonstration projects" intended to test and publicize pricing concepts and their associated technologies. This approach is specifically funded in U.S. legislation passed in 1991 and reauthorized in 1998. Three of the demonstrations currently operating – in Orange County (California), San Diego, and Houston – let travelers chose between two adjacent roadways: one free but congested, the other priced but free-flowing. This scheme is sometimes called "Value pricing" because people are given the option to pay for a more highly valued service, much as train or air travelers can purchase a first-class ticket. In these particular examples, the express lanes also serve carpools at zero or at reduced rates, and so are known as "High Occupancy/Toll" (HOT) lanes. (In Houston, furthermore, the value-pricing option is available only to people in two-person carpools.). The paper explores the importance of heterogeneity in VOT (i.e. difference in travelers' income and other characteristics) for value-pricing demonstrations.

The project SR-91 described in [*Mastako 2002, Mastako 1998, Sullivan*] provides two toll lanes in each direction. The tolls vary between $0.75 and $3.75 according to a published schedule and in relation to demand and congestion on the parallel freeway. Users are required to register and carry a transponder for automated toll collection. There is a 50% discount for vehicles with three or more persons (HOV3+). Within the corridor, the Eastern Toll Road (ETR) competes with the SR91 express lanes (91X) for trips to the southern part of Orange County. All ETR users pay a flat fee ($2.25 or $3.25, depending on the distance traveled) and no one is required to carry a transponder.

Feasible cordon toll schemes were considered for eight English towns and optimal tolls estimated in [*Santos*]. Several other road-user charging systems have been proposed: distance pricing, time-based pricing, and delayed-based or congestion pricing. In the last case a trip maker is charged according to his speed. The slower the speed, the higher will be the likely congestion, and the higher the resulting charge. The system requires the recording of time taken and distance traveled for each vehicle individually on a rolling basis by in-vehicle technology.

Four road pricing systems, with charges based on cordon crossed, distance traveled, time spent traveling, and time spent in congestion, have been tested using the congested assignment network models SATURN and CONTRAM for the two cities of Cambridge and York, UK [*May*]. Overall, cordon pricing proved to be the least effective of the four systems used. This is of concern, since it is by far the most easily implemented.

Results reported in [*Yan*] demonstrate that there is scope for adjusting toll schedules, even in as small as one-hour increments, in order to regulate demand.

In the SR 125 traffic and revenue study [*Wilbur Smith*] it is assumed that ETC equipment will be provided and will be available to all motorists using the project. Electronic tolls will be based on distance traveled. Cash tolls will be assessed by particular vehicle class at each individual cash collection plaza location without differentiation by trip length. Peak period rates are would be slightly higher (by 10-20%). In all cases, the cash toll rates have been set so as to be equal to or greater than the electronic rates for the maximum trip, which can be made through each plaza location (this is to encourage utilization of ETC). ETC/cash market shares were assumed 65/35 for 2005 and 85/15 for 2020. No adjustments have been made to the revenue estimates included in this report for toll evasion, although it is possible that such evasion will occur. A "ramp-up" period of 24 months is assumed, with traffic and revenue expected to be 50% of the nominal forecast in the first month of operation, gradually increasing to 100% of the nominal forecast within 24 month. For ETC different rate levels were explored for three components: 1) a per-mile rate of $0.15-0.2 based on distance traveled between point of entry and point of exit, 2) an additional nominal charge of $0.25 for transaction, 3) a surcharge amount of $0.35 assessed to vehicles crossing the Otay River Bridge portion of the project. Proportionally higher rates will be charged for light (double toll) and heavy (triple toll) trucks. Light trucks include commercial vehicles with 2 or 3-axles. Heavy trucks include commercial vehicles with 4 or more axles.

Historically, there have been three types of toll collection systems in use in the United States: ticket systems, open barrier systems, and closed barrier systems. The Northwest Parkway Project, like almost all new toll roads proposed in the United States, utilizes the closed barrier system in order to maximize the revenue stream while minimizing the operating costs [*Vollmer Associates*]. Closed barrier Systems have both mainline toll barriers as well as ramp toll plazas, placed such that no toll-free traffic movement is permitted. This type of system produces the greatest toll revenues at the lowest operating cost. The disadvantage of the system is the relatively high cost of short trips, which are affected by the placement of the barrier and ramp toll plazas. Annual traffic and toll revenues were calculated at 320 times the average weekday traffic and revenue. Downward adjustments were made to the output of the traffic model to account for an educational ramp-up period: revenue was multiplied by 50%, 67% and 86% for the first three years of toll operation respectively.

A conclusion can be made that application of a simple "flat" toll is not generally recommended. Time of day and (possibly) distance-based structures should be considered for sensitivity analysis with the model.

2.3. Approaches and criteria for optimal toll structure

In the framework of research [*Santos*], the criterion used to assess the benefits from a cordon toll was the increase in social surplus. Social surplus is defined as a total surplus across all travelers and calculated as sum of their individual utilities minus sum of individual social costs. Individual utility is derived from the inverse demand function (binary choice mode) while social costs are calculated as generalized cost described in section 2.1 above.

A historical analysis of the objectives of road pricing is given in [*May*]. Initially, the objective of road pricing was formulated as an economic one related to the efficiency with which congested roads are used. Road pricing, by charging the difference between the marginal social cost and the marginal private cost of a trip, was designed to ensure that the only drivers who traveled were whose benefits from traveling exceeded the cost, which they imposed both on themselves and others. More recently, road pricing has also been seen as a way of reducing the environmental impacts of traffic. It would be possible, in theory, to add the marginal environmental costs to the road price charged, and hence ensure that the only drivers who traveled were those whose benefits exceeded the sum of the congestion and environmental costs that they imposed. A third, and very different objective, is that of raising revenue. However, the design of a road pricing scheme to maximize revenue will be very different from one designed to maximize economic efficiency; the latter should achieve a reduction in car use, while the former is best served by maintaining flows of those who are charged. More recently these objectives have been combined, by analyzing the role of road pricing as part of an integrated strategy, in which it contributes directly to the reduction of congestion and environmental disturbance both by reducing car use and by providing finance for alternatives to the car.

As mentioned in [*Small, 2001*], many criteria might be used to design a value-pricing program. One is to apply the "second-best" toll to the express roadway, chosen to maximize social welfare subject to the zero-toll constraint on the other roadway. Another is to apply a "profit-maximizing" toll, which maximizes revenue, subject to the same constraint. A third is to set the toll just high enough to keep it flowing at a minimum specified speed.

A comprehensive sensitivity analysis for total revenue was implemented in [*Wilbur Smith*] in order to find an optimal toll structure that returns the maximum revenue. Weekend day traffic was estimated as 70% of weekday traffic.

In reviewing the various inputs to the traffic forecasting model, several key inputs have been identified: toll rates, roadway network, land use, and inflation rate [*Vollmer Associates*]. They all were subject to scenario/sensitivity tests. In particular, two toll sensitivity tests were conducted. In the first test, toll at each of the Northwest Parkway toll plazas were lowered by 25 cents. The effect of this was a 14% decrease in revenue. In the second test, all Northwest Parkway tolls were increased by 25 cents. This produced a 14% increase in toll revenue. These reflect the generally inelastic effect of toll changes on the model, as there is only a small effect on traffic (in the adopted framework of binary toll-diversion model – see section 2.1 above).

For a Public-Private Partnership project all of the above criteria are relevant. Experience has shown that a reasonable guaranteed revenue level should be kept in order to ensure Private participation, thus this criterion should be explored first with various sensitivity tests. Within the guaranteed-revenue alternatives the best one should be chosen by a social welfare criterion to ensure that Public interests are met as well.

3. EVALUATION OF THE EXISTING MTQ MODELING SYSTEM

3.1. General structural properties of the SMST existing model

At several previous workshops held in Montreal with participation of SMST and PB Consult the existing modeling system and database of SMST have been reported and intensively discussed. The following key aspects of the modeling approach for the traffic and revenue study were agreed upon:

- The current structure of the travel demand database of SMST that is based on a comprehensive origin-destination survey will be adopted. This structure has individual surveyed records expanded by the person and area type specific weights. This structure allows for aggregation to zone-to-zone trip matrices for assignment purposes by any subset of modes or period-of-day. However, it is preferable to work at individual-record level for modeling travel choices that allows for incorporation of any person, household or fine geographical attributes. This brings the modeling system in line with the contemporary approach of micro-simulation in demand modeling that avoids numerous aggregation biases inherent to the conventional demand models. Forecasting the total travel demand in the base scenario is implemented by means of re-scaling the weights attached to each individual record based on the zonal population and employment targets. Thus, a structure of the travel choice models should be adapted to the individual-record case.
- The model system will be based either on the conventional unit of travel - trip, or on a more advanced approach that operates with tour defined as a closed chain of trips starting and ending in the same base location (home or workplace). The decision will be made finally at the workshop. Tour-based concept is more progressive and the individual-record structure of the demand suits this approach. Thus, switching from the trip-based to tour-based models for MTQ is quite natural and easier than in many other regions. However, it will require additional modeling effort that is not reflected in the current project budget. The principal structure of the choice hierarchy and the spectrum of technical issues discussed in the current memo are quite similar in both cases. In order to prepare for a tour-based version of the model, SMST has prepared a restructured survey file with person tours MTL98CH that will serve as a basis for the model estimation along with the OD-trip file MTL98PV.
- Taking into account the coverage quality and comprehensiveness of the origin-destination survey implemented by SMST in the Montreal region, we can adopt an incremental modeling concept across all travel dimensions. According to this concept, travel choices should be modeled for each individual record taking into account the current (observed) choice as valuable information that should be used not only in the model calibration but also directly in the model application. The current SMST modal transfer model gives an example of such an approach. However, the current framework of the modal transfer model does not allow for generalization for more than three choice alternatives, and as well cannot

incorporate hierarchical structure of additional travel choice dimensions such as toll versus non-toll. Thus, the modeling task for this memo is formulated as the development of an incremental choice modeling structure that can incorporate several hierarchical levels of choices, for unlimited number of alternatives, and in the individual-record environment.

The current modeling concept applied by SMST can be classified amongst the conventional approaches as shown in **Figure 1** below. It is an advanced concept overall that uses individual trip record as a base modeling unit in application. It is preferable to the aggregation by population strata inherent to the standard disaggregate modeling technique, or to averaging within zones inherent to the conventional aggregate models. It is close to the most advanced concept of micro-simulation with the difference being that in the micro-simulation framework individual records are synthetically populated rather than weighted.

The current modeling structure does not have explicit trip generation and distribution stages. The expanded survey provides a comprehensive coverage of the trip generation and distribution in the region for the current year. Forecasting travel demand for future years is based on re-scaling the weights attached to each individual record based on the zonal population and employment targets. This is acceptable for stable areas where neither significant demographic changes nor job relocations are expected.

The main disadvantage of the applied modeling system is that at the mode choice stage the approach essentially applies the concept of aggregate diversion curves. The intention in the current project is to replace this part of the SMST model system with a more advanced discrete choice model that will incorporate multiple mode and (possibly) destination and time-of-day choices in a consistent way. This new choice model will be applied in the incremental fashion, keeping several important components of the current modal transfer model (for example, mode availability rules and thresholds for switching). It will be applied in order to obtain a final model outcome in the form of fractional split of individual record weights, though the same choice model could be effectively employed for the simulation of "crisp" choices in a micro-simulation framework.

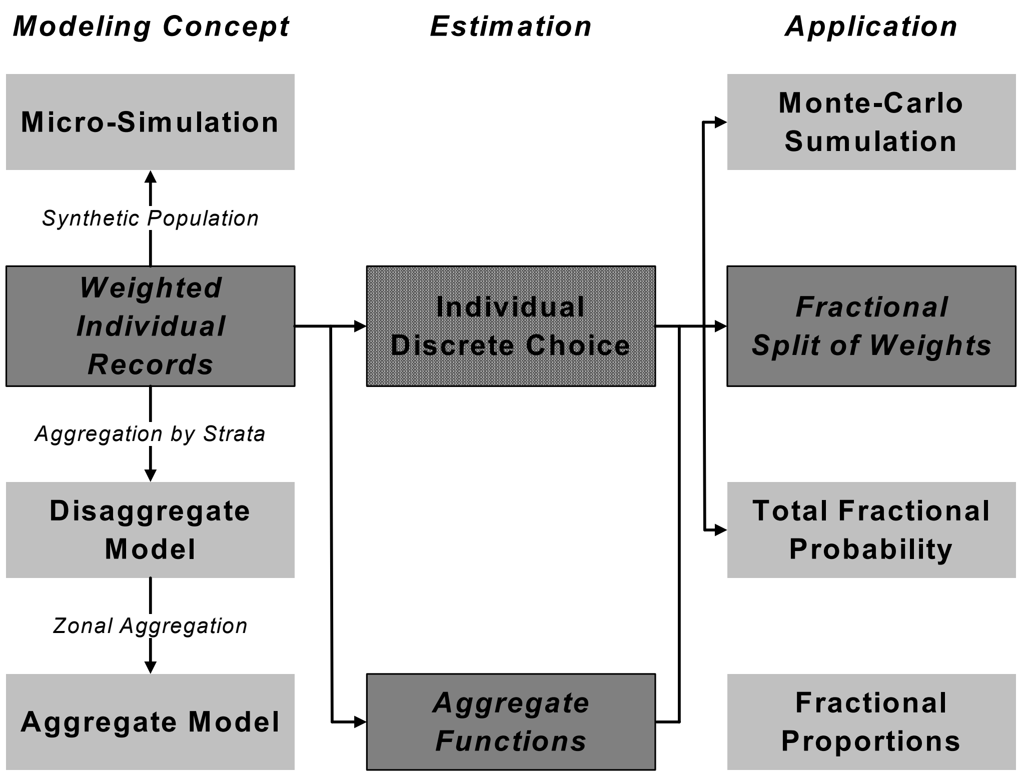

Figure 1. Alternative modeling concepts

It should be noted that the family of logit-based choice models allows for a natural and effective incremental formulation. However, there is a technical problem with the application of the incremental logit model at the level of individual records where observed shares of alternatives always form an extreme pattern of 1 (the observed one) and 0's (the other ones). In this case direct application of the standard incremental model always replicates the observed choice and never switches to alternative choices no matter how they have been improved. Section 4.2 of the current report is intended to resolve this technical issue. It is proposed to construct a pair-wise switching choice model corresponding to the original incremental model. This switching modeling construct allows for a natural generalization on the individual-record case where fractional shares cannot be observed.

3.2. Travel demand forecasting procedure

The existing procedure for travel demand forecasting in the Montreal Region is quite distinctive and is based on the adjustment of individual weights of the OD survey rather than application of trip generation and trip distribution models usual for the most of regional travel demand models. This procedure has been developed by the Research Group MADITUC of the Montreal Polytechnic University and, in our opinion, it definitely deserves wider attention as an interesting and useful concept to be considered among alternative forecasting approaches to be adopted elsewhere. The proposed procedure obviates the need to an explicit trip generation and distribution stages of modeling, and obtains the travel demand matrix for each target year directly from the OD-survey file manipulating weights attached to each record. This procedure also preserves the individual-record based structure though the data can be easily converted to zone-to-zone format for any subset of modes or period of a day.

The base assumption of the proposed method is that the principal spatial and temporal structure of the trips in the region will remain stable over the years. Forecasts reflect changes and growth factors are introduced to take into account demographic projections, changes in the rate of motorization (individual car availability), and spatial shifts in main employment centers. More specifically, the proposed method of forecasting can be expressed by the following general formula:

$$WEIGHT_z^{Future} = WEIGHT_z^{Base} \times \frac{POP_{tsg(z)}^{Future}}{POP_{tsg(z)}^{Base}} \times \frac{STAT_{rtsg(z)}^{Future}}{STAT_{rtsg(z)}^{Base}} \times \frac{MOT_{crtsg(z)}^{Future}}{MOT_{crtsg(z)}^{Base}} \times \frac{EMP_{mp(z)}^{Future}}{EMP_{mp(z)}^{Base}},$$

where:

z	=	individual record,
t	=	aggregate residential zone (territory sector),
s	=	sex,
g	=	age by 5-year groups,
r	=	person status (worker, student, other trip makers, non-mobile),
c	=	car availability index of the person (motorized vs. non-motorized),
m	=	travel purpose (work, non-work),
e	=	employment center (zone),
$WEIGHT_z^{...}$	=	expansion weight for the individual record,
$POP_{tsg}^{...}$	=	population by place of residence, sex and age group,
$STAT_{rtsg}^{...}$	=	proportion of the people of certain status in the population by place of residence, sex, and age group ,
$MOT_{crtsg}^{...}$	=	percentage of motorized/non-motorized people by status, place of residence, sex, and age group,
$EMP_{mp}^{...}$	=	employment by employment center for work purpose, 1-otherwise,
$tsg(z)$	=	combination of residential zone, sex, and age group for the record (individual),
$rtsg(z)$	=	combination of person status, residential zone, sex, and age group for the record (individual),
$crtsg(z)$	=	combination of motorization index, person status, residential zone, sex, and age group for the record (individual),
$mp(z)$	=	combination of trip purpose and employment center for the record (individual).

The adopted method of travel demand forecasting is only valid if the base year OD survey is comprehensive enough to cover all origin-destination zone combinations and population slices. However, this is the case for the Montreal Region. Comparing this method to conventional trip generation and distribution modeling approach, several objective advantages, as well as drawbacks should be mentioned. The following features can be main advantages:

- The method is simple, avoids biases and interpolations that are inherent to any synthetic modeling structure; it assumes that efforts are made to ensure validity of demographic and employment projections rather than develop sophisticated analytical structures generating and distributing trips.
- The method preserves a natural linkage to the observed demand in the base year; any demand growth or structural change in the future year directly relates to the corresponding demographic or employment for forecast; it makes it easier to explain the results to practitioners and decision makers, as well as to verify forecasts against the observed travel patterns.
- The method preserves an individual record-based structure of the demand that is suitable to application of advanced tour-based and micro-simulation models for mode and route choice; the existing procedure can be transformed in future to a contemporary population-synthesizing/activity-generating model with relatively minor efforts.
- The method allows for the easy implementation of sensitivity tests with different demographic and land-use scenarios, since only the expansion factors need to be re-adjusted while the basic database structure remains the same.

However, along with the aforementioned advantages there are several drawbacks and limitations to be taken into account:

- The method is extremely effective for short-term forecasting, however, it can produce problems for long-term forecasting where assumption of structural stability of travel may not hold, and regional travelers may gradually change their habits. In this case a model that uses a wide range of explanatory variables can better predict a number and distribution of trips.
- The method does not explicitly take into account transportation network scenarios. Thus, only mode and route choice will be sensitive to network improvements, while trip frequency and distribution (destination choice) are only subject to demographic change and stay the same across all network scenarios. This aspect of the existing modeling approach can be considered as a conservative one.
- The method is not fully sensitive to land-use developments on the trip attraction side with the exception of trips to work that are balanced by the allocation of jobs. However, trips to non-work purposes (for example, shopping trips) are not automatically sensitive to the corresponding land-use transformations (say building a new shopping mall).

- The method also has an inherent problem with the treatment of newly built residential areas where the concept of expansion of the observed trip records cannot be applied. In this case either an external trip generation and distribution model should be applied or some sort of assumption regarding the number of trips and their destinations is needed in order to generate currently missing records.

Carefully weighting the existing model advantages and limitations in the context of the MTQ traffic and revenue studies for highway projects, and taking into account a practically oriented framework of the current project, the following conclusions can be made:

- The existing demand forecasting procedure is built on reasonable assumptions and an extensive OD survey as the base source of trip generation and spatial distribution characteristics. A certain conservatism of the forecasts and limited sensitivity to the transportation network improvements can probably be considered a positive practical feature, rather than a crucial flaw in the context of the Traffic and Revenue Study. For these reasons, PB Consult proposes to adopt the existing SMST set of forecasting procedures for the current traffic and revenue study.
- In a broader sense, as a part of the project commitment to advise SMST on model development PB Consult proposes to consider the future development of comprehensive travel demand forecasting procedure that will include stages of population synthesizing and trip/tour generation.

3.3. Mode-transfer model

This model is applied to the base or future year total demand in order to predict traveler choice of mode, and then (using EMME/2 for highway simulation and MADITUC for transit simulation) route in the transportation network. This model is of crucial importance in the context of the current project because a toll road essentially constitutes a new mode/route option for travelers. The specific feature of the SMST travel demand forecasting procedure described above is that it preserves the chosen mode from the base year for all demand projections, thus, the mode choice model should be essentially applied in an incremental fashion, i.e. as mode switch (or transfer) modeled as a result of network improvements comparing to the base year. This concept is fully realized in the mode-transfer model currently developed and adopted by SMST. PB Consult has given this model a careful consideration in view of the incorporation of toll roads at the mode choice and assignment stage and according to the modeling experience with toll roads in US, Canada and world-wide (see section 2 above).

The existing mode-transfer model incorporates a trinary choice between private mode, public mode and combined (bimodal) mode (park & ride, kiss & ride). At the level of pair-wise switches (transfers) this yields six potential options:

- Transfer from private mode to public mode,

- Transfer from public mode to private mode,
- Transfer from private mode to combined mode,
- Transfer from combined mode to private mode,
- Transfer from public mode to combined mode,
- Transfer from combined mode to public mode.

The three aggregate modes are not subdivided further. For example, public mode includes a variety of distinctive sub-modes (bus, metro, rail). However, the current structure of the mode transfer mode would lead to a numerous switching combinations to calibrate if the modes were subdivided further. This limitation of the number of mode choice alternatives to three is a serious modeling drawback in view of the toll-road option consideration as an additional quasi-mode.

When the model applied for each individual record, the previously chosen mode is known, thus, there can be essentially only three potential probabilistic outcomes:

- Stay on the same mode (for example, private),
- Switch to the first alternative mode (public),
- Switch to the second alternative mode (combined).

In the current model version only one (the best by total travel time) of the available alternative modes is considered. Thus, each individual choice set contains not more than two alternatives including the currently chosen mode. SMST has developed a set of mode availability rules based on the person car availability, network-based thresholds in access time to public modes, number of transfers to arrive to the destination, etc. These rules are important for making mode choice realistic and they will mostly be incorporated in the proposed mode choice model.

If a choice set contains more than one option, then switch to a new mode is considered and its probability is estimated. This is modeled based on comparison of total travel times for both modes before and after improvement. At first stage, the reasonability of switching is established based on the alternative mode improvement versus the current mode improvement. A psychological threshold of 3 min is introduced to approve mode switch. It is assumed the traveler does not consider mode switch if the relative improvement of alternative mode proved to be insignificant. Constraints of this sort are recognized as important in demand models in order to eliminate illogical switches that otherwise can be produced by the model with small probabilities. At the second stage, if the alternative mode has passed the threshold, a switching probability is calculated based on diversion curves that are calibrated as functions of the total travel time ratio of the alternative mode to chosen mode. The probability to switch is calculated based on the comparison of two points (ratio before and after) on the curve. Finally, the individual record expansion factor is split according to the calculated probability and an additional record with identical person and trip characteristics, but a new mode is produced.

When calibrating the diversion curves, SMST faced the typical problem of detailed travel segmentation that proves to be necessary in order to produce reasonable homogeneous sets of observations. In addition to the usual segmentation by trip purpose the following additional dimensions have been used:

- By trip destination type,
- By transit sub-mode combination,
- By main transit mode in the combination,
- By transit fare zone,
- By level of congestion.

As a result, in the model application for each record, six different diversion curves are applied and the average probability is finally calculated across all of them. This excessive segmentation is actually a consequence of choosing travel time as a single parameter describing the relative mode attractiveness for travelers. The main advantage of a discrete choice model over diversion curve is that a choice model allows for the incorporation of several relevant attributes (time and cost components, person and household characteristics) in the mode utility function with appropriate coefficients estimated from the observed choices by statistical criteria. Thus, a limited number of mode choice models should be estimated (normally, only segmentation by travel purpose is applied) while other attributes are incorporated in the mode utility function.

Having considered the existing SMST mode transfer model the following conclusions can be finally drawn:

- The model is an interesting construct that has several positive features including the incremental fashion of the model application and a set of pair-wise mode transfer (availability) rules and thresholds that can be adopted for the current project.

- The model in its current form has a limitation to incorporate in more than three modes, as well as additional cost-related attributes (such as toll) into the model utility functions. Taking into account that these limitations are crucial for the current project, PB Consult has proposed an alternative mode choice model that retains the positive features of the existing mode transfer model and can incorporate its availability rules and thresholds while being free of the limitations of the existing model. The proposed mode choice model is discussed in section 4 below in detail.

4. THE PROPOSED STRUCTURE OF MODE CHOICE MODEL INCORPORATING TOLL ROADS

4.1. General modeling structure and segmentation

The proposed mode choice model will be estimated and applied at the level of individual trip (or tour) records. Though the final model structure, dimensions for segmentation, and utility components can be finalized only after statistical analysis and model estimation trials, several important structural properties can be formulated at the current stage with a high degree of certainty. First of all, after analysis of the existing modal transfer model of SMST as well as mode choice models calibrated elsewhere including regions where toll roads have already been built and incorporated into the modeling frameworks, the following structural dimensions for the model segmentation are to be considered:

- Travel modes:
  - o Drive alone (SOV) with and without toll,
  - o Shared ride (HOV) with possible subdivision by occupancy level with an without toll,
  - o Transit mode combinations based on bus with subdivision by walk and auto access; the auto access option can include toll/non-toll sub-options,
  - o Transit mode combinations based on metro with subdivision by walk, bus and auto access; the auto access option can include toll/non-toll sub-options,
  - o Transit mode combinations based on rail with subdivision by walk, bus/metro and auto access; the auto access option can include toll/non-toll sub-options,
  - o Additional modes (taxi, school bus, non-motorized) if there percentage significant for the modeled travel segment (purpose and period of a day).
- Travel purposes:
  - o Commuting to work,
  - o Other business-related,
  - o College/university,
  - o School,
  - o Shopping,
  - o Passenger pick-ups and drop-offs,
  - o Other household maintenance and personal business,
  - o Discretionary.
- Time of day periods:
  - o AM peak period (6.00-8.59),
  - o Midday period (9.00-15.29),
  - o PM peak period (15.30-19.29),

- Night period (19.30-5.59).

- Tour (chain) categories:
  - Simple one-destination home-based tours without secondary stops,
  - Home-based tours with a stop on outbound direction,
  - Home-based tours with a stop on inbound direction,
  - Home-based tours with stops on both directions,
  - Non-home-based (at work) sub-tours.

- Person characteristics:
  - Status (worker, student, non-working and non-studying person),
  - Age group (0-5, 6-15, 16-25, 26-35, 36-65, over 65),
  - Sex,
  - Driver license,
  - Individual car availability.

- Household characteristics:
  - Income category (low, medium, high)
  - Number of workers,
  - Number of non-working adults,
  - Number of children by age category,
  - Car ownership and relative car sufficiency (cars vs. workers),
  - Life-cycle indicator composed of the following parameters:
    - age of the household head (young, medium-age, elderly),
    - status (employed, students, not-employed and non-studying),
    - number of adults (single, double),
    - presence of small children,
    - presence of school-age children.

- Zonal characteristics:
  - Residential density and urban type for place of residence,
  - Employment density and urban type for destination (workplace),
  - Parking cost and availability at the destination.

Secondly, model application at the <u>individual-record level</u> implies several specific requirements that are quite similar to the requirements for mode choice component in the micro-simulation framework:

- Mode choice is modeled for individual trip with known person, household, origin, and destination attributes; there is <u>no limitation on a number of variables</u> employed because they do not produce additional multiplicative segmentation usual for conventional zonal-based models.

- The observed mode choice is known, thus mode choice model is applied in an <u>incremental fashion</u>. This allows to explicitly use valuable information on mode chosen in for each observed trip directly in the model application rather than only implicitly through the model parameters' estimation as it is done in the conventional framework.

- The observed mode is represented by a "crisp" all-or-nothing choice made for the corresponding trip, not by a fractional probability (or observed frequency) pertinent to conventional models. However, each individual trip record has an expansion factor representing a group of trips made by persons with identical characteristics. This leaves a room for the model application to be either fractional-probability based (assuming that the final model outcome is split of expansion factors according to mode probability fractions) or a full micro-simulation type of "crisp" decision implying a Monte-Carlo (or alternative) rule to generate the final choice.

4.2. Incremental logit model formulation for individual-record-based data structure

Though a standard discrete choice model does not directly operate with pair-wise switches and return only the final choice probabilities for each alternative in each scenario (before and after) they can be adapted to a switching form by means of additional assumptions. Incremental formulation of the logit-based models is especially convenient and meaningfully tractable for such a transformation. Thus, underlying structure of pair-wise switches that is normally hidden in the final choice-probability outcome of the model can actually be explicitly calculated. This transformation of the model outcome allows for a better treatment of the individual-record situation where the model is applied sequentially for each individual rather than for groups of individuals (strata). In particular, the observed (chosen) mode for each individual-record can be taken into account in the switching modeling framework whereas a standard discrete choice model can only account for aggregate observed shares when applied in the incremental fashion.

In the following subsections 4.2.1-4.2.6 the corresponding technical questions are discussed. Subsections 4.2.1-4.2.2 describe the basics of the incremental logit technique, first for the multinomial model, then for the nested logit model. Then in sub-section 4.2.3 a general formulation of the switching choice model is explained. In the following subsections 4.2.4-4.2.5 a derivation of the switching structure underlying the choice model outcome is given, first for the multinomial model, then for the nested logit. In the final sub-section 4.2.6 application rules are discussed for the switching model in the individual-record case.

4.2.1. Incremental Multinomial Logit Model

Introduce the following notation:

$i \in I$ = set of available alternatives,

$\widetilde{V}_i$	=	utility for the base scenario,
V_i	=	utility for the proposed scenario,
$\Delta V_i = V_i - \widetilde{V}_i$	=	utility increment,
$\widetilde{P}(i)$	=	choice probability in the base scenario,
$P(i)$	=	choice probability in the proposed scenario.

According to the multinomial logit model (MNL) choice probability in the base and proposed scenarios is calculated in the following way:

$$\widetilde{P}(i) = \frac{\exp(\widetilde{V}_i)}{\sum_{j\in I}\exp(\widetilde{V}_j)}, \qquad \textbf{(1)}$$

$$P(i) = \frac{\exp(V_i)}{\sum_{j\in I}\exp(V_j)}. \qquad \textbf{(2)}$$

The proposed-scenario probability can be rewritten in terms of the base-scenario probability and utility increments. The following equivalent transformation of a formula (2) constitutes the *incremental multinomial logit model*:

$$P(i) = \frac{\exp(\widetilde{V}_i + \Delta V_i)}{\sum_{j\in I}\exp(\widetilde{V}_j + \Delta V_j)} = \frac{\exp(\widetilde{V}_i)\times\exp(\Delta V_i)}{\sum_{j\in I}\exp(\widetilde{V}_j)\times\exp(\Delta V_j)} =$$

(dividing both the numerator and denominator by $\sum_{k\in I}\exp(\widetilde{V}_k)$ and using formula (1))

$$= \frac{\dfrac{\exp(\widetilde{V}_i)}{\sum_{k\in I}\exp(\widetilde{V}_k)}\times\exp(\Delta V_i)}{\sum_{j\in I}\dfrac{\exp(\widetilde{V}_j)}{\sum_{k\in I}\exp(\widetilde{V}_k)}\times\exp(\Delta V_j)} = \frac{\widetilde{P}(i)\times\exp(\Delta V_i)}{\sum_{j\in I}\widetilde{P}(j)\times\exp(\Delta V_j)}. \qquad \textbf{(3)}$$

Thus, there is no need in a full recalculation of the utilities and choice probabilities for the proposed scenario by a formula (2). It is enough to adjust the base scenario probability for each alternative by the incremental change of the utility. The advantage of a formula (3) over a formula (2) can be really exploited if the base scenario probability is not calculated by a model but rather observed from a survey. Then the incremental model will use the observed shares as a base and adjust it incrementally according to the utility change. It is also important to note that the utility increment does not include an alternative specific constant that is the most problematic utility component. Thus, utility increment that reflects relative improvements in the level-of-service and other variables included into the utility expression is easer to analyze and explain than the full utility.

It can be shown that observed shares for the base scenario play a role of hidden alternative specific constants that automatically scale the model to replicate the observed shares in the base scenario exactly. It is especially an advantageous feature if the same model is applied across numerous travel segments, for example, like in a case of mode choice model applied for numerous trip interchanges (matrix cells). In this case, the observed shares can be stratified by the segments while the core model is generally cannot be calibrated specific to the each segment. Then, the incremental model is the only formulation that allows for exact replication of the stratified observed shares in the base scenario.

From a formula (3) it is clear why the incremental logit model cannot be directly applied at the level of individual records where observed shares follow an extreme pattern of 1 and 0's. If $\widetilde{P}(i)=0$, then $P(i)=0$ automatically. Thus, in this case incremental logit model will always replicate the observed choice regardless of any improvement of the alternatives.

4.2.2. Incremental Nested Logit Model

The incremental logit technique can be readily generalized for the nested logit (NL) model. Consider for simplicity a bi-level nested structure and introduce the following additional notation:

$m \in M$	=	nests organized as mutually exclusive and collectively exhaustive sub-sets of alternatives,
$i \in I^m \subset I$	=	sub-set of alternatives included into the nest.

According the NL, choice probability in the base and proposed scenarios is calculated in the following way:

$$\widetilde{P}(i) = \widetilde{P}(m(i)) \times \widetilde{P}(i|m(i)), \qquad \textbf{(4)}$$

$$P(i) = P(m(i)) \times P(i|m(i)), \qquad \textbf{(5)}$$

where:

$m(i)$	=	nest which the alternative belongs to,
$\widetilde{P}(m)$	=	marginal probability of a nest to be chosen in the base scenario that is calculated by the following formula:

$$\widetilde{P}(m) = \frac{\exp\left(\mu \widetilde{U}^m\right)}{\sum_{n \in M} \exp\left(\mu \widetilde{U}^n\right)}, \quad \textbf{(6)}$$

$P(m)$ = marginal probability of a nest to be chosen in the proposed scenario that is calculated by the following formula:

$$P(m) = \frac{\exp\left(\mu U^m\right)}{\sum_{n \in M} \exp\left(\mu U^n\right)}, \quad \textbf{(7)}$$

$\widetilde{P}(i|m(i))$ = conditional probability of the alternative to be chosen within the nest in the base scenario that is calculated by the following formula:

$$\widetilde{P}(i|m(i)) = \frac{\exp\left(\widetilde{V}_i\right)}{\sum_{j \in I^{m(i)}} \exp\left(\widetilde{V}_j\right)}, \quad \textbf{(8)}$$

$P(i|m(i))$ = conditional probability of the alternative to be chosen within the nest in the proposed scenario that is calculated by the following formula:

$$P(i|m(i)) = \frac{\exp\left(V_i\right)}{\sum_{j \in I^{m(i)}} \exp\left(V_j\right)}, \quad \textbf{(9)}$$

where:

$0 < \mu \leq 1$ = degree of nesting,

$\widetilde{U}^m$ = composite nest utility in the base scenario that is calculated as the following log-sum of the utilities of the included alternatives:

$$\widetilde{U}^m = \ln\left[\sum_{i \in I^m} \exp\left(\widetilde{V}_i\right)\right], \quad \textbf{(10)}$$

U^m = composite nest utility in the proposed scenario that is calculated as the following log-sum of the utilities of the included alternatives:

$$U^m = \ln\left[\sum_{i \in I^m} \exp\left(V_i\right)\right]. \quad \textbf{(11)}$$

The same way as the incremental MNL model (3) has been derived from the combination of MNL expressions for the proposed (1) and base scenario (2) we can derive the expressions for the incremental marginal and conditional probabilities of NL consequently:

- for marginal probability from expressions (6) and (7):

$$P(m) \quad = \quad \frac{\widetilde{P}(m)\times \exp(\mu \Delta U^{m})}{\sum_{n\in M}\widetilde{P}(n)\times \exp(\mu \Delta U^{n})}, \qquad \textbf{(12)}$$

- for conditional probability from expressions (8) and (9)

$$P(i|m(i)) \quad = \quad \frac{\widetilde{P}(i|m(i))\times \exp(\Delta V_i)}{\sum_{j\in I^{m(i)}}\widetilde{P}(j|m(i))\times \exp(\Delta V_j)}, \qquad \textbf{(13)}$$

where the increment of the composite nest utility can be calculated from expressions (10) and (11) in the following way:

$$\Delta U^{m} \quad = \quad U^{m} - \widetilde{U}^{m} \quad = \quad \ln\left[\sum_{i\in I^{m}}\exp(V_i)\right] - \ln\left[\sum_{i\in I^{m}}\exp(\widetilde{V}_i)\right] \quad =$$

$$= \quad \ln\left[\sum_{i\in I^{m}}\exp(\widetilde{V}_i + \Delta V_i)\right] - \ln\left[\sum_{i\in I^{m}}\exp(\widetilde{V}_i)\right] \quad = \quad \ln\left[\frac{\sum_{i\in I^{m}}\exp(\widetilde{V}_i + \Delta V_i)}{\sum_{j\in I^{m}}\exp(\widetilde{V}_j)}\right] \quad =$$

$$= \quad \ln\left[\sum_{i\in I^{m}}\frac{\exp(\widetilde{V}_i)}{\sum_{j\in I^{m}}\exp(\widetilde{V}_j)}\times \exp(\Delta V_i)\right] \quad = \quad \ln\left[\sum_{i\in I^{m}}\widetilde{P}(i|m(i))\times \exp(\Delta V_i)\right]. \qquad \textbf{(14)}$$

Expressions (4), (12-14) constitute the *incremental nested logit model*. In a similar way to the incremental MNL, the incremental NL does not require that alternative utilities and probabilities to be fully recalculated each time if a new scenario is proposed. It is enough to adjust conditional probabilities based on the utility increment by a formula (13), then calculate composite increments by a formula (14) in order to adjust marginal probabilities by a formula (12) and finally substitute the outcomes of expressions (12) and (13) into the formula (4) to calculate choice probabilities for the proposed scenario. If instead of the base scenario modeled probabilities, observed shares are used then the incremental NL will not require alternative specific constants and replicate exactly the observed shares for the base scenario.

4.2.3. General Formulation of the Switching Model

Switching model constitutes an alternative way to introduce incremental technique into the choice framework. A general formulation of the *switching model* can be written in the following form:

$$P(i) = \sum_{j \in I} \widetilde{P}(j) \times P(i|j), \qquad \textbf{(15)}$$

where $P(i|j)$ reflects probability to switch from one alternative to another. The main difference between the incremental and switching formulations is that the switching model explicitly reveals a matrix of alternative-to-alternative switches as a result of utility changes while the incremental formulation gives only the evolution of final choice probabilities whereas the underlying detailed switches are hidden. Conditional switching probability is defined as a two-dimensional array where the following additional factors can be taken into account (that are usually impossible to incorporate in the incremental model):

- Specific transaction cost associated with switching; for example, purchase of an additional car can be considered as a transaction cost from public transit to private mode. Transaction cost can reflect numerous psychological disutilities like discomfort of changing routine behavior and is strongly associated with a particular time framework,
- Truncated choice set based on the switching thresholds similar to what has been currently used in the SMST modal transfer model. In this case switching probability is set to zero if the new alternative does not exceed the current alternative by a predetermined threshold. In the literature on mode and route choice this threshold is usually specified either in minutes saved (1 through 5 min has been used) or in relative terms (5% through 20% of saving has been used). Absolute and relative threshold can be combined. Additionally a number of switching alternatives can be controlled, for example, in the extreme case (currently adopted in the SMST modal transfer model) only one (the best) competing alternative is considered along with the currently chosen (observed).
- Utility components formulated in terms of perceptional improvements and relative characteristics rather than absolute values of alternative attributes. In this case the previously chosen alternative actually serves as an additional dimension for the choice model segmentation.

Explicit estimation of the switching model requires a duration-panel survey where both the current (after the improvement) and previous (before the improvement) choices are observed for each individual. Alternatively a stated preference survey can be used in order to estimate a switching model. The listed above specific components cannot be captured by a cross-sectional comparison based on a survey implemented in a single point in time. It is different from the estimation of the incremental model that does not require a durational panel and can be done based on a single snapshot in time (either before or after) where the cross-sectional variation supports the estimation of the utility parameters relevant for the increment while the observed shares (before) are used instead of the alternative specific constants.

If durational data on switches is not available, then switching probabilities cannot be strictly estimated. It should be also noted that knowledge on the final model outcome in terms of the choice probabilities before $\widetilde{P}(i)$ and after $P(i)$ is generally not enough to restore the underlying structure of switches unambiguously. The switching model can be put in matrix view where the rows correspond to the previous (observed) choices while columns correspond to the new (modeled) choices. Diagonal cells of the matrix mean staying on the same alternative while the other cells correspond to switching probability. **Tables 1-2** below show two different switching models resulting in exactly the same final probabilities even in the simple case of three alternatives.

Table 1. First switching choice model

Alternative before	Alternative after			Total probability before
	1	**2**	**3**	
1	0.20			0.20
2	0.10	0.20		0.30
3		0.20	0.30	0.50
Total probability after	0.30	0.40	0.30	1.00

Table 2. Second switching choice model

Alternative before	Alternative after			Total probability before
	1	**2**	**3**	
1	0.20			0.20
2		0.30		0.30
3	0.10	0.10	0.30	0.50
Total probability after	0.30	0.40	0.30	1.00

However, using additional assumptions regarding the switching rules, for example, eliminating cross-switches between two alternatives in opposite directions and employing a logit-based structure for the switching probability can reduce significantly a variety of the possible switching matrices or even bring it down to a single construct that is unambiguously derived from the "parent" choice model employed for the alternative probability calculation. It opens a way to plausible restore a switching matrix from the known margins that can be estimated by a simpler incremental model.

The way to make minimal assumptions on the switching probabilities (if anything specific is unknown) is to assume that all switching probabilities are equal across the previously chosen (observed) alternatives and thus depends only on the utilities of new alternatives, i.e. $P(i|j) = P(i)$. This assumption corresponds to the situation where there is no transaction cost or perceptional thresholds to switch from alternative to alternative and all new alternatives are considered regardless of the previously made choices. Under this assumption the formula (15) can be verified in the following way:

$$P(i) \;=\; \sum_{j \in I} \widetilde{P}(j) \times P(i) \;=\; P(i) \times \sum_{j \in I} \widetilde{P}(j) \;=\; P(i), \qquad \textbf{(16)}$$

However this structure has an obvious drawback in creating unrealistic two-directional switches between each pair of alternatives. Since we are interested in final balance of switches for each pair we may calculate it as a difference between switches "to" and switches "from" for each pair of alternatives. This switch between alternatives can be calculated according to the following expression:

$$\Delta P(ij) \;=\; P(i) \times \widetilde{P}(j) - P(j) \times \widetilde{P}(i). \qquad \textbf{(17)}$$

This expression reflects a share of new users of alternative i who previously used alternative j (potential switch from j to i) from which is subtracted a share of new users of alternative j who previously used alternative i (potential switch from i to j). Several logical analytical properties of expression (17) can be mentioned:

1. Symmetry of switches for each pair of alternatives:

   $\Delta P(ij) \;=\; -\Delta P(ji)$.

2. No switch for alternatives preserving the same proportion of probabilities before and after the change (i.e. growing or reduced by the same percent):

   $\Delta P(ij) \;=\; 0$, if $\dfrac{P(i)}{\widetilde{P}(i)} \;=\; \dfrac{P(j)}{\widetilde{P}(j)}$.

3. No switch from alternative to the same alternative (staying on the same alternative is not considered as a switch):

   $\Delta P(ii) \;=\; 0$.

4. Sum of the switches to an alternative from all other alternatives is equal to the increment of the alternative probability:

   $\sum_j \Delta P(ij) \;=\; P(i) - \widetilde{P}(i)$.

5. Sum of the switches from an alternative to all other alternatives is equal to the negative of increment of the alternative probability:

   $\sum_i \Delta P(ij) \;=\; \widetilde{P}(j) - P(j)$.

To relate the calculated switches to the matrix view of probability transformations (**Tables 1-2** above) the following rules should be mentioned:

- Since the matrix view assumes transformation of the row totals (choice probabilities before) to column totals (choice probabilities after), only the positive switches $\Delta P(ij) > 0$ should be written in the intercepts of the corresponding rows $j \in I$ and columns $i \in I$. Symmetrical negative switches will be automatically incorporated by matrix balancing of the row and column sub-totals.
- The diagonal cells that represent staying on the same alternative should be filled with the difference of the probability "before" and all positive switches to the other alternatives calculated by a formula $\tilde{P}(j) - \sum_{i \in I, i \neq j} \max[\Delta P(ij), 0]$.

The described above general principle of restoring underlying switching probabilities from the "parent" incremental choice model will be further applied for logit-based models. The logit-based modeling framework allows for particularly simple and meaningfully tractable derivation of switching probabilities from the incremental model.

4.2.4. Switching Model Derived from the Incremental Multinomial Logit Model

Consider first an incremental MNL model specified by a formula (3). Using this expression, the increment for choice probability (difference between the choice probability for the proposed scenario and base scenario) can be written in the following way:

$$\Delta P(i) = P(i) - \tilde{P}(i) = \frac{\tilde{P}(i) \times \exp(\Delta V_i)}{\sum_{j \in I} \tilde{P}(j) \times \exp(\Delta V_j)} - \tilde{P}(i) = \tilde{P}(i) \times \left[\frac{\exp(\Delta V_i)}{\sum_{j \in I} \tilde{P}(j) \times \exp(\Delta V_j)} - 1 \right] =$$

$$= \tilde{P}(i) \times \frac{\exp(\Delta V_i) - \sum_{j \in I} \tilde{P}(j) \times \exp(\Delta V_j)}{\sum_{k \in I} \tilde{P}(k) \times \exp(\Delta V_k)} = \tilde{P}(i) \times \frac{\sum_{j \in I} \tilde{P}(j) \times [\exp(\Delta V_i) - \exp(\Delta V_j)]}{\sum_{k \in I} \tilde{P}(k) \times \exp(\Delta V_k)} =$$

$$= \sum_{j \in J} \tilde{P}(i) \times \tilde{P}(j) \times \frac{\exp(\Delta V_i) - \exp(\Delta V_j)}{\sum_{k \in I} \tilde{P}(k) \times \exp(\Delta V_k)}. \qquad \textbf{(18)}$$

From the expression (18) it can be seen that the increment of choice probability can be broken into parts that represent switches to and from the alternative:

$$\Delta P(i) \quad = \quad \sum_{j \in J} \Delta P(ij), \tag{19}$$

where a *pair-wise switch* is defined by the following expression:

$$\Delta P(ij) \quad = \quad \widetilde{P}(i) \times \widetilde{P}(j) \times \frac{\exp(\Delta V_i) - \exp(\Delta V_j)}{\sum_{k \in I} \widetilde{P}(k) \times \exp(\Delta V_k)}. \tag{20}$$

The obtained formula (20) is a particular case of the general formula (17). It is possible to arrive to expression (20) starting with the formula (17) and then substituting choice probabilities for the proposed scenario $P(i), P(j)$ with the incremental MNL expressions by formula (3). However, the formula (20) that is written in specific terms of the incremental MNL model gives some additional insights into the underlying structure of the choice process. Specified switching probabilities inherit all logical properties 1-5 listed in the previous section. In particular the property 2 (proportional change of both alternatives) can be reformulated as equal utility increments $\Delta V_i = \Delta V_j$ from which it is clear that the switch in this case should be equal to zero.

From formula (20) it can be logically concluded that absolute amount of switching is proportional to the base shares of alternatives and the difference between the utility increments scaled exponentially. Thus, though the original formulation of the incremental MNL (3) does not refer to any switching probability explicitly, it is possible to restore the underlying detailed structure of pair-wise switches from the "parent" choice model.

4.2.5. Switching Model Derived from the Incremental Nested Logit Model

Using the same logic with a little more complicated technique we derive a switching model from the incremental NL. It should be noted that the NL model is essentially a hierarchical application of linked MNL models. Thus, switches can be analyzed at each level of the nesting hierarchy. In particular, the upper level switches between the nests can be calculated by exactly the same formula (20) where the utility increment corresponds to the composite log-sums expression (14). The lower-level switches between elementary alternatives are subjected to the same logic with the specific complication in order to distinguish between intra-nest switches (more frequent) and inter-nest switches (less frequent). The expected proportion in intra-nest switching propensity versus inter-nest switching propensity reflects the general elasticity properties inherent to the NL structure.

Consider again a bi-level nesting structure. The derivation analogous to formula (18) with the incremental NL specified by formulas (4) and (12-14) will take the following form:

$$\Delta P(i) \quad = \quad P(i) - \widetilde{P}(i) \quad = \quad P(m(i)) \times P(i | m(i)) - \widetilde{P}(i) \quad =$$

$$= \frac{\widetilde{P}(m(i)) \times \exp\left(\mu \Delta U^{m(i)}\right)}{\sum_{n \in M} \widetilde{P}(n) \times \exp\left(\mu \Delta U^{n}\right)} \times \frac{\widetilde{P}(i|m(i)) \times \exp(\Delta V_i)}{\sum_{j \in J^{m(i)}} \widetilde{P}(j|m(i)) \times \exp\left(\Delta V_j\right)} - \widetilde{P}(i) =$$

$$= \widetilde{P}(i) \times \left[\frac{\exp\left(\mu \Delta U^{m(i)}\right)}{\sum_{n \in M} \widetilde{P}(n) \times \exp\left(\mu \Delta U^{n}\right)} \times \frac{\exp(\Delta V_i)}{\sum_{j \in J^{m(i)}} \widetilde{P}(j|m(i)) \times \exp\left(\Delta V_j\right)} - 1 \right]. \qquad \textbf{(21)}$$

Note that $\exp\left(\mu \Delta U^{m}\right) = \left[\sum_{i \in I^m} \widetilde{P}(i|m) \times \exp(\Delta V_i) \right]^{\mu}$. Thus the expression (21) can be further transformed:

$$\Delta P(i) = \widetilde{P}(i) \times \left\{ \frac{\exp(\Delta V_i) \times \exp\left[(\mu - 1)\Delta U^{m(i)}\right]}{\sum_{n \in M} \widetilde{P}(n) \times \exp\left(\mu \Delta U^{n}\right)} - 1 \right\}. \qquad \textbf{(22)}$$

Note that the denominator can be equivalently rewritten in the following way:

$$\sum_{n \in M} \widetilde{P}(n) \times \exp\left(\mu \Delta U^{n}\right) = \sum_{n \in M} \widetilde{P}(n) \times \left[\sum_{j \in J^n} \widetilde{P}(j|n) \times \exp\left(\Delta V_j\right) \right] \times \exp\left[(\mu - 1)\Delta U^{n}\right] =$$

$$= \sum_{j \in J} \widetilde{P}(j) \times \exp\left(\Delta V_j\right) \times \exp\left[(\mu - 1)\Delta U^{n(j)}\right]. \qquad \textbf{(23)}$$

Substituting expression (23) into a formula (22) and implementing a similar transformation of the unit term that was applied in derivation of a formula (18) for the MNL model we obtain finally a formula for the NL probability increment:

$$\Delta P(i) = \sum_{j \in J} \widetilde{P}(i) \times \widetilde{P}(j) \times \frac{\exp(\Delta V_i) \times \exp\left[(\mu - 1)\Delta U^{m(i)}\right] - \exp\left(\Delta V_j\right) \times \exp\left[(\mu - 1)\Delta U^{n(j)}\right]}{\sum_{k \in I} \widetilde{P}(k) \times \exp(\Delta V_k) \times \exp\left[(\mu - 1)\Delta U^{r(k)}\right]}.$$

(24)

From this formula an expression for a *pair-wise switch* can be extracted:

$$\Delta P(ij) = \widetilde{P}(i) \times \widetilde{P}(j) \times \frac{\exp(\Delta V_i) \times \exp\left[(\mu - 1)\Delta U^{m(i)}\right] - \exp\left(\Delta V_j\right) \times \exp\left[(\mu - 1)\Delta U^{n(j)}\right]}{\sum_{k \in I} \widetilde{P}(k) \times \exp(\Delta V_k) \times \exp\left[(\mu - 1)\Delta U^{r(k)}\right]}.$$

(25)

It can be shown that if we sum all switches from alternatives from one nest to alternatives from the other nest we obtain an expression for the nest-to-nest pair-wise switch that suits the upper level MNL model (12-13) for calculation of the marginal choice probabilities:

$$\Delta P(mn) \;=\; \sum_{i\in I^m}\sum_{j\in J^n}\Delta P(ij) \;=\; \widetilde{P}(m)\times\widetilde{P}(n)\times\frac{\exp\left(\mu\Delta U^m\right)-\exp\left(\mu\Delta U^n\right)}{\sum_{r\in M}\widetilde{P}(r)\times\exp\left(\mu\Delta U^r\right)}. \qquad \textbf{(26)}$$

The proposed technique and resulting expressions (25-26) can be readily generalized for a tri-or-more-level NL model. Comparing the expression for NL switching probabilities (25) to the expression for MNL switching probabilities (18) it should be mentioned that they have a similar structure reflecting that a switch between two alternatives is proportional to their base shares and the difference between increments of utilities scaled exponentially. However, in the NL case <u>utilities of elementary alternatives are re-scaled based on the entire-nest composite utilities</u>. Taking into account that $\mu-1\leq 0$, the higher is the nest composite utility improvement the lower is the probability to switch to a particular alternative from this nest (all else being equal) because the other alternatives from the nets will strongly compete with this alternative.

If we have an improvement for one of the alternatives while all other alternatives stay with the same utility, then the nest that contains the improved alternative will also get an improvement for the composite utility while all the other nests stay with the same composite utility. In this case formula (25) will work in such a way that all <u>intra-nest switches will be systematically higher comparing to the inter-nest switches</u> because of the discounting of the positive utility increment for the improved alternative by the scaling down by the (positive) composite utility increment (for intra-nest switches both alternatives will be equally discounted).

4.2.6. Application rules for the Derived Switching Model

As was mentioned above, a <u>standard incremental model cannot be generalized for an individual-record case</u> where the observed shares formally look like all zeros (for non-chosen alternatives) and one (for the chosen alternative). It inherently requires that both observed shares and modeled probabilities to be positive fractional numbers. However, the <u>switching model allows for such a generalization</u>. The base mechanism is shown in **Figure 2** (numbers are picked up for the illustration purpose only).

Individual Record with Observed Choice (Auto without Toll)

Individual Matrix of Switching Probabilities

		Modes After				Total Before
		Auto	Auto/Toll	Transit	P&R	
Modes Before	Auto	0.4	0.2	0.0	0.1	0.7
	Auto/Toll	0.0	0.0	0.0	0.0	0.0
	Transit	0.1	0.0	0.1	0.1	0.3
	P&R	0.0	0.0	0.0	0.0	0.0
Total After		0.5	0.2	0.1	0.2	1.0

Weight-Split Proportions

Auto	0.4/0.7	0.2/0.7	0.0/0.7	0.1/0.7

Figure 2. Application of the switching model

At first stage a calculation of fractional probabilities before and after is implemented for each individual record and a matrix of switching probabilities is constructed based on the technique described in a section 2 above. Then at the second stage a relevant row (corresponding to the observed mode) is singled out and the corresponding probabilities are re-scaled to represent a relative switch from the chosen mode to the other alternatives available. Rescaling essentially means division by the sub-total probability of the chosen mode before the change.

As a summary we will conclude several beneficial meaningful features of the proposed switching model:

- Pair-wise symmetry, i.e. switch from say, bus to car is always equal to a switch from car to bus with a negative sign. Thus, there is always one-way transfer of travelers between any pair of modes. This corresponds to formal property 1 formulated in section 4.2.3 above.
- Exact match to the parent model because total of all switches from or to any mode is equal to the modeled probability increment. It means that the proposed model only disaggregate but do not change the probabilities calculated by the base multinomial or nested logit model. This corresponds to formal property 4 formulated in section 4.2.3 above.
- No switch if two alternatives have equal utility increments, i.e. are not changed or improved equally. This correspond to formal property 2 formulated in section

4.2.3 above and have the following particular properties that are important in view of the model application for individual records:

- Exact replication of observed choices for each individual record if there is no change of the mode utilities comparing to the base case. This property distinguishes the proposed switching model from all alternative constructs like, for example, application of a parent model in full (non-incremental) fashion. The last would produce a lot of meaningless cross-switches at the individual-record level, though they would be eventually totaled to the same aggregate probabilities as for the switching model. Actually, it can be proved that the developed switching model is the only way to disaggregate the parent incremental model (by pair-wise switches) that holds this property.
- Exact replication of probability shifts calculated by the parent model if only one alternative changes. Thus, in this case where the pair-wise switches can be unambiguously restored from the parent model the switching model replicates exactly the switches produced by the parent model.

4.3. Formulation of the mode choice model

In the **Figure 3** below an example of the possible choice hierarchy is shown. The destination and time-of-day choice stages will be at the upper levels of the hierarchy. The mode choice nested structure will include at least three or four levels (not necessarily in exactly the same order as shown in the figure). The first level distinguishes between the private and public nests. The second level can reflect occupancy for private modes and the main transit mode for public modes. The third level can reflect access and/or egress combinations for each of the main transit modes. The fourth level treats toll road as a mode sub-choice including auto access to transit. Final decision on the nesting structure is made during the estimation procedure where alternative structures are estimated and compared with regard to various statistical criteria.

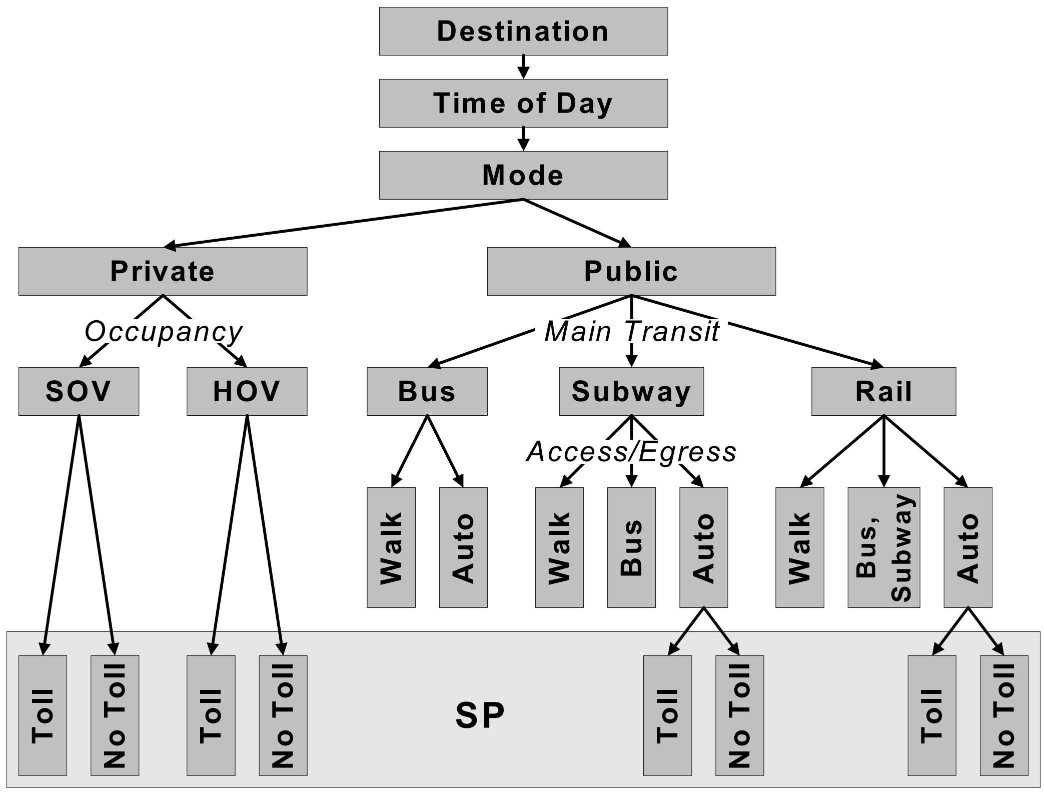

Figure 3. Example of a nested structure

The estimation procedure will include components from the origin-destination survey (observed choices or revealed preferences –RP) and observations from the stated preference (SP) survey. The last will provide coverage for toll-road option that does not exist yet. The corresponding technique for combined RP/SP estimation of choice model has been developed and successfully applied in the last years. It proved to be effective because RP and SP parts of the dataset with observations can be restricted in the estimation procedure to share the same generic coefficients. Thus, the whole SP (less reliable) part is automatically scaled by the RP (more reliable) part. Additionally, the SP survey can be limited to auto users only and concentrated on distinguishing between auto-toll versus auto-non-toll coefficients and constants, because all other modes can be estimated from the RP survey versus the auto-non-toll users. However, a better statistical reliability with respect to the nested structure is obtained if auto-toll option is explicitly treated in SP versus transit modes as well (though it requires a more complicated SP structure with a bigger sample).

Application of an advanced tour-based modeling concept will introduce additional details into the nested structure shown above. In particular, a mode symmetry indicator is applied to distinguish between simple cases when the exactly the same mode combination is applied for both outbound and (in reverse order of modes) inbound directions of the tour (normally, over 90% of cases), and complex cases where different mode combinations are applied by directions (normally, less than 10% of cases). The complex cases require additional nesting levels reflecting conditioning of directional-specific choices on each other. It is mentioned in several sources that outbound direction is generally considered as more important with respect to the schedule adherence (especially for commuters) while inbound direction is more important for visiting secondary stops on the way. Thus, both nesting structures (outbound mode conditional on inbound mode versus inbound mode conditional on outbound mode) will be statistically examined.

Another option that will be considered is the application of an additional trip-level mode choice model for those tours that have secondary stops. The presence of a stop essentially breaks the tour direction into elementary trips. If the tour mode is essentially a mode combination (for example, metro with bus access), then for each elementary trip (from the origin to stop, from the stop to primary destination etc) a sub-mode choice model can be formulated conditional upon the chosen entire-tour mode combination. Final decision regarding the trip-level mode choice model will be made after statistical analysis of frequent cross-combinations of mode combinations and chaining types for each travel segment.

5. DATA STRUCTURE AND REQUIREMENTS FOR THE MODEL ESTIMATION

The proposed switching model does not require any specific effort in the model estimation and subsequent aggregate calibration. As was mentioned in section 4.2.3 above the model structure is open for additional transaction-specific variables if they are available from durational panels or longitudinal surveys. However, in a framework of the current project it is suggested to estimate the mode choice model as a conventional nested logit structure while in forecasting it will be applied in an incremental switching fashion as was described in sub-section 4.2.6 above.

5.1. Integration of stated and revealed preference surveys for the model estimation

One of the basic features of the proposed model estimation is a full integration of revealed preference (RP) and stated preference (SP) technique in order to estimate all the necessary components of the model with maximum statistical confidence. The RP part is based on the comprehensive OD survey and support a very good coverage for all existing modes and person/household/zonal attributes listed in section 4.1 above. The SP part is complementary and relates to the missing toll-road option. More specifically, VOT estimation (based on willingness to pay i.e. ratio of travel time to travel cost coefficient) as well as alternative-specific constants for toll-related options (see figure 3 above) are in the focus of SP, while the majority of the other model parameters are mostly RP based.

In the model estimation both parts are mixed with weights reflecting the expansion factor and relative reliability of the SP survey against RP (usually a 0.3-0.5 coefficient is recommended). The model formulation in the estimation procedure is subject to the following rules:

- The same 4-level nested structure serves as the basis for the combined model estimation depicted in figure 3. However, this base structure degenerates to the following sub-structures according to the mode availability and relevance for either RP or SP part:
    - RP observations are treated in the estimation with the full model structure but truncated to three upper levels excluding toll/non-toll sub-choice. Thus, neither nesting coefficients for the lower level, no utility components for the toll-specific alternatives can be estimated.
    - SP observations are treated in the estimation within the corresponding branch on the modeled structure however extended downward to the lower level. For example, if the person who currently drives alone is offered a set of toll road and (possibly) vehicle occupancy alternatives, it will give rise to a branch of the nested structure from the private nest downward including levels 2-4. Nesting coefficients and utility components for toll-road alternatives can be estimated, however, the upper-level nesting

coefficients as well as utility components for the modes outside the branch cannot be estimated.

- Mutual SP/RP components are specified as generic across SP and RP observations in order to scale SP properly and keep the whole model in a consistent and coherent way. In particular, the following components should be tied as far as the structure of SP games allows to do so:
  - Coefficients for time components and cost-related variables (other than toll) for both toll and non-toll modes,
  - Mode specific constants and coefficients for socio-economic variables for non-toll modes,
  - Nesting coefficients for the second and third levels of the structure.
- Survey-specific parameters will include the following list:
  - RP-based nesting coefficients for the upper level of the choice hierarchy,
  - SP-based nesting coefficients for the lower level of the choice hierarchy,
  - SP-based mode-specific constants for toll-related options,
  - SP-based coefficients for socio-economic variables for toll-related modes (if they are not combined for toll and non-toll options within the nest),
  - SP-based coefficient for toll component in the trip cost.

5.2. Data structure and requirements for socio-economic and land-use variables

The most of the socio-economic variables and (possibly) dimensions for model coefficients' stratification that were mentioned in section 4.1 above are readily available from the corresponding fields in the OD-survey file MTL98PV3. A complementary file MTL98CH that groups trips by tours has also been prepared by SMST. One important household variable – income – is missing in the survey and will be imputed from the census tract file (using relation established in OD98REV1 file). Thus, all households that belong to the same tract will obtain the same tract-average income category. This is not a crucial drawback because census tracts are relatively small and homogeneous. Additionally, the income variable from the RP side of the survey has an impact on choice between private and public modes, but is not used in the toll-non-toll sub-choice estimation.

In view of the possible tour-based formulation of the model the following additional fields will be added to the MTL98CH file:

- Primary destination of the tour indicator (based on the purpose, duration of activity, and distance from the origin).
- Direction indicator for the half-tours. 1-for the outbound direction from the origin to the primary destination, 2-for the inbound direction from the primary destination to the origin.

- Indicator for non-home-based sub-tours (at work, at school, at university) that are parts of the corresponding work, school and university tours.
- Joint household half-tour indicator (if several household members travel together from the origin to the primary destination or from the primary destination back to the origin).

The relevant person and household characteristics (including income category) are included in the SP survey as well. At the final stage a file with SP observations (containing the chosen and non-chosen travel alternatives) will be prepared with the same socio-economic fields that are used in the OD-survey file.

Zonal density (residential and employment) and urban type will be prepared in a special land-use file that will contain zone number, area, population, employment and other land-use variables as well as qualitative urban-form characteristics (CBD, urban, suburban, rural).

5.3. Data structure and requirements for travel time and cost variables

Travel time and cost variables include the following list mutual for both SP and RP parts with the exception of toll-related variables exclusive for SP only. Below is a set of variables needed for the mode choice model calibration. They are needed for each of the trips in the OD file:

- Highway time from the EM/2 assignment (centroid to centroid) for the corresponding period of a day,
- Highway distance from the EM/2 assignment (centroid to centroid),
- Parking charge estimation for the corresponding period of a day and purpose,
- Estimation of parking time search and walk from the origin to the parking lot and from the parking lot to the final destination for the corresponding period of a day,
- Transit time components for the shortest path in the network for the corresponding period of a day that includes the whole set of transit modes:
    - In-vehicle transit time subdivided by modes: bus, subway, commuter rail,
    - Total waiting time (if possible, subdivided by modes that are waited to),
    - Total walking time,
    - Number of transfers subdivided by mode combinations (bus-bus, bus-subway, bus-rail etc),
- Transit time components for the shortest path in the network for the corresponding period of a day that excludes rail (the same set of variables)
- Transit time components for the shortest path in the network for the corresponding period of a day that excludes rail and subway, i.e. only bus is included in the simulation (the same set of variables).

- Transit time components for the shortest path in the network for the corresponding period of a day that includes the whole set of transit modes with park-and-ride access:
    - Auto access time,
    - Parking lot indicator (1-organized, 0-informal)
    - In-vehicle transit time subdivided by modes: bus, subway, commuter rail,
    - Total waiting time (if possible, subdivided by modes that are waited to),
    - Total walking time,
    - Number of transfers subdivided by mode combinations (bus-bus, bus-subway, bus-rail etc),
- Transit time components for the shortest path in the network that assumes park-and-ride access for the corresponding period of a day and excludes rail (the same set of variables).
- Transit time components for the shortest path in the network that assumes park-and-ride access for the corresponding period of a day and excludes rail and subway, i.e. only bus is included (the same set of variables).
- Pure walking/bicycling time from the origin to destination (for non-motorized modes),
- OD estimations of transit cost for each of the access (walk, auto) and transit mode (bus, bus & subway, bus & subway & rail) combinations,
- OD estimation of the taxi cost.
- Origin-zone estimation of taxi waiting time for each of the periods of a day.

Even if the trip record contains observed cost characteristics for the observed (actually chosen) mode (for example, parking), it is necessary to attach the modeled (estimated) value for parking cost that would have been used if this mode had not been chosen. It makes observed and unobserved (alternative) modes comparable in the choice model estimation.

Majority of the requested data has already been prepared by SMST and delivered to PB Consult in two files: TAU98 (for highway time and distance) and TTC98 (for transit time and cost). PB Consult have started preparations of the final files for the model estimation and will evaluate additional needs in the process.

6. MODEL APPLICATION ENVIRONMENT (FOR PRELIMINARY DISCUSSION)

The following general framework is suggested for the model application in the current project framework – see **Figure 4** below.

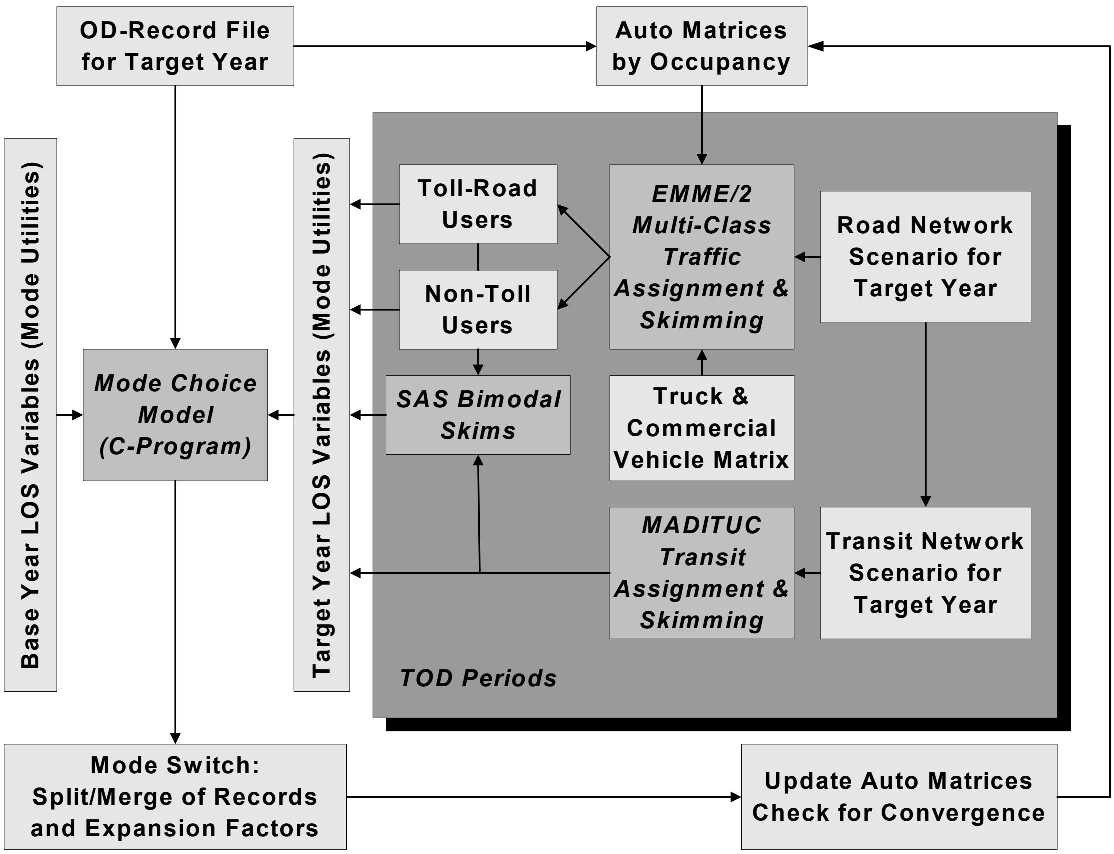

Figure 4. Model application

The mode choice model will be implemented as a stand-alone C program with a fully-automatic interface with the input OD-survey record file expanded for the target year as well as the base and target year LOS files with mode utilities. The base-year LOS variables are calculated once and then fixed during the model calculation and are not dependent on the future network scenario. The target-year LOS variables are dependent on the future network scenarios and are skimmed by means of the network simulation procedures developed in EMME/2 (for the auto LOS) and MADITUC (for the transit LOS). The traffic simulation procedure in EMME/2 will include trucks and commercial vehicles and produce two different skims: for toll-road users and for non-toll users in order to feed the toll vs. non-toll sub-choice (the lower level) in the mode choice hierarchy.

A SAS subroutine developed by SMST will be applied then to produce skims for bi-modal combinations (park & ride, kiss & ride) based on the auto and transit segments of each bi-modal trip. Each bi-modal alternative will have several routes (the best, the second best, the third best etc) with different stations (parking lots) used for mode interchange. In the mode-choice procedure records are proceeded sequentially. Each bi-modal choice is recorded and the capacity of the corresponding parking lot is reduced according to the expansion factor of the record. Completely filled parking lots are closed during the procedure, and routes that use the closed parking facility will not be available for all subsequent records.

The model application starts with the initial auto matrix extracted from the survey expansion for the target year. After the first global iteration of the process a new auto matrix will be produced incorporating mode switches. This matrix should be re-assigned to produce new auto skims, and so forth. Several global iterations are generally necessary to reach a network equilibrium that is considered as a travel forecast for the target year.

7. MAIN CONCLUSIONS

After having carefully considered the existing database and travel demand models developed by SMST along with state-of-the-art and practice in traffic and revenue forecasting worldwide, the following main conclusions and recommendations can be made regarding the modeling system for the current projects:

- SMST has developed a unique comprehensive travel demand database for the Montreal Region derived from the direct OD survey of more than 400,000 trips implemented by the regional population. The size and structure of survey allows for building travel demand matrices with a reasonable coverage of all OD pairs, travel modes and period of a day by a direct expansion of the individual records based on the demographic characteristics of the survey sample versus the entire regional population. This allows for to obviate trip generation and distribution modeling stages usual for most of the synthetic modeling systems developed elsewhere.
- The existing procedure for travel demand forecasting in the Montreal Region is quite unique and based on the adjustment of individual weights of the OD survey based on the demographic projections, tendencies in the personal status of individuals, changes in motorization rate of the population, and spatial shifts in location of employment centers. This procedure preserves the individual-record based structure though the data can be easily converted to zone-to-zone format for any subset of modes or period of a day. A certain conservatism of the forecasts and limited sensitivity to the transportation network improvements inherent to the forecasting procedure can be considered as a positive practical feature rather than a crucial flaw in the project context. For these reasons, PB Consult proposes to adopt the existing forecasting procedure for the current traffic and revenue study.
- The modal transfer model developed by SMST in its current form has a limitation to incorporate in more than three modes as well as include additional cost-related attributes into the model utility functions. Taking into account that these limitations are crucial for the current project, PB Consult has proposed an alternative mode choice model that retains the positive features of the existing mode transfer model and can incorporate its availability rules and thresholds while being free of the limitations of the existing model.
- The propose model has a valid theoretical basis and constitutes a pair-wise switching model directly derived from multinomial or nested logit model. The proposed model has several beneficial meaningful features. In particular it matches exactly the parent choice model aggregate outcomes and exactly replicates the observed choice for each individual record if there is no change of the mode utilities comparing to the base case.
- The mode choice structure will include at least three or four levels. The first level will distinguish between the private and public nests. The second level can reflect vehicle occupancy for private modes and the main transit mode for public modes. The third level can reflect access and/or egress combinations for each of the main transit modes. The fourth level treats toll road as a mode sub-choice including

auto access to transit. Final decision on the nesting structure will be made during the estimation procedure where alternative structures are estimated and compared with regard to various statistical criteria.

- One of the basic features of the proposed model estimation is the full integration of revealed preference (RP) and stated preference (SP) technique in order to estimate all the necessary components of the model with maximum statistical confidence
- The proposed switching model does not require any specific effort in the model estimation and subsequent aggregate calibration. The model structure is open for additional transaction-specific variables if they are available from durational panels or longitudinal surveys. However, in a framework of the current project it is suggested to estimate the mode choice model as a conventional nested logit structure while in forecasting it will be applied in an incremental switching fashion. Majority of the requested data for the RP part has already been prepared by SMST and delivered to PB Consult. PB Consult have started preparations of the final files for the model estimation and will evaluate additional needs in the process.
- The mode choice model will be implemented as a stand-alone C program with a fully-automatic interface with the input OD-survey record file expanded for the target year as well as the base and target year LOS files with mode utilities produced by the EMME/2 and MADITUC subroutines.

8. REFERENCES

- Yan J, Small K, Sullivan E. (2002) Choice Models of Route, Occupancy, and Time-of Day with Value Priced Tolls. Paper presented at the *81st Annual Meeting of the Transportation Research Board*, Washington
- Mastako K, Rilett L, Hickman M, Sullivan E. (2002) Choice Set Estimation for a Value-Priced Corridor. Paper presented at the *81st Annual Meeting of the Transportation Research Board*, Washington
- Mastako K, Laurence R, Edward C. (1998) Commuter Behavior on California State Route 91 after Introducing Variable Toll Express Lanes. *Transportation Research Record 1649*, 47-54
- Sullivan E, Harake J. (1998) The California Route 91 Toll Lanes: Observed Impacts and Other Observations. *Transportation Research Record 1649*, 55-62
- Li J. (2001) Explaining High-Occupancy-Toll Lane Use, *Transportation Research D*, **6(D)**, 61-74
- Vilain P, Bhandari N. (2002) Differences in the Subjective and Social Values of Time: Empirical Evidence from a Traffic Study in Croatia. Paper presented at the *81st Annual Meeting of the Transportation Research Board*, Washington
- Santos G, Newbery D, Rojey L. (2001) Static vs. Demand Sensitive Models and the Estimation of Efficient Cordon Tolls: an Exercise for Eight English Towns. Paper presented at the *80th Annual Meeting of the Transportation Research Board*, Washington
- May A, Milne D. (2000) Effects of Alternative Road Pricing Systems on Network Performance, *Transportation Research A*, **34(A)**, 407-436
- Traffic and Revenue Study. Proposed SR 125 South Toll way. Prepared for California Transportation Ventures, Inc by *Wilbur Smith Associates*. San Diego, California, October 2001
- Dehghani Y, Olsen W. (2000) Potential Pitfalls in Forecasting Travel Demand for Toll Roads: Experience in the US and Overseas. Paper presented at the 79*th* *Annual Meeting of the Transportation Research Board*, Washington
- Mekky A (1995) Toll Revenue and Traffic Study of Highway 407 in Toronto. *Transportation Research Record 1498*.
- Small K, Yan J. (2001). The Value of "Value Pricing" of Roads: Second-Best Pricing and Product Differentiation, *Journal of Urban Economics*, **49**, 310-336
- Small K, Gomez-Ibanez J. (1998) Road Pricing for Congestion Management: The Transition from Theory to Policy, *in* Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility (K.J.Button and E.T. Vehoef, Eds), Edward Elgar, Cheltenham, UK

- Gosh A.(2001) To Pay or Not To Pay: Commuters' Mode Choice Under Real Time Congestion Pricing. Paper presented at the *80th Annual Meeting of the Transportation Research Board*, Washington
- Lin F. (2001) A Delay Model for Planning Analysis of Main-Line Toll Plazas. Paper presented at the *80th Annual Meeting of the Transportation Research Board*, Washington
- Northwest Parkway Traffic and Revenue Study. Prepared for Northwest Parkway Public Highway Authority by *Vollmer Associates*. Denver, Colorado, May 2001

Annexe 2

Analyse des comptages classifiés sur les cinq périodes de la journée pour une extrapolation estimative sur les comptages globaux et pour une équivalence avec les classes de véhicules modélisées

MOTREM98

André Babin
SMST
6 janvier 2000

Table des Matières

Liste des Tableaux

Les périodes de la journée et classes de véhicules du MOTREM98

Le présent document cerne certains éléments pouvant conduire à modéliser dans MOTREM98 les cinq différentes périodes de la journée à savoir :

- NUIT période de nuit (0h à 6h);
- AM période de pointe du matin (6h à 9h);
- HPJ période hors pointe du jour (9h à 15h30);
- PM période de pointe du soir (15h30 à 18h30);
- HPS période hors pointe du soir (18h30 à 0h).

Il y a quatre grandes classes de véhicules du MOTREM98 qui sont affectés sur le réseau routier. Il y a les autobus des AOT qui sont estimés sur le réseau routier à partir des fréquences des lignes TC d'autobus et il y a :

VEHPR	les VÉHicules légers à usage PeRsonnel (c'est la classe de véhicules associée à l'enquête origine-destination)
VEHRG	les VÉHicules RéGuliers (cela inclus les véhicules légers à usage commercial et les camions réguliers)
VEHLO	les VÉHicules LOurds (ce sont les camions lourds nécessairement d'usage commercial).

Pour ces trois dernières classes de véhicules, la façon de les affecter sur le réseau routier repose sur un même principe. Pour chacune de ces classes de véhicules on doit y associer une matrice de déplacements pour chaque période considérée. Chacune de ces classes de véhicules nécessite également un nombre suffisant de comptages pour la période considérée. Dans le cas des véhicules légers à usage personnel (communément appelés autos) et des camions, les comptages, ramenés en véhicules particuliers équivalents, servent à calibrer les fonctions volumes/délais puisque la matrice de déplacements de cette classe de véhicules est fiable provenant de l'enquête origine-destination.

Dans le cas des véhicules réguliers et des véhicules lourds, les comptages servent à façonner des matrices de déplacements de ces classes à partir de matrices initiales potentielles respectivement de camions réguliers et de camions lourds (suivant la base intégrée d'enquête de camions dans la région de Montréal 1994).

Comptages et classes de véhicules des comptages

Le plan de comptages de l'automne 1998 pour la région de Montréal a fait en sorte que nous disposons de données pour 257 stations de comptage. Pour fin de simplification, nous dirons qu'il y a eu des données pour 624 comptages directionnels. Dans le cas où le comptage s'est étalé sur plusieurs journées, nous considérons alors le comptage moyen des journées ouvrables de comptage. Les classes de véhicules des comptages classifiés sont les véhicules légers, les véhicules légers identifiés commerciaux, les camions réguliers et les camions lourds. La définition d'un camion régulier est : un camion à une unité avec 3 essieux ou moins; celle d'un camion lourd : camion à une unité avec 4 essieux ou plus ou camion à plusieurs unités. Étant donné la grande diversité des types de classification associés aux comptages, nous simplifions en trois classes agrégées de véhicules (véhicules légers, camions réguliers, camions lourds) avec une quatrième classe qui est contenu dans la classe de véhicules légers, à savoir, les véhicules légers identifiés commerciaux. Nous considérons toujours le volume global de véhicules. Au fin du présent exercice, les comptages se répartissent en trois grandes catégories.

Voici donc la répartition de ces types de comptages ainsi que certaines de leurs caractéristiques :

- 438 comptages non classifiés (comptages globaux)

  nous avons des volumes de véhicules globaux pour les cinq périodes de la journée : NUIT, AM, HPJ, PM et HPS

- 159 comptages classifiés manuels
  nous avons des volumes pour les véhicules légers identifiés commerciaux, pour les camions réguliers, pour les camions lourds ainsi que évidemment des volumes de véhicules globaux pour seulement les trois périodes : AM, HPJ et PM. Il est à noter que les volumes de véhicules légers s'obtiennent par la différence entre les volumes globaux et les volumes de camions.

- 27 comptages classifiés non manuels
  nous avons des volumes pour les camions réguliers, pour les camions lourds ainsi que évidemment des volumes de véhicules globaux pour les cinq périodes : NUIT, AM, HPJ, PM et HPS. Il est à noter que les volumes de véhicules légers s'obtiennent par la différence entre les volumes globaux et les volumes de camions.

Donc, pour les cinq périodes de la journée, il n'y a que directement 27 comptages qui puissent nous fournir les volumes observés de véhicules légers, de camions réguliers et de camions lourds. Ce nombre de comptages est nettement insuffisant pour pouvoir amorcer la modélisation de l'affectation routière sur la base des périodes HPS et NUIT d'une journée ouvrable d'automne.

Le présent exercice consiste à examiner les données disponibles et à mettre de l'avant une méthode pour estimer les volumes des différentes classes de véhicules (véhicules légers, véhicules légers identifiés commerciaux, camions réguliers et camions lourds) pour chaque période de la journée pour l'ensemble des comptages (particulièrement les comptages non classifiés) afin d'obtenir un nombre maximal d'«observations» dans le cadre du MOTREM98.

Analyse et extrapolation estimative des classes de véhicules agrégées

D'une part nous avons 186 comptages avec des volumes de véhicules légers identifiés commerciaux et des volumes de camions pour les trois périodes de la journée (AM, HPJ et PM) et 27 comptages avec des volumes de camions pour les cinq périodes de la journée, sans compter les volumes globaux de ces comptages. D'autre part, nous savons que nous avons 465 comptages globaux pour chacune des cinq périodes de la journée (NUIT, AM, HPJ, PM et HPS) provenant des comptages non classifiés.

Pour amorcer une extrapolation estimative sur les classes agrégées manquantes pour certaines périodes de la journée et certains comptages, nous allons considérer non plus des volumes mais plutôt des proportions par rapport aux volumes globaux de véhicules. On examinera donc des proportions de véhicules légers identifiés commerciaux, des proportions de camions réguliers et des proportions de camions lourds pour des périodes de la journée.

Nous prendrons en considération le type de route sur lequel a eu lieu le comptage ainsi que le type d'occupation du sol dans lequel le comptage a eu lieu. De plus, seulement pour les deux périodes de pointe, nous considérons le sens de la congestion et le sens inverse. Nous avons défini 8 types de route et nous avons 4 types d'occupation du sol.

Les types de routes considérés sont :

artère (A), artère mineure (AI), artère pont (AP), collectrice (C), autoroute (ou highway) (H), autoroute pont (ou highway pont) (HP), rue locale (LO) et voie de service (VS).

Les vocations en terme d'occupation du sol considérées sont :

commerciale (COm), centre-ville de Montréal (CVM), industrielle (IND), résidentielle (RES) et rurale (RUR).

Les tableaux qui suivent montrent la répartition du nombre de comptages pour chacun des 3 types de comptages (classifié manuel, classifié non manuel, non classifié) et selon le type de route, la vocation (occupation du sol) et le sens ou non de la congestion en période de pointe AM.

Tableau 1
Répartition des 438 comptages non classifiés selon le type de route, la vocation et le sens de la congestion

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	14	1	13	27	14	1	12	28	6	5
highway	1		6	11	1		6	10	1	1
artère mineure	7	1	9	30	7	1	9	30	11	11
collectrice	1		9	15	1		8	14	15	15
artère pont	6			6	6			6		
highway pont			1	8			1	9		
local	1		3	4	1		3	4		
voie de service	3		3	6	2		4	5	2	2

Tableau 2
Répartition des 159 comptages classifiés manuels selon le type de route, la vocation et le sens de la congestion

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	9	1	8	8	9	1	8	8	1	1
highway	1		10	6	1		10	5	10	10
artère mineure			2				2			
collectrice			2				2			
artère pont	5			5	5			5		
highway pont			1	8			1	8		
local										
voie de service			1	2			1	2		

Tableau 3
Répartition des 27 comptages classifiés non manuels selon le type de route, la vocation et le sens de la congestion

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td></td><td></td><td></td><td>4</td><td></td><td></td><td></td><td>4</td><td>2</td><td>3</td></tr>
<tr><td>highway</td><td></td><td></td><td>1</td><td></td><td></td><td></td><td>1</td><td>1</td><td>4</td><td>4</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>highway pont</td><td></td><td></td><td></td><td>2</td><td></td><td></td><td></td><td>1</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

C'est à partir des 159 comptages classifiés manuels que nous allons élaborer des proportions estimatives pour les véhicules légers identifiés commerciaux, pour les camions réguliers et pour les camions lourds. Deux sortes de périodes sont alors considérées : les périodes de pointe (AM et PM) et la période hors pointe (HPJ). Rappelons que les comptages classifiés manuels ont été effectués durant la journée et ne comprennent donc pas la période hors pointe soir (HPS) et la période de nuit (NUIT). Suivant la grille associées à une période de la journée nous formons des groupes ou blocs sur lesquels nous calculerons des moyennes sur les proportions observées des comptages en cause. La grille associée aux périodes AM et PM est : Type de route X Vocation de la route X Sens ou non de la congestion AM. La grille associée à la période HPJ est : Type de route X Vocation de la route.

Donc voici les regroupements des comptages classifiés manuels pour la grille des périodes de pointe AM et PM et pour la grille de la période hors pointe HPJ permettant d'estimer les proportions manquantes sur les autres types de comptages (comptages globaux et comptages classifiés non manuels):

Tableau 4
Regroupement des 159 comptages classifiés manuels selon le type de route, la vocation et le sens de la congestion pour les périodes AM et PM dans l'estimation des proportions

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>9</td><td>1</td><td>8</td><td>8</td><td>9</td><td>1</td><td>8</td><td>8</td><td rowspan="2">11</td><td rowspan="2">11</td></tr>
<tr><td>highway</td><td colspan="4">17</td><td colspan="4">16</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">10</td><td colspan="4">10</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">9</td><td colspan="4">9</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">3</td><td></td><td></td><td colspan="2">3</td><td></td><td></td></tr>
</table>

Tableau 5
Regroupement des 159 comptages classifiés manuels selon le type de route et la vocation pour la période hors pointe HPJ dans l'estimation des proportions

<table>
<tr><th rowspan="2">TYPEROUTE</th><th colspan="4">URBAINE</th><th>RURALE</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th></th></tr>
<tr><td>artère</td><td>18</td><td>2</td><td>16</td><td>16</td><td rowspan="2">22</td></tr>
<tr><td>highway</td><td colspan="4">33</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">8</td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">20</td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">18</td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">6</td><td></td></tr>
</table>

Posons les proportions suivantes :

Pvehco[période] la proportion du nombre de véhicules légers identifiés commerciaux sur le nombre de véhicules légers pour la période de la journée.

Pcamrg[période] la proportion du nombre de camions réguliers sur le nombre total de véhicules (volume global) pour la période de la journée.

Pcamlo[période] la proportion du nombre de camions lourds sur le nombre total de véhicules (volume global) pour la période de la journée.

Les principes et hypothèses conduisant à l'extrapolation estimative des proportions Pvehco, Pcamrg et Pcamlo par période de la journée pour le cas des comptages avec une ou plusieurs de ces proportions manquantes sont les suivants :

- Pour un même type de route, pour une même vocation de la route, pour le même sens de la congestion (dans la cas des périodes AM et PM seulement) et pour une même période de la journée les proportions Pvehco, Pcamrg et Pcamlo estimées sont considérées dans le cas d'un comptage avec ces proportions manquantes à partir des estimateurs du groupe correspondant obtenus par les comptages classifiés manuels.
- Dans le cas des périodes NUIT et HPS, les proportions estimées sont celles de la période HPJ.

La proportion Pvehco

Dans un premier temps, nous examinons la proportion moyenne Pvehco par type de route, par vocation de la route et le cas échéant par sens ou non de la congestion pour chacune des trois périodes disponibles sur les comptages classifiés manuels. Parmi ces 159 comptages, quelques proportions pour chacune des trois périodes ont du être éliminées. Nous en avons retenus respectivement 149, 150 et 147 proportions pour les périodes AM, HPJ et PM pour lesquels nous avons des observations fiables de véhicules légers identifiés commerciaux et de véhicules légers qui se repartissent de la façon suivante :

Tableau 6
Nombre d’observations Pvehco des 149 comptages classifiés manuels retenus pour l’estimation en période AM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	9	1	7	7	9	1	7	8	10	10
highway	16				14					
artère mineure			4				4			
collectrice										
artère pont	9				10					
highway pont	9				8					
local										
voie de service			3				3			

Tableau 7
Nombre d’observations Pvehco des 150 comptages classifiés manuels retenus pour l’estimation en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE				RURALE
	COM	CVM	IND	RES	
artère	18	2	14	15	20
highway	31				
artère mineure			8		
collectrice					
artère pont	19				
highway pont	17				
local					
voie de service			6		

Tableau 8
Nombre d’observations Pvehco des 147 comptages classifiés manuels retenus pour l’estimation en période PM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	9	1	6	7	9	1	6	8	10	10
highway	16				14					
artère mineure			4				4			
collectrice										
artère pont	9				10					
highway pont	9				8					
local										
voie de service			3				3			

Le calcul des moyennes des Pvehco sur les groupes parmi les comptages classifiés manuels retenus a été fait pour chacune des périodes de la journée suivantes : AM, HPJ et PM et ces estimations se retrouvent dans les prochains tableaux sous forme de pourcentage :

Tableau 9
Pvehco moyen des comptages classifiés manuels pour l'estimation
en période AM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	5,0%	3,6%	4,8%	3,5%	5,8%	5,7%	5,3%	4,9%	6,5%	8,0%
highway	3,9%				4,8%					
artère mineure			6,7%				6,5%			
collectrice										
artère pont	3,2%				3,7%					
highway pont	3,1%				4,6%					
local										
voie de service			5,8%				8,6%			

Tableau 10
Pvehco moyen des comptages classifiés manuels pour l'estimation
en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE				RURALE
	COM	CVM	IND	RES	
artère	6,9%	8,5%	6,6%	5,7%	9,9%
highway	5,9%				
artère mineure			12,4%		
collectrice					
artère pont	4,1%				
highway pont	5,2%				
local					
voie de service			10,4%		

Tableau 11
Pvehco moyen des comptages classifiés manuels pour l'estimation
en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	4,0%	4,0%	4,0%	3,1%	3,8%	4,2%	4,2%	2,8%	7,0%	8,2%
highway	3,9%				3,4%					
artère mineure			6,4%				6,0%			
collectrice										
artère pont	3,0%				2,3%					
highway pont	3,2%				2,7%					
local										
voie de service			4,6%				5,2%			

Pour apprécier le degré d'homogénéité des observations Pvehco dans chacun des groupes pour chaque période considérée, nous examinons les écart-types dans les tableaux suivants :

Tableau 12
Écart-types sur les Pvehco des comptages classifiés manuels pour l'estimation en période AM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	1,3%	N/A	3,3%	1,6%	1,9%	N/A	2,3%	1,8%	4,4%	6,2%
highway	2,0%				1,8%					
artère mineure			3,2%				1,9%			
collectrice										
artère pont	2,1%				1,2%					
highway pont	1,0%				2,3%					
local										
voie de service			1,7%				4,1%			

Tableau 13
Écart-types sur les Pvehco des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE				RURALE
	COM	CVM	IND	RES	
artère	1,9%	0,4%	3,6%	2,5%	6,1%
highway	2,7%				
artère mineure			5,1%		
collectrice					
artère pont	1,5%				
highway pont	2,3%				
local					
voie de service			1,9%		

Tableau 14
Écart-types sur les Pvehco des comptages classifiés manuels pour l'estimation en période PM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	2,1%	N/A	3,4%	1,0%	0,9%	N/A	2,7%	1,4%	5,9%	6,5%
highway	2,6%				1,8%					
artère mineure			4,1%				3,2%			
collectrice										
artère pont	1,7%				0,6%					
highway pont	1,5%				1,3%					
local										
voie de service			1,9%				1,4%			

Les proportions Pcamrg et Pcamlo

Dans un deuxième temps, nous examinons les proportions moyennes Pcamrg et Pcamlo par type de route, par vocation de la route et le cas échéant par sens ou non de la congestion pour chacune des trois périodes disponibles sur les comptages classifiés manuels. Parmi ces 159 comptages, quelques proportions Pcamrg et Pcamlo pour chacune des trois périodes ont du être éliminées.

Nous avons retenus respectivement 159, 159 et 154 proportions Pcamrg pour les périodes AM, HPJ et PM pour lesquels nous avons des observations fiables de camions réguliers. Également, ont été retenues 153, 156 et 146 proportions Pcamlo pour les périodes AM, HPJ et PM pour lesquels nous avons des observations fiables de camions lourds.

Nous n'avons pas inclus les 27 comptages classifiés non manuels pour les proportions Pcamrg et Pcamlo dans les estimations pour rester consistant avec le type de comptages (classifiés manuels) et pour rester consistant avec l'estimation des Pvehco (comptages classifiés manuels seulement). De plus, ces 27 comptages classifiés non manuels couvrent les 5 périodes de la journée et vont servir plus loin à démontrer le bien-fondé de l'hypothèse sur la couverture des périodes NUIT et HPS par la période HPJ pour les cas des camions.

Dans les prochaines pages, nous présentons une série de tableaux. Pour le cas des proportions de camions réguliers (Pcamrg), on va retrouver une première série de trois tableaux montrant le nombre d'observations retenus pour l'estimation de la moyenne Pcamrg des groupes considérés pour chacune des trois périodes AM, HPJ et PM. Puis, une deuxième série de trois tableaux présente les moyennes Pcamrg sur les groupes pour les trois périodes de la journée. Enfin, une dernière série de trois tableaux illustre les écart-types obtenus sur ces groupes pour chaque période afin d'apprécier l'homogénéité des observations Pcamrg dans chaque groupe de chaque période de la journée.

Après le cas des proportions de camions réguliers, on retrouve trois série de tableaux concernant les proportions de camions lourds. On a une première série de trois tableaux montrant le nombre d'observations retenus pour l'estimation de la moyenne Pcamlo des groupes considérés pour chacune des trois périodes AM, HPJ et PM. Puis, une deuxième série de trois tableaux présente les moyennes Pcamlo sur les groupes pour les trois périodes de la journée. Enfin, une dernière série de trois tableaux illustre les écart-types obtenus sur ces groupes pour chaque période afin d'apprécier l'homogénéité des observations Pcamlo dans chaque groupe de chaque période de la journée.

Tableau 15
Nombre d'observations Pcamrg des 159 comptages classifiés manuels retenus pour l'estimation en période AM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>9</td><td>1</td><td>8</td><td>8</td><td>9</td><td>1</td><td>8</td><td>8</td><td rowspan="2">11</td><td rowspan="2">11</td></tr>
<tr><td>highway</td><td colspan="4">17</td><td colspan="4">16</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">10</td><td colspan="4">10</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">9</td><td colspan="4">9</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">3</td><td></td><td></td><td colspan="2">3</td><td></td><td></td></tr>
</table>

Tableau 16
Nombre d'observations Pcamrg des 159 comptages classifiés manuels retenus pour l'estimation en période HPJ selon les 10 groupes définis

<table>
<tr><th rowspan="2">TYPEROUTE</th><th colspan="4">URBAINE</th><th>RURALE</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th></th></tr>
<tr><td>artère</td><td>18</td><td>2</td><td>16</td><td>16</td><td rowspan="2">22</td></tr>
<tr><td>highway</td><td colspan="4">33</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">8</td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">20</td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">18</td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">6</td><td></td></tr>
</table>

Tableau 17
Nombre d'observations Pcamrg des 154 comptages classifiés manuels retenus pour l'estimation en période PM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>8</td><td>1</td><td>6</td><td>8</td><td>9</td><td>1</td><td>7</td><td>7</td><td rowspan="2">11</td><td rowspan="2">11</td></tr>
<tr><td>highway</td><td colspan="4">17</td><td colspan="4">16</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">10</td><td colspan="4">10</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">9</td><td colspan="4">9</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">3</td><td></td><td></td><td colspan="2">3</td><td></td><td></td></tr>
</table>

Tableau 18
Pcamrg moyen des comptages classifiés manuels pour l'estimation en période AM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>2,0%</td><td>1,6%</td><td>3,4%</td><td>1,7%</td><td>3,2%</td><td>4,8%</td><td>3,6%</td><td>2,3%</td><td rowspan="2">3,4%</td><td rowspan="2">4,7%</td></tr>
<tr><td>highway</td><td colspan="4">2,6%</td><td colspan="4">4,0%</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">5,4%</td><td></td><td></td><td></td><td rowspan="2">5,7%</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">1,2%</td><td colspan="4">2,6%</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">2,1%</td><td colspan="4">4,1%</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">2,7%</td><td></td><td></td><td colspan="2">3,6%</td><td></td><td></td></tr>
</table>

Tableau 19
Pcamrg moyen des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

<table>
<tr><th rowspan="2">TYPEROUTE</th><th colspan="4">URBAINE</th><th>RURALE</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th></th></tr>
<tr><td>artère</td><td>4,1%</td><td>4,0%</td><td>4,9%</td><td>3,0%</td><td rowspan="2">5,4%</td></tr>
<tr><td>highway</td><td colspan="4">5,3%</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">8,0%</td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">2,7%</td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">4,6%</td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">5,6%</td><td></td></tr>
</table>

Tableau 20
Pcamrg moyen des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>2,8%</td><td>2,3%</td><td>2,6%</td><td>1,3%</td><td>1,7%</td><td>0,9%</td><td>2,6%</td><td>1,2%</td><td rowspan="2">2,8%</td><td rowspan="2">3,0%</td></tr>
<tr><td>highway</td><td colspan="4">2,7%</td><td colspan="4">2,5%</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">3,9%</td><td></td><td></td><td></td><td rowspan="2">4,8%</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">1,5%</td><td colspan="4">1,1%</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">2,9%</td><td colspan="4">1,8%</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">1,6%</td><td></td><td></td><td colspan="2">2,8%</td><td></td><td></td></tr>
</table>

Tableau 21
Écart-types sur les Pcamrg des comptages classifiés manuels pour l'estimation en période AM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>0,4%</td><td>N/A</td><td>2,1%</td><td>0,9%</td><td>1,3%</td><td>N/A</td><td>2,1%</td><td>1,0%</td><td rowspan="2">1,2%</td><td rowspan="2">1,4%</td></tr>
<tr><td>highway</td><td colspan="4">1,1%</td><td colspan="4">1,0%</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">3,0%</td><td></td><td></td><td></td><td rowspan="2">2,7%</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">0,5%</td><td colspan="4">1,1%</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">0,4%</td><td colspan="4">1,1%</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">2,8%</td><td></td><td></td><td colspan="2">2,6%</td><td></td><td></td></tr>
</table>

Tableau 22
Écart-types sur les Pcamrg des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

<table>
<tr><th rowspan="2">TYPEROUTE</th><th colspan="4">URBAINE</th><th>RURALE</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th></th></tr>
<tr><td>artère</td><td>1,4%</td><td>0,7%</td><td>2,6%</td><td>1,0%</td><td rowspan="2">1,5%</td></tr>
<tr><td>highway</td><td colspan="4">2,0%</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">3,5%</td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">1,4%</td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">0,8%</td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">4,3%</td><td></td></tr>
</table>

Tableau 23
Écart-types sur les Pcamrg des comptages classifiés manuels pour l'estimation en période PM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>1,2%</td><td>N/A</td><td>1,3%</td><td>0,6%</td><td>0,7%</td><td>N/A</td><td>1,5%</td><td>0,4%</td><td rowspan="2">0,8%</td><td rowspan="2">1,1%</td></tr>
<tr><td>highway</td><td colspan="4">1,1%</td><td colspan="4">1,2%</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">1,4%</td><td></td><td></td><td></td><td rowspan="2">3,4%</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">0,8%</td><td colspan="4">0,6%</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">0,7%</td><td colspan="4">0,5%</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">1,1%</td><td></td><td></td><td colspan="2">1,6%</td><td></td><td></td></tr>
</table>

Tableau 24
Nombre d'observations Pcamlo des 153 comptages classifiés manuels retenus pour l'estimation en période AM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>8</td><td>1</td><td>8</td><td>6</td><td>9</td><td>1</td><td>7</td><td>8</td><td rowspan="2">11</td><td rowspan="2">11</td></tr>
<tr><td>highway</td><td colspan="4">17</td><td colspan="4">16</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">9</td><td colspan="4">9</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">9</td><td colspan="4">9</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">3</td><td></td><td></td><td colspan="2">3</td><td></td><td></td></tr>
</table>

Tableau 25
Nombre d'observations Pcamlo des 156 comptages classifiés manuels retenus pour l'estimation en période HPJ selon les 10 groupes définis

<table>
<tr><th rowspan="2">TYPEROUTE</th><th colspan="4">URBAINE</th><th>RURALE</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th></th></tr>
<tr><td>artère</td><td>18</td><td>2</td><td>13</td><td>16</td><td rowspan="2">22</td></tr>
<tr><td>highway</td><td colspan="4">33</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">8</td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">20</td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">18</td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">6</td><td></td></tr>
</table>

Tableau 26
Nombre d'observations Pcamlo des 146 comptages classifiés manuels retenus pour l'estimation en période PM selon les 20 groupes définis

<table>
<tr><th rowspan="3">TYPEROUTE</th><th colspan="8">URBAINE</th><th colspan="2">RURALE</th></tr>
<tr><th colspan="4">SENS CONGESTION AM</th><th colspan="4">SENS INVERSE AM</th><th rowspan="2">CONG.</th><th rowspan="2">INV.</th></tr>
<tr><th>COM</th><th>CVM</th><th>IND</th><th>RES</th><th>COM</th><th>CVM</th><th>IND</th><th>RES</th></tr>
<tr><td>artère</td><td>7</td><td>1</td><td>6</td><td>7</td><td>9</td><td>1</td><td>7</td><td>5</td><td rowspan="2">11</td><td rowspan="2">10</td></tr>
<tr><td>highway</td><td colspan="4">17</td><td colspan="4">16</td></tr>
<tr><td>artère mineure</td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td><td rowspan="2">4</td><td></td><td></td><td></td></tr>
<tr><td>collectrice</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>artère pont</td><td colspan="4">9</td><td colspan="4">8</td><td></td><td></td></tr>
<tr><td>highway pont</td><td colspan="4">9</td><td colspan="4">9</td><td></td><td></td></tr>
<tr><td>local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>voie de service</td><td></td><td></td><td colspan="2">3</td><td></td><td></td><td colspan="2">3</td><td></td><td></td></tr>
</table>

Tableau 27
Pcamlo moyen des comptages classifiés manuels pour l'estimation en période AM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	0,9%	0,5%	1,7%	0,9%	1,4%	2,7%	2,8%	1,3%	5,6%	7,2%
highway	4,2%				5,2%					
artère mineure			3,1%				4,4%			
collectrice										
artère pont	0,6%				1,4%					
highway pont	1,7%				4,4%					
local										
voie de service			1,7%				3,5%			

Tableau 28
Pcamlo moyen des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE				RURALE
	COM	CVM	IND	RES	
artère	1,5%	1,5%	4,0%	1,2%	9,9%
highway	7,5%				
artère mineure			5,9%		
collectrice					
artère pont	1,5%				
highway pont	5,1%				
local					
voie de service			3,3%		

Tableau 29
Pcamlo moyen des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	1,6%	1,0%	2,2%	0,5%	0,6%	0,1%	1,7%	0,6%	5,2%	5,4%
highway	4,6%				4,3%					
artère mineure			2,8%				3,2%			
collectrice										
artère pont	0,9%				0,6%					
highway pont	3,4%				1,6%					
local										
voie de service			1,3%				1,4%			

Tableau 30
Écart-types sur les Pcamlo des comptages classifiés manuels pour l'estimation en période AM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	0,5%	N/A	1,8%	0,7%	0,7%	N/A	2,1%	1,5%	3,6%	3,4%
highway	6,2%				3,8%					
artère mineure			2,8%				1,1%			
collectrice										
artère pont	0,7%				1,8%					
highway pont	0,9%				1,9%					
local										
voie de service			1,4%				3,7%			

Tableau 31
Écart-types sur les Pcamlo des comptages classifiés manuels pour l'estimation en période HPJ selon les 10 groupes définis

TYPEROUTE	URBAINE				RURALE
	COM	CVM	IND	RES	
artère	1,1%	0,4%	3,1%	1,1%	4,6%
highway	6,0%				
artère mineure			3,2%		
collectrice					
artère pont	2,1%				
highway pont	1,9%				
local					
voie de service			1,7%		

Tableau 32
Écart-types sur les Pcamlo des comptages classifiés manuels pour l'estimation en période PM selon les 20 groupes définis

TYPEROUTE	URBAINE								RURALE	
	SENS CONGESTION AM				SENS INVERSE AM				CONG.	INV.
	COM	CVM	IND	RES	COM	CVM	IND	RES		
artère	1,6%	N/A	2,0%	0,5%	0,6%	N/A	1,8%	0,4%	2,2%	3,1%
highway	4,5%				5,7%					
artère mineure			2,3%				2,0%			
collectrice										
artère pont	1,7%				0,8%					
highway pont	1,5%				0,8%					
local										
voie de service			0,4%				0,8%			

Tables d'estimateurs Pvehco, Pcamrg et Pcamlo

Puisque nous devons avoir des estimateurs Pvehco, Pcamrg et Pcamlo pour tous les cas couverts par les comptages non classifiés et les comptages classifiés non manuels dans les grilles des périodes de pointe (AM et PM) et de la période hors pointe de jour (HPJ), nous devons compléter ces grilles à partir des tableaux précédents portant sur les cas couverts par les comptages classifiés manuels.

Dans les prochaines pages, on va retrouver les deux types de grilles suivant la période de la journée considérée pour les estimateurs Pvehco, Pcamrg et Pcamlo et pour chacune des périodes AM, HPJ et PM. Les proportions moyennes Pvehco, Pcamrg et Pcamlo obtenues des comptages classifiés manuels sont représentées par des pourcentages en caractères gras. Il est à noter que la notion de groupe disparaît puisque toutes les cellules affectées à un même groupe ont la même proportion moyenne Pvehco, Pcamrg ou Pcamlo dans les grilles ou tables.

Là, où dans les tableaux on a mis des proportions Pvehco, Pcamrg et Pcamrg, estimées par extrapolation et en regard des proportions moyennes des comptages classifiés manuels on retrouve ces valeurs sous forme de pourcentages en caractères italiques soulignés. Ces estimations doivent couvrir les cellules pour lesquelles on retrouve des comptages non classifiés, des comptages classifiés manuels (pour les comptages rejetés dans le cas d'une proportion particulière) ou des comptages classifiés non manuels.

Il y a donc trois séries de trois tableaux chacun couvrant ainsi les estimateurs des trois proportions Pvehco, Pcamrg et Pcamlo pour chacune des trois périodes de la journée AM, HPJ et PM. Les grilles ou tables des périodes de pointe AM et PM sont : Type de route X Vocation de la route X Sens ou non de la congestion en AM, alors que les grilles ou tables apparentées à la période hors pointe de jour HPJ sont : Type de route X Vocation de la route.

Tableau 33
Estimateurs Pvehco selon le type de route, le sens ou non de la congestion AM et la vocation de la route pour la période AM

TYPEROUTE	CONG	CONG	CONG	CONG	INV	INV	INV	INV	CONG	INV
	COM	CVM	IND	RES	COM	CVM	IND	RES	RUR	RUR
artère	5,0%	3,6%	4,8%	3,5%	5,8%	5,7%	5,3%	4,9%	6,5%	8,0%
highway	3,9%	3,9%	3,9%	3,9%	4,8%	4,8%	4,8%	4,8%	6,5%	8,0%
artère mineure	*4,0%*	*3,0%*	6,7%	*5,0%*	*4,0%*	*4,0%*	6,5%	*5,0%*	*5,0%*	*5,0%*
collectrice	*3,0%*		6,7%	*5,0%*	*3,0%*		6,5%	*5,0%*	*4,0%*	*4,0%*
artère pont	3,2%	3,2%	3,2%	3,2%	3,7%	3,7%	3,7%	3,7%		
highway pont	3,1%	3,1%	3,1%	3,1%	4,6%	4,6%	4,6%	4,6%		
local	*3,0%*		*3,0%*	*3,0%*	*4,0%*		*4,0%*	*4,0%*		
voie de service	*4,0%*		5,8%	5,8%	*5,0%*		8,6%	8,6%	*6,5%*	*8,0%*

Tableau 34
Estimateurs Pvehco selon le type de route et la vocation de la route pour la période HPJ

TYPEROUTE	COM	CVM	IND	RES	RUR
artère	6,9%	8,5%	6,6%	5,7%	9,9%
highway	5,9%	5,9%	5,9%	5,9%	9,9%
artère mineure	*6,0%*	*7,0%*	12,4%	*5,0%*	*6,0%*
collectrice	*5,0%*		12,4%	*5,0%*	*5,0%*
artère pont	4,1%	4,1%	4,1%	4,1%	
highway pont	5,2%	5,2%	5,2%	5,2%	
local	*4,0%*		*9,0%*	*5,0%*	
voie de service	*5,0%*		10,4%	10,4%	*10,0%*

Tableau 35
Estimateurs Pvehco selon le type de route, le sens ou non de la congestion AM et la vocation de la route en période PM

TYPEROUTE	CONG	CONG	CONG	CONG	INV	INV	INV	INV	CONG	INV
	COM	CVM	IND	RES	COM	CVM	IND	RES	RUR	RUR
artère	4,0%	4,0%	4,0%	3,1%	3,8%	4,2%	4,2%	2,8%	7,0%	8,2%
highway	3,9%	3,9%	3,9%	3,9%	3,4%	3,4%	3,4%	3,4%	7,0%	8,2%
artère mineure	*4,0%*	*4,0%*	6,4%	*4,0%*	*4,0%*	*4,0%*	6,0%	*3,0%*	*6,0%*	*6,0%*
collectrice	*4,0%*		6,4%	*4,0%*	*4,0%*		6,0%	*3,0%*	*6,0%*	*6,0%*
artère pont	3,0%	3,0%	3,0%	3,0%	2,3%	2,3%	2,3%	2,3%		
highway pont	3,2%	3,2%	3,2%	3,2%	2,7%	2,7%	2,7%	2,7%		
local	*4,0%*		*4,0%*	*4,0%*	*4,0%*		*5,0%*	*4,0%*		
voie de service	*4,0%*		4,6%	4,6%	*4,0%*		5,2%	5,2%	*6,0%*	*6,0%*

Tableau 36
Estimateurs Pcamrg selon le type de route, le sens ou non de la congestion AM et la vocation de la route pour la période AM

TYPEROUTE	CONG	CONG	CONG	CONG	INV	INV	INV	INV	CONG	INV
	COM	CVM	IND	RES	COM	CVM	IND	RES	RUR	RUR
artère	2,0%	1,6%	3,4%	1,7%	3,2%	4,8%	3,6%	2,3%	3,4%	4,7%
highway	2,6%	2,6%	2,6%	2,6%	4,0%	4,0%	4,0%	4,0%	3,4%	4,7%
artère mineure	*2,0%*	*2,0%*	5,4%	*2,0%*	*3,0%*	*3,0%*	5,7%	*3,0%*	*3,0%*	*4,0%*
collectrice	*2,0%*		5,4%	*2,0%*	*3,0%*		5,7%	*3,0%*	*3,0%*	*4,0%*
artère pont	1,2%	1,2%	1,2%	1,2%	2,6%	2,6%	2,6%	2,6%		
highway pont	2,1%	2,1%	2,1%	2,1%	4,1%	4,1%	4,1%	4,1%		
local	*2,0%*		*5,0%*	*3,0%*	*3,0%*		*4,0%*	*3,0%*		
voie de service	*2,0%*		2,7%	2,7%	*3,0%*		3,6%	3,6%	*3,0%*	*4,0%*

Tableau 37
Estimateurs Pcamrg selon le type de route et la vocation de la route pour la période HPJ

TYPEROUTE	COM	CVM	IND	RES	RUR
artère	4,1%	4,0%	4,9%	3,0%	5,4%
highway	5,3%	5,3%	5,3%	5,3%	5,4%
artère mineure	*5,0%*	*4,0%*	8,0%	*4,0%*	*5,0%*
collectrice	*5,0%*		8,0%	*4,0%*	*5,0%*
artère pont	2,7%	2,7%	2,7%	2,7%	
highway pont	4,6%	4,6%	4,6%	4,6%	
local	*5,0%*		*6,0%*	*4,0%*	
voie de service	*5,0%*		5,6%	5,6%	*6,0%*

Tableau 38
Estimateurs Pcamrg selon le type de route, le sens ou non de la congestion AM et la vocation de la route en période PM

TYPEROUTE	CONG	CONG	CONG	CONG	INV	INV	INV	INV	CONG	INV
	COM	CVM	IND	RES	COM	CVM	IND	RES	RUR	RUR
artère	2,8%	2,3%	2,6%	1,3%	1,7%	0,9%	2,6%	1,2%	2,8%	3,0%
highway	2,7%	2,7%	2,7%	2,7%	2,5%	2,5%	2,5%	2,5%	2,8%	3,0%
artère mineure	*3,0%*	*3,0%*	3,9%	*2,0%*	*2,0%*	*1,0%*	4,8%	*2,0%*	*3,0%*	*3,0%*
collectrice	*3,0%*		3,9%	*2,0%*	*2,0%*		4,8%	*2,0%*	*3,0%*	*3,0%*
artère pont	1,5%	1,5%	1,5%	1,5%	1,1%	1,1%	1,1%	1,1%		
highway pont	2,9%	2,9%	2,9%	2,9%	1,8%	1,8%	1,8%	1,8%		
local	*2,0%*		*3,0%*	*2,0%*	*2,0%*		*3,0%*	*2,0%*		
voie de service	*2,0%*		1,6%	1,6%	*2,0%*		2,8%	2,8%	*3,0%*	*3,0%*

Tableau 39
Estimateurs Pcamlo selon le type de route, le sens ou non de la congestion AM et la vocation de la route pour la période AM

TYPEROUTE	CONG COM	CONG CVM	CONG IND	CONG RES	INV COM	INV CVM	INV IND	INV RES	CONG RUR	INV RUR
artère	0,9%	0,5%	1,7%	0,9%	1,4%	2,7%	2,8%	1,3%	5,6%	7,2%
highway	4,2%	4,2%	4,2%	4,2%	5,2%	5,2%	5,2%	5,2%	5,6%	7,2%
artère mineure	*1,0%*	*1,0%*	3,1%	*1,0%*	*2,0%*	*2,0%*	4,4%	*2,0%*	*3,0%*	*5,0%*
collectrice	*1,0%*		3,1%	*1,0%*	*2,0%*		4,4%	*2,0%*	*3,0%*	*5,0%*
artère pont	0,6%	0,6%	0,6%	0,6%	1,4%	1,4%	1,4%	1,4%		
highway pont	1,7%	1,7%	1,7%	1,7%	4,4%	4,4%	4,4%	4,4%		
local	*1,0%*		*3,0%*	*1,0%*	*2,0%*		*4,0%*	*2,0%*		
voie de service	*2,0%*		1,7%	1,7%	*3,0%*		3,5%	3,5%	*5,0%*	*7,0%*

Tableau 40
Estimateurs Pcamlo selon le type de route et la vocation de la route pour la période HPJ

TYPEROUTE	COM	CVM	IND	RES	RUR
artère	1,5%	1,5%	4,0%	1,2%	9,9%
highway	7,5%	7,5%	7,5%	7,5%	9,9%
artère mineure	*3,0%*	*3,0%*	5,9%	*2,0%*	*5,0%*
collectrice	*3,0%*		5,9%	*2,0%*	*5,0%*
artère pont	1,5%	1,5%	1,5%	1,5%	
highway pont	5,1%	5,1%	5,1%	5,1%	
local	*3,0%*		*5,0%*	*2,0%*	
voie de service	*3,0%*		3,3%	3,3%	*10,0%*

Tableau 41
Estimateurs Pcamlo selon le type de route, le sens ou non de la congestion AM et la vocation de la route en période PM

TYPEROUTE	CONG COM	CONG CVM	CONG IND	CONG RES	INV COM	INV CVM	INV IND	INV RES	CONG RUR	INV RUR
artère	1,6%	1,0%	2,2%	0,5%	0,6%	0,1%	1,7%	0,6%	5,2%	5,4%
highway	4,6%	4,6%	4,6%	4,6%	4,3%	4,3%	4,3%	4,3%	5,2%	5,4%
artère mineure	*2,0%*	*1,0%*	2,8%	*1,0%*	*1,0%*	*1,0%*	3,2%	*1,0%*	*3,0%*	*4,0%*
collectrice	*2,0%*		2,8%	*1,0%*	*1,0%*		3,2%	*1,0%*	*3,0%*	*4,0%*
artère pont	0,9%	0,9%	0,9%	0,9%	0,6%	0,6%	0,6%	0,6%		
highway pont	3,4%	3,4%	3,4%	3,4%	1,6%	1,6%	1,6%	1,6%		
local	*2,0%*		*2,0%*	*1,0%*	*1,0%*		*2,0%*	*1,0%*		
voie de service	*2,0%*		1,3%	1,3%	*1,0%*		1,4%	1,4%	*5,0%*	*5,0%*

La période HPJ comme période représentative des périodes NUIT et HPS pour l'estimation des volumes de camions et des véhicules légers identifiés commerciaux

Nous pouvons compter sur les 27 comptages classifiés non manuels pour examiner la pertinence de considérer les estimateurs Pcamrg et Pcamlo de la période hors pointe du jour (HPJ) comme estimateurs des périodes hors pointe du soir et de nuit (HPS et NUIT). Et nous pourrons étendre l'hypothèse au cas des estimateurs Pvehco.

On peut donc avoir une idée du degré de similitude de la période HPJ avec les périodes HPS et NUIT dans les prochains tableaux en regard des moyennes obtenues sur les variables Pcamrg et Pcamlo pour les 27 comptages classifiés non manuels selon le type de route et le secteur. Il faut se rappeler que les comptages classifiés non manuels sont des comptages classifiés par longueur de véhicule ou par nombre d'essieux du véhicule. Des hypothèses d'agrégation de ces classes brutes en camions réguliers et en camions lourds ont été faites. Rappelons aussi que les comptages classifiés non manuels ne nous fournissent pas de volumes de véhicules légers identifiés commerciaux.

Voici la répartition des 27 comptages classifiés non manuels suivant les quatre groupes déjà considérés dans le cas des comptages classifiés manuels pour les trois types de route dans lesquels se répartissent ces comptages et pour les périodes de la journée HPJ, HPS et NUIT :

Tableau 42
Regroupement des 27 comptages classifiés non manuels suivant le type de route et la vocation de la route sur chacune des trois périodes NUIT, HPJ et HPS

TYPEROUTE	COM	CVM	IND	RES	RUR
	PÉRIODE HPJ				
artère				8	5
highway	11				
highway pont	3				
	PÉRIODE HPS				
artère				8	5
highway	11				
highway pont	3				
	PÉRIODE NUIT				
artère				8	5
highway	11				
highway pont	3				

Le prochain tableau présente les proportions moyennes de camions réguliers (Pcamrg) obtenues sur les comptages classifiés non manuels pour chacune des périodes HPJ, HPS et NUIT. Il s'agit de comparer les Pcamrg moyens de la période hors pointe du jour HPJ avec ceux des périodes HPS et NUIT :

Tableau 43
Comparaison des Pcamrg moyens pour les comptages classifiés non manuels sur les trois périodes HPJ, HPS et NUIT

TYPEROUTE	COM	CVM	IND	RES	RUR
	PÉRIODE HPJ				
artère				6,7%	5,0%
highway	5,4%				
highway pont	5,4%				
	PÉRIODE HPS				
artère				1,7%	2,3%
highway	2,6%				
highway pont	3,1%				
	PÉRIODE NUIT				
artère				3,6%	5,0%
highway	5,0%				
highway pont	7,7%				

Tableau 44
Comparaison des Pcamlo moyens pour les comptages classifiés non manuels sur les trois périodes HPJ, HPS et NUIT

TYPEROUTE	COM	CVM	IND	RES	RUR
	PÉRIODE HPJ				
artère				6,0%	6,7%
highway	10,1%				
highway pont	15,1%				
	PÉRIODE HPS				
artère				3,6%	4,2%
highway	12,6%				
highway pont	15,6%				
	PÉRIODE NUIT				
artère				9,0%	10,8%
highway	22,1%				
highway pont	27,2%				

Extrapolation estimative sur les comptages

Donc posons les proportions estimées (déduites des précédents tableaux) :
EPvehco[type_route, vocation_route, sens_congestion, période]
EPcamrg[type_route, vocation_route, sens_congestion, période]
EPcamlo[type_route, vocation_route, sens_congestion, période]

Notez que pour la variable période = HPJ, HPS ou NUIT, les estimateurs sont les mêmes peu importe la valeur de la variable sens_congestion (variable binaire).

Suivant le type de comptage en présence, on utilise les proportions du comptage ou des proportions estimées.

Pour un comptage non classifié sur les périodes (NUIT, AM, HPJ, PM, HPS)
Pvehco[période] = EPvehco[type_route, vocation_route, sens_congestion, période]
Pcamrg[période] = EPcamrg[type_route, vocation_route, sens_congestion, période]
Pcamlo[période] = EPcamlo[type_route, vocation_route, sens_congestion, période]

Pour un comptage classifié non manuel sur les périodes (NUIT, AM, HPJ, PM, HPS)
Pvehco[période] = EPvehco[type_route, vocation_route, sens_congestion, période]
Pcamrg[période] provient du comptage sauf si le comptage est rejeté pour cette proportion
alors prendre EPcamrg[type_route, vocation_route, sens_congestion, période]
Pcamlo[période] provenant du comptage sauf si le comptage est rejeté pour cette proportion
alors prendre EPcamlo[type_route, vocation_route, sens_congestion, période]

Pour un comptage classifié manuel sur les périodes (AM, HPJ, PM)
Pvehco[période] provient du comptage sauf si le comptage est rejeté pour cette proportion
alors prendre EPvehco[type_route, vocation_route, sens_congestion, période]
Pcamrg[période] provient du comptage sauf si le comptage est rejeté pour cette proportion
alors prendre EPcamrg[type_route, vocation_route, sens_congestion, période]
Pcamlo[période] provenant du comptage sauf si le comptage est rejeté pour cette proportion
alors prendre EPcamlo[type_route, vocation_route, sens_congestion, période]

Dans tous les types de comptages, on a toujours le volume total de véhicules par période pour le comptage que nous notons :
Vtot[période]

Pour la ou les journées de comptage, on dispose à partir des tables de facteurs DJMA et du profil de la route d'un facteur associé au comptage (la moyenne des facteurs DJMA des journées de comptages) désigné comme Cdjma. D'autre part, pour les 81 jours ouvrables d'automne 1998 où s'est tenu l'enquête O-D, on obtient pour ce même profil de route un facteur DJMA moyen (noté Fdjma). Bien que ces facteurs s'applique sur des comptages globaux 24 heures, nous les utilisons pour ramener sur la base d'un JOA (jour ouvrable d'automne) le volume total de véhicules par période pour le comptage :
Vtot[période] * Fdjma / Cdjma

Il découle alors que le volume de véhicules légers pour un comptage en équivalent JOA est fourni par la formule :
(1 – Pcamrg – Pcamlo) * Vtot[période] * Fdjma / Cdjma

Équivalence des classes agrégées de véhicules des comptages et des classes de véhicules modélisées

Pour établir l'équivalence entre les classes agrégées de véhicules des comptages, représentées par des proportions de véhicules légers identifiés commerciaux et de camions, et les classes de véhicules modélisées, il faut poser une hypothèse de répartition des véhicules légers identifiés commerciaux suivant leur usage (usage personnel ou usage commercial).

Soit PC[période], la proportion du nombre de véhicules légers identifiés commerciaux à usage commercial sur le nombre total de véhicules légers identifiés commerciaux. Alors nous posons comme hypothèses :

PC[NUIT]= 0,10
PC[AM] = 0,50
PC[HPJ] = 0,90
PC[PM] = 0,50
PC[HPS] = 0,75

Nous posons également comme hypothèse que les véhicules légers non identifiés commerciaux sont strictement à usage personnel.

Les volumes par période de la journée de véhicules des classes modélisées en équivalent JOA sur chacun des comptages se calculent par les formules suivantes.

Les véhicules légers à usage personnel sont les véhicules légers moins les véhicules légers identifiés commerciaux à usage commercial :

VEHPR[période] = (1 – (Pvehco*PC[période])) * (1 – Pcamrg – Pcamlo) * Vtot[période] * Fdjma / Cdjma

Les véhicules réguliers sonr les camions réguliers et les véhicules légers à usage commercial :

VEHRG[période] = Pcamrg + (Pvehco * PC[période] * (1 – Pcamrg – Pcamlo))) * Vtot[période] * Fdjma / Cdjma

Les véhicules lourds sont les camions lourds :

VEHLO[période] = Pcamlo * Vtot[période] * Fdjma / Cdjma

Dans l'environnement Emme/2, nous aurons donc à produire des extra-attributs sur les liens des comptages pour chacune des trois classes modélisées et chacune des cinq périodes de la journée (sauf pour les comptages classifiés manuels qui portent seulement sur les trois périodes AM, HPJ et PM).

Les identifiants proposés pour les extra-attributs seront composés de deux parties. Une première partie pour désigner la classe de véhicules : AUT pour VEHPR, CRG pour VEHRG et CLO pour VEHLO suivi d'une deuxième partie pour désigner la période de la journée : NU pour NUIT, AM, HJ pour HPJ, PM, HS pour HPS. On aura donc 15 extra-attributs sur les liens de ces comptages pour les volumes de véhicules «observés» (il y a 539 liens directionnels distincts, puisque certains comptages classifiés et non classifiés sont localisés au même endroit et portent donc sur un même lien) :

@AUTNU	@AUTAM	@AUTHJ	@AUTPM	@AUTHS
@CRGNU	@CRGAM	@CRGHJ	@CRGPM	@CRGHS
@CLONU	@CLOAM	@CLOHJ	@CLOPM	@CLOHS

Annexe 3

FONCTIONS D'UN CENTRE DE SERVICE À LA CLIENTÈLE

1. Gestion des transpondeurs
    a. Commandes, tests, stockage et tenue d'inventaire
    b. Sécurité
    c. Retours et remplacements
2. Service à la clientèle
    a. Fournitures pour les clients
        i. Demande d'adhésion
        ii. Trousses de transpondeurs
    b. Gestion des demandes d'adhésion
    c. Distribution et encodage des transpondeurs
    d. Gestion du courrier
    e. Gestion de sites web
    f. Système téléphonique
        i. Assistance directe
        ii. Système de réponse par voix interactive (IVR)
3. Gestion des comptes-clients
    a. Gestion des états de comptes
    b. Gestion des paiements
    c. Gestion des transactions
    d. Frais des clients
    e. Factures des clients
    f. Demandes de renseignements, plaintes et divergences
    g. Fermeture de comptes et comptes délinquants
    h. Perception des mauvaises dettes
    i. Invalidation des transpondeurs
    j. Suspension des comptes
    k. Comptes spéciaux (par ex. programmes pour résidants, comptes gouvernementaux, comptes commerciaux pré-payés, transpondeurs pour les voies réservées)
    l. Comptes commerciaux
    m. Comptes administratifs
4. Contrôle par vidéo
    a. Visionnement des vidéos
    b. Recherche à la SAAQ/Identification du client
    c. Production et envois des factures
    d. Perception des recettes
    e. Référence pour le contrôle des infractions
5. Gestion des infractions *(ce processus varie tellement d'une agence à l'autre qu'il est difficile d'en faire ressortir les fonctions principales)*
    a. Contrôle des membres
        i. Avis d'infraction
    b. Contrôle des non-membres
        i. Traitement des images et validation
        ii. Recherche à la SAAQ/Identification du client
        iii. Production et envois des avis d'infraction
        iv. Perception des recettes
    c. Contrôle des infractions et amendes
6. Transmissions de fichiers

   a. Fichiers de validation des transpondeurs
   b. Mise-à-jour des fichiers de validation des transpondeurs
   c. Fichiers des cas d'exception de transpondeurs
   d. Fichiers de transactions
   e. Fichiers des cas d'exception de transactions
   f. Fichiers d'images

7. Suivi de la performance
   a. Rapports requis sur:
      i. Gestion et distribution des transpondeurs
      ii. Service à la clientèle
      iii. Gestion des comptes-clients
      iv. Gestion des infractions
      v. Opérations du système
      vi. Gestion des revenus/coûts et conciliation
   b. Suivi du rendement
   c. Vérifications

8. Gestion des revenus/coûts et conciliation
   a. Distribution des revenus
      i. Péages pré-payés
      ii. Acomptes sur les transpondeurs et revenus des ventes
      iii. Frais de gestion administrative et péages associés
      iv. Frais divers

Note: Les revenus provenant des cartes de crédit, transferts inter-bancaires et agences réciproques sont habituellement déposés directement dans le compte de banque des agences.

9. Marketing et promotion

10. Création et exécution d'un plan de recouvrement en cas de sinistre

11. Administration, entretien et mises à jour des systèmes

12. Réciprocité et inter-opérabilité des comptes-clients
   a. Échange des fichiers de transaction
   b. Transactions après-vente
   c. Processus d'entente
   d. Échange des fichiers de validation des transpondeurs
   e. Service à la clientèle
   f. Comptes conjoints
   g. Rapports de réciprocité
   h. Conciliation des revenus

13. Demandes de subventions non-reliées aux revenus de péage

14. Projets de tarification variable, de tarification de la congestion ou tarification dynamique

Annexe 4

Municipalité: Saint-Laurent
Localisation: à la hauteur de la rue Sunset, face à l'ONF

1997	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	111,810	144,470	151,960	155,210	156,390	147,640	120,270	141,100	
Février	123,820	152,230	153,690	154,260	151,460	157,930	133,840	146,700	
Mars	128,620	155,840	154,630	160,600	164,560	168,060	141,860	153,500	
Avril	131,230	157,380	160,760	165,600	171,680	178,370	153,770	159,800	
Mai	136,780	164,820	165,260	169,020	169,900	173,690	151,300	161,500	
Juin	142,000	165,000	168,000	169,000	173,000	178,000	147,000	163,100	
Juillet	139,000	163,000	164,000	170,000	168,000	174,000	149,000	161,000	
Août	145,000	161,000	165,000	169,000	173,000	173,000	151,000	162,400	
Septembre	137,000	162,000	165,000	165,000	168,000	173,000	158,000	161,100	
Octobre	131,000	156,000	160,000	164,000	165,000	169,000	134,000	154,100	
Novembre	126,000	150,000	150,000	158,000	161,000	171,000	147,000	151,900	
Décembre	114,000	144,000	146,000	151,000	157,000	150,000	131,000	141,900	
Jour moyen	130,500 a	156,300	158,700	162,600	164,900	167,800	143,200 b	154,800	

Jour ouvrable moyen d'automne **162500** c

Jour non-ouvrable équivalence sur 115 jours [(a + b) / 2] / c *115 **96.85** e

75.54

Jour non-ouvrable avec Fejno équivalence sur 115 jours e * Fejno

Jour ouvrable d'automne équivalence sur 250 jours 250 / d

249.38

Jour ouvrable moyen annuel **162100**

automne/ annuel **100.2%** d

Total **324.93**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Laval

Localisation: A-25 approche nord du pont Pie-IX sur la rivière des Prairies

1999	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1999	Jour moyen ajusté 1998
Janvier	50,710	74,840	77,030	79,570	79,230	73,940	53,140	69,800	
Février	52,710	77,070	78,900	80,670	82,540	87,430	57,810	73,900	
Mars	55,560	78,370	82,090	82,720	82,700	88,140	60,700	75,800	
Avril	60,230	83,930	87,990	88,880	91,020	95,740	66,850	82,100	
Mai	66,240	89,340	91,300	91,760	95,420	99,240	70,020	86,200	
Juin	65,490	91,130	93,370	97,190	96,730	101,340	70,370	87,900	
Juillet	63,400	86,520	88,850	91,620	91,900	95,530	65,470	83,300	
Août	59,890	87,370	88,860	88,630	90,450	93,500	64,740	81,900	
Septembre	64,420	88,310	90,930	94,160	92,700	96,210	69,380	85,200	
Octobre	58,930	85,810	89,070	90,530	93,690	98,240	67,530	83,400	
Novembre	55,920	84,800	86,710	88,750	89,850	93,950	65,390	80,800	
Décembre	55,520	81,930	86,130	87,900	89,660	93,730	63,940	79,800	
Jour moyen	59,100 a	84,100	86,800	88,500	89,700	93,100	64,600 b	80,800	

Jour ouvrable moyen d'automne **90900** c

Jour non-ouvrable équivalence sur 115 jours
[(a + b) / 2] / c *115 **78.25** e

Jour non-ouvrable avec Fejno équivalence sur 115 jours
e * Fejno **61.03**

Jour ouvrable d'automne équivalence sur 250 jours
250 / d **243.12**

Jour ouvrable moyen annuel **88400**

automne/ annuel **102.8%** d

Total **304.16**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Bois-des-Filion
Localisation: Rte 335 approche nord-ouest de la rivière des Mille-Îles (sur le pont)

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	12,650	17,400	18,000	17,980	18,800	19,260	14,510	16,900	18000
Février	13,830	18,280	18,740	18,670	19,120	20,850	15,220	17,800	18600
Mars	14,170	18,320	19,140	19,570	19,230	21,020	15,510	18,100	19800
Avril	16,250	19,010	21,240	21,290	21,490	21,590	17,330	19,700	20700
Mai	16,920	19,960	21,950	22,420	22,990	24,210	18,360	21,000	21500
Juin	16,780	21,630	22,530	21,380	23,000	23,980	18,180	21,100	21300
Juillet	15,730	18,640	19,660	19,350	20,400	21,100	15,970	18,700	18600
Août	16,320	20,310	20,580	21,650	22,000	23,320	16,920	20,200	20000
Septembre	15,850	19,690	21,750	22,270	22,750	24,600	17,720	20,700	21400
Octobre	16,660	19,350	21,600	21,590	22,120	23,990	18,300	20,500	19900
Novembre	14,840	19,700	20,520	20,620	21,100	22,340	16,890	19,400	17700
Décembre	13,390	17,650	18,950	19,130	18,750	20,760	15,330	17,700	18600
Jour moyen	15,300 a	19,200	20,400	20,500	21,000	22,300	16,700b	19,300	

Jour ouvrable moyen d'automne	**21600** c	**Jour non-ouvrable équivalence sur 115 jours [(a + b) / 2] / c *115**	**85.19** e	**66.44**	**Jour non-ouvrable avec Fejno équivalence sur 115 jours e * Fejno**
Jour ouvrable moyen annuel	**20700**	**Jour ouvrable d'automne équivalence sur 250 jours 250 / d**		**239.58**	
automne/ annuel	**104.3%** d		Total	**306.03**	note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Laval
Localisation: A-25 au sud du pont Mathieu (entre Laval et l'île Saint-Jean)

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	44,660	58,020	58,690	62,050	60,350	60,040	47,790	55,900	58000
Février	49,240	62,970	63,640	65,700	68,400	72,920	54,450	62,500	61000
Mars	20,800	65,380	66,450	67,910	70,410	73,580	58,590	60,400	64000
Avril	58,310	68,820	75,070	75,960	78,550	77,250	61,020	70,700	67000
Mai	59,150	68,520	77,970	79,140	81,620	86,620	64,070	73,900	75000
Juin	60,190	74,850	78,150	72,910	81,410	84,990	64,360	73,800	79000
Juillet	61,490	71,380	73,730	71,670	76,110	80,950	59,880	70,700	72000
Août	64,240	77,180	76,610	81,390	83,610	87,410	65,150	76,500	78000
Septembre	59,950	64,500	78,790	78,710	82,390	89,540	63,260	73,900	71000
Octobre	60,460	68,010	76,380	77,700	80,330	85,510	66,320	73,500	63000
Novembre	55,110	71,730	73,830	75,400	76,650	82,520	61,970	71,000	63000
Décembre	50,940	63,640	69,690	68,450	69,330	72,510	56,980	64,500	65000
Jour moyen	53,700 a	67,900	72,400	73,100	75,800	79,500	60,300b	68,900	

Jour ouvrable moyen d'automne **77500** c

Jour non-ouvrable équivalence sur 115 jours
[(a + b) / 2] / c *115 **84.58** e

65.97

Jour non-ouvrable avec Fejno équivalence sur 115 jours
e * Fejno

Jour ouvrable d'automne équivalence sur 250 jours
250 / d

237.74

Jour ouvrable moyen annuel **73700**

automne/ annuel **105.2%** d

Total **303.71**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Laval
Localisation: A-15 approche nord du pont Médéric-Martin

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	120,000	146,000	147,000	151,000	152,000	166,600	142,180	146,400	
Février	122,430	151,000	154,000	160,000	163,000	169,000	138,000	151,100	
Mars	131,000	154,000	158,000	165,000	161,000	173,000	143,000	155,000	
Avril	136,490	158,030	169,090	173,200	177,490	173,880	146,770	162,100	
Mai	140,250	152,480	170,820	174,680	178,470	185,890	150,410	164,700	
Juin	143,830	169,880	177,860	161,080	181,470	186,850	156,850	168,300	
Juillet	151,980	175,640	167,000	141,220	188,110	185,010	139,230	164,000	
Août	140,000	168,000	170,000	171,000	178,000	179,000	152,000	165,400	
Septembre	141,000	161,000	162,000	166,000	173,000	176,000	153,000	161,700	
Octobre	126,330	157,060	168,310	174,490	176,270	182,290	141,230	160,900	
Novembre	130,390	160,470	167,170	168,790	171,130	183,760	150,640	161,800	
Décembre	125,750	157,350	165,370	170,100	171,520	182,150	151,970	160,600	
Jour moyen	134,100 a	159,200	164,700	164,700	172,600	178,600	147,100b	160,200	

Jour ouvrable moyen d'automne **169800** c

Jour non-ouvrable équivalence sur 115 jours [(a + b) / 2] / c *115 **95.22** e

74.27

Jour non-ouvrable avec Fejno équivalence sur 115 jours e * Fejno

Jour ouvrable d'automne équivalence sur 250 jours 250 / d

247.35

Jour ouvrable moyen annuel **168000**

automne/ annuel **101.1%** d

Total **321.62**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Saint-Bernard-de-Lacolle
Localisation: A-15 à 1,1 km au sud de la route 202

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	6,750	4,900	4,900	5,100	5,400	5,900	4,900	5,400	5000
Février	5,710	5,600	5,260	5,090	5,530	6,330	5,820	5,600	5200
Mars	6,230	6,010	5,880	5,920	6,260	6,680	5,640	6,100	5700
Avril	7,220	6,080	6,260	6,420	6,560	7,170	6,450	6,600	6400
Mai	7,380	7,490	6,270	6,350	6,790	8,410	7,440	7,200	6600
Juin	8,770	7,000	6,900	7,710	7,350	9,070	7,510	7,800	9200
Juillet	12,640	9,060	7,740	8,230	8,590	11,820	7,320	9,300	10400
Août	9,800	7,700	7,700	7,800	8,100	9,200	8,500	8,400	10500
Septembre	7,310	6,170	6,140	6,220	6,510	8,180	7,420	6,900	6900
Octobre	7,180	6,950	6,100	5,990	6,160	7,580	6,790	6,700	7000
Novembre	6,410	6,080	5,700	5,880	5,980	6,600	5,520	6,000	5800
Décembre	5,290	5,480	5,680	5,830	5,280	5,180	5,000	5,400	5100
Jour moyen	7,600 a	6,500	6,200	6,400	6,500	7,700	6,500b	6,800	

Jour ouvrable moyen d'automne **6400** c

Jour non-ouvrable équivalence sur 115 jours
[(a + b) / 2] / c *115
126.68 e

Jour non-ouvrable avec Fejno équivalence sur 115 jours
e * Fejno
98.81

Jour ouvrable d'automne équivalence sur 250 jours
250 / d
261.72

Jour ouvrable moyen annuel **6700**

automne/annuel **95.5%** d

Total **360.53**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Mercier
Localisation: A-30 à 1,6 km à l'est de la route 132-138

1999	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1999	Jour moyen ajusté 1998
Janvier	6,940	11,710	12,600	13,040	12,950	12,180	8,400	11,100	
Février	8,690	12,710	12,310	13,410	13,570	13,930	8,310	11,800	
Mars	10,000	13,230	13,530	13,970	13,760	14,280	9,980	12,700	
Avril	10,350	13,140	14,570	14,800	15,130	15,130	10,650	13,400	
Mai	11,660	13,840	15,330	15,870	16,190	16,880	12,520	14,600	
Juin	12,710	16,610	16,560	17,720	15,370	17,950	13,990	15,800	
Juillet	12,880	15,470	15,670	16,490	16,100	16,890	12,750	15,200	
Août	12,940	15,380	15,710	15,910	16,630	17,210	13,070	15,300	
Septembre	11,290	13,810	15,320	15,840	16,200	16,880	11,940	14,500	
Octobre	9,820	13,390	14,990	15,420	15,730	16,620	11,120	13,900	
Novembre	9,310	14,330	14,480	15,100	15,310	15,680	10,710	13,600	
Décembre	8,860	13,700	14,470	14,730	15,000	15,360	9,520	13,100	
Jour moyen	10,500 a	13,900	14,600	15,200	15,200	15,700	11,100b	13,800	

Jour ouvrable moyen d'automne **15300** c

Jour non-ouvrable équivalence sur 115 jours
[(a + b) / 2] / c *115

81.18 e

63.32
243.46
Total **306.78**

Jour non-ouvrable avec Fejno équivalence sur 115 jours
e * Fejno

Jour ouvrable moyen annuel **14900**

Jour ouvrable d'automne équivalence sur 250 jours
250 / d

automne/ annuel **102.7%** d

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Vaudreuil-Dorion
Localisation: Rte 540 à 32 mètres au nord du pont d'étagement de la route 340

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	20,000	26,000	27,000	28,000	28,000	30,000	20,000	25,600	
Février	22,000	28,000	28,000	30,000	29,000	31,000	22,000	27,100	
Mars	23,000	28,000	30,000	31,000	31,000	33,000	24,000	28,600	
Avril	26,000	31,000	31,000	32,000	34,000	34,000	23,000	30,100	
Mai	27,000	32,000	32,000	33,000	35,000	38,000	27,000	32,000	
Juin	27,000	32,000	32,000	34,000	34,000	38,000	27,000	32,000	
Juillet	32,000	34,000	34,000	36,000	37,000	40,000	32,000	35,000	
Août	31,920	36,320	35,000	36,000	38,600	40,980	29,300	35,400	
Septembre	29,350	33,760	35,000	35,930	37,130	40,990	29,970	34,600	
Octobre	26,330	32,290	33,580	33,950	34,680	38,120	26,490	32,200	
Novembre	24,380	31,120	32,160	33,040	33,230	35,670	24,340	30,600	
Décembre	22,580	30,590	31,640	32,310	32,480	35,190	23,960	29,800	
Jour moyen	26,000 a	31,300	31,800	32,900	33,700	36,200	25,800 b	31,100	

Jour ouvrable moyen d'automne **34700** c

Jour non-ouvrable équivalence sur 115 jours
[(a + b) / 2] / c *115 **85.84** e

66.95

Jour non-ouvrable avec Fejno équivalence sur 115 jours
e * Fejno

Jour ouvrable moyen annuel **33200**

Jour ouvrable d'automne équivalence sur 250 jours
250 / d

239.19

automne/annuel **104.5%** d

Total **306.14**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Grande-île
Localisation: Rte 201 à l'entrée sud du pont

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	19,220	22,400	22,780	25,570	23,020	26,550	22,550	23,200	24000
Février	22,330	26,400	26,710	26,230	28,740	30,430	23,870	26,400	25000
Mars	23,000	26,700	27,380	28,280	28,530	30,910	24,290	27,000	26000
Avril	25,310	29,090	29,750	30,300	31,960	33,270	26,940	29,500	28000
Mai	26,990	29,470	31,210	32,450	34,610	35,100	28,960	31,300	30000
Juin	27,680	30,850	31,600	32,290	34,920	35,330	29,140	31,700	31000
Juillet	29,800	30,710	31,030	31,880	33,900	34,590	27,830	31,400	31000
Août	27,450	30,000	30,450	32,390	34,500	34,560	28,000	31,100	30000
Septembre	25,820	27,940	30,570	30,550	32,560	34,790	27,880	30,000	30000
Octobre	25,600	27,560	29,870	29,790	32,490	34,040	26,820	29,500	29000
Novembre	23,750	28,010	28,420	29,150	31,190	32,550	26,110	28,500	28000
Décembre	22,440	26,130	27,820	28,150	29,510	29,330	23,990	26,800	26000
Jour moyen	24,900 a	27,900	29,000	29,800	31,300	32,600	26,400b	28,900	

Jour ouvrable moyen d'automne **30600** c

Jour non-ouvrable équivalence sur 115 jours [(a + b) / 2] / c *115 **96.40** e

75.19

Jour non-ouvrable avec Fejno équivalence sur 115 jours e * Fejno

Jour ouvrable d'automne équivalence sur 250 jours 250 / d

245.92

Jour ouvrable moyen annuel **30100**

automne/ annuel **101.7%** d

Total **321.10**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Sainte-Catherine
Localisation: Rte 132 à 2,4 km à l'est de l'autoroute 30

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	29,000	37,000	37,000	39,000	39,000	41,000	33,000	36,400	33000
Février	28,000	37,000	39,000	40,000	40,000	43,000	33,000	37,100	35000
Mars	31,920	37,810	39,300	40,850	39,450	43,770	36,750	38,600	36000
Avril	33,700	40,350	42,110	42,650	44,750	45,840	37,680	41,000	40000
Mai	35,560	40,540	43,630	44,480	45,780	48,960	40,050	42,700	43000
Juin	35,550	40,700	42,470	39,840	44,910	46,800	38,670	41,300	44000
Juillet	36,420	40,060	41,490	40,600	43,870	46,140	36,260	40,700	43000
Août	36,870	42,120	42,940	45,080	46,980	49,640	37,670	43,000	42000
Septembre	33,860	39,190	42,840	43,170	45,380	49,460	38,620	41,800	41000
Octobre	33,590	38,840	42,000	42,230	44,760	48,700	38,590	41,200	40000
Novembre	31,490	39,700	41,550	42,200	43,570	46,480	36,120	40,200	38000
Décembre	29,850	38,230	39,400	39,840	38,970	41,200	33,810	37,300	38000
Jour moyen	33,000 a	39,300	41,100	41,700	43,100	45,900	36,700b	40,100	

Jour ouvrable moyen d'automne **43300** c

Jour ouvrable moyen annuel **42200**

automne/annuel **102.6%** d

Jour non-ouvrable équivalence sur 115 jours
[(a + b) / 2] / c *115

92.56 e

72.20

Jour non-ouvrable avec Fejno équivalence sur 115 jours
e * Fejno

Jour ouvrable d'automne équivalence sur 250 jours
250 / d

243.65

Total **315.84**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne

Municipalité: Saint-Timothée
Localisation: Rte 132 à 5,5 km à l'ouest du tunnel de Melocheville

1998	Dimanche moyen	Lundi moyen	Mardi moyen	Mercredi moyen	Jeudi moyen	Vendredi moyen	Samedi moyen	Jour moyen ajusté 1998	Jour moyen ajusté 1997
Janvier	5,840	7,720	8,110	8,020	8,060	7,950	6,000	7,400	7000
Février	6,500	8,090	8,340	8,250	8,600	9,110	6,680	7,900	7300
Mars	6,260	7,580	7,980	8,330	8,320	8,600	6,810	7,700	7500
Avril	7,290	8,360	9,110	9,330	9,070	9,610	7,690	8,600	8400
Mai	7,950	8,710	9,310	9,990	10,100	10,470	8,170	9,200	9100
Juin	8,110	9,010	9,420	9,220	9,760	10,020	8,040	9,100	9800
Juillet	9,310	8,730	8,880	8,740	9,390	9,690	8,210	9,000	8800
Août	8,650	9,000	9,160	9,780	9,950	10,050	8,300	9,300	9200
Septembre	6,910	8,820	9,430	9,470	10,110	10,190	7,710	8,900	8600
Octobre	7,330	8,300	9,180	9,080	9,560	9,990	7,540	8,700	8400
Novembre	6,670	8,340	8,640	8,890	9,070	9,390	6,990	8,300	8700
Décembre	6,170	7,590	8,120	8,110	7,870	8,680	6,360	7,600	6400
Jour moyen	7,200 a	8,400	8,800	8,900	9,200	9,500	7,400 b	8,500	

Jour ouvrable moyen d'automne **9200** c

Jour non-ouvrable équivalence sur 115 jours [(a + b) / 2] / c *115 **91.25** e

71.18

Jour non-ouvrable avec Fejno équivalence sur 115 jours e * Fejno

Jour ouvrable d'automne équivalence sur 250 jours 250 / d

241.85

Jour ouvrable moyen annuel **8900**

automne/ annuel **103.4%** d

Total **313.02**

note: la simulation d'un jour ouvrable porte sur 63 jours d'automne