Road Congestion Assessment
« From theory to practice »
Case of the Greater Montréal Road Network

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SUMMARY

The first part of the presentation outlines the current congestion-related concepts, the measurements and indicators used elsewhere, and it describes the method and indicators developed for Greater Montréal.

The second part of the presentation explains the computerized methods used to measure queues. The systems were designed in the framework of an MTQ ongoing traffic survey program in the Montréal area, aimed at measuring the evolution of travel times.

Two computerized survey methods were designed to measure the position of vehicles. The first, the Odometer technique (semi-automatic), uses vehicle odometers while the other method relies on GPS (Global Positioning System). Either apparatus allow to record, second-by-second, the exact position of vehicles and to compute running speed, travel time and position, the length and duration of queues, and delay rates. A number of computer applications were developed to process collected data and to generate synthesis reports that yield **a comprehensive rendering of the morphology of congestion on the Greater Montréal road network**. The results depicting queues, and travel times and speeds, were mapped and are shown in MapInfo format.

CONCLUSION

The MTQ has expressed its full satisfaction with the smooth running of the project and the high validity of collected data. The client's initial expectations were surpassed: the wealth of data has spurred different applications than those contemplated at the outset of the project.

In view of the small sampling available, it is impossible at this time to draw pertinent conclusions on the evolution congestion in the Greater Montréal road network. The next phase of the project will therefore consist in the statistical validation of this sampling and to determine the extent of the sampling required to obtain statistically valid results.

While the GPS technique offers numerous operational benefits, it nevertheless requires the installation of a succession system to offset the loss of GPS signal reception at certain road facilities such as tunnels, bridges and in some areas in downtown Montréal.

1. ROAD CONGESTION ASSESSMENT

1.1 Background

Road congestion is a worldwide phenomenon, and increasingly so, affecting most urban and metropolitan roads and highways. Few organisations responsible for the management of road networks have implemented adequate means to systematically measure and analyse the issue.

Congestion is an important factor for the economy, the transportation of goods and overall for the transportation network users. Congestion impacts translate into increases in transit time, fuel consumption, pollution, stress, mishaps and accidents. In addition, it reduces the workforce pool while impinging on the accessibility to economic events or activities.

Congestion also builds on the combination of several factors such as user behaviour, climate conditions, geometry and layout to create randomness and even chaos. Traditional traffic assessment methods using the v/c ratio as well as empirical or modeling methods do not acquire the entire congestion conditions particular to each of the corridors.

In Metropolitan Montréal, the need for assessing congestion relates to the implementation of strategic plans by the *ministère des Transports du Québec*. Actually, it has been decided to make use of indicators that identify road congestion problems, describe how they evolve and eventually establish comparisons with other North American cities.

Part I of this presentation is a reminder of the theoretical concepts and of the measurements and indicators, which can be used to assess congestion. Part II explains the methodology inherent to the computerized plotting of line-ups and traveling time including the application itself.

1.2 Congestion : a concept

The *NCHRP Report 398*[1] defines congestion using two benchmarks - congestion and unacceptable congestion:

- Congestion occurs when the resulting traveling time exceeds the traveling time normally recorded in light traffic conditions or free flowing traffic
- Congestion is unacceptable when the traveling time (and time gap) exceeds a standard generally accepted in the community. This standard will differ with the following :
  - Type of transportation infrastructure
  - Transportation mode
  - Geographic location
  - Time of day.

Congestion is always measured in relation to socio-cultural acceptability thresholds within specific populations. This tolerability can vary within the population (or according to individuals and their state of mind) and according to time of day and time of year. There is no common ground between experiencing a 20-minute congestion in the morning rush hour and going through a 20-minute queue caused by construction roadblocks at 01:00.

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[1] NCHRP Report 398 – *Quantifying Congestion*, Volume 1, Final Report, Transportation Research Board, National Research Council, 1997

The report also emphasizes how important it is to define what is an unacceptable congestion threshold in traveling time measurement applications. An acceptable range of speed or of traveling time may be used to identify where the transportation system requires improvement. This acceptable intensity may be different downtown and in the suburbs as it certainly will be on a highway and on urban streets.

Congestion may be recurring (occurring in the same location, at the same time each weekday or each same weekend day) or non recurrent where it is due to disruptions such as accidents or construction work.

Although the concept circulates in the media, the public, politicians and transportation professionals do not agree on a single, widely accepted definition of congestion based on one and only one measurement.

A definition of congestion should take into account the following crucial and necessarily incidental aspects of the problem :

- Congestion duration (« Duration ») : time of day where the selected indicator confirms the congestion event (time weight)
- Extent of congestion (« Extent ») : the number of persons or vehicles involved and affected by this congestion (quantity weight) and its spread or spill
- Congestion intensity (« Intensity ») establishes different levels of congestion that upsets routing (for example : severe, moderate or none); congestion may also possess speed attributes
- Precision in the measurement of congestion (« Reliability ») : this important aspect of congestion assessment feeds on the fluctuations of the three items above and identifies the range of their possible combinations (using, for example, standard deviation) in order to highlight recurring events and both aberrant or acute situations.

1.3 Congestion Measurement and Indicators

1.3.1 Technical References

There are some references concerned with congestion measurement and indicators. But first, let us differentiate congestion measurement from congestion indicators. One measure of congestion could be an additional travel time per km, while a congestion indicator is not equipped with a measurement unit. Rather, indicators are ratios between a basic situation and the situation observed.

In the Texas Transportation Institute « *Urban Mobility Index 2001* »[2] Report, a measure of congestion is used:

- « Travel Delay » is « the amount of extra time spent traveling due to congestion »

and three congestion indicators :

- The « Roadway Congestion Index (RCI) » is based on the number of hours of the day that might be affected by congested conditions. It is the ratio of daily traffic volume to the roadway demand (with regard to traffic handling capacity).

[2] *Urban Mobility Index 2001*, Texas Transportation Institute, mai 2001

- « Travel Rate Index (TRI) » : the ratio of additional time required to make a trip in congested conditions over the time required in free flowing traffic. A ratio showing 1.30 would mean that it takes 30 % more time to make a trip compared to free flow speeds.
- « Travel Time Index (TTI) » is similar to TRI, except that it includes both recurring and incident congestions.

The NCHRP Report 398, entitled « *Quantifying congestion* », published in 1997 by TRB uses the following measures and indicators :

- Travel rate (min/km) $= \dfrac{\text{travel time (min)}}{\text{length of segment (km)}} = \dfrac{\text{60 (min/h)}}{\text{average speed (km/h)}}$
- Delay rate (min/km) $= \left\{\begin{matrix}\text{actual travel rate}\\ \text{(min/km)}\end{matrix}\right\} - \left\{\begin{matrix}\text{acceptable travel rate}\\ \text{(min/km)}\end{matrix}\right\}$
- Total delay (vehicle-min) $= \left\{\left[\begin{matrix}\text{actual travel time}\\ \text{(min)}\end{matrix}\right] - \left[\begin{matrix}\text{acceptable travel time}\\ \text{(min)}\end{matrix}\right]\right\} \times \text{flow (véhicle)}$
- Corridor mobility index $= \dfrac{\text{number of persons} \times \text{average speed (km/h)}}{\text{normalized value [ex: 25,000 (routes) or 125,000 (highways)]}}$
- Relative delay rate $= \dfrac{\text{delay rate (min/km)}}{\text{acceptable travel rate (min/km)}}$
- Delay ratio $= \dfrac{\text{delay rate (min/km)}}{\text{travel rate (min/km)}}$
- Congested route (véhicle – km) $= \sum \left\{\text{congested segments (km)} \times \text{flow (véhicle)}\right\}$
- Congested road (km) $= \sum \left\{\text{congested segments (km)}\right\}$
- Accessibility $= \sum\limits_{\text{actual travel time} \leq \text{acceptable travel time}} \left\{\text{possible travels}\right\}$

In said report, it is mentioned that it is difficult to develop a measure of congestion that takes into account all features or characteristics of congestion. Hence the development of several such measures.

In most methods of interest, the **measure of travel time and delay** were the key elements in determining the congestion index. Travel time gauges overall travel speed and travel delay. The average annual daily flow (ANDF) is also a significant piece of information towards the quantification of the demand in each road stretch. Using this information, it is relatively easy to devise one or several indexes bearing one or a combination of these parameters (travel time, speed, delay, ANDF or derivatives such as vehicle-km, etc.).

A single index that assesses congestion in all its aspects may prove incomplete. The definition of such an index should include, on one hand, a quantitative measure showing the free flow of traffic in the network under study (i.e. average time/km, delay/km, etc.) and monitoring its evolution over time and space, and it should include, on the other hand, the demand (number of vehicles travelling on each road stretch) and distances travelled by the vehicles (vehicle-km). The selected index must be flexible enough for adaptation to future road network development. It should also be wholly applicable (to the entire network) and severally to every road stretch in a very disaggregated fashion, thus it could measure locally and inclusively the impacts resulting from an intervention, regardless of the chosen data gathering method.

1.3.2 Explored Indicators

As economically as possible, MTQ's *Service de la modélisation des systèmes de transports* (SMST)[3] has studied the use of several complementary indicators. In an attempt to measure the congestion affecting the Montréal region: a synthetic indicator, a descriptive indicator and a line-up indicator. These indicators, intended for public dissemination, must be simple and readers should experience no difficulty in their interpretation. In order to yield useful results, they will therefore be highly aggregated while remaining adequately sensitive to evolving traffic conditions. The indicators should rely on a sound methodology and should be stable over time and consistent throughout the areas covered. They aim at yielding, so to speak, the temperature of the road network at different moments in time.

1.3.2.1 TRI (Travel Rate Index) Synthetic Indicator

The synthetic indicator examined is a standardised measure called (Travel Rate Index) designed by the Texas Transportation Institute.

The TRI is basically an indicator of additional travel time caused by road congestion. It is the ratio of travel time required during rush hour and the time one would usually need to make the same trips in free-flow[4]. For example, a 1.32 TRI (the case of Boston) means that it takes on the average 32 % more time to make a trip during the peak period than if a motorist was alone on the freeway. Los Angeles is the worst metropolitan area in North America with a TRI of 1.51 (in 1997). At the other end of the spectrum, much smaller population centers such as Rochester (NY) display a TRI of 1.06.

TRI is part of a large family of indicators relating to congestion on transportation networks. It is included in annual reports which analyse and compare urban mobility in American cities and has been used for more than fourteen years.

The main methodological input remains network outlining (in kilometer-lane) and data on the average daily flow. This information is already available through HPMS (Highway Performance Monitoring System) which has been in use for many years in the United States and at the ministère des Transports du Québec.

The method calls for several statistical submodels to establish average factors or parameters intended to stand for different traffic conditions and proportions of travelling populations at peak periods.

The TRI is an indicator aggregated over the entire portions of the analysed network based on the respective distance and number of vehicles supported by each section.

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[3] *Développement d'un indicateur synthétique de congestion pour la région de Montréal*, SMST, MTQ, February 2001
Développement d'un indicateur descriptif de congestion pour la région de Montréal, SMST, MTQ, March 2001

[4] Free-flow speed is the average travel speed on non-congested roads taking into account the classification of the road - it may differ from the speed limit.

Therefore, a very long section of freeway located in the outer suburbs which would bear a small flow (i.e., Highway 640 at Lachenaie) may carry much less weight in the result than a shorter, densely travelled section of a central freeway (i.e., the Métropolitaine between des Laurentides and the Décarie interchange.

Of course, the TRI does not comprise the finer traffic events. It is not responsive to exceptional conditions related to climatic events, accidents or construction activity interferences.

1.3.2.2 Descriptive Indicator

The descriptive indicator aims at measuring exact traffic conditions at specific points of control in the road network by computing the proportion of time and vehicles (in two classes: passenger and commercial vehicles) which correspond to different **traffic regimes**.

This indicator is obtained using traffic surveys extracted from the Vehicle Detection Stations (VDS). These were the first types of surveys conducted by the MTQ.

The survey data are obtained from inductance loops located in parts of the freeway network on the island of Montréal. Instrumentation is used for the detection of vehicles via loops in the pavement. Data recorded via twin loops are speed, vehicle classification according to length, flow and occupation. Single loops record only flow and occupation rate. Compiled in 20-second polling periods, the occupation rate represents the number of cycles during which the loop is busy, up to a maximum of 1,200 (60 cycles per second (Hz) for 20 seconds).

These Vehicle Detection Stations are currently used for two purposes: to establish traffic conditions and to observe network incidents.

On the average, the loops are set 500 metres apart and they indicate occupation rate in real time wherefrom traffic free-flow [or congestion] level is inferred for each section surveyed. A weak occupation rate (i.e., less than 14 %) indicates a free-flowing situation while a high occupation rate (in excess of 33 %) indicates congestion. Intergradation points to slow traffic conditions (i.e., OR between 14 and 33 %). Advanced calibration of thresholds and validation of data are nevertheless required.

Detection of incidents comes into play when the occupation rate exceeds the critical threshold. The location of the loop where the event is occurring allows the use of a camera to pinpoint the incident and possibly to determine the nature of the mishap.

With the help of this baseline data, i.e., total flow, average speed, average occupation rate and vehicle classification, it is possible to define traffic regimes in which congestion is translated.

1.3.2.3 Line-up Indicators

Line-up indicators[5] were developed by the MTQ using geographic location surveys of the line-ups, including travel times and speeds. A practical description of this method is provided in Section 2.

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[5] *Évaluation de la congestion, document de travail*, Direction de Laval – Mille-Îles, Service des inventaires et du plan, MTQ, September 2000

The following measurements and indicators were developed using these surveys :

- **delay** is the difference between the time measured in congestion and the time measured in free-flow for a given trip. This family of measurements includes maximum delays in period, average delay in peak periods and the average rush hour delays
- **relative delay rate** is obtained by dividing the average rush hour delay by the free-flow travel time. This indicator is dimensionless. It therefore compares congestion over a number of corridors, establishes an overall annual indicator and makes comparisons from one year to the next
- **delay proportion** is the ratio of the average rush hour delay and the average rush hour travel time
- **maximum length of line-ups** is the sum of the line-ups at least one minute long occurring on a given trip travelled by the control vehicle; its value is computed for each peak period
- **creeping [of the peak]** is the proportion of the peak period during which the network is affected by congestion; in this case, congestion is defined by the occurrence of a line-up lasting two minutes or more.

Where sampling is scarce (departures every 20 minutes), error margins in a number of these measurements and indicators may be significant. The next step consists of statistical validation of the sampling and in the definition of the sampling required to obtain statistically valid results.

2. LINE-UP AND TRAVEL TIME SURVEY METHOD (CASE OF THE GREATER MONTRÉAL ROAD NETWORK)

2.1 General

2.1.1 Project Description

The survey method consists of having a floating vehicle travel around the main congested corridors in the Montréal Metropolitan Census Area. The exact location of the vehicle is recorded at each second. With the knowledge of its position and time elapsed between landmarks (every 500 metres of highways or at intersections), it is possible to compute travel time and therefore speed. Location of the queue is established using a speed of entry into the queue and an exit speed. A vehicle is considered to have joined a highway queue when its speed drops below 25 km/h and is considered to have left the queue when its speed rises above the 60-km/h mark. The location of the vehicle at those threshold speeds indicates both the beginning and end of the queue and it is possible to compute the time used up in the queue.

Eight control cars travel over a predetermined route in each of the corridors and in both directions (2 trips). Each trip is made three times per hour during the morning (06:00 to 09:00) and afternoon (15:30 to 18:30) rush hour periods for a total of 18 readings that day. Readings for each corridor are carried out one day per month over twelve consecutive months. We therefore have 216 readings per trip, and 47 trips are covered. Annually, this represents 10,152 readings (3 readings/hour * 3 hours/period * 2 periods/day * 12 days/year * 47 trips).

The road network under study covers close to 60% of the ministerial CMA (210 kilometres) and 120 kilometres of the urban network, including 21 of the 23 major bridges in the region. Directionally, total coverage is therefore 660 kilometres (Diagram 1).

In view of network coverage and data gathering frequency, these surveys are based on a census in space (survey on the overall observation universe – 100 % of the population) but they are really a sample in time. The survey of one day only in the month for each corridor remains statistically inadequate for monthly validity or comprehensiveness.

2.1.2 Project Objectives

- To scientifically measure congestion in the most traveled corridors of Greater Montréal
- To monitor the evolution of congestion in rush periods across twelve (12) consecutive months
- To automate the data input process
- To survey the location of the vehicles every second and store this data in computer files
- To minimize human intervention
- To cut back on data entry staff
- To process (700 data files) and generate monthly results.

2.1.3 Project Complexity

Project complexity arises from techniques used in computerized data gathering, in processing huge amount of data gathered and in the presentation of results using current software programs such as MapInfo.

Diagram 1 Territory Under Study

2.1.4 Techniques

This Project is based on the Modified Floating Vehicle Technique, which consists of running a control vehicle on a predetermined road trip at a speed representative of the average flow speed. Two data gathering procedures were developed for this Project:

- ***The Odometer Technique (semi-automatic)*** gathers time and location data automatically every second from the vehicle dashboard. Data is recorded in a *Data Collector*.

- ***The GPS Technique*** (***automatic)*** uses satellite positioning (longitude/ latitude) to gather and record vehicle location every second, without human intervention. Data is stored in a *Data Collector*.

2.1.5 Innovation and Originality

This Project is a world premiere in many respects. It is the first Systematic Congestion Assessment Program on a metropolitan scale (population cluster). Although road network managers have long perceived congestion as a substantial problem, never before had the hourly and annual evolution of travel times been systematically measured in an urban road network. Before the implementation of this Project, only tidbits of information were available concerning travel times in some route segments or for a few hours in the year. With this Project, the ministère des Transports du Québec (MTQ) now provides a clear picture, in space and over time, of the overall traffic conditions in the advanced road network of Greater Montréal.

This Project is also a technological premiere in Canada. It is the first large-scale application of the Odometer and GPS Techniques tailored to Mobility Surveys. These new technologies analyse traffic conditions with microscopic precision, which was previously impossible.

Finally, the Project introduces innovation in the interface designed to merge computerized survey data and its graphical representation in the form of a geographic information system.

2.1.6 Social, Economic and Environmental Impact

Social, economic and environmental impacts are indirect and relate to the decisions taken with the newly available data. The comprehensive rendering of the congestion provided by this Project is one of the components used in the preparation of the *Plan de gestion des déplacements pour la région métropolitaine de Montréal* recently released by MTQ.

Data gathered set the transportation investment priorities in the Montréal region according to the impacts on users' actual travel times. The optimal allocation of financial resources to transportation will translate in substantial economic benefits and, by and large they contribute to alleviate the negative transportation-related environmental impacts.

2.2 Survey Techniques

Two computerized data gathering techniques were developed to meet Project objectives.

2.2.1 Odometer Technique (Semi-automatic)

This technique uses the vehicle odometer to determine vehicle location once per every second and a *Data Collector* stores the data permanently. The processing of congestion data (speed, time, queue, delay) is carried out offline for each road trip. The collector functions are : signalling the beginning and end of a trip, passing at the benchmarks, end of queuing, traffic disruptions and detours, using several switches.

Diagram 2 shows the list of components used in this technique, among them a link with the « hall effect » sensor, the control unit, a *Data Collector* and a power pack.

2.2.2 GPS Technique (Automatic)

This technique is based on satellite positioning (longitude/latitude). The DGPS receiver captures the signal from the Coast Guard beacon and conveys it to the GPS for adjustment. The position information (longitude/latitude) is then beamed every second to the *Data Collector* through the serial port. Simultaneous recording of altitude, direction, number of satellites and GPS loss is also secured. In addition, an emergency or backup system is used to offset GPS signal losses. Line-up data is also processed in batch entry mode.

With this technique, the operator's task consists only in booting the *Data Collector* at departure and turning it off at the end of the period. The *Data Collector* provides the reading device with different tonality beeps indicating the passage at the various benchmarks and the beginning of line-ups and enters comments as needed.

Diagram 3 lists the components used in this technique. It includes namely : the Auxiliary Reference System, a *Data Collector*, a one-hour power pack, a GPS receiver with RS2322C serial port, a 296 and 309 KHz DGPS radio receiver and a magnetic DGPS antenna.

2.2.3 Result Accuracy

Odometer Technique (semi-automatic)

At the MTQ, accuracy required from this technique is ± 5 m. The system we have developed complies with this requirement and provides a greater accuracy in the range of 1 m.

GPS Technique (automatic)

Given the novelty of this technique, the data gathered had to comply with MTQ requirements and trip surveys had to match the layout of the roads under study precisely. In order to control precision in linking [concatenation, catenation] yielded by this technique, the GPS-gathered-chaining was compared with that obtained after the coordinates file was converted to catenation for an equal period of time. The variations obtained after converting the file displayed a deviation of less than 0.1 %.

In order to confirm the location of GPS readings in relation to the layout of the trips under study, the positioning of the second-by-second readings (longitude/latitude) was transformed into an MTM Projection using the Lambert program. This Projection provides a coordinates file, which is imported into MapInfo where a plot of the trip is drawn. The plot thus produced is then superimposed with the set provided by the MTQ and on which the coordinates were established in previous surveys. The likeness of the result is remarkable: in every survey carried out for a given trip, the points are for the most part located at the same place; the plot of the GPA readings matches that of the road within ± 25 m and it remains well within the road right-of-way. This variation depends on several factors, including map accuracy.

Diagram 2 Component diagram (Semi-automatic Odometer technique)

Diagram 3 Component diagram (automatic GPS technique)

2.3 Data Gathering

2.3.1 Source Data

In order to operate the data-gathering module, some baseline information is required before data can be entered.

A configuration file is required for each trip, as shown in diagrams 4, 5 and 6. The file contains the definition of benchmarks, their position either in chaining or in longitude/latitude and the type of trip. Benchmarks are sequentially identified starting at one (1). There are three types of trips : highway, urban and mixed (both highway and urban). In this Project, chaining for the preparation of configuration files was provided by the MTQ and positioning (longitude/latitude) was surveyed in the file using the benchmark acquisition module in the GPSMTQ.EXE program.

In addition, a file containing system parameters, calibration factor and vehicle characteristics is also required. Table 2.1 indicates the system parameters, which are urban and highway congestion as well as speed and audible warning signal distances.

2.3.2 Calibration

This module determines the transformation factors required to convert the odometer readings into chaining. The procedure is carried out every week and whenever a change may influence the readings of the vehicle's odometer (ex., changing the tires).

Calibration consists of measuring the number of impulses generated by the Hall Effect sensor along a one (1) kilometre standard stretch. This factor is integrated into the trip acquisition program by the calibration module. Calibration is required for both techniques.

2.3.3 Operation of the Data-gathering Software

The data gathering software is easy to use and allows the collector to concentrate on driving the vehicle.

A monthly schedule indicates which trips are to be travelled, survey dates and departure hours. Precise hourly schedules set trip departures in the direction of the rush while return trips are done at variable hours according to time required to travel the first half of the trip. The crew has no precise instructions indicating the start of the return trip; the new trip is undertaken upon arrival at the point of departure.

The trip acquisition program was developed with QuickBasic in DOS.

Odometer Technique (semi-automatic)

After turning the *Data Collector* ON, the system checks the date and time and requires the user to confirm these parameters. Upon validation of the latter, the RUNMTQ.EXE program is loaded into memory. The program controls the system's various components. A menu shown in Diagram 5 is made available and the user enters pavement conditions, the trip undertaken and the *Begin acquisition* command. At this point, the system is active and ready to collect data. In conjunction with the start-up procedure, the system automatically creates a data entry file. The filename is made up of the last digit of the year, followed by the Julian day, the time and an extension indicating the number assigned to the trip, i.e., 00011520_01.

Diagram 4 Configuration file

Diagram 5 Odometer technical entry display/screen (semi-automatic)

Diagram 6 GPS technical entry display/screen (automatic)

In order to launch trip entries and data recording, the user is only required to push the Start/End button on the control unit when passing the first benchmark. From that moment on, the *Data Collector* receives the information at the rate of ten readings per second. The data is validated, distance travelled and codes of the buttons pressed according to events encountered are recorded every second on the disk. Upon approaching a benchmark (100 m on highways or 30 m on urban roads), an audible signal warns the operator of the proximity of the next benchmark.

At the last benchmark, the *Data Collector* emits a different tone and the operator again pushes the Start/End button, thus informing the Data Collector that the end of the trip has been reached. The software then automatically closes the data file. At this time and while the operator heads for the return trip departure point, the Data Collector automatically changes to the return trip and creates a new data file. Then upon reaching the departure point of the return trip, the user pushes the Start/End button once more, thus launching the return trip.

Once a week, the team leader retrieves the data collected in the files. One copy of the data is copied onto a diskette and another is saved in the Data Collector's Archive directory. The data copied on diskette is used for data processing in the system.

GPS Technique (automatic)

After checking the time and date, the GPSMTQ.EXE program is automatically loaded in memory. A screen (Diagram 6) similar to the previous one then becomes available and enters the pavement conditions and activates the *Begin acquisition* command. In this technique, the *Data Collector* automatically loads the trip at hand according to the longitude/latitude position in the configuration files within the GIRGPS Directory; it creates the data file and is then ready to collect. The filename is generated with a difference in the extension where the letter 'g' is added to the trip designation as follows : 00011520.g01.

As was the case in the other mode, the operator presses the *Start/End Trip* button on the control unit to launch data entry. From this moment, the system writes on the *Data Collector* disk second-to-second information by the reference system such as: longitude, latitude, altitude, and direction, number of satellites, GPS loss and the distance travelled.

Contrary to the procedure in the Odometer Technique (Semi-automatic) and because this system is automatic, there is no switch for the operator to activate. An audible signal is nevertheless emitted by the *Data Collector* when passing the benchmarks, when the vehicle enters a line-up, and at the beginning and end of the trips to witness the system's proper operation. After transiting past the last benchmark, the *Data Collector* exits the acquisition mode, automatically closes the file and prepares for the return trip (it actually loads the file for the return trip, creates the data entry file and waits for the operator to press the *Start/End trip* button to begin recording the return trip data).

The procedure for data retrieval is similar to that of the other technique.

2.4 Data Processing and Presentation of the Results

2.4.1 Processing

Data processing consists of transforming the collected data into a clear picture of the traffic conditions. As shown in Diagram 7, the information is filtered, validated, and sorted and, for each trip the following is computed: speed to the second, travel times and average speed at every 500 metres. More than 700 files containing a line of data per second are therefore processed every month. The following elements are automatically computed by the system :

- Total travel time and average speed – for each trip
- Travel time and average speed – for each section
- Duration and length of line-ups, including average speed in line-ups
- Time at which these extreme conditions are observed for each trip surveyed and for each rush hour period
- Delays for each trip and for the overall road network at both morning and afternoon rush hour periods
- Travel time in the common sections.

2.4.2 Presenting the results

Several types of deliverables are produced: diagrams, tables, and maps showing travel times, speeds, line-ups, delays and a number of reports which assist in managing the mission.

Tables and Diagrams

In order to generate these deliverables, a report driver was developed in Access, which automatically creates the type of deliverables needed by simply defining the basic parameters required for the production of the selected report. Data illustrated represent :

- Travel times and average speeds
- Profile of speeds every 500 metres for the departures at 06:20, 07:20, 08:20, 15:20, 16h:00 and 17:20
- Line-ups
- Delay rates
- Line-ups tables
- Synthesis in table form.

Samples of these deliverables are shown in Appendix A.

Theme Maps

In addition, we have developed an interface with MapInfo that uses MTQ's Map Basic macro, which automatically creates MapInfo theme maps after geocoding the processed readings. These maps represent the congestion features in each of the trips surveyed in both daily rush hour periods :

- Travel time
- Average speeds
- Line-ups
- Delay rates.

These theme maps are shown in Appendix B.

Management Reports

Management reports are useful for mission management. They actually allow for the control and follow-up of trip operators; they yield information on the success rate of surveys; they indicate which surveys were used to generate the maps; finally, in the case of the GPS technique, management reports determine the chaining of validation areas.

Diagram 7 Data processing

2.5 Using the Results

The results are useful for quantifying congestion and for furthering our insights into the behaviour of the network. In addition, they are used :

- To better adjust the intervention measures
- To implement indicators assessing the impacts of intervention measures in the road network [Projects of the *Plan de gestion des déplacements de Montréal* (PGDM)]
- To gauge opportunity studies on highways (des Laurentides, Métropolitaine, Jean-Lesage, etc.)
- To test many freeway bus lane studies
- To calibrate the EMME/2 and AimsunII models
- To study the extension of the electronically monitored network
- And toward other possible applications such as :
  - Measuring actual travel times in traffic studies
    - To compare different itineraries
    - To evaluate accessibility
    - To calibrate micro simulation models (CORSIM)
    - To gain information on the impacts of construction sites
  - To produce space-time diagrams
    - Studying the synchronization of traffic lights
    - Studying the behaviour of halted motorists
    - Analysing shockwaves
  - To calculate the latent demand in highway corridor.

2.6 Summary and Conclusion

2.6.1 Summary

Since March 1997, the ministère des Transports du Québec (MTQ) has recorded monthly surveys of congestion along the major axial highways and roads in the Montréal region. The data collected is processed to yield graphical and cartographic results. Moreover, five performance indicators pertaining to congestion have been established and are computed monthly.

The overall surveys and data processing of phases 1, 2 and 3 have been very satisfactory:

- 91 % of planned departures were completed
- Data collected is valid to 99%
- 100 % of the valid data was processed and presented in graphical form.

Over the years we have improved the data gathering system:

- To increase equipment reliability by fitting the components in a unit (briefcase) and by reducing the number of connections
- To curtail human intervention by reducing the number of connections
- To improve equipment ergonomics by fitting all the components into a briefcase
- To introduce calibration in the vehicle, thus using the data collection equipment apart from vehicle calibration
- To develop a software program for efficient vehicle management.

In addition, we have developed a report generator, which facilitates the production of any reports as needed.

2.6.2 Conclusion

The Project was a success due to its smooth unwinding and the validity of the data collected. A performance, which exceeded the client's expectations. The accomplishment rests namely on the **wealth of collected data**, which has lead to the creation of other applications in addition to those which had been designed at the outset of the Project. Due to the wealth of information gathered, Data **processing** also contributed to Project performance.

In the wake of Montréal's successful Project, other MTQ regional directorates in similar Projects carried out in Québec City, Saint-Jérôme and Trois-Rivières used the computerized congestion management system. For example in Québec City, the Project led to the development of new computer applications to display new themes such as delays per trip, delays in the region overall, common sections, the synthetic table and the management report.

In view of the results achieved, it is impossible to draw adequate/pertinent conclusions on the evolution of congestion. Monthly variations require a comparison of monthly data over many consecutive years. We only have on hand two or three measurements or values for each month and it is impossible to establish trends with two or three values as these may have been influenced by weather conditions, mishaps or construction activity. For this reason, phase 4 of the Project has been promoted in order to statistically validate the sampling method and the adequacy/comprehensiveness of the results so far obtained.

Finally, experience teaches that the GPS Method (automatic) confers many automated advantages to the system (automatic tracing of benchmarks along the road, the loading of trips, etc.), including the minimisation of human intervention. Nevertheless, the loss of GPS signals at certain road facilities such as tunnels, bridges and in some areas in downtown Montréal, require the use of an alternate system (Vehicle Odometer) to maintain the second-by-second automatic recording of the vehicle's position. Therefore, the GPS may not be used to its full extent for this type of survey since it also requires to be supported by the Odometer Method (semi-automatic).

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Appendix A

Tables and graphics samples

Appendix B

Theme maps