DISRUPTION, CONGESTION AND MITIGATION: CHARACTERISATION OF STRATEGIC ROAD INFRASTRUCTURE USING PARTIAL ITINERARY DATA

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ABSTRACT

In large urban areas, high-capacity transit and road infrastructure play a crucial role in the spatiotemporal distribution of economic and social activities. In many cities, the subway is the critical component of the public transit system just as freeways form the effective backbone of the road network. In the case of island cities like Montreal, bridges are also essential to the proper functioning of the transportation system as a whole. As such, subways, bridges and freeways can be considered “strategic” transportation infrastructure since the disruption of just one of them has wide-reaching consequences. It is therefore important, from both long-term planning and operational perspectives, for transportation authorities to identify strategic infrastructure and to have good knowledge of its users’ travel patterns.

In Montreal, methods of analysing public transit usage patterns based on travel survey data have long been used for planning and operational financing purposes. However, a similar methodology has yet to be adopted for roads. This paper presents a methodology for thoroughly characterising the users of strategic road infrastructure (bridges and freeways) based on data contained in a large-sample household travel survey. The Montreal travel survey asks all respondents who completed their trip by driving a car which major bridge or freeway was used. The 2008 survey contained roughly 70,000 trips with at least one bridge or freeway declared. Around 60,000 of these declarations could be validated using a constrained trip assignment algorithm applied to a large and detailed network (117,000 links). Adopting a totally disaggregate approach, the algorithm transforms the bridge and freeway declarations into complete itineraries while preserving the socio-demographic attributes of each traveller. These results can be used to analyse strategic road infrastructure from multiple perspectives: the detailed characterisation of the “clientele”, an estimation of their travel consumption, analysis of congestion and road pricing, and the design of mitigation measures – including alternative public transit options – in the event of closure or failure. An interactive visualisation tool forms the basis of these investigations.

The method is based on a travel survey but could be adapted for emerging passive data sources that provide partial itinerary information such as GPS traces, automatic toll collection systems, mobile device applications and so on.

INTRODUCTION – DISRUPTION, CONGESTION, MITIGATION

To be effective, urban transportation systems depend in large part upon high-capacity and high-speed infrastructure elements. Common examples include freeways, subways and in some cities bridges. Such infrastructure can be considered strategic since a disruption to their normal operating states can have major consequences, including severe traffic congestion.

Traffic disruptions have four primary causes: vehicle collisions or breakdowns, poor weather, road works and special events. While the first two are difficult to anticipate, the third and fourth can be planned in advance. In such cases, it should be possible for the authority responsible for the operation of the infrastructure in question to devise mitigation measures which limit the effects of the disruption. In practice, however, transportation agencies have little reliable information on the users of a specific element of road infrastructure. In the absence of such information, it is difficult to develop effective transportation alternatives and drivers most often have to muddle through on their own by altering their activity schedules and travel behaviour. Unforeseen negative consequences often result for road users, the local economy and the public perception of transportation agencies. The objective of this paper is to demonstrate the use of a household travel survey for the informed design of mitigation measures. The methodology (summarized in Figure 1) converts partial path information contained in the form of bridge and freeway declarations into validated vehicle paths using a constrained algorithm and a detailed road network. The adoption of a totally disaggregate approach conserves all the attributes of the simulated travelers and permits the construction of detailed profiles of strategic road infrastructure users.

The paper is structured as follows. Following this introductory section is a brief discussion of the context of the present work. The third section describes in some detail the data and simulation tools upon which the method is based. The fourth section discusses the core methodology behind the construction of validated itineraries. The fifth section summarizes the results and the sixth section offers some concluding remarks.

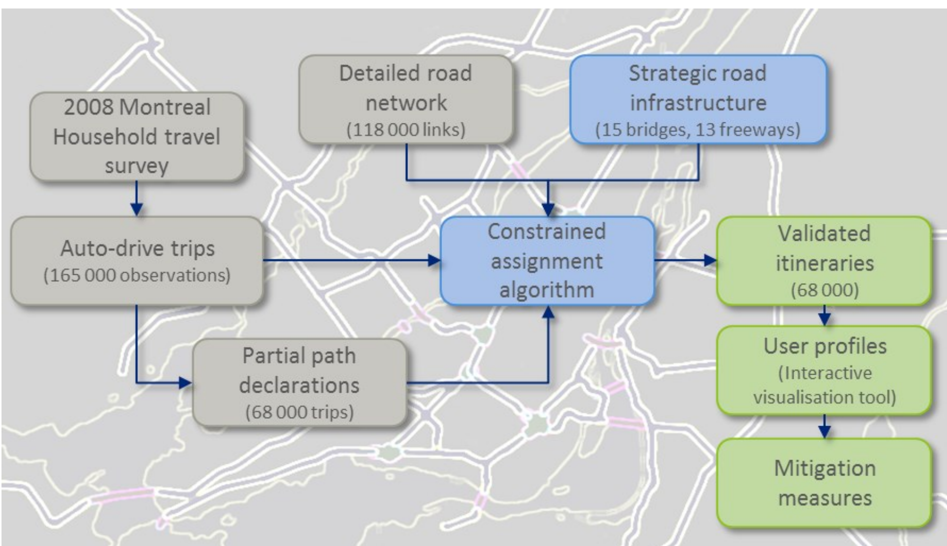


Figure 1: Overview of the methodology

CONTEXT

Urban transportation planning strategies can be classified into three types according to their planning horizon: long-term, medium-term and short-term. In practice, long-term planning is perhaps the most well-known since it deals with the evaluation of proposed projects and policies. Short-term planning deals with incident management and other daily operational objectives. The subject of this paper, falling somewhere between the two, can be classified as a medium-term planning tool for the mitigating the effects of disruptions whose consequences are temporary but last for multiple days or weeks.

Generally speaking, the design and implementation of mitigation measures falls within the realm of travel demand management the aim of which is to “influence the intensity, timing and spatial distribution of transportation demand for the purpose of reducing the impact of traffic or enhancing mobility options”[1].

Short-term responses to congestion mitigation are usually approached from the perspective of advanced traveler information systems (ATIS) technologies designed to permit real-time interventions. Variable message signs located at strategic locations on the road network are commonly used by road authorities. Real-time monitoring of traffic using cameras and loop detectors assist in the deployment of emergency crews. The advent of smart phones and their accompanying traffic monitoring applications provide drivers with a detailed and up-to-date picture of the state of the road network (ref. Google, Waze, INRIX, TomTom and others). These technologies are especially helpful in cases where the disruption is of relatively short duration – few hours at most.

When the disruption lasts multiple days or longer, transportation authorities will often implement temporary mitigation measures in order to minimize the consequences for the travelling population. While major disruptions are common, detailed documentation of their effects on the transportation system are fairly rare. Nevertheless, several studies have used surveys to gauge the impacts of major road network disruptions: the I-35 bridge collapse in the Minneapolis-St. Paul region[2], the closure of freeways in California [3], [4] and the construction of an LRT line in Calgary [5]. Multiple case studies have demonstrated that the traffic congestion resulting from permanent or long-lasting road closures is often less severe than anticipated, especially when effective mitigation measures are implemented [3], [6]. Even with such measures in place, however, Zhu et al [2] found that the travel time costs of disruptions of major infrastructure can be significant. Logically, a mitigation strategy can be effective only if it responds to the needs of the affected travellers. Therefore, a methodological challenge when designing such a strategy is to identify and characterize the people most likely to be affected by the disruption.

Network simulation models can be helpful in this regard since their purpose is to associate travel demand (people and vehicles) with transport supply (roadways and intersections). Although such models are most often used for long-term strategic planning, traffic models for short-term planning have been under development for some time [7] and various types of road network models have also been developed for the design of emergency evacuation plans [8]. Transit network models have been used to estimate the potential impact on passengers of a subway system breakdown [9].

Historically, Canada has played an innovative role in the development of urban transport network modelling. Methods for measuring travel demand using large-sample telephone surveys were applied and progressively refined in Montreal and Toronto since the 1970s, in addition to being adopted periodically by cities across the country. Recent examples include Vancouver[10], Winnipeg [11], Ottawa-Gatineau [12] and Trois-Rivières [13]. Unique modelling tools were developed in Canada to capitalize on the existence large quantities of detailed disaggregate travel demand data, especially for transit planning purposes [14], [15]. In Montreal, "totally disaggregate" methods are applied in numerous transit-related contexts ranging from strategic planning to financing mechanisms. To date, similar methods have rarely been applied to automobile travel, although major bridge usage patterns obtained from declarations in the Montreal travel survey also have contributed to the analysis of network redistributive effects [16], transportation equity [17] and route choice [18].

In the domain of traffic modelling, Emme2 was one of the first commercial tools for the large-scale (macroscopic) simulation of congested road networks. Based on Wardrop's principle of user equilibrium [19] and incorporating the standard four-stage planning process, it was developed by the Montreal firm INRO (for a detailed history, see [20]). Large-scale traffic models of this type have become standard worldwide and rely on iterative optimization algorithms to simulate congestion and require input travel demand to be aggregated by traffic analysis zone (TAZ). Consequently, a typical "Canadian" approach to urban road traffic modelling employs the travel survey for the first three stages of the four-stage approach, aggregates the demand by TAZ, and then proceeds to the standard trip assignment stage. To isolate the users of a specific road infrastructure represented by at least one link in the simulation network, the standard traffic simulation packages can be used to perform a select-link analysis. The select link analysis identifies all the origin-destination pairs of users of the selected link, as well as all the network links used by those travelers. Traveler characteristics, however, cannot be directly examined because the travel demand was aggregated by TAZ prior to the simulation.

As shown in Figure 2, this paper aims to modify the standard approach to urban road network modelling by applying the totally disaggregate approach used for transit modelling to the modelling of the road network. The zone system and the associated aggregation process are eliminated, the individual trip as an object is preserved throughout the simulation and the end products include not only volumes and travel times, but also individual itineraries. The production of individual itineraries makes possible a type of enriched select link analysis particularly well-suited to the elaboration of mitigation measures since household, person and trip attributes, in addition to traffic volumes and OD pairs, may be associated with a specific link or series of links in the road network.

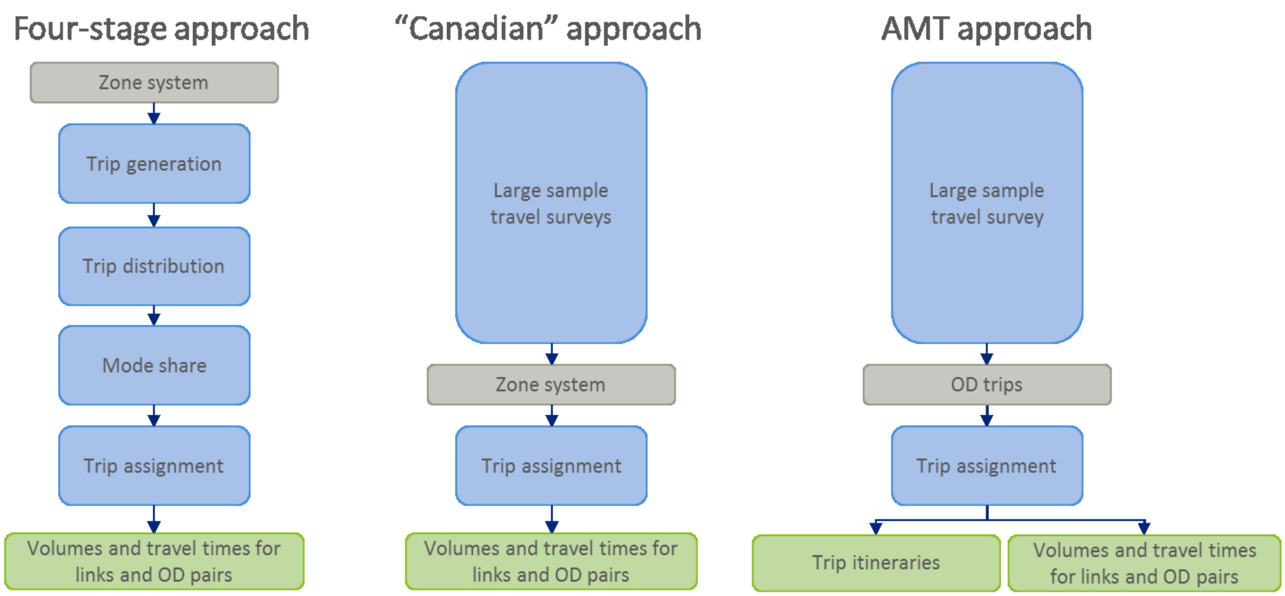


Figure 2: Three approaches to urban road network modelling

DATA AND SIMULATION TOOLS

In this paper, travel demand data are obtained from the 2008 Montreal household travel survey. The computer-assisted telephone interview (CATI) survey contains detailed information on household, person and trip attributes. It also contains partial path information in the form of major bridges and freeways used by auto-drivers. There are two technical objectives that need to be met if this information is to be useful for the analysis of strategic road infrastructure:

1. The plausibility of the bridge and freeway declarations must be assessed. In other words, the declarations need to be validated.
2. The partial path information must be transformed into complete itineraries in order to associated individual travellers with specific network links.

Several ingredients are necessary to achieve these objectives, including some definitions, input data and modelling tools. Each are briefly the described in the following subsections.

STRATEGIC ROAD INFRASTRUCTURE: DEFINITIONS

For the purposes of the present analysis, two very general criteria are used to identify strategic road infrastructure (SRI):

1. Traffic volumes: The number of vehicles using the infrastructure over the period of peak demand must be on the order of several thousand.

2. The number of available alternatives: Many urban streets carry large volumes of traffic during peak periods and throughout the day but the density and geometry of the urban road network means that multiple alternatives are usually available. Disruption on these roads is especially serious where few alternatives exist. Such is obviously the case with major bridges, but freeways also serve a fairly captive market since non-freeway alternatives offer much longer travel times.

In Montreal, as in most cities, it is possible to identify many road infrastructure elements that meet these criteria without performing a detailed empirical analysis. Indeed, the initial list of strategic road infrastructure included most of the freeways in the region and all bridges providing access to the Island of Montreal, as well as some major interchanges. The users of these infrastructure elements will be characterized and analyzed with the intent of developing mitigation plans.

The designation of a road network element as strategic does not necessarily imply that its users and their characteristics can be directly obtained from the survey data. For example, the survey does not ask respondents about their use of interchanges. Also, respondents frequently neglect to mention certain freeways that are only a few kilometres long or that merge unnoticeably into other freeways. Moreover, some sections of freeway have multiple numbers. For these and other reasons, the list of infrastructure elements for which survey declarations can be validated (Table 1) is a subset of all SRIs. The list of SRIs that can be validated includes 13 freeways and all 15 bridges providing access to the Island of Montreal.

CODE	NAME	TYPE	CENTRELINE LENGTH (KM)	AVERAGE NUMBER OF LANES IN THE PEAK DIRECTION	SCALED LANE CAPACITY (VEH/HR)
501	A10 (AUTOROUTE DES CANTONS DE L'EST)	FREEWAY	48.7	2.1	60.0
502	A13	FREEWAY	20.0	3.0	60.0
503	A15	FREEWAY	122.2	2.8	60.0
506	A19	FREEWAY	5.5	3.0	60.0
507	A20	FREEWAY	123.3	2.2	60.0
508	A25	FREEWAY	41.0	3.0	60.0
510	A30	FREEWAY	94.1	2.0	60.0
511	A35	FREEWAY	18.9	2.0	60.0
512	A40	FREEWAY	139.9	2.8	60.0
513	A50	FREEWAY	7.9	2.0	60.0
514	A440	FREEWAY	14.3	3.0	60.0
516	A640	FREEWAY	52.8	2.0	60.0
553	R116 (ST-BRUNO TO LONGUEUIL)	FREEWAY	11.4	3.0	60.0
701	PONT CHAMPLAIN	BRIDGE	3.8	3.0	61.1
702	PONT VICTORIA	BRIDGE	2.2	2.0	39.3
703	PONT JACQUES-CARTIER	BRIDGE	2.9	3.0	52.1
704	PONT HONORÉ-MERCIER	BRIDGE	1.6	2.0	44.8
705	TUNNEL L-H-LAFONTAINE	BRIDGE	3.5	3.0	38.7
708	PONT VIAU	BRIDGE	0.5	2.0	21.0
709	PONT PAPINEAU	BRIDGE	1.0	3.0	36.4
710	PONT PIE-IX	BRIDGE	0.7	3.0	40.6
711	PONT LACHAPELLE	BRIDGE	0.5	3.0	25.0
712	PONT MÉDÉRIC-MARTIN	BRIDGE	1.6	4.0	53.5
713	PONT LOUIS-BISSON	BRIDGE	1.3	4.0	50.1
715	PONT LE GARDEUR	BRIDGE	1.9	2.0	25.2
716	PONT CHARLES-DE-GAULLE	BRIDGE	2.0	3.0	47.9
717	PONT GALIPEAULT	BRIDGE	0.8	2.0	51.0
718	PONT ILE-AUX-TOURTES	BRIDGE	4.2	3.0	39.8

Table 1: List of validated bridges and freeways in the Greater Montreal Area identified as strategic road infrastructure

NETWORK CODING

In order to analyse SRIs as objects with attributes and relations, it is necessary to identify them systematically when coding the simulation network. The links belonging to a specific SRI are assigned a six-digit code. The first three digits are the numbers used to record bridge and freeway declarations in the travel survey (the CODE column in Table 1). The last three digits indicate the link location and direction. In the case of bridges, an even 6th digit indicates the link is directed toward Montreal and an odd 6th digit indicates a link directed off the island. For freeways, eastbound and northbound links have even-numbered codes while southbound and westbound links have odd numbered codes. Similar, although necessarily more complex, rules are adopted for interchanges. These coding conventions greatly simplify the isolation of specific network links within the large quantity of simulation results.

DATA

This section presents a summary of the data used in the analysis. First, the spatial boundaries of the procedure are those of 2008 Montreal travel survey. This region has the following dimensions:

- 8,200 sq km
- 3,940,000 inhabitants
- 1,652,000 households

The transport supply is represented by detailed road network having the following dimensions:

- 118,648 links (of which 1,200 are associated with an SRI);
- 82,298 nodes;
- 2,221 traffic signals;
- 516 turn prohibitions.

The analysed travel demand consisted of all the auto-drive and park-and-ride trips observed in the 2008 Montreal household travel survey (all figures are unweighted):

- 165,372 trips over 24 hours, of which 68,023 include at least one bridge or freeway declaration that can be validated;
- 38,249 trips during the morning peak period (6:00-9:00), of which 18,476 include at least one verifiable bridge or freeway declaration.

As shown in Table 2, just over 1,000 distinct bridge and freeway combinations (from among those listed in Table 1) were observed in the 2008 travel survey. Per trip, the maximum number of bridge declarations is 2 and the maximum number of freeway declarations is 6. As expected, the number of bridges and freeways declared is positively correlated with trip distance. The majority of auto-drive trips did not include any bridge or freeway declarations but the average length of these trips is relatively short.

Table 2: Summary description of bridge and freeway declarations from the 2008 Montreal household travel survey (before validation)

DECLARATION TYPE	DISTINCT COMBINATIONS	NUMBER OF SURVEYED TRIPS	% OF TOTAL	AVERAGE TRIP LENGTH (STRAIGHT LINE KM)
No bridge or freeway	1	97,349	58.9%	6.12
Bridge (1 or 2) only	24	4,378	2.6%	12.79
Freeway (1 to 6) only	205	41,712	25.2%	16.45
Bridge(s) and Freeway	834	21,933	13.3%	20.99
ALL	1064	165,372	100.0%	10.87

SIMULATION AND DATA ANALYSIS TOOLS

The process of converting the origin, destination and partial path information in the survey into complete trip itineraries requires the assignment of each trip to a route that includes the declared bridges and freeways. In addition, for the purposes of analyzing infrastructure users, individual traveler attributes must be preserved during the simulation. For these reasons, the open-source activity-based transportation simulator TRANSIMS (https://code.google.com/p/transims/) along with its associated development environment TRANSIMSStudio (http://transimsstudio.sourceforge.net/), is used for the constrained trip assignment.

The TRANSIMS software consists of roughly 70 modules packaged as executable files which can be run in batch mode. Parameters are passed to the executables using control files containing plain text. The module of primary interest for the current experiment is the "Router" which generates trip itineraries between origin and destination activities. Constraints on the routing algorithm can be specified in the control file. Activity locations, as well as other elements necessary for a TRANSIMS simulation (parking lots, lane connections at intersections and other) are synthesized from the base network data using the "TransimsNet" module.

METHODOLOGY – CONSTRUCTION OF VALID ITINERARIES AND NETWORK LOAD

The validation of bridge and freeway declarations contained in the travel survey is performed using a constrained assignment algorithm that attempts to force each trip to follow a path that includes the bridges and freeways declared by the traveler. In the case of bridges, this is accomplished by removing from the simulation network all bridges except those declared by the traveler. The case of freeways is similar, except that the speed on the declared freeway is set at an unrealistically high value to maximize the chance that it is included in the shortest path.

Three types of constrained trip assignment are performed. In the first type, the algorithm attempts to assign trips to a path that includes all the declared freeways and bridges. In some cases, no shortest path can be found usually because the respondent did not declare the use of a bridge. These trips with no path are subsequently fed into the second constrained assignment in which only the declared freeways are considered. The third constrained assignment generates itineraries for trips without any declared bridge or freeway on a network where these components have been removed.

The result of the three constrained assignments is a set of validated trip itineraries. These itineraries are dynamically loaded onto network links using the TRANSIMS "PlanSum" module to generate validated link volumes by time of day. The application of a scaled volume-delay function (see the Results section) produces estimates of congested travel times. The process is summarized in Figure 3 below.

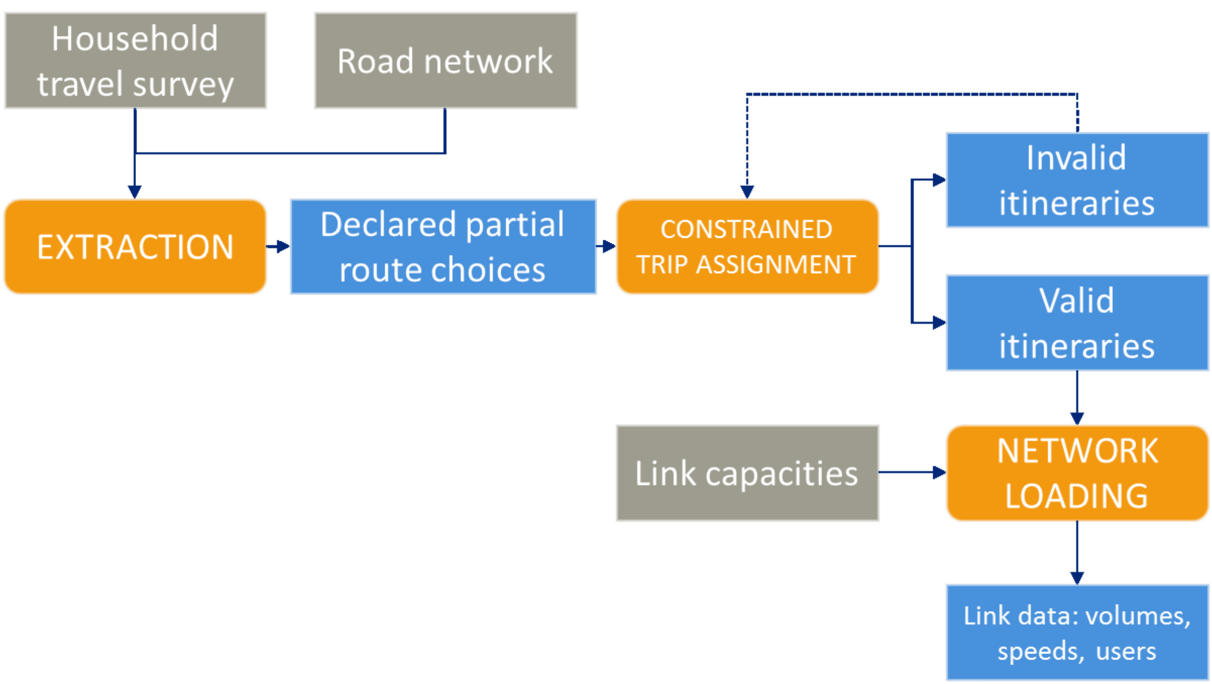


Figure 3: Summary of the methodology for generating validated itineraries and network loading

RESULTS – EVALUATION AND APPLICATION

Detailed models of this kind generate large quantities of results even when based upon relatively small quantities of data. For example, although the 5% sample of travel demand used in the validation procedure represents roughly 165,000 trips, the file of link-by-link itineraries contains almost 8.6 million records.

Of the original 165,372 automobile trips, the above procedure generated 160,319 itineraries representing a base invalidation rate of 3.9%. For the 68,023 trips with a bridge or freeway declaration, the base invalidation rate of 0.2%. The fact that the simulator is able to find a path for a given trip does not necessary mean that the bridge and freeway declarations for that trip are valid. A more detailed analysis of the validation results is described in the next subsection. The second subsection deals with the analysis of link volumes, user characteristics and travel times.

PLAUSIBILITY OF BRIDGE AND FREEWAY DECLARATIONS

The plausibility of the bride and freeway declarations is first assessed by examining the different types of validation. Only the first two constrained assignment algorithms simulate SRI users. The results of the sequential execution of the two algorithms can be classified into four cases:

1. The declared path cannot be simulated (155 trips - 0.2%).
2. The declared path is not reproduced by the validation algorithm (6,355 trips – 9.3%).
3. The declared path is partially reproduced by the validation algorithm (11,407 trips - 16.8%).
4. The declared path is fully reproduced by the validation algorithm (50,106 trips – 73.7%).

In total, 90% of declarations could be partially or fully validated. Only in rare cases (0.2%) could no path be generated for a given trip, usually resulting from network coding problems. In roughly 13% of cases in which the trip had least one bridge or freeway declaration, the path generated by the assignment algorithm included no bridges or freeways. Instances of unused bridges are attributable to survey coding problems: either the bridge was declared erroneously or one of the trip ends is improperly geocoded. Unused freeways (which include most of the 17% of trips with partial validations) can have multiple causes such as:

- Use of service roads (which are not coded as SRIs in the simulation network) rather than the associated freeways;
- Certain roads considered freeways by drivers are not actually freeways, especially major arterials with a provincial route number in a suburban or rural setting;
- Ambiguous definitions of freeways (a single segment can have multiple names).

An analysis of validated trip length distributions by type of validation (Figure 4) shows that trips whose itineraries could not be reproduced by the validation algorithm are considerably shorter than those trips whose itineraries could be partially or fully validated. This suggests that a freeway was not required (and perhaps not used) for many of these trips.

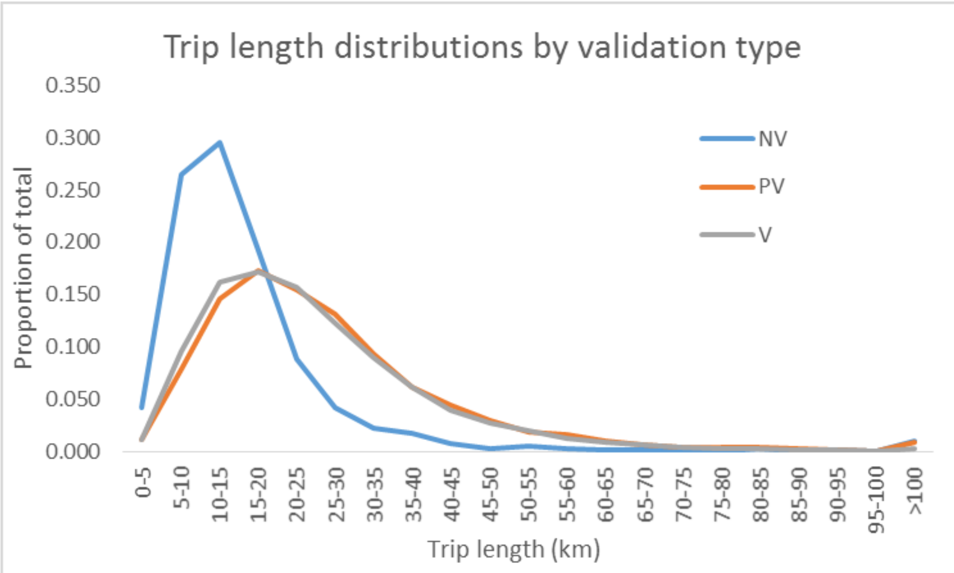


Figure 4: Trip length distributions by validation type (NV - validated path has no bridges or freeways; PV - validated path includes some of the declared bridges and freeways; V - validated path includes all declared bridges and freeways)

Another method for evaluating the validity of the bridge and freeway declarations is to compare the validated travel times with the travel times obtained from an unconstrained assignment of trips to the shortest path. No definitive conclusions can be drawn since the shortest path predicted by the model may not be the shortest path in reality but the comparison can give an impression of the data's validity. Figure 5 shows the cumulative distribution of the relative differences between the validated travel time and the simulated travel time. The graphic indicates that fully half of validated travel times are effectively equal to the shortest path travel time and roughly 85% of validated travel times are at most 30% longer than the shortest path. Deviations from the shortest path can be attributed to well-known factors such as traffic congestion, disruptions on the day of the survey interview, imperfect information possessed by drivers, drivers motivated by considerations other than time in their path choice etc.

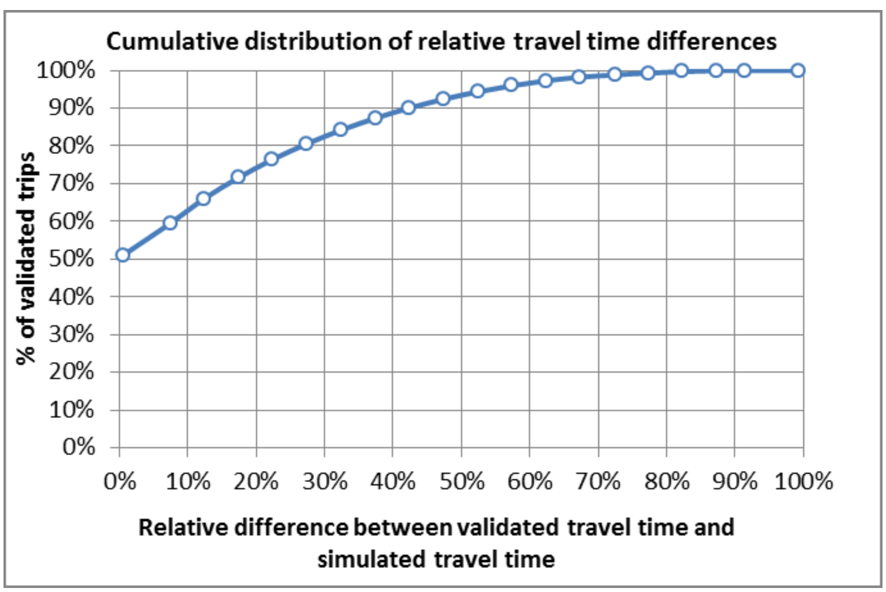


Figure 5: Cumulative distribution of relative travel time differences for trips with a fully or partially validated itinerary

Figure 6 illustrates the two primary types of result that are generated by validation process. The top half of the figure shows links flows, calculated as the sum of individual itineraries, on a portion of the network for the morning peak period. Superimposed on the link flows is a single validated itinerary. The inset box shows the attributes of the trip including the departure time, the length, the duration and a unique "MODE_ID" which allows direct association with travel survey. The bottom half of the figure serves as an anecdotal validation of the bridge declaration by showing the itinerary generated by Google Maps for the same origin and destination. The itinerary proposed by Google follows a path identical to the validated survey path and has a comparable duration.

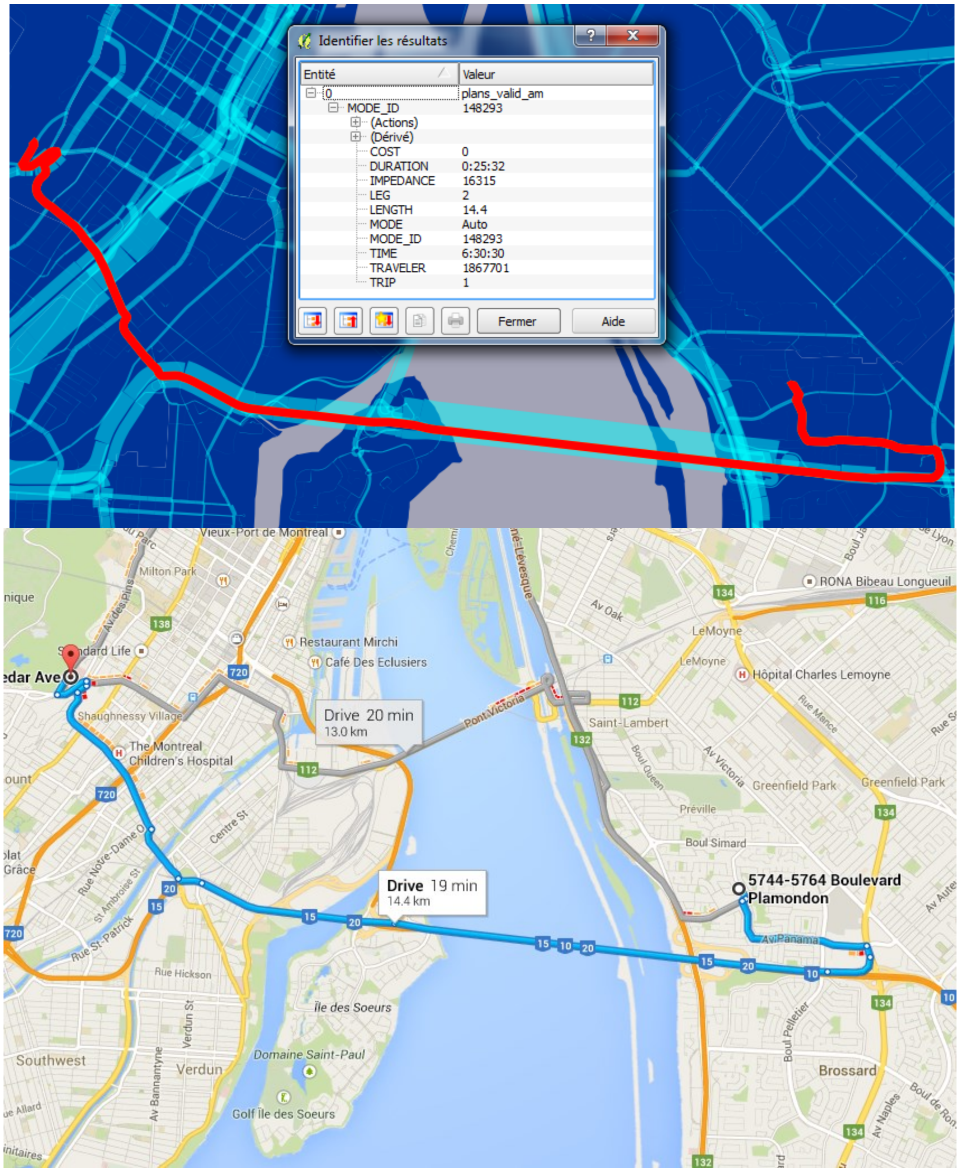
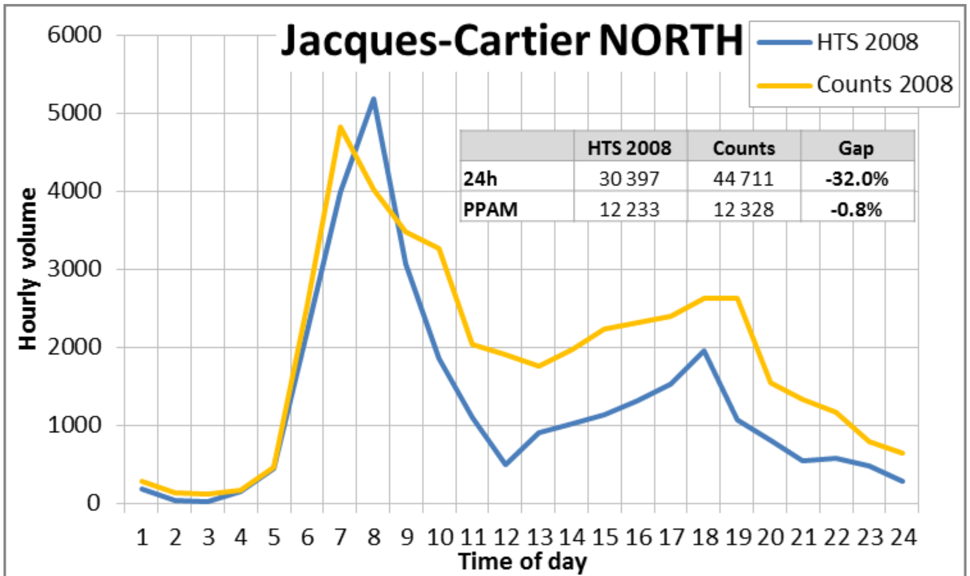
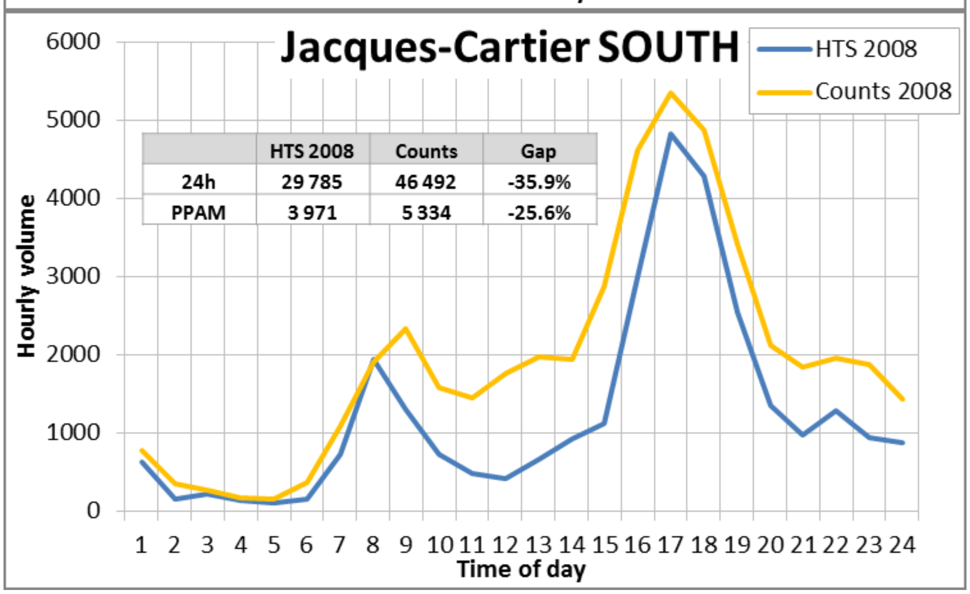


Figure 6: Trip validation results showing a single itinerary and loaded network links (top); the itinerary generated by Google Maps for the same origin and destination (bottom)

Figure 7 presents another means of testing the plausibility of the validated bridge and freeway declarations. The figure compares hourly volumes estimated using the validated itineraries expanded using the person-weights in the survey with observed with roadside counts on the Jacques-Cartier Bridge. The temporal distributions are similar, and the total volumes in both cases are comparable during the morning peak period. However, afternoon peak and off-peak volumes are consistently underestimated by the travel survey. This result is to be expected since the survey excludes commercial traffic and all trips based outside the Greater Montreal Area. This type of comparison was performed for all 15 bridges and the results were broadly similar.



	HTS 2008	Counts	Gap
24h	30 397	44 711	-32.0%
PPAM	12 233	12 328	-0.8%



	HTS 2008	Counts	Gap
24h	29 785	46 492	-35.9%
PPAM	3 971	5 334	-25.6%

Figure 7: Comparison of validated hourly volumes with roadside counts on the Jacques-Cartier Bridge (top: northbound toward Montreal; bottom: southbound from Montreal)

ANALYSES FOR THE DESIGN AND TESTING OF MITIGATION MEASURES

Overall, based on analyses of trip lengths, travel times and comparisons roadside counts described in the previous section, the bridge and freeways declarations can be considered sufficiently credible to form the basis of a detailed analyses of SRI users. Three examples are discussed below: a standard select link analysis; an interactive visualisation tool for the design of mitigation measures; and the development of a traffic congestion model for testing mitigation measures prior to implementation.

Standard select link analysis

Figure 8 shows a result that is typical of traffic assignment models. The figure illustrates a select-link analysis of a specific SRI – the southbound Louis-Bisson Bridge – over a 24-hour period. The density of trip origins is represented in blue and the density of destinations in orange. The locations major trip generators are clearly visible. The load profile generated throughout the network by all bridge users is included as well. The image is informative, but traveller characteristics are absent.

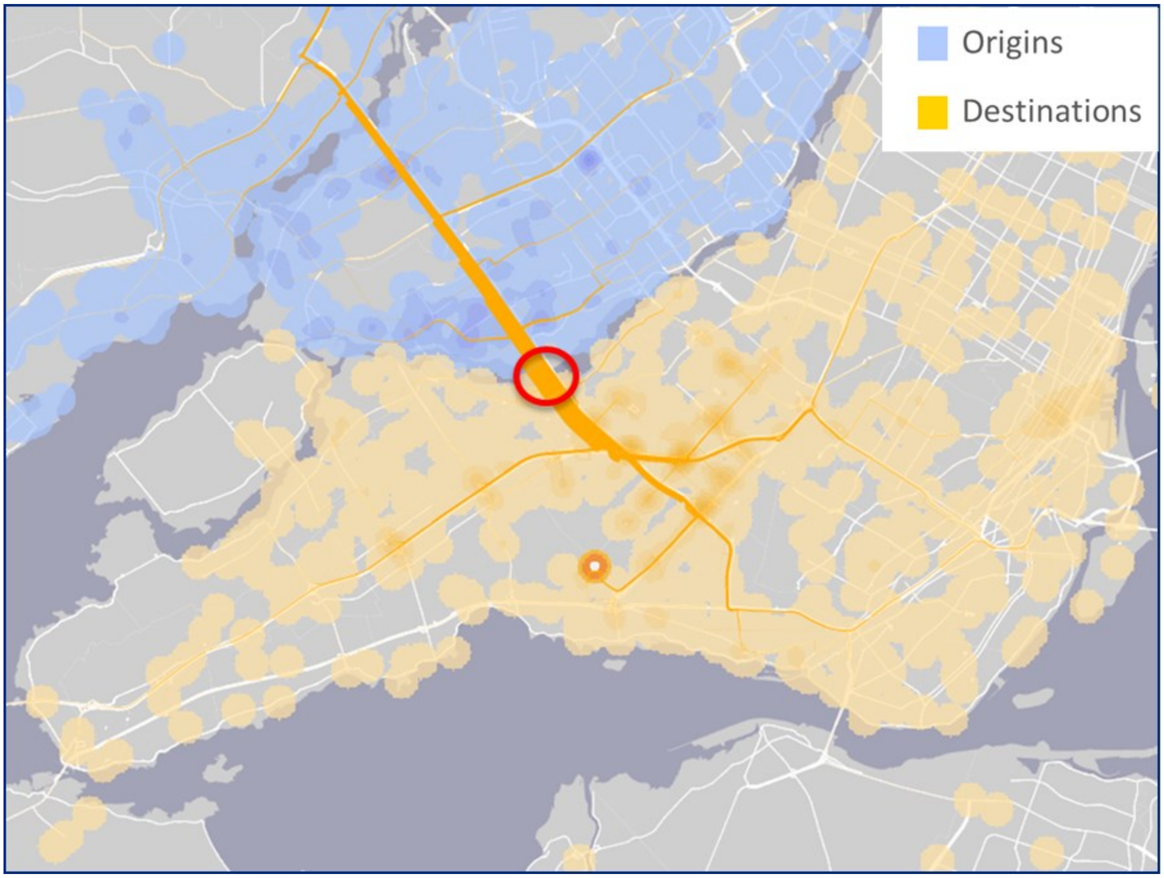


Figure 8: A standard select-link analysis on the southbound Louis-Bisson Bridge (circled in red) generated by loading the network with individual validated trip itineraries

Interactive visualisation tool for the design of mitigation measures

Figure 9 shows a detailed 24-hour select link analysis of the Jacques-Cartier Bridge generated using an interactive visualisation tool. This spreadsheet, built in Excel and based on the validated itineraries described above, allows the user to rapidly generate a report on a specific SRI selected from a drop-down list. The report includes household, person and trip characteristics. The residences of each user are mapped at the top right. Age and gender distributions are on the bottom left. Detailed trip information includes a map of trip origins, profiles of trips by purpose, and an aggregated origin-destination matrix. By assigning these trips to the public transit network, it is possible to identify transit lines that could provide alternative travel options. This kind of tool could be useful for different types of mitigation strategies. For example:

- Communication: the map of user households identifies neighbourhoods that should be kept informed of the disruption and the available transportation alternatives. The demographic profile of users can provide indications of the most effective means of communication.
- Compensation: The map of trip origins and the distribution of trip purposes can help to identify specific economic activities that may be adversely affected by the disruption and could be monetarily compensated for their losses if necessary and if possible.

- Coordination: The origin-destination matrix indicates which regions of the metropolitan area will be most strongly affected and should be consulted regularly during the design and deployment of mitigation measures.
- Transit redeployment: The list of the ten most-accessible transit lines can be useful for the planning of additional transit services. Information on household car ownership (not shown due to space limitations) can provide an indication of the chance of success of such measures.

Strategic road infrastructure user profiles

2008 Travel Survey
Validated itineraries (24h all purposes)

PONT JACQUES-CARTIER

Trips

Purpose (except return home)		Trips		Veh-km		Avg length
Work	1	22,578	67%	492,516	69%	21.8
Study	2	1,589	5%	37,063	5%	23.3
Liesure	4	3,733	11%	74,417	10%	19.9
Shopping	5	[illegible]	3%	20,040	3%	20.3
Other	6	4,572	14%	85,121	12%	18.6
		33,458		709,157		21.2

AM peak period OD matrix

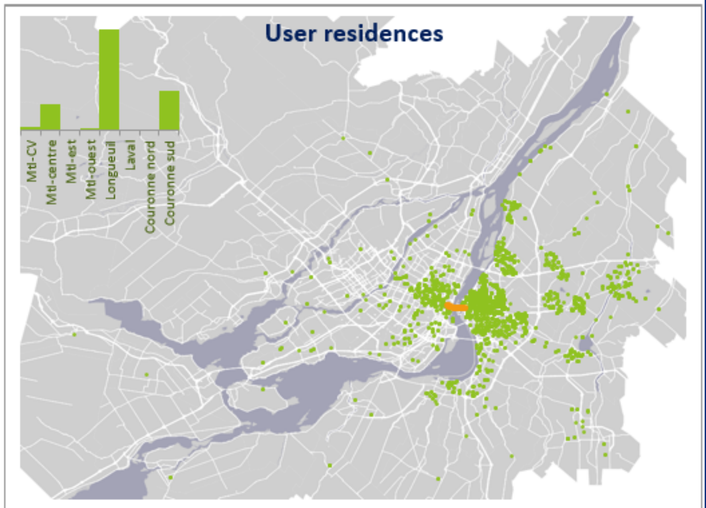
	MTL	LON	LAV	CS	CN	
MTL	0.0%	19.1%	0.0%	4.6%	0.0%	23.6%
LON	54.4%	0.0%	0.3%	0.0%	0.0%	54.7%
LAV	0.0%	0.8%	0.0%	0.2%	0.0%	1.0%
CS	20.5%	0.0%	0.1%	0.0%	0.0%	20.7%
CN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	74.9%	19.9%	0.4%	4.8%	0.0%	

Transit options (AM peak period)

	Lig1	% Vol	Avg time	User time	Competitivity index
1	3008	9.0%	56	42	1.33
2	3073	6.2%	57	52	1.08
3	3020	5.0%	59	59	0.99
4	3010	4.4%	68	54	1.26
5	3	4.2%	56	33	1.71
6	7325	3.7%	75	72	1.05
7	3099	3.3%	67	61	1.10
8	3016	2.9%	54	43	1.26
9	3004	2.4%	65	68	0.95
10	1	2.0%	59	32	1.81
		43.2%	61	51	1.19

Travellers

DEMOGRAPHICS		Men		Women	
16-24 years	16	831	4%	1,461	11%
25-34 years	25	4,235	21%	2,471	18%
35-44 years	35	5,397	27%	3,731	27%
45-54 years	45	4,790	24%	4,125	30%
55-54 years	55	3,282	17%	1,573	11%
65-74 years	65	1,098	6%	409	3%
75 years and above	>75	202	1%	62	0%
		19,834		13,833	



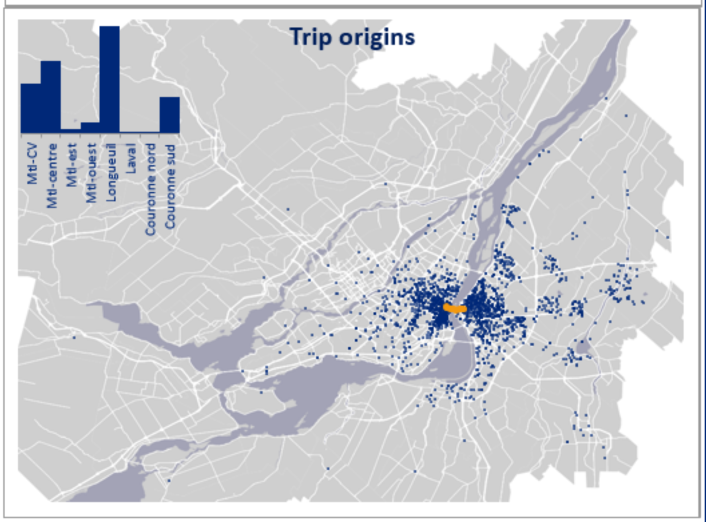


Figure 9: Detailed profile of users of the Jacques-Cartier Bridge

Towards a model of traffic congestion for testing mitigation measures

The detailed interactive tool is useful for conceiving mitigation measures, but a means of testing them before their implementation is surely desirable. A complete traffic model incorporating congestion would be helpful in this regard. This section briefly describes the first steps of the development of such a model.

For the analysis of large urban road networks, the most commonly used congestion model is the volume-delay function which relates the volume of traffic to the average traffic speed on a specific link. More realistic microscopic models exist (queue-based, cell-transmission etc.) but they have at least two significant disadvantages in the present context. First, they are not scalable and therefore require a complete population of travellers in order to generate plausible results. Secondly, microscopic models require the specification of numerous parameters for which little reliable information is currently available, particularly the types of vehicles in the fleet and their dynamic characteristics as well as precise information describing traffic signal timings. Moreover, the automobile travel demand observed in the travel survey represents roughly 5% of private vehicle trips. Commercial vehicles such as taxis, delivery trucks and all freight traffic are excluded. To compensate for the missing demand, a scaled model of congestion is applied based on the classic volume-delay relationship.

A typical volume-delay relationship commonly used in traffic simulation is the Bureau of Public Roads (BPR) function which has the following form:

$$t = t_0 \left[1 + \alpha \left(\frac{V}{C} \right)^{\beta} \right]$$

Where t is the travel time on a specific link, t_0 is the link travel time under free-flow conditions, V is the link volume, C is the link capacity and α and β are calibration parameters. Note that the link travel time depends only on the ratio of V with respect to C. Therefore, if the simulated volume V is 5% of the true volume, then using 5% of the true capacity as the scaled value for C will yield the same travel time as would be obtained using the real volume and capacity. For some road segments, a scaled value of C can be estimated empirically based on the hypothesis that these segments operate at capacity during periods of peak demand. This hypothesis is almost certainly true on most of the 15 bridges that provide access to Montreal. The scaled capacities on bridge links are therefore estimated using the formula:

$$C_s = \frac{V_o}{3}$$

Where C_s is the scaled capacity and V_o is the number of survey trips crossing the bridge in the peak direction during the morning peak period from 6 am to 9 am. The capacity per lane is obtained by dividing C_s by the number of lanes. As shown in Table 1, the scaled lane capacities of the bridges vary significantly from 21 on the Pont Viau to 61 on the Champlain Bridge. While the estimates for the lower-volume bridges may not be reliable, the variation among the higher-volume bridges reflects their differing characteristics which include the functional class of the road they carry, the configuration of access points and the composition of traffic. Accordingly, an upper value of 60 veh/h/lane was used for the regions freeways although a detailed study of the locations of freeway congestion would produce more refined estimates.

A true simulation of traffic congestion would involve an iterative algorithm that converges toward user-equilibrium. Tests of this approach and the calibration of model parameters are on-going, but congested travel times can be obtained by applying the volume delay function to the validated network loads (which, in theory, represent the equilibrium state). The result illustrated in Figure 10 is typical of those produced by standard traffic assignment packages. Traffic volumes are represented by link widths and the ratio free-flow travel time to congested travel time is represented by the link colour. The results are aggregate by thirty minute time periods.

Figure 10: Illustration of congestion simulated using validated trip itineraries.

CONCLUSIONS AND FUTURE WORK

This paper has presented a technique for using partial path information in a large sample travel survey for the detailed characterization of strategic road infrastructure users. The presented methodology is based on bridge and freeway declarations that were found to be plausible based on an analysis of the corresponding validated itineraries. The methodology includes a mechanism for incorporating these itineraries into an interactive visualisation tool which could inform the design of a variety of disruption mitigation measures including communications strategies, detour instructions and the provision of temporary transit services. Moreover, a model of traffic congestion, still in development, could provide a means of testing proposed mitigation measures before they are implemented. The methodology does have several limitations which could be addressed in future work.

First of all, the reliability of the validation procedure could certainly be improved through the acquisition and integration of detailed and reliable estimates of traffic speeds and volumes. Secondly, although the method presented above demonstrates the application of an activity-based modelling framework (TRANSIMS) using non-synthetic travel demand data, only a sample of the total demand is modelled. Activity-based traffic models simulate individual travelling agents but require that the travel demand include the entire population in order to realistically model queues and other vehicle interactions. Since most travel demand models are based on surveyed samples of the population, activity-based models are usually associated with a population synthesis component. Direct measurements of complete travelling populations are now conceivable in the public transit realm since the deployment of smart card-based fare collection systems (for a test case, see [21]) but comparable data for automobile travel are rare.

In addition to quantity, the quality of the source data represents another limitation. Auto-drivers responding to the survey may have difficulty providing accurate itinerary information in a phone interview since the definitions and names of streets and freeways are often ambiguous. In addition, the Montreal travel survey does not ask about access points so the locations at which drivers choose to enter and exit freeways can only be imputed. Eventually, mobile and automobile technology may provide alternatives to the travel survey as a data source. In multiple cities around the world, private automobiles are equipped with transponders that allow the vehicle to be detected at specific locations such as the boundary of a downtown congestion zone or the entrance and exit of a toll freeway. Progressively more vehicles are also equipped with GPS devices that record each trip. However, as this paper has tried to show, complete itineraries can be credibly produced from incomplete path information. In any case, the design of effective planning strategies can always be improved through the use of better information.

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DISCLAIMER

The views presented in this paper belong solely to the author. They do not necessarily reflect the official policy or position of the AMT. Numerical results are for illustrative purpose only and are not intended for official use.

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