

**RÉAMÉNAGEMENT DE L'AUTOROUTE MÉTROPOLITAINE À MONTRÉAL : UNE PLANIFICATION
EFFICACE POUR UN MILIEU DENSE ET COMPACT**

**REDEVELOPMENT OF THE METROPOLITAN EXPRESSWAY IN MONTREAL: EFFICIENT
TRANSPORTATION PLANNING IN A DENSE AND COMPACT URBAN ENVIRONMENT**

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Exposé préparé pour la séance sur les
Succès en planification des transports
urbains

du Congrès annuel de 2011 de l'Association
des transports du Canada

à Edmonton (Alberta)

Paper prepared for presentation at the
Success Stories in Urban Transportation
Planning Practices Session

of the Transportation Association of Canada
Annual Meeting

in Edmonton, Alberta

RÉSUMÉ

L'autoroute Métropolitaine à Montréal ayant été conçue pour des débits passés beaucoup plus faibles qu'à l'heure actuelle, doit maintenant être modernisée afin de répondre aux demandes actuelle et future, notamment sur le tronçon compris entre l'échangeur Côte-de-Liesse et l'échangeur des Laurentides. En effet, la reconstruction nécessaire de diverses structures fournit au MTQ l'occasion de réfléchir aux améliorations à apporter à cette portion du réseau supérieur.

Le tronçon de l'autoroute métropolitaine situé entre l'échangeur Décarie et l'échangeur des Laurentides présente la particularité de combiner la demande en déplacements de deux autoroutes, soit l'A-15 et l'A-40, où des flots de circulation considérables dans l'axe nord-sud et est-ouest s'entrecroisent, affectant ainsi la fluidité de la circulation et créant une problématique de sécurité. Les impacts positifs potentiels d'un réaménagement sont considérables lorsque l'on considère que ce tronçon de l'autoroute métropolitaine est le plus achalandé au Québec. Les débits sont considérables aux heures de pointe mais aussi en dehors de ces plages horaires, ce qui représente un enjeu majeur.

En raison de la géométrie complexe et des multiples interactions avec le réseau local, le logiciel de modélisation de la circulation VISSIM a été utilisé. Recréer les conditions de circulation existantes sur le réseau à l'étude dans ce modèle est un défi majeur de calibrage dû à la congestion endémique et à la sursaturation que présente ce réseau. C'est pourquoi les enquêtes origine-destination réalisées dans le secteur d'étude ont été utilisées afin de pousser l'analyse plus loin que la simple étude des débits en considérant également les patrons de déplacements et les entrecroisements qui en résultent. En utilisant ces données pour le modèle de simulation, on obtient une représentation plus près des observations faites sur le réseau dans des conditions de surcapacité.

L'étude a conclu que le simple ajout de voie de circulation n'augmente pas automatiquement la capacité puisque le tronçon d'étude est circonscrit et que d'autres contraintes à l'extérieur du tronçon limitent les gains potentiels. L'objectif des solutions étudiées est donc d'améliorer la fluidité du tronçon sans pour autant amener plus de véhicules au prochain point de congestion. Ainsi, une refonte complète du réseau a été proposée afin de respecter la hiérarchisation et les principaux patrons de déplacements.

Mots-clés : circulation, VISSIM, autoroute en milieu urbain

ABSTRACT

The Metropolitan Expressway in Montreal was designed for much lower traffic volumes than those of today. This important link needs to be rehabilitated to respond to pressing current and future needs. This rehabilitation is especially needed between the Côte-de-Liesse Expressway to the des Laurentides (Laurentian) Expressway. The rehabilitation or reconstruction of a number of structures comes as an opportunity to examine potential improvements to this important roadway link.

One segment of the Metropolitan Expressway, the busiest freeway in Québec, carries the load of two separate freeways (the A-15 and the A-40) since the A-15 (north-south) has two branches (Laurentian and Décarie Expressways) that are linked together by the Metropolitan (east-west). This situation creates considerable weaving patterns between east-west and north-south traffic that cause congestion and raise safety concerns. One of the major challenges to any rehabilitation is the important traffic volume, which remain high throughout the day.

A VISSIM model was used to modelize this critical freeway link because of its complex geometry and its numerous interconnections with the local road network. Creating a model that accurately reflects existing traffic conditions in this extensive study area is a major challenge since the road network is oversaturated and heavily congested. Traffic analysis had to be pushed beyond a simple analysis of traffic volumes. Origin-destination surveys of vehicles were done to properly simulate and understand weaving patterns. The use of origin-destination information in the VISSIM model improved its portrayal of observed traffic conditions (overcapacity and heavy congestion).

This study concluded that the addition of a single lane on freeway segment would not necessarily increase capacity on the expressway. Bottlenecks outside the study area and weaving patterns limit any potential capacity gains coming from an additional traffic lane. The objective of this study was to improve the fluidity of traffic, without necessarily increasing the number of vehicles reaching the next bottleneck. A complete overhaul of this freeway segment was proposed that would respect roadway hierarchy and better serve prevailing traffic patterns.

Keywords: traffic, VISSIM, urban expressway

INTRODUCTION

The retrofit of existing infrastructure is an important challenge for various agencies throughout Canada. This can be especially challenging when road infrastructure is located in a relatively compact urban area. In addition to coming close to the end of their lifespan, many of these infrastructure are poorly integrated into the urban environment, are heavily congested, have safety deficiencies (left-hand exits) and travel patterns have changed considerably after their opening. The current state of practice has changed considerably since these facilities were designed. The Décarie interchange in Montreal, one of the first freeway interchanges in Canada, presents these challenges. The Décarie interchange is at the junction of the Metropolitan and Décarie expressways.

The Metropolitan Expressway on the Island of Montreal is part of the only continuous roadway, Highway 40, which crosses the island along its east-west axis. The most heavily travelled portions are built as an elevated six lane expressway with at-grade one-way collectors. The collectors also serve as local arterials in addition to allowing access to adjacent buildings. The land adjacent to the Metropolitan is entirely developed.

The Metropolitan Expressway was opened in 1960, but was never built to carry today's traffic loads. Highway planners never anticipated that it would become the backbone of the Montreal road network. Most structures are over half a century old and will need to be renewed or replaced in the coming years. Therefore, there is an opportunity to address some of its deficiencies such as its urban integration, weaving zones and left-hand exits. Because of the general structure of the road network which concentrates traffic in the study zone, a concentration of on and off-ramps, this zone is often severely congested. A better configuration was sought, particularly the Décarie Interchange.

BACKGROUND

Opened in 1960, the Metropolitan Expressway (Highway 40 or A-40) is the major east-west roadway corridor in Montreal. It is the second freeway opened in Quebec. The Metropolitan Expressway was designed as an urban freeway to carry regional traffic. The Metropolitan Expressway only became part of the Trans-Canada Highway later in the 1960s when Highway 40 was expanded westwards towards Ontario and east towards Québec City. The Décarie Interchange was built at the same time as the Metropolitan was opened, but the Décarie Expressway was only opened a few years later in time for Expo 67. The Décarie Interchange is a five branch interchange that connects the Metropolitan Expressway, the Décarie Expressway, two arterial streets (Marcel-Laurin Boulevard/Highway 117 and Décarie Boulevard) in addition to service roads (Metropolitan and Décarie). This interchange is relatively compact considering the number of ramps and roads. The design of this interchange does not properly separate local and expressway traffic flows. Some local connections can only be made via the expressway. Some expressway to expressway connections are made via local streets.

The Metropolitan Expressway carries close to 204,000 vehicles on an average weekday (34,000 vehicles per lane per day) (Ministère des transports du Québec, 2009) and the Décarie Expressway carries also over 200,000 vehicles per day on only 6 lanes. Traffic loads in the area are extremely heavy since:

- The structure of the road network concentrates local, regional and transit traffic on this part of the road network;
- Three freeways terminate on the Métropolitain Expressway (Côte-de-Liesse Expressway/A-520, Décarie Expressway/A-15 and the des Laurentides Expressway/A-15). In addition to east-west traffic, many vehicles also use the Metropolitan Expressway to travel between these three connecting freeways.

The initial study at first only encompassed the Décarie interchange (see figure 1) but was expanded since traffic patterns elsewhere have impacts on this interchange. The study area thus encompassed over 10 kilometres of freeways (over 40 freeway lane-kilometres) and over 12 kilometres of service roads.

Each roadway element has been identified as a specific subzone (see figure 2):

- A – Côte-de-Liesse Interchange;
- B1 – A-40 East section between Côte-de-Liesse and Décarie Interchanges;
- B2 – U-turn located under A-40 between CN rail tracks and Décarie Interchange;
- C1 – On-ramp from A-40 East to Décarie Expressway South;
- C2 – On-ramp from Marcel-Laurin Boulevard to A-40 East;
- C3 – On-ramp from Marcel-Laurin Boulevard to Décarie Expressway South;
- C4 – Junction of the Côte-de-Liesse Expressway and Décarie Expressway service roads;
- C5 – Local roadway link from Décarie Boulevard to the North and West service road;
- D1 – Décarie Expressway South section between Décarie Interchange and Jean-Talon Street off-ramp;
- D2 – Décarie Expressway section South between Jean-Talon Street on-ramp and Décarie Interchange;
- E – A-40 East section between Décarie Interchange and Stinson Street off-ramp;
- F – A-40 East section between Stinson Street off-ramp and Des Laurentides Interchange;
- G – Des Laurentides Interchange.

Figure 1 Décarie interchange



Figure 2 Study Area



DATA AND METHODS

Data

The Metropolitan Expressway carries over 200,000 vehicles per day on an average weekday. Manual and automatic traffic counts were undertaken along expressway portions, ramps, collectors and local streets with a particular attention on morning and afternoon peak hours.

One of the challenges of using this traffic count data is that this freeway is heavily congested during peak periods, therefore since traffic counts are undertaken on multiple days. The extent and location of congestion varies considerably from one day to the next. Traffic counts during peak periods therefore varied considerably.

Because of the proximity of on and off ramps (located on both the left and right) on the Metropolitan and Décarie Expressways and recurrent congestion, simple traffic counts are not sufficient. Traffic counts were supplemented with vehicular origin-destination surveys. A number of segments of the express and collector lanes were surveyed. Cameras were placed on various segments of the freeway, collector lanes and ramps. Plate numbers were entered into a database to find origins and destinations of vehicles. These origin-destination surveys found that there a number of weaving traffic patterns. Many vehicles enter and exit the freeway on both the left and right ramps, and many vehicles cut across three to four lanes of traffic within a short freeway segments. The assumption that origin-destination patterns are the same for all entrances and exits is not valid in this case.

The routes and number of transit vehicles were also gathered as they were different from general traffic.

Methodology

The objective of this study was to find an optimal solution that addressed safety concerns, improved vehicular traffic fluidity, did not necessitate a property acquisition, respected the roadway hierarchy and maintained accessibility for enclosed adjacent sectors.

The evaluation of alternatives had to take into account for conditions outside the Décarie interchange (including any modifications). The study area was thus expanded beyond this interchange to comprise over 10 kilometres of freeways. A two stage approach was used to find a preferred alternative: local evaluation of alternatives and an evaluation of global alternatives. The first step consisted of dividing the study area into 13 subzones to evaluate possible alternatives. Any local alternative was eliminated if it was not geometrically feasible, did not respect the preferred hierarchy (local traffic does not need to use the freeway, freeway to freeway movements do not need to use the local road network) and did not improve safety (left-hand on- and off-ramps). In addition, any alternative needed to minimize impacts on accesses to adjacent properties, maintain transit service on the service roads, maintain pedestrian routes and minimize congestion delays.

The second step consisted of generating and evaluating global scenarios. These global scenarios are created based on the results of the evaluation of local alternatives. These global alternatives were evaluated using multi-criteria analysis. The analytical hierarchal process (AHP) method was used to determine the ranking of the various objectives of the study (Department for Communities and Local Government, 2009). Because of the important number of objectives, impacts and costs that needed to be taken into account in this project, these benefits, impacts and costs were categorized using a hierarchy (see table 1). The ranking was obtained by doing pair-wise comparisons for each objective. In other words, each objective was compared one on one to determine which one was more important. These comparisons were done for each of the three levels of the hierarchy. The first step compared the importance of the goals, externalities and costs of the project to obtain their relative weight. In the second step, the various goals are compared to obtain their share of the weight of the goals. Finally, when more than one criterion was used to evaluate a goal, these were compared. Otherwise, the relative weight of important objectives would be diluted comparatively to the other objectives. This yielded the weighting of objectives for the multi-criteria analysis. A VISSIM model was used to evaluate a number of criteria used in the multi-criteria analysis: length of traffic queuing on ramps with limited visibility or high differential speeds, travel times of vehicles on the expressway and the service road, travel times for transit vehicles and the vehicular capacity of freeway links.

A VISSIM model of the entire freeway network of the study area was generated. VISSIM was chosen due to heavy congestion in the study zone and the level of control of simulations. Other simulation tools are not appropriate to model severe congestion, freeway links and origin destination patterns over long distances. Two models were created: one for the morning peak hour and the second for the pm peak hour. Traffic volumes were supplemented with origin-destination routing on freeway and service road segments. These origin-destination patterns were particularly useful to simulate observed weaving patterns. Separate routes were also created for trucks since their origin patterns and desired speed curves are different than general traffic. The base scenario model was first calibrated based on field observations to represent actual traffic conditions. The principal criterion to determine if the simulation is accurate is the average speed on a link which was compared to a historical database provided by MTQ. Vehicle type (car, truck, articulated truck) was coded according to the provincial classification. Because the network is oversaturated, some characteristics of the car following model and the lane change model have been calibrated to represent the driving behaviour in these conditions. Parameters such as, look ahead distance, average desired distance between stopped cars, headway time, maximum acceleration and deceleration accepted and security distance factor have been adjusted to assure the simulated output traffic flows equal the input traffic volumes. This also permitted the proper simulation of Montreal drivers aggressive driving techniques.

Then, the local alternatives were individually coded and simulated. The input volumes were increased in an iterative method to recreate the equilibrium from the base model and determined the capacity gain of each scenario. This hypothesis is logical since the upstream network is currently oversaturated. A gain of capacity for a particular subzone will result in a

traffic volume growth until average speed reaches base scenario values and the network is in equilibrium.

Table 1 Weight of Goals and Criteria

Category	Goal/Impact	Measure	Weight
Goals (benefits)	Safety	Presence of traffic queues in ramps	25%
		Visibility	5%
	Separation of local and freeway traffic	Number of direct freeway to freeway connections	18%
	Functionality of the road network	Travel times on expressway	8%
		Travel times on service road	3%
		Capacity of road network	4%
	Transit performance	Travel times on roads with transit service	7%
Economic development	Access to adjacent neighbourhoods and businesses	3%	
Externalities	Urban and environmental impacts	Land acquisition	2%
		Impact on the surrounding community (noise, visual impact, etc.)	10%
Costs	Costs	Capital cost	15%

FINDINGS AND DISCUSSION

The two most conventional solutions for freeway capacity problems are road widening and elimination conflict points, in this case some of the closely spaced on and off-ramps. Both solutions are not applicable because they run counter to some of the primary objectives of the study. Road widening is nearly impossible without property acquisition or building demolition. Moreover, the addition of lanes did not increase the capacity of the Metropolitan Expressway, because major bottlenecks downstream from the study area currently severely limit capacity. The simple addition of a lane on the expressway within the study area would not yield significant capacity gains and would only result in providing additional stacking area for the queues. That being said, the addition of an additional lane extending well beyond the study area

could yield travel time savings and/or capacity gains, but this was not examined in this study since this would require examining two entire expressway corridors.

Furthermore, the elimination of ramps would be beneficial for traffic conditions on the Metropolitan Expressway but will jeopardize accessibility for adjacent sectors that are enclaved by a multitude of adjacent expressways and railway tracks.

That being said, by properly organizing the road hierarchy into three independent and parallel networks, local roads, service roads and expressways allowed for some potential gains in capacity. There were also opportunities to recreate or create missing links in the roadway network and better increase the permeability of the interchange. Actually, there are some discontinuities with the local road network. Currently, many local links force vehicles to use the expressway network. This results in a multiplication of traffic on expressway segments and an ineffective local road network that is not independent. Worse still, some expressway-to-expressway movements require using the service road network and even passing through traffic signals to undertake these manoeuvres. These hierarchy issues were very important since they affected not only vehicular traffic, but also public transport and active transportation by making some linkages difficult or impossible for these modes.

Elimination of left-hand ramps will correct safety issues by reducing lane change manoeuvres and place all merging traffic in the slowest lane. That, added to the relocation of some ramps to more appropriate locations also allows gains in fluidity by reducing the two most important weaving zones on the expressway where a number of vehicles were doing important weaving movements (800 vehicles per hour doing 3 lane changes in 500 metres; 1,200 vehicles per hour making 3 lane changes over 2 kilometres).

The local evaluation of alternatives yielded only a few areas with multiple alternatives that met the basic objectives of the redevelopment of the interchange. The retained local alternatives were used to create a global scenario. Currently, the MTQ is negotiating with Cities involved to reach a consensus on the recommended scenario before going forward. To avoid prejudicing these negotiations, the global scenario cannot be presented at this time.

With the hard economic situation and other critical infrastructures needing massive investments in the Great Montreal Area, MTQ does not when and how much funding will be available to invest in this project. Therefore, the overall project was subdivided into seven separate standalone phases of work. Each phase can be built on its own and continue to operate indefinitely. This gives the MTQ the flexibility to invest in small increments when funding is available and space the work over a long period of time if necessary. Phasing the works into independent phases also required that the design be optimized to ensure that the works can be terminated after each phase without needing additional work.

CONCLUSION

The retrofit of existing infrastructure is an important challenge for various agencies throughout Canada. This can be especially challenging when road infrastructure is located in a relatively compact urban area. In addition to coming close to the end of their lifespan, many of these infrastructure are poorly integrated into the urban environment, are heavily congested, have safety deficiencies (left-hand exits) and travel patterns have changed considerably after their opening. The current state of practice has changed considerably since these facilities were designed. The Décarie interchange in Montreal, one of the first freeway interchanges in Canada, presents these challenges. The objective of this study was to address these deficiencies.

The study area was expanded beyond the interchange since configurations and travel patterns upstream and downstream has impacts on proposed modifications for the interchange.

The use of origin-destination surveys of vehicles on congested freeways and with multiple closely spaced ramps is an extremely useful tool to understand traffic patterns on a freeway. These origins and destinations were vastly different than what would be expected if an assumption of proportional distribution was used. These origin-destination surveys found extremely important weaving patterns on expressways which acerbates congestion in the study zone.

A two stage multicriteria analysis was used to evaluate the various alternatives. The first step comprised the evaluation of local alternatives for 13 subzones. The second step consisted of creating global scenarios that examined the elimination of weaving zones and widening. VISSIM models were used as part of the second stage of this analysis. These VISSIM models were used to project future queuing (minimization of travel queues in freeway to freeway ramps), travel times (vehicular and transit) and capacity. Reducing weaving travel patterns generated travel time gains for users. On the other hand, the addition of a lane on the freeway did not increase capacity.

In a highly congested environment, the additional lanes on a freeway does not necessarily increase capacity or improve travel times. In this case, the reduction of weaving on freeways can yield significant travel time and capacity gains. That being said, it is still possible to propose modifications that increase safety in a highly constrained environment.

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