LOG ANALYSIS OF TRIP CALCULATION ON A TRANSIT WEBSITE

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Abstract

The Montreal Transit Commission (MTC) and the Laval Transit Commission (LTC) put in place a transit user information system a few years ago which is accessible through their website. The functions of the system (calculation of transit paths, calculation of service accessibility, schedules) are used daily by thousands of Internet surfers. Of course, these systems have a dual function: in addition to providing information to transit users, they inform the organization about the mobility behaviors and trip patterns of these users. Moreover, examination of the logs of the localization search features of these websites makes it possible to enrich the subjacent geographical information system (GIS).

This article emphasizes the potential of the analysis and use of trip calculators as tools in transit planning. First, it describes the fundamentals that should form the basis of transit websites in order to support planning: the Totally Disaggregate Approach (TDA) and Transportation Object-Oriented Modelling (TOOM). Then, it describes the system architecture and major functionalities of the trip calculator. Following presentation of some useful statistics, the focus shifts to an examination of the space-time characteristics of the website declarations and possible resections with origin-destination survey data. Finally, we list the informational problems arising related to the search for georeferences in such an information system for the transit user.

This paper introduces a new planning tool: the Transit User Information Website. In the coming years, it will be possible to use this site to conduct on-line transportation-class surveys, with instant validation. The embedded GIS in this kind of tool will also put it in a better position to integrate the new technologies that are developed for Intelligent Transportation Systems (ITS).

Keywords: Transport planning; Urban transport; User information system; Trip calculation
Topic Area: B1 Public Transport and Intermodality

1 Introduction

Today, most transit authorities provide information to their users through Internet websites, which usually contain detailed information on routes, schedules, fares and paratransit services. Some of them also provide a "trip calculator" (Federal Transit Administration, 2002). Trip calculators are advanced Web tools which will create transit itineraries based on user input of a specific origin and destination pair. Of course, these calculators serve a dual function: in addition to providing information to users, they also provide the organization with information about their mobility behaviors and trip patterns. Moreover, by examining the logs of the map reference search features of these websites, the subjacent geographical information system (GIS) can be enriched.

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This article underlines the potential for the analysis and use of trip calculators as tools in transit planning. Following a brief background overview of website usability, logfile analysis and transit websites, it describes the fundamentals that should form the basis of these websites in order to support planning: the Totally Disaggregate Approach (TDA) and Transportation Object-Oriented Modelling (TOOM). Then, it describes the system architecture and trip calculation process offered on the websites studied here. Some useful statistics are provided, followed by an in-depth examination of the space-time characteristics of the user's website declarations and possible resection with origin-destination survey data. We also list the informational problems related to the search for georeferences in such an information system for the transit user. Finally, the principal results of this research are given.

2 Background

It is usually difficult to adequately track user behaviors on a website because of the different "surfing paths" that can be followed by Internet users, depending on their needs (Piroli and Pitkow 1999). Some tools are designed to evaluate usability for general-purpose websites (Ivory and Hearst 2001), but a few authors have tried to use website logs to improve the website functions themselves, and not just the interface. Usability refers to ease of use, access to website functions and the extent to which user needs are met. Murphy et al. (2001) report that website logfiles can reveal valuable marketing information on customer habits and preferences. In the transportation field, the Internet, with the help of adequate websites, can be a powerful survey tool for tracking people trips (Golob and Regan 2001).

In public transportation, websites are seen as a natural extension of normal service activities and public relations tools. Efforts have been made to describe the elements that could be used to feed a transit information website for transit users. Lee, Baumgartner and Kim (1999) presented a Web-based bus information system (WBI) implementation with data stored in a Microsoft Access database. Peng and Huang (2000) have also used Access to store route and transit networks, bus stops and time-point data, and their database is linked to a GIS and to network servers. The Federal Transit Administration (2002) reports that about 20% of American transit websites have a trip calculator, but does not rate these in terms of features. The Montreal Transit Commission (MTC) and the Laval Transit Commission (LTC) have both implemented transit trip calculators on their websites (http://www.stm.info and http://www.stl.laval.qc.ca). At first glance, very few of these trip calculators have a true calculation function such as those in Montreal and Laval, where users can specify any location on the territory (address, intersection, trip generator, station and maps) and where they are not limited to lists of stations. In recent work (Trépanier and Chapleau 2002), we have shown that a trip calculator must rely on a comprehensive geographic information system (GIS) in order to meet the needs of transit users.

3 Methodology

While many tools are available for analyzing logs from common websites, there is no such tool for analyzing a transit calculator website. In this section, we will explain why these calculators need to rely on a strong methodological basis in order to provide the kind of results subsequently needed by planners.

3.1 Totally disaggregate approach

The methodology for both the construction and the operation of trip calculators is a blend of the Totally Disaggregate Approach (TDA) and TOOM. The use of the TDA for the storage, validation and analysis of large household origin-destination surveys constitutes the foundation of the data structure and the data itself for both the MTC and the LTC calculators. The main principles are the following (Trépanier et al. 2002):

- Every single piece of information from origin-destination surveys is kept in "tripfiles". These flat files contain data on households (size, home location, number of cars), people (age, gender, car ownership) and trips (trip chain, origin and destination locations, junction points, mode, purpose, transit routes and time of departure). The data are normalized and coded so that they can be rapidly retrieved and analyzed by software developed for the individual processing of trips. For the trip calculators, simplified tripfiles are used in which information on origin and destination locations, date and time, and transit routes is retained. The core information is the individual transit trip, as seen in Figure 1.
- Spatial districting, such as Traffic Analysis Zones (TAZ), is rejected for analysis in favor of the examination of individual trips, and trip extremities are geocoded at the most refined level of resolution. This is an essential feature of the trip calculator, because it enables users to specify precise origin and destination locations (such as addresses, intersections, monuments). Geographical information systems are thus essential at this point.

3.2 Transportation object-oriented modeling

The second approach (TOOM) structures the database and the software environment in such a way as to link the Geographic Information System, the Operational Information System and the calculator logfiles. TOOM was developed to address problems related to transportation data processing. These problems have been partially reported by Goodchild (2000):

- Temporality: transportation data always contain strong intrinsic temporal components (speed, time of movements), as well as extrinsic temporal components (date of effectiveness, time of collection).
- Geography: transportation data are spatially referenced, without zones if general usage is the goal.
- Structure: transportation data must be normalized so that they can be analyzed over time, by different software programs and for different purposes.
- Collection: transportation data are usually collected for a single purpose; far-sighted data collection can help to widen their range of use.

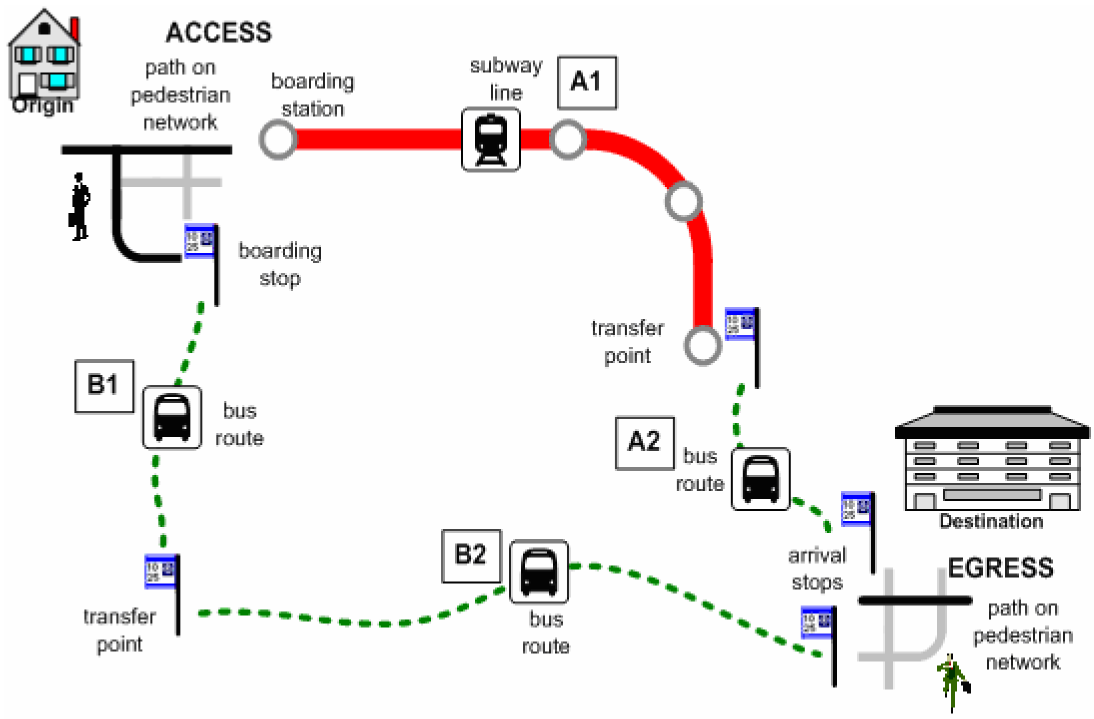


Figure 1. The individual trip in the Totally Dissagregate Approach

An object-oriented approach is well suited in this case, because of its openness and its flexibility. Based on traditional OO approaches (computer science), TOOM is characterized by its special metaclasses of objects, which are used to describe every transportation system (Trépanier and Chapleau 2001):

- Dynamic objects are elements which move within the system and are at the heart of transportation activities. The most common dynamic objects are people, cars and goods, and they have properties which express social, demographic or economic features.
- Kinetic objects describe the movement itself. Examples are transit routes, trip chains and individual trips. A road is a kinetic object when seen as a car link between two locations. These objects are characterized by length, capacity, service level, etc.
- Static objects refer to all the supporting elements of the transportation system that do not move. Home places, trip generators, transit stops, subways stations and depots are all static objects. These objects are related to spatial properties and to network connectivity.
- System objects are groups of objects embedded in the general transportation system. A transit network, for example, contains dynamic, kinetic and static objects which are interrelated. No transportation activity can exist without one of these metaclasses.

TOOM always attempts to create a wide view of every system, even though the data for each object may not be available. Figure 2, for example, presents a general TOOM for transit trip calculation. At the base of the model is the transit user, who uses two major systems to complete his trip. On the left, the territorial network defines the pedestrian network, and includes streets and static objects (trip generators, addresses, intersections, postal codes). On the right, the operational network is composed of the bus, subway and commuter train networks, and is seen as a single transit supernetwork by the user. The transit path is then defined as a sequence of route sections between two pedestrian paths (at the access and egress points, see Figure 1).

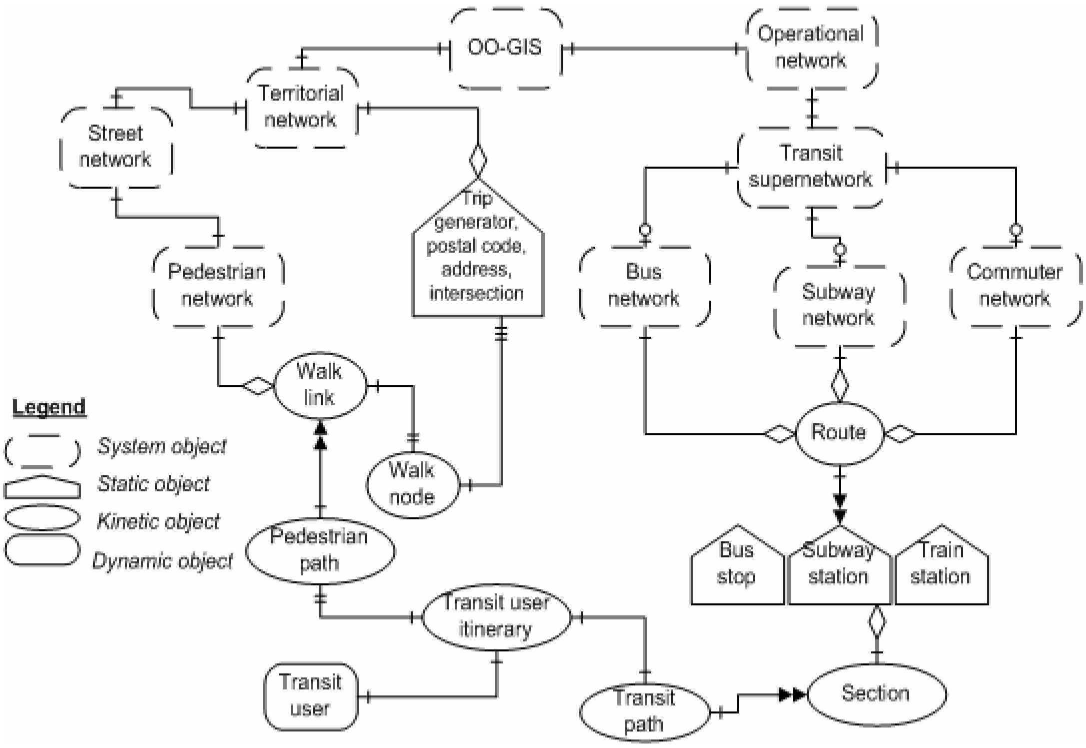


Figure 2. A transportation object-oriented model (TOOM) for transit trip calculation

3.3 System architecture

Without going into too much computing detail, let us examine the system architecture that is needed to obtain both the trip calculator and the related logfiles.

Figure 3 illustrates the information technology environment required for this project. Data are divided into territorial data (addresses, intersections, trip generators, map databases) and operational data (routes, schedules, stop databases), all implemented in an Object-Oriented GIS (OO-GIS). This GIS uses the TOOM approach to store and process data. Data are obtained from planning and operational systems at the MTC, and validated at the call center, which is staffed by qualified individuals with very good knowledge of the transit network and territory. Then, asynchronous transfers are made to the Web server, which has its own on-site database in order to improve website server performances. The trip calculation engine is located on the same computer. Updating frequency depends on the nature of the data: at the MTC, operational data on the transit network are updated every two months, while territorial data can be updated once a month. When needed, specific updates are made on both components (Trépanier and Chapleau 2002).

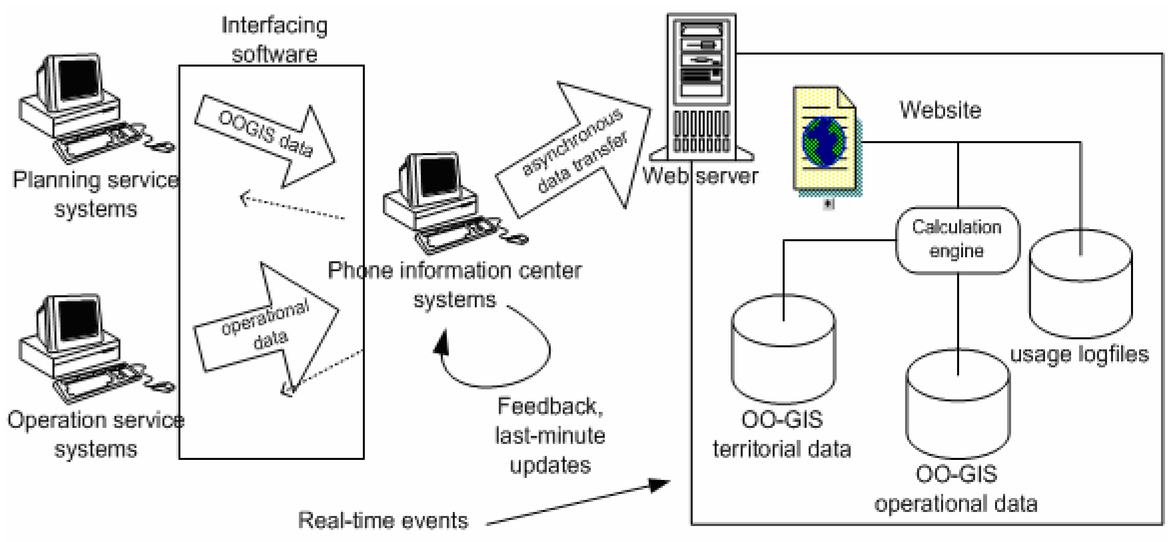


Figure 3. System architecture for transit trip calculation at the MTC

3.4 Trip calculation process

In order to better understand the analyses presented below, let us describe the typical trip calculation process on the MTC website (Figure 4). First, the user specifies his origin and destination locations in one of three ways: browsing through generator and stop lists; clicking on a map; or searching the database for a given intersection or address (the most common). Then, he specifies the day and the time of the trip, and has the option of applying penalties on certain transit modes (subway or train).

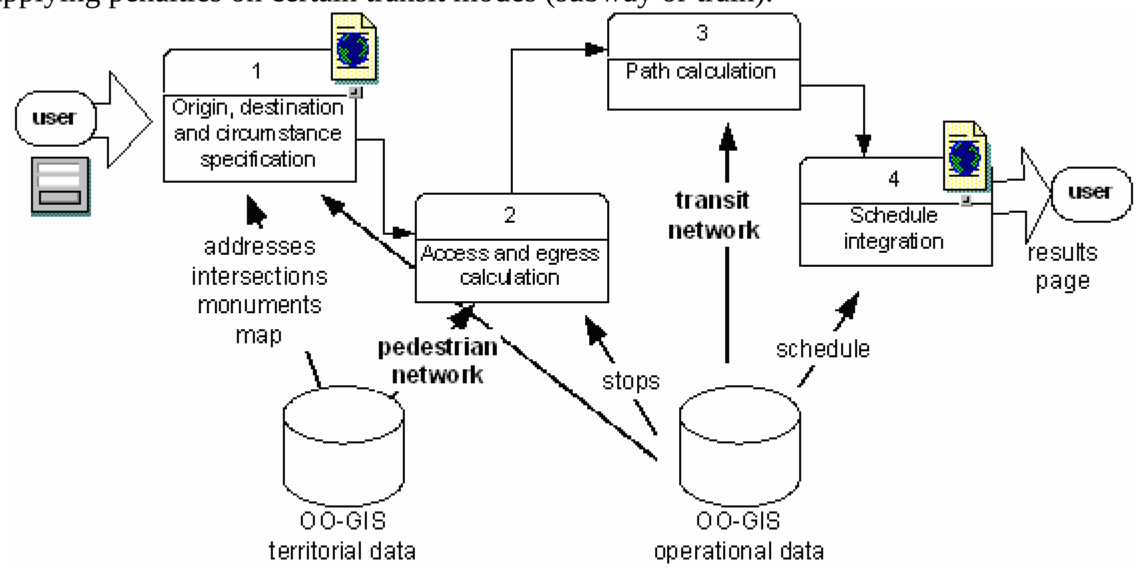


Figure 4. Trip calculation process on MTC and LTC websites

The rest of the process is handled by the calculation engine beneath the website. Access and egress are calculated using the pedestrian network. This determines the shortest walking path between the trip extremities and the transit network (which is reached through bus stops, train stations or subway stations). Then, there is a path calculation on the transit network (more than 50 paths can be calculated at a time, depending on the network complexity). A final selection of the best possible paths is made based on the schedule, which is fully integrated into the paths. Figure 5 shows the kind of result that can be obtained on the MTC website: route selection, walking distances, path chronology, sequence of bus stops and subway stations.

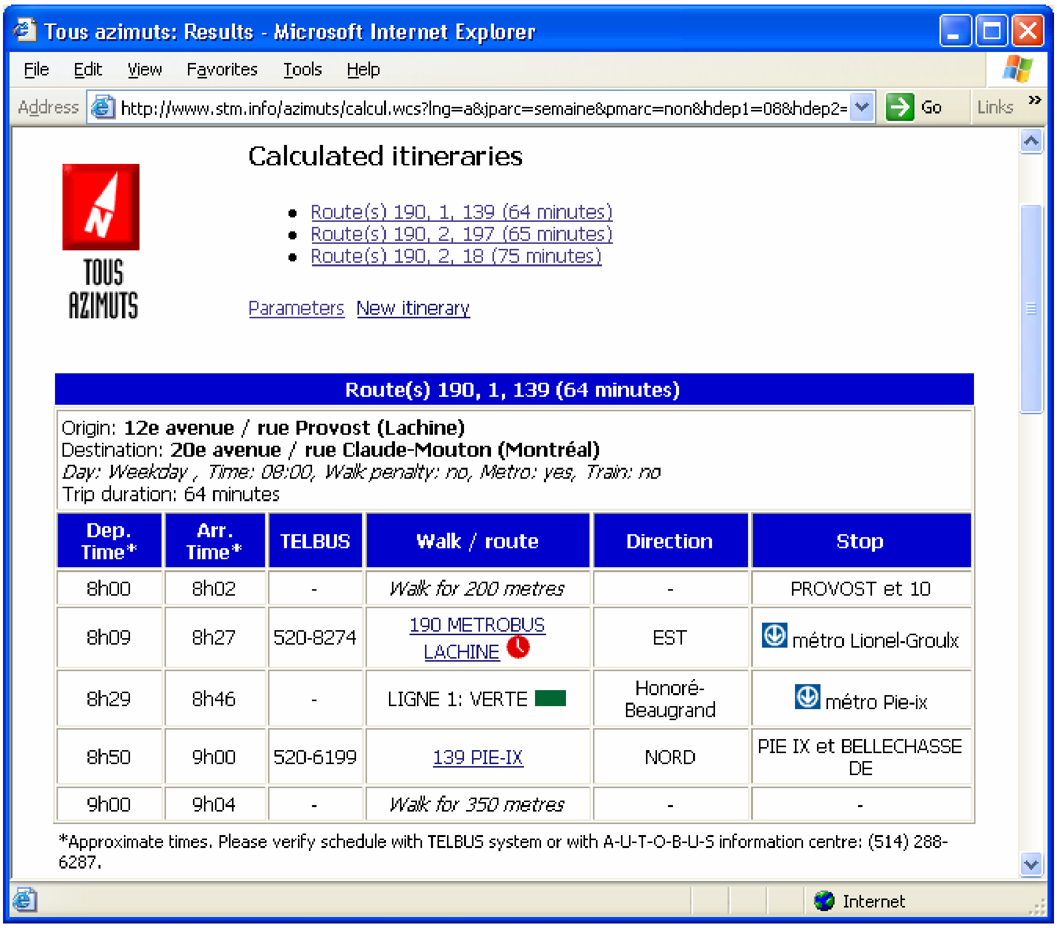


Figure 5. Trip calculation results page on the MTC website

Logfiles are kept for all transit trip calculations. They typically contain the date and time of the visit, the location of the origin and destination points (expressed in terms of identification, source and coordinates), the parameters specified by the user, a summary result of the calculation (route sequence) and the number of calculations made in a single visit. Only the last calculation is retained in the logfiles. At the MTC, there is also a full entry logfile, containing all text entries and clicks made by users during their visits.

4 Website-oriented analysis

In this section, the principal results that can be obtained from website-oriented analysis are demonstrated. These analyses are intended to show the popularity of the trip calculator function among users, to examine evolving trends in usage and to improve the website functions themselves with the help of appropriate indicators.

4.1 Statistics on visits

Table 1 shows monthly statistics for the trip calculation sub-website of the MTC website. A visit occurs when an Internet user accesses the website and performs a trip calculation. As we can see, users usually calculate about two trips per visit. The number of clicks and the average time per calculation are good indicators of the usability of the website. There is a click for every Web request sent (change of Web page). Between 2002 and 2003, these indicators are quite stable events, although there was a 57% increase in number of visits.

Table 1. Monthly statistics for the MTC website (trip calculator sub-website)

Month	*Calculations*	*Visits*	*Average clicks per calculation*	*Average time per calculation (s)*
Jan 2000	9,158	4,970	n/a	n/a
Jan 2001	32,321	14,738	n/a	n/a
Jan 2002	62,355	27,625	5.41	241.16
Jan 2003	93,758	43,316	5.12	247.17

The number of people using the trip calculator is relatively small, compared to the total number of MTC users (there are about 300 million trips per year on the MTC network). There were 333,611 visitors to the entire MTC website during the month of March 2002. Of this total, 27,625 (8.3%) used the trip calculator.

4.2 Trends

The number of users of the MTC and LTC trip calculators has been increasing steadily since these applications were launched in 2000. In 2001 alone, there was an increase of 221% for the MTC site. During the same period, CyberAtlas (2003) reported a 7.3% increase in the number of Internet users in general, and the average monthly average Web usage had increased from 8 hours and 17 minutes to 19 hours and 57 minutes.

Figure 6 shows the increase in the number of visitors between January 2000 and March 2002. The time series decomposition function starts at x=0 on January 1, 2000. In addition to the increase in the number of visits related to the growth of the Internet itself, two time-related effects can be observed. In a regular week, the number of calculations is 40% lower on the week-end days. In Figure 7, we observe that the peak period is on Monday and Tuesday. We can also see that there is a slight yearly peek during August and September, when most of the transit network changes are made, and students use the site to access new schools.

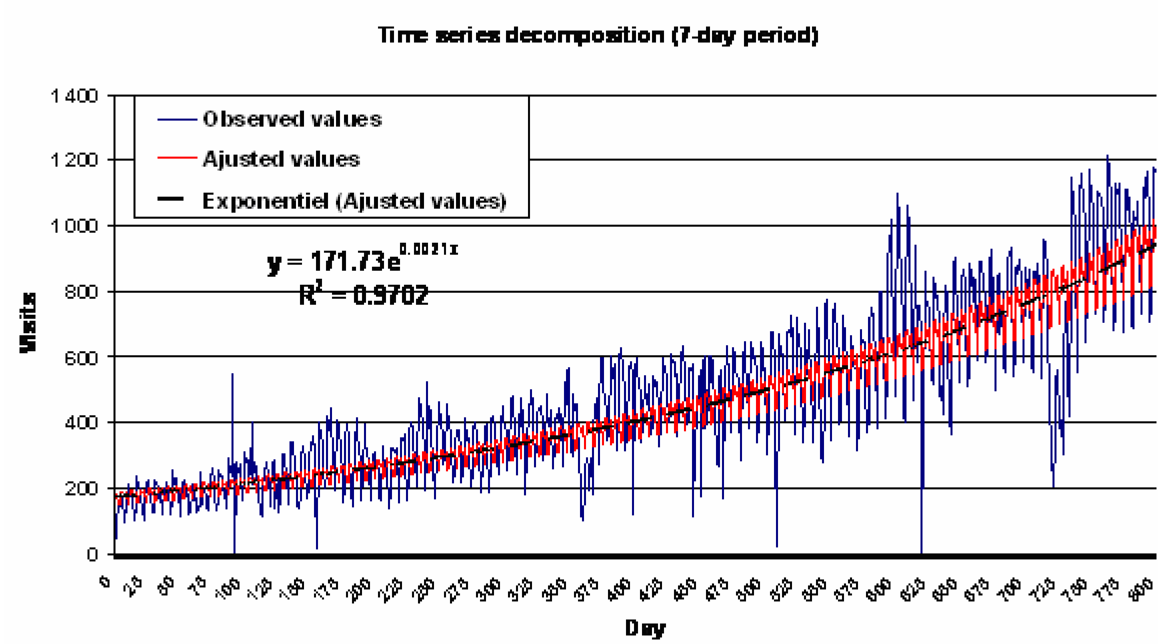


Figure 6. Number of visitors to the MTC website calculator, January 2000 to March 2002

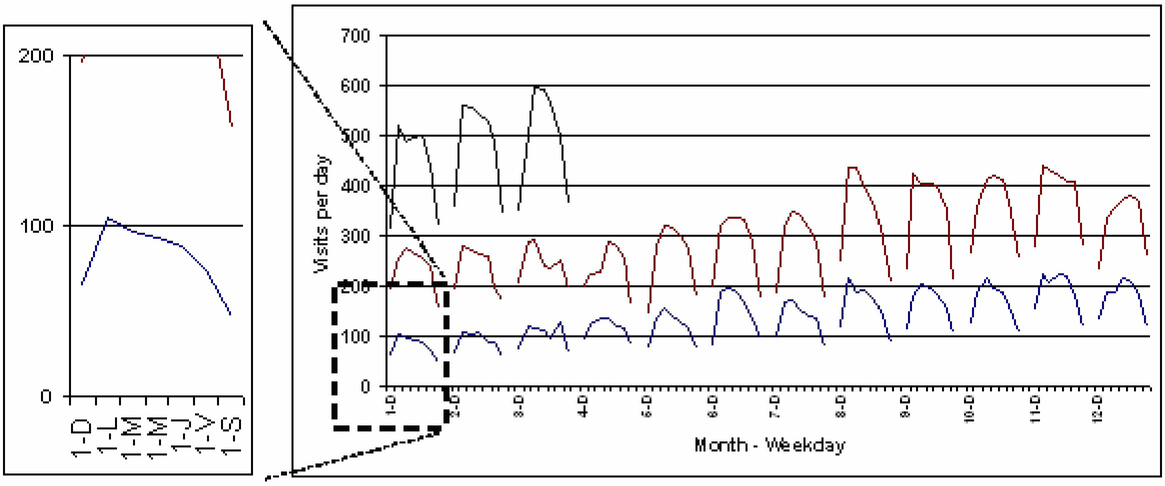


Figure 7. Average number of visitors per day to the MTC website calculator, January 2000 to March 2002

4.3 Location specification

Also of interest is a look at the location specification mode itself, in order gain a better understanding of the use of the tools provided in the calculator, and, when possible, to improve GIS data and the search engine. Figure 8 presents the distribution of location specification modes for the Laval website (2001). Note that there is no address search on this website. The study shows that the map-based search is much less used than the intersection or trip generator searches, which are more popular.

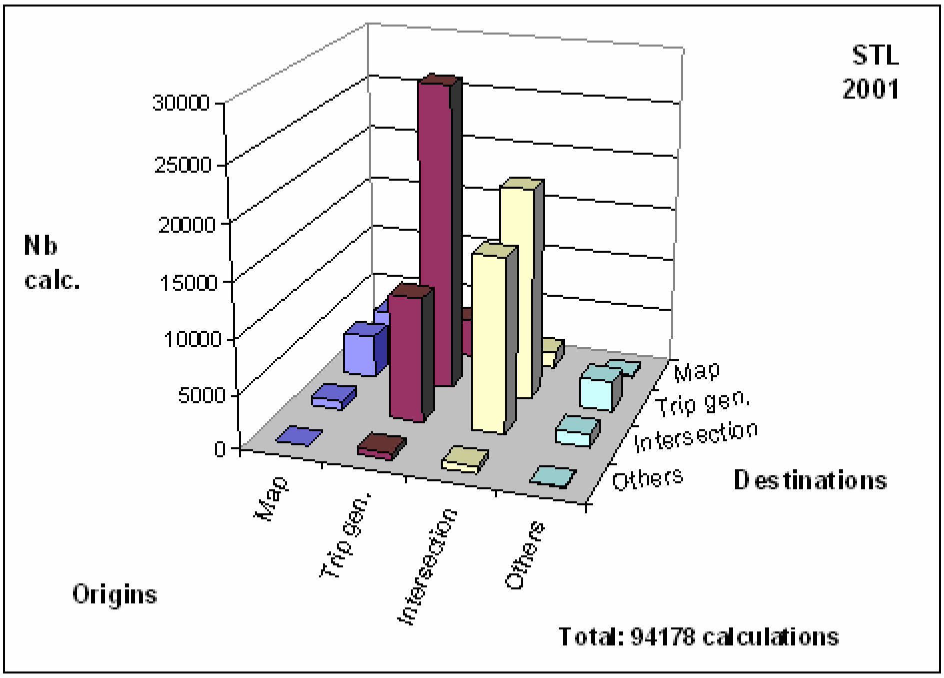


Figure 8. Location specification mode distribution for the LTC website, 2001

The same type of analysis has been conducted on the MTC website, and shows that few visitors use only one type of location mode when they calculate their trip. Only 9.3% of all calculations are from civic address to civic address. The number of calculations made with intersection pairs represents less than 5% of the total. The main finding is that users need a wide choice of location modes in order to adequately specify their origin and destination points, and to do so quickly.

4.4 Entry log

On the MTC website, the search functions have been thoroughly analyzed to search for the causes of data errors and typographical errors. A logfile collects all keyboard entries and clicks on the calculator sub-website. There were about 2,760,000 data inputs between June 2001 and March 2002. About 8.1% resulted in the display of an error message due to incorrect use of the interface by users, or because the desired location was not found (see Table 2). Of the 528,000 trip-calculator visits made during this period, there was an abort-search rate of 3.9% which could be related to these error messages.

Table 2. Distribution of entry error messages for the MTC website (2001/06 to 2002/03)

Location type	*Error message*	*Error type**	*Count*	*% of total*
Address	Address not found	G	44,806	19.9%
Address	Unspecified civic number	I	15,284	6.8%
Address	Unspecified street name	I	2,115	0.9%
Address	Street not found	G	76,228	33.9%
Trip generator	Not found	G	21,444	9.5%
Intersection	Unspecified 1st street	I	847	0.4%
Intersection	1st street not found	G	21,458	9.5%
Intersection	Unspecified 2nd street	I	7,257	3.2%
Intersection	2nd street not found	G	19,065	8.5%
Intersection	Intersection not found	G	16,204	7.2%
Total			*224,708*	*100%*

** G = GIS-related, I = interface-related*

Table 2 shows that a small proportion of the errors were due to incorrect use of the website interface by users. Missing fields, for example, are common, and one of a number of problems which can be easily corrected by changing the behaviors of the Web pages. GIS errors, commonly features not found, are harder to tackle. A spelling error or language mismatch (both French and English are used on MTC website) can be the cause. Geographical corrections can help reduce missing intersection problems. Aliases were added for some street names, so that spelling variations would be accepted. More than 1,000 features are updated each year in the MTC's GIS.

5 Transit-oriented analysis

Although statistics on the number of visitors and their length of stay on the websites are useful for Internet designers, they do not provide information on the trip behavior of transit users. Let us now examine the log files in order to characterize the origin and destination locations, and the use of the transit network. Of course, the underlying hypothesis is that website calculator users do, in fact, make the trip that they calculated. This cannot be verified at the present time because no specific survey has been carried out for this purpose.

5.1 Main destinations

In 2001, Montreal International Airport in the suburb of Dorval was the destination most often selected on the MTC website trip calculator (4,514 calculations), followed by major subway terminal stations (Henri-Bourassa, Longueuil, Berri-UQAM and Côte-Vertu). The relative difficulty in accessing the airport via the public transit network could be an explanation for the popularity of this destination. The map in Figure 9 shows all destinations over 100 trips for year 2001. Here, we can see some local concentrations in four places: A – the airport zone, B – the Saint Laurent industrial zone, C – the University of Montreal, and, of course, D – the Central Business District (CBD) zone.

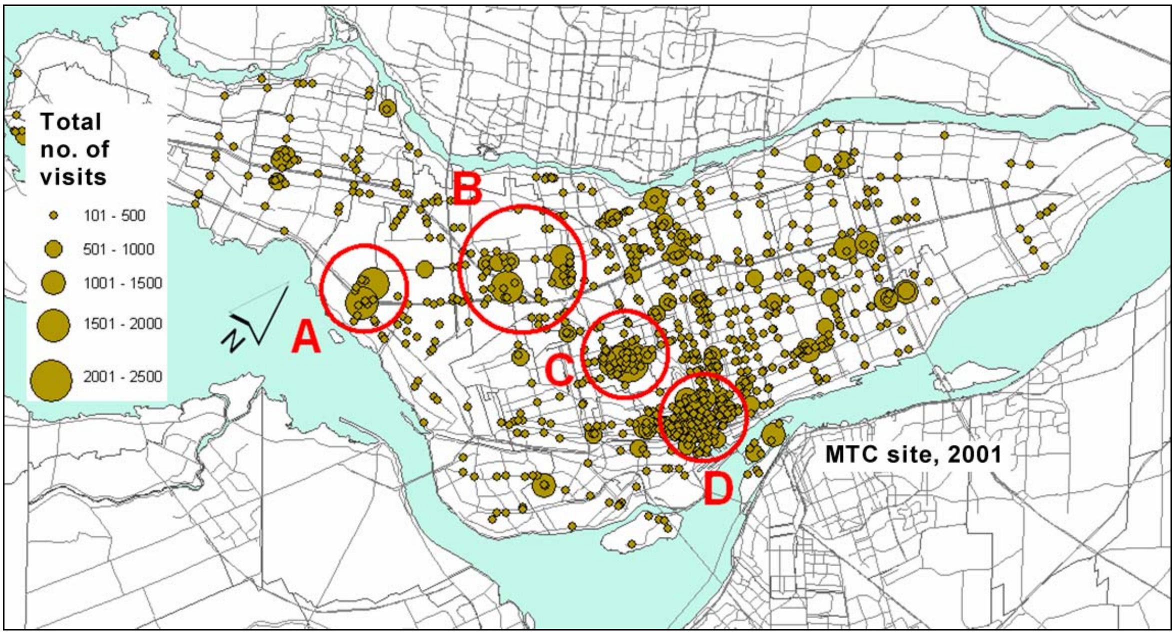


Figure 9. Map of major destinations of calculator users, MTC website

On the Laval website, it is possible to obtain a path which leaves the LTC to go into the Montreal territory, and vice-versa. In Figure 10, the map shows the distribution of destinations over Laval's urbanized area for the whole of the year 2001. While the distribution is more spread out, there is a concentration in the CBD of Laval (A). On the Island of Montreal, calculations are made towards subway terminal stations, where users can easily find their way to their final destination (B – Henri-Bourassa and C – Montreal CBD stations).

5.2 Network usage

Evaluation of transit network usage from individual trip declarations is a common feature of the TDA. The software MADITUC was used for this task. The following steps were carried out to obtain network load profiles and data on network components (MTC website):

- Individual trips are extracted from the website logfile (pairs of origin and destination X-Y coordinates);
- Each trip is simulated using MADITUC's trip calculator, which is basically the same as the website calculator;
- The trips are "loaded" into the transit network objects to obtain the load profile.

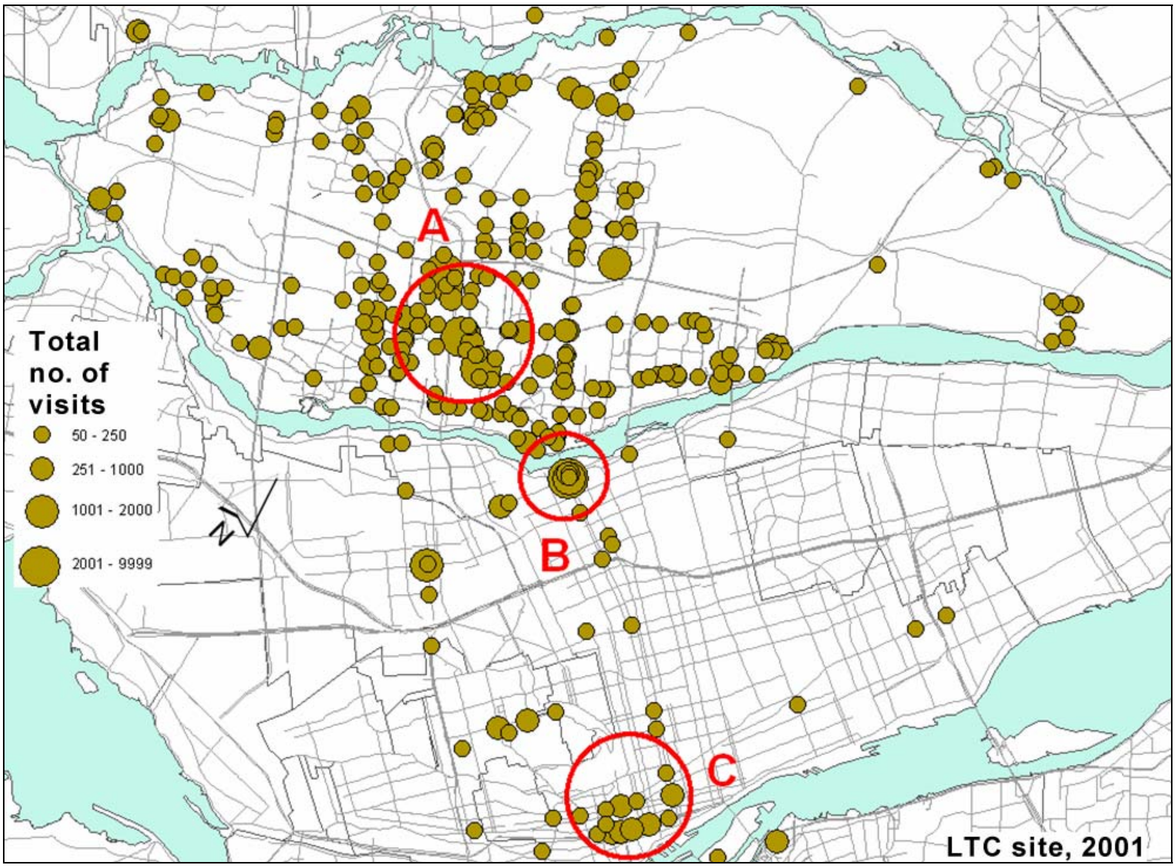


Figure 10. Map of major destinations of calculator users, LTC website

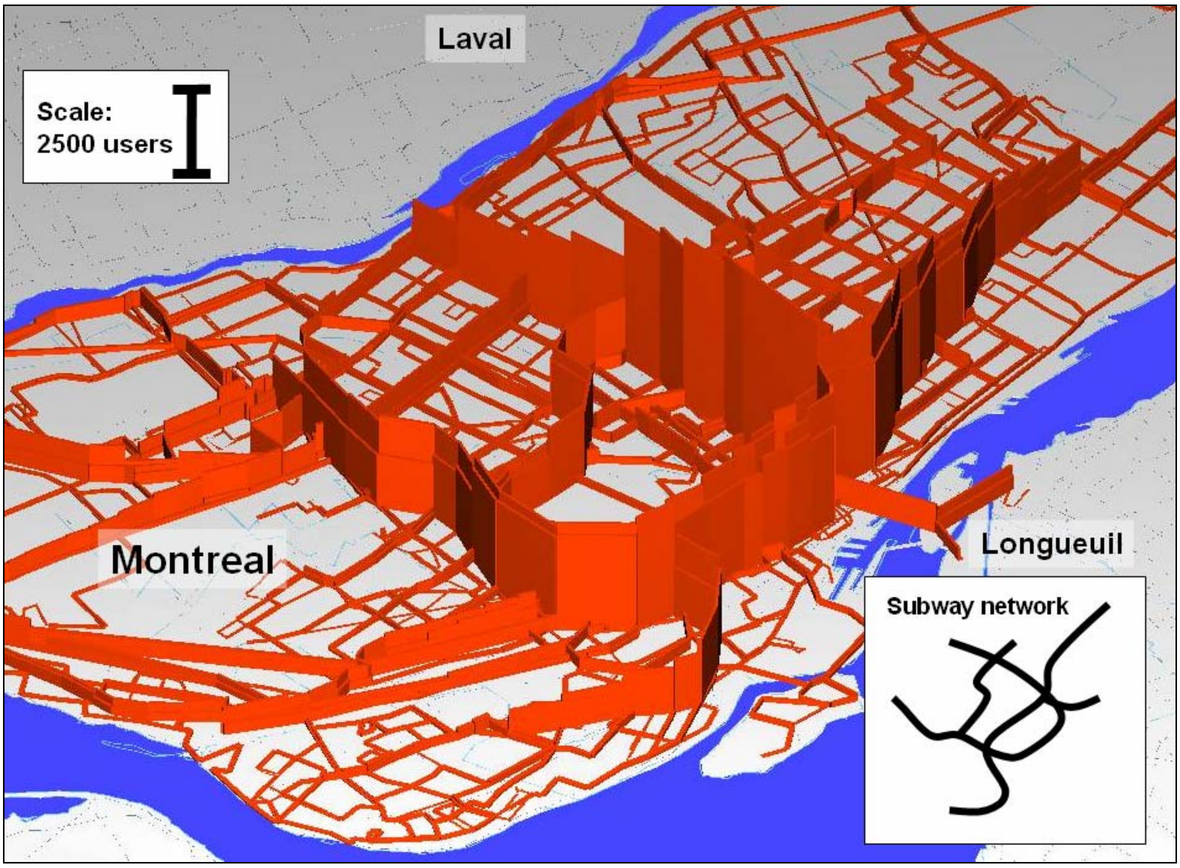


Figure 11. Transit load profile for calculator users, January 2003, MTC website

The load profile for the trips calculated on the MTC website in January 2003 is shown in Figure 11. It is significant on the subway network (enclosed map), which is considered normal for transit usage in Montreal. There is also an increased load on bus routes going to the western part of the Island of Montreal, compared to the normal load profile (not shown). The average duration of the 43,316 trips is 50 minutes, including 20 minutes on-board. An average of 2.02 routes are used for each trip (about 1 transfer per trip).

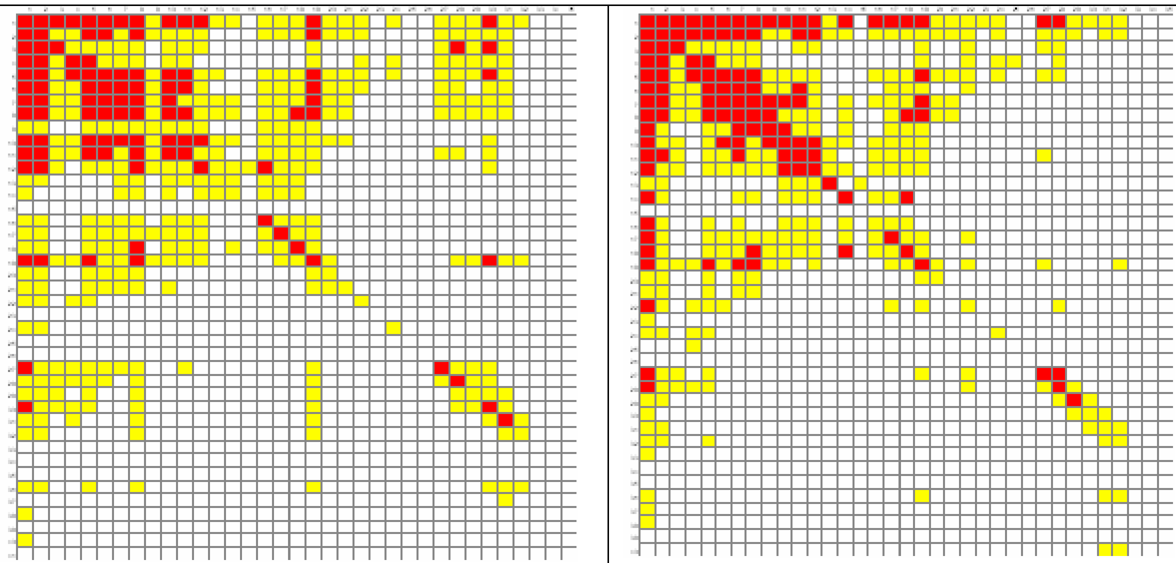
5.3 Comparison with Origin-Destination survey

Even though the websites do not collect any information on trip attributes such as purpose or trip mode habits, we can compare the O-D matrices obtained from the website trip calculator to those obtained from 1998 O-D survey, in the hope of better characterizing the website users. In Montreal, we defined 41X41 sector matrices. Table 3 presents the correlation coefficient (R at a 95% confidence level) between these matrices, obtained by single cell couple comparison. First, it shows a strong correlation between 2000 and 2001 for the website, confirming that the calculator user's behavior remains constant, in spite of a 221% increase between these two years. Next, it shows that the correlation is stronger for transit trip and work trip matrices. This would identify the main characteristics of the Internet users, who are, we suppose, mostly transit users.

Table 3. Correlations between survey and website matrices

O-D matrices for trip calculation on STM site	*WEB2000*	*WEB2001*
STM website, 2000 (*WEB2000*)	**1.000**	**0.982**
STM website, 2001 (*WEB2001*)	**0.982**	**1.000**
1998 survey O-D matrices		
All trips, Montréal residents (TOT98MTL)	0.694	0.689
All trips, all residents (TOT98TOT)	0.707	0.701
Transit trips, Montréal residents (TC98MTL)	0.790	**0.825**
Transit trips, all residents (TC98TOT)	0.795	**0.830**
Work trips, Montréal residents (TRAV98MTL)	0.797	**0.812**
Work trips, all residents (TRAV98TOT)	**0.822**	**0.834**
Study trips, Montréal residents (ETUD98MTL)	0.586	0.581
Study trips, all residents (ETUD98TOT)	0.592	0.587
Transit trips, work trips, Montréal residents (TCTRAV98MTL)	0.565	0.610
Transit trips, work trips, all residents (TCTRAV98TOT)	0.571	0.616
Transit trips, study trips, Montréal residents (TCETUD98MTL)	0.683	0.709
Transit trips, study trips, all residents (TCETUD98TOT)	0.688	0.713

A quick look at Figure 12 demonstrates the similarity between the website usage matrix and the matrix developed from the transit trips in the O-D survey (the cells are colored at proportional scales). The upper right-hand part of matrix A is the airport zone, and shows the importance of this zone for Internet users. Our hypothesis is that the website captures users who are not interviewed in O-D surveys, such as tourists and non-resident business travelers. In Figure 13, a comparison based on the importance of the matrix diagonal and CBD destinations confirms our previous analysis. The pattern for transit trips (TC98MTL) is similar to the pattern of users' website declarations (WEB2001).



A – MTC website (2001)

B – 1998 O-D survey, transit trips (1998)

Figure 12. Matrix pattern for MTC website 2001 and 1998 survey (transit trips)

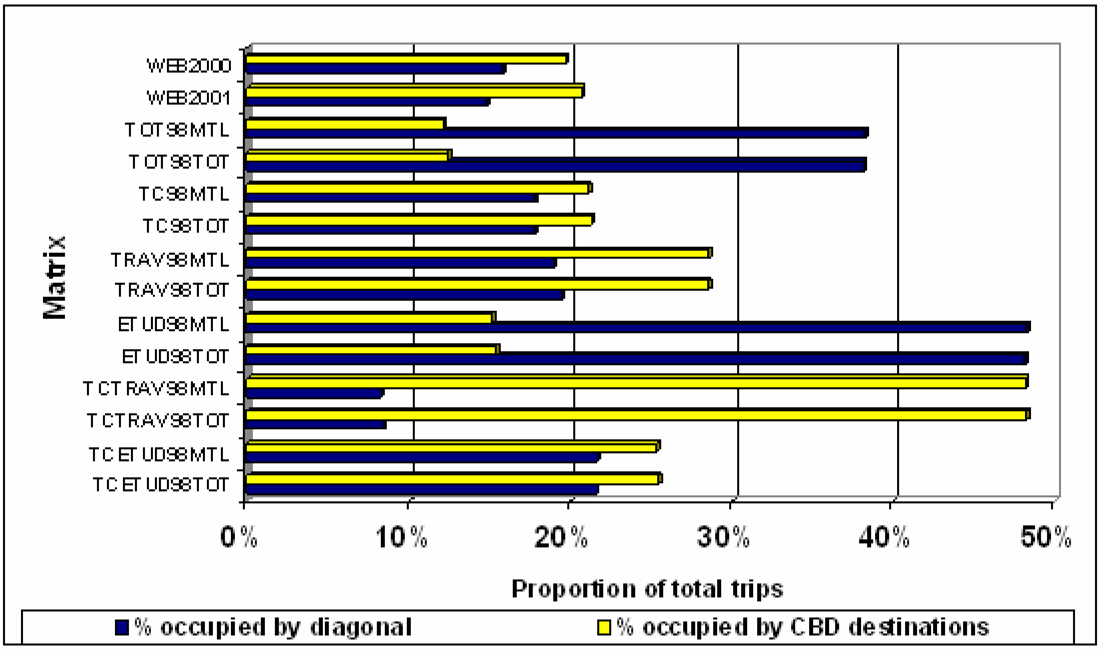


Figure 13. Matrix comparison based on diagonal and CBD destinations (MTC website)

6 Conclusion

The aim of this paper was to stress the importance of providing transit websites with a well-designed architecture, especially when there is a trip calculator involved. This widens the range of possible analyses on transit user behaviors that could be conducted. In our view, the elements of the website must be strongly linked to both operational and territorial databases.

In this project, examination of the log files of the transit trip calculators of the Montreal Transit Commission and the Laval Transit Commission websites has led to the following observations:

- The growth in usage of this kind of website is faster than the growth of Internet usage itself, showing that there is interest in the availability of transit trip calculators on the Web.
- The Internet user usually performs more than one calculation during a visit. The tool can be accessed whenever it is needed.
- The trip calculator is used to access destinations which are more difficult to reach by public transit. Such a tool is useful when the transit network is complex (several transfers) or when the areas are not well serviced.
- The user of a trip calculator is typically a regular transit user (a worker). The trip calculator can also be accessed and used by other commuters and by tourists relatively easily.
- The trip calculator entry log helps to improve the underlying GIS and the website interface. Often, calculations are needed to access newly built structures or new developments; the GIS must, in this case, be updated as soon as possible.

This paper has introduced a new planning tool: the Transit User Information Website. In the coming years, it will be possible to use these sites to perform on-line transportation-class surveys, with instant validation. With its embedded GIS, this kind of tool will also be in a better position to integrate the new technologies that are developed for Intelligent Transportation Systems (ITS).

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Rereferences

Chapleau, R., 1986. Transit Network Analysis and Evaluation with a Totally Disaggregate Approach, World Conference on Transportation Research Proceedings, Vancouver.

Chapleau , R., Allard, B., Trépanier, M., 1997. Transit Path Calculation Supported by a Special GIS-Transit Information System. Transportation Research Record, 1521, Washington, 98-111.

CyberAtlas, 2003, http://cyberatlas.internet.com/ .

Federal Transit Administration, 2002. Effective Use of Transit Websites: A Synthesis of Transit Practice, Transit Cooperative Research Program (TCRP) 43, Washington, 80

Golob, T.F., Regan, A.C., 2001, Impacts of information technology on personal travel and commercial vehicle operations: research challenges and opportunities, Transportation Research Part C, 2001(9), 87-121

Goodchild, M.F., 2000. GIS and Transportation: Status and Challenges, GeoInformatica, 4(2), 127-139.

Ivory, M.Y., Hearst, M.A., 2001. The State of the Art in Automating Usability Evaluation of User Interfaces, ACM Computing Surveys, 33(4) , 470–516.

Kimball, R., Merz, R., 2000. Le data webhouse, Eyrolles, Paris, 310 pages.

Lee, J. S., Baumgartner, J.A., Tschango, J.K., 1999. A Web-based Bus Information System, ESRI User Conference Proceedings, no 494.

Lee, M., Su, S.Y., Lam, H., 2001. A Web-Based Knowledge Network for Supporting Emerging Internet Applications, World Wide Web, 2001(4), 121–140.

Murphy, J., Hofacker, C.F., Bennett, M,. 2001. Website-generated Market-research Data, Cornell Hotel and Restaurant Administration Quarterly, February 2001, 82-91.

Peng, Zhong-Ren, Beimborn, Edward A., 1998. Internet GIS and Its Applications in Transportation, Transportation Research News, volume 195, March-April, 22-26.

Piroli, P.L.T., Pitkow, J.E., 1999. Distributions of surfers' paths through the World Wide Web: Empirical characterizations, World Wide Web, 1999(2), 29-45.

Preuner, G., Schrefl, M., 2000. A three-level schema architecture for the conceptual design of web-based information systems: from web-data management to integrated web-data and web-process management, World Wide Web, 2000(3), 125–138.

Trépanier, M., Chapleau, R., 2002. A Transit User Information System for Transit Itinerary Calculation on the Web. Journal of Public Transportation, 5(3), 13-32.

Trépanier, M., Chapleau, R., 2001. Linking Transit Operational Data to Road Network with a Transportation Object-Oriented GIS, Urban and Regional Information Systems Association Journal, Park Ridge, IL, 13(2), 23-27.

Trépanier, M., Chapleau, R., Allard, B., Morency, C., 2001. GIS-based Websites for Metropolitan Travel Information System: Orientation and Informational Approach, 9th World Conference on Transportation Research, Seoul.