Information technologies for household survey management

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Abstract

Nowadays, large transportation household surveys cannot be conducted without the help of powerful management and support tools, and the information technologies are useful for preparing, conducting, and post-analyzing such surveys. In the Greater Montreal Area (GMA), the 2003 household survey followed the general methodology that has been developed over the past twenty years to integrate the finest software, databases, and methods. The tools making up the household survey information system (HSIS) are based on the Totally Dissagregate Approach and its object-oriented extension.

This paper presents the background and the fundamentals of the Montreal 2003 survey information system, and describes the way in which it has been assembled, illustrating the functional and technical architectures that were used. It also emphasizes the transposability of the method to other transportation survey activities and planning tools. The final discussion stresses the "winning" elements involved in conducting a modern transportation household survey successfully.

1 Introduction

Large household surveys have always presented a methodological challenge for transportation planners and authorities. Conducting a survey of more than 70,000 households is not a single task because of the sample size and the complexity of the survey itself. Every planner knows that transportation data are strongly related to the spatial elements of a territory and to the transportation network (roads and public transit), and that the survey tool must take into account these specificities. Today, even though intelligent transportation systems (ITS) have provided new ways to collect data, large transportation surveys are still needed in Canada, especially in the Montreal region. Data collected from these operations are now well integrated in the fields of transportation planning, finance, and management.

This paper presents the information technologies that were used for the 2003 Greater Montreal Area Household Survey. It also emphasizes the technological background and architectures that were required to yield the best results possible from the survey. Following a recounting of the history of the household survey in the Montreal area, the Totally Disaggregate Approach and Transportation Object-Oriented Modelling, two key elements which helped support and develop the 2003 tools, are presented in the second section. The third part of the paper (section 3) describes the methodology that was used to prepare and synchronize the various software programs and databases. Section 4 is aimed at demonstrating the functions of the software that was used for the survey. The conclusion reports some findings on the 2003 experience in Montreal.

2 Background

2.1 Household surveys in the Greater Montreal Area

The history of origin-destination household surveys in Montreal begins in the 1960s, when the first large-scale survey in the region was conducted (Figure 1 shows a map of the Montreal region). Since 1972, 8 large surveys have been conducted, at 5 to 6-year intervals. Through the years, the process has evolved both technically and methodologically.

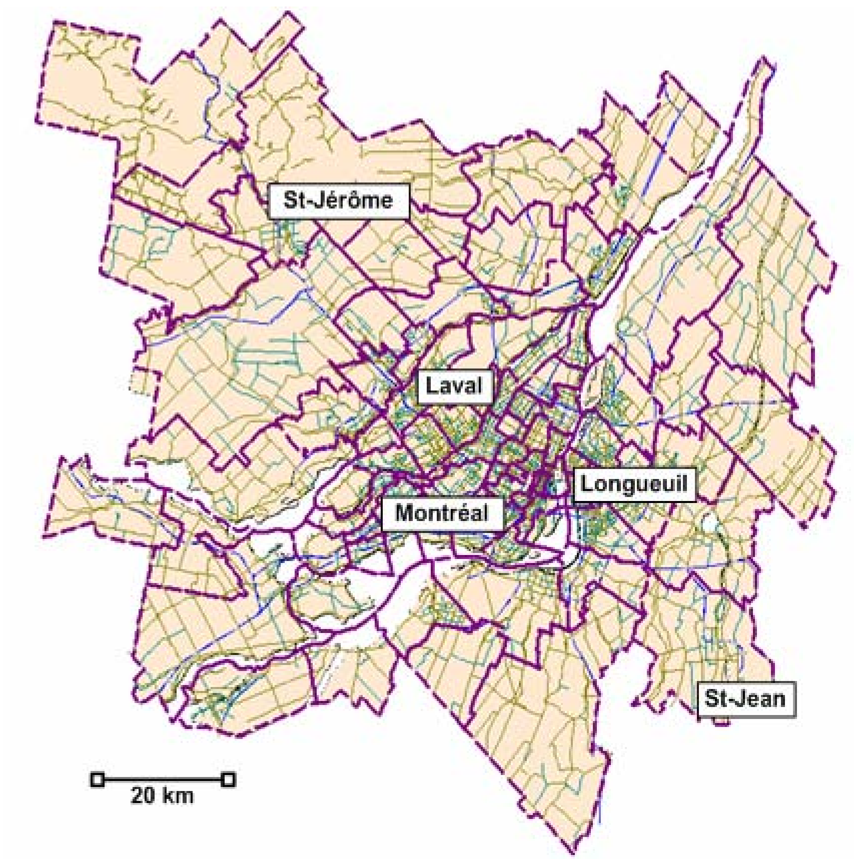

Figure 1. Territory of the 2003 survey.

2.1.1 Technical evolution

Technically, the surveys have benefited from the evolution of computer technology. The first survey data were post-treated with computer programs running during weekends on large computers rented to sizeable organizations like the Montreal School Board. In 1982, data was validated using computer procedures which now form the basis for the well-known MADITUC system and the Totally Disaggregate Approach (both of which are defined below). In 1987, survey data was coded, geocoded, and validated with the help of microcomputers. In 1993, a survey firm was contracted to conduct the survey, and data was captured by means of its own in-house software, based on the VAX system. Due to data post-validation and survey quality concerns, it has been decided that computer-assisted interviewing software (CATI) will be developed for future surveys. In 1998 and 2003, a software suite was used, which combined the best practices and procedures from past surveys. It also took advantage of the evolution of computer technology (both hardware and software) that had occurred during this period (Chapleau 2003).

2.1.2 Methodological evolution

Most of the advances of the 1970-2000 period were methodological. Many aspects of survey methodology have evolved since 1970:

- Spatial zoning. Prior to 1970, the territory was divided into several zones (the transit equivalent of traffic analysis zones, or TAZ), reflecting the general usage in transportation planning of synthesized and aggregate models for which little precision is needed. This was also due to a lack of spatial search engine capabilities in the survey tools. With the advent of the Totally Disaggregate Approach, zones have been abandoned at coding level for a much higher spatial level of resolution. In 1987, the postal code, then considered the best means of location definition, was used. Now, every trip extremity is coded at the X-Y coordinate level (in metres), which is the best means available currently. In 1998 and 2003, every location was stored and treated as well. For example, a trip generator can now be identified under many naming.

- Transit network definition. In the Greater Montreal Area, household surveys tend to be oriented towards transit planning usage and have been remarkably successful in this field (Chapleau 2000). Moreover, transit network data for analysis have been becoming more and more precise over the years. Early on, the network was specially coded for the survey. Now, a more "real" representation of the transit network is derived from operational datafiles obtained from transit authorities.

- Sampling and weighting (expansion). Significant changes have been made to sampling methods over the years. In the beginning, expansion was based on households only. Today, it is categorized by both people and households, and different weights are given to people and households within strata, depending on their attributes (age and size respectively).

- Survey execution. Initially, a survey would be conducted by employees of the transit authorities because of the absence of CATI software and the complexity of the task. Since 1993, a specialized survey firm has been mandated to do this. The firm provides expertise in conducting surveys, and in staff and telephone infrastructure, but uses the CATI software selected by the survey Board Committee (Chapleau 1995).

The question as to whether or not to use specialized CATI survey software has long been decided in the GMA. CATI provides the flexibility and the power that are needed in conducting such a complex survey (see Figure 2). It is complex because questions on households, people, and trips are interleaved with looping; every trip extremity needs to be geocoded; on-line transit trip declarations must be validated; and the validity of trip chains within the household must be checked.

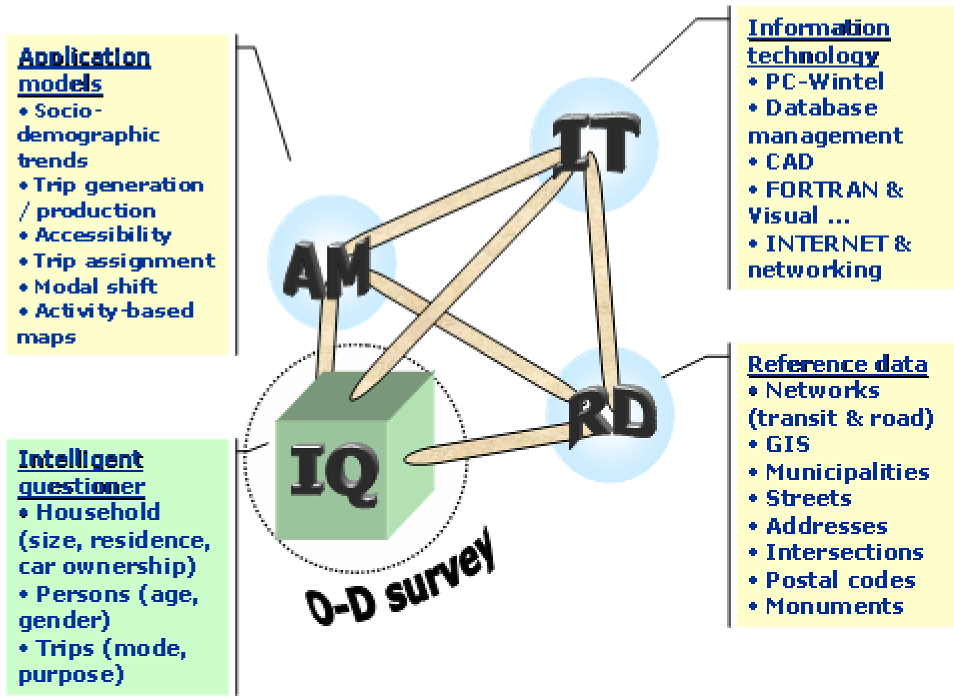

Figure 2. The travel survey scheme questions in context (source: Chapleau, 2003)

Table 1. Comparative statistics for the last six household surveys in Montreal.

Year	**1974**	**1978**	**1982**	**1987**	**1993**	**1998**	**2003**
Total area	2,331 km^2	2,331 km^2	3,341 km^2	3,350 km^2	4,500 km^2	5,300 km^2	6,445 km^2
Population	2,824 000	2,954,000	2,895,000	2,900,000	3,263,000	3,493,000	3,505,810
Sampling rate	4.8%	5.3%	7.0%	5.0%	4.7%	4.5%	about 5%
Surveyed households	43,000	50,000	75,000	54,000	61,000	64,000	72,000
Surveyed trips	265,000	305,000	492,000	338,000	350,000	380,000	388,000
Zoning system/ Geocodes	1,192 zones	1,264 zones	1,500 zones	70,000 PC	30,000 TG 70,000 PC 9,000 SN 40,000 IN	44,600 TG 100,000 AR 89,000 PC 34,000 SN 191,000 IN	77,800 TG 160,000 AR 119,000 PC 40,200 SN 201,000 IN

AR: Address ranges, IN: Intersections, PC: Postal codes, SN: Street names, **TG: Trip Generators**

2.2 Totally Disaggregate Approach

The Totally Disaggregate Approach (TDA) was developed in the 1980s in the Greater Montreal Area for the validation, processing, and modeling of large computer-assisted household origin-destination surveys conducted by telephone interview. It was used in particular to process transit usage declarations, but was then extended to other survey information. Typically, in 1998, a telephone survey would involve more than 70,000 households (5% overall sampling). To use such a quantity of data, even a 1500-zone system and its aggregate approach could not satisfy planners (Chapleau 1986), so a new method had to be developed to store and process data on households, persons, and trips. Setting aside its many features and special functionalities, the TDA is briefly defined here by its two essential elements:

- Individual trip data processing throughout the transportation analysis process, maintaining all trip characteristics (time, purpose, modes, itinerary) with their associated person and household;
- Use of X-Y co-ordinates, monuments, and place declarations as the basic spatially referenced system for origin, destination, residential, and intermodal junction locations for each trip and other spatialized objects in the system.

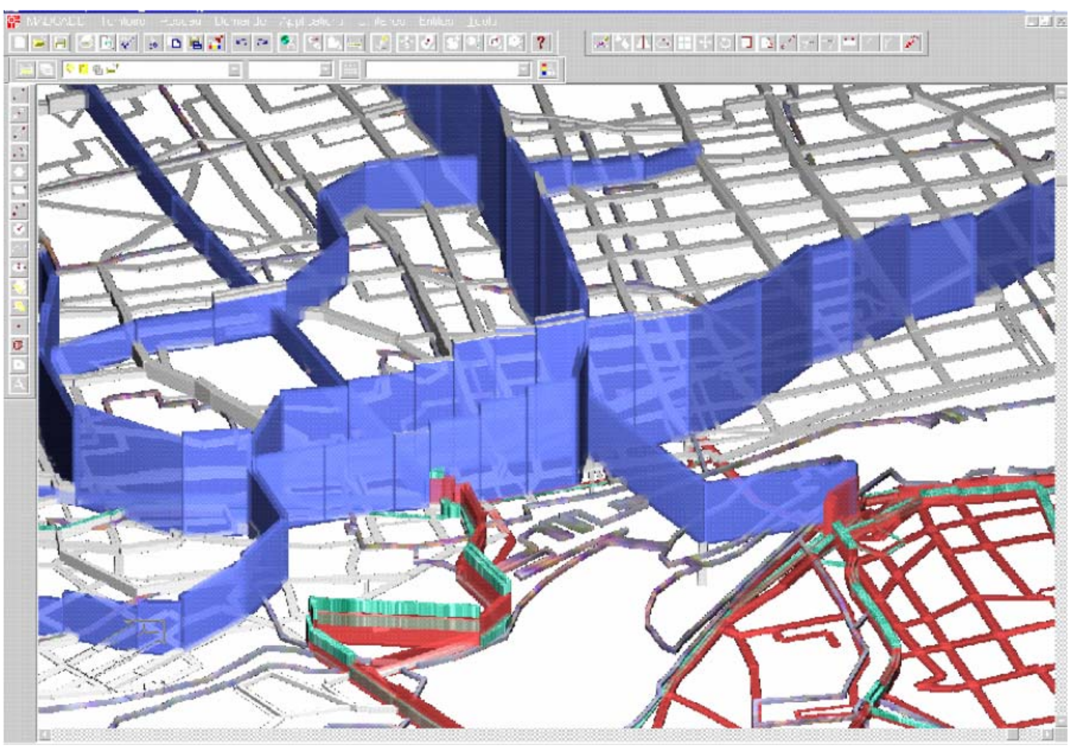

Figure 3. 3D transit load profile of AM peak period, Montreal, 1998 household survey.

In terms of data completeness, the Totally Disaggregate Approach does not use an origin-destination matrix, which would aggregate and dissolve information, but rather maintains origin-destination survey trip files containing information on trips, persons, and households intact. The use of the most fully defined information improves the level of resolution of the system, while at the same time preventing any possible aggregation. As reported by O'Donnell and Smith David (2000), possibilities are widened because the number of dimensions distinguished by the information system is increased. The use of special analysis modules, combined with the presence of an underlying GIS, provide the planner with useful tools such as three-dimensional load profiles, where every network link can be interrogated to obtain further information about the users passing through that particular location (see Figure 3).

2.3 Transportation Object-Oriented Modeling

Transportation Object-Oriented Modeling (TOOM) is based on the use of transportation objects, which are special components intended for the modeling, observation, planning, and analysis of a transportation system. For this purpose, these objects have a variable state in time and space, and are characterized by special properties and methods. A RoadLink object, for example, has common road properties (length, name, number), but can also have time-varying properties (like pavement condition).

There are four metaclasses of transportation objects involved in dynamic and spatialized relations:

- Immobile (static) objects have a fixed location in time and space. Their role is to describe the territory and serve as transportation movement beacons. Some examples are the TripGenerator, PostalCode, CensusTract, and Zone objects.
- Dynamic objects are the transportation actors. These objects "decide" and contribute to their movements. They represent a group of persons (Household, Person), a moving object (Bus, Car), or even moved objects (Goods).
- Kinetic objects are the movement describers. Some examples are the Trip, TransitLink (simple kinetics), Path and TransitRoute (compound kinetics) objects.
- System objects are groups of embedded objects, with their set of relations. They can be operational (TransitNetwork, RoadNetwork), informational (Survey, Census) or globally comprehensive (UrbanSystem).

A transportation method is an "intelligent" sequence of procedures used to manipulate and transform one or more transportation objects. It blends models with information, creating "infomodels" to be reapplied to similar objects. It is important to mention that transportation object-oriented modeling is not primarily aimed at software design or database structure, and is not a database issue. First and foremost, TOOM is a "way of thinking" about the role and specific use of every piece of information in the system. With adequate object diagrams, objects can be rapidly identified, along with their properties and methods that are engaged in the analysis (Trépanier and Chapleau 2001). The software implementation can easily integrate these underlying concepts, but not all software languages are adapted to this methodology.

Figure 4 shows the object-model of the Montreal survey. There is an obvious link between Household, Person, and Trip objects, which constitute the core model of the interview. But the figure also shows derived objects like Car, Activity, and Status, which can be identified and analyzed with the help of the other objects, even though they were not clearly declared in the survey.

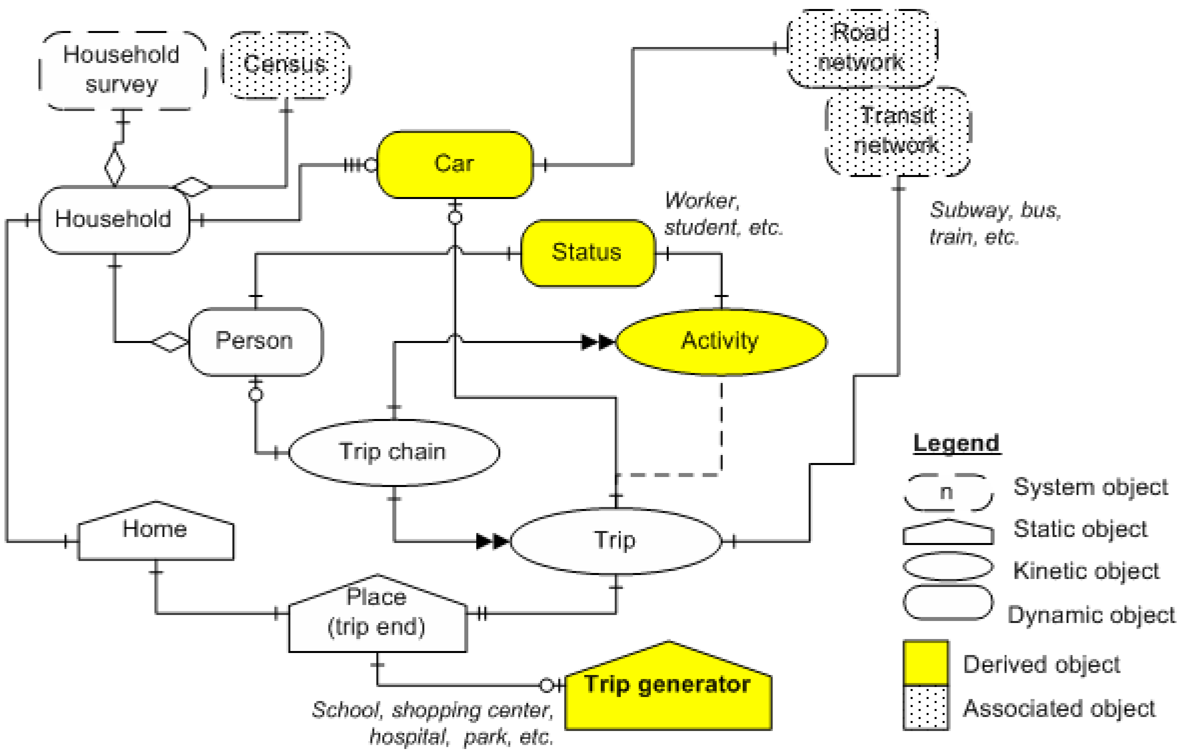

Figure 4. Object model for household surveys in Montreal.

3 Methodology

Because the Montreal household survey is a short-term endeavor (September to January), it must be well prepared at the beginning, most of this preparation involving the assembly ("montage") of information systems, which requires mounting data structures, and collecting, normalizing, and storing data using a convenient software technology.

3.1 Assembly of the Geographical Information System for Transportation

Undoubtedly, there is a need for a Geographical Information System (GIS) to support CATI during the interview. GIS is mainly used to geocode trip extremities and junction locations, but is also called upon to validate walking distances for transit access or to geocode places of work and home locations (see Figure 5 for an GIS illustration). A GIS for transportation (GIS-T) is used for this purpose, because of its awareness of transportation specificities which are different from those of general GIS usage (Trépanier et al. 2002).

A comprehensive road network database is developed first, to ensure:

- Adequate identification of all streets within the region. This includes the various aliases (alternative street names) used by inhabitants, and also considers the language differences between French and English.

- Integrity of the list of civic numbers, which is based on street arc geometry and refers to the street-name database.

- Automatic building of the intersection list from the geometry of the street network. (There is also a need to generate all possible identification combinations.)

- Normalization of the postal code list. When possible, postal codes are linked to the road network to ensure a better identification (always on the same multiple-alias basis).

The trip generator database is critical because: 1) most respondents give trip generators as trip extremities; and 2) mistakes can easily be made when choosing such locations in the database. Research projects by Trépanier et al. (2003) have identified important issues about trip generators, such as the fact that a "good" trip generator database must not be too narrowly? defined because of possible mismatches between two places (for example, two franchise locations), but must contain all "major" generators. To discover what these major generators are, data from previous surveys were analyzed. In constructing the trip generator database, it is important not to simply amass lists of companies provided by commercial data vendors, because these data have not been validated (they may contain double entries, spelling errors, and deleted entries (what about incomplete entries?), usually not well geocoded and not classified. For the 2003 survey, every trip generator was well characterized (class, exact location, named with aliases) and uniquely identified.

Each location in all the tables (civic addresses, intersections, postal codes and trip generators) is characterized and positioned at the finest level of resolution, although variable definitions can be used in surrounding regions. This ensures good geocoding during the survey. However, the CATI-software also accepts locations which are not so well defined, as is often the case in household surveys because respondents do not know, or do not want to give, precise information. For example, a street name alone can be given if the street is not too long, or a municipality name alone is acceptable for places outside a territory, and so on.

For the household survey, the GIS-T also integrates the best possible definition of the transit network. An analytical transit network (ATN), built up from the information provided by each operator, is also required. When respondents describe transit trips, they give the sequence of routes taken. With the help of the ATN, the CATI-software immediately validates the information, while at the same time rejecting bad sequences and asking for precision. Mistakes are often made when operators' routes have the same number. Also, there can be trips with too much walking distance to the stops, in which case the CATI software flags the problem and asks for a second validation.

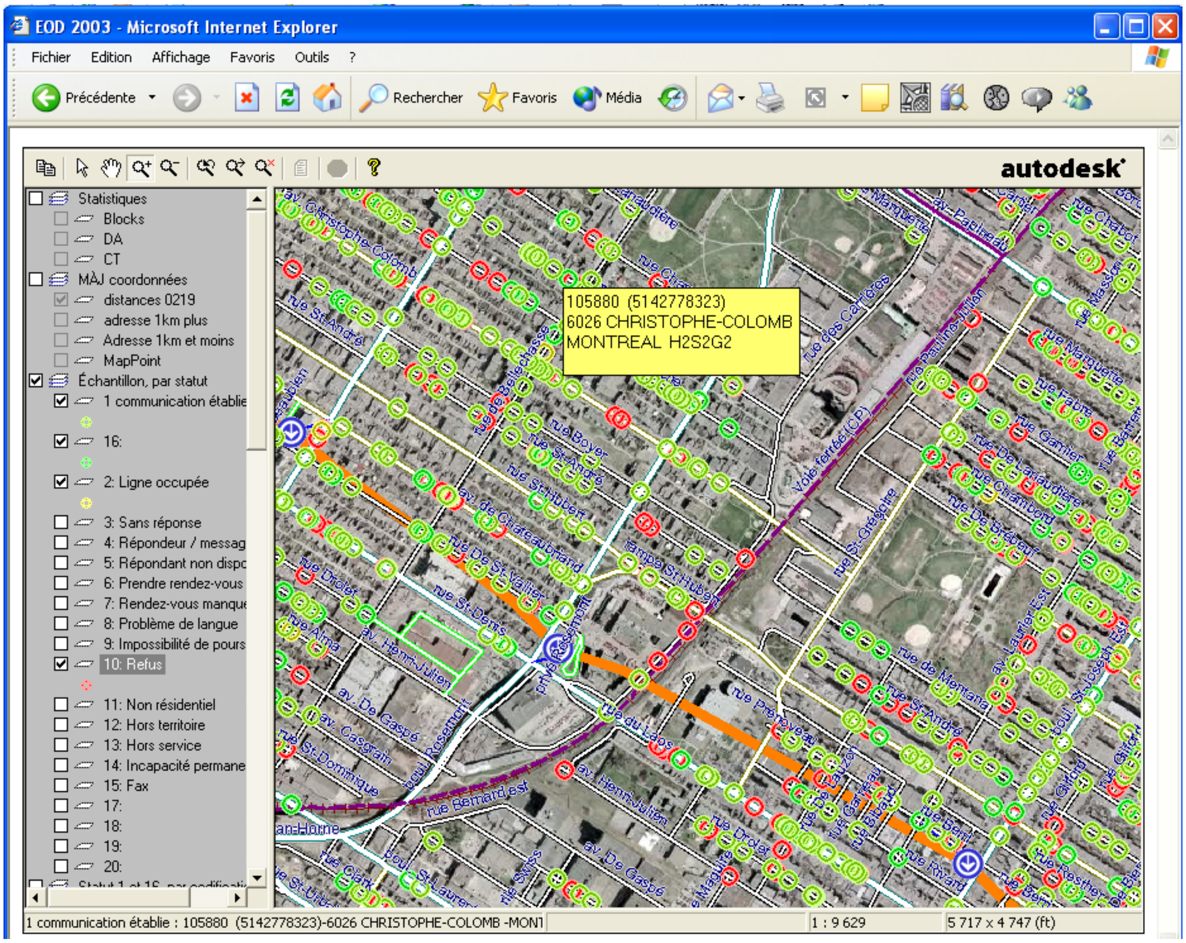

Figure 5. Internet application showing the available database of the GIS-T that supported the 2003 survey

3.2 Assembly of the Household Survey Information System

The household survey information system (HSIS) gathers all the information necessary to conduct the survey. The main data tables are:

- Households. This table contains all the information gathered about the households surveyed (respondent name, size, car ownership).

- Persons. This table stores data on people, such as age, gender, status (worker, retired, student, etc.) and possession of a driver's license.

- Trips. This table describes each trip described during the survey (purpose, time of departure, origin and destination locations). It also contains the sequence of modes (car, transit routes, bike, foot, paratransit, school bus, taxi, etc.), bridges crossed (if any), parking information and freeways traveled (if any).

- Locations. This table groups together all the described locations in a single structure which identifies them by civic number, street, intersection, generator's name, coordinates, region, categories.

- Calls. Each call made by an interviewer is stored in this table, and is characterized by a status (completed, refused, busy signal, voice mail, language problem, etc.)

- Sample. This table contains household home location data (civic number, street, municipality, postal code, telephone number). To ensure spatial portioning of the sample, every household is geocoded at the finest level with the help of the civic address. Experience has shown that: 1) the postal code is not precise enough and is prone to error; and 2) a precise location is needed in the case of boundary streets between two sampling districts.

- Stratum. This table describes the group of sampled households within a given area of the territory, ensuring a uniform sampling rate during the survey.

- Batches. This table describes the group of sampled households that must be chosen for a single survey day, ensuring uniformity of interviews over time.

- Interviewers. Each interviewer is a user in the system, and his username serves to identify individual analyses.

- Queries. Pre-stored queries are used by survey monitoring staff and by transportation planners before, during, and after the survey.

- GIS-T tables, all of which are part of the HSIS (streets, addresses, intersections, postal codes, generators, routes, road geometry, transit geometry).

3.3 Technical architecture

The survey software suite works on Microsoft Windows and is installed on standard personal computers. In 2003, the survey floor was composed of 50 interviewer stations, 5 supervisor stations (supervisors could also use interviewer stations when needed), and a server station. All were equipped with Microsoft Windows 2000 (workstation and server). The database architecture reflects the needs of survey operation. Large GIS-T tables are placed directly on workstations to make CATI more powerful by accessing its own tables directly. In fact, these tables are not updated often during the survey, and so a centralized database management system is not needed.

Survey management tables containing the sample data and state of each household are stored on the server to ensure integrity. To facilitate data exchange, requests between workstations and the server are made with XML files, as these provide flexibility and, more importantly, variable data structures and length in cases where all the declaration information associated with a household has to be transferred.

The software was developed with Microsoft Visual Foxpro, using tools provided by the Windows technologies: Microsoft's Internet Information Server (IIS), the Microsoft Extended Markup Language (MSXML) component model and the Microsoft Office (MSO) component model. Applications also involved the use of Adobe Portable Document Files (PDF) and Microsoft Excel spreadsheets.

4 Implementation

This section presents the features of the tools that were used in the Montreal 2003 survey. The intention here is not to focus on the software itself (which is an in-house product and not commercially available), but rather on the various procedures employed, the conduct of the survey itself, and some associated statistics.

Three software components were used in the 1998 and 2003 surveys. The technology evolved, but their principal roles remained the same (Chapleau et al. 2001):

- CATI software used by interviewers (*MADQUOI, module Questionneur Utilisé pour l'Obtention d'Information*).
- Real-time survey management software (*MADASARE, module d'Application de Suivi et d'Analyse Rigoureux de l'Échantillon*)
- Survey surveillance and statistics software (*MADVIJIE, module de Validation Incontournable Journalière des Informations d'Enquête*)

4.1 Computer-Assisted Telephone Interview

CATI is the core component of the survey software. Its role is to guide the interviewer through the interview process, gather, validate, and store information (Figures 6 and 7 display CATI structure and interface). The following are its main functions:

- To display questions to the interviewer in suitable order, according to the survey protocol. CATI also constructs the necessary loops of questions when, for example, many people are interviewed for many trips. The answer to each question is stored with the entry, according to the authorized domain of answers (especially for locations). Then, it quickly analyzes the answers and prompts the next question.

- To geocode every location related to the interview (home location, place of work, origins, destinations, junction points) with a special interface supported by the GIS-T database. CATI needs, and has, an "intelligent" way of dealing with locations. A location list is made up for each household, and so a previously searched location can be easily reused. The spatial logic of locations for a trip chain must be ensured: the origin of a trip is the destination of the preceding one.

- To proceed to immediate answer validation in the case of spatially-driven questions like transit routes and bridges taken. In the case of a transit route, the walking distance to access the network is checked. Then, the sequence of routes is checked with the help of the transit network geometry.

- Finally, to proceed to overall interview validation. As needed, the software checks the integrity of all answers using a special procedure. This is usually done following each respondent's answer and after the whole interview has been completed. Warnings and error messages are displayed to the interviewer. Because of productivity concerns, the interview can be accepted even with such messages, final decisions being made by supervisors.

In addition to the integrity of the interview itself, CATI, used by all the interviewers, ensures the uniformity of the survey, in that it provides a single database for all locations, declarations, route sequences, and so on, and facilitates post-survey analysis.

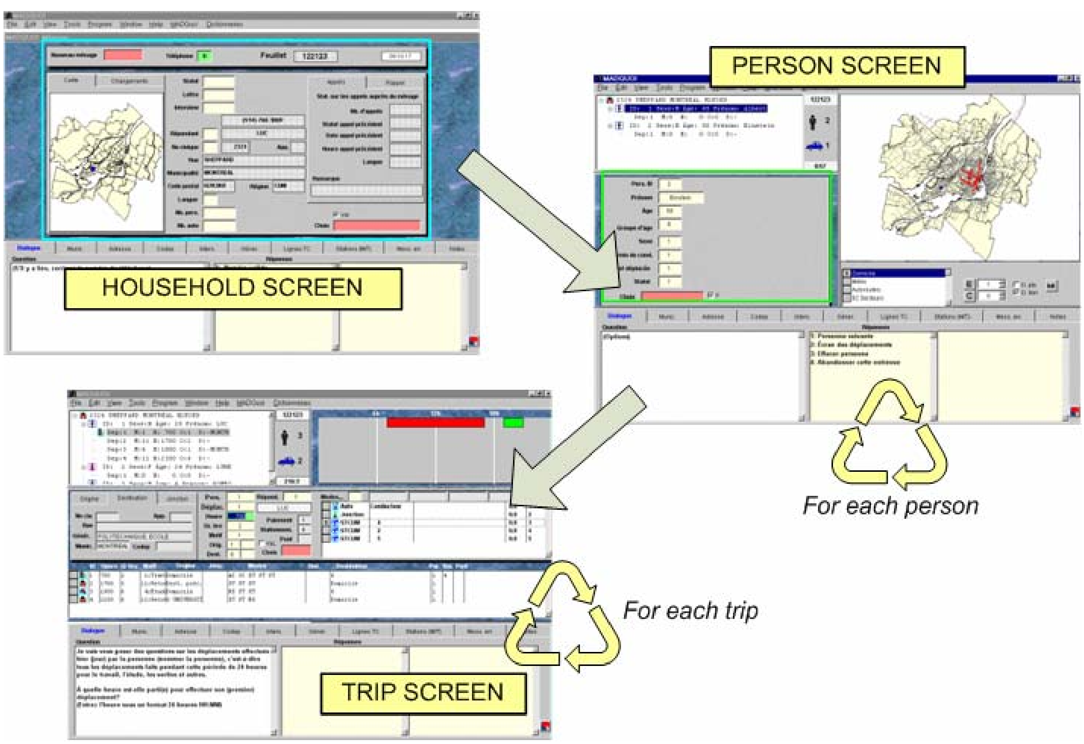

Figure 6. CATI software interface structure

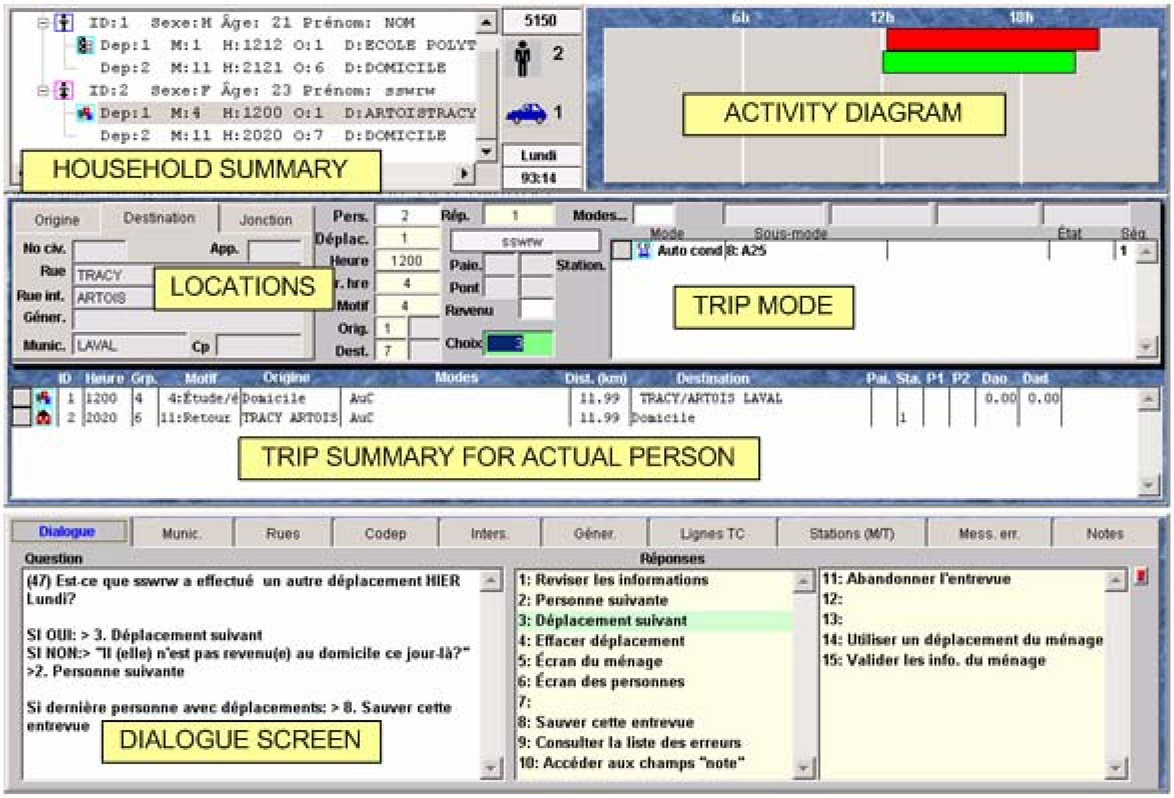

Figure 7. CATI software interface for trip declaration

4.2 Real-time survey management

To ensure real-time survey management, extended markup language (XML) files were used for information exchange between workstations and the server. XML files were helpful because their data structure can change when needed (see Figure 8 for sample XML file). The server application controlled the distribution of the sample to the interviewer. This describes the process:

- From a workstation, CATI requests individual household information as needed by an interviewer for an interview. The request is written in an XML file.

- The server processes the XML file in sequential order to avoid data collision and double sample distribution. Many criteria are evaluated in the choice of a household: language (some interviewers can speak a foreign language), appointments made with respondents, batches which must be treated on a priority basis, and so on. Then, it sends the information to CATI in the same XML file (header and workstation data are kept).

- CATI processes households one at a time. It completes the XML file with the information that is gathered by the interviewer. This ensures data integrity, because the

XML file is also used for validation. Whether the interview is postponed, stopped, or completed, or an appointment is made, the XML file is updated and sent back to the server. The XML file also contains performance indicators for the interview, such as duration, number of errors, etc.

- The server receives the XML files from the workstations. It processes the data to transform and store them in the centralized survey database.

Meanwhile, the workstation stores a copy of each interview. CATI also logs every entry made by the interviewer, for later use. In addition, the server stores raw XML files.


```xml
<?xml version="1.0" encoding="ISO-8859-1" ?>
<!--  Infos sur un ménage produit par MADQUOI -->
<Menage>
	<Feuillet>9999</Feuillet>
	<Requete>
		…
	</Requete>
	<Domic>
		…
	</Domic>
	<Stat_appels>
		…
	</Stat_appels>
	<Localisations>
		…
		<Localisation>
			<Categ>LIEU_HAB</Categ>
			<Rue_int>SHERBROOKE</Rue_int>
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			<Munic>MONTREAL</Munic>
		</Localisation>
		…
	</Localisations>
	<Personnes>
		<Personne>
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			…
			<Deplacements>
				…
				<Deplacement>
					<Heure>600</Heure>
					<Orig>1</Orig>
					<Dest>3</Dest>
					<Mode1>3</Mode1>
					<Mode2>4</Mode2>
					<M2>21 CADILLAC</M2>
				</Deplacement>
				…
			</Deplacements>
		</Personne>
		…
	</Personnes>
</Menage>
```


Figure 8. Extract of a household XML information exchange file

4.3 Survey statistics management

When conducting large household surveys, planners must be able to follow survey activities on a day-to-day basis. Traditionally, this is done through daily reports which are distributed among them. This generates large amounts of paper and is not always suited to specific needs.

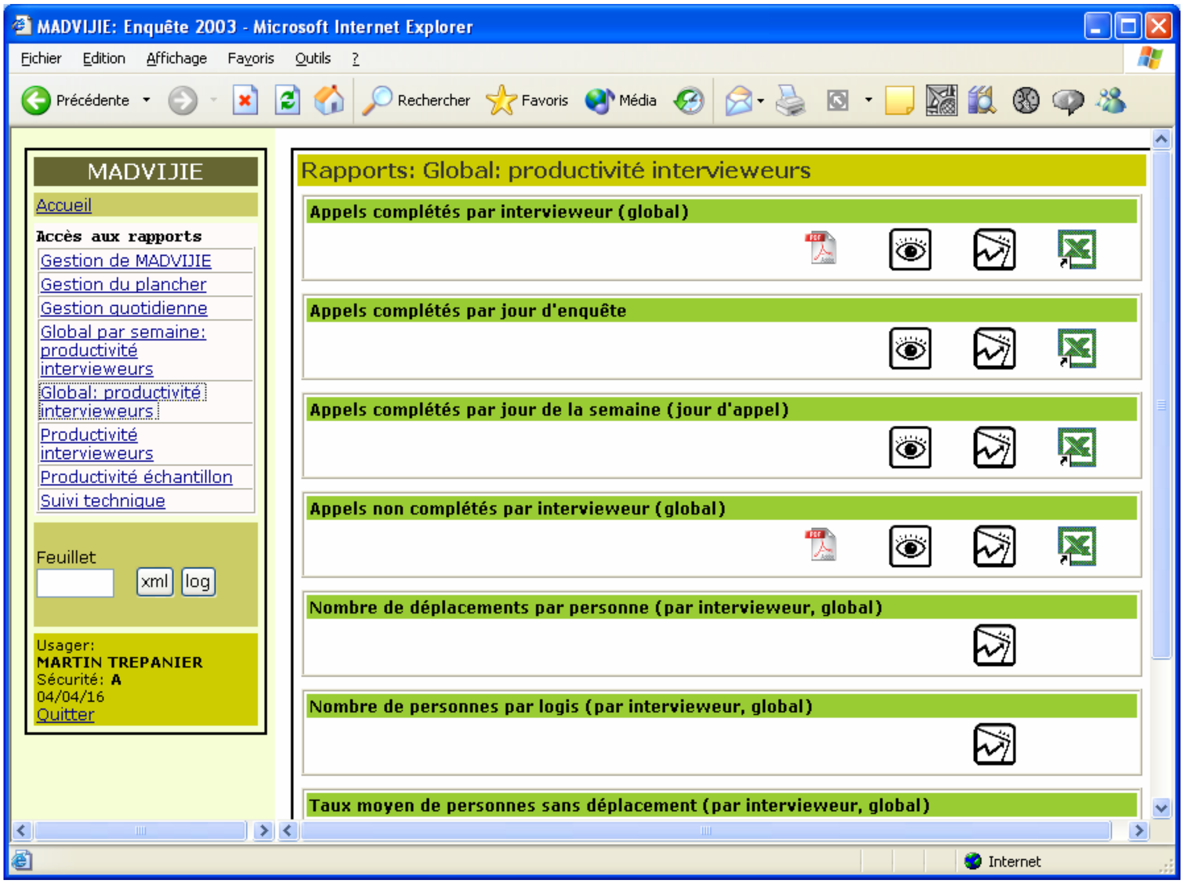

Figure 9. Sample screen of reporting application, showing a list of reports on the productivity of interviewers

In 2003, the on-line survey statistics application provided information on:

- Global productivity per day or per week, or of the whole survey (number of completed calls, trip rate per household, person, overall call status);
- Productivity of each interviewer per day (completed calls, average interview duration, call status evolution);
- Sample productivity (non completed calls per stratum, batch progress, stratum household statistics, batch household statistics);

- Technical maintenance for the survey (list and types of errors, list of households to be completed, locations to be geocoded, list of new trip generators, comments, error rates);
- Daily maintenance (calls to a single household, interviewers on duty, list of current appointments);
- Survey staff management (list of interviewers);
- Reporting software management (list of reports, user accesses, logfile).

To generate reports, the application stores queries based on Structured Query Language (SQL), parameterized when needed to input text, date, or number (see Figure 9). Reports are available in four formats, depending on their structure: paper-like reports in a PDF file, on-screen table-format reports, on-demand charts, or Excel spreadsheets.

5 Conclusion

Nowadays, it is our view that a large telephone household survey in transportation cannot be conducted without the help of powerful software components which will support all the functions surrounding this labor-intensive and costly activity. There is a particular need for an adequate geographical information system for both territorial and operational data. This GIS-T must be exhaustive and entities well identified for searching for address, intersection, postal code, and transit stop locations, and trip generators must be carefully selected to avoid bias in location choice.

In our system, in addition to including an appropriate GIS-T, data normalization is ensured by the use of specialized CATI software which validates and stores data. A server manages the sample and another application reports on survey evolution and statistics. In the Montreal region, this architecture has been dictated by the use of household survey data: transportation planning, transit network development, user behavior, transit financing, road network usage, trip generator analysis, and so on.

In the future, many elements will affect the way in which household surveys are conducted. The use of smartcard payment systems on a large scale will provide fresh data to update and complete those obtained via telephone survey. The ever-growing difficulties encountered in reaching people by telephone at home, the increasing number of single-person households (these are hard to reach), and the growing use of cell phones which sometimes replace home telephone service will challenge the traditional ways of conducting surveys and will prompt a rethinking of the methods used.

6 Acknowledgments

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