# Trip generator relocation impact analysis methodology based on household surveys

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**Trip Generator Relocation Impact Analysis Methodology Based On Household Surveys**

by Trépanier, Martin, Chapleau, Robert, Allard, Bruno, and Morency, Catherine

## Abstract

In cities, large trip generators, such as hospitals, shopping centers, schools and industries, are influencing both people movement and goods movement. The relocation or grouping of these trip generators has an impact on customers, especially workers, in terms of both their trip habits and their use of transportation networks. Traditional planning models cannot address questions at this spatial and temporal level of resolution. In this paper, a methodology based on household surveys using the Totally Disaggregate Approach and on Transportation Object-Oriented Modelling is presented to tackle the problematic issues of trip generator relocation in urban areas.

## Introduction

Each day, millions of people travel based on trip generators in conducting their activities: work, study, health care, visiting, shopping, etc. Undoubtedly, these trips have an effect on transportation networks and infrastructures linked to the locations involved. When hospitals, shopping centers, plants and offices are closed, merged or relocated, there is a need to fully understand and measure the impacts of such actions on the people, the networks and the infrastructures affected, either directly or indirectly.

Despite the importance of trip generators in daily urban activities, the traditional four-step transportation planning process (generation, distribution, modal split and assignment) is not really adequate to address the task of measuring relocation impacts at the required level of resolution[1]. It is worth stressing the importance of analyzing the impacts of the relocation of urban trip generators with the help of new methods, based on household surveys, which are more likely to measure the effects of relocation, both on people and on transportation infrastructures.

This paper examines the problematic issues related to trip generator relocation in urban areas. The proposed method is based on the Totally Disaggregate Approach (TDA) and on Transportation Object-Oriented Modelling (TOOM). These modeling approaches, developed in the Montreal Area, are explained in the background section of this paper. Then, the methodological fundamentals are introduced: the importance of trip generators in household surveys, object-models associated with the trip generator and a step-by-step methodology for relocation analysis. To provide concrete examples of the use of the method, the paper presents case studies concerning the relocation of two groups of hospitals in the heart of downtown

Montreal involving three French-speaking hospitals and three English-speaking hospitals. We end with some concluding remarks on the exercise and further research possibilities.

## Background

Researchers have tackled location problems on a broad scale. Series of algorithms aimed at finding new locations for warehouses, points of sale, plants and other buildings already exist[2]. Authors are now tending to improve older algorithms. Andersson et al.[3] propose an aggregation method to limit the size of the mathematical problem. Melkote and Daskin[4] present an integrated model to optimize both facility location and the underlying road network, which introduces the consideration of infrastructures in the design of new facilities. Successive evolutions in the field of geographic information systems (GIS) now permit a better integration of trip generators as components of urban land use[5]. Vlachopoulou et al.[6] use GIS to visualize possible facility location sites before making a choice. This kind of GIS usage has already been presented in the case of interactive planning[7]. However, as mentioned by Hernandez and Bennison[8], most decisions concerning facility location are based on the planner's experience, not on mathematical models. Furthermore, as there is little open land available in dense cities in which to establish new buildings, the real problem is to choose from among a given number of possible sites rather than find a hypothetical one. From these considerations, we conclude that there may be a need for an evaluative method for facility location, rather than a suggestive method.

In parallel, several attempts have been made to develop trip generation models for many types of facilities[9]. Recent research has revealed that a degree of specialization is emerging among generation models.: Examples include hotels and casinos[10], convenience stores[11], retail developments[12], multiuse highway commercial developments[13], consolidated schools[14] and airports[15]. In addition to these specific generation models, a quick-reference model is necessary to derive some general characteristics for trip generators within a region, and to appreciate their evolution over the years.

Some early attempts were made by Chapleau[16] to derive land use maps from household surveys. Survey data were examined to identify and classify the numerous destinations mentioned by respondents. Subsequent work was related to the characterization of groups of trip generators and to the analysis of the clientele in these places: trip purpose, trip modes, temporal distribution of activities, the spatial distribution of homes, etc. This research led to the integration of trip generators in the interview software for the 1998 household survey of Montreal. Two key elements were used to develop the trip generator relocation analysis methodology: the Totally Dissagregate Approach and Transportation Object-Oriented Modeling.

### *The Totally Disaggregate Approach*

Large household surveys in Montreal (about 5% sampling) have been continuously reshaped since 1982 with the use of the Totally Disaggregate Approach (TDA) in transportation[17]. The TDA involves two basic principles:

- Every single piece of information collected from household or other surveys is kept in a trip file grouping together data on households, people and trips. Attributes include household size, car ownership, age, gender, trip purpose, mode, departure time, origin and destination, transit route sequence, bridges crossed, carpool locations, etc. The method requires the retention of a maximum of information.

- The information is intended to be at the best possible level of resolution. For location specification, zoning systems were abandoned early. Instead, addresses, intersections, postal codes, stations, and now trip generators, are used to specify origin, destination and junction points. Locations are stored with both a description and X-Y coordinates. Since the mid-80s, GIS technologies have been used for this task.

The TDA leads to a series of developments and applications: transit network resource evaluation, subway extension analysis, survey data dissemination[18], transit financing, user information over the Web, socio-demographic analysis, subway shutdown analysis, to name only a few.

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

| **Year** | **1974** | **1978** | **1982** | **1987** | **1993** | **1998** |
|---|---|---|---|---|---|---|
| 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$^2$ |
| Population | 2,824,000 | 2,954,000 | 2,895,000 | 2,900,000 | 3,263,000 | 3,493,000 |
| Sampling rate | 4.8% | 5.3% | 7.0% | 5.0% | 4.7% | 4.5% |
| Surveyed households | 43,000 | 50,000 | 75,000 | 54,000 | 61,000 | 64,000 |
| Surveyed trips | 265,000 | 305,000 | 492,000 | 338,000 | 350,000 | 380,000 |
| Zoning system / Geocodes | 1,192 zones | 1,264 zones | 1,500 zones | 70,000 PC | **30,000 TG**<br>70,000 PC<br>9,000 SN<br>40,000 IN | **44,600 TG**<br>100,000 AR<br>89,000 PC<br>34,000 SN<br>191 000 IN |

AR: Address ranges, IN: Intersections, PC: Postal Codes, SN: Street Names, **TG: Trip Generators**

### ***Transportation Object-Oriented Modelling***

Transportation Object-Oriented Modeling (TOOM) is an adaptation of the object-oriented approach to the transportation fields of planning and operation. It is partly based on Rumbaugh's object modeling technique (OMT)[19]. OMT makes a clear distinction between conceptual object models and programming language, which is where OO methods are usually employed. TOOM is not only a programming language and a database model, but also a conceptual model which helps to identify the ontology of a problem (objects and the relationships between them). To maintain the analogy with OO terms and permit the creation of object models, TOOM defines classes of transportation objects. Each instance of a transportation object deriving from one of these classes has properties (attributes) and methods (actions) defining its own behavior. Four meta-classes (families of classes) have been identified by Trépanier[20]:

- Static objects, which have a "relatively" fixed location in space, and for a given time period. They describe the territory and support transportation activities. Trip generators are static objects.

- Dynamic objects, which are the transportation actors. They "decide" and contribute to their movements. People, cars and goods are dynamic objects.

- Kinetic objects, which describe movements. They trace spatial and temporal limits for dynamic objects. Trips, trip chains, transit routes and pedestrian paths are kinetic objects.

- System objects, which are groups of objects. They can be operational (a road or transit network), informational (a survey or census) or multifunctional (downtown, suburban).

A transportation object-model must contain at least one object from each class, otherwise the object-model would not represent a transportation reality. TOOM has been applied to the following problematic issues in recent years: GIS linkage between operational and territorial data[21], household survey analysis and the development of coherent and integrated information systems.

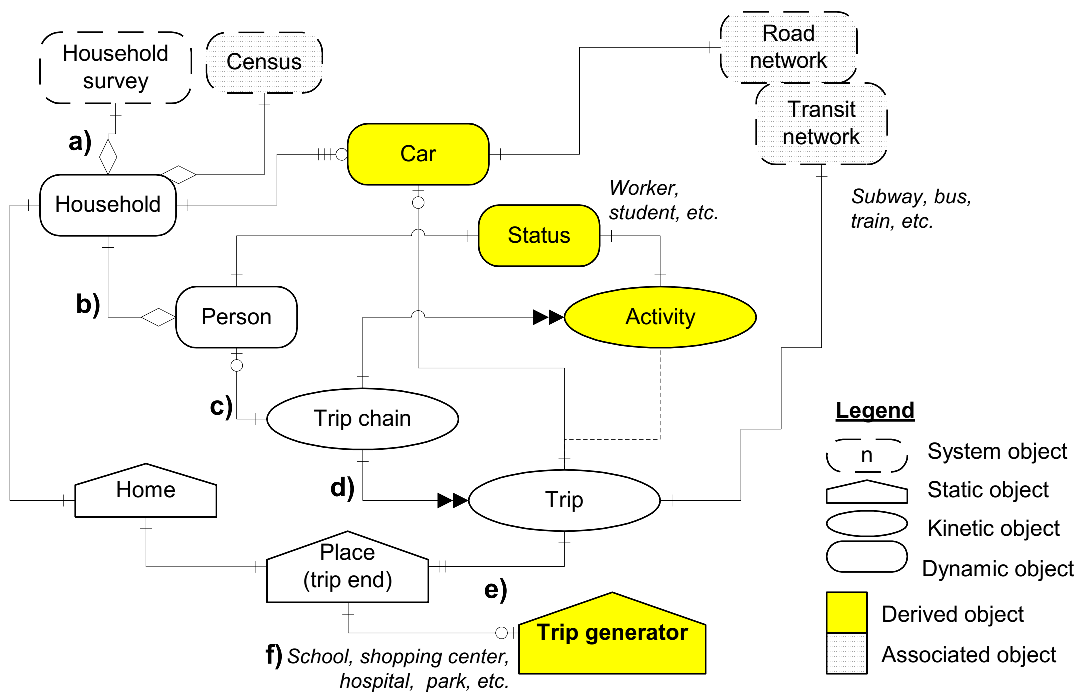


*Figure 1: Extended household survey object-model*

## Methodology

### *The Trip Generator Object*

The trip generator (static object) is one of the objects belonging to the enriched household survey object-model shown in Figure 1. The figure draws attention to the four metaclasses seen before, and confirms the presence of derived objects (which are created from respondents' statements) and associated objects (which are linked to the object-model when needed). To explain the instantiation of the trip generator object, let us look at the relationships between the objects, starting with the survey object (see Figure 1):

a) The Household survey object is a collection of Household objects;

b) The Household object is a collection of Person objects;

c) Each person is related (or not) to a TripChain object;

d) A TripChain object is an oriented collection of Trip objects;

e) Each Trip object possess two Place (trip end) objects;

f) A Trip Generator object is created from a Place object.

***Trip Generators in Household Surveys***

An adequate analysis of trip generators from household surveys requires that the destination statements be correctly identified during the interview with the respondent. In the GMA, an effort was made throughout the year to build a trip generator knowledge base (TGKB) which can be used to conduct surveys as well as for other purposes such as user information on websites. The TGKB has to be strongly integrated with GIS. While the spatial locations of places are usually fixed in time, problems arise when generators such as shops or schools move or change their names[5]. Special attention must be paid to identification, since more than one generator can have the same name. For example, there are seventeen "Notre-Dame" schools in the GMA.

The TGKB contains data from several sources. In particular, statements gathered from respondents in previous surveys helped identify the most relevant categories, as well as permitting the constitution of a database of aliases containing different names for generators.

French and English names were also gathered, when possible. Commercial listings were used for businesses, shopping centers and industries. Unfortunately, these listings are not always adequate, since alias names and geocodes must be added. Public inventories were used for government offices and municipal buildings, but a great deal of work has to be done to weed out and sort information which is not useful.

In the 1998 survey, a 47,000-record TGKB was integrated into the phone interviewing software. Because of the ability to link statements and the associated GIS, it was possible for the in-house software to validate the origins and the destinations provided by respondents. This was done by checking the access time to the road or transit network and the estimated trip duration. Though respondents were not obliged to declare a trip generator as a destination, half of them were sourced in the TGKB. The proportion of trip generators in statements is about 50% for trips taken in the direction of the central business district. Further research work will be carried out to associate other statements, such as intersections, with the nearest trip generators in order to increase the number of usable declarations for this analysis.

***Step-by-step methodology***

The proposed methodology involves a reverse analysis of the household survey data. Instead of following the natural household--person--trip sequence, the analysis begins with the selection of trip generators. For each generator, a set of trips related to it is built. These trip objects are identified either directly (specifically named) or indirectly (nearby intersection or address). From each of these trips, trip-chain objects are gathered along with their associated person objects. Statistics are compiled form these object sets. To measure the impacts of relocating generators, four simulations are carried out on each trip to construct situations before and after the relocation, both on transit and on road networks.

## Application: Montreal Hospitals

### *Overview*

As an example of the use of the TOOM methodology, we present an application involving two groups of hospitals, all located in downtown Montreal. The first group is composed of St-Luc, Notre-Dame and Hôtel-Dieu hospital pavilions (which form the *Centre hospitalier de l'Université de Montréal, CHUM*). The second group is composed of The Montreal Children's, Montreal General and Royal Victoria hospital pavilions (which form the *McGill University Health Centre, MUHC*).

### *Objects statistics overview*

Hospitals have characteristics which differ from those of other types of trip generators. Table 2 contains overall statistics compiled from eight types of trip generators, for the 1998 survey. It shows that hospitals have a higher percentage of trips involving women and trips involving cars than do other classes.

Table 2. Overall statistics for major trip generator classes, Montreal 1998 survey.

| 1998 survey | No. analyzed trip gen. | % trips - work | % trips - women | % trips - car | Activity duration (h) | Average dist. (km) |
|---|---|---|---|---|---|---|
| Shopping centres | 133 | 13% | 61% | 79% | 2.9 | 5.6 |
| **Hospitals** | **31** | **44%** | **62%** | **73%** | **5.4** | **9.5** |
| Cultural locations | 6 | 41% | 48% | 48% | 5.6 | 8.5 |
| Elementary schools | 74 | 8% | 55% | 38% | 5.2 | 3.3 |
| High schools | 134 | 7% | 50% | 24% | 6.7 | 5.0 |
| Colleges and univ. | 30 | 12% | 51% | 37% | 6.7 | 9.3 |
| Office buildings | 11 | 66% | 51% | 43% | 6.8 | 10.6 |
| Large industries | 25 | 94% | 42% | 62% | 5.2 | 11.5 |

Table 3. Evolution of trip characteristics for the study groups, Montreal 1987-1993-1998 surveys.

| | % trips - work | | | % trips - women | | | % trips - elderly | | |
|---|---|---|---|---|---|---|---|---|---|
| **3 surveys** | **1987** | **1993** | **1998** | **1987** | **1993** | **1998** | **1987** | **1993** | **1998** |
| - The Children's | 48% | 54% | 43% | 60% | 66% | 65% | 1% | 1% | 3% |
| - Montreal General | 58% | 55% | 42% | 58% | 58% | 56% | 11% | 15% | 22% |
| - Royal Victoria | 57% | 50% | 45% | 62% | 62% | 55% | 9% | 10% | 24% |
| *Total MUHC* | *55%* | *53%* | *43%* | *60%* | *61%* | *57%* | *8%* | *10%* | *20%* |
| - Hôtel-Dieu | 57% | 52% | 39% | 72% | 64% | 54% | 11% | 14% | 24% |
| - Notre-Dame | 49% | 46% | 39% | 62% | 60% | 57% | 10% | 10% | 23% |
| - St-Luc | 55% | 49% | 46% | 62% | 61% | 61% | 8% | 9% | 18% |
| *Total CHUM* | *52%* | *48%* | *41%* | *65%* | *62%* | *57%* | *10%* | *11%* | *22%* |

There was also an evolution in some trip characteristics over time for hospital study groups. In Table 3, it is reported that the proportion of work trips has generally declined since 1987. There is a significant increase in trips involving the elderly. The table also shows that the two groups of hospitals are similar in terms of the percentage of trips involving work, women and the elderly. The proportion of transit trips is also similar (about 33%, since all the hospitals are located in the downtown area), as is the average activity duration (about 5.5 hours). Seventy percent of the time spent away from home involves the main trip generator. However, there is a difference in the spatial distribution of the respondents' homes, due to language. While 60% of all the homes are located in downtown Montreal for both groups, about 20% of the MUHC clientele live in the western part of the city, as against 10% for the CHUM. About 10% of CHUM's clientele live in

Laval, compared to less than 1% for the MUHC.

***Direct relocation impacts***

The physical relocation and regrouping of hospitals have an impact on the clientele's travel time, depending on their current mode of transportation. Figure 2 shows the travel time variations (as a percentage) of users from nine regions in the Greater Montreal Area. The variations are calculated by comparing individual simulated 1998 travel times to individual simulated travel times after the relocation. Travel times were obtained from the transit and road network simulations, as illustrated in the step-by-step methodology. The map reveals that the effect of travel time on people in the central regions is greater than the effect on those in the suburbs. Transit times are generally shorter, due to the better transit service provided for the new sites: CHUM's projected site is near the Rosemont subway station, while the MUHC's is near the Vendôme subway station. The proximity of the freeway network also reduces road travel time for the English-speaking group. For the second projected site of the CHUM (not shown), there is less impact on travel time because the site is located downtown.

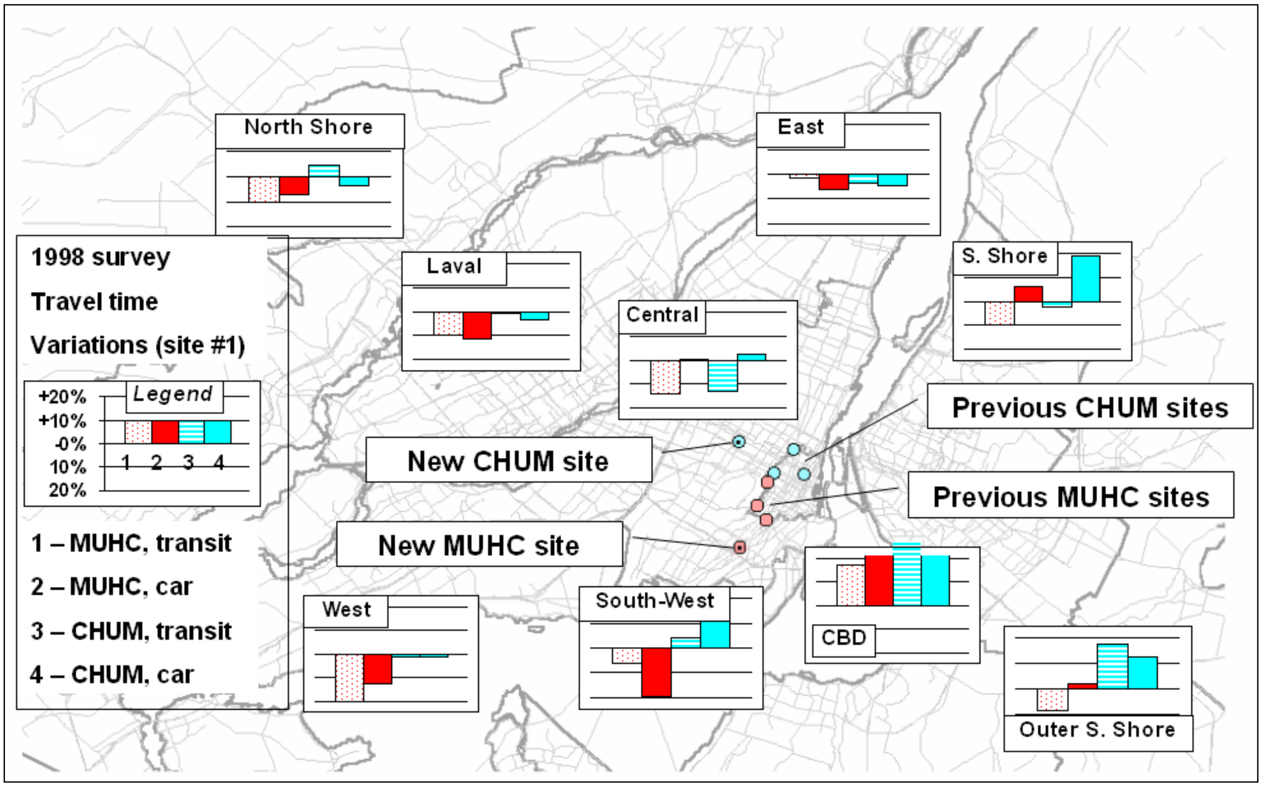


Figure 2. Spatial distribution of variations in travel time (after relocation compared to 1998 situation), 1998 survey, site #1 for MUHC and CHUM.

To evaluate the impact on infrastructures, we used TDA procedures such as transit network load and node activity statistics. A transit network load profile of the future situation (both groups relocated) is illustrated in Figure 3. The analysis of the database associated with the load profile shows that there will be an increase of 3,500 trips per day at the Rosemont subway station and 4,000 at the Vendôme subway station. Transit users will be using an average of 1.99 routes after the relocation compared to 2.26 in the current situation.

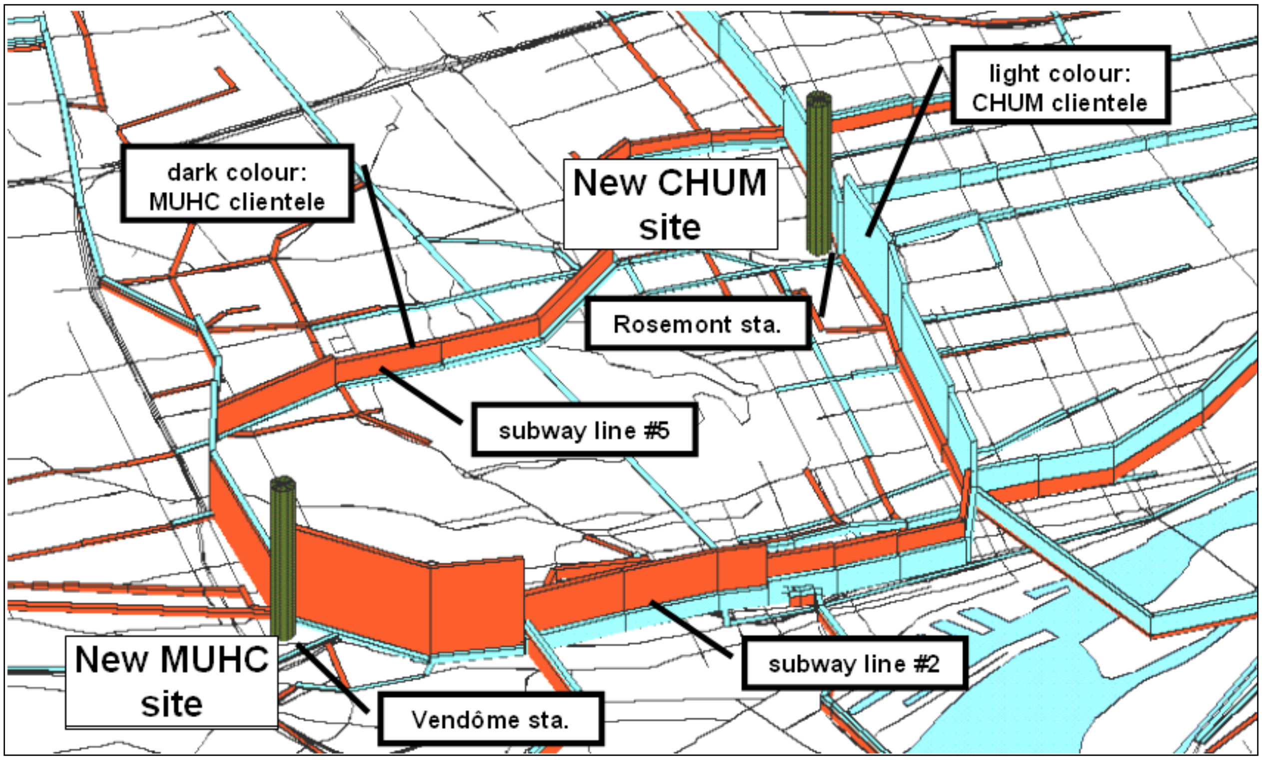


Figure 3. Simulated transit network load profile for the clientele of the MUHC and CHUM, after both relocations (E1=English group, site #1, F1=French group, site #1)

## Conclusion

This paper has presented a methodology, based on the Totally Disaggregate Approach (TDA) and Transportation Object-Oriented Modelling (TOOM), to evaluate the impacts of relocating trip generators in urban areas. The cases of two groups of hospitals in the Greater Montreal Area were presented. Preliminary results show that the methodology first serves to better characterize the trip generator's clientele (people, trip chains, trips). It is then used to estimate direct impacts of the relocation in terms of travel time variations, transit usage and road network usage. However, additional research is needed to appraise the indirect impacts on other trip generators and to evaluate the modal shifts that could occur.

The research also involved the reversal of the traditional household survey analysis by looking at destinations as objects instead of looking at households. Transportation Object-Oriented Modelling has demonstrated its ability to analyze survey objects (existing, derived or created). Due to its strong link to trip generator' declaration, the research also demonstrates the importance of integrating, as far as possible, trip generators into household survey interview software, and of validating this type of declaration, in order to pursue such analyses in the future.

## Acknowledgements

The authors wish to acknowledge the contribution of the major research partners of the MADITUC group involved in the 1998 household survey technical committee: the *Société de transport de Montréal* (STM), the *Agence métropolitaine de transport* (AMT) and the Quebec's Ministry of Transportation (MTQ). Thanks also to the Natural Sciences and Engineering Research Council of Canada (NSERC).

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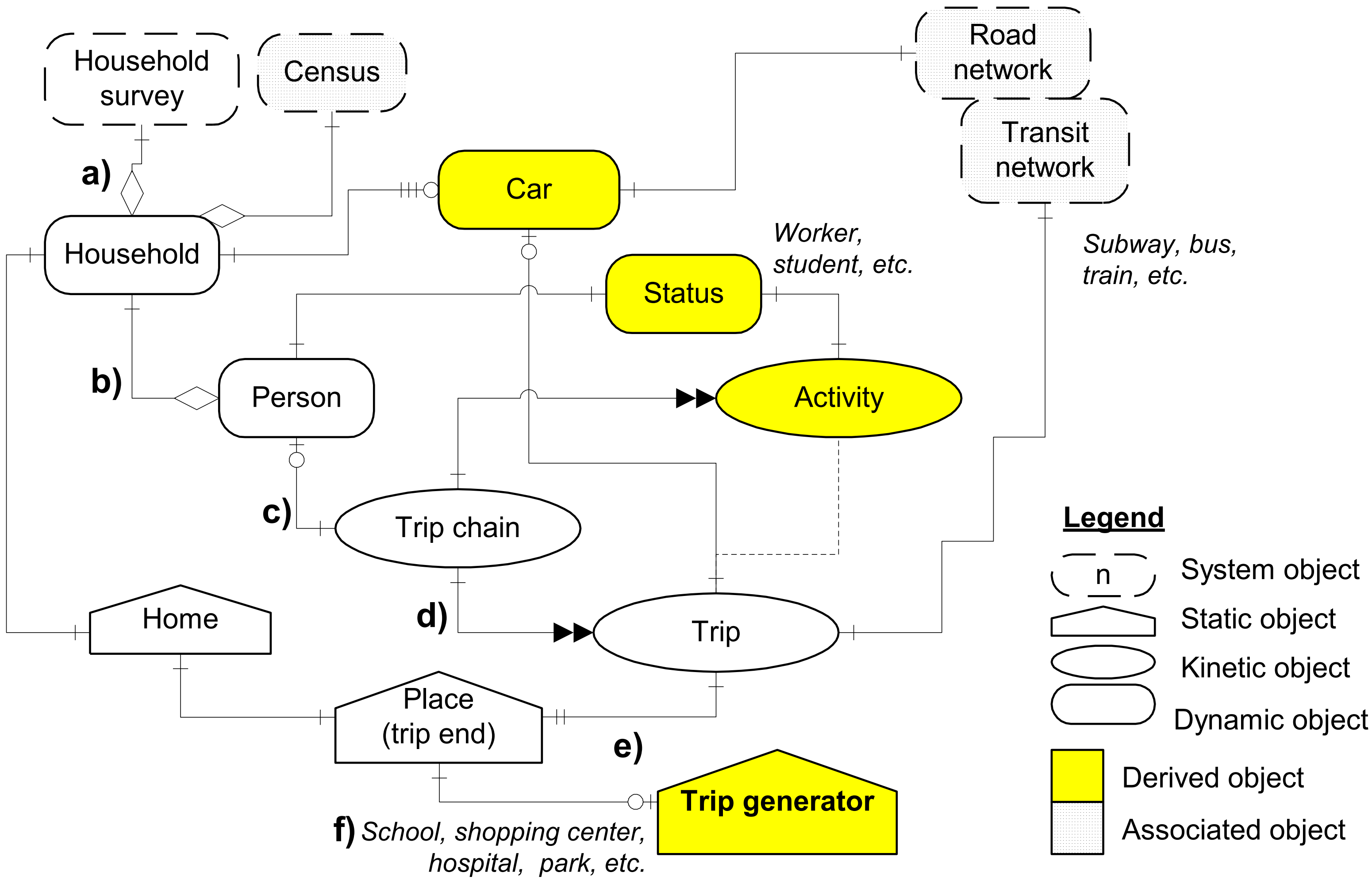


*Figure 2: Extended household survey object-model*

Table 2. Overall statistics for major trip generator classes, Montreal 1998 survey.

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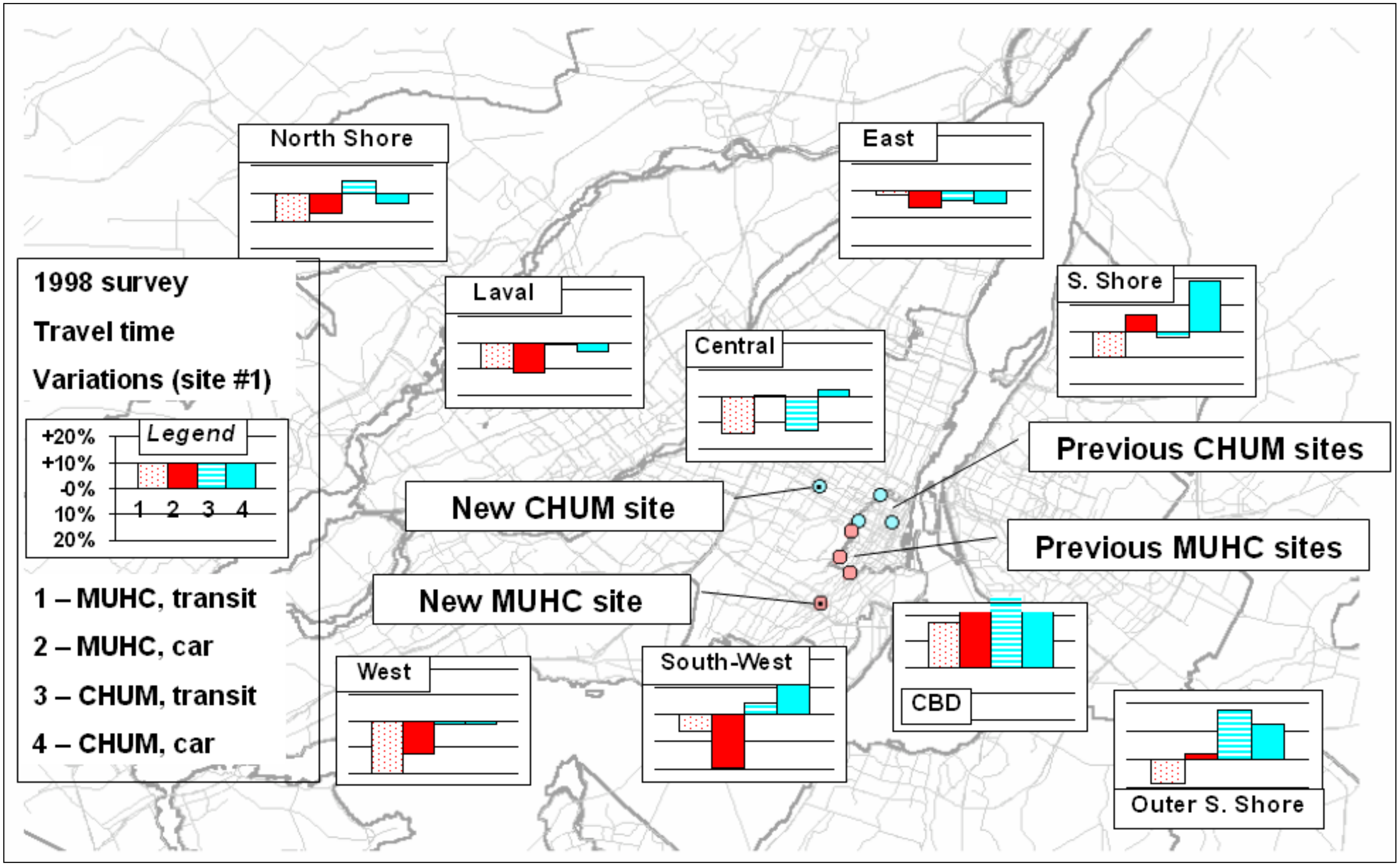


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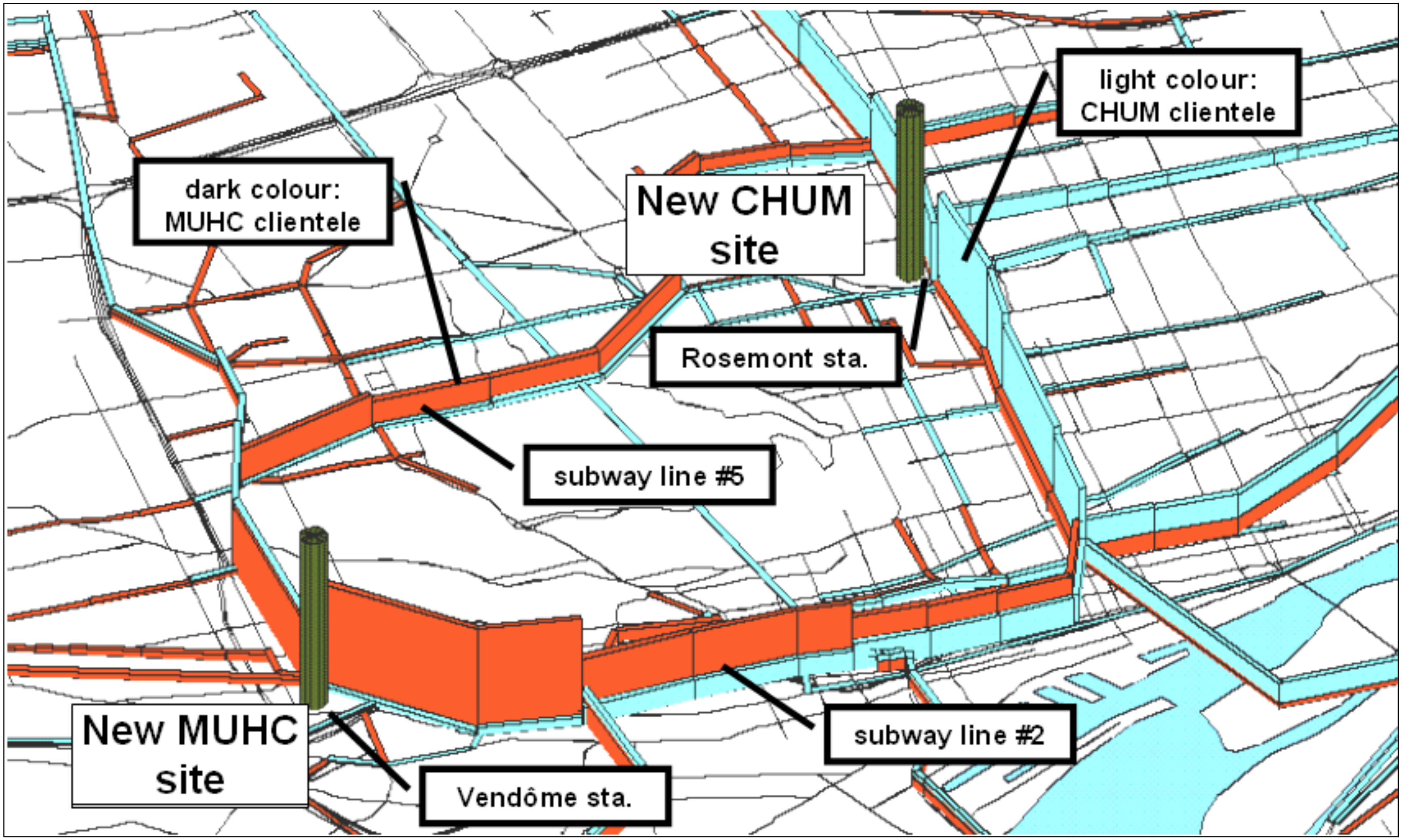


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