Transportation Data Collection in the Greater Golden Horseshoe: A Framework and Priorities for Improvement

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Preamble

This report is sponsored by the Data Management Group (DMG). While background information has been obtained from the DMG about their past experiences with the conduct of the Transportation Tomorrow Survey (TTS), the recommendations are based on the independent research and opinions of the authors of the report.

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1. Introduction

A well-conceived and well-executed transportation data collection program is central to good public-sector decision-making towards a prosperous, liveable and sustainable city. In the Greater Golden Horseshoe (GGH), there exists a long history of high quality transportation data collection to support many forms of transportation planning and research performed by a wide range of organizations. The centrepiece of this history is the Transportation Tomorrow Survey (TTS), a 24-hour retrospective telephone interview of the personal travel conducted of all household members (aged 11 or older) in the household. This survey has the largest sample of its kind in the world, with a sample of 5.2% in 2006, resulting in interviews with 150,000 households, involving 400,000 persons and 865,000 trips (DMG, 2007a). It has been conducted by the Data Management Group (DMG) of the Urban Transportation Research Advancement Centre (UTRAC[1]) every 5 years since 1986. Over its history, the TTS has been used to support a wide variety of planning, modelling and analysis efforts, including regional transportation infrastructure and land use analysis, transportation analysis at the local level, environmental assessments, transit service planning, university research, etc.

Looking forward to 2011 and beyond, two data-related challenges face the DMG and the transportation planning community in general. The first question relates to the content of the TTS and where it resides in the larger transportation data collection picture.

Will the TTS, in combination with other data sources, provide sufficient information to answer key transportation questions that will arise over the next 10 years?

While it is essential that data collected in the Greater Golden Horseshoe continue to support current modelling and analysis efforts noted above, we expect, over the next decade, that vigorous public debate and discussion will surround major transportation-related issues such as greenhouse gas emissions and air quality, transit investment, transportation pricing, cost of fuel, alternate fuels and electric autos, changing demographics, changes in nature of the regional economy, and the growing significance of personal travel to destinations other than work or school.

Clearly, no single survey can provide enough information to answer all questions surrounding each of these issues. However, there are significant opportunities to develop an integrated system of data collection that minimizes important data gaps, maximizes compatibility of data sources, and allows for comprehensive modelling and analysis that provides better decision-support on these major transportation policy issues.

The second question relates to the method by which information is gathered:

How should the TTS be effectively and responsibly conducted in the future, recognizing significant technological and societal changes that are occurring?

[1] Formerly known as the Joint Program in Transportation.

Clearly, there are competing objectives in a comprehensive data collection program, and these must be balanced within the constraint of limited resources. There is, on the one hand, a need to maintain continuity in survey instruments over time to allow for trend analysis, to prevent changes in instrument bias, to support legacy modelling techniques, and to build upon knowledge gained from previously collected data.

On the other hand, the social and technological context for data collection is clearly changing. Methods that have worked in the past are no longer working as well. For example, telephone interview response rates have declined substantially over time and directories of land telephone lines that have traditionally been used do not capture an increasing population of individuals that only use mobile telephones or voice over internet protocol (VoIP).

Data collection programs can also take advantage of technological developments. Several new instruments for data collection are available and are being increasingly accepted internationally as robust and reliable state-of-practice tools, such as Global Positioning System (GPS) assisted surveys, internet-based data collection and a variety of ITS-based passive data collection techniques. However, investment in a new survey technique bears risk, because of uncertainty as to what the technological future will look like. Will land-lines be obsolete in 10 years? Will VoIP become the new communications medium or will it be replaced by something else? Will the current generation of computer literate youth maintain that literacy into old age?

The objective of this report is to provide insights towards answering these two questions based on an analysis of data needs in the Greater Golden Horseshoe and a review of international data collection practices. The report is organized as follows. Section 2 presents a transportation data collection framework outlining the major components of travel, how the TTS and other data sources together cover some of those components and where the major data gaps are. This section is primarily focused on providing insights for the first question above. Section 3 focuses in more detail on the future conduct of the Transportation Tomorrow Survey for personal travel data collection, the challenges and opportunities for improvement. This section is intended to address the second question above. Section 4 summarizes the key recommendations from the analysis in this report. The report focuses on data suitable for transportation planning, rather than data for transportation operations (e.g. signal timing, freeway traffic management, and transit scheduling) or safety analysis. While operations-level data can and possibly should be integrated with planning data with potential synergies, such discussion is beyond the scope of this report.

The technical appendix to this report includes a detailed and extensive review of travel survey methods world-wide. This is an important backdrop to the recommendations made in this report, since many other jurisdictions are experiencing the exact same concerns as those faced in the Greater Golden Horseshoe.

2. Transportation Data Collection Framework

In order to make good decisions about future implementations of the TTS and other data collection efforts to be undertaken in the Greater Golden Horseshoe, it is critical to a) understand what the "universe" of travel is, b) understand which components of the "universe" are being observed in established data collection programs, c) prioritize those components of travel that we need to better understand in order to inform good public policy decisions, and d) identify improvements to the current transportation data collection strategy that would allow us to better achieve that understanding.

2.1 Defining the universe of travel

Figure 1 depicts the universe of travel in the GGH, categorizing travel by traveller (who), the purpose of travel (why), the travel location (where), the mode of transportation (how), and various time periods (when). Different travel behaviour occurs at different times of day, on different days of the week (with the primary difference between weekdays and weekends), and over different seasons.

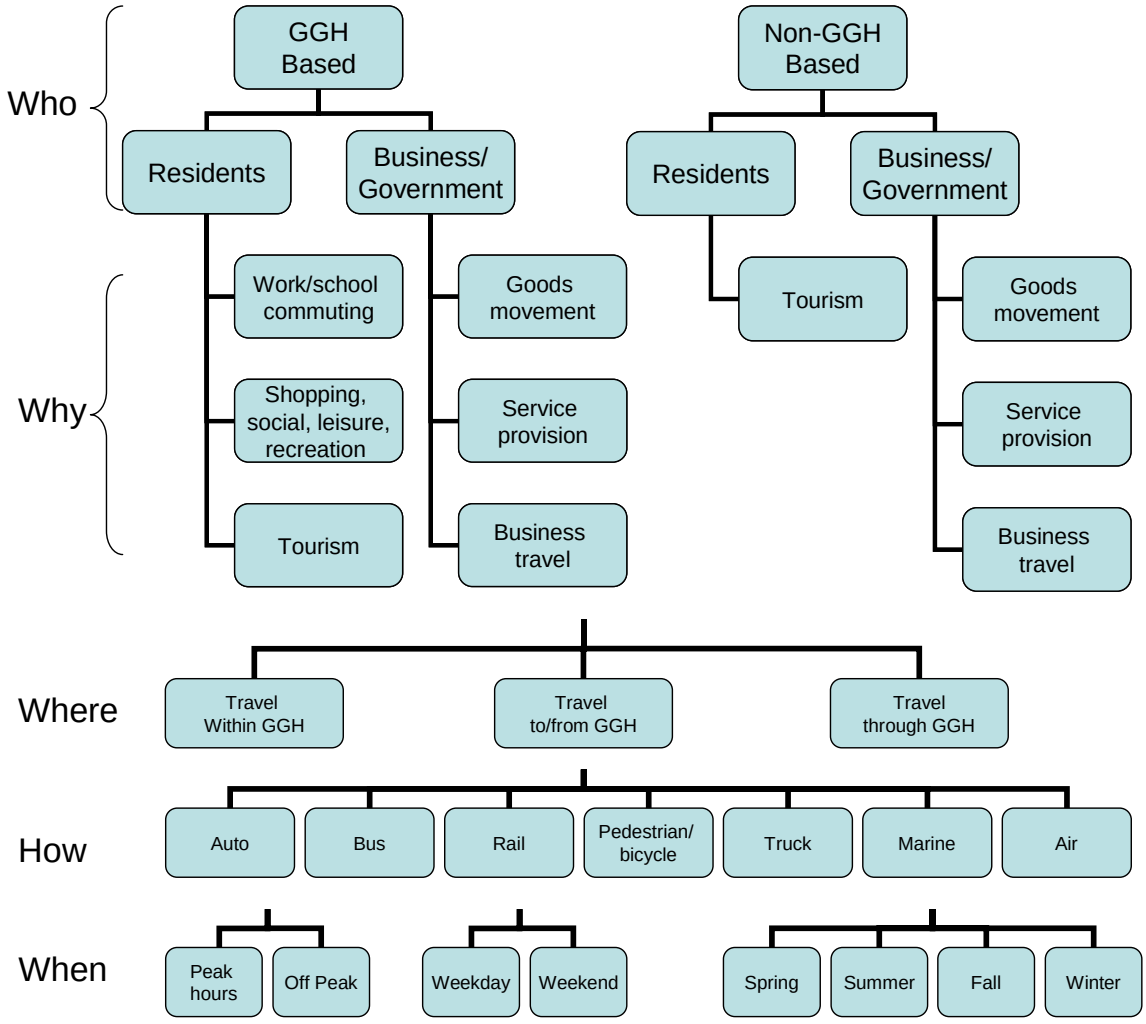

Figure 1 – Categorizations of travel

2.2 Transportation data collection in the GGH

Significant information is already collected about travel in the GGH. Several high-quality established data collection programs focus on important parts of the "universe" of travel in the GGH. Rich databases are also collected in the private sector. However, the transportation data collection cannot be considered comprehensive because significant gaps remain. This section briefly describes the major data sources available in the GGH for transportation planning purposes, their key limitations and the remaining gaps.

TTS and other major established transportation data collection programs

These data sources have strong institutional inertia, and provide a valuable historical record of transportation-related trends. To maintain and add to this historical record, they should be considered the necessary base for data collection in the future. However, critical analysis of the limitations of these established data sources is also appropriate. This section describes the scope of the existing data sources, while discussion of data quality of the TTS is described in Section 3.

TTS

Clearly, the TTS is the centrepiece for collection of data about the personal travel behaviour of GGH residents. The TTS collects information about trips made on a single fall weekday by all household members 11 years of age or older, by all modes of transportation. The TTS has been conducted on approximately a 5% sample of the population every 5 years from 1986 to 2006. A complete description of the TTS data can be found in DMG (2007a). The TTS does not attempt to capture:

- Non-motorized trips (i.e. walk and cycle) for non-work/non-school purposes;
- Weekend travel;
- Seasonal variations in travel (TTS only collects information for fall (and in some cases spring) weekdays);
- Business travel that a person undertakes as part of his or her employment, aside from commuting;
- Travel information for children under the age of 11;
- Economic information including income and costs of travel and parking;
- Information about the types and ages of vehicles owned by the household; and
- Detailed information on activities and travel routes (e.g. activity start time, travel route for auto and other non-transit trips).

Traffic count programs

Extensive cordon count programs are undertaken every 2-3 years by the Regional Municipalities of York, Peel, Durham, and Halton and by the City of Toronto (DMG, 2007b). This program collects 12-13 hour traffic counts for all roads crossing one of a large number of screenlines throughout the regions, separately classifying automobiles, truck configurations and buses. Intersection traffic counts are also routinely conducted by individual regional municipalities throughout the GGH. Traffic counts are also obtained automatically *via* loop detector devices embedded into the pavement of freeway and arterial roadways as part of the freeway traffic management systems of the MTO

(COMPASS) and the City of Toronto (RESCUE). Traffic counts provide information about the totality of vehicles travelling for all purposes at specific times, but they do not provide any information about the origin and destination of travel, who the traveller is or the purpose of travel. Thus, count information can only provide limited insight for policy assessment in most cases, and is most useful for model validation purposes.

Transit surveys

The major transit agencies in the GGH carry out field surveys, some regularly and others on as-needed basis, to gather data on transit operations and usage for service planning and scheduling purposes. The most common and regular surveys include Speed-and-delay surveys and Transit Ridership Surveys. The former collect data on transit line travel time, broken down to running, dwell and delay times. Typically, the survey is done manually for street transit lines, but a growing number of agencies are increasingly relying on archived data from AVL (Automatic Vehicle Location) systems. The objective of transit ridership surveys is to collect data on passenger volumes at individual stops and sections of transit lines *via* boarding and alighting counts. Transit ridership surveys are performed regularly (a few times a year by some agencies) using manual methods. However, new technologies, such as APC (Automatic Passenger Counters) and Smart Card systems are increasingly being considered as promising sources of such data. Major transit agencies also conduct Attitudinal Surveys to collect data on transit passenger preferences of service characteristics such as speed, reliability, accessibility and frequency. However, these surveys are not usually conducted on a regular basis.

MTO Commercial Vehicle Survey (CVS)

The most extensive survey of travel initiated by businesses is the MTO CVS. The MTO CVS is a province-wide road-side vehicle survey, conducted at over 150 road-side directional sites in the province of Ontario (in the 2001 implementation of the survey), in which drivers are asked to report on truck activity characteristics related to the trip, driver, carrier, commodity and vehicle. This survey does not collect travel information for any business-related travel except that which moves by trucks over 4500kg GVW, and that passes one of the CVS data collection sites. Thus, little information is collected about urban pick-up and delivery trips, and no information is collected about commercial travel by automobile or other modes.

Private sector databases

A variety of private sector databases are collected for railway companies, truck carriers and business establishments. Rail freight data include Rail Commodity Origin and Destination Statistics, Rail car loadings survey, the Rail Transport survey. Commercial vehicle data are also collected and maintained by fleet service providers such as Turnpike Global Technologies, who maintain a commercial GPS-enabled fleet management database for over 30,000 trucks associated with over 300 major business establishments located in the Greater Golden Horseshoe. Records are also kept by port operators with regards to the small number of marine movements into/out of the minor seaports in the GGH. The Greater Toronto Airport Authority (GTAA) collects information about the passenger vehicles arriving at or leaving Pearson International Airport, as part of their Groundside Passenger Travel Survey.

The challenge with all private sector databases is that they include proprietary data, such that the databases are not necessarily available for all types of analysis. Furthermore, private data sources do not necessarily maintain the same standards of sample control such that it can be difficult to make inferences about the full population.

Gaps in behavioural transportation data collection in the GGH

Figure 2 summarizes those components of travel that are currently captured in a systematic large-scale behavioural data collection effort and those that are not. By "behavioural" travel data we mean data that not only counts vehicles/passengers, but also captures sufficient background information about the individuals and the trips to be able to model or otherwise analyze the underlying behaviour that might be influenced by policy intervention. Gaps in the behavioural transportation data currently collected in the GGH are summarized as follows:

- Local (within GGH) goods movement and service provision by truck;
- Goods movement, service provision and other business travel by automobile;
- Non-motorized personal trips to/from non-work/non-school trip purposes;
- Tourist and business travel, aside from such travellers captured through private surveys at the airports, on transit systems, or intercity tourism studies;
- Travel information for children under the age of 11;
- Weekend travel and seasonal variation in travel;
- Economic elements of personal travel, including income and costs of travel and parking;
- Information about the types and ages of vehicles owned by the household;
- Detailed information on activities (e.g. activity start time, activity scheduling), to enable modelling and assessment of policies and technologies that target activity participation (e.g. telecommuting); and
- Detailed information on trip routes, specifically auto trip routes, to enable modelling and assessment of congestion pricing schemes.

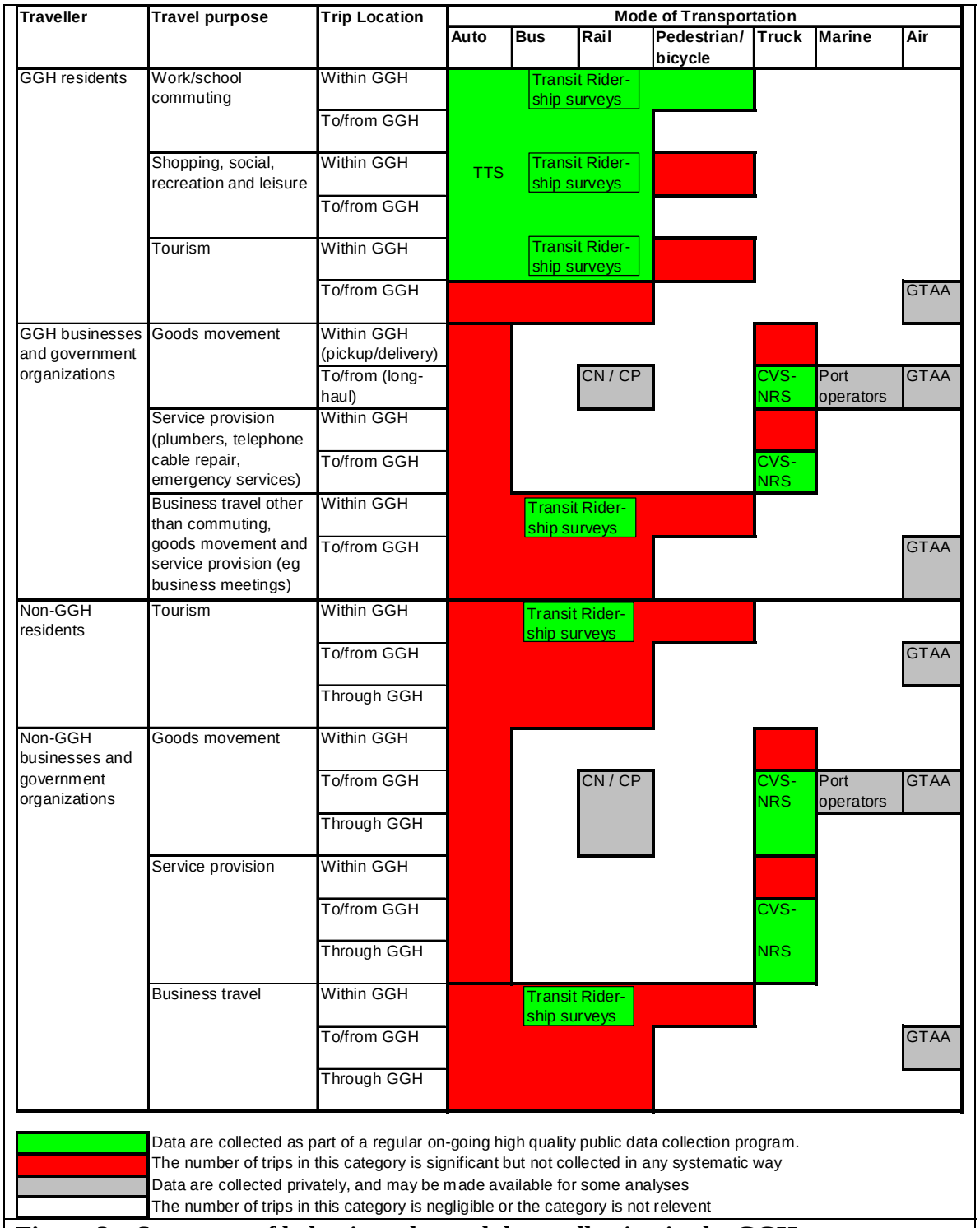

Figure 2 – Summary of behavioural travel data collection in the GGH

2.3 Which Data are Important for Public Policy Decision-Making?

A gap in information does not necessarily warrant a new data collection effort. A rational transportation data collection program captures information that is most useful for providing decision-makers with the means to make good public policy decisions on issues that have high impact on the residents and businesses of the Greater Golden Horseshoe. Thus, the following criteria can provide guidance about the sub-markets of travel that should be targeted for data collection.

- The amount of travel occurring within the transportation sub-market;
- The positive and negative impacts of that sub-market on infrastructure; operations, environment and on the well-being of GGH residents and businesses;
- The influence that public policy interventions can have on that sub-market and its impacts; and
- The extent to which quality information can be cost-effectively gathered to link policy interventions to outcomes.

Amount of travel by sub-market

An in-depth quantitative analysis of travel in each transportation sub-market is beyond the scope of this report. Furthermore, it is not possible to precisely assess the amount of travel in each transportation sub-market without holistic data collection. We make the following general observations/ judgements:

- Personal travel by GGH residents (commuting and travel to shopping, leisure, and social and personal business activities) is clearly the largest component of travel-kilometres in the GGH. In the AM Peak period, home-based work and school trips dominate, while in the PM peak, mid-day, and evening periods, a greater variety of travel purposes is found.
- Travel initiated by GGH businesses and government organizations is most significant during business hours with some avoidance of peak periods, especially in the AM. Although a large proportion of goods movement is by truck, we can expect that a very significant proportion of light goods movement, service and business travel is by automobile. We have little local information, however, to assess this.
- Tourist travel by non-GGH residents is most significant on weekends, holidays, and the summer, and is more concentrated at specific tourist locations. There exists little information to assess the amount and type of tourist travel in the GGH aside from the Travel Survey of Residents of Canada (Statistics Canada, quarterly), which does not acquire detailed geographic information.
- Non-GGH businesses initiate travel into/out of, and through the GGH. Through travel is small compared to the amount of travel with trip origins or destinations in the GGH, since the GGH is both a major supplier and consumer of transported goods and services.

Impact of travel by sub-market

Impacts of travel are diverse, including environmental, social, economic, health and safety, operational, etc. Differences in impacts between modes of transportation are well known and are not discussed in detail here. However, to provide insights for data collection we recognize the following salient facts:

- Auto, transit and other motorized personal travel by GGH residents, as collected by the TTS, cause the lion's share of most major categories of impact.
- While passenger and bicycle travel involve less impact, they are also very important to understand because they are healthy and "sustainable" alternatives to higher impact (motorized) modes for a large number of short trips.
- Commercial vehicles, and in particular loaded trucks, have a disproportionately large effect on infrastructure deterioration, traffic safety, congestion, air quality and greenhouse gas emissions, noise, and vibration. Many of these impacts are experienced most acutely when trucks enter into urban areas. As well, the extent to which commercial vehicles travel efficiently through the GGH road network has a direct bearing on the region's economy.
- The composition and age distribution of the vehicle fleet in the GGH has a very significant relationship with GHG emissions and air quality. Especially, with the coming to market of alternative fuel technologies and electric vehicles, there is potential for mitigating the impacts of automobile and truck transportation.

Data needs to support policy interventions

Agencies funding data collection should focus on the data most relevant to high impact decisions that are within their jurisdiction/mandates. Over its history, the TTS has been used to support a wide variety of modelling and analysis efforts to provide decision support for the funding agencies. Some of the more prominent of these have included:

- Regional transportation infrastructure and land use analysis, modelling and planning;
- Transportation analysis, modelling and planning at the local level including transportation master plans, corridor/sub-area studies and site impact analysis;
- Environmental assessments;
- Management of traffic and transit operations; and
- Transit service planning.

The influence of these government functions on all transportation sub-markets in the GGH has been profound. Even those transportation sub-markets that are not directly targeted by many of these functions (such as the rail freight industry), are indirectly affected through, for example, increased competition from trucking as a result of roadway infrastructure improvements.

While it is essential that data collected in the Greater Golden Horseshoe continue to support current modelling and analysis efforts listed above, we expect, over the next decade, that vigorous public debate and discussion will surround the following major transportation-related policies and issues:

- Major investment in transit infrastructure (e.g. Transit City, Metrolinx RTP, MoveOntario 2020);
- Policies and strategies towards improvement of air quality and reduction of greenhouse gas emissions;
- Transportation pricing mechanisms (congestion pricing / tolls / carbon taxes);
- Promotion and regulation of new transportation technologies (e.g. ITS, electric vehicles);
- Meeting transportation needs of a retired baby boom generation;

- Movement from a manufacturing-based to a service/knowledge-based economy; and
- Large increases in fuel prices for both personal travel and goods movement.

Arguably, the TTS and other major established data collection programs provide substantial information to support decision-making about transit investment, the first item on the above list. It is for such large-scale infrastructure programs that TTS-style surveys were originally designed.

However, the TTS and other established surveys do not provide enough information to adequately inform decisions on other policies and issues on this list. For example:

- The TTS does not collect information about household income or the cost of travel, both of which are primary determinants of an individual household's response to transportation pricing, fuel price increases, and the purchase of new transportation technology such as hybrid-electric vehicles.
- Transportation air quality and greenhouse gas emissions are heavily influenced by vehicle type and age, neither of which is linked to household or travel information in any of the established data collection systems. Particulate matter and NOx emissions largely originate from truck engines, which are not well observed in the urban areas of the GGH.
- No comprehensive information is collected about urban goods pick-up and delivery or service truck movements, which cause disproportionately high impacts as described above, and which could be influenced by pricing policy, transportation infrastructure and regulation of various sorts. These movements should be expected to alter significantly with continued changes in the regional economy of the GGH away from its traditional manufacturing base to a service/knowledge based economy.
- The transportation needs of an aging baby boom generation can be reasonably assessed through analysis of historical data from the TTS. However, non-work non-school trips by non-motorized modes, which are not collected by the TTS, can be expected to represent a greater proportion of this population segment's travel.

New or expanded data collection efforts should be considered to address important gaps in transportation data for the Greater Golden Horseshoe. Emphasis should be placed on collecting information about missing components of the "universe" of travel in the GGH, that are high in volume, high in impact, that can be influenced by public policy within the jurisdiction of those funding the data collection, and that can be collected cost-effectively and with high quality. The judgement of the authors of this report is to examine further the collection of additional data as shown in Table 1. These additional data are ranked in order of priority of importance by the authors for the purposes listed above. The best measure of the feasibility of new or expanded data collection is to observe the success of other metropolitan areas, or individual regional municipalities within the GGH, that have engaged in different data collection practices. Thus, Table 1 also briefly describes some of the most relevant precedents in Canada and the US where the additional data elements are collected.

Table 1 – Priorities and precedents for new data collection

Priority	**Data Collection Need**	**Discussion of precedents** (this is not a comprehensive review, but rather a selection of the most relevant studies)
1	Goods movement, service provision and other business travel, by automobile and truck, within the GGH.	Urban goods and service movements have been collected through in person interviews with business establishments in the Cities of Calgary and Edmonton (2003), a mail-out survey of business establishments in Peel Region (Roorda et al. 2007) and a mail-out O-D driver survey in Vancouver (2004). Trade-offs exist between the higher quality of data obtained from in-person interviews and the lower cost of mail-out surveys. Of note is that new commercial vehicle data collection efforts are being considered in Durham Region (as part of the Durham Region Long Term Transit Strategy Study), and considered for the City of Hamilton. Coordination is needed to ensure consistency between data collection efforts.
2	Economic elements of personal travel, including income and costs of travel and parking	Household income questions are commonplace in household travel surveys. Income questions are considered to be sensitive by some, resulting in lower response rates to this type of question. Nevertheless, asking the question at the end of the survey and in the form of a categorical question are methods that improve the question response rate and prevent bias to the rest of the survey. The Montreal household travel survey (AMT 2008), and the US National Household Travel Survey (NHTS) (2004), are two examples of major surveys that do include an income question. Costs of travel are imputed, with greater precision in surveys where the type of vehicle is collected.
3	Information about the types and ages of vehicles owned by the household	The US NHTS (2004) asks questions about the make, model and vintage of vehicles owned by the household (in addition to determining which household vehicle was used for each trip), allowing for much more refined analysis of fuel economy, fuel costs, and emissions.
4	Non-motorized personal trips to/from non-work/non-school trip purposes	The Montreal household travel survey and the US NHTS do not restrict the collection of non-motorized trips to work and school destinations. As of 2001, the US NHTS includes a specific reminder to include walk and bike trips for trips that start and end in the same place.
5	Travel of children under the age of 11	The Montreal household travel survey collects travel information for children 5 years old and older. The US NHTS collects travel information (by proxy) for all children, as of 2001. In the TTS, travel of children under 11 years of age is only collected indirectly (and incompletely) through the reporting of "daycare" or "facilitate passenger" trips of parents.
6	Weekend travel, and seasonal variation in travel	Weekend travel surveys have been conducted in Calgary (IBI Group, 2002), as well as other cities in the US (see Hunt et al., 2005). Little information appears to be collected showing seasonal variations in travel, aside from traffic counts and intercity travel survey data from the Travel Survey of Residents of Canada (see below).
7	Tourism and intercity business travel	The Travel Survey of Residents of Canada (Statistics Canada, quarterly) is a quarterly survey that obtains information about intercity travel behaviour of Canadian residents over a one month period, however, geographic details of tourist related trips are not collected. Similarly, the US NHTS (2004) includes a module in which trips over 50 miles are collected. Tourist travel information at a refined level of geographic detail within the GGH appears to be very difficult to collect.

2.4 Coordination of Data Collection

A high quality, comprehensive transportation data collection program requires significant coordination.

First, there is a need to properly process, manage, secure and disseminate data that are collected to maximize its value. The Data Management Group is already recognized world-wide for its ability to successfully fulfill this role for the TTS and the cordon count program. Given this expertise, the DMG should be considered for a broader role in additional data collection to fill existing information gaps.

Second, there is a need to maintain consistency between data sources over time. The fact that the TTS has used the same instrument (with some minor modifications) from 1986 to 2006 has allowed for robust trend analysis and should be considered a major success that warrants continuation. Similarly, the MTO Commercial vehicle survey, the cordon count program and transit ridership surveys have been designed to maintain valuable consistency over time. Any significant changes to the TTS or any of the other major established data collection instruments need to be carefully evaluated. Where change is desired, as described in Table 1 and in Section 3, it must be phased in so that changes in instrument bias can be measured and accounted for, and the ability to conduct robust trend analysis is not lost.

Third, there is a need to develop a mechanism for bringing new data collection methods into practice in such a way that they are consistent and coordinated with existing data collection instruments. For example, consistency in classification systems for common variables, careful avoidance of or accounting for double-counted travel, and careful definition of terms, are essential. Only with careful attention to coordination can a holistic understanding of transportation be constructed, rather than a “patchwork” of incompatible databases.

Fourth, there is a need for a continuous program of research on data collection and integration. While a significant amount of survey methods research is conducted in academic environments, these efforts are not sufficiently well aligned with the objectives, constraints and timelines of the organizations that collect transportation data at the large scale. A more effective program that moves research on data collection techniques into practice could be provided by the DMG.

3. Addressing Challenges Facing the TTS for Personal Travel

While the previous section offers a broad overview of transportation data collection priorities and needs in the GGH, this section focuses on the TTS which is concerned with the collection of data on the personal travel sub-market. The section provides an overview of the main challenges facing future implementations of the survey and recommends strategies to address such challenges. The discussion provided in this section is informed by recent experiences of conducting the TTS over the past decade and the changing environment and context of this data collection effort. Also, the discussion and insights provided in this section are based on an extensive review of the recent travel survey literature. An annotated bibliography of this literature is included in the appendix.

3.1 What are the Challenges?

Like any personal travel survey, the TTS involves selecting a representative sample of the population and subsequently contacting the sample subjects to gather the desired data using an appropriate survey instrument. The challenges facing the future conduct of the TTS, as well as similar travel surveys, are related to sample selection issues, contact and recruitment methods, and survey instruments used for gathering the data. We discuss next in more specific terms those challenges.

Sample selection challenges

Sample selection is typically done by drawing a random sample from a comprehensive "sampling frame" which should ideally include a list of all population units being surveyed. In the case of the TTS, which is a household travel survey, the sampling frame used thus far has been the directory of residential telephone land-lines in the survey area. Although this sampling frame provided in the past an adequate base to draw a representative sample, it is increasingly becoming an incomprehensive list of all households in the survey area, potentially affecting the representativeness of the sample. Several emerging developments have contributed to this problem.

A major contributing factor has been the growing number of households with no land-lines, where members rely solely on their cell-phones. Cellphone-only households are not listed in residential phone registries, and are therefore underrepresented in TTS-type samples. The growing numbers of cellphone-only households and the resulting sampling issues are noted in the literature on survey design of many developed regions, such as the Chicago Regional Household Travel Inventory (Bricka, 2007) and the National Survey of America's Families (Abi-Habib et al., 2003), to name two. Research has shown that the socioeconomic characteristics and trip patterns of individuals in cellphone-only households are different from those with land-lines, which makes this a significant sampling issue due to the potential sample bias that might be introduced if not treated carefully. Keeter and Kennedy (2006), through a comparison of land-line and cellphone-only samples, concluded that cellphone-only Americans tend to be younger, less affluent, and less likely to be married or own their home. Moreover, Russell et al. (2004), in their study of non-response bias in RDD (Random Digital Dialling) samples, found that households with no land-lines are more likely to have less than a high school education, have children in the household, be younger than 35 years old, be males, have no household vehicles, and have a lower than average household size.

Another issue with phone land-line sampling is the growing subscription to phone services through Voice over Internet Protocol (VoIP). VoIP is a technology that allows users to make voice calls using a broadband internet connection instead of a regular (or analog) phone line service. VoIP providers allow users to keep their phone numbers, including the original area code, when moving to a different city or country, since the telephone service is provided through the internet. This causes issues for surveys using a phone land-line directory sampling frame, as households outside the survey area may be sampled and contacted while households with external phone numbers but residing in the survey area may not be captured.

The National Do Not Call (DNC) registry is also considered by some researchers as an emerging issue in telephone sampling. While no significant effect has been observed by the Do Not Call registry in the US, Stopher and Greaves (2007) suggests that the implementation of a similar registry in other countries may raise issues for public service oriented surveys. Research by Link et al. (2006) proposes that while no negative impact on response rates are observed as a result of the DNC registry, the system may in fact improve response rates by subscribing households if they can be identified and included in a travel survey, as it reduces the number of telemarketing calls that such households receive and consequently results in reduction of respondent fatigue. The Canadian DNC service will come in effect on September 30, 2008.

It may be hard at this point to predict accurately the relative penetration and use of the above technologies and services in the GGH over the next decade. Currently, cellphone-only households are probably the largest group of households without listed land-line phones. Since such households are more likely to live in apartments and to consist of young residents, survey samples drawn exclusively from land telephone lists will under-represent these household types and their members, introducing some bias into the socioeconomic and travel characteristics of the sample. This warrants an explicit treatment of sampling cellphone-only households to avoid sample bias. At this point, there are no research results to show whether VoIP only households and potential DNC subscribers have distinct characteristics that might introduce sample bias without explicit treatment.

We expect the challenges associated with the selection of a representative sample from land telephone lists to grow in significance over the years as the above technologies and services take a bigger hold of the market.

Respondent contact and recruitment challenges

Even if we select a representative sample, there remain several issues related to how survey subjects are contacted/recruited and how the data are gathered. The TTS is conducted through a telephone interview with a resident of each household in the sample. In the early versions of the TTS, households were contacted directly by phone without any prior notification. The proliferation of telemarketers and growing penetration of call screening services have posed a major challenge to keep response rates of travel surveys at reasonable levels. As such, the TTS has started since 1996 a practice of sending an

invitation letter by regular mail to each household in the sample prior to the interview in order to explain the objective and significance of the survey and to specify the targeted day for the interview. The invitation letter has proven to be effective in improving the response rate, specifically of households living in single family housing units. Nevertheless, one lingering challenge is to contact the apartments in the sample by regular mail prior to the interview. This is a problem because of the lack of information on apartment numbers in the used sampling frame (i.e. telephone land-line lists), so letters sent to apartments are not forwarded to the intended dwelling units but instead are likely kept in a common area in the apartment building. Some letters may be noticed and picked up by dwellers of the targeted apartments while others are not.

The next stage of the TTS process is to interview a resident of each household in the sample. On the date and time specified in the letter, a TTS interviewer calls the subject household to conduct the interview. If there is no response, TTS staff call repeatedly at later dates until a successful contact is made or a maximum number of attempts has been reached. Although this approach has generally been effective, it has been a challenge to make successful contacts with apartment households, partly because of the invitation letter problem discussed above, and because young highly-mobile apartment dwellers are hard to contact at home.

The above discussion points to the fact that representative survey samples are becoming increasingly harder to select, and sample subjects are proving more challenging to successfully recruit and interview using telephone as the main survey instrument. This is a particularly acute problem for households living in apartments and where mainly young people reside.

Survey instrument challenges

Another limitation of the TTS telephone interview method is its collection of retrospective data of the interviewee's travel on the previous day. In addition, the interviewee is asked to report (by proxy) on the previous-day travel of each other household member. The retrospective and proxy reporting employed by the TTS has long been known to produce inaccurate estimates of travel to destinations other than work and school, namely home-based discretionary trips and non home-based trips. These types of trips, as well as short trips, are known to be under-represented by the TTS due to retrospective and proxy reporting. This travel market has grown over the years in significance (measured by size and impact), and is expected to continue to grow in the future. In 1986, home-based work trips were the single largest sector of personal weekday travel (about 38% of all personal trips), and by 2006 this percentage had declined to 32%. In 2006, home-based discretionary trips became the largest personal travel sector (about 37% of all personal daily trips). This percentage is definitely larger than 37% because of the current under-representation of this travel market in the TTS database. The rise in home-based discretionary and non home-based trips reflects the increasingly complex trip chains and travel activity patterns that people engage in.

Another contributing factor is the emergence of non-traditional work arrangements, some enabled by new technologies and policies (such as telecommuting), which aim at

reducing work travel but tend to increase other activity participation. The impact of non-work, non-school activities and associated travel is fairly significant, since these trips are predominantly made by the car during off-peak times on weekdays and on weekends. When combined with tourist-based travel and commercial vehicle movements, these trips can result in high traffic congestion levels comparable to those of the weekday peak periods. These trends are expected to persist, and as such more attention to this travel market is expected from government agencies over the next decade. Therefore, it is important to measure this travel market more accurately than currently done.

3.2 Strategies to Address Personal Travel Survey Challenges

As mentioned in earlier parts of this report, it is very important to maintain, at the least in the short term, the general sampling approach and instrument of the TTS in order to allow for trend analysis, to minimize changes in instrument bias, and to support legacy modelling systems. Nevertheless, it is crucial to address the identified challenges so as to maintain and enhance the quality of the collected travel data in the future. This should be done through a gradual approach, phasing in new survey methods and technologies.

The challenges identified above are not unique to the TTS, as demonstrated by a detailed review of the recent travel survey literature (an annotated bibliography is included in the appendix). The review also sheds light on recent efforts and strategies in other parts of the world to address the emerging personal travel survey challenges. This review has shown that several jurisdictions around the world are experimenting with dual frame sampling techniques and with various survey instruments to overcome the limitations of traditional telephone interviews. We provide below a summary of those techniques and instruments, and we follow that with a proposed approach for future implementations of the TTS.

Dual-frame sampling

Recently, this sampling technique has been implemented successfully in major jurisdictions (specifically Washington and Chicago) as an effective solution to some of the contemporary issues faced in surveys relying on landline-based samples and contact methods. Paskota (2004) suggests that the best approach to dealing with sample selection problems is to combine more than one sampling frame and target different types of people using various methods. There are generally two approaches to capturing cellphone-only households in dual-frame sampling. The first approach involves matching the names and addresses of all cell-phone users (assuming a comprehensive list is available) in the survey area to those in the telephone land-line directory in the same area so as to identify cellphone-only households. Subsequently, a sample of these households is selected and contacted (*via* cell-phone) to complete the survey using the cell-phone or another survey instrument option (e.g. internet) if made available. This sample augments the main sample of households with land-lines which is selected and surveyed using telephone interview or optionally another method (such as the internet). The challenge with this approach is the requirement of a comprehensive cell-phone list, which may not be possible to compile and obtain because of the potential reluctance of the numerous service providers to disclose the lists of their customers. Additionally, it may not be

feasible to distinguish between residence-based and business-based numbers, which would pose a challenge to household survey samples, such as that of the TTS.

The second approach involves identifying households without listed land-line services, which is achieved through address matching of a sample drawn from an address-based sampling frame (e.g. Census list of all residential households, compiled list of residential properties from municipal taxation and assessment agencies, or list of residential addresses from Canada Post) against the land-line phone list in the same survey area. Through the matching procedure, it is possible to identify households in the sample without listed land-line phones, which include not only households relying exclusively on cell-phones but also those having VoIP phone services, those subscribing to the DNC registry, and combinations of the three types. The sampled households without listed land-line phones would then be contacted through regular mail. This is known as "passive recruitment" because it does not follow the recruitment letter with another contact by phone (as no phone contact information is available at that point) but relies on the sampled household to respond to the letter. In order to improve the response rate, sampled households would be sent numerous reminders and possibly offered an incentive to provide their contact information. In addition, such households could be offered alternative methods to complete the survey (e.g. cell-phone, internet), which helps improve the response rate.

The Washington Council of Governments Household Travel Survey in 2007 is one example of a dual-frame sample survey, using the address-based method, and has been shown to provide considerable savings in costs compared to a single frame sample with a similar level of precision. In this survey, an address-based sample was obtained, and addresses and names were matched with the list of all land-lines. Following the address matching, sampled households were assigned to one of two groups, those with and those without land-lines. Households in both sample groups were contacted initially through mail, while the latter group was offered a $50 incentive for agreeing to participate, asking households to send further contact information (Zmud, 2007). Bricka et al. (2007) provides a description and assessment of the Chicago Regional Household Travel Inventory, which also had a similar dual-frame sample.

New survey instruments

As noted above, new survey instruments have been used in some surveys to supplement traditional telephone interview methods, mostly when dual frame sampling is employed and in some cases as the sole method. Like the telephone survey instrument, new instruments have their advantages and disadvantages, and none is superior in the absolute sense. As such, targeting different sample sub-groups in a single survey with different instruments and offering each sub-group multiple instrument options to complete the survey should have a positive effect on the survey response rate and should minimize sample bias. Below, we introduce new survey instruments and we discuss briefly the advantages and disadvantages of each.

Internet

Lately, there has been a growing interest in web/internet-based surveys for travel data collection. Several researchers have outlined the benefits of such surveys, but also pointed out risks and challenges that need to be carefully addressed. Advantages of using internet-based surveys mentioned in various papers include the following:

- The cost of conducting these surveys (including personnel, communication and data acquisition) is relatively low;
- They enable the incorporation of interactive features, visual aids, animation, automated skip patterns and randomization of questions;
- They have good potential to capture non-respondents to conventional travel surveys (young and busy people);
- They enable automated data entry and checking;
- Interviewer bias is avoided;
- They provide privacy to respondents; and
- They result in quick response times.

Several papers suggest that incorporating internet-based questionnaires to a multi-instrument survey can help attract younger and more affluent respondents, while using them exclusively is advised against (Adler et al., 2002; Alsnih, 2004; Dijst et al, 2006; Dimitris and Kanaroglou, 2008).

Despite the above advantages, internet-based surveys bear some potential risk that need to be addressed and minimized in practical applications. Regarding recruitment, one study found that response rate and speed of response were less for sample subjects contacted with non-electronic means, such as postal mail, compared to e-mail having a URL to the survey forms (Dimitris et al, 2008). Several researchers have noted that although internet-based surveys eliminate interviewer bias, there are doubts about data quality due to misleading/inaccurate/incomplete information by some respondents who may be frustrated with the survey forms, and by some who may view the internet as means of entertainment (Alsnih, 2004; Dillman et al., 2007). Server availability and browser compatibility are examples of issues that need to be addressed to prevent frustration and non-response (Alsnih, 2004; Li and Shalaby, 2008). Completing the survey requires access to a computer and the internet, computer literacy, and familiarity with the software (Alsnih, 2004), thus raising issues of socio-economic and demographic bias if the internet was used as the sole survey instrument.

Assuming the internet is used to complement other instruments in any given survey, comparability of data can affect the quality of results and the potential for trend analysis. Some research suggests that if responses are similar across instruments, lower response rates in internet-based surveys would not be as critical, especially with its low cost (Manfreda et al., 2008; Alsnih, 2004). Consistency checks, reminders, and graphical shortcuts available in internet questionnaires have resulted in more trips being reported than through either telephone interview or mail-back (Adler et al., 2002). Also, differences between visual and audio stimuli as well as the significant effect of design elements on how respondents interpret and answer questions must be taken into consideration (Dillman et al., 2007). Several papers recommend that further research be done into whether data collected using different survey media result in comparable data.

Thus far, internet-based travel surveys have been used on a limited scale and in specialized applications. One example is the Internet Prompted Recall survey where GPS tracking information is presented to the respondent on the internet to confirm interpretation of processed raw data and collect additional information (Stopher et al., 2004, Li and Shalaby, 2008).

Cell-phones

Cell-phones have also attracted recent attention as a medium for travel data collection. The greatest potential of this medium is to capture cellphone-only households and young people who are the main residents of such households. Possible recruitment methods include postal mail, cell-phone calls and SMS (Short Messaging Services).

Cell-phones share many features with land-line phones as a tool for travel data collection. However, there are some differences between the two instruments. Keeter and Kennedy (2006) have conducted a study on the feasibility of conducting a telephone survey in a cell-phone sampling frame. Results of this research suggest that such surveys are feasible, but they are more difficult and expensive to conduct than land-line surveys. As part of a pilot survey, it was found that while it was easier to contact individuals through cell-phones, the rate of cooperation was about 30%, compared to 50% in land-line phone contacts. The following is a list of potential issues with surveying individuals/households using cell-phones:

- Charges associated with the calls and the need for offering incentives. Research by Yuan et al. (2005) for the Joint Program in Survey Methodology (JPSM) at the University of Maryland suggests that higher incentives result in higher response rates.
- Safety of respondents in case they are involved with another activity when contacted, (e.g. driving), although Keeter and Kennedy's study (2006) suggest that cell-phone respondents are not distracted more substantially than land-line users.
- Privacy of conversations, since the person might be in a public location when interviewed.
- Higher percentage of ineligible individuals (e.g. very young cell-phone owners), compared to land-line samples.

Some research has been conducted on improving cell-phone surveys. A study by Brick et al. (2006) on the JPSM 2004 survey found that cellphone-only households are more likely to respond to cell-phone surveys than households that have both types of service. As such, it is suggested that in order to avoid non-response bias, households with both phone types should be identified and contacted through their land-line service only.

GPS-based surveys

GPS (Global Positioning System) technologies have recently seen growing levels of interest in their application to travel and activity data collection. Over the past decade, GPS-enabled devices have enjoyed a continuing trend of improved accuracy, lighter weight, and cheaper price, which have given rise to a proliferation of applications in

various fields. Over the same period of time, a number of real-world applications of GPS to travel data collection have taken place around the world, accompanied by a surge of research and pilot studies to further develop and enhance enabling tools. GPS-based surveys have several attractive advantages and its key limitations have been addressed by various research and technology developments. This type of survey has achieved a reasonable level of maturity, resulting in real-world applications at a relatively wide scale.

Based on several recent studies (Chung and Shalaby, 2005; Tsui and Shalaby, 2006; Li and Shalaby, 2008; Stopher and Greaves, 2007; and Stopher, 2008), we provide below the main advantages of GPS-based travel/activity surveys.

- They provide *accurate information* on activity locations, start and end times of trips, travel route paths, and the breakdown of transit trip components (access walk time/distance, waiting time, in-vehicle time, transfer time and egress walk time/distance).
- They collect *complete information* of all trips, addressing the problem of underreporting of trips (specifically short and discretionary trips) typical of conventional methods.
- They enable *ease of response*, because of the reduced respondent burden involved in data collection compared to the conventional travel diary.
- They are appropriate for *data collection over extended time periods*.

GPS-based travel surveys are typically conducted using a combined GPS receiver and data logger held by the survey participant for a specified period of time (e.g. a day). Upon retrieval of the unit, raw data are downloaded and automatically processed using a system of post-processing algorithms that filters the data and decomposes the GPS data trail into activities and trips, with each trip further decomposed into its components (e.g. access walk, waiting, in-vehicle, etc.). Following data processing, a *prompted recall* interview with the participant is typically conducted in order to confirm trip and activity details and collect further information. Lately, there has been a significant amount of algorithm and system development for data processing and prompted recall surveys (see Chung and Shalaby, 2005; Tsui and Shalaby, 2006; Li and Shalaby, 2008; Stopher and Greaves, 2007). Also, some technical issues that challenged GPS-based travel surveys have largely been addressed of late. For example, commercial GPS sensors are now so sensitive that problems of signal detection and loss are no longer a major issue at locations of tall buildings or inside surface vehicles (there are even ongoing technological advancements of in-door GPS). Another challenge has been limited battery life. For extended periods of data collection, say a few days, asking the survey participant to re-charge the GPS unit was viewed as a burden. However, many new GPS units used for surveys have built-in accelerometers that detect motion of the unit and shuts down power following an interval (set by the user) of standstill. Similarly, it “wakes up” once the unit starts moving again. This development has enabled collection of data for a few days on a single charge.

The remaining challenges and limitations of GPS-based surveys include the respondent burden of conducting the prompted recall interview, privacy (collection of sensitive and private activities and travel), logistics for delivery and pick up of GPS units, timing of

prompted recall interview (has to be shortly after data collection so that the respondent could recall the trip and activity details), and the survey cost.

GPS-based surveys have been implemented in several jurisdictions around the world, namely Halifax in 2006-2007 with a sample of 2000 households (GPS as the sole instrument) and France in 2007-2008 where GPS has been used to supplement the main survey of 20,000 households.

Proposed Approach for the 2011 TTS

Based on the analysis of issues and challenges facing the TTS and also on a review of the strategies and techniques used in other jurisdictions around the world, we propose for the next TTS to employ a modified approach for sampling and data collection, and we also propose to augment the TTS with a supplementary smaller survey. Specifically, we propose for the main survey to use a dual-frame sampling technique for sample selection and to use multiple survey instruments for data collection. The dual-frame sampling approach would involve drawing a household sample from a comprehensive address-based list, which could be obtained from Statistics Canada, MPAC (Municipal Property Assessment Corporation) or Canada Post. The records in this comprehensive sample would be matched against a land-line phone list of households in the same survey area so as to identify records in the sample without listed land-line numbers. Recruitment of the sub-sample with listed land-line numbers should be made by mail and followed by phone contact, similar to the strategy used in recent TTS editions. The other sub-sample, including households without listed land-line phones, should be recruited by mail. If a third frame of residential cell-phone numbers could be compiled (possibly through the support and help of CRTC), cellphone-only households as well as households with both cell-phones and unlisted home phones (e.g. DNC subscribers or VOIP with external area codes) could be identified and recruited by cell-phones or SMS in addition to regular mail. The sub-sample of households with listed land-lines should be given the option to undertake the survey either by land-line phone interview or using the internet version of the survey, while the sub-sample of unlisted land-line numbers should be given the options of a phone interview (by cell-phone or land-line phone) and the internet.

In addition to the main survey, we propose to augment the TTS with a GPS-based travel survey of a subset of the sample (approximately 1000 households). The purpose of this survey is multi-fold, namely to estimate the magnitude of under-reporting of discretionary trips in the TTS as well as other instrument bias, to help develop next-generation travel forecasting models, and to build a knowledge base and expertise in GPS-assisted travel surveys for wide-scale applications in the future.

4. Recommendations

Responsible transportation planning decisions cannot be made without a comprehensive, coordinated, well-executed and properly managed transportation data collection program. The Transportation Tomorrow Survey (TTS), as managed by the Data Management Group (DMG), has successfully fulfilled this role for over 20 years for household personal travel, in parallel with other established data collection programs, including traffic count programs, transit surveys, and the MTO Commercial Vehicle Survey.

At the outset of this report, two questions were framed regarding challenges for data collection in the Greater Golden Horseshoe (GGH). Our recommendations are structured to respond to these questions.

Will the TTS, in combination with other data sources, provide sufficient information to answer key transportation questions that will arise over the next 10 years?

In short, the authors strongly believe that strategic expansion and modification of the current data collection program is needed to answer these questions. We recommend the following:

Recommendation 1) Continue and improve the major established data collection systems including the TTS, the cordon count programs, the MTO commercial vehicle survey and transit surveys. Discontinuation of any of these data programs would be a major setback for transportation planning in the GGH.

Recommendation 2) Undertake new or expanded data collection efforts to address important gaps in transportation data for the Greater Golden Horseshoe. Emphasis should be placed on collecting information about missing components of the "universe" of travel in the GGH, that are high in volume, high in impact, that can be influenced by public policy within the jurisdiction of those funding the data collection, and that can be collected cost-effectively and with high quality. The following additional data should be collected either by adding questions to existing surveys, or developing new surveys. This list is ranked in order of priority:

1. Goods movement, service provision and other business travel, by automobile and truck, within the GGH.
2. Economic elements of personal travel, including income and costs of travel and parking.
3. Information about the types and ages of vehicles owned by the household.
4. Non-motorized personal trips to/from non-work and non-school trip purposes.
5. Travel of children under the age of 11.
6. Weekend travel and seasonal variation in travel.
7. Tourist and intercity business travel.

Recommendation 3) Develop an on-going research program that is dedicated to the identification and testing of practical data collection instruments that focus on unmet travel data needs of the GGH. This research program should focus on technology/

knowledge transfer, as opposed to cutting edge innovation, and should bridge the experience of the organizations responsible for the major established surveys within the GGH, with expertise from other metropolitan areas and academic researchers in survey methodology. It should promote coordination between surveys in order to prevent double counting, coordinate classification systems, and ensure that changes in survey methodology over time are tracked and can be accounted for. The DMG is the organization best suited to provide this function.

How should the TTS be effectively and responsibly conducted in the future, recognizing significant technological and societal changes that are occurring?

The TTS, as currently operated, is faced with growing challenges in sample selection, respondent contact/recruitment and survey instrument non-reporting, primarily because of changes in technology and changing attitudes toward telephone surveys. These exact same issues are being experienced in many other jurisdictions world-wide, and are resulting in changes to the state-of-practice in travel survey methodology. It is imperative that the personal travel survey in the GGH prepare for these changes in 2011 by experimenting with the new methods. Based on a detailed review of the most promising solutions that others have found world-wide, we recommend that the 2011 TTS be conducted with the following modifications:

Recommendation 4) Develop and implement an internet version of the 2011 TTS. Respondents should be given the option of responding to the TTS either by computer aided telephone interview or through the internet version of the survey. Extensive testing should be undertaken to fully understand and account for the differences in instrument bias between these two retrieval methods.

Recommendation 5) Enhance the 2011 TTS by using a dual-frame sampling approach, as follows:

- A list of all residential households in the survey area should be obtained from Statistics Canada, MPAC, or Canada Post.
- A land-line telephone list should also be obtained and compared with this list.
- Those residences with listed land-line numbers should be contacted/recruited as in previous TTS implementations (mail-out followed by telephone calls). Those residences without listed land-line numbers should be contacted/recruited by mail.
- If a list of residential cell-phone numbers can be obtained (possibly through the support and help of CRTC), it should be compared with the land-line telephone list to identify cellphone-only households as well as households with both cell-phones and unlisted home phones (e.g. DNC subscribers or VoIP with external area codes). These households should then be contacted/recruited by cell-phone and/or SMS in addition to regular mail.
- The sub-sample of households with listed land-lines should be given the option to undertake the survey either by land-line phone interview or using the internet version of the survey, while the sub-sample of unlisted land-line numbers should be given the options of a phone interview (by cell-phone or land-line phone) and the internet.

Recommendation 6) Conduct a supplementary GPS-assisted survey in parallel with the main 2011 TTS. The survey results should be used to estimate the magnitude of the under-reporting of non-work/school trips and other instrument biases in the main survey. The survey results should also be used to validate/enhance route choice and traffic assignment models and to support the development of the next generation of travel demand forecasting techniques. Experience attained with this technique will be invaluable if GPS-assisted surveys become the new state-of-practice beyond 2011 (as they already are in France and Halifax and several jurisdictions in the United States). We recommend a reasonably-sized sample of approximately 1000 households in 2011.

Recommendation 7) Ensure that our capability for long term transportation trend analysis is not lost, regardless of what changes are made to the TTS. This means that a major portion of the 2011 TTS should be continued with no more than minor changes (e.g. addition of a small number of new questions as outlined in Recommendation 2), and tests must be undertaken for changes in instrument bias with the new methods.

Most of these recommendations involve investment of limited funds, time and energy. The authors of this report strongly feel that such investment is warranted given the importance of data for transportation planning decision-making and ultimately for the long-term prosperity, liveability, and sustainability of the GGH.

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