PANELS AND OTHER SURVEY EXTENSIONS TO THE TRANSPORTATION TOMORROW SURVEY

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1. INTRODUCTION

The Transportation Tomorrow Survey (TTS) program is a highly successful travel behaviour data collection program undertaken in the Greater Toronto Area (GTA) since 1986. As is described in greater detail in Section 2, three large-scale surveys have been undertaken under this program to date, in 1986, 1991 and 1996. The next survey in this series is scheduled for the year 2001. While there is universal agreement among the TTS sponsors concerning the usefulness of the current TTS format, there is also recognition that, like any survey instrument, the current TTS format contains some weaknesses and is not well suited to address all planning and modelling needs of potential interest to planners within the GTA. **The purpose of this report is to discuss the strengths and weaknesses of alternative survey methods and to investigate the extent that one or more of these methods might be used to <u>supplement</u> the current TTS format in the 2001 data collection exercise.** That is, the issue is not one of replacing the current format. Rather, it is whether some of the resources normally allocated to the TTS exercise (or, perhaps, additional funds over and above the amount required by the usual TTS exercise) should be used to undertake some form of parallel, supplementary data collection effort.

In particular, the question has been raised as to whether a **panel survey**, in which the same sample of households is repeatedly interviewed at several points over an extended period of time, might prove to be an effective means of gathering information of practical use to GTA planners and modellers which cannot be obtained through the conventional **repeated cross-sectional** TTS format (in which different, randomly selected households are interviewed at each point of time). **The primary purpose of this report is to investigate the question of developing and implementing a panel survey within the TTS data collection program.**

At the same time, however, a number of other travel behaviour survey methods exist which might be of potential interest to GTA planners. These include:

- **multi-day** (as opposed to the current single day) cross-sectional surveys;
- **activity-based** (as opposed to the current trip-based) surveys;
- use of **alternative data collection methods** (e.g., computer-based methods as opposed to the current telephone-based method); and
- **stated preference** surveys in which respondents are placed in hypothetical choice situations (as opposed to the current "revealed preference" method of observing actual choices made).

Indeed, both the current TTS procedure and panel surveys represent individual "points" within a broad "continuum" of potential survey methods (loosely illustrated in Figure 1.1) defined over such "dimensions" as: number of days over which information is collected; the number of times a given respondent is interviewed; the nature of the information collected; and the means by which this information is obtained from the respondents. No one "optimal" point exists within this continuum. Selection of a given survey design obviously depends upon a host of criteria such as: the type of information required; the intended application(s) of the information; budget; the technical capabilities of both the agency conducting the survey and the survey respondents; etc.

The key point to note concerning Figure 1.1, however, is that travel survey methods have developed considerably over the past 10-15 years along all of the dimensions shown, particularly relative to what was the operational state of practice/art in the mid-1980's when the current TTS procedure was first being designed. At the same time, both planning needs and modelling capabilities have (and will continue) to evolve. In starting to plan for the 2001 TTS, therefore, the time seems opportune to take a reasonably broad look at our travel survey options and needs. Thus, while maintaining a focus on the issue of panel surveys, this report does so within the context of a more comprehensive discussion of survey methods and design issues.

In undertaking this review, several assumptions are made at the outset. These include the following:

1. Again, the intent is not to replace the current TTS procedure outright, but rather to augment/extend/complement this procedure, if opportunity and need exists.

2. There is no intent to "tinker" with the current TTS format. Thus, for example, the report does not investigate replacing the current telephone interview with some form of mail-back procedure, modifications to the current telephone procedure, etc. There is no desire to fix what isn't broken.

3. Any new survey procedure which is implemented must address practical planning needs within the GTA which are not addressable within the current TTS format. These include:

    (a) Providing improved "base information" about travel behaviour in the GTA which provides improved insights to GTA planners about this behaviour, improved ability to "diagnose" current and emerging planning issues, etc.

    (b) Providing enhanced databases for the development of improved modelling methods for forecasting travel demand in the GTA and for analyzing the likely impacts of alternative transportation-related policies.

4. Any new survey procedure must be cost-effective in the sense that the diversion of resources from the current TTS procedure (or the allocation of new resources) must be seen to provide a more effective "return on investment" than that obtained from other uses of these resources.

5. This report deals only with **revealed preference** surveys, in which actual behaviour is observed. In general, stated preference methods are best suited to addressing specific policy questions or modelling issues which cannot be directly dealt with using revealed preference

data.[1] Thus, while certainly not ruling out such methods for specific applications within the GTA, they would seem to fall outside the mandate of this current study, and so are not dealt with further within this report.[2]

The remainder of this report is organized as follows. Section 2 provides a brief overview of the current TTS procedure and its historical evolution, as well as a summary critique of its strengths and weaknesses. Section 3 follows with a brief discussion of transportation planning issues and processes within the GTA in order to provide a context for understanding travel data collection needs and opportunities within the GTA. Section 4 then discusses panel survey methods and issues in some detail, with emphasis on the possible application of such methods within the GTA context. Section 5 discusses other, related survey methods and issues, in particular, multi-day surveys, activity-based surveys, and computer-based survey methods. Section 6 then evaluates the range of travel survey options available relative to GTA needs and current capabilities, leading to a recommended survey program for the year 2001 and beyond.

2. THE TRANSPORTATION TOMORROW SURVEY (TTS) PROGRAM

TTS is a series of household travel surveys undertaken within the Greater Toronto Area (GTA), which consists of the regional municipalities of Toronto[3], Durham, York, Peel, Halton and Hamilton-Wentworth[4] (see Figure 2.1). Table 2.1 summarizes the aggregate statistics for the three surveys which have been undertaken to date, in the fall of 1986, 1991 and 1996. The years were chosen to correspond with Canadian Census years so that Census data could be used to maximum effect in validating survey results. The fall season (starting immediately after Labour Day and ending by early December) was chosen as being a "representative" time period for travel in the GTA. It also represents a reasonably homogenous period of time with respect to weather, and it contains only one

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1 A common example is the case of high-speed intercity rail service, for which no revealed preference data can be obtained since such services do not presently exist within Canada.

2 For a good introduction to stated preference methods, see Polak and Jones [1995].

3 Prior to January 1, 1998, this was the Municipality of Metropolitan Toronto, consisting of the five Cities of Toronto, North York, Scarborough, Etobicoke and York and the Borough of East York. As of January 1, 1998, Metro Toronto ceased to exist as a political entity, as did the six local municipalities, replaced by the amalgamated City of Toronto. The new City of Toronto and the old Metro Toronto have the same boundaries and for present purposes can be generically referred to as "Toronto".

4 Although having its own, identifiable commuter shed, Hamilton is included in the definition of the GTA for most transportation data collection and modelling purposes due to the considerable overlap between the Toronto and Hamilton travel markets, particularly within Halton Region.

holiday (Thanksgiving, the second Monday in October). All three surveys employed essentially the same design, consisting of:[5]

- random selection of households from the list of Tele-Direct (Bell Canada) household telephone numbers;

- use of an advance letter to notify each household that it had been selected for the survey and that it would be contacted shortly;

- a telephone interview of a single adult member of the household, from whom travel information for the preceding day for all adult members and older children in the household was collected;

- storage in a common relational database management system; and

- geocoding of all residences, workplaces, trip origins and destinations.

As indicated in Table 2.1, the survey method has evolved somewhat over time, with computerized "Direct Data Entry" (DDE) being first introduced in 1991, relatively minor new questions being introduced in both 1991 and 1996, and reductions in the information being gathered concerning travel by younger children being introduced in 1991. In addition, the 1991 survey collected a much smaller sample (1.4% overall) than the other two (4.1% and 5%, respectively).

Emphasis is placed within the TTS on gathering detailed trip information, especially concerning transit trips, while limited socio-economic information is gathered. In particular, income information is not collected, and a very aggregate occupation indicator was first collected in 1996. Detailed documentation of the survey methods and databases can be found in Data Management Group [1987, 1988, 1992, 1994, 1997a, 1997c, 1997d].

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[5] In addition, the 1986 TTS had as an associated follow-up activity a small sub-sample one-day mail-back travel diary survey (generally referred to as the TDS) in February, 1987 [Data Management Group, 1990a, 1990b]. The objective of this mail-back travel diary was to assist in the validation of the full-sample 1986 TTS and to provide more detailed socio-economic and travel data for special-purpose analyses (for example, income and occupation questions were included in the TDS). A relatively low response rate (45%) reduced the perceived utility of the survey somewhat (despite an analysis which indicate that little response bias appeared to exist in the dataset [Data Management Group, 1990a]), and relatively little use has been made of this dataset outside of academic studies.

The TTS design clearly emphasizes large sample size over detailed information per observation. The design deliberately attempts to minimize the cost per response so as to be able to obtain very large samples at an acceptable total cost. Advantages of obtaining such large samples include:

1. The ability to construct base year origin-destination (O-D) flow matrices at a reasonably fine spatial scale (i.e., traffic zones), by trip purpose, by time of day, by mode with a high degree of statistical reliability.

2. The ability to cross-tabulate (or conduct other multi-variate analyses of) the observed trip data with respect to a relatively high number of dimensions while maintaining statistical reliability.

3. The ability to have statistically reliable estimates of travel by the full range of available modes, including relatively "minor" modes such as commuter rail and park & ride access to subway.

4. A sufficiently large and detailed database of transit O-D trips, including route choice information, to directly support short-range transit service planning by the Toronto Transit Commission (TTC) and other transit agencies within the GTA.

TTS data have been found in tests against Census data to reproduce the base population distribution well. TTS travel data have also generally been found to capture morning peak-period travel conditions well, where the morning peak-period has traditionally been the focus of GTA planning analysis and modelling.

The efficient collection of large samples, however, does not come without its own set of "costs" or difficulties. These include the following.

1. The lack of detailed socio-economic data is a problem, given the importance of socio-economic factors in the determination of travel demand. Income is probably the single most important variable omitted from the survey, but more detailed information about household structure might also be useful in explaining household-level interactions with respect to travel decision-making.

2. Much of the simplicity and economy of the survey method derives from the use of a single respondent to report trip-making activity for all household members. While this has been found to generate reliable information for the respondent and for peak-period travel by non-respondents (especially for "major" trips such as to work and school), it is clear that a significant bias exists in the under-reporting of non-peak period and non-work travel by non-respondents [Data Management Group, 1991]. While attempts have been made to adjust for this "non-respondent bias", use of TTS data to analyze or model off-peak and/or non-work/school (NWS) travel is clearly problematic.

3. Non-vehicular (walk, bicycle) trips are only recorded for work and school trips. This obviously results in an under-reporting of total trip rates and makes a "full" analysis of non-work/school modal choice impossible. This is particularly problematic since it introduces a spatial bias into NWS trip rates computed from TTS data: central area zones (where high densities and corresponding shorter trip lengths encourage walk/bicycle trips) have significantly lower (vehicular) NWS trip rates than lower density suburban zones (which generate far fewer walk/bicycle trips). Thus, conclusions concerning the relative NWS trip generating propensities of different locations/land use designs cannot be drawn given the incomplete trip data collected.

4. HOV/ridesharing behaviour cannot be adequately addressed using TTS data, since auto occupancies cannot be unambiguously determined from the available data. Auto occupancies are not explicitly recorded. Trip records indicate if an auto driver makes a "facilitate passenger" stop, but not whether this is a drop-off or a pick-up. Household auto drive trip records can be matched with household auto passenger trip records in order to deduce within-household "ridesharing", but this is a labourious and error-prone process, and does not solve the problem of determining the amount and detailed nature of inter-household "carpooling" which occurs.

5. No observations of weekend (Saturday/Sunday) travel are obtained. This issue is discussed further in Chapter 4.

If the "normal" cycle of surveys were to continue, the next TTS would occur in the fall of 2001, consisting of a "small update" sample of approximately 1%, followed by a "full" 5% sample in the year 2006. **In this report it is assumed that the "full" 2006 survey will proceed as planned.** The availability of a "solid benchmark" every 10 years which provides a detailed cross-sectional view of travel behaviour in the GTA has, I believe, been well established by the use to which the 1986 and 1996 TTS has been put. Each additional data point added to this time series adds considerably to the utility of the entire database, and **it is strongly recommended that the full 2006 TTS be undertaken -- thereby providing the GTA with consistent travel behaviour information over a full 20 year period.**[6]

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[6] A "fourth data point" exists in the form of the 1964 MTARTS survey which has been "kept alive" at the University of Toronto and currently resides in the same database manager as the TTS data. Although differing in survey method and content to a degree, the 1964 MTARTS data have been found to be useful in combination with TTS in looking at long term trends [Badoe and Miller, 1995; Elmi, *et al.*, 1999]. It is recommended that fuller use be made of this dataset, thereby providing by the year 2006 a **forty-year** time series of travel behaviour in the GTA. Presumably much can be learned from the analysis of this time-series which would not only better educate us about our past but also better inform us of where we might be heading in the future.

The rationale for a "small sample" 2001 survey is less clear, and presumably a major motivating factor for this study involves the question of what might best be done in 2001. Although the 1991 survey provided valuable "update" information relative to 1986, it is not clear that simply repeating a 1991-style small sample survey is now the most cost-effective use of our resources. The primary value of the 1991 TTS probably was in terms of providing updated, fairly aggregate information on overall trends in modal splits, trip rates, etc. It clearly was not a large enough sample to provide reliable updated detailed O-D matrices, nor could it support detailed cross-tabulations -- two of the major strengths of the 1986 and 1996 "full sample" surveys. At the same time, the survey was probably larger in size than would have been necessary to provide the aggregate trend update briefly described above.

Several options exist with respect to 2001. One is to conduct a full 5% sample standard TTS. This proposal certainly has considerable merit, and is taken as the default alternative against which other options are compared in Section 6. The argument made above concerning the usefulness to GTA planning of having a time-series of repeated cross-sections is only enhanced if the "snapshots" of GTA travel behaviour provided by TTS are available on a five-year rather than ten-year basis.

Alternatives to this option, however, also exist. In particular, the focus of the discussion in Section 6 is on variations on this option involving some form of panel survey. As basis for developing these panel-based options, a range of travel behaviour survey issues and options are first presented and discussed in Sections 4-7.

3. PLANNING ISSUES WITHIN THE GTA

A detailed discussion of transportation planning issues in the GTA is well beyond the scope of this study. At the same time, however, it is impossible to discuss travel behaviour data requirements in the absence of the planning context which generates these requirements. What follows is a very abbreviated view of the planning context driving travel behaviour data collection needs within the GTA.

First and foremost, one must acknowledge the obvious fact that the GTA is a major, complex, dynamic urban region.[7] It is the 9th largest urbanized area in North America and, as of 1996, accounted for 42% of Ontario's population and 50% of it's GDP -- which, in turn, translates into 20% of Canada's GDP [Golden Commission, 1996]. Despite being hit hard by the extended recession of the 1990's, the GTA has experienced, and will continue to experience, significant, sustained, long-term growth, with a projected 2021 population level of 7.2 million, up 2.3 million (47%) from the 1996 level of 4.9 million [IBI Group, 1997; Data Management Group, 1997b]. Up-to-date information on population, labour force and employment spatial distributions and socio-economic

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[7] The following statistics **exclude** Hamilton-Wentworth. Inclusion of Hamilton-Wentworth would obviously further increase the magnitudes involved.

attributes, **and** information on the travel behaviour of this population and labour force, are essential to planning for GTA travel needs. Census data provide information on population and labour force characteristics, but do not provide the comprehensive travel behaviour data needed for transportation planning. Hence, put very simply, the need for local travel demand surveys.

Second, the dynamic nature of urban regions such as the GTA cannot be overemphasized. Not only does the urban area grow with respect to population, economic activity and geographic size over time, but demographic, social, political, economic and behavioural changes occur which all impact on travel needs and behaviour in a variety of ways. The resident baby boom generation is aging, while at the same time the GTA receives a steady stream of new immigrants, by and large falling into younger age categories, as well as possessing varying socio-economic attributes. The nature of work and the workplace is changing under the influence of information technologies and other macro structural changes in the economy. Our tastes and preferences for cars, transit and travel in general change over time in response to a host of factors including experience with the existing system, demographic and economic changes, advertising, etc. If we are to plan for the future, we must both understand historical trends and attempt to project their implications for the future. This implies the need for **time-series** data which allow us to observe the system and the behaviour of people within this system over time.

Third, a large number of issues exist which urban transportation policy must address. Expressed at a fairly "high" or abstract level, these include:

1. **Economic sustainability.** The urban transportation system is a fundamental element within our economy, both as an important economic sector in its own right and as an absolutely essential "enabler" of economic activity -- the transportation system is quite literally the "medium" through which all of our goods and much of our services must flow.

2. **Environmental sustainability.** Transportation systems are major polluters of the atmosphere and major generators of greenhouse gases. The long-run environmental sustainability of our urban areas depends in no small way on how we control the undesirable outputs of our transportation systems.

3. **Social sustainability.** The transportation system links people and communities together. It also takes land from other uses, erects physical barriers, generates local noise and air pollution, accidentally kills and maims, etc. Balancing provision of accessibility with minimization of local area adverse impacts and with maximization of safe operations is an on-going problem, especially in dense urban areas.

4. **Equity.** The distribution of transportation benefits and costs is always an issue of considerable political and social interest. Transportation impacts are inevitably differentially distributed over both space and socio-economic. Planning analyses, forecasts, etc. need to be able to identify these impact distributions if the full ramifications of alternative policy

options are to be properly assessed.

5. **Efficiency.** The efficiency with respect to which transportation services are provided to the travelling public is obviously of considerable concern within the planning process, both to ensure that public and private money, time, etc. are not being needlessly expended, and to maximize the "bang per buck" received from the investment of increasingly scarce resources in the transportation system.

6. **Effectiveness.** The performance of the transportation system (levels of service, capacities, level and extent of accessibility provided, etc.) are clearly a central concern to the planning process. Indeed, the planning process is fundamentally about "the three E's": providing an effective, efficient and equitable transportation system.

The link between these high level issues and data needs is not direct. Ultimately it comes down to having the data needed to build the analytical capability (through formal models or otherwise) to say useful things about the likely impacts of various policy options with respect to these issues. Again expressed at a very high level, policy options generally can be categorized as follows:

- **pricing** (taxes, fares, tolls, etc.);
- **regulation** (speed limits, mandatory vehicle inspections, etc.);
- **provision of infrastructure** (roads, transit, etc.);
- **provision/management of services** (transit operations, freeway traffic management systems, etc.); and
- **marketing/information dissemination** (advertising, traveller information systems, etc.).

In operational terms these policy options manifest themselves in terms of specific projects or programs. Examples of typical current interest within the GTA include:

- road pricing (typically currently toll roads rather than congestion pricing);
- provision of HOV lanes;
- transit service and fare policies; and
- investment in transportation infrastructure (both roads and transit).

With respect to travel demand survey needs, the key question is: are we collecting the "right" information to allow us to say useful things about the likely impacts of such projects, programs and policies? Such information might be used in any or all of the following ways:

- describe the current base case and historical trends;
- provide insights into the mechanisms/processes affecting the historical trend;
- project a future trend/assess a policy impact based on the observed historical data, professional judgement, simple analyses, etc.; and/or

- develop formal models based on the observed historical data which can then be used to project future trends/assess policy impacts.

With respect to current TTS data, it has already been observed, for example, that considerable information is available concerning transit usage to support a wide variety of transit service operations and policy analysis, but insufficient information is available to say much if anything about HOV usage or HOV policy-related impacts. Similarly, the 1996 TTS unfortunately predates the opening of Highway 407 and so does not provide us with any insights into toll road usage. Continuing with the example, a 2001 TTS will be able to provide information on Highway 407 usage, if the current survey design is extended to ask a question concerning toll road or non-toll road usage for auto-driver trips.

In summary, the need exists for time-series information on people, activities and travel within the GTA which supports policy-sensitive planning analyses and projections. As has been discussed in Section 2, TTS provides time-series data with respect to some of this information in the form of repeated cross-sections. The following sections discuss a range of survey methods, which represent extensions to current TTS practice in various ways, within the context of this fundamental need for policy-relevant, time-series information on GTA travel behaviour.

4. PANEL SURVEYS[8]

The basic concept of a panel survey is straightforward. Once a respondent (e.g., a household) has been recruited, this respondent is then interviewed two or more times over a period of time, typically using essentially the same survey instrument and set of questions each time.[9] As a very simple

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[8] Paaswell [1997] provides a more detailed discussion of the role of panel data in transportation planning than is possible here. Similarly, Raimond and Hensher [1997] review the empirical experience with a wide range of panel surveys (transportation related and otherwise), discussing in some detail many of the technical issues associated with panel survey design. Both of these papers are drawn from Golob, *et al.* (eds) [1997] which provides an excellent summary of the state of the art in transportation panel survey methods. Kitamura [1990] and Cambridge Systematics [1996c] also provide good overview discussions of panel survey methods. For more general discussions of transportation survey methods, see, among others Cambridge Systematics [1996c], Richardson, *et al*. [1995], and Transportation Research Board [1995]

[9] Although questions can and do sometimes change over time. In particular, follow-up questions may be added in later waves, or special-purpose questions addressing specific issues (e.g., a stated-preference segment addressing a particular policy issue of interest) may be added in one or more of the waves. The key point is that one generally wants the "core information" being collected in each wave to be comparable so that the evolution over time of the respondent's attributes and behaviour can be consistently and comprehensively tracked.

example, one could take a sub-sample of the full 2001 TTS sample and re-interview the households in this sub-sample at selected points in time, say every two years over a ten-year period, using exactly the same TTS instrument each time. Each time panel members are interviewed is referred to as a **wave** in the panel survey. Thus, the example just given would consist of 6 waves (the original interview in 2001 and 5 follow-up waves every 2 years thereafter through to 2011).

The fundamental advantage of panel surveys is that they provide information about the same respondents over a period of time. With this information, the **dynamics** of travel behaviour can be explicitly traced in a way which is simply impossible with repeated cross-section surveys. That is, with panel survey data we observe **changes** over time in household travel behaviour in response to the **specific changes** which have occurred in their attributes (household size, employment status and location, auto ownership level, residential location, etc.) and in the urban system within which they are making their travel decisions (changes in congestion levels, opening of new facilities or services, fare changes, etc.). Such detailed, dynamic information must, as a matter of principle, provide planners and modellers with greater insight into travel behaviour relative to that which can be obtained from cross-sectional surveys. To illustrate this point, consider the following three examples drawn from local experience.

1. In 1986 a small panel survey was conducted by the University of Toronto on behalf of the TTC to examine the impacts of a service headway change on a bus route's ridership [Miller, 1987; Miller & Crowley, 1989]. The panel survey was able not only to identify the loss in route ridership which occurred due to the headway increase (something which could have been determined by conventional before and after on-board surveys), but also what happened to the lost riders (some walked further to another route and so were not lost to the system, some switched to the auto mode, some stopped making trips). In addition, the distribution of the impacts across different types of people was identified (workers walked to the subway for work trips, used the car for evening non-work travel where previously they used the local bus for both types of trips; the elderly simply made fewer trips). This sort of detailed information concerning behavioural changes and impact distributions could only be obtained by following the same group of users over time through the use of a panel survey.

2. Changes in work trip generation rates between 1986 and 1996 have been examined using the 1986 and 1996 TTS datasets [Miller, *et al*., 1998]. While some insight into the factors affecting trip rates can be obtained from analysis of the two cross-sectional TTS datasets, very little can be said concerning the **dynamics** of trip generation that might help us project changes in rates into the future. The result is that future year trip rates must be estimated based on a combination of professional judgement and extrapolation of current values and trends. Observing a panel of trip-makers over time would provide a far greater opportunity to observe **why** trip rates change over time and hence eventually develop improved capabilities (e.g., models) for projecting future year trip rates.

3. Similarly, the "temporal transferability" (i.e., how well a model calibrated in one year predicts travel behaviour in another year) of both work trip mode choice and trip distribution models has been investigated using a combination of 1964 MTARTS and 1986 and 1996 TTS data [Badoe and Miller, 1995; Elmi, *et al.*, 1999]. For both mode choice and trip distribution models it was found that, while models calibrated in 1964 did, in fact, produce generally credible forecasts of 1986 and 1996 travel behaviour, model parameters for a given model specification have definitely changed over time. That is, the utility function parameters in a logit model choice model calibrated to 1964 data are different from the parameters obtained for the same model calibrated using 1986 data. As with the trip generation rates previously discussed, with the available cross-sectional datasets we can identify that such a change has occurred, but we have no basis for determining **why** the change occurred, nor can we reliably estimate how these parameter values might change in the future (and, hence, how our estimates of work trip mode choice might change). Panel data, by tracing changes in individual mode choices over time in conjunction with changes in the "choice contexts" within which these changes occur, provide a far better opportunity for developing truly transferable models.

Models based on cross-sectional data inevitably must assume that the urban area is in "equilibrium" -- a very strong assumption given that we know that urban areas are, in fact, undergoing constant change and evolution (people move in and out of the area, and move from place to place within in it; land uses change over time; workers are hired and fired while firms expand, contract, and move about; etc.). Cross-sectional models inevitably models of **structure**, attempting to explain an existing spatial distribution of work trip flows or to explain an existing distribution of modal choices across types of people and their spatial locations. In such situations there is little guarantee that a model will predict future behaviour well, even if this model is found to fit the observed base case well.

Models built with panel data, on the other hand, need not assume system equilibrium. They can be explicitly dynamic (i.e., explicitly account for the passage of time and for the fact that behaviour may well change over time). They can be models of **process**, attempting to explain why and how the spatial distribution of work trip flows or modal choices at one point in time is likely to change into a new distribution at some future point in time. If "properly" built (always an important caveat!) such models, must, as a matter of principle, possess higher predictive credibility than comparable static models.

A particularly important issue with respect to the dynamics of system change involves the questions of **lagged responses** to policy initiatives (or other stimuli to the system). Static models must assume "instant adjustment" to a given change: change the transit system and ridership will instantly adjust to this change. We know, however, that adjustment takes time, as information about and experience with the changed situation is obtained. "Feedback" effects exist in terms of secondary and tertiary responses to a given initial effect which may take considerable time to play out (a service cut to a feeder bus route in the short run may lead to workers walking further to access the subway station;

in the longer run, these people may buy cars and drive to work, or they may move out and be replaced by less transit oriented people). Lagged responses are impossible to observe through repeated cross-sectional surveys; they can only be directly observed through a panel which runs for a sufficient length to capture the "full" adjustment process.[10]

At the same time, panels possess the same virtues of repeated cross-sectional surveys, since each wave of the panel provides information about the observed system state at a particular point in time. Thus, in terms of tracking (as opposed to explaining) trends over time, panels serve the same purpose as repeated cross-sectional surveys such as TTS. The two major differences between the two in this regard is that the panel is likely to provide such information at shorter time intervals (e.g., every year or two, whenever a new wave is executed, versus every 5 or 10 years for typical repeated cross-section surveys such as TTS), but typically at smaller sample sizes (e.g., perhaps a few thousands for a panel versus tens of thousands for TTS).

As with anything, panels possess weaknesses and costs in addition to their strengths and benefits. Significant issues/problems associated with panel surveys include the following.

1. **Expense.** Panels require a considerable expenditure of resources, over a long period of time. Relatively few agencies are willing to enter into such long term commitment of significant amounts of money and effort, especially given the long "payback" period associated with this investment. This may be slightly less of an issue in the GTA, with its strong commitment to long-term data collection (in 2001 TTS will be in its fifteenth year and counting). Nevertheless, commitment to a panel is a non-trivial undertaking, and certainly involves the expenditure of resources which might otherwise be allocated elsewhere.

2. **Attrition/response bias.** Panels are demanding of respondents' time, patience and energy. There is a natural tendency for people to "drop out" of the panel over time as they get tired/bored/fed up with the exercise. People also move out of the study area, die, etc. Thus, a major challenge in panel surveys is maintaining a high response rate, retaining people throughout the life of the panel, and maintaining a representative sample throughout the panel. In the face of panel attrition it is often necessary to "refresh" the panel with new members. This adds expense to the survey and significantly complicates the statistical issues associated with it. This is an extremely important issue, and may well represent the single biggest technical obstacle to a panel survey achieving its intended objectives.

3. **Staleness.** Even in the absence of attrition, a panel will tend to become less representative of the actual population over time, simply because it ages and undergoes other transformations which may reduce its representativeness. In such cases, refreshment may still be required.

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[10] "Leads" may also exist in addition to "lags". A husband-wife household, for example, may buy a house in anticipation of having children rather than in response to their arrival.

4. **Conditioning.** As with any survey instrument, the act of asking people questions about their behaviour can potentially influence that behaviour (by making them self-conscious of their actions, making them think differently about how and why they do things, etc.). This is not a serious problem with a random cross-sectional survey asking questions about yesterday's activities. It can, however, create problems with people participating in long-term panel studies in which they are asked the same questions many times over a period of time. In large sample panels, with frequent waves, a **rotating panel** is sometimes used to address this issue, in which not all panel members are interviewed in each wave (e.g., perhaps half the panel is interviewed in Wave 2, with the other half being interviewed in Wave 3, and so on).

5. **Recruiting/response bias.** Given the onerous and on-going nature of panels, it is possible that biases can enter the sample in terms of the type of people who are willing/unwilling to participate in such activities. As a simple example, it might be the case that people who are relatively inactive might be more willing to participate in a travel panel survey than very active people, leading to obvious biases in trip rates, etc. that one would obtain from such a survey. Hence, care must be taken (as in all surveys) to ensure that as a representative sample as possible is obtained (and maintained) in the panel. Associated with this issue is the question of the need for/nature of incentives (gifts, money, etc.) to be used to induce people to participate in (and stick with) the panel.

6. **Staffing.** Maintaining a well trained, efficient staff throughout the lifetime of the panel can be a challenging task. The nature of this issue obviously depends upon the survey instrument used (e.g., a mail-back survey will have different staffing requirements than a telephone interview survey). It also depends upon length of time between waves (i.e., can a permanent interview staff be maintained or does one have to be hiring and training a new staff complement each time a new wave is "cranked up"?).

7. **Tracking the system state.** Not only must the behaviour and attributes of the panel members be tracked over time through the successive waves of the panel, but the state of the system within which this behaviour is occurring must be similarly tracked if one is going to be able to "explain" the observed behaviour over time. Thus, for example, road and transit networks for each wave time period will be required to generate the travel times and costs faced by the panel trip-makers in their travel decision-making. Similarly overall population and employment distributions would be useful to have to help place observed residential and employment relocations into context. The availability of such databases should be of general benefit to the planning agencies involved, over and above their contribution to the analysis of the panel survey data, but they also clearly represent an additional expenditure of time and money which might otherwise not have been made.

8. **Analysis/modelling complexity.** While it is easy to say that the availability of time-series panel data will lead to significantly improved planning analyses and models, the fact is that dynamic analysis and modelling is a challenging proposition, requiring advanced

econometric techniques. Transportation planners/modellers as a profession have little experience or (except in rare instances) expertise in this field. This, of course, creates a dilemma: few agencies will take on the uncertainties of a panel study since they lack the expertise to exploit the complex data structures generated by the panel; but without panel data to experiment with, it is difficult to develop the experience/expertise needed. This too represents a very serious, practical obstacle to undertaking a panel survey: one must ensure that the technical capability to exploit the panel data exists or can be obtained; otherwise the data will tend to be treated as if they were repeated cross-sectional data, and the expense and effort involved in maintaining the panel will be largely wasted.

In addition to these "problems" more specific design issues which must be faced in developing a panel survey (many of which are generic to the survey design problem, while some are unique to panels) include (among others):

- the time period between waves;
- how many waves to have (and, hence, the overall duration of the panel study);
- the survey instrument to use (mailback, telephone, etc.);
- the detailed design of the questionnaire (content, complexity, layout, etc.);
- sample size;
- panel selection/recruitment process;
- need for/nature of incentives; and
- panel refreshment procedures (if required).

Given the considerable list of issues associated with the use of panel surveys listed above, it is perhaps not surprising that few transportation-related panel surveys have been undertaken. Raimond and Hensher [1997] provide a fairly comprehensive list of major panel surveys undertaken in a number of fields, including transportation. The few transportation panels undertaken to date can generally be divided into four groups:

- panels which have focussed on automobile ownership and usage, including studies in Britain [Goodwin, 1986], the U.S. [Gilbert, 1992] and Australia [Hensher, *et al.*, 1991].

- panels focussing on transit, primarily in the U.K.; examples include: transit fare reductions in South Yorkshire [Goodwin, 1986]; bus service level impacts on ridership in Oxford [Stokes, 1988]; and ridership trends in London [Stokes & Goodwin, 1988].

- "special purpose" surveys addressing quite specific policy issues, usually involving "before and after" studies associated with a transportation system change; examples include: HOV lanes in San Diego [Golob, *et al.*, 1997]; trip reduction incentives in Los Angeles [Giuliano and Wachs, 1997]; staggered work hours in Honolulu

[Giuliano and Golob, 1990]; telecommuting in Sacramento [Pendyala, *et al.*, 1991; Koenig, *et al.*, 1996]; travel time information system impacts in Osaka [Iida and Uchida, 1992]; shopping behaviour in Cardiff[11] [Wrigley, *et al.*, 1985]; and transit service responses in Toronto [Miller & Crowley, 1989; Miller, 1987]

- "general purpose" panels designed to address a range of travel behaviour and transportation policy analysis issues.

To date, only two such "general purpose" panels have been undertaken: the Dutch National Mobility Panel and the Puget Sound Transportation Panel.[12] Assuming that a general purpose panel is of greatest direct interest for possible GTA application, we focus our discussion below on these two panels.

The Dutch National Mobility Panel (DNMP) was a nationwide panel undertaken in The Netherlands [Baanders and Slootman, 1983; Golob, *et al.*, 1986; van Wissen and Meurs, 1989]. Ten waves were undertaken in total: nine at six month intervals between March, 1984 and March, 1988, with a tenth wave occurring one year later in March 1989. Each wave involved a week-long travel diary completed by all household members 12 years of age or older. Sample size ranged from 1,673 (Wave 2) to 1,926 (Wave 7) households. Attrition rates were high, necessitating considerable reweighting of observations and refreshment [Meurs and Ridder, 1997]. Considerable within-wave response bias was also encountered due to reduced reporting towards the end of the week-long diary [Golob and Meurs, 1986]. The DBMP has been used for a wide variety of travel behaviour analyses and modelling efforts, one of the more notable being the development of the MIDAS (Microanalytic Integrated Demographic Accounting System) microsimulation model [Goulias and Kitamura, 1992, 1997].

The Puget Sound Transportation Panel (PSTP) is an on-going transportation panel in the Seattle metropolitan area [Murakami and Ulberg, 1997]. To date, it consists of nine waves, usually undertaken one year apart, beginning in 1989, with a tenth wave likely to be undertaken within the next year or so [Sicko, 1999]. Each wave involves a two-day travel diary which is mailed-out/mailed-back, combined with an upfront telephone interview. Incentives are used to encourage responses, as is an extensive program of "keeping in touch" between waves via holiday greeting letters, mailing out summaries of survey results, etc. The PSTP sample size is approximately 1,800 households per wave (i.e., essentially the same as for the DNMP). Diaries are completed by all

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[11] The Cardiff panel is rather unique in its construction. It involved daily records of shopping activities by panel members over a 24-week period.

[12] Reports exist of plans for general purpose panels in San Francisco [Purvis, 1997; Cambridge Systematics, 1996a], New York [Cambridge Systematics, 1996a] and Houston [Cambridge Systematics, 1996a]. Details on the status of these activities in these cities are still being sought.

household members 15 years of age or older. Attrition rates between successive waves ranged from 16 to 30 percent. As with the DNMP, the PSTP has provided data for considerable university-based research, as well as for descriptive planning/monitoring analyses. It has, however, had relatively little impact to date on Seattle travel demand modelling procedures, over and above what could be obtained through a comparable cross-sectional survey [Murakami and Ulberg, 1997; Sicko, 1999].

As with any data collection exercise, one should not enter into a panel survey without a clear understanding of the information needs to be addressed by the survey. In the case of the DNMP, the explicit objectives were [van Wissen and Meurs, 1989]:

- provide a time-series database which would permit the analysis of temporal lags and other dynamic features of causal relationships which cannot be determined from cross-sectional data;
- provide a "general purpose" longitudinal dataset which permits in-depth analyses of the determinants of changes in mobility;
- provide a survey tool which provides rapid access to respondents for current policy issues; and
- provide the data required to evaluate new public fare policy during the period 1984-87.

In Seattle, the PSTP has three basic objectives [Murakami and Ulberg, 1997]:

- to monitor changes in household composition, location and employment characteristics in the Seattle region;
- to monitor changes in travel behaviour and responses to changes in the transportation environment; and
- to examine the effects of changes in attitudes and values on mode choice and travel behaviour.

In the GTA planning context, what needs might a panel survey address? It is ultimately up to the planning agencies who are the potential sponsors of such an effort to define this. One starting point for this discussion, however, is to note that the coming decade is likely to be a highly dynamic one for transportation in the GTA, for a number of reasons, including the following.

1. **Toll roads.** The Highway 407 "experiment" is going to continue to play out in the coming years, with further extensions, potential privatization, and a host of potential impacts on GTA travel patterns, land-use and locational decision-making, etc. Other toll roads (e.g., a buried

Gardiner Expressway) are also possibilities.

2. **Transit services.** "Disentanglement" of provincial and municipal responsibilities will continue to play out, both with respect to the health and nature of local transit services, and with respect to the evolution of GO Transit under GTSB supervision.

3. **Demographics.** At least three major demographic trends will be simultaneously occurring over the next decade. The baby boom generation will continue to age (alas!), and will continue to play a major role with respect to everything from housing prices to labour markets to travel behaviour. At the same time, the "baby boom echo" generation will start to "come on-line" (be eligible to drive, be entering the labour force or going to college/university, etc.) in the later half of the decade. Finally, continuing, significant immigration into the GTA from around the world can be anticipated. Each of these individual trends carries its own implications for travel demands, none of which can necessarily be reliably inferred from past behaviour (e.g., aging baby boomers will not necessarily behave in the same way the current middle-aged or elderly do). The interactions between these various groups is also hard to predict *a priori*.

4. **Urban form.** The GTA continues to develop in a variety of ways. The Toronto central area continues to grow (after stalling significantly during the recession), with respect to employment and population, while at the same time "edge cities" continue to develop in the 905 region. Land development decisions and the resulting location/relocation decisions of households and firms ultimately drive the demand for travel. The dynamics and interconnections between, in particular, location decision-making and travel are still not as well understood as one would like.

5. **Environmental impacts and global warming.** Despite widespread skepticism concerning the achievability of the Kyoto Accord target reductions in CO_2 emissions, environmental sustainability issues simply are not going to disappear, and urban transportation with its heavy dependency on fossil fuels is going to continue to be a major focus of policy concern. In addition, it is almost certainly the case that environmental sustainability objectives (however defined) are not going to be achieved through technological innovations alone. A deeper understanding of urban travel behaviour responses to a range of policy instruments is required if significant progress in achieving such objectives is to be obtained.

Each of these issues involves questions of dynamics, of behaviour adapting over time to a range of stimuli, of complex interactions. Each could be potentially usefully informed through a properly designed and executed panel survey. In addition to these fairly broad, policy-related issues, more specific, modelling-oriented issues which could be usefully addressed using panel data include:

- evolution of trip generation rates by trip purpose over time;
- identifying the relative importance of modal level of service, auto ownership level, and urban form on travel mode choice; and
- developing improved representation of lifecycle and household structure effects on travel behaviour.

5. OTHER SURVEY ISSUES & METHODS

5.1 Introduction

This section deals with other survey issues and methods which either need to be considered as part of a panel survey design process and/or are deserving of consideration in their own right as possible extensions to/modifications of current TTS practice. These are: multi-day surveys; activity-based surveys; and computer-based survey methods. Each of these topics is briefly dealt with in the following sub-sections.

5.2 Multi-Day Surveys

Conventional travel surveys such as TTS typically gather travel behaviour information for a single twenty-four hour period for each household sampled. The day of the week for which this information is gathered is randomly varied from one household to the next, so that across the entire sample a statistically valid sample of travel on each day of the week of interest is collected. In the case of TTS, survey days are restricted to weekdays (Monday through Friday, inclusive), with no information being collected concerning weekend (Saturday/Sunday) travel. In practice, little use is made of the day of week information in GTA planning analyses and modelling exercises: in general, travel data for the five weekdays are simply lumped together to yield an overall composite or "average" travel day.

Day-to-day variations and interactions in travel behaviour are, however, significant and of potential interest to the planning process for several reasons, including:

1. Weekend travel is fundamentally different from weekday travel in terms of trip purposes, modal splits, destination choices, and time of day distributions. Within the GTA we know almost nothing about weekend travel except that it is different from weekday travel. In at least certain areas, however, weekend road congestion levels may be as high or higher than during weekday peak periods. Similarly, it is difficult to "optimize" weekend transit service when very little is known about the weekend travel market (over and above what transit agencies learn through trial and error scheduling of these services and observing the demand response to these changes).

2. If we are ever to achieve comprehensive audits of transportation energy use and emissions in the GTA, then weekend travel must be included in the analysis.

3. As ITS plays a bigger role in the real-time control of our road and transit systems, an understanding of day-to-day (and within-day) variations in travel behaviour becomes more important.

4. A proper understanding of travel behaviour (in particular, non-work travel and work - non-work interactions) may well require observation of household behaviour over more than a single day, in order to capture the day-to-day interactions which determine this behaviour (this household didn't shop today because it went shopping yesterday; this worker drove the household car to work today because it wasn't needed at home, but tomorrow will be driven to the train station so that the spouse can use the car to go shopping; this person made a complex, multi-stop, multi-purpose trip chain on the way home from work today so that the household would be errand-free tomorrow and so could go to the cottage; etc.).

The last of these four points most directly depends on the availability of multi-day survey data, since the first two can be addressed in the first instance by extending the survey to include weekends, and the third can be addressed at least in the aggregate with existing single-day data. It can be argued in each of these three cases, however, that multi-day data may provide better insights into underlying processes and interconnections than can be achieved with cross-sectional, single-day data.

Another argument in favour of multi-day data is one of sampling efficiency: for a given number of "travel days" of information required, fewer households need to be interviewed, implying potential cost savings. Whether this potential is realized, however, depends upon the impact on response rate of the multi-day format (i.e., the increased response burden of a multi-day survey will tend to decrease the willingness of households to participate in the survey and/or fail to complete it if they agree to participate), as well as the efficiency of collecting multi-day relative to single-day data. In particular, multi-day data almost certainly require a travel diary format (in which each respondent records his/her travel information for each day in the survey) in order to ensure reasonably accurate recall of trip-making behaviour over more than a single day's time-span. Retrieving and coding a complex travel diary is certainly more expensive "per travel day of information collected" than the current TTS single-respondent, telephone-based method, for example.

Relatively few travel surveys covering a week or more per respondent have been attempted. Examples of such surveys include:

1. A 5 week survey of 300 households in Uppsala, Sweden in 1971 [Damm, 1983]. This survey is unique in its time-span and is unlikely to be repeated elsewhere.

2. A two-week mail-back travel diary survey of 700 households in Hamilton-Wentworth in 1978, undertaken by researchers in the Department of Geography, McMaster University

[Webber, 1978]. A unique feature of this survey is that no evidence of response fatigue was found. That is, respondents did not tend to drop out of the survey during the two week period, and reported trip rates did not decline over the course of the two weeks (a typical indication of respondents losing interest in completing the survey accurately as the survey "drags on").

3. As described in Section 4, the Dutch National Mobility Panel used a one-week travel diary.

4. A one-week computer-based activity diary of 42 households in Hamilton in 1997-8, undertaken by researchers in the Department of Civil Engineering, University of Toronto [Doherty, 1998]. This survey is discussed further in Sections 5.4 and 6.

The question of the "optimum" length of travel surveys was addressed in detail by Pas [1986]. While generally arguing strongly in favour of multi-day data, Pas concluded that a two-day survey is likely to be most cost-effective in most cases. The argument is that the second day's information represents a significant, cost-effective increase in our knowledge about each household's travel behaviour, while each additional day's information provides decreasing marginal returns on our survey dollar, and that dollar will usually be better spent on observing a new household, rather than continuing to observe the first one.

Largely based on Pas' recommendations, two-day surveys are currently common in the United States (although a majority of recent surveys still are one-day surveys [Cambridge Systematics, 1996a]). Examples include Seattle (panel, on-going, see Section 4); New York (1994), Raleigh-Durham (1995), San Francisco (1996), and, probably the best known of all, Portland, Oregon (1994) [Lawton and Pas, 1995; Cambridge Systematics 1996a, 1996b]. While variations on a theme exist, all of these surveys are essentially **activity-based** surveys (discussed further in Section 6), in which each household member fills out a two-day activity/travel diary which is then retrieved through a lengthy telephone interview. Response rates are typically significantly lower than those obtained in TTS. In Portland 53% of households contacted agreed to participate in the survey. Of these, 63% actually completed the two-day activity diary, yielding an overall response rate expressed in terms of completions per contact of 33% [Cambridge Systematics, 1996b]. This is less than half of that obtained with TTS (see Table 2.1). Typical total costs per completed survey run in the order of $100 US or more [Lawton and Pas, 1995; Cambridge Systematics, 1996b].[13]

5.3 Activity-Based Surveys

The basic unit of travel in conventional travel surveys such as TTS is the single, "unlinked" trip by

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[13] Some caveats must be noted in comparing typical U.S. survey costs with the GTA TTS experience. U.S. planning agencies typically contract their surveys out to specialist market research firms who seem to have higher cost structures than what we tend to experience here with our "quasi in-house" procedures.

an individual from an origin to a destination for a single purpose (person 1 travels from home to work; person 2 travels from shopping location 1 to shopping location 2; etc.). Figure 5.1 illustrates how a "typical" travel day for a working parent ("person 1") and young child ("person 2") is represented within this **trip-based** schema.

Note that in this figure that the **behaviour** exhibited by these two household members is very straightforward: the parent must spend the day at work; she drops off/picks up her child at a daycare on the way to/from work. She may well choose to drive because this is by far the most convenient way to deal with taking the child to/from daycare relative to having to get on, off and on transit again, rather than due to any inherent time/cost advantages of auto relative to transit for the straight home-to-work trip. During her lunch hour she walks to a nearby shopping area to do some shopping, perhaps because this is more convenient than trying to squeeze a shopping stop into the time-constrained afternoon trip from work to the daycare. Other explanations for the observed behaviour are, of course, possible, as are other ways in which this parent and child might have chosen to schedule their day. The key point is that the observed behaviour is very understandable and explainable (and, hence, potentially modellable) when viewed in terms of the **activities** which are being undertaken and the associated overall travel patterns or **tours** or **trip-chains** (the two terms are used essentially interchangeably) which are employed to execute these activities.

Conversely, when this pattern of activity and travel is decomposed into a set of unlinked person trips, the logic underlying this particular set of trips is largely lost, and hence so is our ability to explain or model this trip set. The basic home-to-work-to-home nature of person 1's travel is obscured by the "facilitate passenger stops". The rationale for these facilitate passenger stops is not apparent in this data structure, nor is it easy to recover from the trip data once they have been placed in this trip-based representation. In the same way, the ability to explain the work-based shopping trips (as opposed to say, a home-based shopping trip at some other point in time) is lost. Similarly, explaining modal choices in the trip-based representation is likely to be more difficult, given the loss of linkage between the parent's and the child's activity patterns and travel needs (i.e., the parent drives <u>because</u> she needs to drop off/pick up the child). Thus the trip-based representation "abstracts away" much of the information -- in particular the linkages between activities and the interconnections between household members -- inherent in observed behaviour and essential to our ability make sense, explain and, ultimately, model this behaviour.

For some time now, travel demand modelling has been undergoing a paradigm shift from trip-based analysis to **activity-based** analysis. The basic premise of the activity-based paradigm is taking seriously the truism that travel is a derived demand: we travel so that we can participate in activities. Thus, in order to understand travel we must first understand the processes by which we decide where and when to participate in activities of various types. Some activities occur within the home and hence do not require travel, while others occur at dispersed locations and so do generate travel. In-home activities (eating at home, watching television, telecommuting) can substitute for out-of-home activities (going to a restaurant, attending a concert, working at the office). Interconnections between activities can alter travel decisions (the parent drives to work so that she can take the child to daycare; a person leaves work early to go to the dentist; a worker shops downtown, close to his office, during his lunch hour rather than at the mall close to his home because he won't have time to shop in the evening due to other scheduled activities). Travel is simply the means by which we execute our daily out-of-home activity schedule, and we will never properly understand travel behaviour if it is abstracted out of this context of activity scheduling and participation.

The need for moving from a trip-based to an activity-based framework has traditionally been minimized by focussing our analyses and modelling efforts on morning peak-period work travel, under the assumption that morning home-to-work trips can be adequately handled with trip-based methods. This approach is increasingly untenable for a number of reasons, including:

1. The morning peak period is not the only critical time period in most urban areas. The afternoon peak period is often at least as congested, often over a greater period of time, and possesses at least somewhat different attributes. As noted above, weekend travel can also impose serious loads on the system in particular locations.

2. Home-based work trips represent a minority of travel, and are typically decreasing in importance over time, even within the morning peak period, both as work trip rates decrease and non-work travel increases.

3. Many transportation issues (most notably those pertaining to greenhouse gas emissions and air quality emissions) depend upon an understanding of the total demand for travel, not just the demand for work and/or morning peak-period travel.

4. Even to understand home-based work travel in today's complex society requires an understanding of the interconnections between work and other activities. As has been noted above, home-to-work trip mode choices may well be motivated by the activity/travel needs of other household members, rather than straightforward modal time/cost tradeoffs assumed in conventional models. Work trip generation rates and departure times (e.g., before, during or after the morning peak period) may depend upon a variety of activity-related factors which cannot be understood by examining the home-to-work trip in isolation.

While the activity-based approach has been discussed since at least the early 1970s, the obstacle to its use has always been a lack of operational modelling methods. While still certainly not state-of-practice, activity-based modelling methods are currently emerging as operational planning tools in a number of cities around the world. Examples include:

- Stockholm [Algers, *et al.*, 1991];
- tour-based statewide modelling system for the State of New Hampshire;
- a "journey-base" model (where a "journey" is "half a tour, say from home to work, including any intermediate stops) under development for Honolulu [Ryan and Forinash, 1999]; and

- an extensive tour-based, microsimulation modelling system in Portland, Oregon [Bradley and Lawton, 1998], representing the implementation of the seminal work of Bowman and Ben-Akiva [1995].

In addition, many special-purpose, smaller-scale, activity-based models have been developed and applied in a number of problem-specific applications (e.g., Jones, *et al*., 1983; Clarke, 1986; Recker and McNally, 1986; Ettema, *et al*., 1993; Resource Decision Consultants, 1995]. Finally, activity-based modelling methods represent an area of extremely active research world-wide, results of which are beginning to impact operational modelling and are expected to move into operational planning practice at an increasing rate over the next decade [Travel Model Improvement Program, 1996].

A shift to activity-based analysis obviously requires a refocusing of our surveys to explicitly capture activities (by time of day and duration as well as by type and location) as well as travel. In its simplest manifestation, this may involve only relatively minor changes in survey questioning, since even trip-based surveys tend to use a "quasi-activity-based" method of data collection. For example, in TTS, it is usual for the interviewer to solicit information about the next trip made by asking "and what did you do next?", while the overall sequence of trips is invariably collected as a connected chain or tour of trips, beginning with the first departure from home for each person in the household. Explicitly collecting activity durations (an important piece of data for modelling activity scheduling) represents a very modest extension to conventional trip-based questioning.

More serious extensions to conventional survey methods result from the decision to collect information on in-home activities and to collect activity/travel data for more than one day. Multi-day data collection has already been discussed, and so it perhaps suffices to say at this point that the rationale for multi-day activity data is probably even stronger than that for pure trip data (since how I schedule today's activities is probably heavily conditioned by what happened yesterday, as well as, perhaps, my expectations about tomorrow's activities). As a result, as noted in the previous section, most activity-based surveys are at least two days in duration.

The question of whether in-home activities need to be collected for (ultimately) travel modelling purposes is somewhat more debatable, although certainly virtually all researchers and many practitioners argue strongly in favour of collecting at least some in-home activity information, given the considerable opportunities which exist for substitution between in-home and out-of-home activities, as well as the inherent "utility tradeoffs" which exist between the two types of activities (e.g., the time spent out with friends is time not spent at home with the family). In practice, the question is probably not one of whether to collect in-home activity data, but rather one of how much detail is required (level of disaggregation of in-home activity types, temporal precision with respect to in-home activity durations, etc.) and of how cost-effectively these data can be collected within the overall survey effort.

Given the almost certain need to collect multi-day data, as well as in-home data, as well as the generally higher level of detail concerning out-of-home activities/travel associated with activity surveys, some form of diary format for information recording is inevitable. The current state-of-practice is to mail out paper diaries for each respondent, which are filled out by the respondent for the specified survey day(s), and the diary information is then retrieved via a telephone interview (although mail-back of the diaries is always an option). The next section, however, discusses current and emerging computer-based alternatives to this standard paper diary approach.

5.4 Computer-Based Survey Methods

Computers play an important role in modern telephone surveys, since they are used by interviewers to enter the information being received over the telephone from respondents directly into a computerized database, thereby eliminating the costly, time-consuming and error-prone process of recording the information first on paper forms and then coding the paper-based information into the computer. TTS was in the forefront of developing such a Direct Data Entry (DDE) or Computer-Assisted Telephone Interview (CATI) process[14], but CATI methods are now very standard state-of-practice throughout the industry.

Computer-Assisted Personal Interviewing (CAPI) is also possible, and has been employed in a number of different ways for a wide variety of purposes. CAPI involves using the computer in a face-to-face interview, either with the interviewer entering data directly into the computer, or the respondent doing so (in which case the method is referred to as CASI -- Computer-Assisted Self Interviewing), or some combination of both. CAPI/CASI systems are particularly useful when engaging respondents in gaming simulations or other complex tradeoff situations typical of stated preference surveys. Maps, pictures, tradeoff matrices, etc. can be readily presented to the respondents and complex responses can be easily recorded through the use of the computer. CAPI/CASI methods have been employed since at least the early 1980's, although the emergence of very powerful, highly portable laptop computers has greatly extended the ease of application of these methods.[15] The increasing penetration of the internet into our lives raises the potential for further ease of access of CAPI methods, although sample selectivity bias and other issues still exist with respect to using the internet for general purpose surveying (discussed further below).

More recently Geographic Positioning System (GPS) devices have been combined with small computers to provide an alternative approach to home-based interviews (CATI, CAPI, or otherwise) for collecting out-of-home activity/travel data. In these systems, a GPS device is attached to a vehicle in order to record all movements of the vehicle in three-dimensional space (thereby providing detailed destination and route information, by time of day, as well as travel time and speed

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[14] See Ng and Sarjeant [1993]. In the GTA we tend to use the term DDE, in the U.S. (and elsewhere) CATI tends to be the more common term.

[15] Originally, people had to be brought "into the lab" to conduct computer-based experiments. Now people can be interviewed in their homes, in shopping malls, or virtually anywhere else where they can be readily intercepted and sat down in front of a laptop.

information), and the driver typically enters additional trip information, such as stop purpose, number of passengers in the car, etc. into a small computer. On-going experimentation with such methods is occurring in Canada, the U.S. and the U.K.

A particularly promising CASI procedure has recently been developed at the University of Toronto [Doherty, 1998]. The Computerized Household Activity Scheduler (CHASE) is a Visual Basic program which allows each household member to record his or her daily activities over an entire week in a very convenient "day-timer" type format on the computer. All in-home and out-of-home activities are recorded, currently within fifteen minute time slots. The program is designed to minimize the response burden on the individual (given the extensive nature of the information being requested), and in tests to date, no evidence of response fatigue has been observed. Originally designed for use on a laptop computer which was given to a respondent household to use for the week of the survey, the program is currently being rewritten in Java for use on the Web. The program is also being extended to interface with a GIS to provide on-line map referencing (in the original application, hardcopy maps were provided to respondents to use in entering their activity locations into the computer). A complete description of CHASE is provided at http://www.transport.utoronto.ca/Chase.

While CHASE possesses many promising features, from the point of view of this report, it is of potential interest because it represents a potentially cost-effective means of collecting activity-based data relative to conventional methods. In particular, it collects very detailed activity/travel data for all household members for an entire week. This information is self-completed by the respondent and so no interviewer is required (although an extensive up-front interview is required). The data obtained are automatically stored in a relational database management system. The process thus appears to be very efficient and accurate relative to other multi-day activity diary methods.

6. PANEL SURVEY OPTIONS

6.1 Introduction

Given the discussion in the previous sections, if a panel survey were to be undertaken in the GTA, what might a reasonable design (or designs) look like? Before attempting to answer this question, two points should be noted:

- It is assumed that "conventional" TTS surveys will be undertaken in 2001, 2006 and 2011. These surveys will continue to address their current planning objectives.

- What follows is not a detailed panel survey design. Rather, it represents a "first cut" at the key dimensions of such a design in order to sketch out the likely capabilities and possible costs of a GTA panel survey, as a basis for deciding whether it is worthwhile proceeding with a more detailed design for further assessment.

In particular, in Sub-section 6.2 the following design issues are each briefly discussed and preliminary recommendations concerning panel survey designs are put forward with respect to each issue:

- panel duration;
- time between waves;
- number of days surveyed per wave;
- survey method;
- survey content; and
- sample size.

Not all of these issues have a clear-cut "dominant solution", particularly at this very early stage of the process. Rather, what emerges is a set of presumably feasible panel surveys, which share a number of common elements, but which also present a range of interesting options requiring further consideration. Based on this set of suggested designs, some very preliminary cost estimates are presented in Sub-section 6.3 as a first step in assessing the budget implications of taking on a panel survey in the GTA.

6.2 Design Options

The discussion and preliminary recommendations in this sub-section are all conditional upon the assumption that a panel survey is to be undertaken. That is, they address the question of what a GTA panel survey might/should look like if it is to be undertaken. In order to keep the discussion as unencumbered as possible, the qualifying statement "if a panel survey is undertaken" is taken as understood and not continuously repeated throughout this sub-section.

Duration. While a panel in principle can run indefinitely (or, at the other extreme, over a short period of time), in practice one needs to commit to a minimum time period, such as 10 years, to achieve significant benefits. On the other hand, given the attrition rates normally experienced with such surveys, it is not clear that it is a very feasible proposition to run a panel much longer than 10 years. It also would be sensible to "anchor" the panel within cross-sectional TTS surveys at the beginning and end of the panel survey, for validation and cross-referencing purposes.

--> **The first wave of a GTA panel survey should be undertaken concurrently with the 2001 TTS. The panel should be 10 years in duration, with the final wave occurring concurrently with the 2011 TTS.**

Time between waves. As has been briefly discussed in Section 4, real trade-offs exist with respect to the selection of the time between waves in the survey. Shorter time periods help maintain contact with the panel members, provide finer grain temporal detail in the information obtained, require less effort on the part of respondents to recall events which have occurred since the last survey wave, and may help maintain survey team "momentum" and expertise. At the same time, short time periods between waves may generate response fatigue more quickly among the panel members (and hence encourage dropping out), increases the chances of unwanted "conditioning" of the panel members, will be more expensive to undertake, and may be inefficient if they are so short that "not much changes" between waves. On the other hand, longer time periods will be less costly to run and impose less response burden on the panelists (in terms of the number of times they are required to respond), but they will require greater effort to "keep track" of panel members between waves, they will inevitably provide coarser grain temporal detail concerning behavioural changes over time, and they will require greater efforts on the part of respondents to recall events over the longer time periods involved.

To establish some bounds on the time between waves, it is almost certainly the case that the six-month intervals used throughout most of the DNMP are too short for GTA purposes, while simply running a wave of the panel every five years concurrently with TTS is clearly too coarse. As a further constraint, it is strongly advisable to run a wave of the panel concurrently with the 2006 TTS, for the same reasons that the panel is assumed to begin and end with waves undertaken concurrently with the 2001 and 2011 TTS's. Two options which meet these various constraints, which appear to be feasible, and which possess various pros and cons are:

- One year time periods between waves. A wave would be run in the Fall of each year during the period 2001-2011, inclusive, resulting in 11 waves in all.

- Approximately 2.5 year time periods between waves. This would result in 5 waves occurring approximately at the following times:[16]
  Wave 1: Fall, 2001 (concurrent with 2001 TTS)
  Wave 2: Spring, 2004
  Wave 3: Fall, 2006 (concurrent with 2006 TTS)
  Wave 4: Spring, 2009
  Wave 5: Fall, 2011 (concurrent with 2011 TTS)

Detailed comparisons between these two options are beyond the scope of the current discussion, and so both options are retained at this stage for further consideration. Choice between these two options will largely hinge on whether the additional temporal detail provided by the one-year time intervals is of sufficient utility to GTA planning analyses and modelling efforts to warrant the significantly

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[16] The choice of 2.5 years between waves is arbitrary and is adopted for simplicity of discussion. There is no absolute necessity for equal time periods between waves, so Wave 2 (4) could be held in the Fall of either 2003 or 2004 (2008 or 2009). The possibility of running Waves 2 and 4 in the spring, however, is a potentially intriguing one, since it would permit comparisons of travel behaviour between these two time periods.

increased associated costs.[17]

--> **At least two options exist with respect to the time between panel waves, which should be considered further in greater detail. Option 1 involves one-year time periods, resulting in 11 waves in total over the panel duration 2001-2011. Option 2 involves nominally 2.5 year time periods, yielding a total of 5 waves over this same time period. In all cases, it is strongly recommended that a wave of the panel survey occur concurrently with the 2006 TTS.**

Single or multi-day surveys. Despite the reasonably strong argument presented in Section 5.2 for multi-day (or at least two-day) surveys, it simply is not clear at this stage of the design process whether the additional complexity and expense of a two-day survey is justified in terms of the additional information obtained. It is certainly the case that relatively little use has been made in practice (or even in research efforts) to date of two-day survey data. Typically the second day information has been treated to date by most analysts/modellers as simply a "second observation" in the dataset, with no attempt being made to link behaviour on the second day to what occurred on the previous day. Given this, one is strongly tempted to stick with a one-day format. In order to maintain options, however, as well as in recognition that practical methods for dealing with multi-day data may well emerge in the near future, both one-day and two-day survey options are maintained for further consideration.

--> **While a one-day survey per wave is most likely sufficient for anticipated GTA planning/modelling purposes, both a one-day and a two-day survey design option should be pursued for further consideration.**

Survey method. Certainly the lowest cost, most straightforward approach to running a GTA panel survey is to simply use the existing TTS method (telephone interview, single respondent) in each wave of the panel survey. This would require minimal new development costs, utilizes a proven procedure and would generate information in "non-TTS" waves which is absolutely compatible with that obtained in the TTS years. Given these pragmatic advantages, this option should be retained for further consideration. Clearly, if this survey method was adopted, it would dictate the choice of a single-day format, since the TTS method simply cannot support a two-day recall of travel behaviour.

At the same time, several limitations in the current TTS procedure have been outlined in Section 2. Of these, the non-respondent bias associated with the use of a single respondent and the somewhat restricted range of information obtained from TTS are particularly important. A strong case can be

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[17] Assuming the same sample size for both designs. Alternatively, costs could be fixed for both designs by reducing the sample size for the one-year interval case, with associated reduction in statistical significance. Either way, the increased temporal detail comes at a price, which may or may not be worth paying.

made that, if one is undertaking the considerable effort and expense of a panel survey, as "full" a set of information should be collected as possible, in order to maximize the usefulness of the data obtained for as full a range of analysis as possible. In particular, each relevant household member should be directly surveyed. The PSTP provides a proven alternative to TTS for this purpose, consisting of, for each wave:

- an upfront telephone interview to help re-establish contact with the household, to gather updated socio-economic information, etc.; and

- a mail-out/mail-back travel diary to collect current travel behaviour information for each household member.[18]

Variations on this theme exist (such as mail-out/telephone retrieval), but typically are more expensive. Mail-back surveys have been demonstrated in Toronto [Toronto Transit Commission, 1984a, 1984b; Miller and Crowley, 1989; Hollingworth and Miller, 1996; Pushkar, 1998] and elsewhere [Richardson, *et al*. 1995] to be cost-effective, high quality survey instruments, especially when combined appropriately with use of the telephone to establish/maintain contact and to perform selected portions of the interview. Incentives also can play a role in improving response rates and panel retention [Miller and Crowley, 1989; Murakami and Ulberg, 1997]. In particular, response rates and data quality comparable to telephone surveys can and are obtained with such methods when proper care is taken in their design and execution [Dilman, 1978]. The PSTP approach also is inherently flexible with respect to the number of days per survey involved (PSTP is a two-day survey), and with respect to the content of the survey (e.g., travel- versus activity-based, discussed further below). For all of these reasons, it is recommended that a combined telephone interview, mail-back travel diary be included as an option for further consideration in the panel survey design.

--> **Two survey methods are recommended for further consideration: the current TTS telephone interview procedure and the PSTP procedure which involves a combination of telephone interview and mail-back travel diaries.**

Survey content. At least four levels of detail with respect to survey content exist:

- current TTS content;
- "extended" TTS with additional socio-economic information (possibly including more detailed occupation classifications, income, more detailed household structure information, etc.);
- "augmented" TTS which, in addition to the socio-economic extensions, includes additional travel behaviour information, most likely gathered in a "quasi-activity-based" format; this information might include:

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[18] TTS-like assumptions concerning cut-off ages for which household members are required to respond are still possible and likely to be adopted.

        - durations of activities at stops (in addition to the currently gathered trip start times);
        - more detailed auto usage information (e.g., which car is used by which person for each trip);
        - explicit auto occupancy information; and
        - use of database structures which facilitate tour-based analysis and modelling.
    - full activity-based data, including some level of in-home activities.

It is suggested that the current TTS content is somewhat restricted in its ability to support the full range of analyses envisioned for the panel survey data and so can probably be rejected from further consideration. At the same time, a full activity-based approach represents a considerable leap relative to current GTA practice and may well not be necessary to support current planning and modelling needs. This leaves the "extended TTS" and "augmented TTS" options as presumably viable options for further, more detailed consideration. The extended TTS option is certainly supportable by either the current TTS or the PSTP survey methods, while the augmented TTS option would certainly stretch the TTS method considerably and is perhaps best associated solely with the PSTP method.

--> **Both an "extended TTS" survey content (involving additional socio-economic information about respondent households) and an "augmented TTS" or "quasi-activity-based" survey content (involving both additional socio-economic and travel/out-of-home activity information) are recommended for further, more detailed design considerations.**

Sample Size. It simply has not been possible to date within this project to undertake any meaningful statistical analysis in support of the determination of an appropriate sample size for a GTA panel survey. As a starting point for some "back of the envelope" calculations, it is noteworthy that both the DNMP and PSTP had panel sizes in the order of 1800 households. Both used a stratified sample (the DNMP stratified by income, life cycle and region [van Wissen and Meurs, 1989]; the PSTP is stratified by usual mode to work of household members [Murakami and Ulberg, 1997]) to improve the statistical properties of the sample. Cost considerations will inevitably dictate a similar approach for any GTA panel survey; i.e., the use of a relatively small, carefully stratified sample. While selection of a specific stratification scheme is well beyond the current study's scope, at first glance the DNMP approach seems to be a more defensible one (and more appropriate to GTA needs) than that adopted by PSTP.

In order to undertake some very crude, first cut cost calculations in the next section, let us take as a working assumption a sample size of 2000 households, which will be maintained throughout the course of the panel through an appropriate refreshment strategy. Cost estimates can be readily scaled up (or down) as need be as this sample size estimate is refined.

--> **A GTA panel survey will consist of a small sample (relative to conventional TTS practice), carefully stratified so as to maximize its statistical power. A nominal sample size of 2000 households is assumed for preliminary calculations.**

Figure 6.1 summarizes the design options and their logical combinations which have been retained for further consideration (with the exception of sample size, which, at this point in the discussion, is assumed to be constant across the alternatives). Although it was stated above that the PSTP survey method could support either the "extended TTS" or the "quasi-activity-based" survey contents, only the later is shown associated with the PSTP method in the figure. This is partially simply to simplify the diagram. More substantively, however, it reflects the judgement that if the PTSP method is to be used, then the quasi-activity-based approach to survey content would almost certainly also be adopted.

The net result is six different potential survey designs, which have been simply labelled for convenience of reference in the next sub-section as designs 1 through 6.

6.3 Cost Implications

The current TTS procedure has cost, in 1996 dollars, between \$16.65 (1996) and \$22.07 (1991) per completed household to undertake, including both fixed (including development costs) and variable costs. In order to begin to cost out the six design alternatives developed in the previous sub-section and summarized in Figure 6.1, the following working assumptions are made:

1. For the TTS-based options (Designs 1 and 4) a cost per completed household per wave of \$20 is assumed.[19] While standard TTS costs include development costs which presumably are nearly nil for non-TTS year waves for these options, panel refreshment costs plus fixed start-up costs for non-TTS years will exist.

2. In TTS years (2001, 2006, 2011) for the TTS-based options, panel members will be considered part of the "regular" TTS sample. Further, panel refreshment in these years will be drawn from the full TTS sample. Hence, the marginal cost of running the panel waves in these years should be minimal relative to "normal" execution of the cross-sectional TTS.

3. For PSTP-base options (Designs 2, 3, 5 and 6), a cost per completed household per wave of \$40 for a one-day survey and \$45 for a two-day survey is assumed for non-TTS year waves. This is almost surely a conservative figure relative to the \$20 per completion for the TTS-based options. It is intended to include amortization of the development costs of the method over the lifetime of the panel, refreshment costs, and the cost of running both telephone interviews and a mail-back activity/travel diary each wave.

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[19] For simplicity of discussion -- in particular with respect to comparison with historical TTS costs -- all assumed costs are expressed in 1996 dollars.

4. For PSTP-base options in TTS years, the incremental cost of processing panel households within the overall TTS procedure is assumed to be $20 for a one-day survey and $25 for a two-day survey.

Table 6.1 takes these assumptions and simply multiplies them by the number of waves for an assumed sample size of 2000 households. Given these assumptions (which clearly are extremely crude and are clearly subject to debate and eventual refinement), the projected range of panel survey costs is from $80,000 (Option 4) to $870,000 (Option 3), spread over a 10 year period.

Given these cost estimates, some preliminary pruning of the option list may be possible. Options 2 and 3 (involving the PTSP method applied to yearly waves) are clearly far more expensive than the other options (by a factor of at least 2), and so are unlikely to be found cost-effective in a more detailed evaluation. Option 4 (involving the TTS method applied to the five-wave option) probably does not return sufficient additional information relative to the three cross-sectional TTS planned for the same time period to warrant the effort, despite its relatively low cost (i.e., it provides only two additional data points mid-way between the three cross-sectional surveys, with relatively little augmentation of the data collected per time period).

Thus, if we provisionally restrict our attention to the remaining Options 1, 5 and 6 (which still provide considerable variations in design options), we arrive at cost estimates in the range of $300,000 for the panel survey (the actual range is estimated to be from $280,000 to $330,000), or approximately $30,000 per year, annualized over the lifetime of the project.

Thus, to finance a GTA panel survey will either require augmenting the TTS budget over the 2001-2011 time period by an amount in the order of $300,000 (and thereby leaving the repeated cross-section TTS budget -- and hence sample size -- the same) or by redirecting this amount from the standard TTS to the panel. At an assumed TTS cost of $20 per completed household, this later approach implies the loss of a total of 15,000 households from the cumulative TTS cross-sectional database over the 2001-2011 time period. This loss could be taken as a "one-time-only" cut by deducting the entire amount from the 2001 TTS (or either other year for that matter), or could be spread uniformly across the three surveys, resulting in a net reduction in sample size per survey of 5000 households. Using 1996 numbers as a convenient point of reference, the latter option implies, at most, a reduction in cross-sectional sampling rate from a nominal value of 5.0% to 4.78%[20] -- presumably not a major cause for concern.

One can undertake any number of sensitivity tests with respect to these numbers. As one simple experiment, note that a 50% increase in cost estimates would either increase the net cost of the panel

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[20] This calculation assumes the 1996 sample size of 115,000, which represented a 5% sample of households in the TTS study region (i.e., the extended GTA). Given the expected growth in the study region during the 2001-2011 period, the actual sample rate reduction will be slightly smaller than this.

to a total of $450,000 ($45,000 per year) or, equivalently reduce the nominal TTS cross-sectional sampling rate across the three surveys to 4.65% -- still hardly an exorbitant price to pay.

7. RECOMMENDATIONS

Given the analysis in the preceding section, as well as the discussions underlying this analysis in Sections 2-5, two major findings emerge, which, in turn, lead to two major recommendations, which are put forward for consideration.

The first finding is that the repeated cross-sectional TTS program has served the GTA extremely well, and should be continued through the next decade. While needs for additional survey information may exist and be justifiable on a cost-effectiveness basis, such additional survey activities should not detract from the "core" TTS data collection activity. This conclusion leads to recommendation 1.

Recommendation 1:

> **"Full" cross-sectional TTS surveys, similar in design to the preceding three surveys, should be undertaken in the Fall of 2001, 2006 and 2011. The nominal sample rates for these surveys should be 5%.**

The second finding deals with the primary subject of this report: the possibility of undertaking a panel survey within the GTA, as a complement to the current TTS. Based on the preliminary analysis presented in this report, a GTA panel survey undertaken in parallel with the cross-sectional TTS survey during the 2001-2011 time period possesses the potential to provide considerable benefits in terms of significantly increased information concerning temporal trends in GTA travel behaviour and the underlying factors affecting these trends. Such a survey also appears to be feasible to execute in a cost-effective fashion, with a preliminary cost estimate in the order of $300,000 over the lifetime of the project. Such a panel survey can be "financed" either by adding additional funds to the GTA survey budget over this time period, or by reducing the cross-sectional TTS sample rates marginally (to approximately 4.75%, relative to the nominally desired target of 5%).

Recommendation 2:

> **These findings are sufficiently promising that it is recommended that a panel survey, commencing as part of the 2001 TTS exercise, be provisionally included in the GTA travel survey agenda, and that a detailed design for such a survey be developed. Once a detailed design has been developed, a much firmer estimate of the benefits and costs will be available as a basis for making a final decision concerning whether or not to proceed with the panel survey in 2001.**

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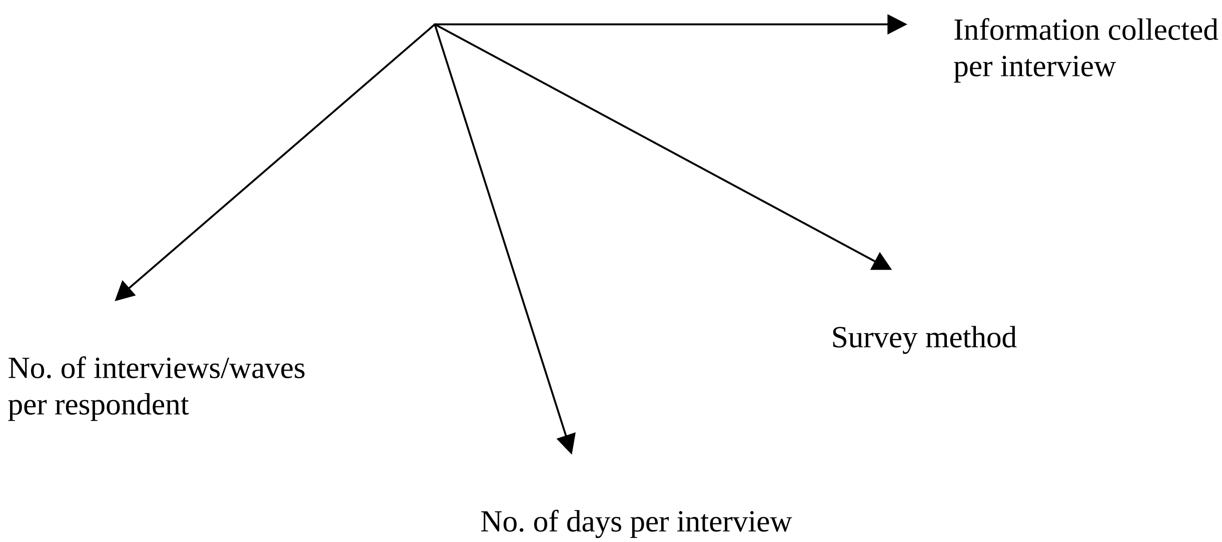

Figure 1.1
Survey Design Dimensions

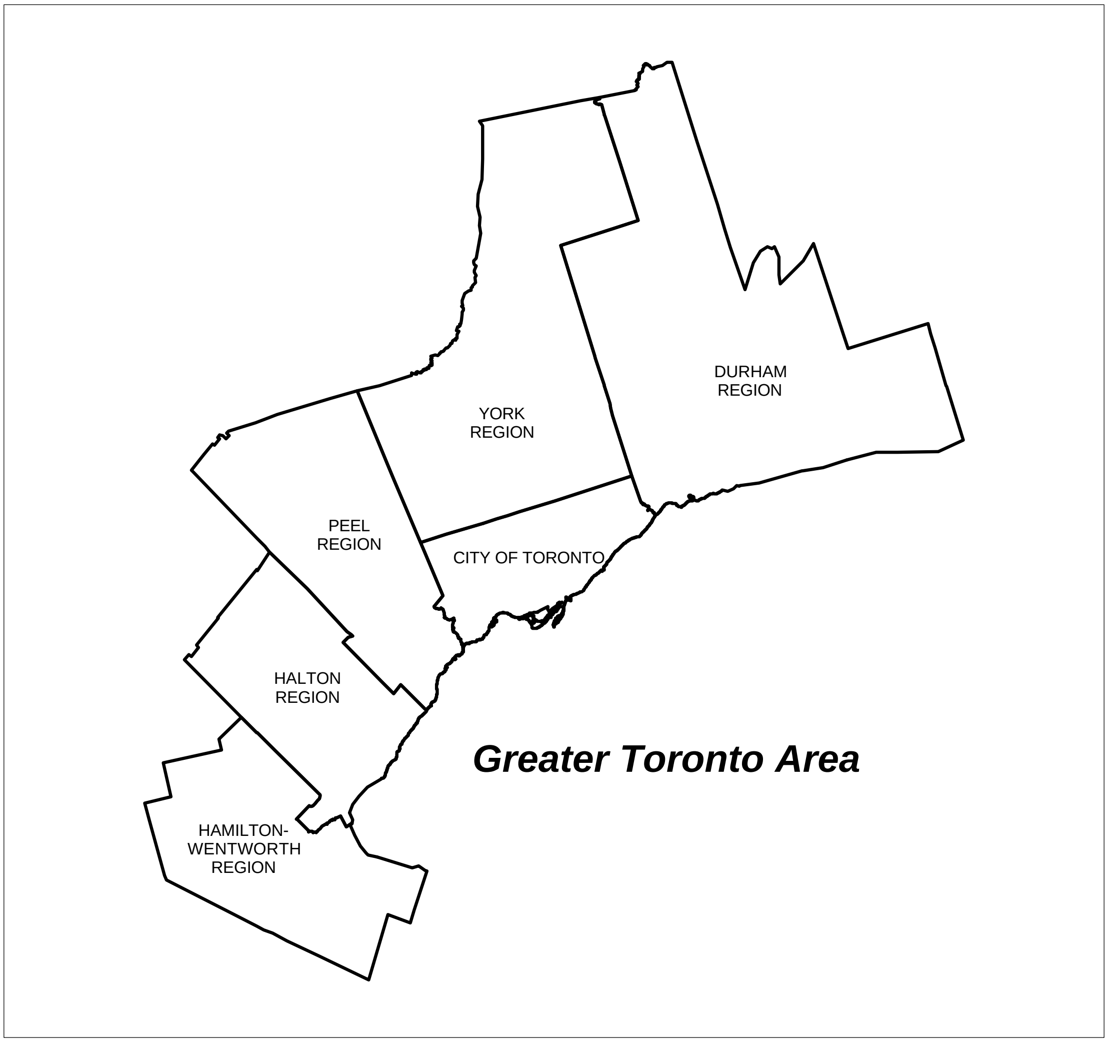

Figure 2.1
The Greater Toronto Area

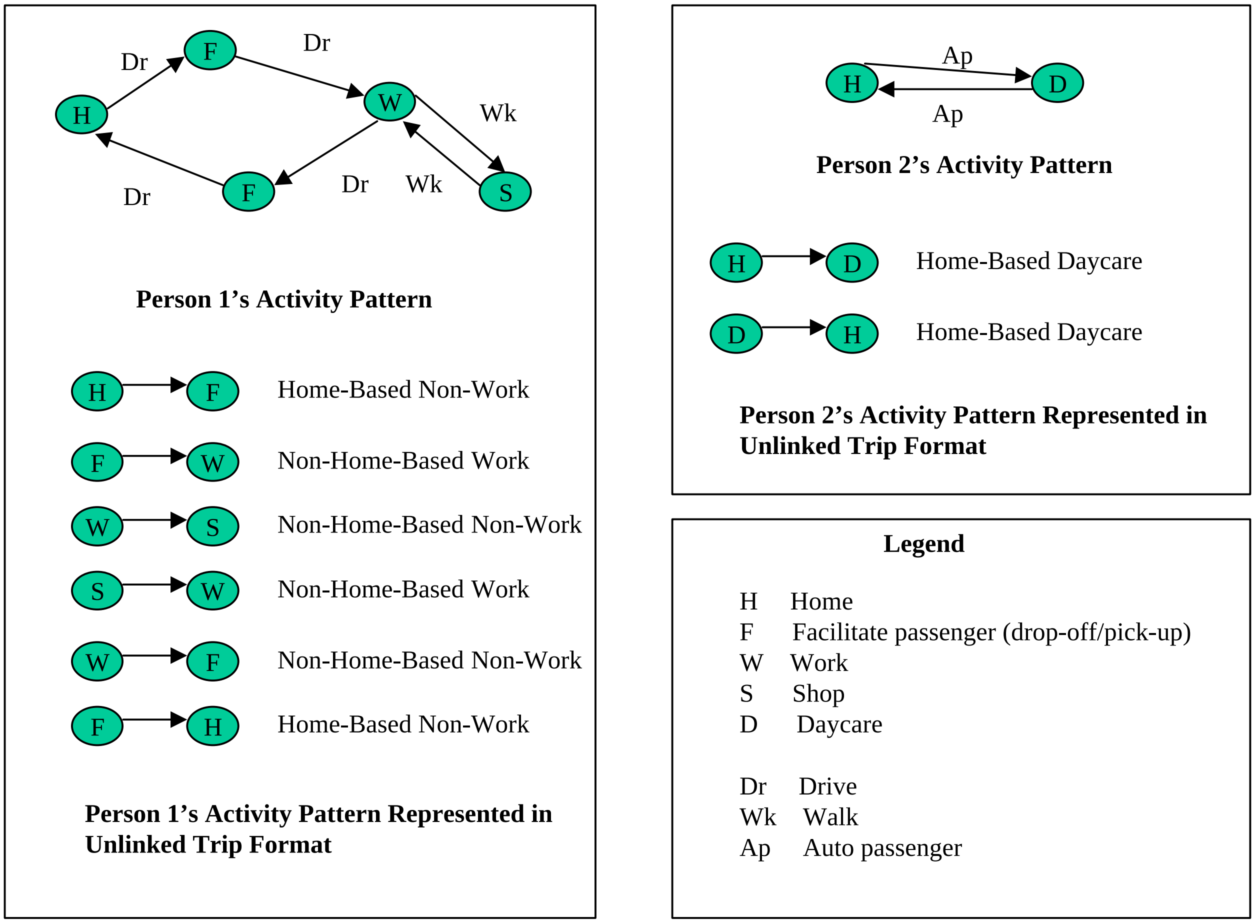

Figure 5.1 Example Daily Activity Pattern & Trip-Based Representation

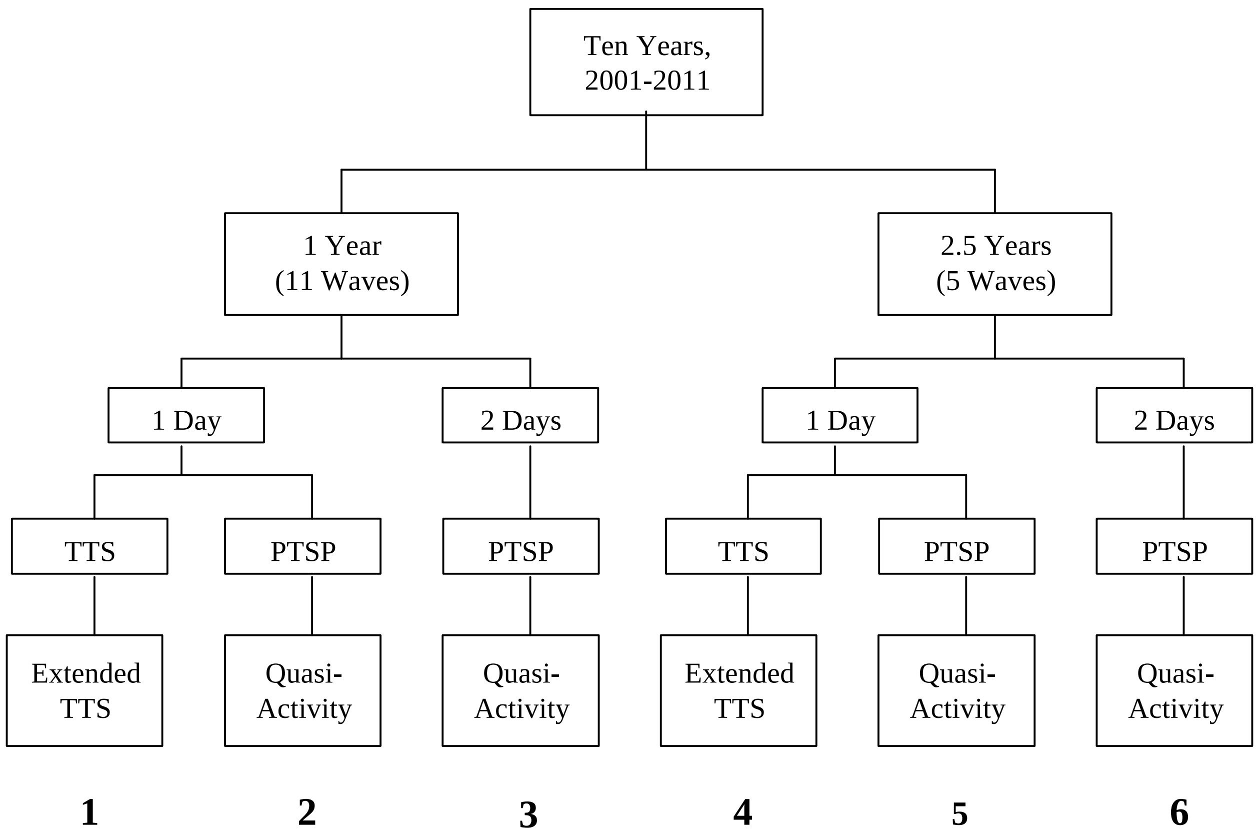

Figure 6.1
Alternative GTA Panel Survey Design Options

Table 2.1
TTS Aggregate Attributes
(Source: Data Management Group, 1987, 1992, 1997b)

	1986	**1991**	**1996**
Sample Size (households)	61,453	21,507	115,193
Average Sample Rate	4.1%	1.4%	5.0%
Study Area	6 GTA Regions	6 Regions + "fringe"	Extended GTA
Survey Method	Advance letter Telephone Interview Single respondant	Advance letter Telephone Interview Single respondant	Advance letter Telephone Interview Single respondant
Data Recording Method	"Pencil & paper"	Direct Data Entry	Direct Data Entry
Geocoding	Yes	Yes	Yes
Questions Added		1. Place of work 2. Name of school 3. Free work parking	1. Transit pass? 2. Occupation 3. Work at home?
Min. Age for Inclusion in Survey	6	11	11
Total Cost (1996$)	$1,335,000	$664,516	$1,918,600
Cost/(Completed Household)	$21.72	$22.07	$16.65
Stratification	Uniform random, Regionally balanced	Stratified: - 4.5% in "high growth areas" - 0.5% in "low growth areas"	Uniform random, Regionally balanced
Completion Rate (Comp/Total Sample)	60.1%	72.2%	70.0%
Refusal Rate (Refusals/Contact)	25.9%	11.3%	21.8%

Table 6.1
Preliminary Cost Estimates for a GTA Panel Survey

Design Option	Sample Size	# of Waves		# of Days Per Wave	Cost/Completion		Total Cost
		TTS*	Non-TTS		TTS*	Non-TTS	
1	2000	3	8	1	0	20	$320,000
2	2000	3	8	1	20	40	$760,000
3	2000	3	8	2	25	45	$870,000
4	2000	3	2	1	0	20	$80,000
5	2000	3	2	1	20	40	$280,000
6	2000	3	2	2	25	45	$330,000

Notes:

* TTS refers to waves occuring concurrently with a cross-sectional TTS (i.e., in the fall of 2001, 2006 and 2011).
Non-TTS refers to waves occuring at other time periods.