Use of Direct Data Entry for Travel Surveys

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Telephone interviews are a popular way to collect survey information. In the traditional paper-and-pencil method, the interviewer records the responses on paper forms, and later the information is input into a computer file for error checking and further analysis. The quality of the data depends not only on interviewing skill but also on the ability of the interviewer to write legibly, the accuracy of the data entry staff, and the feedback process in reporting ambiguous or incorrect information. Data of higher quality can be obtained by having the interviewer directly enter the data into a computer file as the interview proceeds. Direct data entry would minimize data entry errors while enhancing quality control and the overall processing of the data. The design and use of a direct data entry system in the conduct of a major household travel survey in the greater Toronto area are discussed. Besides obtaining good-quality data, the DDE software also improved sample control, the rate at which interviews were completed, and the monitoring of interviewers' performance and progress. To identify the costs and benefits of direct data entry, extensive comparisons are made with a survey that was similar in terms of survey area and questionnaire design but conducted using the paper-and-pencil method.

In the fall of 1991, a comprehensive household travel survey—the 1991 Transportation Tomorrow Survey (TTS)—was conducted in the greater Toronto area. The 1991 survey was intended to update a survey performed in 1986, which was also called the Transportation Tomorrow Survey. The earlier survey has been the primary data source for transportation planning in the greater Toronto area. Both the 1986 and 1991 surveys were conducted by telephone and preceded by an advance letter informing households about the survey. The survey area includes the regional municipalities of Durham, York, Peel, Halton, and Hamilton-Wentworth and the municipality of metropolitan Toronto (Figure 1). Households were sampled randomly using telephone listings supplied by Teledirect, a subsidiary of Bell Canada. The most significant difference in the conduct of the two surveys was in the area of automation, especially in the use of a direct data entry (DDE) system in the 1991 survey.

The 1986 TTS used the traditional paper-and-pencil technique [despite some promising results from a prototype DDE system that was tested as a part of the pilot study for that survey (*1*)]. The interviewer recorded the responses on standard paper forms. After the interview supervisor checked them visually, the interview forms were passed to a data entry team for data entry and then on to a coding team. The sampling of households was done manually, and no logic or range checks were performed on the data collected until the whole household interview had been fully coded.

Because of the size of the survey (about 61,700 completed household interviews were performed), the data entry and coding processes were unable to keep pace with the interviewing, a problem that worsened as the survey progressed. In some cases, households with ambiguous information were not called back until weeks after the original interview. Although the 1986 survey data were reliable and informative, it took more than a year of postprocessing and checking before the data were available for detailed analysis. At the conclusion of the 1986 survey, the need to improve both quality control and the efficiency of the data processing was clearly identified, so the use of DDE for the 1991 survey was recommended (*2*).

WHY A TELEPHONE SURVEY?

There were a number of reasons for the original decision to conduct a telephone survey instead of a self-reporting mail-back survey. The experience in a number of Canadian urban travel surveys had been that telephone surveys, with sufficient interviewer training, can achieve a relatively high response rate. Telephone interviewers can clarify confusing questions when interviewees register confusion or resistance, which tends to increase the response rate. In mail-back surveys, the respondent burden is high, especially on detailed travel survey questionnaires. Therefore, mail-back surveys can underrepresent groups that are not fully literate in English or not accustomed to filling out complex forms; examples of such groups are seniors and recent immigrants.

It was understood that telephone surveying tends to underreport discretionary and non-home-based travel. To assess this, the 1986 TTS was followed up with a mail-back diary survey to a random sample of the interviewed households. The results of this survey indicated that the telephone survey collected peak-period trips just as well as the mail-back trip diary survey (*3*). In addition, measures such as proper follow-up calls to those persons whose behaviors could not be reported accurately by the person who answered the telephone can (and do) result in improved overall trip reporting.

BENEFITS OF DIRECT DATA ENTRY

The benefits achieved by the DDE system, as implemented for the 1991 TTS, were twofold. First, it enhanced the quality of the data collected during the course of the survey. The

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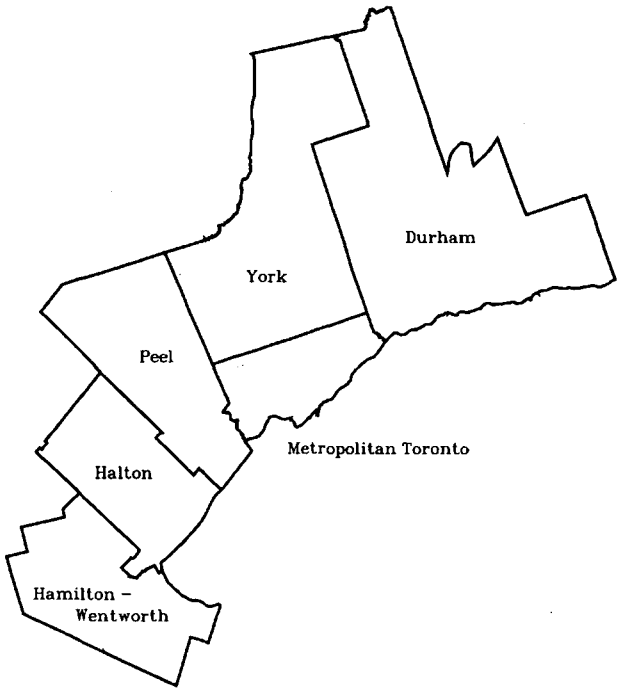

FIGURE 1 Survey area: greater Toronto area.

ability of the interviewer to enter the information as the interview proceeded eliminated the need for data entry after the interview had been completed. This capability saved time and effort and minimized the potential for data entry errors. Having the interview in electronic format also enhanced the efficiency of sample and quality control. The DDE system was fully integrated with a sample control software system. The interview status (for example, "successfully completed," "call back required," or "answering machine encountered") of each household was monitored daily by the sample control software. By integrating the sample control and interviewing software, a household could be scheduled to be interviewed on a specific date at a specific time if necessary.

Second, it dramatically reduced the amount of time required for the postprocessing of the survey data. The postprocessing task for the 1986 survey included data entry, coding of transit routes, and assigning X and Y geocodes to all location information. For the 1991 survey, DDE eliminated the need for post-survey data entry. By implementing look-up tables of transit routes (and their interconnections) within the DDE software, transit routes were verified and coded as the interview proceeded. Geocoding of location data (e.g., trip origin, destination, transit transfer point) was also aided through the use of look-up tables of street and municipality names. Logic and range checks were also part of the DDE system. Fundamental errors, such as driving under age or without a driver's license, were noted and corrected immediately, thus minimizing the number of call backs and post-survey edits required. The substantial reduction in elapsed time to code, check, and validate the collected data was viewed as one of the greatest benefits achieved through the use of this software (*4*).

SOFTWARE DESIGN

The DDE system has been written using a DOS-based data base management software package to run on stand-alone IBM-compatible personal computers (PCs). The key design criterion was to automate as much as possible of the data collection and verification process, without sacrificing speed to the point that the interview would become unacceptably long. The speed of the DDE system is evidenced by the fact that it can be run satisfactorily on a 16Mhz 80286-based microcomputer. Key features of the system include an integrated household sample selection and control capability, a built-in interview script, and cross referencing of information. The data verification features include on-line logic and range checking and look-up tables for verification of key items, including school names, transit routes, municipalities, and street names.

Sample Selection and Control

At the beginning of every interview session, each interviewer receives a sample group of households on a floppy diskette. The sample is generated by the sample control software running on a central sample control and data processing machine. The sample issued to each interviewer consists of households with three interview status levels, scheduled times to call back, prior unsuccessful attempts to make contact (e.g., no answer), and no prior contact histories. The sample file is first copied from the floppy diskette to the hard disk of the PC being used by the interviewer, and subsequent work is performed directly from the hard disk. To avoid loss of information during an interview, information is saved onto the hard disk at the end of each data field entry, and the complete file is copied back onto the floppy diskette at the end of each interview.

The DDE software automatically sequences the households for the interviewer by first drawing households with scheduled call-back times, followed by the physical order of the households in the sample file. There are two types of scheduled call backs: those set by the interviewer and those set automatically by the DDE software. An interviewer can schedule a call back if a household requests to be interviewed at a later date and time or if additional information is to be provided at a later time. Automatic call backs are set by the DDE software if an interviewer encounters a busy signal, no answer, or an answering machine. In the latter case, the interviewer is also given a brief message to leave on the answering machine. Up to eight attempts are made to contact each household.

An interviewer can also specify which household to interview or review. There are two ways to do this: interviewers can select one of the interviews they have worked on earlier during the same interview session, or a supervisor logged into the system (i.e., running the software in supervisor mode) can specify a household by its telephone number. Running the software in supervisor mode is most useful in dealing with a household that calls in response to a message left on its answering machine and to perform post-interview corrections and edits.

Working Screens

Every working screen in the DDE system is divided into three sections. Relevant information collected during the interview is constantly updated and displayed in the top portion of the screen. For example, on the trip data screen, the person's name, age, gender, and home and work addresses are shown while trip information is collected. The middle portion of the screen is the active area where the interviewer keys in the required information. Full screen editing capability is available in this middle section. The bottom section of the screen contains instructions to the interviewer, including the interview script for the current data item, available options, and valid response codes. Function keys are used to jump from one screen to another for quick editing and review. Most responses are subject to logic and range checking. When the keyed data are in error, a warning message is displayed and the interviewer is instructed to either change the keyed entry or confirm that it is the intended response.

The five main working screens are described in the following.

Household Selection Screen

The Household selection screen is the first screen presented to the interviewer after logging into the system. Interviewers may choose to either interview the next household or review a previously interviewed household. Supervisors may choose two additional options: selecting a specific non-English-speaking household or selecting a household by its telephone number.

After a choice is made, the DDE software locates an appropriate household in the interview sequence or the household specified by the user. The household's family name, address, and telephone number are then displayed, along with information about any previous contact attempts. This contact history includes the time and date of previous calls, the reasons for having to call back (such as no answer, line busy, answering machine encountered, or incomplete interview), and any memo messages left behind by previous interviewers. These memo messages can be reviewed or edited at any time during the interview. The objective is to familiarize the interviewer with the household as much as possible before contact is made.

Using a series of messages, the screen guides the user through the process of contacting members of the appropriate household, finding out if they received the presurvey mailing informing them of the purpose of the survey, and determining if they are willing to participate at this time. If so, the interview proceeds to the household data screen.

Household Data Screen

Household information collected during the survey includes confirmation of the household's address, the dwelling type, the number of household members, and the number of vehicles available for the use of household members. Because of the multicultural nature of the greater Toronto area, the language used for the interview is also indicated by the interviewer on this screen (Figure 2). If the household indicated a preference to be interviewed in a language other than English, the interviewer would terminate the interview, indicating to the software that a call back was desired by someone with skills in that language.

The information collected on this screen, particularly the number of people, sets logical and sequence conditions for the collection of person and trip information.

Person Data Screen

Personal information is collected for one person at a time, for each member of the household, before the travel information is collected. Person data include the person's name or some other identification label (such as mother, father, or respondent), age, gender, possession of a driver's license, employment and student status, and the person's usual place

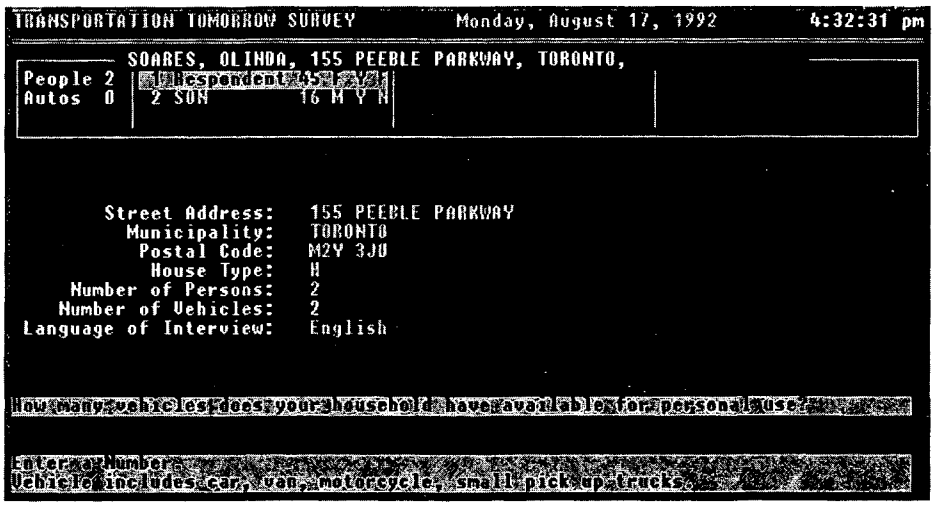

FIGURE 2 Household data screen.

of work or school, if applicable (see Figure 3 for example of screen). The work or school address is entered as a street address, an intersection, or a monument name. Monument names are identifiers for particular buildings, landmarks, or attractions. This information is verified as it is entered using the look-up tables described in the following. If the person is employed, the interviewer asks whether free parking is available at work. Employment, student, and trip information are not collected for persons younger than 11.

Trip Data Screen

The aim of the DDE system is to reconstruct sequentially the complete 1-day travel activities of each person in the household. To do this the interviewer establishes whether each person made any trips on the travel day. This travel day is usually the weekday previous to the day on which the survey takes place. If an individual made one or more trips, the information collected is the first origin of the day (usually the home) followed by all subsequent trip destinations.

The trip end point is entered as a street address, intersection, or monument. This information is again verified using the look-up tables. Because a person's daily trip activities are often made up of his or her home, work, and school locations, trip destinations can also be specified with a home, usual place of work, or usual place of school choice. The address information collected in the household and person data screens are automatically transferred to the trip records. This feature not only speeds up the interviewing process, it also eliminates duplication of effort during geocoding and gets rid of a potential source of error.

Trip purpose, start time, and mode of travel are also recorded. The start time is checked to ensure that trips are being recorded sequentially. If the mode of travel is automobile driver, the software checks for the possession of a driver's license and the availability of a private vehicle.

The trip data screen (Figure 4) contains the most information of all the working screens. Not only does it display the current person's personal and trip information, it also shows the same trip information for all other members of the household. If several members of the household traveled to the same location, a simple copy command can duplicate an entire trip. Full screen editing capability is available so that any trip record can be edited. However, only trips for the current active person can be inserted or deleted.

Transit Data Screen

One of the requirements of the survey was to collect detailed routing information for transit trips. Thus, a special screen was designed solely for these trips (Figure 5).

The transit data screen is activated when public transit is specified as the mode of travel. Besides individual transit routes, access and egress modes to and from transit are also recorded. When the first or last route is commuter rail or subway and the access or egress mode is automobile driver, automobile passenger, or taxi, the transfer station name is also recorded. On-line transit coding is performed using look-up tables of transit routes and station names. Transit routes are identified by either their formal or alias names or their route numbers. Every route is also checked for connectivity with the previous route.

Because a commuter will often use the same routes to return to their initial origin, an option to reverse the routings of a previous transit trip is made available to the interviewer.

LOOK-UP TABLES

Providing on-line detailed tables of helpful information on the different working screens is one key to the smooth operation of the DDE system. It reduces key strokes while enhancing data quality by minimizing spelling errors and ensuring that a description complete enough to allow accurate geocoding has been recorded. For example, when recording a street address, it is important that its street type (e.g., "Av-

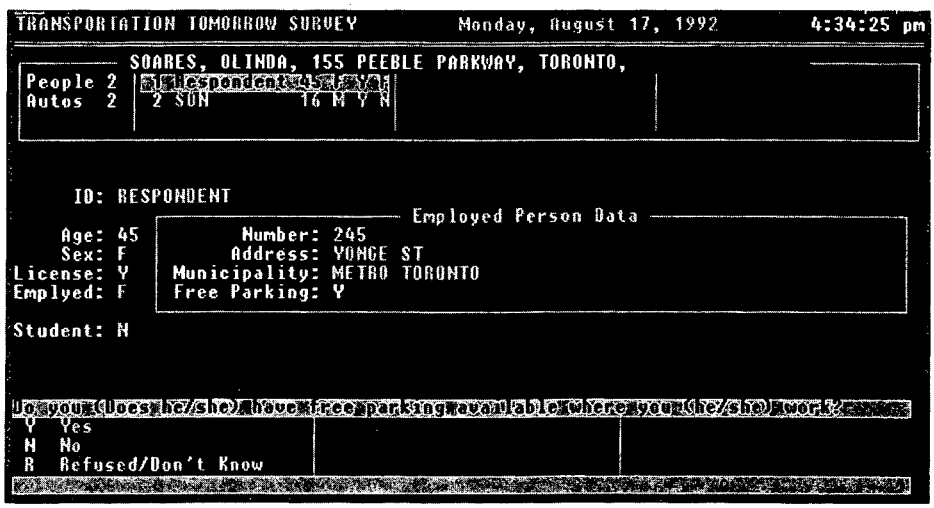

FIGURE 3 Person data screen.

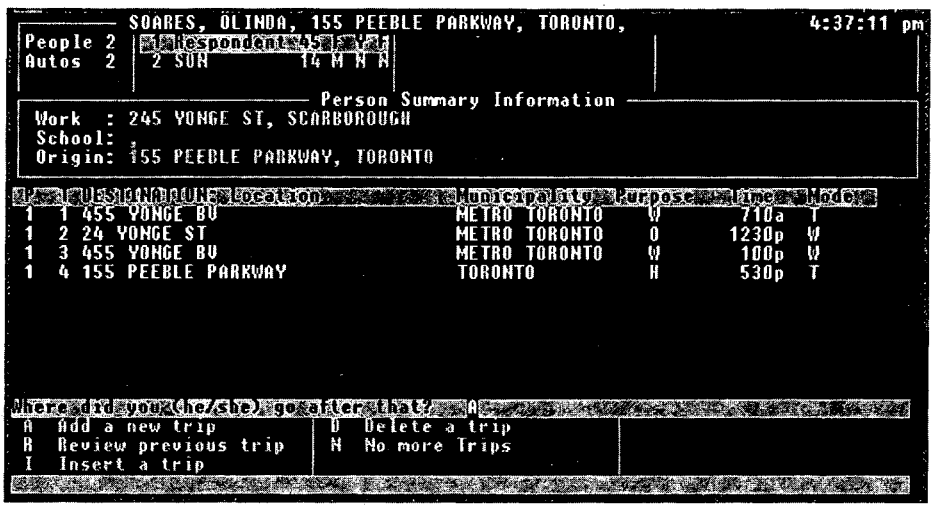

FIGURE 4 Trip data screen.

enue," "Road," "Court") and direction (e.g., "East," "West") are also recorded. Because many streets have similar or exact names ("King Street" being the worst offender in the survey area), it is also important to have the interviewer confirm the correct municipality for the street address. Another example is in the recording of schools and community colleges for which the campus name and the institution type are vital.

The tables are presented in pop-up "browse and select" windows. There are five of these windows for listings of municipalities, streets, schools, transit routes, and transit stations. All of these windows can be operated in two ways. First, as the interviewer enters information character by character, the software searches for a unique match in the look-up table. If enough information is entered to locate a unique match, the software displays the match and prompts the interviewer to confirm that this is the correct entry. The interviewer can either accept the match or override the selection and continue to input the rest of the information. The second way is to enter the first few characters, then press "Enter" to bring up a list of all the entries in the look-up table that match the characters typed so far. The list appears in a pop-up window, and the interviewer can scroll through the list to select an entry. This feature is particularly useful when the information being entered is lengthy or difficult to spell, or if the interviewer expects a short list of matches. If no entry in the look-up table matches the typed characters, the software automatically displays a box in which the interviewer can type the rest of the name. A summary of these five browse-and-select windows is presented in Table 1, and examples are given in Figures 6 and 7.

The data for the look-up tables come from several sources. The municipality look-up table is based on a local listing from the Ministry of Transportation, Ontario. The street look-up table is an extraction from the Street Network File (SNF), which is managed by Statistics Canada. The SNF is similar to the TIGER file maintained by the U.S. Department of Commerce. The school listing is a result of a file on public and secondary schools from the Ontario Ministry of Education

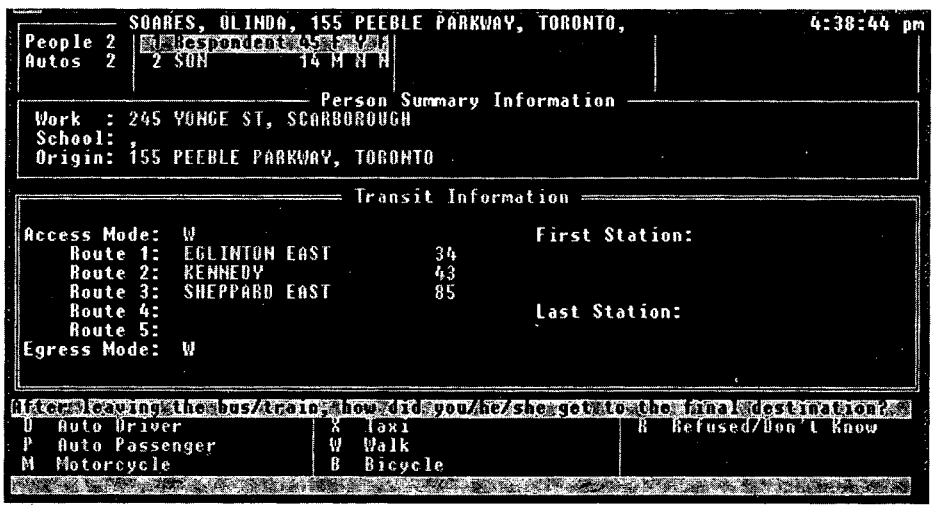

FIGURE 5 Transit data screen.

TABLE 1 Summary of Look-Up Tables

Type	Table Contents
Street	A listing of streets in the survey area sorted by name, type, direction and area municipality. Where there were two or more streets with the exact same description within a municipality, they were differentiated by hamlets. Selection of a street also determined the municipality name.
Municipality	In addition to the area municipality names, entries also included the names of local postal districts and hamlets.
School	All public, private, separate schools and post-secondary institutions in the survey area were included in this table. In addition, individual campuses were listed for all post-secondary institutions. The list was sorted by school name and area municipality.
Transit Route	Transit routes were searched by their formal name or alias name or route number. The list contained both the route and the operator names and included inter-city transit properties, as well as some privately operated shuttle services. Interconnections between transit routes were recorded in a separate database.
Transit Station	Commuter rail and subway stations were presented in separate listings.

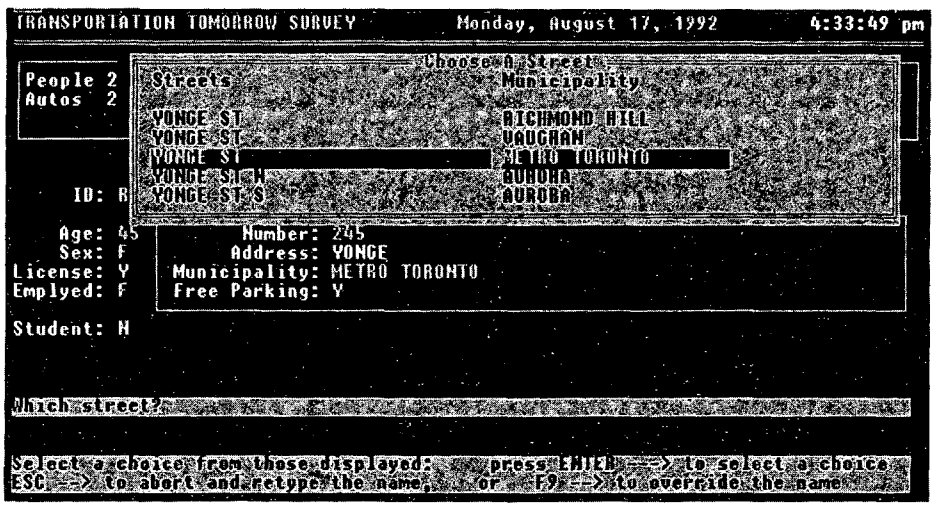

FIGURE 6 Street look-up table.

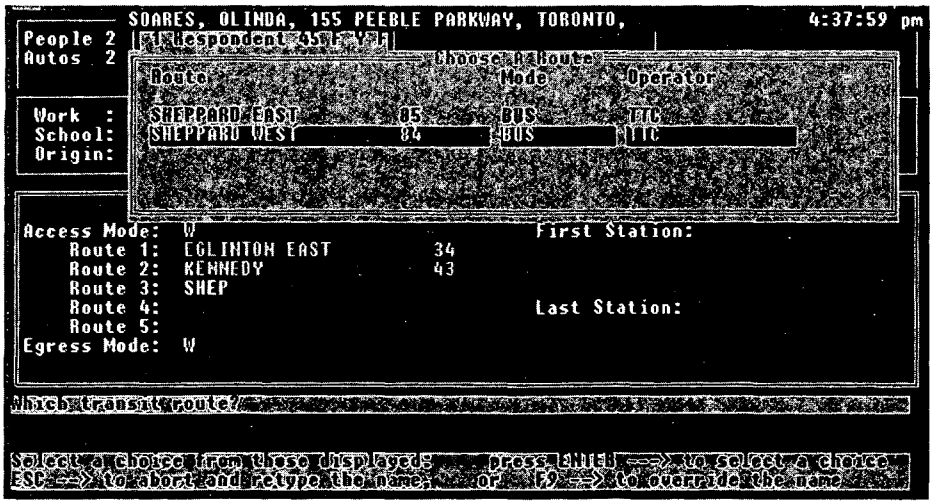

FIGURE 7 Transit route look-up table.

and a file on post-secondary schools collected from the individual regional municipality planning offices. Transit routes and station names are extracted from a transit modeling data base that is managed by the Data Management Group on behalf of the same agencies that sponsored the survey.

COMPARISON WITH 1986 SURVEY

To identify the costs and benefits of DDE, the 1991 survey (using DDE) and the 1986 survey (using paper and pencil) are compared extensively. The two surveys are nearly identical in survey area and questionnaire design.

Interview Statistics

A summary of the interview statistics is given in Table 2. When the DDE system was designed, it was not anticipated that the rate at which interviews could be completed would be increased over that achieved using the pencil-and-paper technique. The focus was on increasing the quality of the data and reducing the postprocessing requirements. In fact, the average number of completed interviews per paid hour of interview started at 3.0 and increased to about 4.0 at the end of the survey. Overall, the average rate was 3.76 interviews per hour. The better interviewers consistently recorded 4.5 to 5.0 completions per hour. These rates are higher than the rates achieved in 1986, when the average rate was 3.5 interviews per hour.

Monitoring procedures ensured that the high 1991 rates were not achieved at the expense of data quality. For quality control, some of the interviewers' computers were connected to monitoring screens accessible only to the survey supervisor. The supervisor was able to choose which interviewer to monitor by means of a master control panel. When using the panel along with a telephone monitoring system, the supervisor could visually monitor data being entered while listening to the interview. This direct monitoring system was especially useful during the interviewer training process. Interviewers with the highest completion rates also tended to have the fewest problems requiring call backs, and their trip rates per person were consistently uniform at or slightly above the overall average. The number of contacts required to complete a household interview was not tracked by itself. Instead, the combined number of call attempts (including unsuccessful call attempts) and post-interview edits was recorded. In total, 40 percent of the completed interviews required only one call/edit attempt, and another 40 percent were completed by the third call/edit attempt.

Several factors contributed to the exceptionally low refusal rate, which was 11 percent in 1991 (compared with 27 percent in 1986). Keeping this rate low was a function of the advance letter sent to inform the household about the survey, intensive interview training, smooth and quick responses of the DDE system, and the practice of keeping the interview short.

Despite the complexity of the travel survey and the amount of information collected, according to the telephone billing the average household interview took approximately 7 min to complete. This includes recording of basic household data (such as address, number of persons and vehicles), person information (such as age, gender, place of work, and place of school) and all trips made by household members 11 and older on a given weekday. Keeping this time short was again a function of the advance letter (which confirmed the legitimacy of the survey), the interviewer script built into the DDE system, intensive interviewer training, and the efficiency of the software in generating look-up tables and cross referencing the data.

The average household size observed in the 1991 survey was 2.8 persons, the same as in 1986. The trip rate increased slightly from 2.4 trips per person in 1986 to 2.6 in 1991. In terms of survey content, the 1986 and 1991 surveys collected almost identical information. The major difference was that a person's usual place of work or school was collected, if applicable, in 1991 but not in 1986.

Postprocessing Statistics

One of the goals of the survey was to ensure that the geocoding process kept pace with the conduct of the interviews. In that way, any problems could be corrected immediately and call backs could be made while the interview was still fresh in the

TABLE 2 Interview Statistics

	1986 TTS	1991 TTS
Number of interview stations (computers and telephones for 1991)	75	33
Number of staff recruited (interviewers and supervisors)	225	70
Average completion rate (interviews per paid hour)	3.50	3.76
Number of households in study area	1,466,000	1,716,600
Population in study area	4,063,000	4,730,000
Sample used (attempted to contact)	102,606	34,167
Eligible contacts (excluding wrong numbers, numbers out of service, etc.)	83,764 (82%)	27,813 (81%)
Refusal rate (%)	27	11
Completed interviews	61,453	24,507
Invalid or unusable interviews	255	146
Households in final data base	61,453	24,507
Overall completion rate (%)	60	72

minds of the respondents. This objective was achieved by a team of six geocoders and one supervisor, a ratio of 1:5 to the number of interviewers on an average interview night. In 1986 the geocoder-to-interviewer ratio was about 1:2. With few exceptions all location information was geocoded within 3 working days of the actual interview, and the entire coding operation was fully completed within 1 month of the end of the survey. In 1986 it took an additional 6 months after the completion of the survey to fully code all of the information.

The success of the coding operation may be credited partly to the high quality control throughout the conduct of the survey and partly to the efficiency of the geocoding software. Geocoding was straightforward when survey data were complete and accurate as a result of the on-line look-up tables in the DDE software. In fact, 48 percent of all location data were batch-geocoded by matching the surveyed data with a geographic information system (GIS) data base. The GIS data base included listings of postal codes, street names with address ranges, intersections, and major monuments (activity centers) such as hospitals, educational institutions, shopping malls, and large employment generators. The monument file was created by including listings from various government ministries (such as Health and Education) and monument files from other survey projects. Only 7 percent of the interviews required call backs to clarify ambiguous location descriptions. One of the most time-consuming tasks in the 1986 survey was the coding of transit route information, which had to be done entirely manually. In 1991 only 5 percent of this information needed to be manually coded, a significant savings in postprocessing effort.

Cost Comparisons

A comparison of the 1991 survey variable costs with the variable costs of the 1986 survey is given in Table 3. An inflation factor of 27 percent, the rise in the consumer price index, has been used to adjust the 1986 cost to 1991 values. The unit cost of interviewing was 30 percent higher than in 1986. The higher cost was primarily due to the significantly higher wages paid to recruit and retain good interviewers and the need for individual computers and the electronic monitoring equipment. The higher interviewing costs were more than offset by the reduction of 70 percent in unit coding cost, a direct result of better quality control in the conduct of the survey by using DDE and improvements in the geocoding procedures. The other variable costs remained basically unchanged. The small saving in the printing and mailing of the advance letter is due to the higher overall completion rate in 1991 (72 versus 60 percent), resulting in fewer letters having to be mailed relative to the number of interviews completed. The total variable costs for the 1991 survey, at $12.69/completed interview, are estimated to represent a 19 percent saving relative to the cost of the 1986 survey.

TABLE 3 Variable Cost Comparison Between 1986 and 1991

	Adjusted 1986 Cost per Household	1991 Cost per Household
Interviewing		
Interviewers & Supervisors	$ 4.73	$ 6.29
Equipment & Supplies	$ 1.81	$ 2.20
	$ 6.54	$ 8.49
Coding		
Data Entry	$ 1.44	n/a
Geocoding/Transit coding	$ 5.41	$ 2.03
	$ 6.85	$ 2.03
Other Variable Costs		
Advance Letter	$ 1.23	$ 0.85
Other Direct Costs	$ 1.09	$ 1.33
	$ 2.33	$ 2.18
Total Variable Cost	**$15.72**	**$12.69**
Per Person	$ 5.67	$ 4.29
Per Trip	$ 2.62	$ 1.98

Comparing the fixed costs associated with the two surveys is more difficult because of the difference in management structures between the surveys. In 1986 a significant amount of staff time and ancillary support was contributed by the agencies for whom the survey was performed. This included staff assistance in the management of the survey, training interviewers, software development, and use of office space and computers. These costs were never specifically accounted for. In 1991 the costs for all of these tasks and resources were accounted for by the survey managers (the Data Management Group).

Another difference between the surveys was the size. Economies of scale were achieved in 1986 since three times more interviews were completed than in 1991. As a result, the documented 1991 development costs were significantly higher, at about $7.00/interview as opposed to $0.80/interview in 1986. Despite the high development cost, the overall cost of the 1991 survey was about $27.00/completed household interview. The fact that DDE is a relatively new technology to travel surveys meant that its development cost was expected to be high initially, but it should be reduced substantially in future applications.

CONCLUSIONS AND RECOMMENDATIONS

The DDE system as implemented for the 1991 TTS was found to be a success. The system was effective in

- Maintaining high standards of quality control,
- Enabling a higher-than-expected rate of successful interview completion,
- Reducing dramatically the effort required for postprocessing the survey data, and
- Achieving all of this in a cost-effective manner.

Its use in other surveys, either telephone or home interview, can be recommended with the following provisos:

- Other parts of the process, including sampling selection, performance monitoring, and coding, should be automated as part of a totally integrated process.

- Adequate lead time must be available for development, testing, and interview training on the use of the software.
- Support staff, with the appropriate computer skills, must be available for trouble shooting at all times during the conduct of telephone surveys.

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