A Small Sample Mail-Out/Telephone Collection Travel Survey

DAVID L. KURTH

The development, application, results, and costs of a small-scale mail-out/telephone collection travel survey conducted in the Denver metropolitan area from April to May 1985 are described. Steps taken to minimize the survey administration costs are discussed. Methods used to include households with unlisted telephone numbers, collect the travel data, and adjust the survey results to ensure that they matched observed distributions of households across various socioeconomic data are also discussed.

As the metropolitan planning organization (MPO) for the Denver metropolitan area, the Denver Regional Council of Governments (DRCOG) maintains the travel modeling capabilities for the region. The current regional travel model is based on a large-scale travel survey taken in 1971. Because the Denver area has experienced tremendous growth, two gasoline shortages, and a substantial reinvestment in and reemphasis on public transportation since 1971, the acquisition of current travel data is necessary to update and validate travel models. The acquisition of current travel data began in 1982 with the purchase of the 1980 Urban Transportation Planning Package (UTPP) data for the Denver area from the U.S. Census Bureau. This data has been used for validating portions of the current regional trip distribution model and for calibrating portions of subarea transportation models (*1*). However, because the UTPP data contain information on only the journey-to-work and is of marginal use in calibrating trip-generation models due to differences in the way travel questions were asked in the 1980 census and the way travel questions are normally asked in travel surveys, the need for a travel survey to supplement the UTPP data was obvious.

Based on the results of the 1971 travel survey, it was determined that at least 1,600 samples would be required to provide the statistical accuracy desired for the survey results (*2*). The need to ensure statistical accuracy and maintain consistency with normal travel survey procedures were in direct conflict with the limited budget available for outside consulting services. These constraints were satisfied using the following means:

- Much of the sample design was performed by DRCOG staff with review by the consultant;
- A simple random sample rather than a quota sample was used;
- A mail-out/telephone collection survey instrument was used to reduce the cost of surveying while maintaining the personal contact necessary to ensure full reporting of trips; and
- DRCOG performed the survey editing and geocoding.

Denver Regional Council of Governments, 2480 West 26th Avenue, Suite 200B, Denver, Colo. 80211.

Use of these methods resulted in obtaining the required number of samples at a reasonable cost. Preliminary summary statistics from the travel survey are reasonable when compared to the results of the 1971 travel survey.

Several aspects of the survey methodology are emphasized in this paper, and a brief overview of some of the survey results is provided. Under survey methodology, the process for obtaining sample households, including households with unlisted telephone numbers, innovations in the survey form/travel diary, and the importance of the pretest will be discussed. The brief overview of the survey results will include discussions of response rates, geocoding problems, the need for weighting of survey results, the differences in travel characteristics between households with listed telephone numbers and unlisted telephone numbers, and the total cost per sample.

SURVEY METHODOLOGY

Development of a Random Sample

One key to obtaining an unbiased travel survey is the selection of a random set of households from which the actual samples are drawn. Because it was predetermined that the survey data would be collected via the telephone, the development of a random set of households was reduced to the generation of a random set of telephone numbers. Several well-known options were available: random digit dialing, random telephone-book search, or purchase of a list from a third party.

Random digit dialing was rejected as a methodology because of the survey cost involved with dialing invalid or commercial numbers. The random telephone book search was less costly in terms of invalid numbers, but had the drawback of a possible bias because of failure to account for households with unlisted telephone numbers. In the Denver area it is estimated that about 28 percent of working telephones have unlisted numbers, so the possible bias was substantial.

Fortunately, a company was found that solved the aforementioned problems and that eventually reduced the cost of drawing a sample. The company was able to draw a random sample of telephone numbers from a computerized listing of the telephone directories covering the survey area. The random sample provided included telephone numbers, names, addresses, and zip codes. In order to supplement the original list for unlisted telephone numbers a set of random telephone numbers was generated in such a way that only numbers in working exchanges were included. Also, the block of numbers (100 consecutive numbers) that bounded the random number had to include at least one valid working number. This list was compared to the listed numbers in the region to remove possible duplications and was also compared to a data base of commer-

cial numbers to reduce the likelihood of reaching a commerical firm. Therefore, the probability of each of the random digit telephone numbers being a valid household was increased substantially.

The cost per telephone number from the third party was about 30 cents, or approximately $1,500 for the entire sample. However, later cost savings were substantial. These savings were a result of the name, addresses, zip codes, and telephone numbers of each sample household being transmitted on computer tape. After the data were transferred to floppy diskette, the consultant was able to write a survey management program to generate surveyor assignment sheets, track the outcome of the initial contact, and, if the household agreed to participate in the survey, to generate mailing labels and track the progress of the data collection.

Methods to Maximize Survey Participation

The initial contact was very important in increasing participation in the survey. Because the surveyor assignment sheets were generated by the data-base management program, it was possible to contact most households by name (except the households with unlisted telephone numbers). Initial contact included a brief explanation of the purpose of the survey, several brief questions including household size, automobile ownership, and whether or not the address was still valid. Travel dates were assigned and the fact that the household would be receiving a travel packet with diaries and instructions several days before their travel day was explained. The initial telephone contact did not include the question, "Are you willing to participate in this survey?" This removed one readily available reason to decline participation.

Travel survey packets were mailed to participating households so that they arrived several days before the assigned travel day. The packets included travel diaries, a form listing the household questions that would be asked, simple instructions, and a letter urging participation in the survey that was signed by the governor.

Telephone collection of the survey data began 1 or 2 days after the actual travel day. Collection forms were identical to the household questionnaire and travel diaries mailed to participating households to minimize confusion in the collection process. The survey pretest indicated that there was a possibility of under-reporting trips, therefore several memory-jogger questions were added to the final survey. For example, surveyors asked if any trips were made while the person was at work on the travel day. If the response was yes, surveyors made sure that at least one nonhome-based trip had been recorded for that person. In addition, surveyors were instructed to probe for trips that are easily forgotten.

The Travel Diary

Travel diaries were sent to each participating household in an effort to ensure the full reporting of travel. The diaries were printed on card stock (front and back) for durability and designed to fit easily into a coat, pocket, or purse (Figure 1). Several innovations in the diary made it easy to use. First, a "cascading destination" recording process was used to eliminate the duplication of effort caused by recording both the origin and destination of each trip. Because the destination of one trip is generally the origin of the subsequent trip, no information was lost by recording only trip destinations. However, a space for recording the origin of the first trip of the day was necessary.

The second innovation was the method of coding destinations of trips. Four methods of coding destination locations were accepted: the actual address, nearest intersecting streets, an actual place name, or home. In the actual survey, about 52 percent of the recorded destinations were home. Since home addresses were available from the data-base management program, coding home substantially reduced coding time, keypunch costs, geocoding costs, and data recording and entry errors.

BASIC SURVEY RESULTS

Response Rates

The outcome of the random sample of telephone numbers contacted for the travel survey is summarized in Table 1. Over 40 percent of the households initially contacted agreed to participate (or, more precisely, did not refuse to participate) in the travel survey, and about 34 percent of the initial contacts resulted in successful interviews. Therefore, about 83 percent of the households that agreed to participate in the survey completed successful interviews.

The survey was scheduled to run from April 15 through May 23. Because the disposition of each sample was monitored continually throughout the survey using the data-base management system, the consultant was able to schedule surveyors quite effectively. The current information on the status of samples to date enabled the consultant to complete the survey on schedule.

Geocoding

In order to maximize the amount of money available for actual surveying, editing and geocoding of the travel survey were performed by DRCOG staff. Geocoding is an expensive and time-consuming process even when computer programs such as UNIMATCH are used. In small sample surveys, it is important to resolve as many errors and geocoding problems in order to avoid losing samples. Therefore, when one trip record listed only the name of a restaurant chain as the destination, it was believed acceptable to expend the time necessary to track down the actual location of the only feasible restaurant of that chain based on travel time from the traveler's last stop.

As was mentioned previously, four different methods were used for recording addresses: the actual address, nearest intersection, place name, and home. The distribution of the various address-recording methods on the household and trip portions of the travel survey along with the percentage of addresses automatically geocoded is given in Table 2. Based on Table 2, out of 20,373 actual addresses requiring geocoding, 79 percent were automatically geocoded. The remaining 4,210 addresses

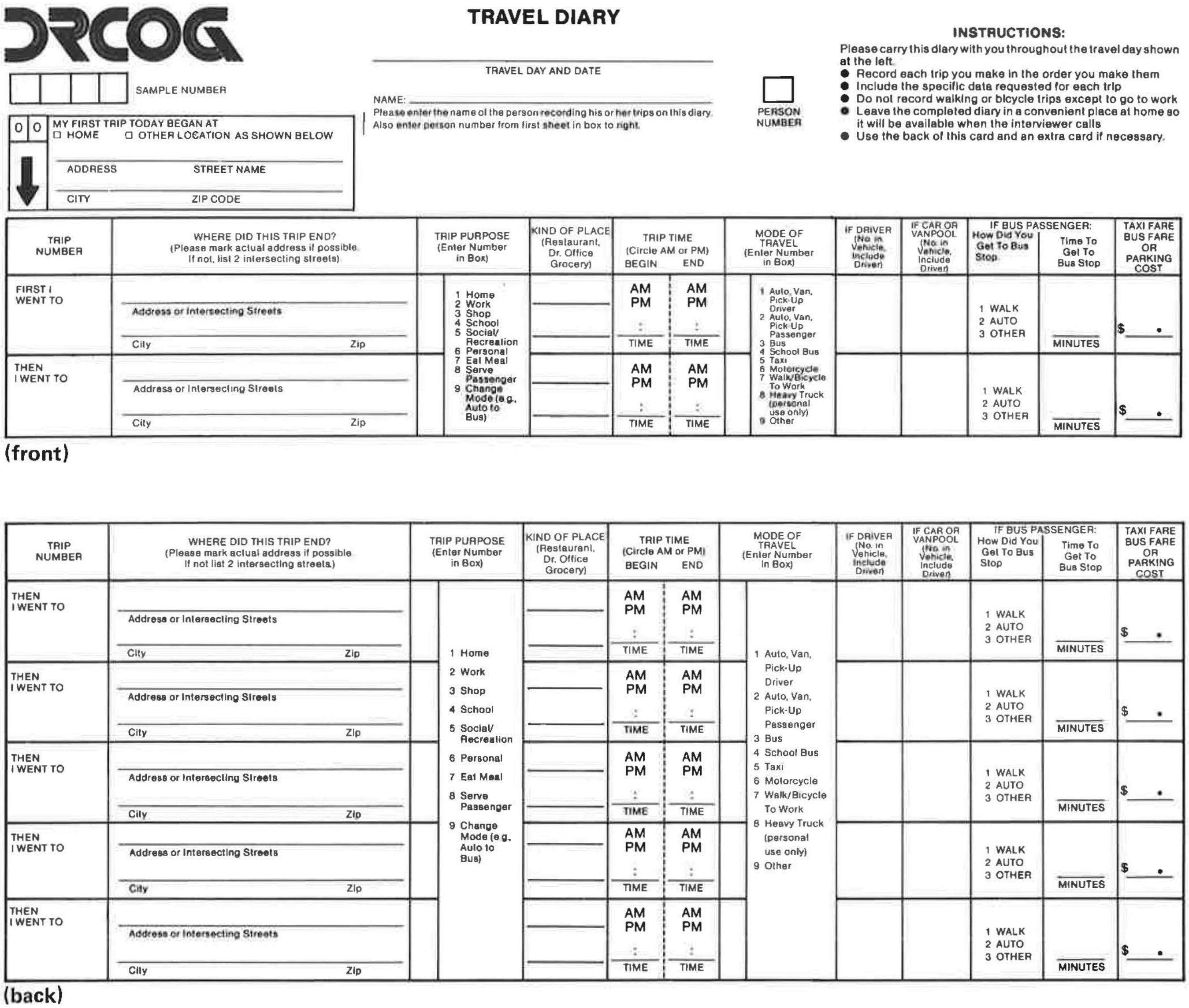

FIGURE 1 DRCOG travel diary.

TABLE 1 DISPOSITION OF TRAVEL SURVEY TELEPHONE CONTACTS

Item	Number	Percentage of Initial Contacts
Initial contacts	4,871	100
Refused to participate	1,302	26.7
Agreed to participate	1,988	40.8
Disconnected numbers	640	13.1
Moved	137	2.8
Commercial[a]	220	4.5
Continually busy or no answer[b]	370	7.6
Outside of survey area	214	4.4
Successful interview	1,646	33.8
Interview pending	30	0.6
Refused to report trips	312	6.4

[a]From random digit dialing for unlisted numbers.
[b]After three attempts.

required manual geocoding. This manual geocoding took about 400 hr, or about 6 min per address.

Sample Biases and Corrections

As with any survey, there was a possibility of bias in the travel survey. There were two possible sources of error: error in the original sample frame and error introduced due to refusals to participate in the survey. When the travel survey was compared to regional distributions of households by income group, household size, automobile ownership, and geographic location the undersampling of low-income households, low-automobile-owning households, one- and two-person households, and households in the central city was obvious.

In order to correct for the biases in the survey, a marginal weighting technique (*3*) was used to calculate survey expansion factors. Under this technique, the number of samples in each

TABLE 2 ADDRESS CODING METHOD RESULTS

Method	Number of Addresses	Percentage of Addresses	Percentage of Addresses Automatically Geocoded
Household records			
Actual address	1,645	100	71
Trip records			
Actual address	3,493	18.7	65
Intersection	5,353	28.6	57
Place name	190	1.0	0
Home	9,691	51.7	100
Total	20,372	100	79

cell of the distribution of households by income group, household size, and automobile ownership was summarized. Expansion factors for households in each cell were then calculated so that the expanded samples matched the marginal distributions of households in the region for each of the three strata. Expansion factors varied from 251 for two-person households with two automobiles and an annual income between $25,000 and $34,000 to 1,531 for one-person households with no automobiles and an annual income of less than $10,000. For reference, if every sample had been weighted uniformly so that the total reflected the actual number of households in the region, the expansion factor for each sample would have been 398. After the expansion factors were applied, the distribution of sampled households by geographic location also matched the observed regional distribution even though the calculated expansion factors did not explicitly account for this bias.

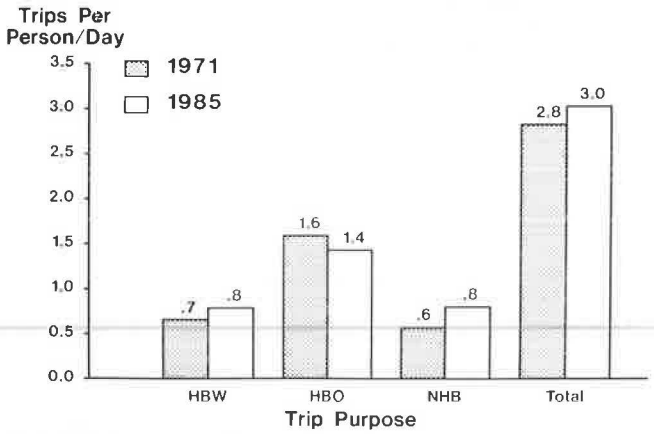

FIGURE 3 Average trips per person.

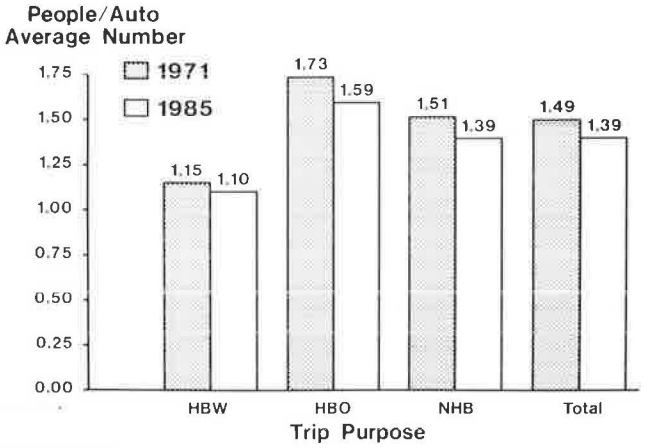

FIGURE 4 Average automobile occupancy.

Preliminary Survey Results

Some of the preliminary survey results are compared to results from the large-scale origin-destination survey taken in the Denver region in 1971 (*4*) in Figures 2 to 5. As can be seen in Figures 2 and 3, travel habits in Denver have changed since 1971. An increasing proportion of daily travel is associated with work. This should be expected due to the increasing number of multiworker households in the region. In addition, the proportion of home-based other travel has decreased, being replaced, instead, by nonhome-based travel. The substitution of nonhome-based travel for home-based other travel is also probably due to the increase in multiworker households in the region.

Total trip making per person has increased by about 7 percent in the 14 years since 1971. This fact, along with the increase in population, has increased personal travel in Denver from 3,155,000 trips per day in 1971 to 5,012,000 trips per day in 1985. Although the number of person trips per day increased 58.9 percent between 1971 and 1985, the number of vehicle trips per day increased 81.2 percent from 2,099,000 trips per

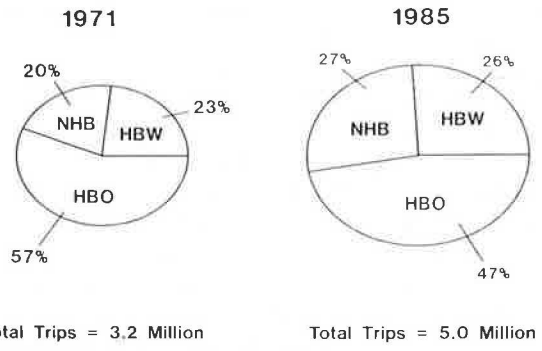

FIGURE 2 Trip making by trip purpose.

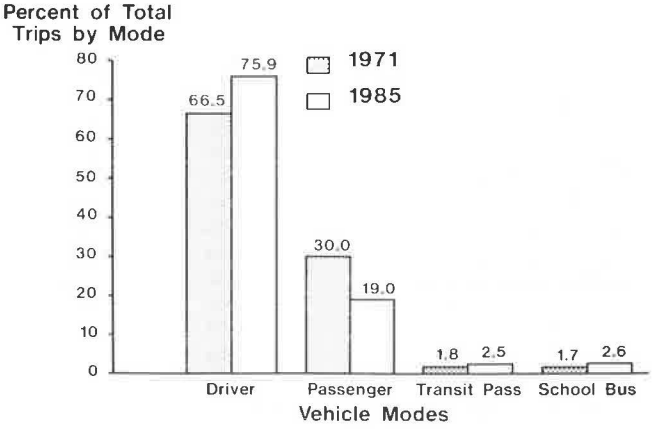

FIGURE 5 Percentage of trips by mode.

day to 3,803,000 trips per day. This increase is due mainly to a shift to more single-occupant automobile trips being made each day.

Average automobile occupancies for 1971 and 1985 are shown in Figure 4. Average automobile occupancies for work trips have decreased about 4 percent, and average automobile occupancies for nonwork trips have decreased about 9 percent in the past 14 years. During the same period, the average number of automobiles per household has increased 8 percent from 1.69 vehicles per household to 1.83 vehicles per household, while the average household size has decreased from 3.10 persons per household to 2.54 persons per household. Because more vehicles are available per household on the average, a general decrease in automobile occupancy should be expected. In addition, because nonwork carpooling is highly related to family travel, and the average household size is decreasing, a larger relative decrease in average automobile occupancy for nonwork trips is reasonable.

The percentage of daily trips carried by mode in 1971 and 1985 is shown in Figure 5. Although automobile-driver and automobile-passenger modes are reported here, it is probably more interesting to look at carpooling versus driving alone. Because there must be an automobile driver for each automobile passenger, carpooling should be about 1.5 times the automobile passenger percentage for 1971, and 1.4 times the automobile passenger percentage for 1985. Therefore, in 1971 about 45 percent of total daily trips involved carpooling and only about 52 percent of the trips involved driving alone. In 1985, carpooling has decreased to about 27 percent of total daily trips and driving alone has increased to about 68 percent of total daily trips.

The percentage of travel carried on public transit has increased since 1971 from about 1.8 percent to 2.5 percent of the total daily trips. About 126,000 transit trips are carried per day (not counting transfers) with 40 percent of the trips being home-based work while 60 percent are for other purposes. The Regional Transportation District (RTD) estimates that it carried about 150,000 riders per day [exclusive of the central business district (CBD) mall shuttle] with about 19,000 transfers during April through May 1985. Therefore, RTD estimates that about 131,000 transit trips were carried daily during the survey period.

As shown in Figure 5, more trips are made on school buses than on RTD buses on the average day. To verify this, the public school districts in the Denver area were asked to provide their daily scheduled school bus ridership. This independent survey showed that about 84,800 students are scheduled to ride school buses daily, which implies that there are over 169,000 school bus trips scheduled per day. The travel survey suggests that around 129,000 school bus trips are made on the average day. This is reasonable considering absenteeism, missed rides, and temporary switching to other modes (e.g., walk, bicycle, automobile passenger, etc.).

The share of trips carried by transit varies substantially with the orientation of the trip. In Figure 6 the percentage of special-purpose trips carried by transit to the CBD is compared with the percentage of special-purpose trips carried by transit to nonCBD destinations. The percentage of trips carried on transit is 10 to 15 times higher for trips with one end in the CBD than for trips with neither end in the CBD. This should be expected

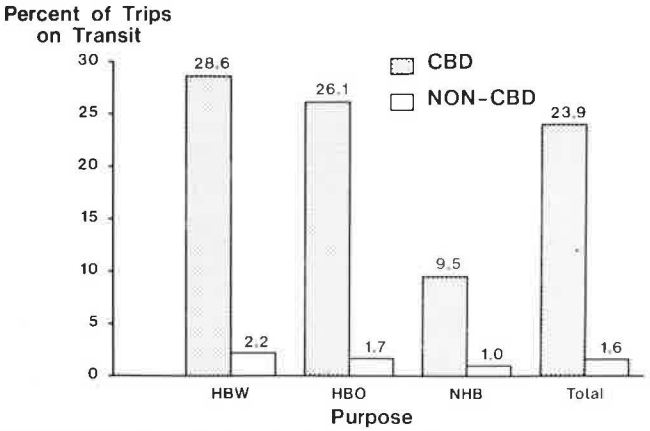

FIGURE 6 Transit share by trip destination.

because the CBD is the focus of most transit lines, experiences high congestion, and has parking costs.

The distribution of travel over an average day is shown in Figure 7. Both the morning and afternoon peak periods are obvious. The morning period begins between 6:30 a.m. and 7:00 a.m. and is over between 8:00 a.m. and 8:30 a.m. The afternoon peak period is somewhat longer, starting between 2:30 p.m. and 3:30 p.m. and ending between 6:00 p.m. and 6:30 p.m. The early beginning of the p.m. peak period is due to school trips (as evidenced by the small peak between 2:30 p.m. and 3:30 p.m.). Factoring those trips out (because many take place in school buses) leaves a 3-hr afternoon peak period from 3:30 p.m. to 6:30 p.m.

The composition of trips during the day is also shown in Figure 7. The morning peak period is primarily work trips and secondarily home-based other trips (mainly school trips). Work trips decline dramatically after 8:00 a.m. and home-based other trips decline slightly. Nonhome-based travel grows throughout the morning and peaks between 11:30 a.m. and 1:30 p.m. Home-based other travel has a small midafternoon peak at 2:30 p.m. through 3:30 p.m. (school trips) and a plateau between 4:30 p.m. and 7:30 p.m. This home-based other plateau is a major factor contributing to the 3-hr duration of the afternoon peak period.

Differences Between Households With and Without Listed Telephone Numbers

One of the unique aspects of the travel survey was the sampling of homes with unlisted telephone numbers. Overall, 9 percent of the households interviewed in the travel survey had unlisted telephone numbers (Table 3). Although this percentage of unlisted telephones is substantially lower than the 28 percent unlisted telephone numbers estimated for the Denver region, it might be reasonable considering the number of unlisted commercial telephone numbers due to multiple extensions within an office.

As shown in Table 3, the average trip rate per household for households with listed telephone numbers is substantially less than the trip rate per household for households with unlisted telephone numbers. This difference in trip rates might be totally explained by the differences in socioeconomic charac-

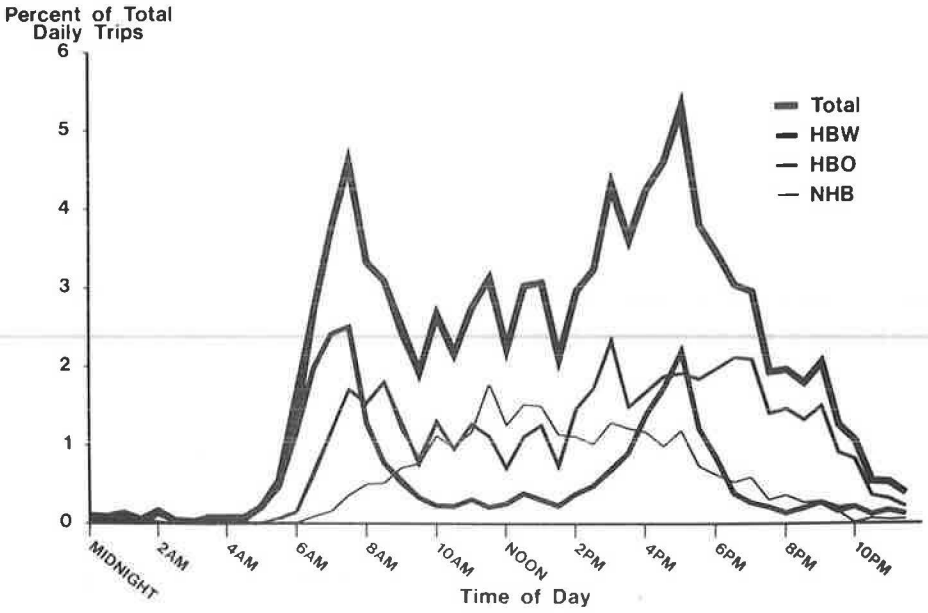

FIGURE 7 Trips by time of day.

TABLE 3 CHARACTERISTICS OF HOUSEHOLDS BY LISTED AND UNLISTED TELEPHONE NUMBERS

	Listed	Unlisted
Number of samples	1,503	142
Percentage of samples	91.4	8.6
Trip rate[a]	7.8	7.3
Average household size[a]	2.54	2.47
Average automobiles available[a]	1.83	1.77

[a]Based on weighted data.

teristics between households with and without listed telephone numbers. The fact that the average household size and average automobile availability for households with unlisted telephone numbers is less than the average household size and automobile availability for households with listed telephone numbers support this hypothesis. However, more detailed analysis is necessary to determine if the differences in travel characteristics can be fully explained by differences in socioeconomic characteristics.

Travel Survey Costs

Costs for the travel survey can be broken into two components: the cost of the actual data collection and in-house costs for contract administration, preliminary survey design work, and geocoding and data editing. The cost of the actual data collection (contractor costs, postage, printing, supplies, and additional telephones) was about $40 per sample. The in-house costs cannot be calculated as accurately as the data collection costs but are estimated to be about $45 per sample.

SUMMARY AND CONCLUSIONS

DRCOG was successful in developing a 1985 travel survey in the Denver region. Data on travel characteristics were obtained for low outside contracting costs through judicious use of DRCOG staff time to design various parts of the travel survey and innovations in survey instrument design and data collection procedures. Although there were biases in the sampled households when compared to regional distributions of households by various socioeconomic and geographic strata, the biases were easily correctable through well-documented techniques. Based on a comparison to 1971 data and other more recent observed data, the weighted survey results appear to be reasonable.

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