Processing the Denver Travel Survey to Support Tour-Based Modeling: Methods, Data and Lessons Learned

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Introduction

The Denver Regional Council of Governments (DRCOG) is in the process of a complete restructuring of its regional model. The restructuring effort began with the conduct, in the late 1990s, of the Travel Behavior Inventory (TBI) project, a suite of regional surveys, including a household travel survey. Following the completion of the TBI, DRCOG commenced its Integrated Regional Model project, through which we are re-building the regional model based on the TBI data, in three phases:

- The Refresh Phase, a partial re-estimation and full re-calibration of DRCOG's existing trip-based model (now complete);
- The Vision Phase, an evaluation of advanced modeling techniques and projects throughout North America and Europe (also complete); and
- The Update Phase, a project to build an integrated modeling system including tour-based travel model and disaggregate land use model components (underway).

The paper is intended to aid modeling practitioners who are considering implementing advanced techniques such as tour-based models, by describing the type of survey DRCOG has used in its tour-based model development, the techniques and assumptions used to structure the survey data for that use, and trip and tour statistics that the survey produced.

Survey Description

In the mid-1990s, when DRCOG began preparations for the TBI project, advanced modeling approaches were just beginning to be attempted in practice in the nation's metropolitan planning organizations. In the early phases of the TBI, DRCOG convened a panel of modeling practitioners to assess the current and possible near-future state of modeling practice in the nation, so that travel surveys could be designed to support those likely approaches. Data collected in 1997 included a home-interview survey, a brief on-board transit survey, a commercial vehicle survey, and an external station survey.

The initial home interview survey design was in an activity-based format where one record of data was collected for each activity in which the household members engaged. While METRO in Portland, Oregon concluded that their activity-based survey was only marginally more complex than a traditional trip-based survey (*1*), respondents to the pilot survey in the Denver region found the format confusing. These findings led to the development of a "place" format for the main survey, based on a similar survey then being conducted in New York City. The place survey asked respondents to describe the sequence of places they were through the day, including the address, what kind of place it was (from a list of categories), and what they did there (their activity). Respondents were asked to select primary and secondary activities at the place from a list of twelve possibilities (a write-in "other" was permitted.) The survey included a standard sample of 4,196 households, as well as 677 households recruited via the on-board transit survey.

Riders on 51 routes responded to the transit on-board survey, which collected basic information on the trip purpose and demographic characteristics of the rider. The survey was used primarily to identify transit riders who could be recruited to participate in the home-interview survey, and 677 households were recruited in this manner. The primary advantage of this method is that the full day activity patterns of the riders and the other household members could be collected, rather than information only on the transit trip in question. The onboard survey itself did not collect origin and destination information in sufficient detail to be used to estimate mode choice models.

Method of Coding Trips and Tours

Three traditional trip purposes were used: home-based work (HBW), home-based non-work (HBNW) and non-home-based (NHB). These were coded based on a lookup table of the 517 possible combinations of production place, production activity, attraction place, and attraction activity.

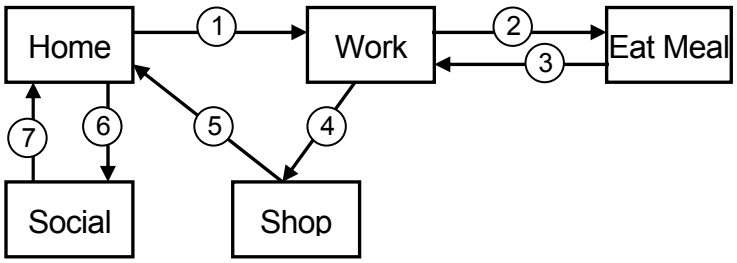
The data were then coded into a tour format. Several codes were developed to support the most common approaches to tour-based modeling:

- Tour code: trips in the same tour must be given a common tour ID number,
- Tour mode: the primary travel model for each tour must be designated, and
- Primary destination: one of the stops on each tour must be designated as primary.

The method described here builds upon the method outlined in the Integrated Regional Model Final Report (*2*), which in turn builds upon the work of previous tour-based modeling work in San Francisco (*3, 4*), Portland (*5, 6*), New York (*7*), Columbus (*8*) and Atlanta (*9*).

First, DRCOG developed a program to group trips into tours. Figure 1 illustrates an example of an individual's all-day activity pattern. A tour is a sequence of trips starting and ending at home, defining a single "round-trip". A sub-tour is a sequence of trips starting and ending at work, defining a single "round-trip". The example below includes three tours, one of which is a sub-tour. Trips 1-4-5 comprise tour 1, trips 2-3 comprise tour 2, and trips 6-7 comprise tour 3. Notice that because of the sub-tour, the trips in tour 1 are not adjacent in time.

Figure 1: Tour Pattern Illustration



To code the tours, the program makes a forward pass through each trip, incrementing the tour ID whenever the traveler departs home. For each trip, it also keeps track of when the traveler last departed home and last departed work. For example, on trip 5, the traveler last departed home on trip 1, and last departed work on trip 4.

Next, the program makes a reverse pass through the trips, flagging any trips where the traveler departed work more recently than he or she departed home. In the backwards pass, if a traveler arrives at work, and has departed work more recently than departing home, the trip is part of a sub-tour. The previous trip is also part of the sub-tour, until the trip is reached that actually departs from work.

Having flagged the sub-tours, the program makes one more forward pass through the trips, incrementing the ID of the sub-tour and of all subsequent tours. Most standard household trip surveys contain all the information needed to perform these steps.

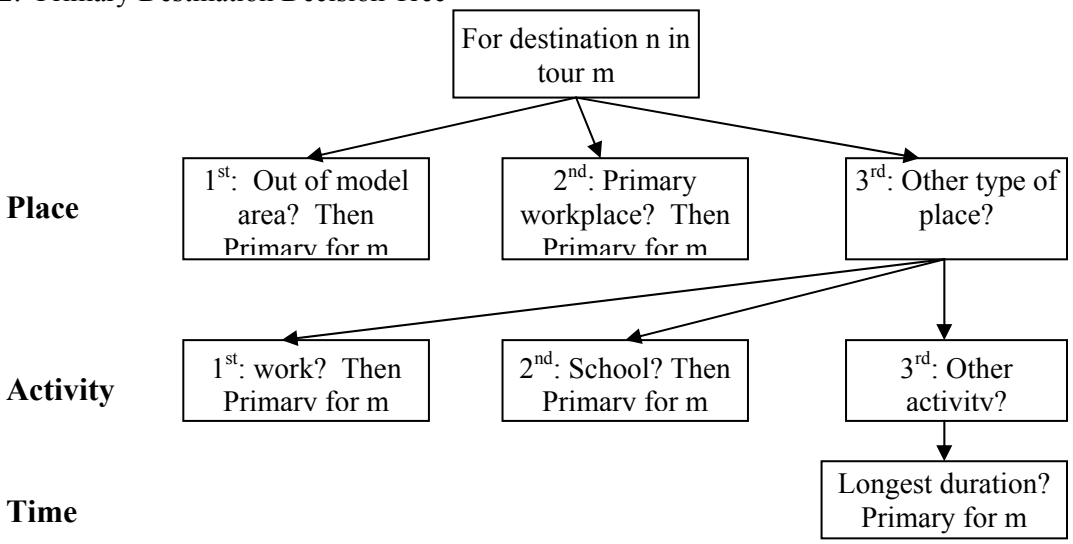
The primary mode of each tour was assigned by assigning a priority to the mode of each trip, in the following order: 1: School Bus, 2: Kiss-and-Ride, 3: Park-and-Ride, 4: Walk to Transit, 5: Drive Alone, 6: Shared Ride 2, 7: Shared Ride 3+, 8: Bicycle, 9: Walk, and 10: Other. For example, if any trip on the tour is a school bus trip, then the primary mode of the entire tour is labeled school bus. It is not necessary that all trips in a tour have the same mode. For example, drivers switch between drive-alone and shared-ride modes when they pick-up or drop-off a passenger.

Finally, for each tour, one place is designated as the primary destination. The primary destination is important because standard tour-based model structures assume that the activity at this destination controls the behavior of the tour, and that the other stops are scheduled around it. For example, if a

traveler goes to work, and stops for coffee on the way to work, the work activity is far more likely than the coffee stop to dominate that person's decisions regarding schedule, destination, and mode. The primary destination is set such that it is never home for any tour, and it is never the workplace for work-based sub-tours. However, it is possible to have work-based sub-tours where the activity at the primary destination is work, such as when someone visits a print shop or another company's office.

In general, the place type, activity and stop duration of each stop in a tour are the variables on which the designation is based. A variety of methods may be used to designate the primary destination, from assuming that one of these variables has sole priority, to developing a two or three dimensional weighting table (for example, one that assigns higher "scores" as duration increases for any given stop activity, and then selecting the highest-scoring stop based on the table.) DRCOG has adopted a simple decision tree structure, as shown in Figure 2.

Figure 2: Primary Destination Decision Tree



Data and Results

The data from this survey first were used in a trip-based format for the Refresh phase, and will again be used in a tour-based format for the Update phase. Of particular interest to practitioners deliberating a switch from a trip-based to tour-based model is how the same data compare when coded in the two formats. A selection of such comparisons is included here. Table 1 shows basic statistics associated with the trip records, and Table 2 shows those same statistics associated with the tour records. Table 3 compares the trip purpose to the primary purpose of the tour for each trip record. As discussed below, these data can provide important insights into the areas of travel behavior where a trip-based model and a tour-based model might provide differing results.

First, notice that in Table 1, only 17% of trips are HBW trips, while in Table 2, 33% of tours are work tours. This discrepancy suggests that work remains a very important driver of travel, even though the number of HBW trips is relatively small due to trip chaining. This observation is supported by Table 3, which shows that only half of all trips on work tours would be coded with an HBW purpose, while the other half would be HBNW or NHB trips. School tours account for another 16% of all tours, and when viewed together, these two mandatory activities are central to almost half of all tours.

It is useful to examine how the NHB trips are distributed across various tour purposes, as shown in Table 3. NHB trips account for between 15% and 39% of the trips in each tour purpose. Having a meaningful

purpose associated with these NHB trips has the potential to be one of the biggest advantages of a tour-based model.

Table 1: Basic Trip Statistics

Trip Purpose	Expanded Trips	Column Percent	Trips / Person	Trips / Household	% on Tours with 3+ Trips	% Shared Ride	% Transit
HBW	1,505,685	17%	0.8	1.7	26%	9.1%	5.1%
HBNW	4,444,067	51%	2.2	5.1	43%	53.6%	1.5%
NHB	2,788,283	32%	1.4	3.2	88%	42.2%	1.3%
Total	8,738,035	100%	4.4	10.1	55%	42.3%	2.1%

Table 2: Basic Tour Statistics

Tour Purpose	Expanded Tours	Column Percent	Tours / Person	Tours / Household	% with 3+ Trips	% Shared Ride	% Transit
Work	1,060,271	33%	0.5	1.2	44%	8.1%	5.3%
School	514,967	16%	0.3	0.6	29%	44.9%	4.7%
Shopping	386,200	12%	0.2	0.4	49%	42.7%	0.9%
Social/Rec.	291,877	9%	0.1	0.3	39%	58.5%	3.1%
Drop-off/Pick-up	268,781	8%	0.1	0.3	19%	32.2%	0.0%
Other	701,429	22%	0.4	0.8	36%	50.5%	1.5%
Total	3,223,525	100%	1.6	3.7	38%	33.9%	3.2%

Table 3: Comparison of Tour Purpose and Trip Purpose for Trips

	Trip Purpose							
	HBW		HBNW		NHB		Total	
Tour Purpose	Expanded Trips	Row Percent	Expanded Trips	Row Percent	Expanded Trips	Row Percent	Expanded Trips	Row Percent
Work	1,497,387	50%	495,971	16%	1,012,793	34%	3,006,151	100%
School	180	0%	1,017,667	77%	299,596	23%	1,317,443	100%
Shopping	1,591	0%	689,607	62%	424,438	38%	1,115,635	100%
Social/Rec.	653	0%	560,063	71%	227,082	29%	787,797	100%
Drop-off/Pick-up	248	0%	528,673	85%	90,260	15%	619,180	100%
Other	5,626	0%	1,152,088	61%	734,116	39%	1,891,829	100%
Total	1,505,685	17%	4,444,067	51%	2,788,283	32%	8,738,035	100%

On average, each person in the Denver region makes 4.4 trips per day and 1.6 tours per day, for an average of 2.7 trips per tour. 38% of all tours include three or more trips, and 55% of trips are on tours with 3 or more trips. These results show that a large fraction of travel includes some trip chaining, and developing a model that properly accounts for it could have a significant influence on the model's performance.

Finally, notice the difference in mode shares between trips and tours. These differences result from the prioritization scheme used to define the primary mode of the tour. Shared ride was defined as a lower priority than drive alone, such that if any trip on a driving tour is a drive alone trip, the primary mode would be drive alone. Drive alone takes a higher priority because it requires the exclusive use of a vehicle, and the tour-coding of the modes correctly captures that the driver at some point needs use of the vehicle. Conversely, transit is a high priority in defining the primary tour mode, and the transit mode

share is 50% higher for tours than for trips. This result indicates a substantial level of trip chaining on transit tours, where travelers may stop to shop at some point during their transit trip.

Conclusions

In total, the survey data present a reasonable picture of travel behavior, and one that is both more interesting and more intuitive than traditional trip-based statistics. They make plain the degree of trip-chaining that the trip-based statistics hint at, and also show primary destination/purpose statistics that make sense given most people's perception of their primary daily activities (work for older adults and school for children and young adults.)

DRCOG's experience with the use of its home interview survey in the development of tour codes strongly suggests that complex, advanced activity-based surveys are not necessary to develop reasonable tour codes to support the development of tour-based models. The "place" survey conducted by DRCOG was not noticeably more complex than a traditional trip survey, and our experience with the data suggests that it would also be possible to develop tour codes using a trip-based survey. These results suggest that many metropolitan planning organizations may already possess the data they need to develop tour-based models.

Finally, one specific lesson learned from DRCOG's experience is that there is no substitute for a robust transit on-board survey. DRCOG used a brief on-board survey to recruit transit riders to participate in its home-interview survey. While this transit over-sample provides extremely useful data, the sample size is too small to provide a complete picture of the use of the transit system, and a full on-board survey would provide a nice complement to the over-sample.

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