A Comparison of Census Journey-to-Work and Model-Generated Transportation Data in the Puget Sound Region

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Journey-to-work trip data from the 1980 Census and output from the Urban Transportation Planning System are compared for the Puget Sound Region in Washington State. The purpose of this comparison is twofold: to identify where regional transportation models may need adjustment and to determine whether census journey-to-work data are a valid substitute for large-scale origin-destination surveys. Home-based total work trip tables and home-based transit work trip tables from the census and the model are compared using two methods: a trip length frequency distribution comparison and mapping the differences between the two sets of trip tables using the FLOWMAP mapping program. The trip length frequency distribution comparison shows that census work trips averaged slightly longer than model trips. FLOWMAP analysis, which maps the differences between the two sets of trip tables, reveals that, for total trips, census trips exceeded those from the model for trips attracted to the central business district of three major cities in the region. A second significant finding in the FLOWMAP analysis is that the model shows a few more longer transit trips than do the census data. An evaluation of census journey-to-work data is undertaken.

This research is focused on a comparison of the model output from the Urban Transportation Planning System (UTPS) with transportation data developed from the 1980 Census, known as census journey-to-work data or the Urban Transportation Planning package (UTPP). Home-based work trip tables from both of these data sources are compared in terms of total daily trips and transit daily trips for the most heavily urbanized parts of three counties of the central Puget Sound region in Washington State. Differences with respect to the outputs of trip generation, trip distribution, and mode-split model are discussed. Also, the way the questions on the census form were worded and the way the census data were factored uniformly, with no regard for varying trip generation rates, are examined as possible causes for discrepancies between the two trip tables.

Conclusions, in the form of potential causes of these differences, are discussed; recommendations are made regarding the need to recalibrate the Puget Sound Council of Government's (PSCOG) trip generation, distribution, and mode-split models, and recommendations regarding the use of census data are made. In general, the analysis assumed that census data provide the base with which model output should be compared because they are observed data and the model output is considered estimated data. Caveats to the use of census data will be discussed later.

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PURPOSE OF STUDY

Transportation planners, including transit planners, use several methods to plan future transportation facilities and services. In the past, origin-destination surveys were an excellent source of valid information on which to structure a planning study. Unfortunately, such surveys have become expensive to conduct and consequently are done rarely. Another method involves the use of large-scale transportation models, which frequently rely on origin-destination surveys for calibration. UTPS models generate trips at places of employment and residences; distribute them among appropriate zones; and apply a mode split to determine how many of these trips are by automobile, carpool, transit, and so forth. Models, however, may contain inaccuracies that are hard to detect if an origin-destination survey has not been conducted for quite a while. Most urban regions have not had large-scale origin-destination surveys since the 1960s. Since then, land use changes have generated changes in trip patterns, especially in metropolitan areas that have experienced high growth. Demographics, such as household size and the number of workers in the work force, have also changed, and these changes affect trip-making characteristics. Ground checks of actual traffic or transit volumes can be used to check some aspects of the model runs.

Census journey-to-work data compiled in 1980 are the most recent data source available to transportation planners for comparison with UTPS model output to determine if additional calibration work is needed. It is hoped by many transportation planners that the census journey-to-work data can be used as an inexpensive partial substitute for origin-destination surveys. This would involve using the census data to recalibrate the UTPS models. The goal of this research, however, was not to prove that one or the other is incorrect but to compare them and hypothesize about the causes of differences between them.

STEPS IN ANALYSIS

The zone-to-zone trip interchanges from the census journey-to-work data and the UTPS model are compared. The types of trips to be compared include total home-based work trips and transit home-based work trips. Total home-based work trips are compared because that will help identify any problems with the UTPS trip generation and distribution process. The transit home-based work trip comparison shows if there are problems associated with the mode split model.

The two trip categories from the two data sources are compared at two different levels of aggregation. The first is a 16-zone aggregation of the three most heavily urbanized Puget Sound counties: Snohomish, King, and Pierce. The next level of analysis is a 40-zone aggregation of the same area, which focuses on areas in more detail.

When the trip tables are analyzed at these separate levels, broad, general trends become apparent (e.g., intra-Seattle transit trips are underestimated and suburban transit trips are overestimated) if the larger zones are examined.

The trip tables from both UTPP and UTPS were originally in a 295 x 295 matrix [at the Transportation Analysis Zone (TAZ) level, which is too small for this analysis]. These large-scale trip matrices were combined into the desired 16- and 40-zone trip tables. The UTPP trip tables were multiplied by a factor so that they could be compared with the UTPS model trip table.

The first phase of comparison involved the use of the origin-destination data-mapping program, FLOWMAP. The capabilities of FLOWMAP are such that it can graphically display trip tables; that is, it plots the flow of anything (in this case, trips) between geographic zones using an arrow proportionate in width to the number of trips between zones. The utility of FLOWMAP for this particular exercise is that it can subtract one trip table from another; this ability enables it to work with a table of differences between the two trip tables. The FLOWMAP program can also plot positive and negative differences. In this manner differences in the two data sets can be shown on a map and significant spatial patterns (if any) of differences can be readily spotted *(1)*.

In addition to the FLOWMAP analysis, trip length frequency distribution comparisons with implications for the trip distribution model have been run for both data sets.

The objectives and conclusions focus on interpreting spatial differences (revealed from the use of FLOWMAP) and aspatial differences (revealed by plots of the trip length frequency distributions). Findings should help identify problems that are isolated with the mode-split model for transit, with the trip generation and distribution models, or by using census data as a measure of transportation model accuracy. Again, this exercise is not intended to use one as a basis for judging the other but to point out the differences and, if possible, provide reasons for them.

Conclusions from this analysis concerning the transportation models and their calibrations can be considered directly applicable to the Puget Sound region because these models have been tailored to fit that region only. Conclusions reached concerning the census journey-to-work data should be of interest to UTPP users around the nation.

BACKGROUND INFORMATION

In this section is provided background information on three important components of this analysis: the travel-forecasting process used to produce simulated trips, the 1980 Census journey-to-work data and the UTPP, and the basis for adjusting the census journey-to-work data into a form comparable with trip model output.

Trip Forecasting

The travel-forecasting process currently used by the PSCOG documents the basis for some of these models grounded in previous surveys. Assumptions underlying the trip generation, trip distribution, and mode-split models (the results of which will be tested against the UTPP data) are examined.

The transportation-modeling process, simplified here somewhat, uses population and employment data for particular geographic zones to generate trips from population and employment data and to distribute these trips among zones (according to their proximity to one another and relative sizes in addition to other factors). A mode split is then applied to those zone-to-zone interchanges to arrive at trip tables by mode of transportation.

Trip generation actually consists of two models, a trip production model and a trip attraction model. These models estimate trip productions and attractions from demographic and economic data developed for each analysis zone. These productions and attractions are calculated using trip production and attraction rates for each of several land use categories. Attraction rates relate to trips attracted to destinations such as places of employment and other activity centers. Employment data used by PSCOG were obtained from a 1980 employment inventory. Trip generation rates are assigned to attractions on the basis of land use, which is usually divided into the retail, office employment, manufacturing, and educational categories *(2)*.

Trip productions are generated by applying rates to total population, households, and income categories in a particular analysis zone. As with attractions, productions looked at in this exercise are only home-based work trips.

The trip generation models were calibrated in 1976 using as a basis the 1970–1971 origin-destination survey conducted by the PSCOG (then known as the Puget Sound Governmental Conference). This was a survey of 2,339 households in the region. The trip generation model has been further validated using 1980 Census data for population. It has also been checked with actual ground counts.

After trips are generated they are distributed between zones by the trip distribution model. The model that is used by PSCOG is a gravity-type model programmed for UTPS operation. The gravity model assigns the number of trips between any two zones as directly proportional to the number of productions and attractions in each zone and inversely proportional to the travel time between them. Like the trip generation models, the trip distribution model has been calibrated with data from the 1970–1971 origin-destination survey conducted in the region.

The mode split model uses a multinomial logit framework to determine the mode of travel for each zone-to-zone trip interchange. The model used during the period when this analysis was conducted was originally developed for the Minneapolis–St. Paul region, but the model had been calibrated and validated for the Puget Sound region using passenger screenline counts from 1980 and 1977 on-board bus surveys and vehicle screenline counts. The trip assignment model, used to assign trips along actual paths (roads, bus routes), is not examined in this paper.

For this exercise, total work trips from the UTPP are compared with total work trips from the model to see if there might be a problem with trip generation and distribution models. If a difference that is unlike what was observed in the total trip comparison occurs with the transit trip comparisons, the mode split model is a likely source of the problem *(2)*.

Census Journey-to-Work Data

In the past, census data have played an integral part in transportation modeling. Population data are a critical part of the trip generation step of the transportation-planning process. In recent decades, the Census Bureau has included questions on its form to obtain journey-to-work information. In 1960 the Census Bureau provided journey-to-work information coded to the county or place level. These large zonal areas were not small enough for use by transportation planners. Also, zonal definitions were ususally not compatible with zones used by transportation planners.

For the 1970 Census, the development of the Geographic Base File/Dual Independent Map Encoding (GBF/DIME) capability enabled census data to be coded by block; these data could then be translated into a local area's transportation analysis zone (TAZ) structure through the use of an equivalency table.

The 1980 Census provided an expanded questionnaire for journey-to-work items, which made possible observation of travel times and mode choice and elicited answers to detailed questions about carpooling. On the basis of these data, a table of work trips, split by mode, from TAZ to TAZ was developed *(3)*.

The journey-to-work information is contained in the UTPP. This information is available to metropolitan planning organizations (MPOs), coded specifically for the MPO's regional TAZs. The PSCOG purchased this information from the Census Bureau in early 1984. These data were coded to the PSCOG's TAZ structure by the Census Bureau.

The UTPP, as received by the PSCOG, consisted of six parts:

1. Demographic data at the residence end, at the TAZ level;
2. Demographic data at the residence end, at the large-area level (major city, county, standard metropolitan statistical area);
3. Demographic data at the workplace end, at the TAZ level;
4. Trips from residence to work, at the TAZ level;
5. Demographic data from the worker end, at the block group level; and
6. Trips from residence to work, at the county or city level.

All of these categories are broken down into travel times and modes of travel and are grouped in such demographic categories as income, race, sex, and age.

This research was concerned exclusively with data from Part 4—trips from the residence end to employment—coded by the Census Bureau to the PSCOG TAZs. These trips were split into 12 different mode categories. The long form of the census asked the following questions to obtain journey-to-work data:

- Did this person work at any time last week? (yes or no)
- How many hours did this person work last week?
- At what location did this person work last week? (address)
- Last week, how long did it usually take this person to get from home to work (one way)? (minutes)
- How did this person usually get to work last week? (check mode of travel)
- When going to work last week did this person usually drive alone, share driving, drive others only, or ride as a passenger only?
- How many people, including this person, usually rode to work in the car, truck, or van last week? (2, 3, 4, 5, 6, 7, or more)
- Was this person temporarily absent or on layoff from a job last week? (layoff, vacation/illness, no)

Although the long form of the census was sent to one of every six households, the place of work responses of workers in about only one in twelve or about 8 percent of all households were actually coded due to budget constraints. Trips were coded from the residence census block to the work end census block and then inflated to 100 percent *(3)*.

Adjusting the Census Journey-to-Work Data

Adjustments must be made to census journey-to-work data, which are in trip table form, before any comparison can be made with the results from the PSCOG's transportation models. The census data must be adjusted to compensate for several shortcomings in the 1980 Census long-form questionnaire and the fact that it is not in the trip production and attraction format that is typically used by MPOs such as PSCOG in their trip-modeling process. The major shortcoming of the census form is that the question asks how a person usually got to work in the previous week not how the person traveled to work on an average day.

Most MPO transportation model calibrations are based on transportation surveys that ask questions about work trips on the previous day. This statistical sampling accounts for occasional sickness, occasional change in mode of travel, and people who do not work a full workweek. By asking how an individual usually traveled to work in the previous week, the census cannot account for these occasional changes in travel characteristics during the workweek.

One approach to correcting the problem created by the inconsistent wording underlying the two sources of work trip data is discussed by William Mann of the Metropolitan Washington, D.C., Council of Governments (WASHCOG). WASHCOG staff derived several factors to apply to the UTPP trip table in Part 4 of the census journey-to-work data *(4)*.

The first factor is designed to account for work trips made by people who worked in a standard metropolitan statistical area (SMSA) yet lived outside it. This factor is calculated by dividing the total number of workers residing inside the SMSA by the sum of the number of workers reporting work sites inside the SMSA and the number of workers reporting work sites outside the SMSA:

$$\text{Factor} = \text{Total}/(\text{In} + \text{Out})$$

Total = Total number of workers residing inside SMSA
In = Number of workers reporting work sites inside SMSA
Out = Number of workers reporting work sites outside SMSA

The second factor is designed to account for those people who do not make it to work on the average day. This is to correct the overreporting of work trips in response to the question, "how did you usually get to work last week?" This question does not account for workdays missed during the week due to absenteeism, a reduced workweek, or other related reasons that would have shown up had the question been worded, "how did you get to work yesterday?"

Factor three is designed to convert census trip data to the MPO trip production and attraction format. This factor would be 2 if everyone who traveled from home to work also traveled directly back from work to home. However, that is not the case because there is a tendency to go somewhere else after work instead of directly home. This factor can be calculated by dividing a region's total work trips, from and to home, by the number of trips from home to work.

The fourth factor is designed to account for occasional mode shift during the week. This would apply to situations in which the census respondent would report his usual mode of work trip for last week (e.g., drive alone) yet take the bus or carpool once or twice a week, or vice versa. The way the census question was worded, there is no way the occasional mode change can be detected.

These four factors are multiplied to form one factor to apply to the UTPP trip table so that it becomes more comparable with the

PSCOG's transportation model output. The factors for the Puget Sound region were calculated in the following manner.

The data necessary to calculate the first factor were derived from the UTPP. The data used were derived from a cross-classification by mode of SMSA totals for workers. Table 1 gives the calculations resulting in a factor of 1.080 applied to the transit trip table and 1.081 to the total trip table.

TABLE 1 ADJUSTMENT FACTOR FOR WORKERS INSIDE AND OUTSIDE THE PUGET SOUND REGION (Snohomish, King, and Pierce counties)

Place of Work	Transit	Total
Inside SMSA	73,034	812,441
Outside SMSA	3,054	53,754
Not reported	6,056	72,983
No fixed place	0	5,069
Total	82,144	944,249

Note: Mode of travel factor for transit is 82,144/(73,034 + 3,054) = 1.080 and for the total is 944,249/(812,441 + 53,754) = 1.081.

Subsequent analysis has revealed that this first factor need not have been applied. Mann's application of this factor was to the 1977 Travel-to-Work Supplement to the Bureau of the Census Annual Housing Survey. However, the 1980 UTPP did not need to be factored in such a manner to make it comparable to MPO transportation model output. The implication of this, with regard to the findings of this analysis, is discussed under Summary and Conclusions.

The second factor, to account for non-travel to work on an average day, was determined to be 0.85 on the basis of a 1968 home-interview survey conducted in the Washington, D.C., area *(5)*. This conclusion is based on the fact that 15 percent of the working population does not make a work trip on a given day for the reasons previously discussed. This number was also used by Mann *(4)*.

However, the census data do take into account people who did not work the entire previous week. The factor of 0.85 may be somewhat low because part of the 15 percent of the working population not making a work trip is already accounted for in the census journey-to-work data. The effect of this on the 0.85 factor is difficult to objectively calculate because of insufficient data, especially for the Puget Sound region. However, this figure may be derived using certain assumptions:

Number of weekdays in a year, excluding holidays = 250
Days of vacation per year = 10
Percentage of absentees that has already been accounted for in UTPP = 10/250 = 0.04

A figure of 0.89, which is the 0.85 factor adjusted to accommodate the fact that the UTPP already accounts for weekly vacations, can be derived:

0.04 + 0.85 = 0.89

Assuming that 10 days of vacation per year is average and dividing that figure by 250 gives a factor of 0.89 for Factor 2 by adding 4 percent to 0.85.

The third factor, converting the census trip data into the PSCOG trip production and attraction format, is calculated in the following manner. Total work trips in the region, to and from home, are divided by trips from home to work to arrive at a factor for the Puget Sound region. These trip data come from PSCOG's 1970–1971 origin-destination survey results *(6)*.

As the following calculation shows, the UTPP trip table is multiplied by 1.889 to make it comparable with the PSCOG trip table in production and attraction format.

Trips to work 452,642
Trips home 402,522
Total 855,164
855,164/452,642 = 1.889

The fourth factor is designed to compensate for occasional mode shifts during the week. It is difficult to quantify because no data exist for the Puget Sound region that can be used to calculate this factor. It is likely that shifts between modes throughout the week could offset one another. A behavioral change like this is hard to speculate on without data. For the Puget Sound region, it is left at 1 (i.e., no adjustment is made).

Multiplying these four factors, an overall adjustment factor is obtained for application to the UTPP transit and total trip tables to make them comparable to the PSCOG's transportation model outputs:

For transit trips, 1.080 x 0.89 x 1.889 x 1.0 = 1.81.
For total trips, 1.081 x 0.89 x 1.889 x 1.0 = 1.81.

For purposes of this study, both census total trips and transit trip tables were multiplied by 1.81 to make them comparable to the UTPS model output.

Description of TAZs

Both the model-generated and the census trip tables were originally in a 295 × 295 zonal matrix. This corresponds to the 295 TAZs into which the PSCOG has divided the urban areas of Snohomish, King, and Pierce counties for transportation-modeling purposes. The census data, normally coded to census blocks within census tracts, were coded to these TAZs by the Census Bureau as part of the UTPP using a TAZ/census block equivalency table supplied to them by the PSCOG. It should be noted that external trips outside the three-county urban area were not included in the analysis. This is because this information coded to the zone level was not provided as part of the UTPP.

Trip Length Frequency Distribution

The first step of the analysis, using the 295 x 295 TAZ trip table matrices, is to compare the two data sets using a trip length frequency distribution. The trip length frequencies of both model and census data sets (for their total or transit trips) were plotted on the same graph. Zone-to-zone travel times are an additional input to this program.

Travel times between the 295 zones were obtained for the regional street and highway network and are used for the total trip length frequency distribution comparison. The regional transit network, with much slower intrazonal travel times, is used for the transit trip length frequency distribution comparison.

The first comparison was of trip lengths for the total trip tables plotted using over-highway travel times. In analyzing this plot, it was apparent that the model produced slightly shorter trips than were obtained from the census.

The second comparison was of transit trips, which are plotted using interzonal transit travel times. Results were similar to those observed with the total trip length frequency distribution comparisons. The census travel times are slightly longer than those of the model for both the total and the transit trip tables.

The second step involves the comparison of the two data sets on a much larger scale. The 295 zones are compressed into 16 very large zones. This 16-zone aggregation is shown in Figure 1. The reason for the aggregation into bigger zones is so major differences between the data sets can be shown and analyzed as being a certain type of work trip.

Areas of large differences in the trip tables have been examined in greater detail by splitting the 16-zone trip tables into 40-zone trip tables, as shown in Figure 2. This enables further analysis of areas of significant differences and a more specific pinpointing of possible reasons for any discrepancies. Another reason for a smaller level of analysis is that some interzonal differences may only be apparent at the 40-zone level; in the 16-zone analysis they may disappear because they were aggregated into internal (intrazonal) trips.

FIGURE 1 16-zone division of Seattle-Everett-Tacoma urban region.

FIGURE 2 40-zone division of Seattle-Everett-Tacoma urban region.

The census trip tables were subtracted from the trip tables generated from the model. The reason it was done in this order and not vice versa was that the model produced a total of 1,535,767 trips whereas the census had only 1,482,715. Therefore it was known that census trips, even after having been factored upward, are still fewer than those produced by the model. Part of this discrepancy may be explained by home-based college trips being included in the model and not in the census.

The end result of the matrix subtraction is four matrices of differences—transit trip differences for 16- and 40-zone trip tables and total trip differences for 16- and 40-zone trip tables. Most of these flows are positive, although a significant number of negative flows exist (where the volume produced by the census exceeded that of the model).

The differences in the flow of trips between zones is displayed using the origin-destination mapping program FLOWMAP.

Description of FLOWMAP

FLOWMAP was developed in 1979 by Bob Evatt, Jr., under the guidance of Jerry B. Schneider of the Urban Transportation Program at the University of Washington and has been extensively revised by Harvey Greenberg since its development. The FLOWMAP program can map origin-destination data interactively on a Tektronix 4014 graphics terminal. Several types of flow maps are possible. This exercise primarily uses one type of display: interzonal flows displayed as variable width arrows the widths of which are proportional to the volume of flow. All zones are considered origins or destinations. Another type of display used in this report is for intrazonal flows; this display takes the form of circles proportional in diameter to the intrazonal flow.

Needed inputs to FLOWMAP are a geographic feature file and a data file. The geographic feature file is a set of gridded zonal coordinates. In this case, universal transverse mercator (UTM) coordinates are used for both the 16-zone and the 40-zone division of the Puget Sound region. Also, centroid points loaded in approximately the geographic center of each zone are included as part of the geographic feature file. These centroid points mark the origins and destinations of the arrows *(1)*.

The data files are the actual matrices of zone-to-zone trip differences created by subtracting the census trip tables from the corresponding model trip tables and modified for use by FLOWMAP. In this case, the four matrices (total and transit trip differences for 16 and 40 zones) contain both negative and positive numbers. The positive numbers occur when the model-generated trips exceed those of the census, and negative numbers occur when the census exceeds the model. On the maps generated by FLOWMAP, positive flows are shaded and negative flows are not shaded.

After the geographic and data files were set up, the analysis proceeded as follows. First, a histogram of each difference table was produced. This showed a distribution of the flow volumes. Following that, the 16-zone trip tables (actually, trip difference tables) for transit and total trips were mapped. One of the features of the FLOWMAP program is that the number of arrows shown on a particular map can be screened for minimum and maximum absolute values of flows to be shown. This way, only the few maximum difference flows can be shown on a particular map, so that the significant pattern of the largest flows can be seen. Figure 3 shows the distribution of difference flows for total trips at the 16 x 16 zone level.

Several maps were produced for each trip difference table. These ranged from the maximum value of the flow difference down to a point where lowering the minimum flow would have produced too many arrows, rendering the map overly complex and incomprehensible.

The 40-zone analysis using FLOWMAP was conducted in the same way, although the difference flows are somewhat smaller because there are more zones and consequently fewer trips between them. Previous intrazonal trip table differences that occurred in the 16-zone analysis started to show up as intrazonal differences in the 40-zone analysis.

Figure 3 shows that the vast majority of difference flows have an absolute value less than 1,000. The FLOWMAP analysis looked at the major flows toward the ends of the distribution spectrum. The distributions of the other three trip table differences were similar.

Examples of the FLOWMAP analysis are shown in Figures 4 and 5. Figure 4 shows the difference flows between 1,000 and 1,500 in value for the transit trip tables aggregated into a 16 x 16 matrix. This figure shows two shaded flows, which indicate that the model transit trips exceed the census transit trips for those particular zone-to-zone interchanges. The lower arrow indicates model transit trips that exceed census transit trips produced in the suburban area known as Federal Way and attracted to the central business district (CBD) of Seattle. The other arrow indicates a situation in which model transit trips exceed census transit trips produced in the zone representing South Seattle and attracted to North Seattle.

Figure 5 shows the transit trip differences in the 40 x 40 zone comparison. This figure shows model transit trips exceeding census transit trips (shaded flows) attracted to Northeast Seattle

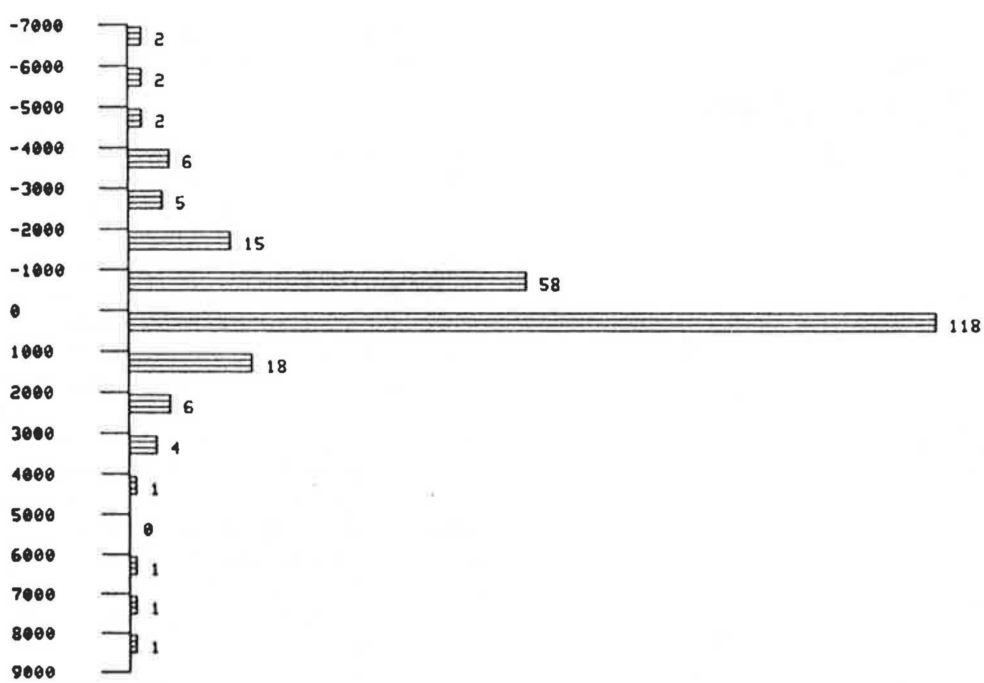

FIGURE 3 Distribution of 16-zone total trip differences.

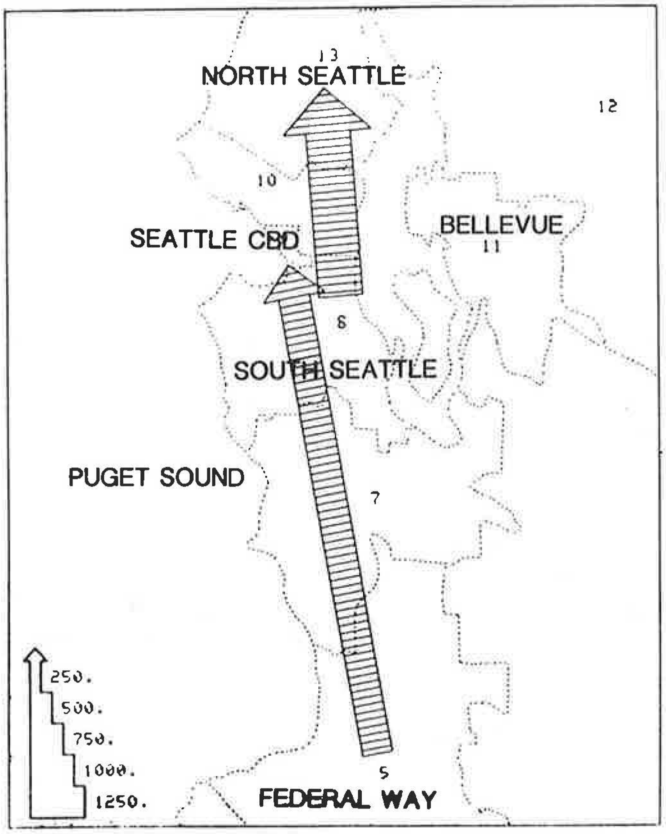

FIGURE 4 Example of 16 x 16 zone matrix transit trip difference flows.

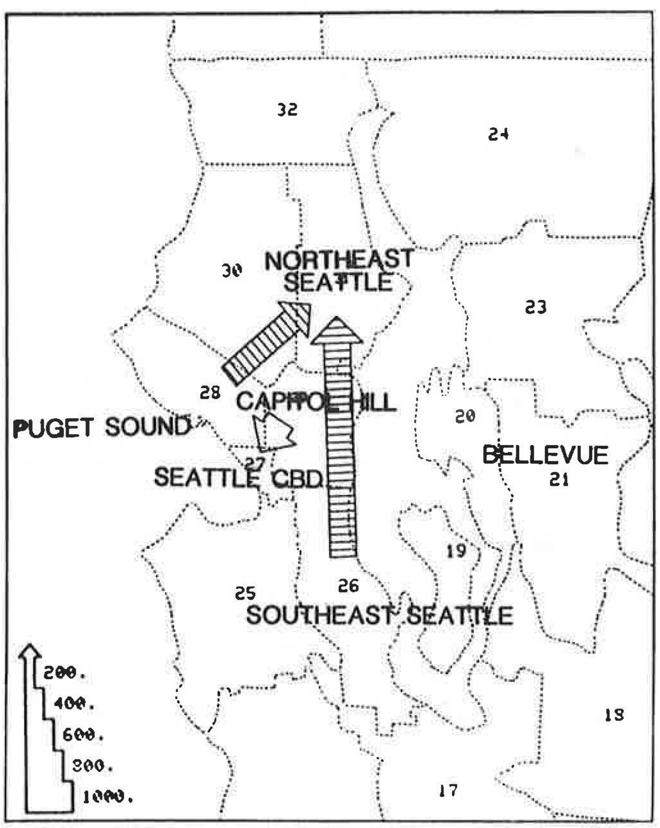

FIGURE 5 Example of 40 x 40 zone matrix transit trip difference flows.

from nearby areas. Also, it shows census transit trips exceeding model transit trips attracted to the Seattle CBD from the adjacent Capitol Hill residential area.

Comparison of 16-Zone and 40-Zone FLOWMAP Analysis

The 16-zone and 40-zone analyses using FLOWMAP to display differences between the model-generated and the census-generated trip data yielded similar results in both the total trip comparison and the transit trip comparison.

Similarities observed in the total trip comparison for both sets of zones include model trips exceeding census trips bound for the zone representing the North Seattle area from several other zones. In the 16-zone analysis, a large number of model transit trips exceeding census transit trips within this zone were noted. In the 40-zone analysis, it becomes clear that this zone is better defined as Northeast Seattle, which includes the University of Washington.

Similarities with regard to census total trips exceeding model total trips in both the 16-zone and the 40-zone analyses can be summarized as follows. There appears to be a pattern for this difference for trips attracted to the CBDs of three major cities from close-by residential zones.

For transit trips, similarities in the 16-zone and 40-zone analyses that show the model exceeding the census include transit trips attracted to North Seattle (as was noted in the total trip comparison) and transit trips attracted to the Seattle CBD from zones medium to far away in distance from the Seattle CBD (from North Seattle, the suburban eastside communities, and southern King County). This latter observation is exactly the opposite of that made in the total trip analysis, where the census generally exceeded the model for trips attracted to the Seattle CBD.

Similarities in the 16-zone and 40-zone analyses with regard to census transit trips exceeding model transit trips show that this occurs for the transit trips attracted to the Seattle CBD from the neighborhoods immediately to the north and east. This corresponds to what was observed in the total trip analysis. Intrazonal differences that did not appear in the 16-zone analysis became interzonal differences.

EVALUATION OF FINDINGS WITH RESPECT TO MODELS

The total trips comparison is examined with regard to the trip generation and the trip distribution models. The trip length frequency distribution comparison and implications for the trip distribution model are also discussed.

The transit trip comparison is used to make judgments about the mode split model. If differences in the volumes of transit trips correspond to differences observed in the total trip comparison, that reflects the trip generation and trip distribution models and not the mode split model. When differences in the transit trip comparison do not match those in the total trip comparison, the mode split process is isolated as the source of the discrepancy.

Total Trip Comparison—Trip Generation and Distribution

Some areas of spatial trip differences between the two data sets, documented in the previous section, can be explained by acknowledging certain basic differences in the two data sets. For example, the home-based work trip table generated by the model also contained college trips; the census trip table did not. The indicates that it may be assumed that zones with large colleges and universities may have more model trips attracted to them than census trips. The FLOWMAP analysis confirmed this. The University of Washington, the largest university in the region, is the main attraction of the large shaded flows into the zone in which it is located. Other zones with significant model attractions that can be explained by the omission of college trips in the census data include the Capitol Hill and Queen Anne zones, which have universities of significant size, although not as large as the University of Washington.

After the difference arrows caused by basic differences in the two data bases are discarded, one predominant type of discrepancy is left. That is where the census trips exceed those from the model for trips attracted to the CBDs of Everett, Seattle, and Tacoma.

These discrepancies may be explained by reviewing the trip generation attraction rates. The CBDs of Everett, Seattle, and Tacoma consist mainly of large numbers of places of financial, insurance, real estate, other services and wholesale, transportation, and communication and utilities employment. The distribution of retail employment is relatively more evenly spread throughout the region (suburban shopping centers, etc.). The significance of this is that the types of employment that are concentrated in these CBDs have a lower trip attraction rate than does retail employment; this gives rise to a lower-than-average trip attraction rate for the entire region. However, the methodology used in factoring the census data into a form comparable to the transportation model output applied a uniform factor for the whole region, with no regard to employment types and the various trip attraction rates associated with them.

This leaves the possibility that the average rate applied across the board to the census was higher than that associated with certain types of employment concentrated in specific geographic areas, namely the CBDs of Everett, Seattle, and Tacoma. This would explain the excess of census total trips attracted to these areas. This also leaves open the possibility, in analyzing this objectively, that it is the trip generation attraction rates of the model that may be too low, or a combination of the two.

There is also a possibility that this problem can be traced to the trip distribution model. The trip distribution model is a gravity-type model used to calculate the number of trips between Zones i and j:

$$T_{(ij)} = (P_i \times A_j \times F_{ij} \times K_{ij}) / \sum_{j=1}^{n} (A_j \times F_{ij} \times K_{ij})$$

P_i and A_j are the production and attraction inputs from the trip generation process described earlier. If they are not correct, the trip distribution process will be affected. If they are correct, however, that leaves the time distance friction factor (F_{ij}) and the socioeconomic adjustment factor (K_{ij}) as sources of error.

The trip length frequency distribution comparisons described earlier help with the analysis of the F_{ij} factor. The distribution comparisons showed that the census trips averaged slightly longer in length than those trips estimated by the model. The next step is to explore why this difference is occurring. It appears that the observed data (census) are showing longer travel times to work than the estimated travel times (model). Travel times from the census are longer than the model estimates. It can be concluded that the journey-to-work travel time increased in this region between the 1960s when the origin-destination surveys on which the travel forecasting model was based were conducted and 1980 when the census journey-to-work data were gathered.

There are many possible reasons or combinations of reasons for the increase in travel time to work in this region during the past 10 to 20 years. The main reason is that the urban area has expanded: vacant land has been urbanized along the freeway network that was just opening in the 1960s. Along with that came the growth of not only suburban areas, but also rural areas, with many people seeing a slower-paced way of life or cheaper land while still working in the urbanized area. The increase in transit trip length can be attributed to the longer bus service routes. Countywide bus service was established in King County in 1974 and in Pierce and Snohomish counties in the late 1970s. The use of commuter park-and-ride lots in suburbs and rural areas has also contributed to the increase in transit trip length.

The adjustment to be made to the trip distribution model centers on the F_{ij} factor. The F_{ij} factor, as described earlier, is a travel time friction factor. There is a different F factor for each minute of travel time. For a particular travel time, the friction factor

$$F_{ij} = 1/t_{ij}^{n}$$

where T_{ij} is the travel time between Zones i and j and is an exponent that can vary among travel time increments between zones *(2)*. Because the propensity to take longer trips is shown by the trip length frequency comparison, the n factor must be adjusted on both the short end and the long end of the distribution curve.

Transit Trip Analysis—Mode Split

The observed differences in transit trips between the model and the census can be separated into two categories. The first category consists of those differences that are similar to those observed between the total model and the total census trip tables. This would appear to indicate that the mode split model was not at fault; it was just reflecting those differences caused by basic differences in the two data bases or the trip generation or distribution process, or both.

The second category is those differences between the model-generated and the census-generated transit trip tables that are different from those observed for the total trip comparison. It is these differences that show where the mode split model is over-estimating (there were no cases of underestimating).

The FLOWMAP analysis of the transit trip tables showed an excess of model transit trips attracted to the zones containing the major colleges in Seattle; this too was reflected in the total trip comparisons. Also, the transit trip comparison shows an excess of census trips attracted to the Seattle CBD from the close-in neighborhoods of Queen Anne and Capitol Hill; this, again, was reflected in the total trip comparisons.

However, the excess of model transit trips attracted to the Seattle CBD from suburban areas is not reflected and is in some cases contradicted by the results of the total trip analysis. The conclusion that can be drawn from this analysis is that the mode split model overestimates transit trips bound for the Seattle CBD from suburban areas.

SUMMARY AND CONCLUSIONS

Some findings that resulted from this comparison were not related to the questions of whether the transportation models needed calibrating and whether the census data were inaccurate. That college trips were included in one data set and not the other for both sets of trip tables complicated the analysis somewhat. However, when these differences had been recognized and accounted for, a clearer picture emerged of the real differences between the two trip table sets and what explained these differences.

The real differences discovered between the two sets of trip tables that relate to trip generation, distribution, and mode split are as follows. The FLOWMAP analysis of total trips revealed an excess of census trips attracted to the CBD areas of Everett, Seattle, and Tacoma. The trip generation process was examined with respect to this pattern of total trip difference and a plausible explanation, that of varying trip generation rates, was discussed.

It is possible, however, that the reason for the excess census trips attracted to the CBDs of Everett, Seattle, and Tacoma rested not with the production and attraction inputs to the trip distribution model but with the friction of time-distance factor. The trip length frequency distribution comparison showed that the distribution of travel time was slightly different, which indicates that census trips averaged slightly longer in travel time than model trips. This would appear to indicate that the average trip length is longer than the models are estimating, which means that the friction of time-distance factor could be adjusted so that time-distance is not as much of as an inhibitor as it is in the present trip distribution model.

The mode split model was found to overestimate transit trips from suburban residential areas to Seattle's CBD. The mode split model, using travel time and monetary cost variables to determine mode choice, clearly is making the transit mode more attractive than do census data for these particular types of transit trips. On the basis of this comparison, some adjustment to the travel time or monetary cost variables, or both, may be in order.

In this analysis, most of the findings and conclusions are based on the assumption that the factors used to adjust the census journey-to-work trip tables to a form comparable to that of the model trip tables are accurate. These factors, discussed earlier, can be adjusted either up or down depending on the methodology used in calculating them and the subjective judgment of the individual determining these factors. The methodology set forth by WASH-COG, modified somewhat because of the lack of availability of certain types of data for the Puget Sound region, was used.

The later realization, after the analysis had been performed, that the first of the four factors need not have been applied to the 1980 Census package serves to emphasize the statements made in the previous paragraphs. Leaving out the factor of 1.08 would have resulted in an overall adjustment factor of 1.68 instead of 1.81 for both the total and the transit trip categories.

If the factor used to adjust total census trips had been smaller, the overestimation of census trips attracted to the CBDs of Everett, Seattle, and Tacoma would not have occurred or been as large. In this example, other areas would show an overestimation of model trips where none existed in this analysis. If the factor used to adjust transit trips had been smaller, the model's apparent overestimation of long-distance transit trips into the Seattle CBD would have been even greater. If, on the other hand, the factor used to adjust transit census trips had been larger, the excess of model transit trips from some suburban areas to Seattle's CBD would have been less significant or disappeared completely, and instances in which census transit trips would have exceeded model transit trips would have occurred. It is the researchers' position, however, that the factor of 1.81 provided reasonable results. Conclusions from this analysis also reflect what travel forecasters at the PSCOG suspected about their trip models. Perhaps with some additional information, particularly about occasional mode shifts during the week for the Puget Sound region, these factors could have been tuned more finely.

A significant portion of this factoring process, and therefore a significant portion of the room for error, could be eliminated by making the wording on the long form of the census questionnaire match that used by transportation surveys. This would involve asking where people worked and how they traveled to work on the previous day instead of how they usually traveled to work the previous week.

ARE CENSUS DATA GOOD VALIDATORS OF TRANSPORTATION MODELS?

The answer to this question is yes, with certain important qualifiers. The first and foremost would be to change the wording on the census questionnaire to match that typically used in transportation surveys, as noted previously. This would reduce the room for error in factoring the census trip table to the transportation models' production and attraction format.

The second change would be to separate college trips from work trips in the transportation model's generation and distribution process. Including college trips with work trips is not a requirement of the UTPS modeling process.

Supplemental surveys concerned with trip generation production and attraction rates would make up for the shortcoming in this particular area, in which large concentrations of land use areas that have different-from-average trip generation rates are located.

In summary, with these qualifiers, the data from the census journey-to-work questions provide a great opportunity for transportation planners at all levels to obtain a good picture of the actual condition of the transportation system. For those engaged in transportation modeling at the MPO level, the chance to compare these data with transportation model output is a much less costly alternative than a full-scale origin-destination survey.

The 1990 Census will provide an opportunity to change the wording of the census form to conform to those questions typically asked in transportation surveys. This would eliminate a good deal (but not quite all) of the "apple and orange" comparisons that cause this kind of analysis to be subject to skeptical scrutiny. With that kind of "fine tuning" in the production of the UTPP, it appears that census journey-to-work data can fill an important role in supplementing and supplanting large-scale regional origin-destination surveys.

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