Use of Census Data for Transit, Multimodal, and Small-Area Analyses

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Journey-to-work census data have become an indispensable resource for tracking a host of megatrends that have had and continue to have a profound effect on how Americans commute. Among these have been suburbanization of jobs and the emergence of edge cities, increases in the number of multiple-earner and small households, steadily rising vehicle ownership rates, the growth in telecommuting and homeworking, increasingly automobile-dependent land use and settlement patterns, and the geographic spread of metropolitan boundaries. Collectively, these and related factors have brought about strong shifts in commuting behavior over the past two decades, most notably a sharp rise in drive-alone automobile commuting (*1*). Worsening traffic congestion, persistent air quality problems, and an apparently widening gap between levels of accessibility of different social classes have been by-products of America's growing dependence on the car for commuting. The public policy response to trends of the 1980s has been unprecedented. At the federal level, passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 (CAAA) have radically changed the process of transportation planning and decision making, requiring that proposed highway and transit investments be judged in broad societal terms. At the state and local levels, transportation authorities and private developers today have to cope with an imposing array of government mandates, including concurrency rulings, congestion management regulations, trip reduction requirements, and adequate public facilities ordinances, to name a few.

All of these regulations and imperatives have a need for better data and information to guide public policy making. The decennial census has become one of the most dependable and consistent sources of information for monitoring and evaluating not only how Americans get to work, but also for tracking trends in population and employment, household composition, industrial classifications, and metropolitan structure. For transportation planning purposes, the census provides the richest source of small-area geographic information on the location of people, housing, and employment within a metropolitan area. It also provides a basis for reassessing the validity of previously calibrated transportation models and for estimating new, updated ones.

For multimodal transportation planning purposes, the Census Transportation Planning Package (CTPP) is the crown jewel of census data because it provides flow (as well as trip end) data at a small geographic scale of analysis. The Urban Element of the CTPP, in particular, supports small-area analysis of commuting within metropolitan statistical areas (MSAs).

Prepared by the U.S. Bureau of the Census for metropolitan planning organizations (MPOs) to use in their long-range planning efforts, the CTPP/Urban Element comes in parts (2). Part 1 (CTPP-1) contains data tabulations by area of residence, and Part 2 (CTPP-2) contains data by area of employment (defined by workers in households). Zone-to-zone work trip interchanges, stratified by travel modes and times, are available in Part 3 (CTPP-3). For small-area analyses, records are usually identified by transportation analysis zone (TAZ), though data can also be obtained by census tract, block group, special study area, and central business district (CBD), when requested.

Other national data sources on journey-to-work, like the Nationwide Personal Transportation Study (NPTS) and the American Housing Survey (AHS), contain no flow data and use much coarser geographic identifiers than the CTPP. The most refined intrametropolitan spatial analysis permitted by NPTS is comparisons of commuting patterns between central city and non-central city locations. Except for a handful of metropolitan areas (New York–New Jersey–Connecticut, Los Angeles–Orange County, Hartford, Chicago, San Francisco–Oakland–San Jose, and Philadelphia), sample sizes from the 1990–1991 NPTS are too small (under 400) for in-depth intrametropolitan studies of commuting. The AHS likewise has too few cases and geographic coding that is too coarse to support intrametropolitan analyses of commuting behavior. Since NPTS and AHS only provide data by area of residence, it is not possible to carry out any corridor-level analyses or trip interchange modeling with either.

In its raw tabular or electronic form, the CTPP is often too voluminous to be easily analyzed. Summary statistics, thematic mapping, and GIS outputs are today commonly used to distill CTPP data to a more comprehensible and digestible form. With GIS, the physical features of transportation can be referenced to a coordinate system as points (a bus stop, park-and-ride lot), lines [highway segments, high-occupancy vehicle (HOV) lane], or polygonal areas (a two-block zone around a bus stop, a TAZ). Since spatial arrangements are central to most transportation activities, GIS has found a natural home within the transportation profession.

A number of possible uses of journey-to-work census data for transit and multimodal analysis and planning are outlined in this paper. The focus is on the use of data at a small geographic area (i.e., TAZs, census tracts, block groups). Both current and future small-area applications of census transportation data are discussed.

Multimodal Analyses

ISTEA encourages state and local authorities to act on transportation matters from a multimodal perspective. This does not simply mean that plans should weigh the investment needs of the highway, transit, rail, aviation, and maritime sectors, but rather that transportation itself should be looked at holistically, as an interdependent and integrated system.

All MPOs have some in-house capabilities for forecasting and evaluating travel demand within their regions. With the CTPP/Urban Element, multimodal analyses of commuting flows can be easily conducted. Characteristics of both the origin (place of residence) and destination (place of employment) can be statistically correlated with data on commute flows as a basis for building predictive models. Whereas CTPP allows a rigorous analysis of home-based work trips from zone to zone, one of its shortcomings is that it treats all work trips as if they were unlinked. Thus, non-work-related segments of a linked work trip are effectively ignored in CTPP tabulations. Ideally, transportation planners will use metropolitan travel survey data on linked trip making in parallel with CTPP data to enrich our understanding of the dynamics and complexities of contemporary commuting behavior.

Area-Specific Analyses

From Parts 1 and 2 of the CTPP, the journey-to-work can be examined with reference to characteristics of the residential and employment ends of the trip. Trip generation estimates can easily be derived from trip end data, though the census geography of the CTPP is not fine-grained enough to produce site-level rates, as found in the Institute of Transportation Engineer's *Manual on Trip Generation.*

From CTPP-1, work trip production rates can be estimated by indexing total daily vehicle trips in a zone to the number of households or total acreage. At place of employment, work trip attraction rates, expressed in terms of total workers or acreage, can be estimated for CBDs and large suburban employment centers (using CTPP-2). When pooled over all zones in a study area, trip rates (e.g., vehicle work trips per dwelling unit) can be cross-classified by such factors as vehicles per household and population density.

The CTPP also contains critical inputs into Urban Transportation Planning Systems (UTPS) modeling. Zonal-level regression models predict total counts of work trip ends produced by or attracted to a zone. Possible predictor variables available from CTPP-1 for estimating home-based work trip production models are numbers of persons, households, and employed residents, as well as such sociodemographic attributes as age, ethnicity, education, employment status, household size, household income, vehicles available, worker occupations, and occupational status. For home-based attraction models, CTPP-2 offers such possible predictors as numbers of workers by occupational class, employment densities, and median earnings. Of course, CTPP data might also be supplemented by other sources, such as local land use inventories that contain the square footage of building space and measures of land use heterogeneity within TAZs.

Flow Analyses

At the regional level, the CTPP is well suited to the task of estimating and validating trip distribution and modal choice models for journeys to work. Various kinds of multimodal studies of commuting flows, carried out across TAZs or other small geographic units, are outlined below.

Trip Distribution and Spatial Interaction Models

Zone-to-zone flow data from CTPP-3 can be used for simple visual displays as well as more advanced behavioral modeling. The following applications are possible:

- The easiest and perhaps most revealing use of flow data is to prepare point-to-point origin-destination (O-D) (desire line) maps. Since flow images can be undecipherable due to the large number of zonal pairs, some agencies present attraction-constrained desire line maps (i.e., flows to a subarea with large employment concentrations) for particular corridors and specific modes. Interactive mapping tools, such as FLOWMAP, can also be used to customize O-D maps to display variable-width directional flow arrows (*3*).
- The CTPP/Urban Element allows the calibration of conventional trip-interchange gravity models. Also, existing gravity models can be cross-checked using CTPP flow data. Part 3 of the CTPP provides the necessary trip interchange and travel time matrices for calibrating new models and validating existing ones. More sophisticated gravity formulations are also possible, such as stratifying interchanges by modes and trip end data by the occupation of employed residents (at the place of residence) and workers (at the place of employment). Once specified, new friction factors and other model coefficients can be estimated.

The CTPP-3 data are the most complete source of zone-to-zone travel times available for work trips. One limitation of CTPP data is that most cells in the interdistrict travel time matrix are empty. Techniques have been developed for imputing travel times for empty cells by extracting and synthesizing data from cells with current destinations (*4*). This allows zone-to-zone travel times in the CTPP to be cross-checked against zone-to-zone highway and transit travel time matrices generated from regional computerized highway and transit network data bases.

- During the past decade, census flow data have been used to study such public policy topics as jobs-housing balance, spatial mismatches, residential mobility, and intrametropolitan migration (*5,6*). Most spatial policy analyses use some variation of a constrained gravity model. Constraining the model at the workplace end of a trip can be used to study the correlates of spatial mismatches (e.g., between employment opportunities and low-income concentrations) and reverse commuting. Production-constrained models support studies of retail tradesheds and the market areas of health care centers and other institutional land uses (*7,8*). The U.S. Bureau of the Census itself uses interchange data from CTPP/State Element to define overlapping laborsheds as a basis for delineating the boundaries of a defined census region (e.g., the formation of a CMSA depends on a minimum threshold amount of inter-MSA "external" commuting). Flow data have even been used to guide theory. For example, a series of studies in recent years on the phenomenon of "wasteful," or excess, commuting has emerged. Researchers have applied linear programming algorithms to compare optimal work trip interchanges predicted by the "commute-cost minimization" model of residential location with actual commuting distances. Studies in metropolitan Baltimore (*9*), Los Angeles–Orange County (*10,11*), and other regions (*12*) have estimated excess commuting to be in the range of 11 to 85 percent. Such findings have led to a recasting of the traditional monocentric model of residential choice to account for the influence of polycentrism and nontransportation factors (e.g., quality of schools) on residential location decisions (*13*). In addition, 1980 census data have been used to estimate population and employment density gradients for multiple subcenters in Southern California in the study of how polycentrism influences commuting (*14,15*).
- CTPP flow data also allow for the cross-checking of screenline counts used to validate UTPS models. In addition, the State Element, which provides commute flow data between counties, small places (population exceeding 2,500), and regions, is sometimes used to validate work trip flows at external cordon lines and boundaries between metropolitan and nonmetropolitan areas.

Modal Split Analyses

Work trip modal split models are also frequently estimated from census commute flow data. Modelers face two trade-offs, however: unit of analysis and geographic resolution. The Public Use Microdata Samples (PUMS) provides 1990 census data for individual households (which completed the long census form), allowing for disaggregate utility-based modeling of mode choice for the journey to work. (For most metropolitan areas, PUMS provides approximately a 1 percent sample of households and the persons in them, with personal identifiers removed). The trade-off, however, is that the smallest level of geographic disaggregation is the PUMA (Public Use Microdata Area). PUMAs are amalgams of census tracts that represent 100,000 to 200,000 people (e.g., the PUMA for Bronx County, New York, contains three PUMAs). Thus, PUMAs are too coarse for pinpointing trip origin or destination. For many areas, sample sizes are too small for statistically reliable mode choice modeling.

With CTPP, the opposite holds. Unlike PUMS (or NPTS or AHS), CTPP allows the statistical association of work-trip modal flows between small geographic areas. (CTPP is also available for all MSAs, big and small; for NPTS and AHS, geographic breakdowns are only available for MSAs with a population exceeding 1 million.) However, CTPP only provides aggregate zone-to-zone flow data, so it does not allow for discrete choice modeling, such as is statistically possible with PUMS, NPTS, and AHS.

If there are sufficient data observations, modal split models can be developed for every modal option in a metropolitan area (e.g., car/truck/van, bus, streetcar/trolley car, heavy rail, commuter rail, bicycle, walking). An important predictor variable of any well-specified modal split model is the travel time differential between modes (e.g., transit versus automobile). For the zone of residence, possible predictor variables (from CTPP-1) might include median household income and vehicle availability, occupations of employed residents, residential density (households per acre), and perhaps even departure time. For the zone of work, predictors (from CTPP-2) might include variables on class/occupation of workers and employment density (workers per acre). To build more completely specified models, however, CTPP data should be supplemented with data from local surveys, such as information on the availability and price of parking at the workplace. Land use data from regional inventories (e.g., land use mixes) might also be merged with the CTPP. From a modal split modeling standpoint, one of the more serious limitations of CTPP is the availability of travel time data only for the elapsed portion of work trips. Since access, waiting, and transfer times are known to be more serious deterrents to transit commuting than elapsed times, modal split models estimated from the CTPP alone are unavoidably partial models. Supplementing the CTPP with travel time data for access and egress portions of trips from regional travel surveys would be one way of overcoming this problem.

More simplified trip end modal split models can also be estimated from the CTPP. At the destination end, for instance, the percentage of trips by carpool and vanpool could be estimated as a function of location within the MSA (e.g., CBD, central city, remaining area), employment density, and factors provided from other data sources (e.g., existence of HOV facilities).

Data Conversions

For integration of CTPP data into UTPS modeling, several types of data conversions are necessary for conducting small-area analyses. On the basis of 1980 journey-to-work data, Mann (*16*) recommended applying a factor of 1.96 for converting (one-way) journey-to-work data to (two-way, daily) home-based work trips. Also, since the 1980 and 1990 censuses compiled commuting data for the "usual" trip made to work last week, CTPP understates average vehicle occupancy (since occasional ridesharing and transit trips are not counted). Mann (*16*) suggests a conversion factor of 1.04 for estimating average vehicle occupancy, though the appropriate factor for 1990 might be different, especially given the sharp declines in vehicle occupancy levels during the 1980s. Daily work trips can also be converted to peak-hour work trips, using either tables from the National Cooperative Highway Research Program Report 187 or locally derived conversion factors.

Transit Service Analyses and Planning

ISTEA strengthened the nation's commitment to public transportation, calling for the adoption of metropolitan planning "methods to expand and enhance transit services and to increase the use of such services" (Section 134d). Census data provide a backdrop for carrying out long-term strategic transit planning. Existing and potential markets of transit customers can be identified by tracing, over time, structural changes in a region's population and employment base and sociodemographic makeup. Regional travel demand models (UTPS), driven by census data inputs, can also be used to evaluate the likely cost-effectiveness of corridor-level transit projects. Census data even find application at the level of operations planning of bus services, such as quantifying population residing within 0.25 mi of a bus stop. For the most part, however, journey-to-work data are too coarse for detailed route-level transit planning or fine-tuning an existing service. Census data can be supplemented by on-board ridership surveys, on-off counts, and other sources to carry out finer analyses. Today, a number of U.S. transit agencies are combining census data with GIS to display existing and potential markets of transit customers, using successive overlay techniques.

Area-Specific Analyses

Census data, including CTPP-1 and CTPP-2, are increasingly relied on by transit planners for carrying out several kinds of market analyses at place of residence and place of work.

Study of Captive Riders

Census data at the tract level allow areas with large transit-dependent populations to be pinpointed. For example, planners at SamTrans, serving the western peninsula of the San Francisco Bay Area, merged census data with GIS to graphically display census tracts within their service district that have high concentrations of captive riders. Such thematic mapping techniques shade areas to highlight, in this case, zones with significant shares of residents who are dependent on transit services. In the case of SamTrans, transit dependency was defined by using a composite index of automobile availability, household income, age (stage of life cycle), and mobility impairment status. Overlaying route maps onto such displays of captive riders can also be used to evaluate compliance with Title VI requirements. All transit properties receiving federal assistance are required to submit an updated Title VI report every three years to ensure that Federal Transit Administration-assisted transit services do not discriminate with regard to race, color, or national origin. Successive overlays of sociodemographic census data are the best way to assess whether all segments of the population are receiving equal and adequate services.

Demand Projections

As inputs to both short-range and longer-range strategic planning, many transit agencies rely on census data for trend analyses of changes in population, age, fertility rates, and income within their jurisdictions. Factors like changes in ratios of jobs to employed residents can also be generated from CTPP-1 and CTPP-2, enabling transit agencies to project the likely work trip directional flows for specific areas. Zones with labor force deficits (housing rich/job poor) will experience predominantly out-commuting in the a.m. peak, whereas job-rich zones with a labor force surplus will experience more in-commuting. Such projections could guide transit agencies in route planning, such as in identifying areas where services might be efficiently interlined.

Demographic and Employment Profiles

Some rail transit agencies compile census data from CTPP-1 and Summary Tape File 3A (small-area summary) to draw sociodemographic profiles of residents currently living near stations. Planners with the Bay Area Rapid Transit (BART) district, for example, have created a data base containing 18 sociodemographic variables for neighborhoods around all 34 stations. They use GIS to interpolate census data for station areas that lie within a 1/4- or 1/2-mi ring of BART stations. By comparing station-area demographic profiles with 1992 survey data compiled from on-board ridership surveys (geocoded by residence), BART planners have been able to identify potential markets of rail commuters who live near stations. These data are also being used by BART's joint development office to screen neighborhoods that might be candidates for real estate ventures. An example is the leasing of land formerly used for parking to developers for building mid-rise apartments, as is currently being done at the El Cerrito Del Norte and Pleasant Hill BART stations.

Similarly, transit agencies can use CTPP-2 to identify employment concentrations within their service districts. Employment data can also be stratified by occupational and industrial class. For instance, premium subscription bus services might be aimed at areas with known concentrations of management and professional personnel as a market development strategy.

Transit Trip Rates

Trip end data can be used to estimate transit work trip rates. When produced over time, these rates provide a benchmark for gauging market penetration. A possible source of error in using census data for transit trip analysis is the confusion between subway/elevated, railroad, and even streetcar/trolleycar among some laypersons. For example, the 1990 CTPP/State Element showed that 2,125 residents of suburban Contra Costa County were "railroad" commuters heading to San Francisco, even though BART is the only fixed-guideway service connecting the two.

These "railroad" commuters were in all likelihood BART riders who consider BART a railroad instead of a subway/elevated (*17*). Similar miscoding problems also arise between Muni light rail service (which operates underground in downtown San Francisco but is a "streetcar/trolleycar" service) and BART. One way to reduce the confusion is to tailor census questionnaires so that they refer to popular names of transit services used by local residents in large rail-served metropolitan areas (*18*).

Performance Evaluation

Place of residence and employment data offer only a few opportunities for conducting transit performance studies and planning route-level operations. Many transit agencies use census population and household counts over time to study trends in service utilization (e.g., annual ridership per capita within the service district). Tract-level data can also be used to calculate the percentage of population within a district residing within a ¼-mi walking distance of a bus route, another commonly used indicator of service effectiveness.

Commute Flow Analyses

Transit agencies can use zone-to-zone commute flows from CTPP-3 for route planning, identification of existing and potential markets of transit riders, and evaluation of transit accessibility.

Routing Planning

Desire line maps of transit commutes can be overlaid with maps depicting existing route configurations to evaluate how closely they match. Existing and forecast transit O-D patterns can be used to guide facilities planning and investment. Travel time ratios between transit and the automobile can also be computed for zonal pairs along major corridors. Such information can be used to modify routes with poor comparative travel times or excessive circuity and run segments that poorly align with travel desires.

For some transit properties, especially those in large metropolitan areas, CTPP-3 might be too big and unwieldy for transit planners to conduct TAZ-level travel flow analyses. MPOs will likely be called on to extract trip interchange tables from CTPP-3 that correspond to TAZs within the service boundaries of individual transit districts. From the local transit planner's perspective, this would be a much appreciated, valuable service.

Market Studies and Evaluations

CTPP-3 supports several kinds of transit market studies and evaluations. BART is currently combining CTPP-3 files and GIS to study the O-D patterns of rail versus nonrail commuters in BART-served Alameda, Contra Costa, and San Francisco counties. BART planners will concentrate on workers who reside near stations but who commute to San Francisco and other BART-served urban centers by a nonrail mode. BART planners are drawing sociodemographic profiles of these potential yet latent rail trips and are attempting to identify factors that might explain nonrail commuting in these instances, such as inadequate feeder bus services or the availability of free parking at the workplace. Census data allow fairly refined analyses, such as the ability to net out workers in sales occupations who likely need vehicles for midday business travel. BART planners are also using census data to project the additional rail trips, and the likely sociodemographic composition of new rail users, who might be priced over to BART following the introduction of congestion pricing on the San Francisco–Oakland Bay Bridge. O-D pairs along the transbay corridor are being used to estimate the potential ridership effect of peak-hour tolls on the Bay Bridge.

In Baltimore, transit planners are using CTPP-3 to compare O-D patterns of "streetcar" versus single-occupant vehicle trips along the central light rail line. By understanding the O-D patterns of their chief competitor, the drive-alone automobile, Baltimore's transit planners hope to improve feeder services at key stations and win over appreciable numbers of automobile commuters to the light rail mode.

Golden Gate Transit (GGT), serving the north counties of the Bay Area, used county-to-county flow data from CTPP/State Element to evaluate screenline crossings at the Golden Gate Bridge. GGT planners were concerned about the steady decline in bus commuters across the Golden Gate Bridge and wanted to determine whether this was due to an overall decline in commute flows or deteriorating transit services. Planners found that bus transit commutes fell at roughly the same rate (3.5 percent) as nonbus commutes along this corridor between 1980 and 1990. Thus, bus commuting trends paralleled overall intercounty commute patterns. GGT's fastest-growing bus commuting market was found to be reverse commutes from San Francisco and Marin counties to new, large-scale suburban employment concentrations in Sonoma County and the East Bay. GGT planners are responding by proposing a phased expansion of reverse-direction and cross-haul commuter bus runs. Some expect that the trend toward more balanced bus trip flows will improve GGT's operating efficiency by increasing revenue service hours and reducing back-haul and deadhead losses.

Intermodal Travel

ISTEA requires, for the first time, that state departments of transportation develop a statewide multimodal transportation plan. It also requires states to develop management systems for intermodal activities, including for goods and freight movement. New data sources will be required to inform policy makers which intermodal investments will do the most to improve goods movement and passenger interchanges.

Journey-to-work census data, as currently compiled, can only play a limited role in intermodal transportation planning. The absence of data on linked trip making and for nonwork purposes (e.g., to change travel mode) restricts the applicability of journey-to-work data to intermodal planning. Trip interchanges to major transportation hubs, such as an international airport, might suggest levels of intermodal activities. However, the CTPP-3 tabulations only record journeys by those working in the TAZ occupied by the airport. Correctly speaking, the purpose of a ground access trip from one's home to the airport to catch a flight is to "change travel mode." Whereas census data provide no help in this area, several recent metropolitan travel surveys provide data on linked trip making for multiple purposes, including those in the Chicago (1991), San Francisco Bay Area (1990), and Seattle (1991) regions.

Transportation Demand Management, Ridesharing, and HOV Services

It is widely accepted that cities will never be able to build themselves out of traffic congestion. Transportation demand management (TDM) techniques, like flextime and ridesharing, can increase the throughput of existing roadways by shifting travel demand by time and mode and over space. CTPP data on time of departure can be used to study the temporal distribution of work trips among zones. Stratifying O-D patterns by departure time intervals and occupational class might be one way to match potential ridesharers. Employment zones can also be classified in terms of the departure time characteristics of work trips that flow into them. Regional rideshare agencies might use this information to identify flows to large employment concentrations that are good candidates for targeting marketing campaigns.

For example, CTPP tables could be used to identify industries (e.g., manufacturing, wholesale) with fairly consistent work shifts (i.e., departure times by workers) that operate from a single fixed location. TAZs with large counts of workers in these industries can then be identified (CTPP Table 2-3). Employers in TAZs with large counts of targeted industries might later be approached about forming a transportation management association (TMA) to promote carpooling and vanpooling. Rideshare agencies might then identify the origins of trips that are destined to targeted TAZs. They can also check whether workers in the origin zones have jobs in the industries in the targeted TAZs (CTPP Table 1-18). Large numbers of trips originating from the same areas would identify prime locations for siting park-and-ride lots or timed-transfer depots. Attraction-constrained flow models (showing flows from all origin zones to major employment centers) could also be used to identify possible locations for park-and-ride lots. Flows might then be assigned to a network and scanned to identify junctures with large numbers of cross-flows, signifying possible locations for siting park-and-ride lots and transfer points.

Similarly, O-D flows might be used to identify corridors where HOV facilities are planned. Overlaying existing commute patterns, color coded by occupancy level, would be a good way to assess the market potential of a proposed HOV corridor. Any demand projections would need to be adjusted for the latent multioccupant vehicle trips that might be induced by the opening of a new HOV lane.

Other Small-Area Analysis Applications

A host of other possible small-area transportation-related analyses can be conducted with census data, including studies of traffic operations, alternative modes, neighborhood travel, and regional accessibility.

Traffic Operations

O-D pairs that might jointly use a section of a road can be assigned, either manually or using a computer algorithm, to that segment. This might be used to assess the traffic operational effects of future development at either end of the assigned O-D pairs. Census data on residential and employment densities can also be used for traffic planning, such as estimating the additional arterial lane and spacing requirements likely to be imposed by a major new traffic generator (e.g., shopping mall, industrial park) (*19*). As part of a network study, travel time data from CTPP-3 might be integrated with results from speed-delay studies to evaluate current and projected traffic levels of services. Commute flow and travel time data might also be used as input in confirming and validating skim trees. Whereas first-cut performance evaluations might be possible with census flow data, in general the geographic coding of CTPP data is too coarse to support any refined traffic operations analyses.

Telecommuting and Working at Home

The number of Americans working at home increased by more than 1 million, or 50 percent, from 1980 to 1990 (*1*). CTPP-1 data can be cross-tabulated by occupational and industrial classifications to identify work-at-home markets. Currently, however, it is difficult to distinguish telecommuters from independent business persons and sole proprietors who work out of their home.

Bicycle and Walk Commuting

As with automobile and transit commutes, census data can be used to compare existing O-D patterns of bicycle and walk commutes with current infrastructure provisions. Overlay maps can reveal the degree to which existing sidewalk networks and bicycle path systems align with O-D flows. For evaluating the demand for nonmotorized recreational and social trips, local travel survey data might be combined with census data. CTPP data might also be used to assess the level of internal ("within neighborhood") commuting by bicycle and pedestrian modes. High levels of internal nonmotorized commuting in specific TAZs or census block groups might suggest the need for targeting improvements in those areas (e.g., more pedestrian-actuated signal crossings, addition of dedicated bicycle lanes). Under ISTEA, bicycle and pedestrian improvements qualify as transportation enhancements that are eligible for National Highway System and Surface Transportation funds.

Neighborhood Travel Studies

Census data have also been used by researchers to study the commuting choices of residents from neotraditional versus conventional suburban, automobile-oriented neighborhoods. The central premise of this line of research is that those residing in relatively dense, mixed-use neighborhoods with traditional grid street patterns are likely to be less automobile dependent. Using 1990 census data at the block group level from Summary Tape File 3A and CTPP-1, researchers recently found that residents of traditional neighborhoods in the San Francisco Bay Area and Southern California averaged higher shares of transit commuting than their counterparts from nearby automobile-oriented neighborhoods with similar median household incomes and transit service levels (*20*). Transit-friendly neighborhoods in the San Francisco Bay Area averaged between 2 and 5 percent more commutes by mass transit than their matched-pair automobile-oriented neighborhoods. A comparable study of commuting by residents of traditional neighborhoods in Montgomery County, Maryland, using 1980 journey-to-work data reached similar conclusions (*21*).

Accessibility Studies

Accessibility indices have long been used to measure and compare the relative proximity of neighborhoods to employment centers, health facilities, and other urban facilities and services. Typically, an accessibility index is equivalent to the denominator of the gravity model. It is computed by multiplying the number of trip attractions by the interzonal friction factor (which declines with interzonal travel time) and summing the results over all attraction zones. Production-constrained gravity models are commonly used for measuring the geographic extent of laborsheds, where TAZs with large employment bases represent the constrained production end of interchanges. When census data are supplemented by other data sources, gravity-based accessibility indexes can be derived to, say, identify the number of child-care centers or restaurants/retail plazas within a 3-mi radius of an employment center. Attraction-constrained gravity models might likewise be estimated from journey-to-work data to study whether mismatches between worker occupational classes and housing prices have led to relatively long commutes (*5*). Recently, accessibility-based gravity models have also been used to compare how accessible different types of suburban communities (e.g., traditional versus automobile-oriented planned unit developments) are to employment and shopping opportunities in Southern Florida (*22*).

CONCLUSION

Census journey-to-work data have become increasingly vital to transportation planning and evaluation. These data are the most consistent and dependable source of information on where Americans live and work and how they commute. The CTPP is the most detailed source available for the study of intrametropolitan commute flows at a fine-grained level. It is finding its way to an ever-widening constituency of users—metropolitan planning organizations, state departments of transportation, public transit agencies, rideshare organizations, TMAs, market researchers, urbanologists, and others.

One of the most important applications of journey-to-work data for small-area analyses remains long-range multimodal transportation planning. The CTPP provides essential data inputs for long-range travel demand forecasting and can be used to cross-validate and update previously used transportation models for work trips. Many public transit agencies today rely on census data for both strategic long-range planning and ongoing service planning. Census data also provide background information from which to carry out link segment analyses, examine market receptivity to specialized facilities like HOV lanes, and compare the accessibility of residential neighborhoods to different employment opportunities.

The growing popularity of GIS has apparently elevated census data to a new height of usefulness. Since transportation is inherently a spatial phenomenon, GIS allows data on the characteristics of origins, destinations, and commute flows to be conveniently displayed, replacing what in the past were tabular presentations. The ease with which successive overlay maps can be produced from GIS bodes well for a future of strategic transportation planning that is grounded in rigorous analysis yet is accessible to a wider public. The marriage of GIS and journey-to-work census data has allowed transportation planners to push the profession in new and exciting directions. The litmus test of the benefits of these tools and data bases, of course, is the quality of decision making that results and ultimately how smoothly our streets, transit systems, and alternative commute programs operate.

ACKNOWLEDGMENT

Thomas Speakerman of the Bay Area Rapid Transit District and Lisa Ives of the San Mateo County Transit District provided information on census applications for their respective transit authorities. Chuck Purvis of the Metropolitan Transportation Commission also provided useful advice in the preparation of this paper.

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