Disaggregated Travel Forecasting

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Abstract

GIS-T has become an essential tool for transportation planning and travel forecasting. In this study, a disaggregated travel forecasting model is used to predict journey to work changes in regional development, demographics, and transportation supply. The Census Transportation Planning Package (CTPP) summarizes information by place of residence, by place of work, and for worker flows between home and work. However, its spatial unit is too broad to be used in transportation planning. Thus, travel models with aggregated data often mislead the transportation planning. Twin Cities Metro Area is selected as a study region. There are 689 census tracts in Twin Cities Metro Area while 42,189 census blocks as of year 2000 are available. The results show that disaggregated GIS-based approach to transportation modeling is a fundamental means of improving travel forecasting.

Keywords: GIS, CTPP, transportation, aggregated, disaggregated

1 Introduction

As time passes, the structure of cities significantly changes, especially in metropolitan areas. The seven counties around the Twin Cities in Minnesota have tremendous traffic flows, which continue to increase as the counties continue to expand their urban/suburban structures dramatically. Thus, there are many transportation issues such as the task of commuting to and from the workplace, and the tremendous monetary costs needed to reconstruct or maintain arterials. The spatial mismatch between jobs and housing is one of critical issues because it can increase commuting costs for an individual,

and for society as a whole. To delve into this issue, the better understanding of commuting flows is necessary. Using the Census Transportation Planning Package (CTPP) data including three categories of (1) residence, (2) work, and (3) flows between home and work, the relationship between jobs and housing can be thoroughly understood. Moreover, it can analyze travel patterns and consequently the design of city structures. The existing environment as a whole and the need for a supporting infrastructure can be re-evaluated based on the disaggregated flow analysis.

2 Background

Most metropolitan areas are expanding their boundaries toward suburban areas, thus these patterns cause spatial imbalance between two areas due to insufficient housing capacities in urban areas. Theoretically, the jobs-housing balance means that the opportunity of housing is to set the equilibrium to the opportunity of workplaces. Thus, it reduces an inequality between jobs and housing, and alleviates average commuting distance. However, in reality, it is not easy to balance between jobs and housing because of housing capacity and other social issue. If jobs and housing are balanced, then it could diminish traffic jams because the balance can make a shorter distance between jobs and housing. Cervero (1989) showed that fixing the imbalance between jobs and housing could ease traffic congestion and make workers commute less to workplaces. Kan (2002) demonstrated that the relationship between job changes and residential mobility is positively related to each other. For example, employees wanted to change their jobs to make the commuting distance shorter from their housing due to rising gas prices. Thus, having good mobility enhanced job possibility for future employee. Kwan (1999) addressed gender differences with respect to jobs and housing by illustrating ‘out-of-home’ and ‘non-employment’ activities. Examples of out-of-home and non-employment activities include child-serving activities and shopping. According to Kwan, the fixity constraints (non-employment activities) played an important role on women’s work. The constraints were childcare or shopping. For example, women had more part time jobs in order to take care of their children and a short commute distance between jobs and housing. Reducing the fixity constraint would increase the probability for women employees, and improve their labor market position as well.

A spatial mismatch is one of urban transportation phenomena. Majority of workers reside in some areas where opportunities of employment are too low. The spatial mismatch can be caused by imbalance of job opportunities and social factors. It tremendously affects minorities such as black or Spanish population groups. Kain (1968), the precursor of spatial mismatch, mentioned that spatial mismatch between urban and suburban areas occurred through the time period because of imbalance of job opportunities, commuting cost, discriminatory issues in regard to black employees. He insisted that poor job conditions in the inner city could influence declining labor force in terms of these workers. Moreover, these employees could not afford to reside in suburban areas where the housing price was high. Thus, as urban areas are expanding toward suburban areas, these workers had more severe spatial mismatch than white workers. It is known that black people are not willing to search for a job in suburban areas because of social issues. For example, the black employees have difficulties in finding their jobs in suburban areas for the following reasons: (1) higher commuting costs, (2) an inverse relationship between distance and job opportunities, (3) more discrimination, and (4) tendency to hostile environment. Thus, they focus on job searching in urban areas rather than in suburban areas. These reasons contribute to the existence of spatial mismatch (Sjoquist 2001; Brueckner and Martin 1997). Patacchini and Zenou (2005) used types of transportation modes to explain spatial mismatch. They found that the white employees use more private vehicles to commute than the non-whites do whose main transportation mode is public transportation. In their results, whites had higher job accessibility to find a job than non-whites because of high chance of getting job information. Thus, car ownership allowed for shorter commutes in terms of job access and search activity, compared to public transit, which had lower search activity and longer commuter time.

3 Subcategory Flow Estimation

This section addresses the procedures of implementation and calibration based on current interaction flows between jobs and housing in the Twin Cities metropolitan area in Minnesota. The gravity model of spatial interaction model is used to calibrate the current flows. Using the CTPP data, it obtains variables for residence (p1), workplace

(p2), and journey-to-work flows (p3) respectively. Based on the centroids of each zone, distance was calculated. Four input data are necessary to calibrate the current flows: (1) journey-to-work flows, (2) distance, (3) balance factor of p1 and p2, (4) parameter (*a*, *b*, and *c*). Based on the current flows and linear programming, optimized flows were calculated. The problem of journey-to-work flows can only obtain the total workers' flows rather than subcategories such as female or male flows and etc. Thus, it has to modify the total workers' flows to make some subcategories such as gender, means of transportation, race, and time. Two methods (proportionally estimated flows and estimated flows by parameters) are compared to obtain subcategorized flows.

3.1 Estimated Flows by Parameter

An estimated flow by parameter method is proposed to calculate commuting flows for different categories based on total workers. It acquires the parameter (*c1*) based on total workers' flows and distance, calibrate the flows, and obtain a new parameter (*c2*) based on the modeled flows. By using the balance of different categories, the new parameter (*c3*), and distance matrix, it generates new flows for subcategories. Calibration makes data valid by checking the estimated results are similar to the observed flows. After calibrating the flows, parameter is found and applied to the gravity model to generate the calibrated flows. The formula of the exponential gravity model is as follows:

$$F(d_{ij}) = e^{-c*d_{ij}} \qquad (1)$$

where:

d_{ij} : Distance,

c : Parameter, and

e : Exponential.

3.2 Proportionally Estimated Flows

The commuting flows by gender can be determined by proportional estimation. For instance, it uses ten interaction flows from tract zone 101 to tract zone 3800 in terms of total workers (p3) and includes information about residence (p1) and workplace (p2). The number of female employees is 750 and male workers are 820 in tract zone 101. In terms of workplace, there are 300 female and 850 male in tract zone 3800. It calculates

female and male proportion based on the p1 and p2. Female proportion is (female in p1 / all workers in p1) * (female in p2 / all workers in p2). The same as the female proportion formula can calculate male proportion. It has female proportion as 0.12 and male proportion as 0.39. After fining the each proportion, it adds female and male proportion. Next step is to find extra proportion by calculating 1 – (female proportion + male proportion). In our case, extra proportion between the two zones (101 -> 3800) is 0.49.

After finding the extra proportion, it divides the extra-proportion by two to give extra-proportion to female or male. Thus, final female workers can be extracted by (female proportion * p3) + ((extra-proportion / 2) * p3). The number of female workers is 3.65 and the number of male workers is 6.35. It proportionally estimates the journey-to-work flows by gender, means of transportation, race, and time. Here is a formula to describe the above procedure:

Female Flow: $\alpha * \beta + \frac{1}{2}\left(\alpha(1-\beta) + \beta(1-\alpha)\right)$ (2)

Male Flow: $(1-\alpha) * (1-\beta) + \frac{1}{2}\left(\alpha(1-\beta) + \beta(1-\alpha)\right)$ (3)

where:

α : Female in origin,

β : Female in destination,

1 - α : Male in origin, and

1 - β : Male in destination.

4 Analysis and Results

Numerical results are presented based on the seven-county metropolitan area around the Twin Cities in Minnesota. Data sources include geographic data (census tracts boundary) and transportation data (CTPP interaction flow). By using the CTPP data, transportation planners can develop travel demand models or analyze demographic and travel trends. Some unique characteristics can be categorized as household and work location. The variables of household include income, vehicle availability, gender, and occupation. The variables of work location are departure time for work, arrival time to work, travel time to work, and types of travel mode (U.S. Bureau of Transportation

Statistics 2005). There are some important issues such as data change, rounding, and threshold. The CTPP has changed some variable types from 1990 to 2000. The changed variable types are carpool occupancy, travel time, and rounding. For instance, the maximum travel time is 200 minutes in 2000, compared to 99 minutes in 1990 (U.S. Depart. of Transportation 2005). In terms of rounding and threshold, all tables in part I and II and some tables in part III are rounded with threshold. Any value in OD matrix that is less than three un-weighted records is dropped. Christopher and Srinivasan (2005) explained that the problem with rounding and threshold was that some errors could be generated including "inconsistencies, undercount of employees, and elimination of most OD matrix, especially small areas." During the process of analyzing small geographic areas, the results are different whether it uses rounding and threshold issue or not. In general, origin and destination matrices may loose some values in small areas because of threshold. The loss of data will degrade the quality of the results when it attempts to implement a model.

The seven counties have 689 Census Tract zones in 2000. Hennepin County has the most tract zones (298). Ramsey County has the second largest tract zones (136). Carver County has the fewest zones as tracts (18) respectively. Scott County has the highest population change (54.7 percent). Carver County (46.5 percent) is the second fast growing county among the seven-county areas, and Ramsey County has the least population change (5.2 percent). In general, the seven counties have grown by 15.4 percent in comparison to 12.4 percent in all counties of Minnesota.

4.1 Race and Means of Transportation

As of race such as non-white and white, non-white workers reside in downtown areas and commute to the downtown workplace. However, white workers scatter in the seven counties and commute to urban areas or near suburban areas. Suburban areas have severe spatial mismatch between jobs and housing in terms of non-white workers. These workers have to stay in the downtown areas and find jobs around a small range of workplaces. Thus, as urban areas are expanding toward suburban areas, non-white workers will have more severe job conditions (see Figure 1). As of means of transportation, the commuting patterns by non-public transportation are widely scattered in the seven counties metropolitan areas, compared to public transportation, which is

mainly located in downtown areas. As urban sprawl occurs, there are many job opportunities in suburban areas. For instance, non-white workers mostly use public transportation and live in downtown areas because of having difficulty in buying expensive houses in suburban areas and in affording car accessibility. However, white workers have high car ownership, which can improve their job searching. Thus, the white tend to live in suburban areas and commute to urban areas or near suburban areas (see Figure 2).

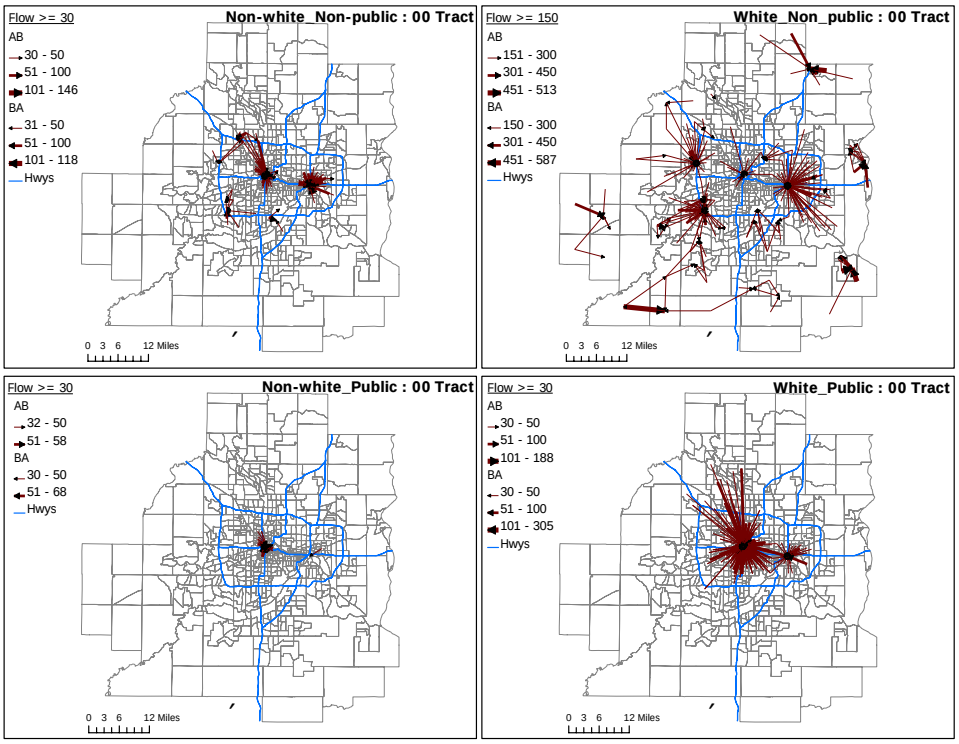

Figure 1. Estimated Flows by Parameter by Race and Means of Transportation in 2000

In terms of race and means of transportation, the proportionally estimated and the parameter methods have almost the same commuting patterns. In terms of white workers who use public transportation, the values are increased in the parameter method. In term of non-white employees who use non-public transportation, the proportionally estimated method has more commuting flows on the south of I-494. In general, white workers have better job accessibility than non-white workers because their commuting ranges are much wider than non-white workers. Moreover, public transportation usually takes in urban

area and non-public transportation scatters in the seven-county region (see Figure 1 and Figure 2).

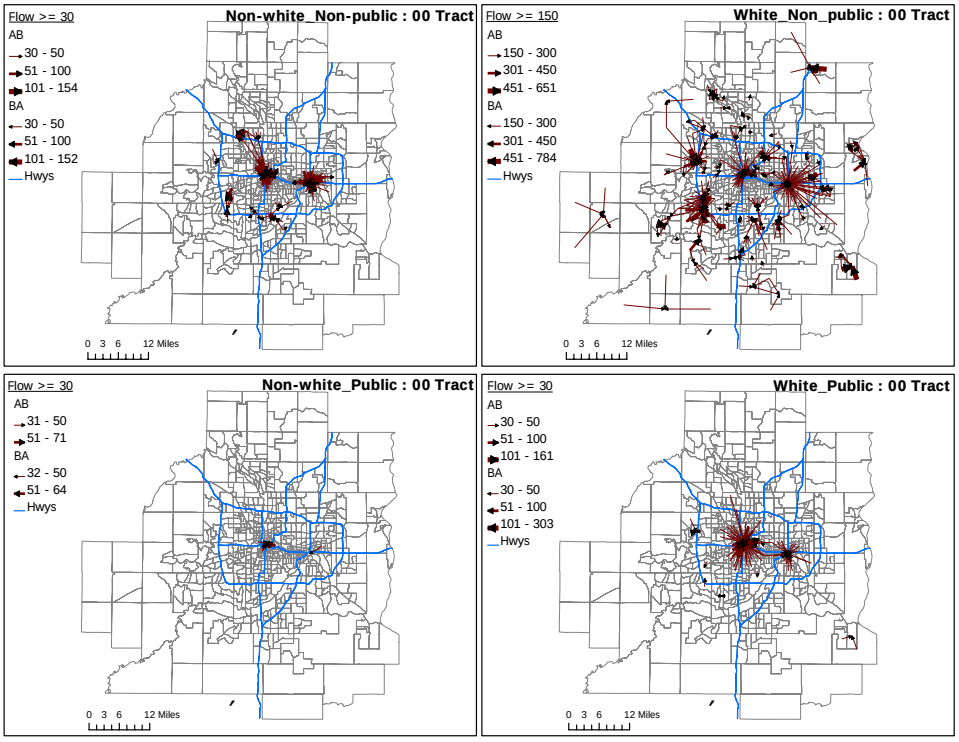

Figure 2. Proportionally Estimated Flows by Race and Means of Transportation in 2000

4.2 Summary of Results

This study attempted to find the some facts with respect to spatial mismatch between jobs and housing. Based on numerical results, the study found that there were spatial mismatch between jobs and housing in the seven-county metropolitan area, as urban areas were expanding toward suburban areas during the last decade. Especially, the west and southwest side of I-494 had significant spatial mismatch between jobs and housing. From the perspective of transportation planners, these areas such as Plymouth and Eden Prairie are highly probable congestion areas in the future.

Based on two methods proposed, there are some significant perspectives with respect to commuting flows. For subcategories such as race (non-white vs. white) and means of transportation (non-public vs. public), proportionally estimated method and parameter method extracted the almost same commuting flows from the total workers. Uniquely, the commuting flows have changed in Eden Prairie and Plymouth on the west

side of I-494. Thus, transportation planners can investigate the road structures of these areas to prevent severe traffic jams. Moreover, city planners can develop more east side of the Twin Cities than west side to enhance local economy or put more taxes on the west side of the Twin Cities to prevent severe housing problems in the future (see Figure 1 and 2).

5 Conclusions

Workers tend to live in suburban areas and commute to urban areas. This pattern causes spatial mismatch between jobs and housing. Using transportation problem optimization, it could suggest optimal commuting flows to alleviate traffic jams or area of congestion. This research provided two methods to capture the current flows by subcategories. Two methods are proposed to calculate the interactions for subcategories. The study divided the categories into the subcategories. For example, it found white commuting flows using public transportation. Using the CTTP was helpful to analyze current traffic flows. The methods help to understand the relationship between jobs and housing around the Twin Cities in Minnesota. Based on the analysis of the current data, many congestion areas were found among high flows, possibly increasing commuting costs. The study provided the empirical results of the current and the calibrated flows based on census tract illustrating commuting flows.

Further research will provide more details about commute behaviors, mode choice, and travel time in term of spatial imbalance between jobs and housing. Based on travel time, it can analyze who works peak or off-peak time. Various job types in regard to journey-to-work can be studied. Job-rich and job-poor conditions among the seven counties can be interesting topics for future study. Comparative research between Twin Cities in Minnesota and Dallas–Fort Worth in Texas will be interesting. They have similar transportation network structure. However, their size and location of the cities were different to each other. For example, the Twin Cities has two big cities (Minneapolis and St. Paul). Minneapolis is bigger than St. Paul while Dallas is bigger than Fort Worth. Minneapolis is located in the west of the Twin Cities while Dallas is located in the east of Dallas-Forth Worth metropolitan area. Dallas–Forth Worth International (DFW) airport is located in the north of Dallas-Fort Worth while

Minneapolis and St. Paul airport (MSP) is located in the south of the Twin Cities. Thus, it would be useful for city planner to figure out how urban structure can affect traffic flows.

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