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Abstract:

Journey to work trips account for approximately one-third to one-half of all trips taken in urban areas (Deskins 1972). During the last three decades, metropolitan areas have expanded rapidly in terms of population, area, housing units, jobs and economic growth. At the same time, they have experienced problems maintaining a balance between housing and jobs. Due to this imbalanced relationship, workers need to travel longer distances to work. This increases urban problems such as traffic congestion, environmental degradation, lack of affordable housing, and segregation by race or income. This study mainly explores the dynamics between residence and workplace in Twin Cities, Minnesota using the Census Transportation Planning Package (CTPP) and Local Dynamic Employment data. Geographical patterns of intra-metropolitan commuting flows are examined in terms of daily urban traffic flows. It was found that about 38 percent of daily traffic on major highways can be explained by journey to work flows.

Keywords: commuting, CTPP, local dynamic employment, network assignment, daily urban traffic flow

1 Introduction

As traffic volume increases in an urban area, urban traffic congestion becomes a serious problem. Cervero (2005) addressed that traffic congestion not only wastes time, money, and energy but affects productivity. In terms of monetary loss, the traffic congestion wasted 63.2 billion dollars in urbanized areas of North America in 2002 (Schrank and Lomax 2004). Urban travel consists of various daily travel activities by home, workplace, day care center, food store, health club, etc. (Hanson 2004). Among these trips, journey to work trip is the most important factor in urban traffic flows. In 1983, the FHWA (1988) estimated that 30.7 percent of vehicle-trips are related with work or work related business purposes, 20 percent with shopping, 1.2 percent with health, 14.9 percent with family related, 5.9 percent with school or religion, and 22.2 percent with all social and recreation including vacation, visit friends, pleasure driving, etc. Reports show that commuting flow is the highest proportion of overall urban traffic flows. McGuckin and Srinivasan (2003) addressed that the drive alone percentage is relatively higher than any other modes; also it has increased gradually. This implies that the number of people driving to work alone is almost as high as the total commuter traffic flow. The commuting trend is affected by various sources of factors such as job trend and size of urban area. Hu and Reuscher (2004) indicated that the total number of vehicles is greater than the total number of households and licensed drivers.

Urban commuting patterns are categorized into several groups: within urban area, urban to suburbs, suburbs to urban, and within suburbs.

Commuting flow also varies in different size of urban area. Sousslau (1986) described the distribution of the type of journey to work by different size of Standard Metropolitan Statistical Area (SMSA) in 1980. Author summarized that the percent of within the central city flow is low while population is high, the percent of central city to suburbs flow is low while population is high, the percent of suburbs to central city flow is low while population is high, and the percent of within the suburbs flow is high while population is high. In general, overall commuting cost has increased especially in urban areas. The reasons are that workers reside far from workplace and there are peak-time traffic congestions.

For the enhanced transportation or urban planning, traffic flows need to be understood. Assigning traffic to a network is a good way to estimate traffic flows. This helps us understand route choice of travel, quantity of flow, zone-to-zone travel costs for a given level of demand, and heavily congested links (Ortuzar and Willumsen 2000). Contemporarily, many heuristic traffic assignment models are developed, and most models are based on the common methodologies as follows: [1] travel network consists of a set of linkages and nodes where each node can be represented as origins and/or destinations, [2] flow occurs on a linkage which is between node to node, [3] most linkages have a certain limit of flow capacity, and [4] traffic assignments model assigns traffic flows in context of minimizing cost flow. The most basic concept of the traffic assignment model is assigning traffic flows with a minimum traveling cost between a given pair of locations (Wilson and Nuzzolo 2004). Traffic data became important resources of State DOTs, cities, counties, and metropolitan planning organizations (Mergel 1997). The Minnesota Department of Transportation has been collecting and forecasting traffic volume (Levenson 2006). With help of this data source, transportation practitioners and researchers can understand the mobility of people, accessibility of location, dynamics betweens jobs and housing and derivative problems of urbanization.

Locations of residences and workplaces have changed greatly in most metropolitan areas since 2000. In general, many workers have moved to the suburban. As can be seen in Figure 1, the number of residing workers has been increased in suburban areas with decrease in the core metropolitan area. Areas along the major highways and urban fringe areas have seen a large increase. The workplaces have also changed accordingly with residences. Figure 2 shows changes of workplace locations between 2000 and 2003. The number of workplaces has been increased along the areas where residences have increased and where the area has high accessibility to major highways. It also illustrates that many workplaces have spread to the outer fringe of suburban areas from the core area. Overall, the locations of residing workers and workplaces have clear patterns. The number of people in both residences and workplaces has increased in close vicinity to major highways.

The remainder of this paper is organized as follows. Section 2 provides a relevant literature review. Section 3 discusses analysis method and data. The results are presented in section 4. Finally, section 5 presents conclusions and discussion.

2 Previous Studies

Traffic flows and congestion do not occur randomly, continuously and evenly over time. There are certain situations or conditions that cause urban traffic flows and congestions. In urban areas, most travels are generated between origins and destinations for commuting, shopping, traveling, social activity, or recreation. Although various types of people travel for their own various purposes, each similar type of travel occurs in a similar time period and location. In other words, each type of travel has a different favorite traveling time period (Barber 1995). For example, a high percent of work trip is allocated between 7 a.m. and 9 a.m. and, after 8 hours shift, 4 p.m. and 6 a.m. Also, a high percent of social and recreation traveling is allocated between 6 p.m. and 12 a.m., a high percent of shopping traveling is allocated between 9 a.m. and 3 p.m. with some degree of shopping traveling between 6 p.m. and 11 p.m. In the same manner, overall traffic flow has unique patterns temporarily and spatially. In context of time, urban traffic flow pattern can be described as daily, weekly and weekend flow pattern. Based on previous research, the daily traffic flow is influenced by the commuting trips within urban areas. It can be observed in the hourly distribution of traffic flow. Festin (1996) compared four different calendar years (1978, 1983, 1992, and 1995) of national traffic patterns. There are two notable peak hours of traffic. One is a morning peak hour between 6:00 a.m. and 7:00 a.m. and the other one is an afternoon peak hour between 4:00 p.m. and 5:00 p.m. He found that [1] the afternoon peak hour of traffic did not change for those years except 1992, [2] the amount of traffic in the early morning between midnight and 4 a.m. was significantly decreased, [3] morning rush hour ends by 10 a.m. traffic begins to increase steadily until 4 p.m., and [4] general weekday trends of traffic pattern for the years are similar. The results demonstrate the general average of national data, thus it may deviate at the regional level. During weekends and holidays, traffic flow relatively relates with other activities such as shopping, social events, recreation, etc. rather than commuting activity. The pattern of weekend traffic flow shows the bell curve shape where the peak hour is 3:00 p.m., and the lowest point of traffic flow is 4:00 a.m. In addition, he showed a clear difference of traffic pattern between urban and rural area based on the monthly average traffic flows during the years 1970-1995. The difference is that urban traffic flow has less seasonal variation than rural traffic, and rural traffic flow has a wide variation than urban traffic flow. In case of congestion in urban area, mostly, the total flow is less than the average daily weekday flow.

A high proportion of traffic congestion occurs in the morning and evening time. Daily peak hour commuting may be the most serious time for traffic congestion in an urban area because it involves a large number of people and locations in a limited time. In order to manage urban traffic congestion, researchers believe that controlling the amount of incoming traffic is a better choice than adjusting a fixed capacity of road segment. Safavian and McLean (1975) focused on how traffic flow changes when an alternative work hour system is applied in Ottawa, Canada. In their research, they figured out the alternative work hour system significantly alleviates urban traffic congestion during peak hour. The peak hour and pattern during the weekend is different in comparison to daily traffic volume during the work week. This implies that weekend traffic is generated by different human activities or similar activities in a different time and different traveling behaviors. In general, the average daily traffic flow on weekends is less than the average daily traffic flow on weekdays. However, traffic congestion also occurs over the weekends. Although, traffic congestion on weekends exists in urban area, it is observed in rural area notably also. In case of congestion nearby recreation areas, recreational areas can become congested due to a lack of accessibility as compared to commercial, industrials or residential areas. Because of less demand during weekdays and off-season, the capacity of infrastructure is lower than others.

Therefore, daily weekday traffic flow is centralized more on urban area; on the contrary, weekend traffic flow is more centralized on rural area (Evertte and Wolfgang 1978). In their study, two locations' daily total traffic volumes are compared; one location, in Connecticut, is considered to be a rural or recreational area, while the other location in Nashville, TN is considered to be in an urban area. From Monday to Friday, daily total traffic volume is found to be higher in Nashville; however, daily total traffic volume of Connecticut is relatively higher than Nashville from Friday to Monday morning. So far, characteristics of traffic flow patterns are discussed in terms of trip purpose, time and location. As shown in this section, traffic flow pattern is affected by temporal and spatial variations.

In terms of characteristics of commuting modes in the U.S., there are many choices such as public transit, carpooling, cycling and walking; however, people are willing to drive alone rather than carpooling or using public transit. This implies that roughly, the number of people driving to work "alone" is almost as high as the total commuter traffic flow. The commuting trend is affected by various sources of factors such as job trend and size of urban area. The job trend in the U.S. has changed considerably year by year. Kasarda (1988) devoted to identify the demographic and employment dynamic that shaped in the U.S. The author addressed that the population of the blue-collar employment has decreased, while the population of the white-collar employment has increased in Central Cities. In addition, the author found that the total number of jobs for the less educated employment has decreased, and the total number of jobs for higher educated employment has increased. In general, highly educated workers represent a group who has higher-wages and a better chance to possess a private vehicle. However, even the group of workers who have low-wage jobs in the U.S. possesses private vehicle by the well established social security system and by large economy growth.

Theoretically, an employee needs to reside nearby the workplace in order to minimize cost of commuting. However, in reality, residents are not close to their workplace (Ihlanfeldt 1994). These are the reasons why residential location and workplace is not matched. First, people's choice of residential location has a deep relationship with his or her income. Lonsdale (1966) examined the commuting patterns of production workers at two industrial establishments in eastern North Carolina. He found that the higher-wage workers' commute distance is considerably farther than lower-wage workers' commute distance. Second, people seek a better dwelling area in order to keep their children safe (Conlin 2005). Traditionally, the urban core has higher crime and a low quality educational environment. Third, housing is not only shelter for family but also it is a good investment for the future. In general, through urban expansion, suburban's land and house price increases in the U.S. have been steady.

3 Data and Methods

This study examines the relationship between commuting flows and urban traffic volume in Twin Cities, Minnesota. This section describes the data, models and methods that are used. The Census block level journey to work data by Local Employment Dynamic and the Census Transportation Planning Package (CTPP) are mainly used to analyze the commuting traffic flow and dynamics between jobs and housing. The Stochastic User Equilibrium (SUE) method is used to allocate journey to work flows to networks. Flows are assigned by a performance of link. Equation (1) states that the performance of link is calculated by link volume, capacity, free-flow time, and calibration parameter. The Bureau of Public Roads (BPR) developed the most commonly used formulation where traveling cost is calculated by ratio between volume and capacity with parameter α and β. The values of parameter α and β are determined as 0.15 and 4.0 based on previous studies. Iteration and convergence are set as 100 and 0.6

respectively. As a result, equation (2) captures flows on links cumulated on each link.

$$\overline{C}_{y} = t_{f}\left[1 + \alpha \cdot \left(\frac{v}{c}\right)^{\beta}\right] \tag{1}$$

Where:

$\overline{C}_{y}$ = Cost on route between i and j,

t_{f} = Link free − flow travel time,

v = Link volume,

c = Link capacity,

$\alpha,\ \beta$ = Calibration parameters.

$$C_{k}^{rs}(n) = \sum_{a} t_{a}^{n} \cdot \delta_{ka}^{rs} \tag{2}$$

Where:

t_{a}^{n} = Traveling time on link a,

δ_{ka}^{rs} = path-link inchidence indicator,

n = Iteration.

This analysis consists of two major parts: [1] general traffic pattern analysis, and [2] journey to work flow analysis. For the general traffic pattern analysis, traffic volume is manipulated in various time scales and the results are applied to case studies. Variations of traffic volume are examined temporary and spatially with impact of the new transportation system. In the journey to work analysis, changes of residence (Part 1), workplace (Part 2) and journey to work flows (Part3) are examined chronologically. As journey to work flows are assigned on the network using traffic assignment methods, a number of vehicles for commuting are identified per each link. Finally, when comparing results from the general traffic pattern analysis and journey to work analysis, the degree of contribution of commuting traffic on daily traffic volume is identified. The framework for the analysis is drawn in Figure 3.

4 Dynamics between Jobs and Housing

In this section, a numerical difference between the number of outflow and inflow is examined along with journey to work flows. The number of job opportunities has been increased from 1990 to 2000. However, job opportunities have decreased between 2000 and 2003. According to the Minnesota Department of Employment and Economic Development (City of Minneapolis 2003), the number of unemployed residents increased in the same period. For example, the total number of jobs has been decreased by 3.7 percent in the Minneapolis area. Figure 4 and Figure 5 show differences between outflow and inflow for each census track in the years of 2000 and 2003. The values are calculated by subtracting inflow from outflow. Generally, most suburban areas have high outflow and low inflow, whereas the core metropolitan area has low outflow and high inflow. Moreover, both flows have been increased in the outer side of the metropolitan area. Maps also show that outflow has dramatically increased in the cities of Shakopee (north side of Scott county), Brooklyn Park (northeast side of Hennepin county), Farmington and Lakeville (northwest side of Dakota county along Interstate Highway 35). On the other hand, inflow has increased particularly in Roseville (Ramsey county), Eden Prairie (southeast side of Hennepin county), Spring Lake Park (south side of Anoka county), Minnetonka (Hennepin county), Bloomington (Hennepin county), and

Eagan (Dakota county).

Journey to work flows of 2003 in particular are examined to see the interactions. Figure 6 shows the journey to work flows where both residences and workplaces are within the metropolitan area. The interaction flows are clearly clustered. In 2003, about 25 percent of flows in the top 100 flows have destinations in Minneapolis and about 10 percent of flows have destinations in Saint Paul respectively. The interaction flows with Saint Paul contain a high proportion of commuting to government workplaces.

The journey to work flow itself does not provide the information about how commuting flows are allocated to a network. In this section, the commuting flows from census blocks to blocks are assigned to a network. There are about 570 million pairs of commuting flows in year 2003. Non-symmetric matrices of 33,019 (residence) by 17,261 (residence) are designed. Each pair of the commuting flows is assigned to the network based on the traveling cost and speed of road segments (Dial 1971). The capacity of road segments is assumed to be unlimited. As can be seen in Figure 7, a high proportion of commuting flows are found in the major highways such as I-35W where it intersects with 28th Street (Figure 8). The average and standard deviation of the commuting flows are shown in Table 1.

The Average Annual Daily Traffic volume (AADT) and the commuting flows on the major highways are obtained to compare each other. As can be seen in Figure 9, the commuting flows on the daily urban traffic volume are estimated. In order to compare those values, the commuting flows are captured by the stations using the spatial relationship. Figure 10 shows the degree of commuting flows on urban traffic for 2003. The inbound traffic flows from the suburban area to the metropolitan core area has a higher percent of commuting flows than outbound flows. Moreover, major highways within the core area have higher commuting flows than the suburban counterparts. Table 2 shows the overall percent of commuting flows on the major highways for 2003. Overall, about 38 percent of daily traffic flows are defined as the commuting flows in the study area in 2003.

5 Conclusions and Discussion

The empirical results help us understand the patterns of residences, workplaces and interaction flows in the study area. Many workplaces are located in the urban area, and a high proportion of workers reside in the suburban areas. However, the number of workplaces has been increased over time in the suburban area. Among the commuting flows, a high proportion of commuting flows is based on destinations in metropolitan core areas. These commuting flows have a high dependence on major highways. This study found that about 38 percent of daily traffic on the major highways can be explained by journey to work flows.

Several areas to understand the relationship between journey to work flows and daily urban traffic volume are still left for future research. Future research needs to incorporate public transit service as a commute mode and to consider multiple commute modes such as park and rides. All commuters are considered as one category in this study, but it can be classified into several categories by job types.

Figure 1. Residence area changes (2000-2003)

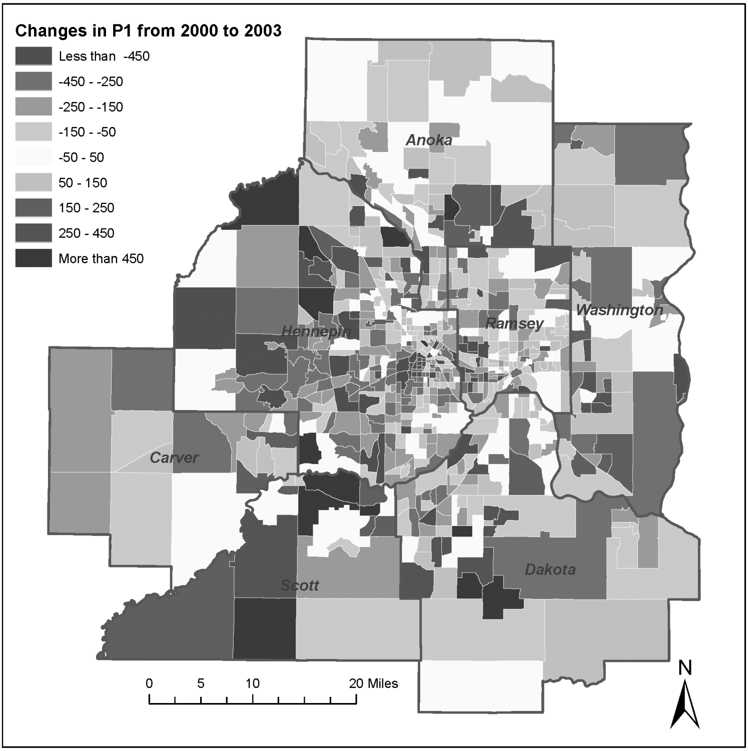


Figure 2. Workplace area changes (2000-2003)

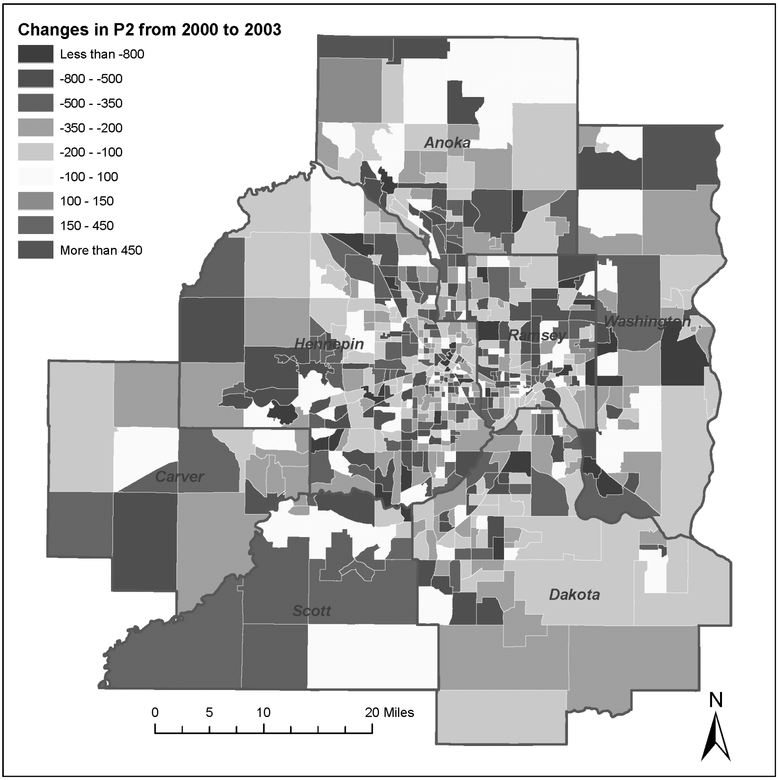


Figure 3. Analysis Framework

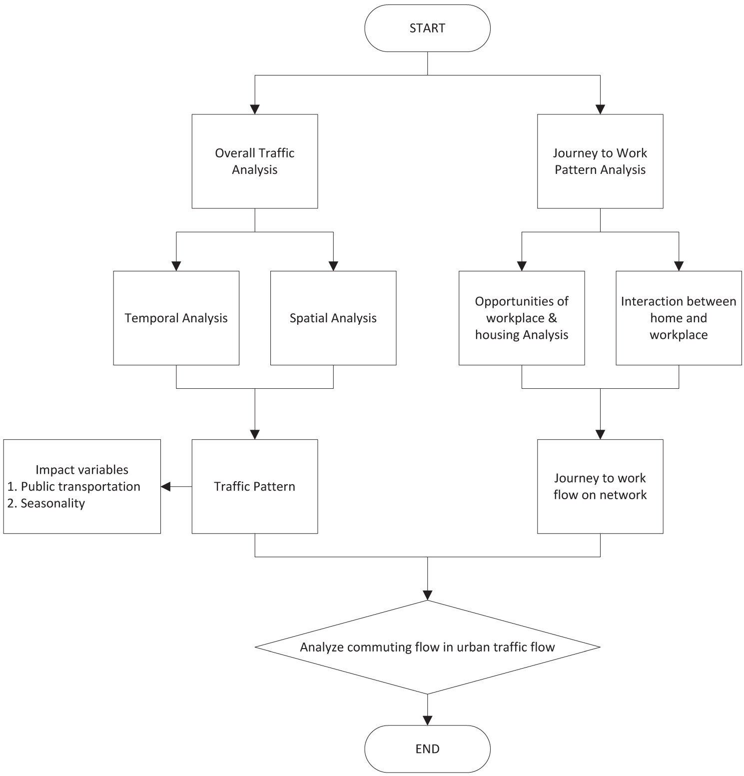


Figure 4. Difference between outflow and inflow (2000)

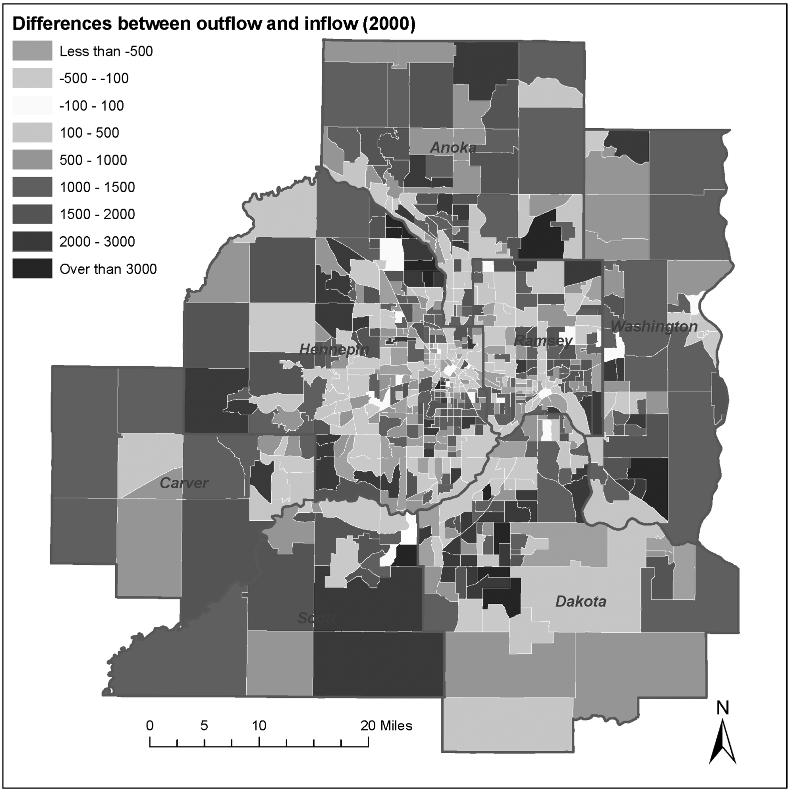


Figure 5. Difference between outflow and inflow (2003)

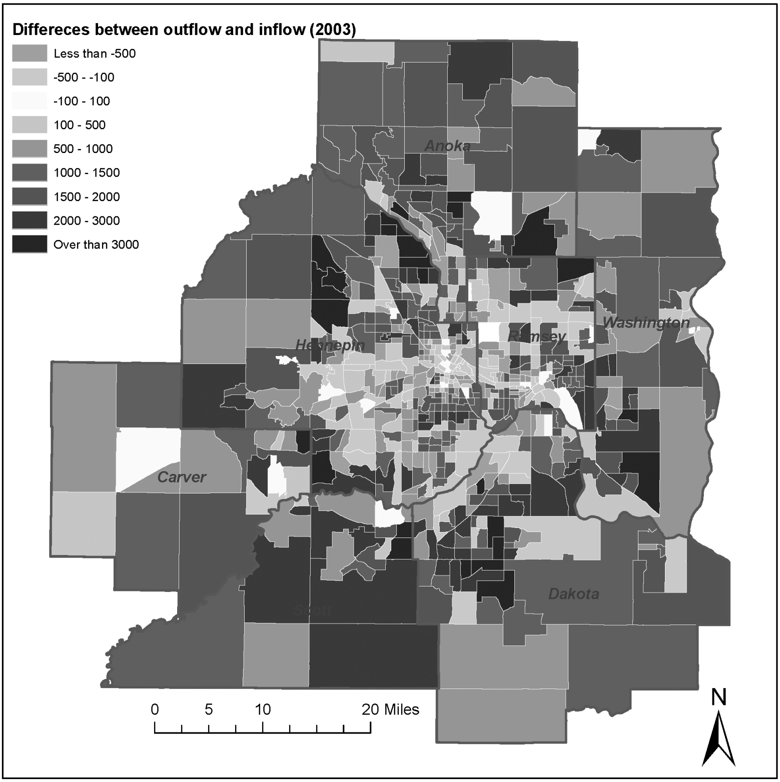


Figure 6. Top 10 percent interactions (2003)

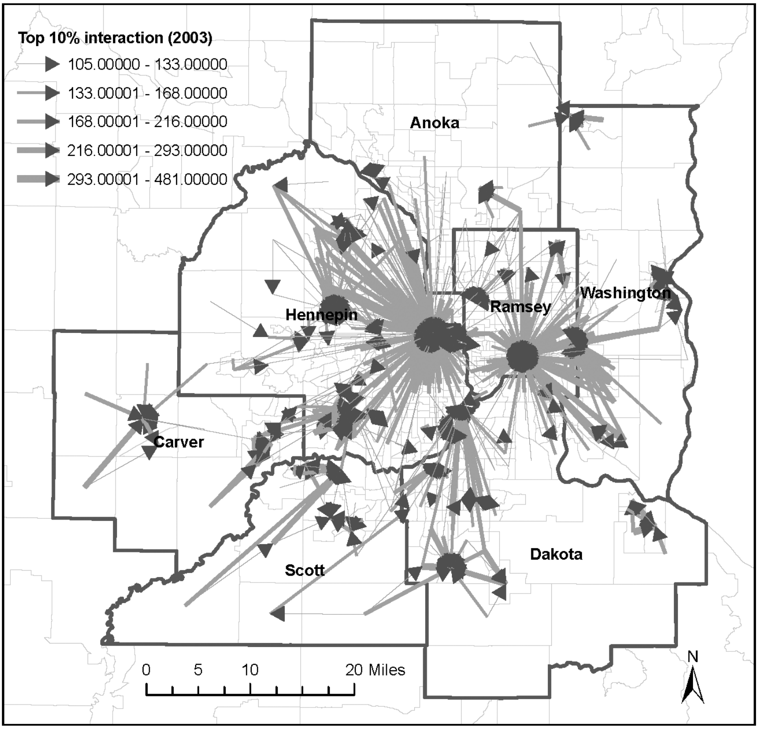


Figure 7. Commuting flows on networks (2003)

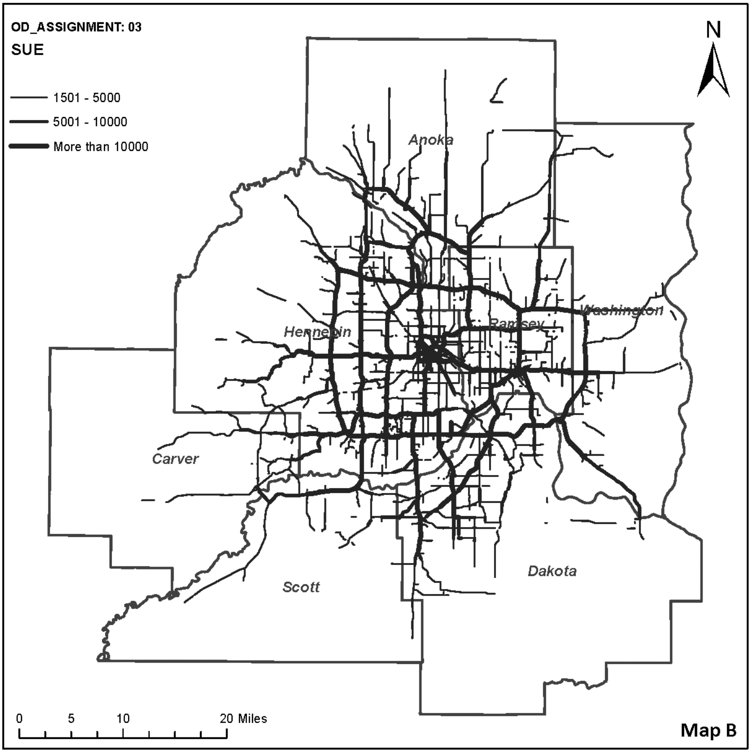


Figure 8. The network segments of large commuting flows

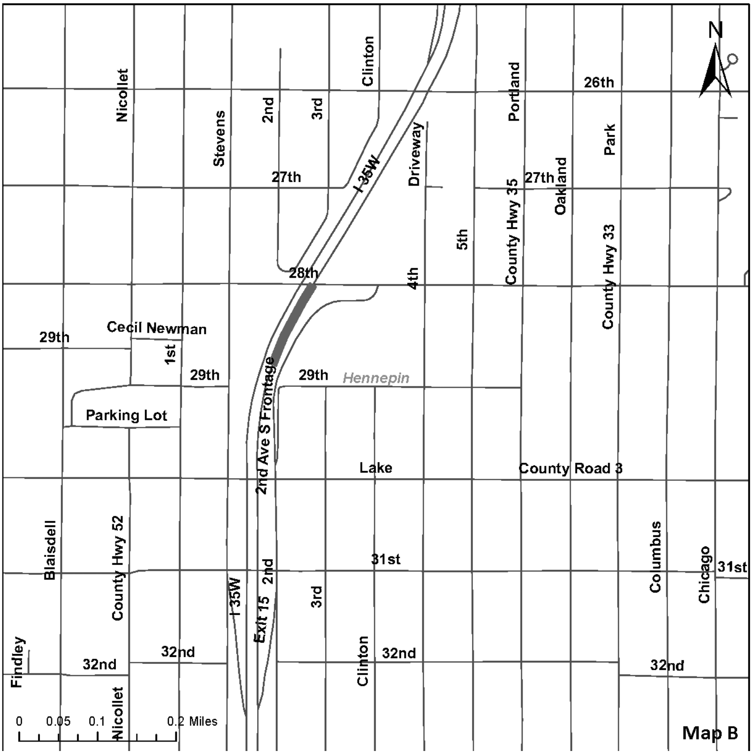


Table 1. Flow assignment statistics

Year 2003	Max	Mean	Standard deviation
Traffic Flow	62,034	640	3,008

Figure 9. Traffic Volume (2003)

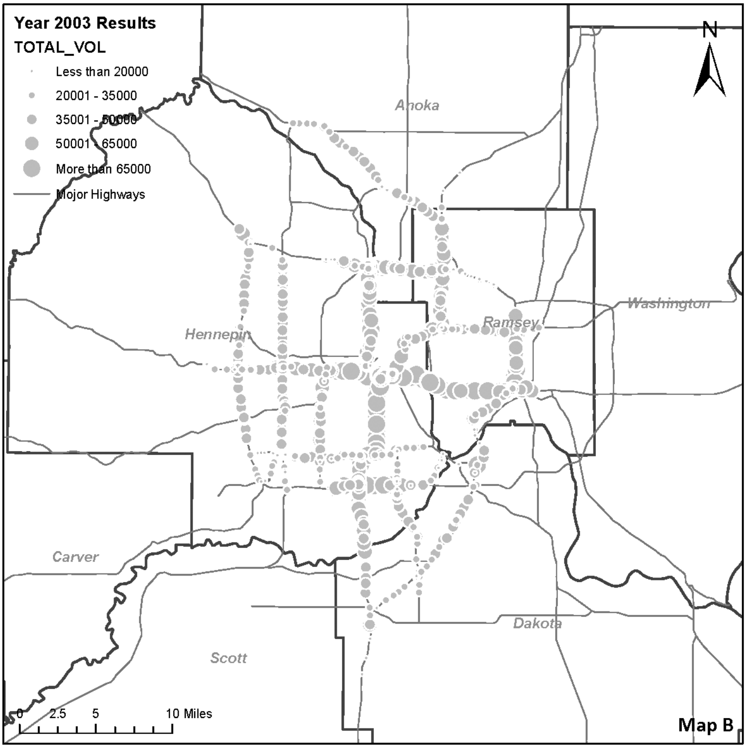
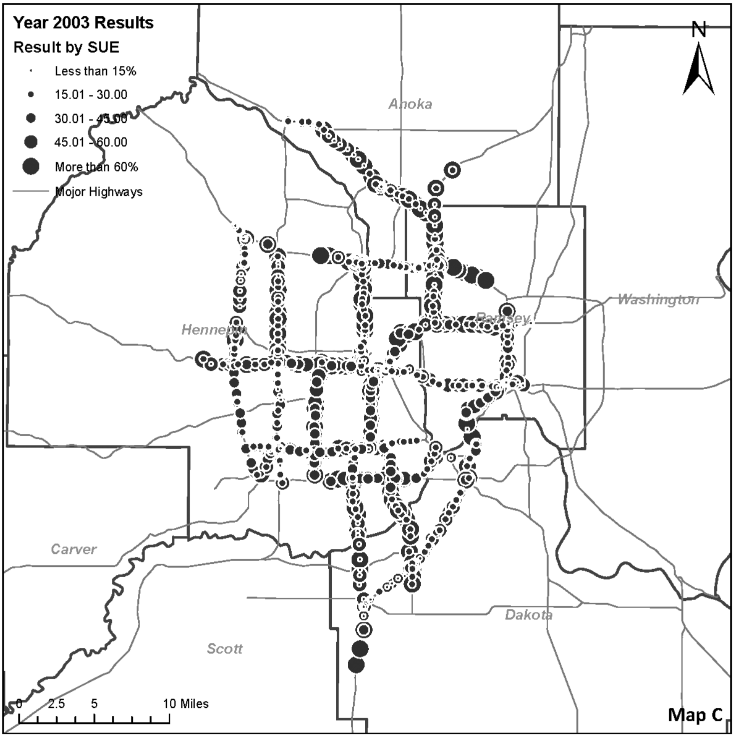


Table 2. Percent of commuting flows on urban traffic

Year 2003	Mean	Standard deviation
Percent (%)	38.4	19.88

Figure 10. Degrees of commuting flow on urban traffic (2003)



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