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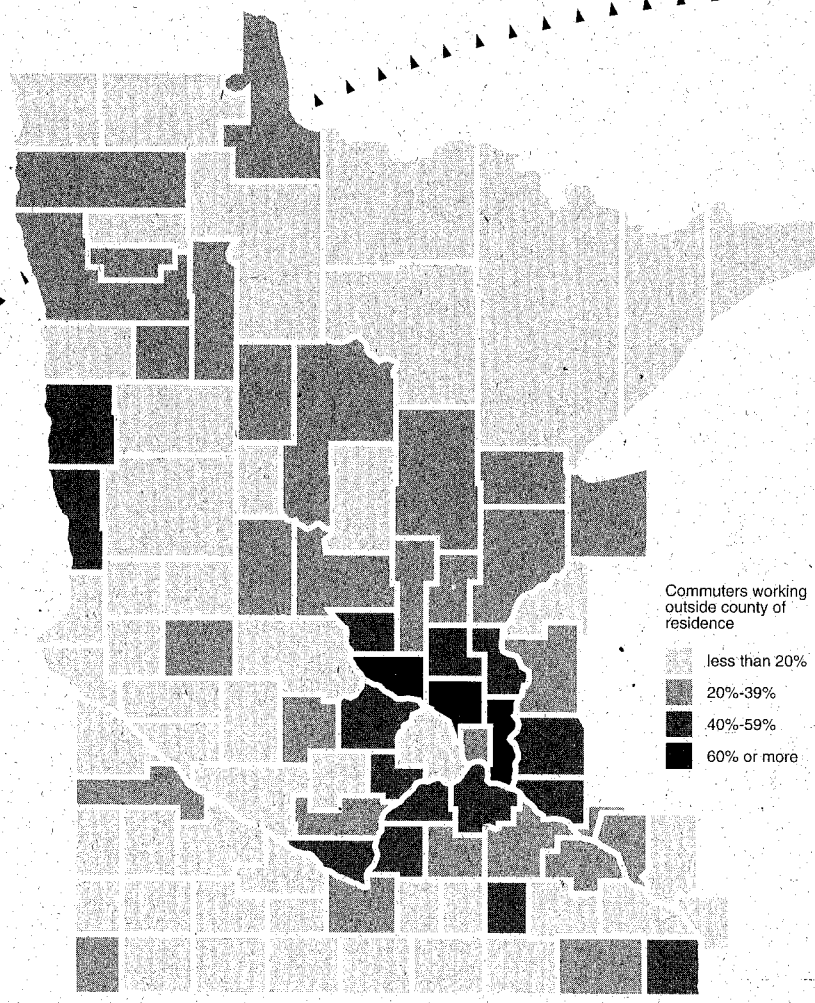

Transportation-Based Classifications of Minnesota's Counties and Metropolitan Statistical Area Tracts Using Measures from the 1990 Census of Population and Housing

UNIVERSITY OF MINNESOTA
CENTER FOR TRANSPORTATION STUDIES

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Census measures are used to classify Minnesota counties and metropolitan area census tracts according to demographic, journey-to-work, and mobility characteristics in 1990. Counties differ regarding scores calculated with respect to **Population Mass**--reflecting measures such as numbers of persons, of commuters, and of vehicles available for personal use; and a general **Commuting** tendency--reflecting proportions of commuters traveling more than 30 minutes, average commute time, and average number of vehicles per household. Three other basic characteristics of counties--average **Socioeconomic Status** of residents, degree of **Mobility Impairment** of residents; and **Solo Commuting** tendency--provide scores further differentiating counties. County scores are used to group Minnesota's 87 counties into six diverse clusters: 1) Hennepin (Minneapolis); 2) Ramsey (St. Paul); 3) Anoka and Dakota (Twin Cities suburbs); 4) St. Louis (Duluth); Olmsted (Rochester), Stearns (St. Cloud), Washington (Twin Cities); and 6) all others.

The second analysis examines 833 census tracts in the Minnesota's five MSAs, classifying them with the procedures used for counties. Resulting classifications illustrate that relationships between travel activity and socioeconomic characteristics vary considerably for different metropolitan contexts. As a demonstration of potentially useful methods applied to census data for Minnesota, the study provided results. On other grounds, its value is more limited.

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FINAL REPORT

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EXECUTIVE SUMMARY

This study examines variations in journey-to-work patterns among different commuter groups in Minnesota using 1990 census measures to classify Minnesota counties and metropolitan area census tracts according to their demographic, journey-to-work, and other mobility characteristics. We initiated the study to investigate and assess whether those measures could provide areal classifications potentially useful for transportation planning and management. Secondly, we wanted to demonstrate the application of certain statistical procedures (correlation analysis, factor analysis, factor scoring of areal units, classification of areal units using methods of numerical taxonomy, mapping of clusters from the numerical taxonomy).

As a consequence of recent and dramatic adjustments in the world of work, in the geographical redistribution of job locations, and the dispersal of new residences beyond metropolitan statistical areas (MSAs), commuting patterns by different groups of workers have been changing. Exurbanites (people living beyond the built-up MSA suburbs) select residences ever farther from the MSA, yet continue working at jobs throughout the MSA economy. Workers living beyond the exurban fringe find jobs requiring commutes of an hour or more, yet remain in their houses. Meanwhile, as settlement and commuting fields spread out, disadvantaged populations become increasingly isolated from jobs and other opportunities.

Census attributes of counties and MSA tracts include: total population; population over age 65 (number, and percentage of total); commuters driving to work alone; solo commuters as a percentage of all commuters; commuters with work journeys exceeding 30 minutes (number, and percentage of all commuters); average duration of work journeys; handicapped population with limited mobility (number, and percentage of total population); persons below the poverty level (number, and percentage of total population); vehicles owned; and average number of vehicles per household.

Findings: County-Scale Analysis

Counties differ from one another in terms of scores calculated with respect to five basic and statistically independent (i.e., uncorrelated) features. First is **Population Mass**, reflected in measures such as numbers of persons, of commuters, and of vehicles available in the county for personal use. In this regard, Hennepin County (7.9) scores highest, with Ramsey (3.7) ranking second.

A second feature distinguishing counties is a general **Commuting** tendency, reflecting the proportion of commuters traveling more than 30 minutes, average time of commute, and average number of vehicles per household. Counties scoring highest on this feature include Anoka (2.0), Chisago (2.9) Isanti, which has the highest average travel time in the state (3.3), Sherburne (2.7), and Wright (2.7).

Three other basic characteristics of counties--average **Socioeconomic Status** of residents, degree of **Mobility Impairment** of residents; and **Solo Commuting** tendency--provide scores that distinguish each county from others. When the set of five scores for each county is used to classify Minnesota's 87 counties, six diverse clusters of counties are defined: 1) Hennepin (Minneapolis); 2) Ramsey (St. Paul); 3) Anoka and Dakota (Twin Cities suburbs); 4) St. Louis (Duluth); Olmsted (Rochester), Stearns (St. Cloud), Washington (Twin Cities); and 6) all other counties.

The six clusters vary in average population from over one million (Hennepin) in Cluster 1, to 22,388 (average of 79 members of Cluster 6). The percentage of commuters with work journeys exceeding 30 minutes range from a low of under 17 percent in Cluster 4 (St. Louis), to an average of almost 33 percent for counties in Cluster 3 (Anoka, Dakota). Average journey to work in minutes varies from a high of almost 23 minutes in Cluster 3, to a low in Cluster 6 (all other Minnesota counties) of just over 16 minutes. Percentage of populations with limited

mobility is small in all counties, with cluster averages reaching a low of .4 percent in Cluster 3 (Anoka, Dakota), and a high of only .7 percent in Cluster 3 (Ramsey).

Cluster averages for percentage of population below the poverty level were lowest in Cluster 3, at 4.8 percent (Anoka, Dakota), and highest in Cluster 6--mainly counties outside the MSAs, where counties average over 13 percent.

Vehicles per household range from a low average of 1.6 in counties comprising Clusters 1 (Hennepin), 2 (Ramsey), and 4 (Olmsted, Stearns, Washington), each of which contains older high density urban cores, to a high of 2.0 in the suburban counties of Cluster 3 (Anoka, Dakota).

Findings-Tract-Scale Analysis

The second scale of analysis focuses on the 833 census tracts within the Minnesota portions of the state's five MSAs. Tracts are analyzed and classified as a group using the same procedures employed with the 87 counties. Tract classifications appear to illustrate the point that relationships between travel activity and socioeconomic characteristics vary considerably for different metropolitan contexts.

Cluster 1's 10 tracts contain young, relatively well off populations likely to drive alone long distances to work. Households display high levels of home ownership and low incidence of poverty. Financially secure persons seeking low population densities at the expense of longer work trips appear to be the norm--mainly large suburban and exurban tracts that built up fast in the 1980s.

Cluster 2's 163 tracts house populations that are fewer in number, older, poorer, and generally living closer to work than the residents in Cluster 1. Tracts house the highest percentages of mobility-impaired residents, but levels average only about one percent. Average car ownership of 1.2 vehicles per household stands lowest among the six clusters. The majority

of Cluster 2 tracts fall within central areas of Minneapolis and St. Paul, although a few occur in old centers of small towns engulfed by suburbanization since the 1950s.

Cluster 3's 53 tracts feature the highest mean counts of poverty population, and average just over 6 percent below the poverty level. Journeys to work are long, and percentage of workers driving alone to work averages second highest among the clusters. The tracts are mainly in the Twin Cities area, with one group between Minneapolis and St. Cloud, and another in the third and fourth ring suburbs south of Minneapolis and St. Paul.

Cluster 4's 402 tracts are the most typical of the entire set, with average values on the various measures used to classify. Many Minneapolis-St. Paul area inner city tracts belong to this cluster, with a second zone of tracts sharing these features lying in a broad ring that encompasses the third- and fourth-tier suburbs and adjacent exurban areas. The same geographical patterns repeat in and around the other MSAs.

Cluster 5's 111 tracts display a "middle of the road" flavor, somewhat like those in Cluster 4, but with notably high percentages of persons with mobility limitations, and relatively large numbers of persons below the poverty line.

Cluster 6's 94 tracts resemble those in Cluster 1, with low average poverty rates, high vehicle ownership rates--places where growth has been recent and large tracts have not had time to subdivide. The profile of tracts in Cluster 6 resembles that of tracts in Cluster 1. Similar patterns appear in fast growing suburban areas of the other MSAs.

As a demonstration of some potentially useful methods applied to census data for Minnesota, the study provided results. On other grounds, its value is more limited.

INTRODUCTION

There seems to be substantial variation from place to place across Minnesota, and from one group of daily commuters to another in journey-to-work profiles, and in transportation opportunities available to local residents. Patterns differ between urban and rural areas, from one region of Minnesota to another, and from inner city neighborhoods to outer suburbs.

This study examines systematic variations in journey-to-work patterns among different commuting groups, then uses 1990 census measures to classify counties and metropolitan area census tracts according to their demographic, journey-to-work, and other mobility characteristics. The study is basically an examination of 1990 census data relating to transportation use in Minnesota, and an exploration of whether these new data can provide fresh insights useful to transportation planners and analysts at the state and local levels in Minnesota.

The study employs cluster analysis and other statistical techniques to classify counties and census tracts within Minnesota's metropolitan areas using variables reporting age, poverty status, mobility limitation status, and journey-to-work characteristics. Results are summarized in maps and tables that portray a classification of places based on different types and levels of transportation needs and usage. Findings may help inform policies (e.g., appropriate spatial jurisdiction for development planning frameworks for the greaterTwin Cities metropolitan area, or effective demand for rural transit) developed at distinct geographical areas of jurisdiction (county, metro, state) to assist specific user groups (handicapped, elderly, poor).

Steps in the analysis and presentation include the following: 1) preparation and analysis of summary census measures for the state, and for the five Metropolitan Statistical Areas (MSAs) in Minnesota--Minneapolis-St. Paul, Duluth-Superior, Fargo-Moorhead, St. Cloud,

Rochester; 2) collection, analysis, and formatting of detailed measures by county (for the state) and by census tract (within MSAs); 3) identification of distinctive patterns of statistical covariation among variables in the analysis; 4) classification of counties and tracts using methods of cluster analysis; and 5) presentation and interpretation of the areal classification systems as they are patterned on annotated maps.

County-level analysis yields several interesting results. Maps portray neat, concise statements about the underlying dimensions of travel-related activity. A "commuting dimension" reveals the transformation of the settlement fabric within an overwhelmingly automobile-reliant tier of counties surrounding the state's largest metropolitan area, a fact in line with the observation that the concepts of "city", "town", and "farm" have lost much of their precise meaning over the past four decades.

This kind of insight might have been gleaned from simpler maps, such as "share of daily commuters going to an MSA", for example. The advantage of the classification technique used here is the ability to summarize the combined effects of several variables (share of long-distance commuters, average travel time, number of vehicles per household, etc.) into a single index.

Census tract classifications illustrate the point that relationships between travel activity and socioeconomic characteristics vary considerably for different metropolitan contexts. The overall complexity of the classification of census tracts suggests a more heterogeneous settlement fabric than many planners or geographers acknowledge in suburbia or exurbia. Normal practice is to examine differences among small areas such as census tracts or traffic assignment zones by analyzing sample arithmetic means, medians, or other measures of central tendency. It is less common to investigate statistical variations within small areas and how such variations may influence travel patterns.

Results are mixed, but the demonstration purpose is accomplished, with the results of statistical and cartographic procedures applied to 87 Minnesota counties and to 833 census

tracts. Methods work well, but the answer to the initial problem posed appears to be that the transportation-related measures from the 1990 census as analyzed in this study fail to provide substantial insight in the form of areal classifications potentially useful for transportation planning and management.

County-level analysis distinguishes among several types of metropolitan area counties around the state, with a residual category of non-metropolitan counties. This result matches distinctions readily drawn using a variety of different variables, especially population density. Tract-level analysis generates maps of clusters that disclose a few important distinctions, but most of the map patterns prove difficult to interpret. Yet the geographical patterning of two or three of the clusters provide some insight into substantive questions. For example, the distribution of tracts in Cluster I in Sherburne county appears to pinpoint metropolitan hinterlands being transformed into "metropolitan-style" commutersheds. Elk River and Eagan emerge in the same cluster, and the fact is that they "feel" similar when we drive through them or consider where their residents work and live.

The raw data set could be expanded to include additional measures of households or housing characteristics, but additional non-transportation-related measures are known or suspected to be closely correlated with measures included in our study. Adding variables that are highly correlated with variables already in the problem supplies nothing new to final results. As a demonstration of some potentially useful methods applied to census data for Minnesota, the study provides results. On other grounds, its value appears limited.

I. RESTRUCTURING OF METROPOLITAN AND NON-MSA SETTLEMENT FIELDS

The past four decades saw a major overhaul of Minnesota's settlement fields and their associated movement patterns. The highly localized settlement fields and associated commuting and other movement patterns that were common before 1950 have enlarged in volume, expanded areally, and in many cases have come to substantially overlap or merge since that time. (Adams and Wyly 1994)

Reorganization of manufacturing and improved transportation systems have facilitated the dispersal of factories and other industrial facilities across the countryside. (Borchert 1987) Increased specialization of medical, legal and financial services has encouraged their concentration into a smaller number of more comprehensive centers, away from the larger number of smaller and more generalized centers of a simpler time. Specialized retailing such as antique dealers and art stores has moved to small town Main Streets and now attract shoppers from long distances, while general retailing increasingly concentrates in the Wal-Marts, Targets, Pamidas--superstores or hypermarkets--that attract shoppers from up to a hundred miles to do the weekly or twice monthly shopping for the household. (Anding *et al.* 1990; Lukermann *et al*. 1991)

As geographical patterns of goods and service production and distribution have changed, the residential map of Minnesota has been redrawn. The concepts of "city", "town", "farm", and "agricultural countryside", which implied so much and were useful before and shortly after World War II, have lost much of their precise meanings during the past four decades. (Hart 1992) Town residents work in modern industrialized agriculture and in the processing of agricultural output. The smallest hamlets and villages have lost most or all of their role as retail and service centers, but they persist as residential "neighborhoods" linked to wide regions. (Hart 1991)

Today's farmstead residents typically work off the farm unless they are retired, and often are uninvolved in farming the land surrounding their houses. Metropolitan area residents in increasing numbers travel daily to jobs outside the MSA, and while doing so pass non-MSA residents driving in the opposite direction to jobs inside the MSA. (Clemente and Summers 1975; Davis 1993)

II. CONSEQUENCES OF CHANGE FOR COMMUTING BY DIFFERENT GROUPS

As work arrangements become more varied and as job locations and residential opportunities become more dispersed than in earlier times, the resulting settlement and commuting fields define increasingly complex patterns on our maps. Full time, 8:00 to 5:00 jobs, Monday through Friday, are giving way to part time, evening, weekend, seasonal, and flex-time employment. Work for employers is being replaced by consulting and contract work by the self-employed. (Brooker-Gross and Maraffa 1985)

The fixed work place in the office, store, factory or on the farm is increasingly supplemented or replaced by telecommuting, and by people working out of their homes, their cars, or at scattered work sites depending on where contracts, customers, and consulting services take them. Sometime such work replaces traditional jobs; sometimes it constitutes a second or even a third job. (Telecommuting 1994)

Steady improvement in quantity and quality of high-speed highways, telecommunications, and computers serving Minnesota allows workers to select residential settings with less regard for the locations of their current jobs than was the case a generation ago. Household members might hold two or more jobs at different locations, and may change or add jobs more frequently than they change their residence. In this way, the householders'

journeys to work become a consequence of their house choice and job opportunities, rather than a variable that weighs heavily on other locational choices they may make, either individually or together. (Adams 1987)

To summarize, as a consequence of dramatic adjustments in the world of work, in the geographical relocation of job locations, and the dispersal of new residences beyond the MSAs, commuting patterns defined by different groups of workers have been changing. Exurbanites--persons living beyond the MSA suburbs--select residences ever farther from the MSA, yet continue working at jobs throughout the MSA economy. Workers living beyond the exurban fringe find jobs requiring commutes of an hour or more, yet remain in their houses. Meanwhile, as the settlement and commuting fields spread out, disadvantaged populations become increasingly isolated from jobs and other opportunities. (Maraffa and Brooker-Gross 1984)

This study classifies Minnesota counties and MSA tracts that appeared to be similar according to transportation-related measures reported by the 1990 U. S. Census of Population and Housing, but differ in significant ways in terms of socioeconomic features. The fourteen transportation-related measures extracted directly from Summary Tape File 3 (STF 3) using D-BASE software included:

- 1) **Total population** [Population size corresponds to demand for transportation services; corresponds roughly with population density; and serves as the base for calculations of certain ratios.]

- 2) **Total population over age 65** [Labor force participation diminishes with increasing age, which leads in turn to a reduction in commuting; and as elderly persons reduce their driving, they increase their dependence on others for rides and on transit.]

- 3) **Percentage of total population over 65 years** [The proportional significance of the elderly within a county or a census tract.]

- 4) **Total commuters driving to work alone** [Reflects the extra capacity for carrying commuters between similar origins and common destinations, but also reflects the dispersal of origins and destinations, and diverse work schedules.]

- 5) **Percentage of all commuters who drive to work alone** [Reports by county and by census tract the proportional significance of the automobile commuter traveling alone.]

- 6) **Total commuters with work journeys greater than 30 minutes** [An aggregate measure of long distance commuting from each county and from each census tract.]

- 7) **Percentage of all commuters with work journeys over 30 minutes** [The share of commuters from each county and tract engaged in long distance commuting to work.]

- 8) **Average duration of journey to work in minutes** [Reports average accessibility in terms of time of workers from a county or a tract from home to their jobs.]

- 9) **Total population with limited mobility** [Persons with handicaps that limit their mobility options, and who may therefore depend on forms of private or public transit to meet their transportation needs.]

- 10) **Percentage of total population with limited mobility** [The share of persons in a county or census tract who may have special transportation needs that they cannot meet alone.]

- 11) **Total population below the poverty level** [Insufficient financial resources restrict mobility just as physical handicaps may limit movement, and may imply an unmet need or demand for publicly or privately supplied transit services.]

• 12) **Percentage of total population below the poverty level** [The share of the population in a county or tract that may lack an appropriate level of transportation service.]

• 13) **Total vehicles owned** [A measure of mobility opportunity for the households within a county or tract. Used in calculating rates of ownership at the household level.]

• 14) **Average number of vehicles owned per household** [Variations in level of mobility opportunities for workers and other residents are reflected by average vehicle ownership rates at the county and tract levels.]

The study proceeds at two scales: the county, for statewide analysis, and the census tract, for the MSA scale analysis. The case for using these two scales is mainly one of convenience. At these scales, the maximum amount of comparable, detailed census data is available. In addition, these two scales seem appropriate for examining both the shorter trips characteristic of intra-MSA commuting, as well as long-distance travel that frequently occurs outside the MSAs of Minnesota, and between MSAs and their surrounding areas.

III. MINNESOTA COUNTIES AND 1990 CENSUS TRANSPORTATION MEASURES

To begin the statistical comparison of Minnesota's counties, the fourteen measures listed above were tabulated for the state's counties in a raw data matrix of 87 rows (counties or cases), and 14 columns (variables). Although there are 14 separate variables used, their information content is somewhat redundant. For example, a correlation analysis of the 14 variables reveals that the average duration of the journey to work, measured in minutes, is highly correlated with the percentage of commuters with journeys to work exceeding 30 minutes (correlation coefficient R=.96; Table 1). As the proportion of a county's population over age 65 rises, the

Table 1. Correlations of Transportation-Related Measures, Minnesota Counties, 1990*

	Percent over age 65	Percent of all commuters driving alone to work	Percent of all commuters with work journey durations over 30 minutes	Average duration of journey to work (minutes)	Percent limited mobility population	Percent population below poverty level	Average Vehicles per Household
Percent over age 65							
Percent of all commuters driving alone to work							
Percent of all commuters with work journey durations over 30 minutes							
Average duration of journey to work (minutes)	-0.58		0.96				
Percent limited mobility population							
Percent population below poverty level	0.50						
Average Vehicles per Household			0.68	0.61			

*Only correlations greater than 0.50 are shown. N = 87. Correlations significant at 99.9 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

percentage of the population living below the poverty level also rises (R=.50), while the average duration of the journey to work declines (R= -.58).

The correlation matrix tells us that the fourteen variables contain overlapping and redundant information, so we apply the procedure of factor analysis to the correlation matrix to identify the separate and distinct underlying transportation-related features of Minnesota's commuters and other sub-populations. (Appendix A) The first of these basic, underlying features or "factors" is represented in the data set by various measures of **Population Mass** and associated commuting volumes originating in counties. Thus, the more population there is in a county, the greater the number of persons over 65 years; the greater the number of persons commuting alone; the greater the number of long-distance commuters; the greater the number of persons living below the poverty line; the greater the total number of personal vehicles in the county, and to some extent the greater the number of persons with mobility impairments.

A second of the basic, underlying features of counties, and a characteristic that is substantially uncorrelated with the presence or absence of the first factor, is reflected in the data by measures disclosing various degrees of dependence on or involvement in **Commuting**. Thus, the more a county's residents depend on commuting, the greater the proportion of workers making long-distance commutes, the greater the average commuting time for county workers, and the greater the number of vehicles per household.

A third basic feature that varies in its expression from county to county seems to reflect the average **Socioeconomic Status** of county residents. "Status" means the position of an individual in relation to another or others of the same class or social standing within the community. The higher the status of the average county resident, the lower is the proportion of persons over 65, the lower the poverty rate, and the higher the number of vehicles per household.

A fourth feature of counties that seems to be essentially uncorrelated with other basic or fundamental attributes is the proportion of the population that is **Mobility Impaired**, a characteristic that is reported directly by the census and seems to be largely uncorrelated with other variables included in this analysis. The census question asks: "Because of a health condition that has lasted 6 or more months does this person have any difficulty ... going outside the home alone, for example, to shop or visit a doctor's office?"

The fifth and last of the basic features of Minnesota counties portrayed by the factor analysis reflects the tendency for a county's commuters to engage in **Solo Commuting**. The census measure reflecting this tendency is the percentage of all workers who drive to work alone, a variable that is essentially uncorrelated with other measures included in the analysis.

The factor analysis procedure identifies for us the five most basic and uncorrelated features according to which Minnesota's 87 counties are shown to differ:

- 1) **Population Mass**
- 2) general **Commuting** tendency
- 3) average **Socioeconomic Status** of residents
- 4) degree of **Mobility Impairment** of residents
- 5) **Solo Commuting** tendency

These five features summarize over **94** percent of the total volume of information that is contained in the original 87x14 data matrix. About **52** percent of that basic information is associated with Population Mass; **23** percent with Commuting; slightly more than **7** percent

with Socioeconomic Status; something more than **6** percent with Mobility Impairment; and just under **6** percent for Solo Commuting. (Appendix A)

IV. CLASSIFYING MINNESOTA'S COUNTIES USING FIVE INDEPENDENT MEASURES

Through a weighting (of variables) and scoring (of counties) procedure, we can calculate what is called a factor score for each of the five basic features for each of the 87 counties. Each county gets five scores--one for each of the five fundamental features that express themselves in different, overlapping, and sometimes redundant fashion by means of the 14 original variables.

The factor scores tell us how the counties differ from one another with respect to each of the five basic features that we identified. For example, the first feature we labeled **Population Mass**, which was reflected in the raw data set through variables reporting simple counts like number of persons, number of long distance commuters, and number of vehicles available in the county for personal use. The array of scores is standardized, with a mean of zero and a standard deviation of 1.0. Not surprisingly, the county with the highest score is Hennepin (7.9); the second highest scoring is Ramsey (3.7). (Figure 1) (See Appendix B for county scores)

The second feature we labeled a general **Commuting** tendency, which reflects a county's record regarding, for example, the proportion of commuters traveling more than 30 minutes, the average time of commute for county workers, and the average number of vehicles per household. The counties scoring highest with respect to this feature included Anoka (2.0), Chisago (2.9), Isanti, which has the highest average travel time in the state (scoring 3.3), Sherburne (2.7) and Wright (2.7). (Figure 2) (Appendix B)

The other three basic characteristics--average **Socioeconomic Status** of residents, degree of **Mobility Impairment** of residents, **Solo Commuting** tendency--also provide scores for each

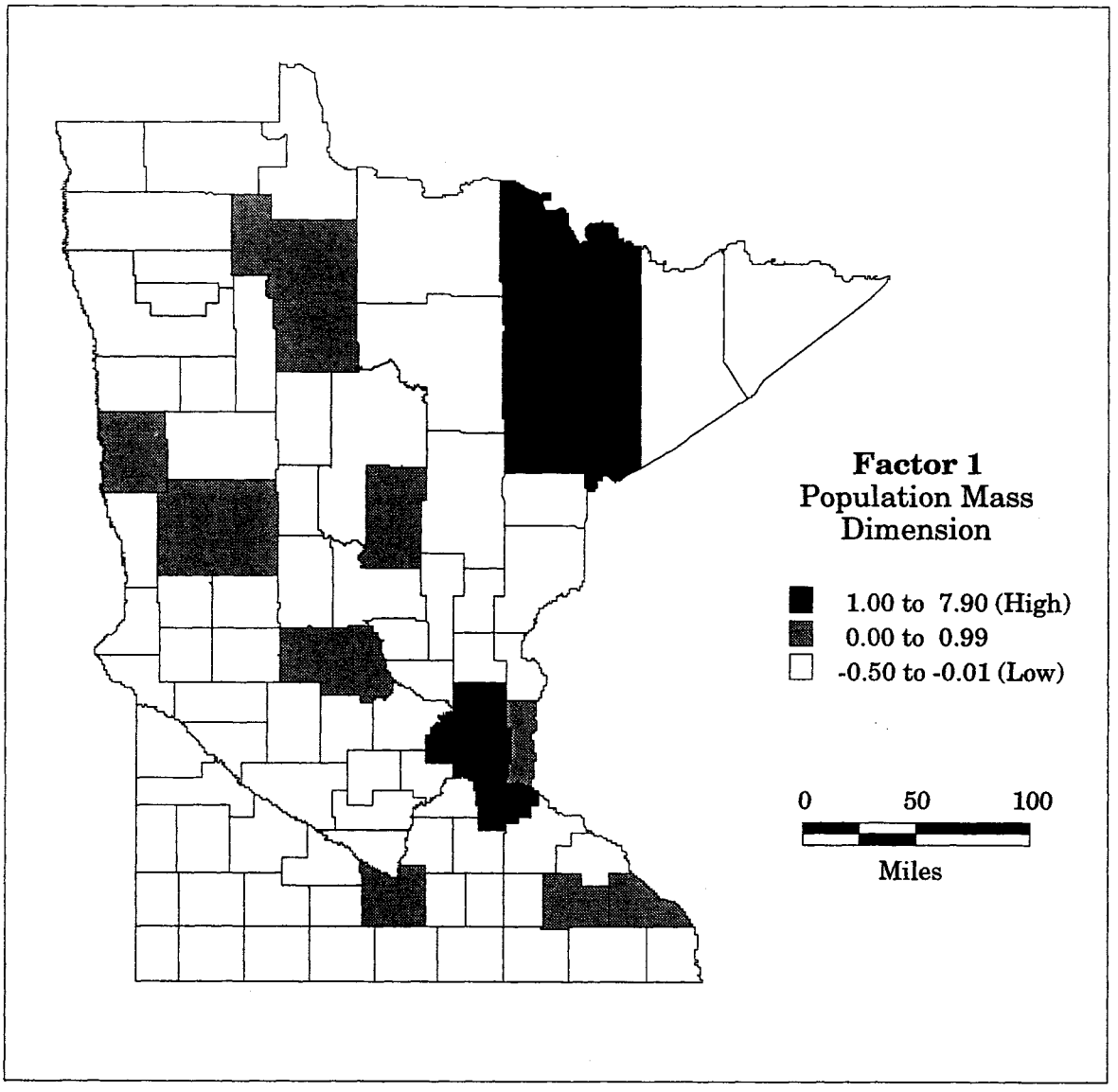

Figure 1. Population Mass of Minnesota Counties. Values reflect the following at the county level: population, elderly population, solo commuters, long distance commuters, mobility-impaired population, population below poverty, and average vehicles per household. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

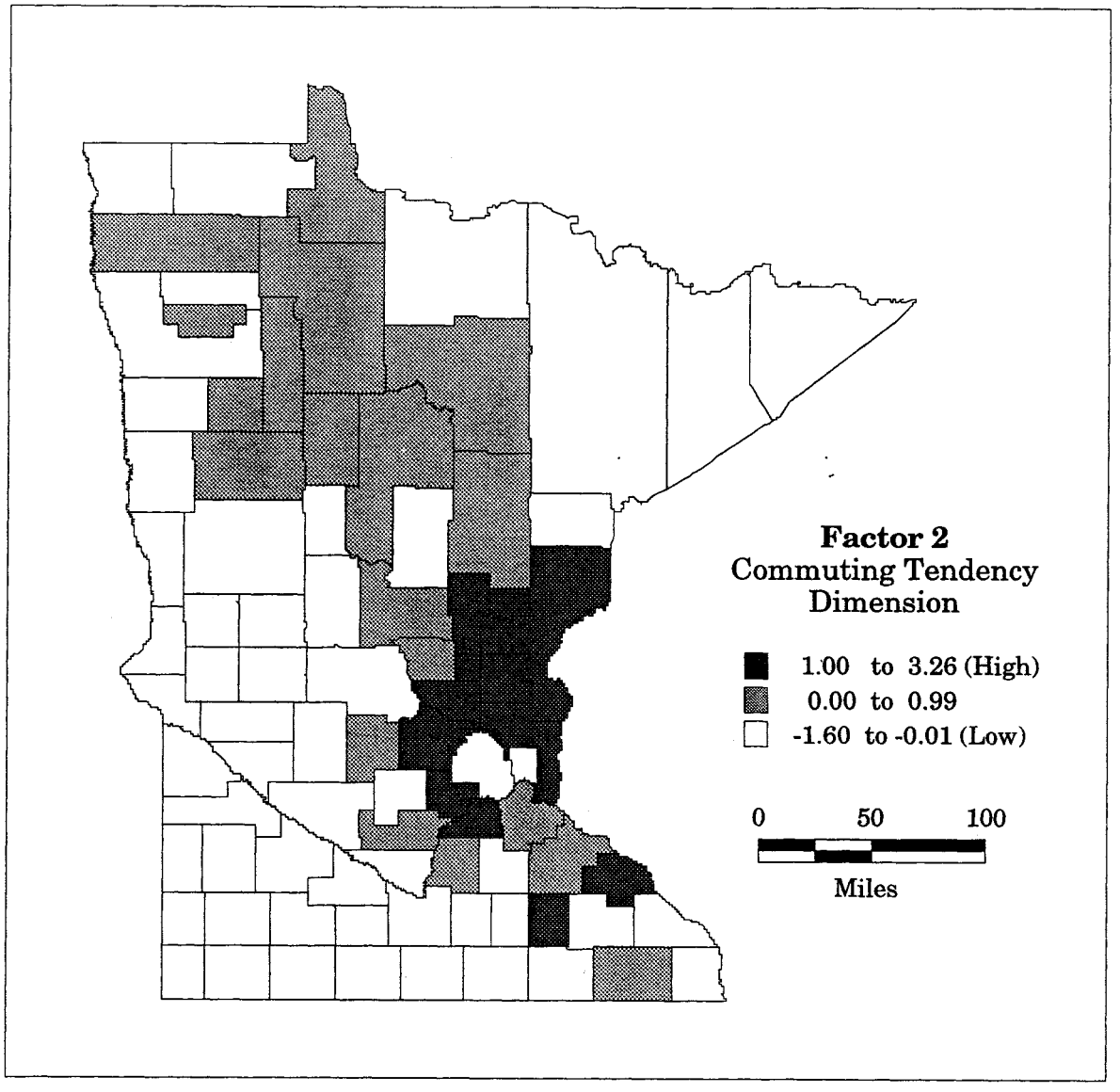

Figure 2. Commuting Tendency in Minnesota Counties. Values reflect the following at the county level: percentage of long distance commuters, average travel time, average number of vehicles available per household. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

county. (Figs. 3, 4, and 5) The set of five scores for each county permits the next step, which is the classification of Minnesota's counties based on the transportation-related measures, from which the redundancies and the effects of correlated variables have been removed. Classifying counties using correlated variables means making distinctions when none is present; using redundant variables means adding weight to features that inadvertently are counted more than once. By using the five statistically independent (uncorrelated) factor scores, each of the scores receives the same weight, thereby avoiding invalid distinctions and double counting.

The classification method used to group the counties is called numerical taxonomy. It is called "numerical" because it employs numbers representing measured differences among the cases, which are the 87 counties in this study. It is called "taxonomy" because the word means classification, after the Greek term "taxon", which means class. (Appendix C)

The basic idea is as follows. Let us assume that the 87 counties were arrayed in a two-dimensional coordinate system with the horizontal axis labeled **Population Mass (Factor Score)**, and the vertical axis labeled **Commuting Tendency (Factor Score)**. Then, since we have a population mass score and a commuting tendency score for each county, we can plot all 87 counties within the coordinate space according to each county's pair of scores. Now, once all counties have been plotted, each county is located in the space at a point that lies a measurable distance from every other county, just as points on a map are located at different distances from every other point on the same map.

Next, the distances separating each county from every other are used to classify counties according to a systematic grouping or clustering procedure, of which there are several. (See Appendix C) The goal of clustering is to join counties into groups or classes with other counties plotted nearby in the coordinate space, and to proceed with the clustering procedure in such a

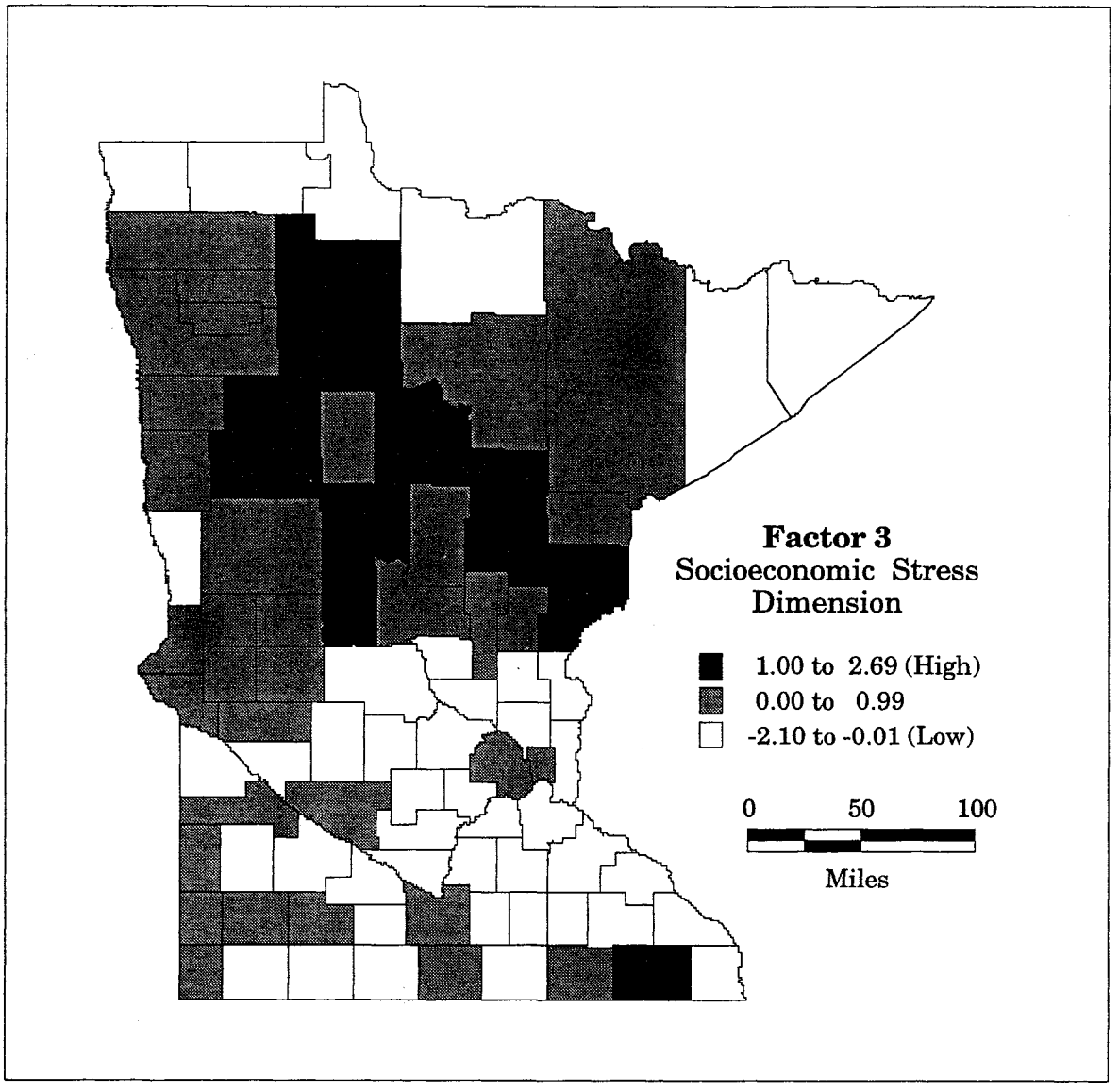

Figure 3. Average Socioeconomic Stress Facing County Residents. Values reflect the following at the county level: percentage of population over age 65, and percentage of population below poverty. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

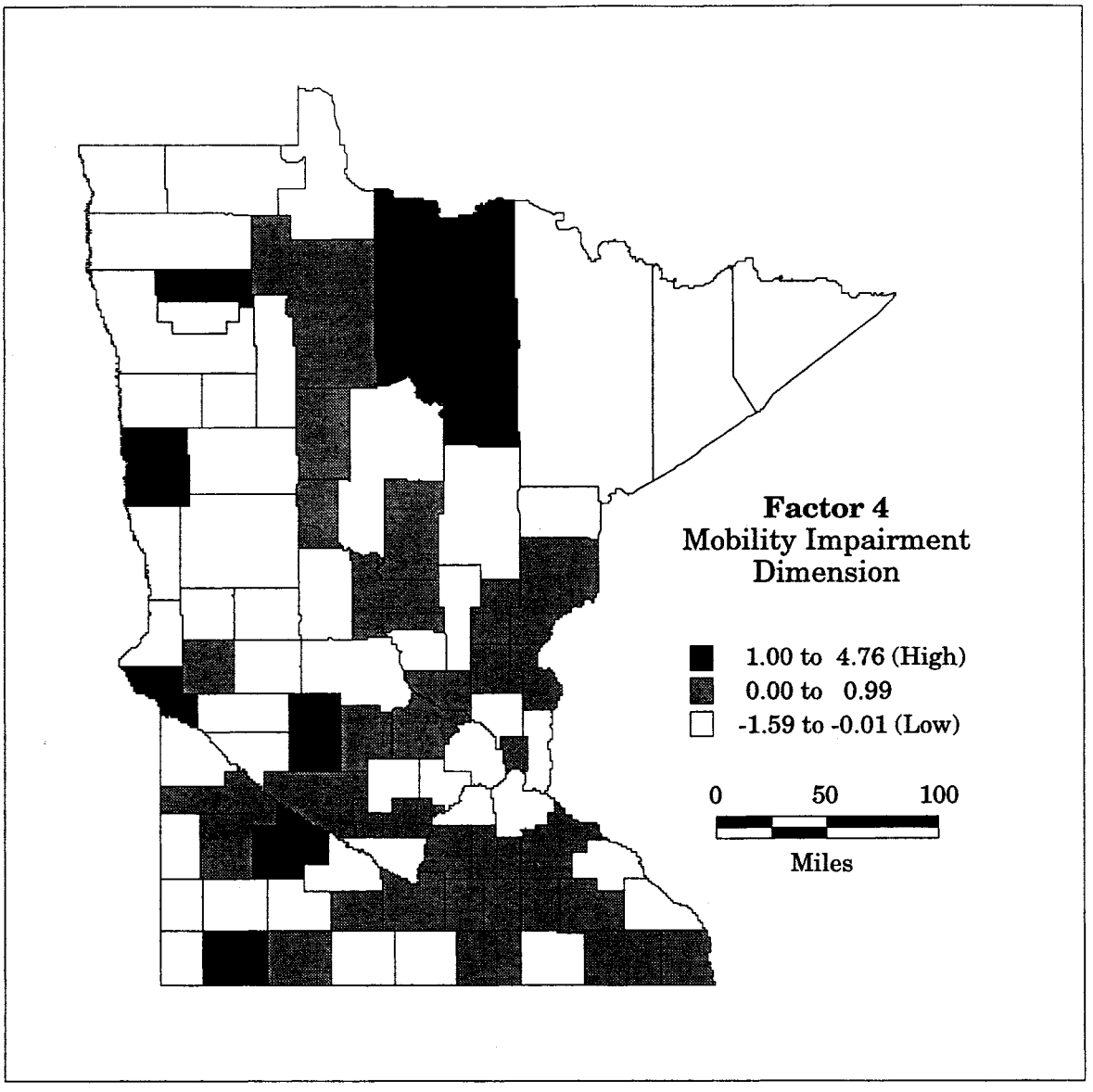

Figure 4. Degree of Mobility Impairment of County Residents. Values reflect the following at the county level: percentage of population with mobility limitations. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

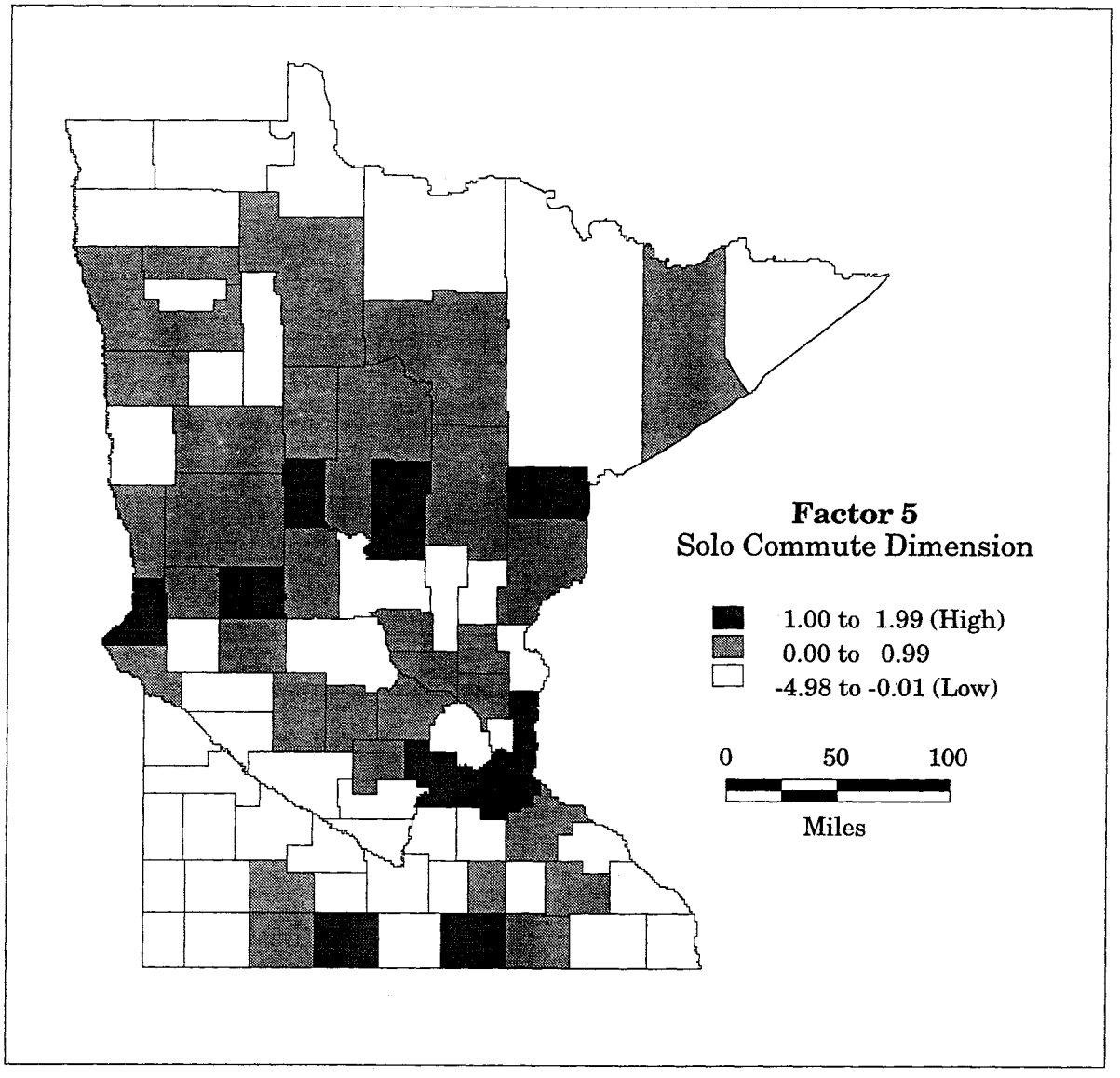

Figure 5. Solo Commuting Tendency Among Minnesota Counties. Values reflect mainly the following at the county level: percentage of population commuting alone to work. County values range from 75 percent to 83 percent. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

way that variation among cases within each cluster is minimized, while variation between members inside the cluster and those outside and in other clusters are maximized.

It is straightforward to imagine a county classification that is based on a clustering procedure that proceeds within a coordinate space (called a taxonomic space) of two dimensions, defined by only two attributes. But our study identifies not two, but five basic attributes. So we define mathematically a five-dimensional coordinate space, then array the 87 counties within this five-dimensional taxonomic space. Once each county is assigned to its location within this space according to its five factor scores, then clustering can proceed based on the measured distances separating each county from the 86 others in the state..

V. RESULTS OF CLASSIFYING MINNESOTA COUNTIES INTO SIX MOST SIMILAR CLUSTERS

When 87 Minnesota counties are grouped systematically into six clusters, the contents of each cluster are as follows:

1) Hennepin (Minneapolis)

2) Ramsey (St. Paul)

3) Anoka, Dakota (Twin Cities suburbs)

4) St. Louis (Duluth)

5) Olmsted (Rochester), Stearns (St. Cloud), Washington (Twin Cities)

6) All other Minnesota counties

The clustering process begins with 87 individual counties, each taken as a separate, unique cluster with a single member. As the clustering proceeds, counties join other counties according to their similarities as measured by their five factor scores from the previous analysis. As the clustering proceeds step by step, the "between group variation" diminishes and "within group variation" accumulates. Before the clustering begins, we have a situation of complete uniqueness. Each county is taken as an entity distinct from every other. At the conclusion of the clustering, if taken to the last step, all 87 counties are members of one cluster, and all distinctness is obscured. A situation of complete generality obtains. Useful classifications occur between these two extremes--between 87 separate groups, and one group containing all cases.

It happens that by terminating the clustering procedure with six clusters, we seem to achieve useful, interpretable results. With seven or eight clusters, the group "all other Minnesota counties" is split into subgroups that are difficult to interpret. By averaging some of the individual measures from the list of 14 variables on the original list, we can see some of the differences among counties that fall into the six diverse clusters. For example, the six clusters vary in average population from over one million (Hennepin County, the solitary member of Cluster 1), to 22,388 (average of 79 members of Cluster 6). (Table 2) The average percentage of commuters driving alone to work is similar from cluster to cluster, varying from a high of over 83 percent for the counties in Cluster 3 (Anoka, Dakota), to a low of 75 percent in St. Louis (Duluth).

The percentage of commuters with work journeys exceeding 30 minutes ranged from a low of under 17 percent in Cluster 4 (St. Louis), up to an average of almost 33 percent for counties in Cluster 3 (Anoka, Dakota). The average journey to work in minutes, varies from a high of almost 23 minutes in Cluster 3, to a low in Cluster 6 (all other Minnesota counties) of

Table 2. Minnesota Counties Grouped into Six Most Similar Clusters, Summary Information, 1990

	CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6
Average Population	1,032,431.0	485,765.0	259,434.0	198,213.0	123,719.0	22,388.0
Percent over age 65	11.3	12.2	5.9	16.9	9.0	17.2
Percent of all commuters driving alone to work	76.8	75.5	83.1	75.2	79.1	76.6
Percent of all commuters with work journey durations over 30 minutes	23.1	19.7	32.9	16..9	18.5	18.2
Average duration of journey to work (minutes)	20.2	19.1	22.7	17.4	17.7	16.3
Percent limited mobility population	0.6	0.7	0.4	0.5	0.5	0.6
Percent population below poverty level	9.3	11.4	4.8	14.2	7.8	13.1
Average vehicles per Household	1.6	1.6	2.0	1.6	1.9	1.8
COUNTIES INCLUDED	**HENNEPIN**	**RAMSEY**	**ANOKA, DAKOTA**	**ST. LOUIS**	**OLMSTED, STEARNS, WASHINGTON**	**ALL OTHERS**

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

just over 16 minutes. The percentage of populations with limited mobility was low in all counties. Cluster averages reached a low of .4 percent for Cluster 3 (Anoka, Dakota), and a high of .7 percent in Cluster 3 (Ramsey). Cluster averages for the percentage of population below the poverty level were lowest in Cluster 3, at 4.8 percent (Anoka, Dakota), and highest in Cluster 6, mainly counties outside the MSAs, where the counties averaged over 13 percent. Vehicles per household ranged from a low average of 1.6 in the counties comprising Cluster 1 (Hennepin), 2 (Ramsey) and 4 (Olmsted, Stearns, and Washington), each of which contains an older, high density urban core, to the high average of 2.0 in the suburban counties of Cluster 3 (Anoka, Dakota).

VI. METROPOLITAN STATISTICAL AREA TRACTS AND TRANSPORTATION-RELATED MEASURES FROM THE 1990 CENSUS OF POPULATION AND HOUSING

Our second scale of analysis focuses on 1990 census tracts within the five Metropolitan Statistical Areas (MSAs) of Minnesota, three of which spill over into adjacent states. They include Duluth-Superior (MN, WI), Fargo-Moorhead (MN, ND), Minneapolis-St. Paul (MN, WI), St. Cloud (MN), and Rochester (MN). A total of 833 census tracts are analyzed and classified, using the same procedures that were employed in the county-level analysis.

The largest of the MSAs is Minneapolis-St. Paul with 2.5 million population (including 50,251 in St. Croix County, Wisconsin), or 55 percent of Minnesota's population. The smallest is Fargo-Moorhead, with just over 50,000. (Table 3) MSA poverty rates ranged from under 7 percent in Rochester to almost 17 percent in Duluth-Superior. Elderly populations comprised under 10 percent in fast growing Minneapolis-St. Paul and Rochester, but reached almost

Table 3. Socioeconomic and Transportation Measures, State of Minnesota and Metropolitan Statistical Areas, 1990

Variable	Minnesota	Duluth-Superior	Fargo-Moorhead	Minneapolis-Saint Paul	Rochester	St. Cloud
Total Population	4,375,099	198,213	153,296	2,413,873	106,470	190,921
Population Below Poverty Level	435,331	27,201	7,355	191,821	7,155	20,065
As percentage of total population	*9.95%*	*13.72%*	*4.80%*	*7.95%*	*6.72%*	*10.51%*
Persons over age 65	546,562	33,496	5,981	237,743	10,625	19,114
As percentage of total population	*12.49%*	*16.90%*	*3.90%*	*9.85%*	*9.98%*	*10.01%*
Persons in Labor Force with Mobility Limitation	12,741	444	218	7,292	362	472
Average Number of Vehicles Per Household	1.77	1.62	1.78	1.75	1.80	1.91
Average Travel Time to Work (minutes)	19.11	17.35	15.39	21.06	14.84	18.67
Average Auto occupancy for work journeys	1.08	1.10	1.08	1.07	1.08	1.08

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

17 percent in Duluth-Superior, a region of steady net outmigration. Persons with mobility limitations enumerated by the census totaled 12,700 statewide in 1990, with almost six out of ten of the state wide total living in the Twin Cities. Average number of vehicles per household was lowest in the Duluth-Superior MSA at 1.62, and highest in the St. Cloud area at 1.91.

Minnesota's average travel time to work was just over 19 minutes in 1990, but ranged from an MSA low in Rochester at 14.84 minutes, to a high in the Twin Cities where workers averaged just over 21 minutes. Throughout Minnesota the average automobile occupancy for work journeys was 1.08 in 1990, but there was little difference among MSA averages. The Twin Cities average was lowest at 1.07; in Duluth-Superior it was 1.10, the highest among the MSAs.

VII. INTERCORRELATIONS OF TRANSPORTATION-RELATED VARIABLES AT THE TRACT LEVEL

The 1990 U.S. Census of Population and Housing supplies us with the same fourteen transportation-related variables at the census tract level that were used in the preceding county level analysis. Seven variables report simple tract totals (population, population over age 65, solo commuters, commuters with journeys exceeding 30 minutes, population with mobility impairments, population below the poverty level, vehicles owned). Seven others enter the tract level analysis by means of ratios:

- **Percentage of tract population over age 65**
- **Percentage of tract population with incomes below the poverty level**
- **Percentage of tract population with mobility limitations**

- **Percentage of commuters living in the tract driving alone to work**
- **Percentage of commuters with commutes longer than 30 minutes**
- **Average commuting time for commuters living in the tract**
- **Average number of vehicles per household**

The seven raw measures of sheer size all correlate closely with population, but the seven ratio measures tell more complex stories. When the seven ratio variables are evaluated over the 833 census tracts within Minnesota's MSAs, two appear essentially uncorrelated with the others: 1) percentage of persons over age 65; and 2) percentage of persons with mobility limitations. (Table 4) The other five are intercorrelated, and thus contain redundant or overlapping information. Measures that might have been expected to be included in the analysis were left out, such as average household income or income per capita, because they are highly correlated with measures such as percentage of population below the poverty level and average number of vehicles per household and we anticipated that they would add little to the overall analysis.

When the seven ratio variables describing the 643 tracts within the Minneapolis-St. Paul MSA are evaluated, the same pattern of intercorrelations appear as emerged state-wide--with one exception. In the Twin Cities MSA, there is a significant correlation between the level of the poverty population and the percentage of the population with mobility limitations. (Table 5) This correlation means that when the poverty population percentage rises above average in Twin Cities area tracts, the percentage of the population with mobility limitations rises above

Table 4. Intercorrelations Among Selected Transportation-Related Variables, All Minnesota MSA Tracts, 1990*

	Percent over age 65	Percent below poverty level	Percent with mobility limitation	Percent solo commuters	Percent long duration commuters	Average commute time	Average vehicles per household
Percent over age 65	1.00						
Percent below poverty level		1.00					
Percent with mobility limitation			1.00				
Percent solo commuters		-0.54		1.00			
Percent long duration commuters					1.00		
Average commute time				0.48	0.90	1.00	
Average vehicles per household		-0.59		0.81	0.48	0.55	1.00

*Only correlations greater than 0.40 are shown. N = 833. Correlations shown are significant at 99.9 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

Table 5. Intercorrelations Among Selected Transportation-Related Variables, Minneapolis-St. Paul MN-WI MSA Tracts, 1990

	Percent over age 65	Percent below poverty level	Percent with mobility limitation	Percent solo commuters	Percent long duration commuters	Average commute time	Average vehicles per household
Percent over age 65	1.00						
Percent below poverty level		1.00					
Percent with mobility limitation		0.42	1.00				
Percent solo commuters		-0.64		1.00			
Percent long duration commuters					1.00		
Average commute time				0.49	0.89	1.00	
Average vehicles per household		-0.64		0.83	0.53	0.56	1.00

*Only correlations greater than 0.40 are shown. N = 643. Correlations shown are significant at 99.9 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

average levels as well. Similarly, when one of these measures falls below average in a set of tracts, the other one tends to fall below average as well. The two measures vary together and in the same direction across the Twin Cities. (Adams 1991; Adams and VanDrasek 1993)

In the St. Cloud area, the significant state wide correlations are repeated to varying degrees with two exceptions. (Table 6) Whereas statewide, as the percentage of the population living below the poverty line rose, long distance commuting declined, as did the average number of vehicles per household. In the St. Cloud area, these correlations failed to appear. That is, the tendency for solo commuting by St. Cloud area commuters occurs largely independently of the occurrence of poverty at the tract level. Similarly, poverty at the tract level appears to be relatively unrelated to the number of vehicles available per household.

In Rochester area tracts, the percentage of a tract's population with mobility limitations is the only tract level measure lacking an important correlation with the other measures. (Table 7) Duluth-Superior tracts showed the same patterns as those for the St. Cloud area tracts. (Table 8 vs. Table 6) In the Fargo-Moorhead tracts, only the measure of percentage of population over 65 years appeared uncorrelated with the other tract level measures. (Table 9)

The six tables of correlation coefficients present a profile for the MSA tracts from around the state, then for the five MSAs on an individual basis. The tables reveal certain key facts. First, the statistics used in the analysis are shown not to be independent of one another. To the extent that pairs of variables are significantly correlated, they contain redundant information that can muddy up our analysis. Secondly, the MSAs differ one from another in the ways in which the variables present or fail to present correlated or redundant information. On the basis of the correlation analysis, we are encouraged to look at the MSAs individually, rather than to assume that patterns disclosed in one are repeated in the same way in others.

Table 6. Intercorrelations Among Selected Transportation-Related Variables, St. Cloud MN MSA Tracts, 1990*

	Percent over age 65	Percent below poverty level	Percent with mobility limitation	Percent solo commuters	Percent long duration commuters	Average commute time	Average vehicles per household
Percent over age 65	1.00						
Percent below poverty level		1.00					
Percent with mobility limitation			1.00				
Percent solo commuters				1.00			
Percent long duration commuters					1.00		
Average commute time				0.56	0.89	1.00	
Average vehicles per household				0.55	0.41[a]	0.65	1.00

*Only correlations greater than 0.40 are shown. N = 43. Correlations shown are significant at 99.9 percent level unless otherwise marked.

a: significant at 99 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

Table 7. Intercorrelations Among Selected Transportation-Related Variables, Rochester MN MSA Tracts, 1990

	Percent over age 65	Percent below poverty level	Percent with mobility limitation	Percent solo commuters	Percent long duration commuters	Average commute time	Average vehicles per household
Percent over age 65	1.00						
Percent below poverty level	0.69[b]	1.00					
Percent with mobility limitation			1.00				
Percent solo commuters	−0.45[a]			1.00			
Percent long duration commuters					1.00		
Average commute time				0.69[b]	0.80[b]	1.00	
Average vehicles per household	−0.47[a]	−0.40[c]		0.94	0.45[a]	0.81	1.00

*Only correlations greater than 0.40 are shown. N = 22. Correlations shown are significant at 99.9 percent level unless otherwise marked.

a: significant at 99 percent level.
b: significant at 95 percent level.
c: not significant at 95 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

Table 8. Intercorrelations Among Selected Transportation-Related Variables, Duluth-Superior MN-WI MSA Tracts, 1990*

	Percent over age 65	Percent below poverty level	Percent with mobility limitation	Percent solo commuters	Percent long duration commuters	Average commute time	Average vehicles per household
Percent over age 65	1.00						
Percent below poverty level		1.00					
Percent with mobility limitation			1.00				
Percent solo commuters				1.00			
Percent long duration commuters					1.00		
Average commute time				0.54	0.87	1.00	
Average vehicles per household				0.82	0.56	0.76	1.00

*Only correlations greater than 0.40 are shown. N = 89. Correlations shown are significant at 99.9 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

Table 9. Intercorrelations Among Selected Transportation-Related Variables, Fargo-Moorhead MN-ND MSA Tracts, 1990*

	Percent over age 65	Percent below poverty level	Percent with mobility limitation	Percent solo commuters	Percent long duration commuters	Average commute time	Average vehicles per household
Percent over age 65	1.00						
Percent below poverty level		1.00					
Percent with mobility limitation		0.51[a]	1.00				
Percent solo commuters		-0.49[a]		1.00			
Percent long duration commuters					1.00		
Average commute time					0.89	1.00	
Average vehicles per household		-0.72	-0.47[a]	-0.48[a]		0.46[a]	1.00

*Only correlations greater than 0.40 are shown. N = 36. Correlations shown are significant at 99.9 percent level unless otherwise marked.

a: significant at 99 percent level.

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

There are two alternative procedures for carrying out a statistical analysis of each of the five MSAs' tract level data. One way takes the tract data for the first MSA and analyzes it as we analyzed the 87 Minnesota counties. This approach would analyze the correlations among the 14 raw variables, then reduce them to five basic, uncorrelated features that can then be used to calculate for each tract a set of five factor scores, which disclose how each tract reflects each of the fundamental features or factors of variation. Factor 1 scores could be mapped for the MSA tracts to disclose patterns of geographical variation. Then Factor 2 scores could be mapped, and so forth for the remaining three sets of scores, one set and one tract level map for each remaining factor. This effort would produce five separate maps for each MSA.

In addition to the production of the five separate maps, the set of five scores for each tract may be used to classify the MSA's tracts into 6 clusters. Why 6 clusters? Because that number turned out upon inspection to be the most useful set of clusters in the state-level analysis.

A second procedure for carrying out a statistical analysis of the five MSAs' tract level data considers all 833 tracts as a single data set. This approach permits the simultaneous evaluation of all the state's MSA tracts in strictly comparable terms, and permits the mapping of tract clusters so that each cluster has meaning and can be interpreted within a state-wide context. The second procedure is the one we used to define the six clusters of tracts described and discussed below.

VIII. CLUSTERING CHARACTERISTICS FOR MINNESOTA'S 833 MSA TRACTS

The cluster frequencies were as follows: Cluster 1, 10 tracts; Cluster 2, 163 tracts; Cluster 3, 53 tracts; Cluster 4, 402 tracts; Cluster 5, 111 tracts; and Cluster 6, 94 tracts. After the tracts contained within each of the six clusters are identified, the mean values and the standard

deviations of the transportation-related variables are calculated for each cluster. (Table 10, and Appendix C)

A. Cluster 1.

Tracts within Cluster 1 have the largest populations on average (10,140 persons). Overall, the populations within these tracts are young, likely to drive alone for long distances to work, and are relatively well off financially. Their tracts display high levels of auto ownership, and low incidence of poverty. Financially secure persons seeking low population densities at the expense of longer work trips appear to be the norm. (Table 11, and Appendix C)

The mean values for this cluster of tracts are produced from only ten tracts. For all raw variables, the standard deviations within the cluster are high. The tracts in the cluster are mainly large suburban and exurban tracts that built up fast in the 1980s, and according to normal census criteria would ordinarily have been subdivided into a larger number of smaller places. (Figures 6, 7, and 8)

B. Cluster 2.

Characteristics for tracts in this cluster are largely the opposite of those recorded for Cluster 1. Populations are smaller, older, poorer, and generally live closer to work than the residents of tracts in Cluster 1. (Table 12, and Appendix C)

Cluster 2 contains the highest percentages of mobility-impaired residents, however at the level of one percent it cannot be considered a strong factor in the analysis. Of greater

Table 10. Minnesota MSA Tracts Grouped into Six Most Similar Clusters, Summary Information, 1990

	CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6
Average Population	10,140.0	1,503.0	7,438.0	3,302.0	4,906.0	5,769.0
Percent over age 65	3.1	13.1	7.5	12.4	10.6	7.5
Percent of all commuters driving alone to work	85.9	57.1	82.9	76.3	78.7	82.4
Percent of all commuters with work journey durations over 30 minutes	33.2	17.8	29.1	22.5	23.9	27.9
Average duration of journey to work (minutes)	23.4	16.6	21.5	19.7	20.1	21.2
Percent limited mobility population	0.3	1.0	0.4	0.6	0.6	0.4
Percent population below poverty level	3.6	20.5	6.1	8.9	8.0	4.9
Average vehicles per Household	2.0	1.2	2.0	1.7	1.8	2.0
TRACTS INCLUDED	**10**	**163**	**53**	**402**	**111**	**94**

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

Table 11. Travel-Related Characteristics, Cluster 1 (10 Minnesota MSA Tracts), 1990

	Within Class		Among Classes		
Variable	**Mean**	**Standard Deviation**	**Maximum**	**Minimum**	**Rank**
Population					
Total	10,139.8	783.93	X		1
Population Over Age 65					
Total	325.0	226.14			5
Percent	3.1	1.95		X	6
Commuters Driving Alone to Work					
Total	4,654.6	553.14	X		1
Percent	85.9	2.74	X		1
Commuters with Work Journey Duration Over 30 Minutes					
Total	1,776.7	356.81	X		1
Percent	33.2	7.80	X		1
Duration of Journey to Work					
Average, in minutes	23.4	2.28	X		1
Limited Mobility Population					
Total	18.6	11.08	X		1
Percent	0.3	0.19		X	6
Population Below Poverty Level					
Total	369.5	214.34			3
Percent	3.6	1.99		X	6
Vehicle Ownership					
Total	6,972.8	638.17	X		1
Average Vehicles per Household	2.0	0.10	X		1

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

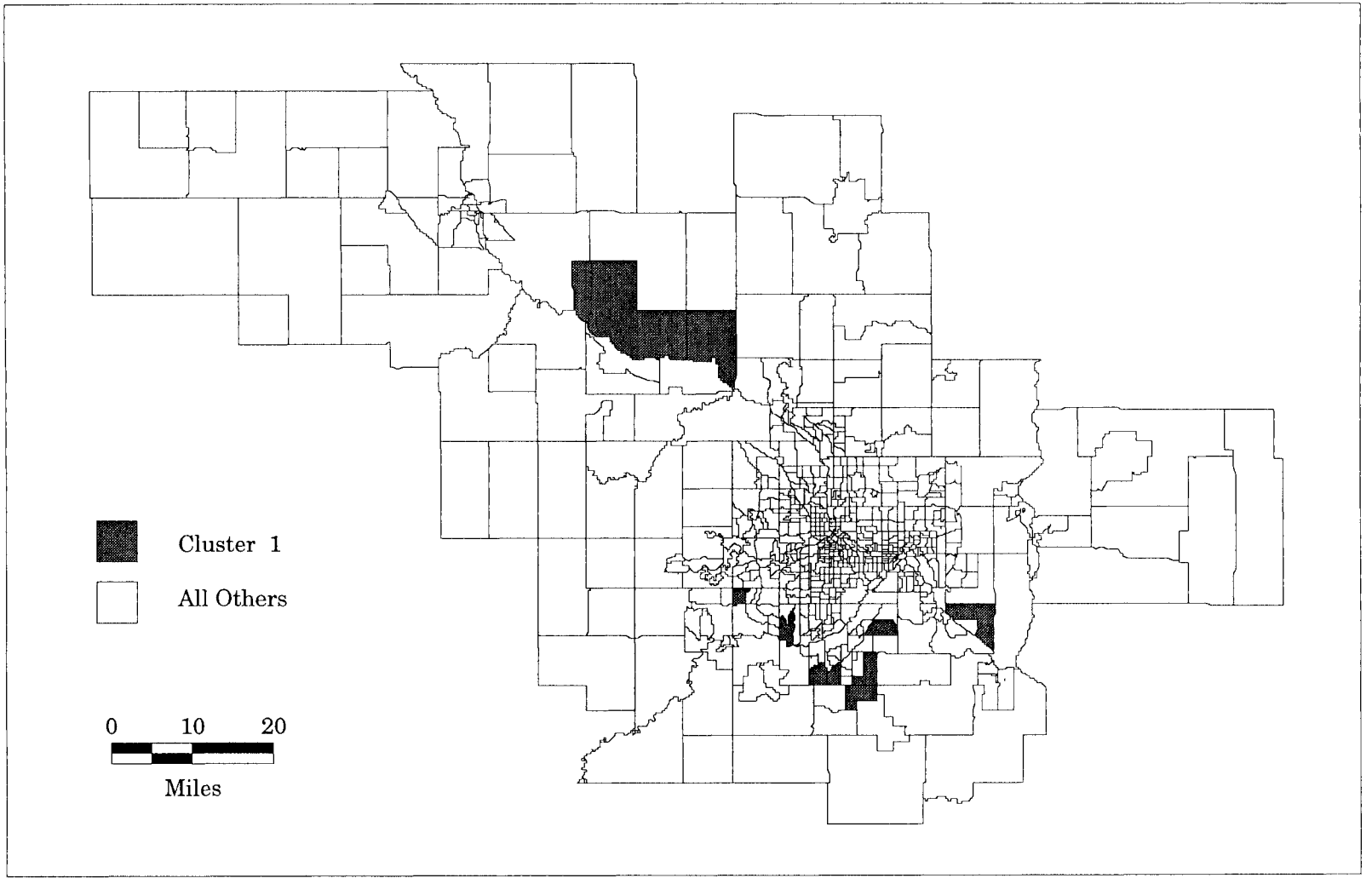

Figure 6. Distribution of Cluster 1 by Census Tract within the Twin Cities - St. Cloud Metropolitan Statistical Areas. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

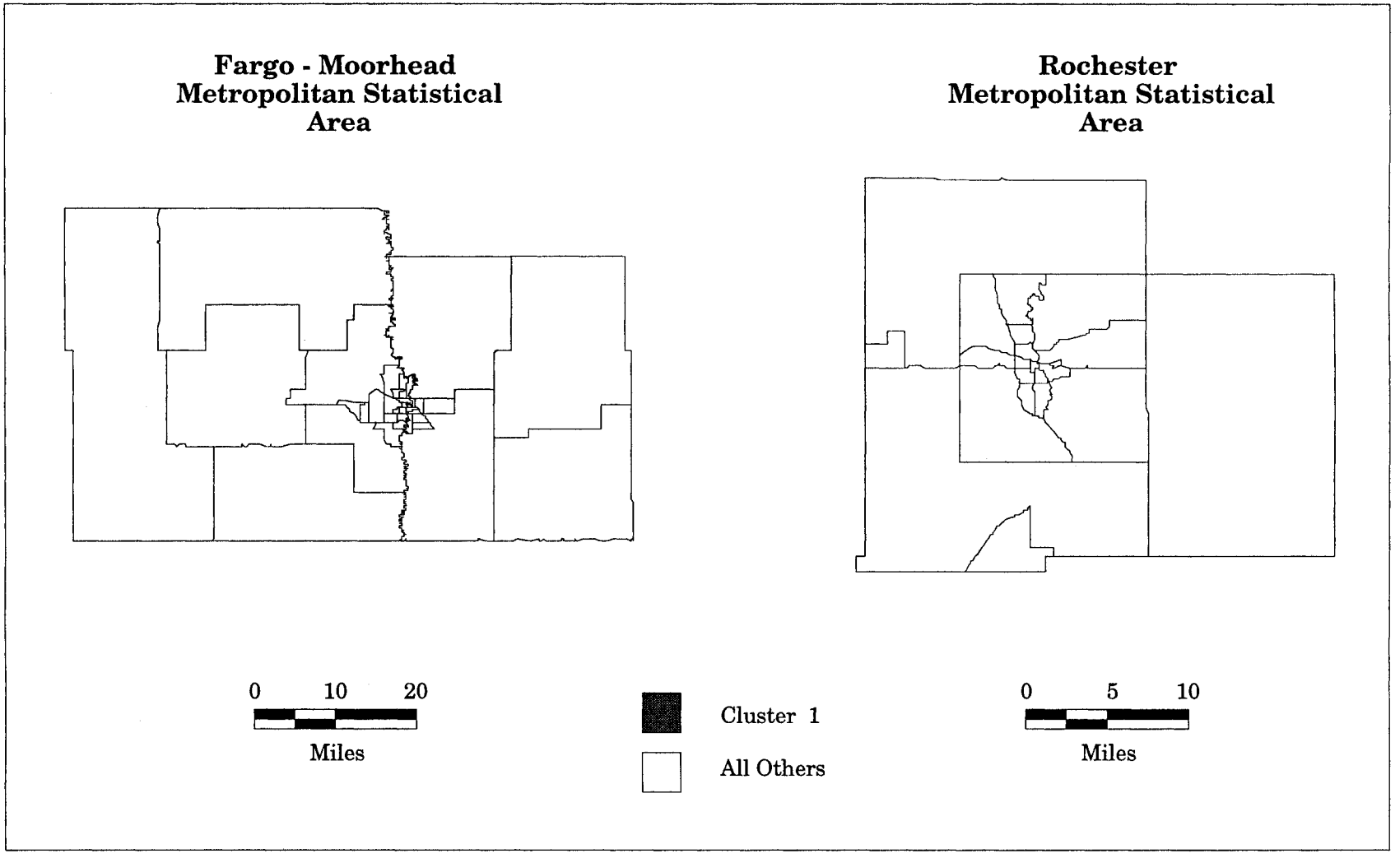

Figure 7. Distribution of Cluster 1 by Census Tract within the Fargo Moorhead MSA and Rochester MSA.
(Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

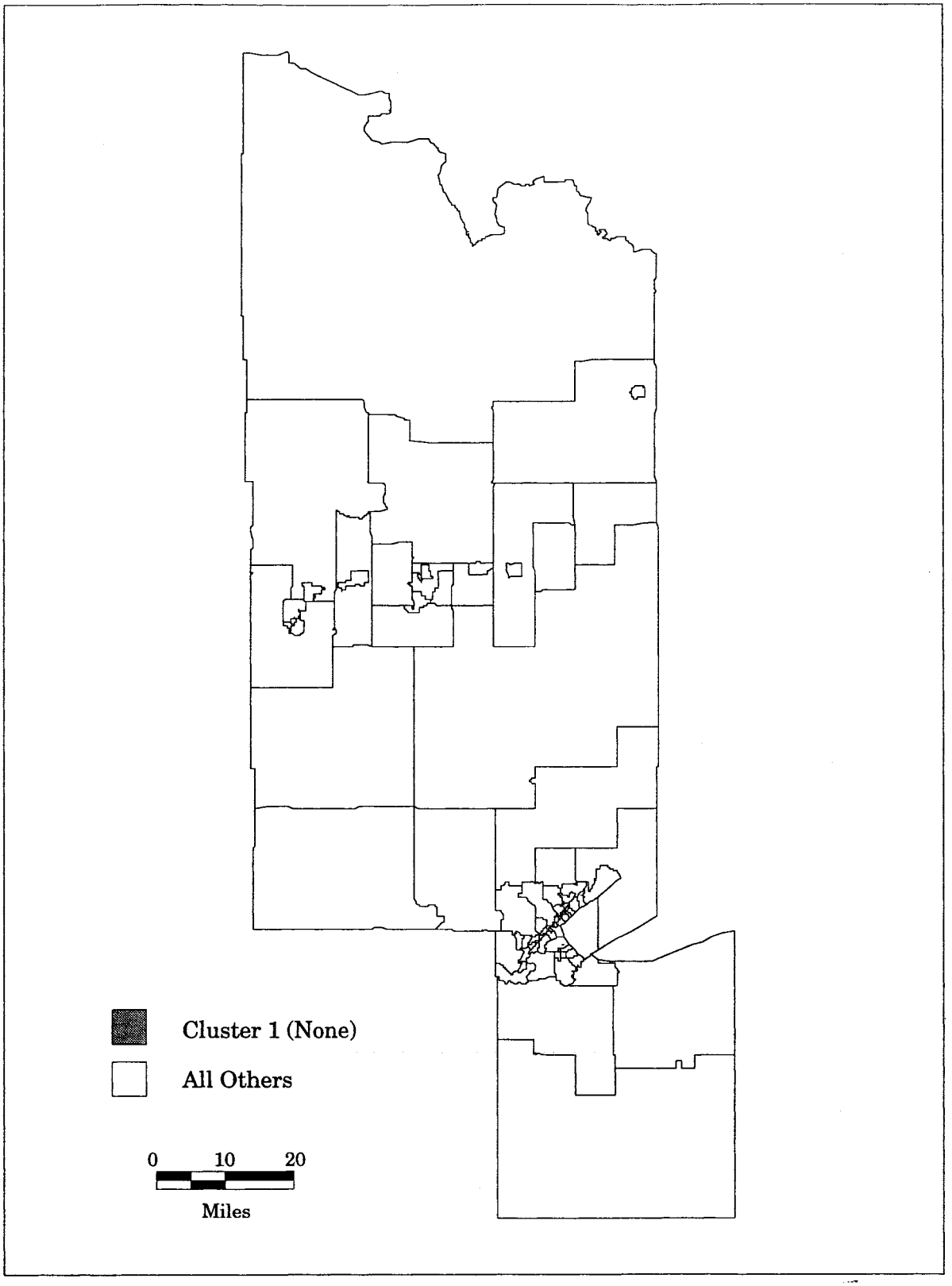

Figure 8. Distribution of Cluster 1 by Census Tract within the Duluth - Superior Metropolitan Statistical Area. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

Table 12. Travel-Related Characteristics, Cluster 2 (163 Minnesota MSA Tracts), 1990

Variable	Within Class		Among Classes		
	Mean	Standard Deviation	Maximum	Minimum	Rank
Population					
Total	1,503.2	722.12		X	6
Population Over Age 65					
Total	196.9	173.56		X	6
Percent	13.1	12.47	X		1
Commuters Driving Alone to Work					
Total	395.3	261.49		X	6
Percent	57.1	25.44		X	6
Commuters with Work Journey Duration Over 30 Minutes					
Total	123.0	92.26		X	6
Percent	17.8	10.61		X	6
Duration of Journey to Work					
Average, in minutes	16.6	6.37		X	6
Limited Mobility Population					
Total	7.1	13.28		X	6
Percent	1.0	1.84	X		1
Population Below Poverty Level					
Total	347.2	367.94			4
Percent	20.5	18.39	X		1
Vehicle Ownership					
Total	740.7	445.58		X	6
Average Vehicles per Household	1.2	0.69		X	6

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota),

significance are both the high number and high percentage of elderly persons in the 163 tracts within this cluster.

Automobile ownership per household is significantly lower than in other areas. With an average of 1.2 vehicles per household, it stands well below the next lowest average of 1.7 in Cluster 4. Whereas the total population living below the poverty level is not high relative to other clusters, approximately one of five people in tracts in Cluster 2 live below the poverty level.

The majority of the 163 tracts belonging to Cluster 2 are located in the central areas of the Minneapolis-St. Paul MSA, although a few occur in old centers of small towns that have been engulfed by suburbanization since the 1950s. (Figure 9) Some additional members of the cluster occur in the core areas of the other MSAs as well--in Duluth-Superior, in Fargo-Moorhead, and in Rochester. (Figures 9, 10 and 11) Because of the scale of the map and the small areas of the tracts in the cluster, they do not show up well on some of the maps.

C. Cluster 3.

The third cluster contains 53 tracts, which have the second highest mean population (7,438) on average, a measure that is pronounced enough to rank the cluster first or second on all raw data categories, including persons with limited mobility, number of elderly, commuters, and persons below the poverty line. (Table 13)

Just over 6 percent of the tract populations fall below the poverty level, although this cluster has the highest mean size of poverty population (496 per tract) of any of the clusters.

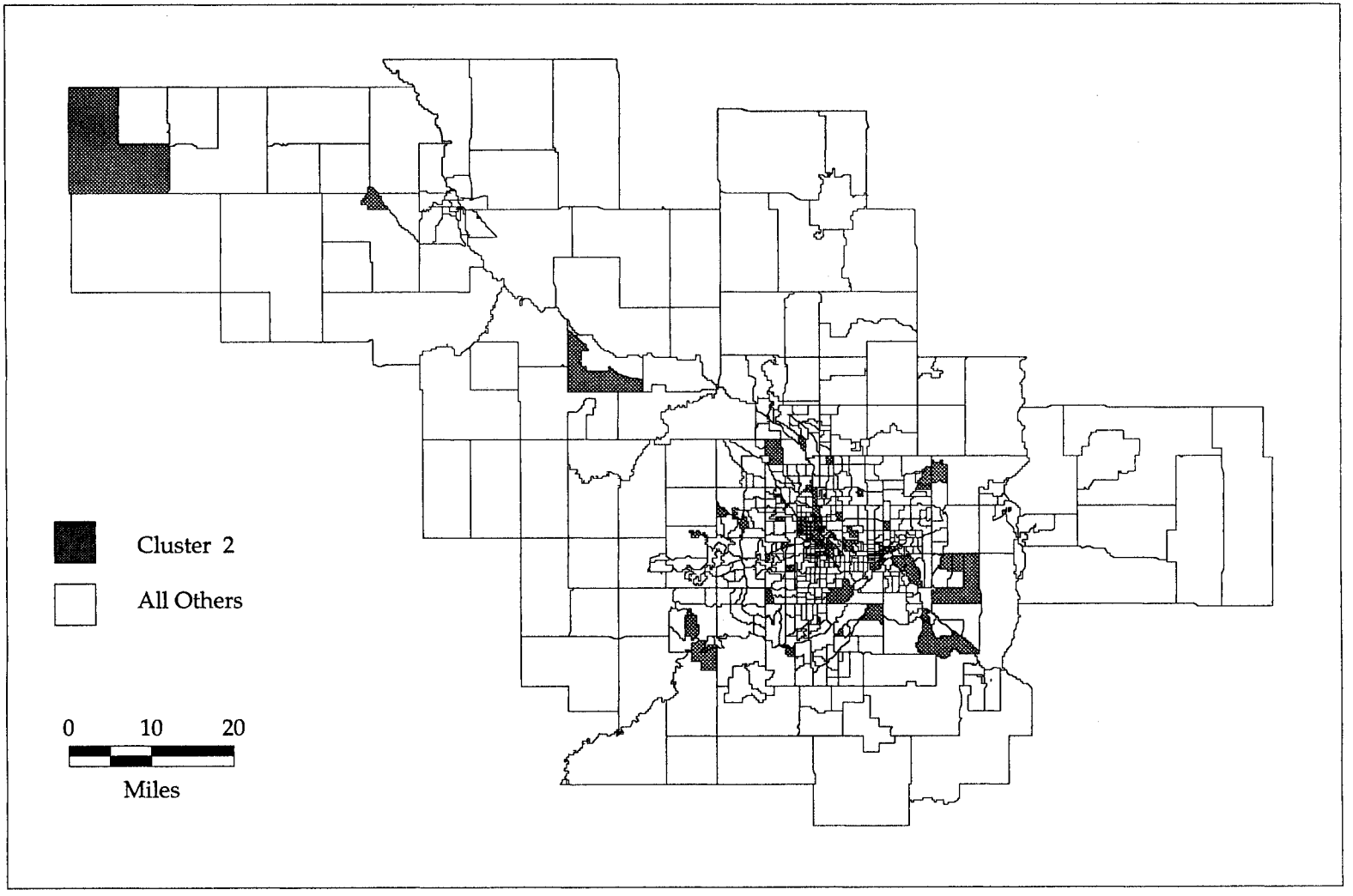

Figure 9. Distribution of Cluster 2 by Census Tract within the Twin Cities - St. Cloud Metropolitan Statistical Areas. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

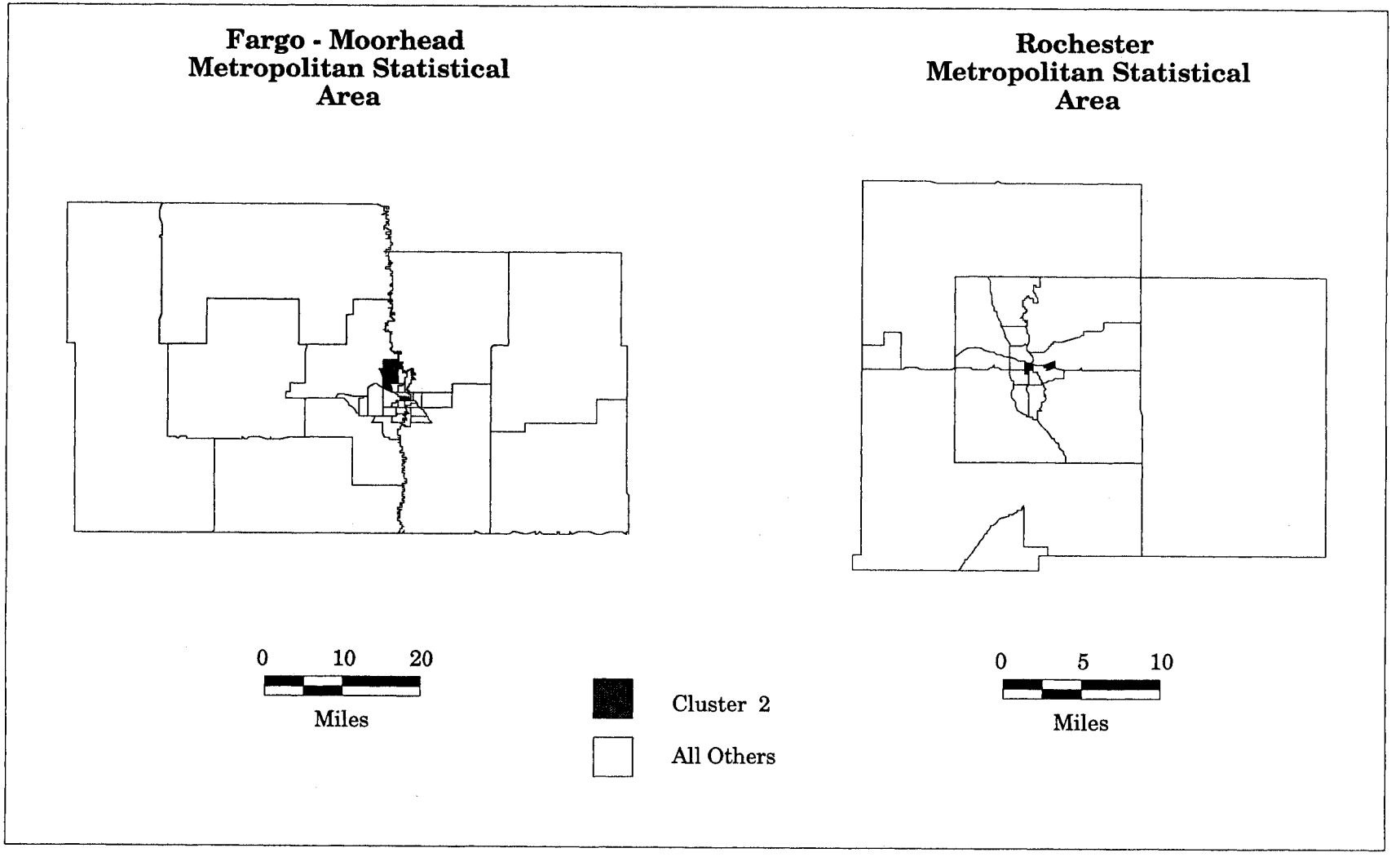

Figure 10. Distribution of Cluster 2 by Census Tract within the Fargo-Moorhead MSA and Rochester MSa.
(Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.

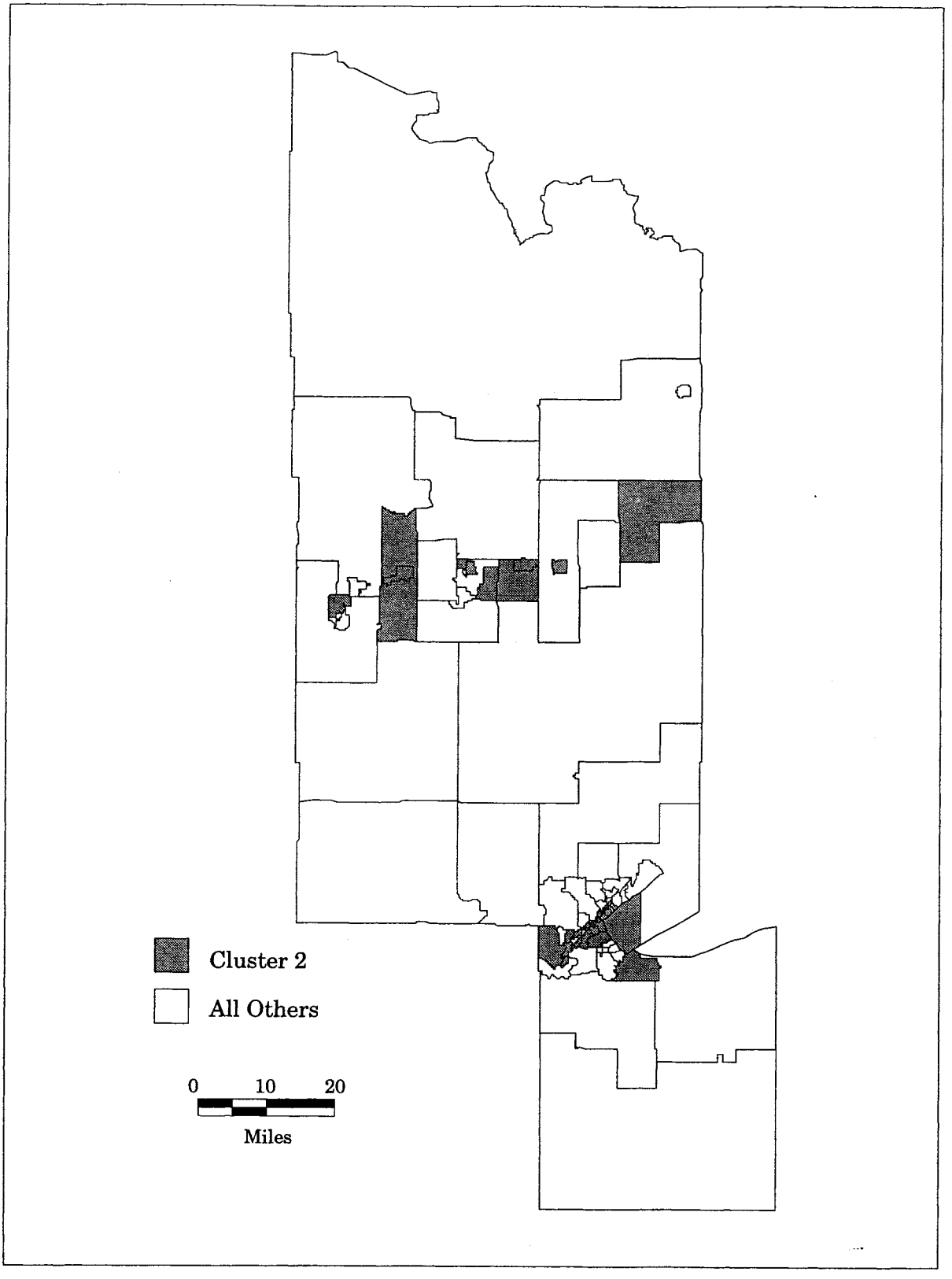

Figure 11. Distribution of Cluster 2 by Census Tract within the Duluth - Superior Metropolitan Statistical Area. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

Table 13. Travel-Related Characteristics, Cluster 3 (53 Minnesota MSA Tracts), 1990

	Within Class		Among Classes		
Variable	**Mean**	**Standard Deviation**	**Maximum**	**Minimum**	**Rank**
Population					
Total	7,437.9	638.98			2
Population Over Age 65					
Total	552.4	415.92	X		1
Percent	7.5	5.68			5
Commuters Driving Alone to Work					
Total	3,220.4	447.09			2
Percent	82.9	3.98			2
Commuters with Work Journey Duration Over 30 Minutes					
Total	1,093.0	488.07			2
Percent	29.1	14.24			2
Duration of Journey to Work					
Average, in minutes	21.5	4.65			2
Limited Mobility Population					
Total	18.3	16.90			2
Percent	0.4	0.40			4
Population Below Poverty Level					
Total	454.5	496.45	X		1
Percent	6.1	6.81			4
Vehicle Ownership					
Total	5,203.9	494.59			2
Average Vehicles per Household	2.0	0.25	X		1

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

Journeys to work are long, averaging two minutes longer that the state-wide mean travel time to work. This class of tracts has the second highest percentage of workers driving alone to work. (Table 13)

The 53 tracts in Cluster 3 are located mainly in the Twin Cities area. (Figure 12) One group occurs in the northwest edge of Hennepin County between St. Cloud and Minneapolis. Another group lies in the outer third- and fourth-ring of suburbs south of Minneapolis and St. Paul. A few additional tracts sharing these characteristics occur in the outer suburbs of Rochester, and the Fargo-Moorhead area. (Figure 13) There are no Duluth-Superior area tracts in the cluster. (Figure 14)

D. Cluster 4.

The 402 tracts comprising this cluster are the most typical of the entire set of Minnesota MSA tracts in terms of our select set of transportation-related variables. In one sense, this cluster has a "catch all" quality. In other terms, it contains the average tracts on the various measures. Populations of the tracts average lower than average (3,302). Percentage elderly is higher (12.4 percent). Persons with limited mobility are higher than average (0.6 percent), and poverty rates are above the average for all Minnesota MSA tracts (8.9 percent) although rates vary among tracts within the cluster. (Table 14) The standard deviations among the tract level variables within this cluster are high.

According to tract averages, persons living in tracts within Cluster 4 have shorter commutes than most others, and generally own fewer cars. Many Minneapolis-St. Paul area inner city tracts belong to this cluster. (Figure 15) A second broad zone of tracts sharing these characteristics lies in a broad ring that encompasses the third- and fourth-tier suburbs and

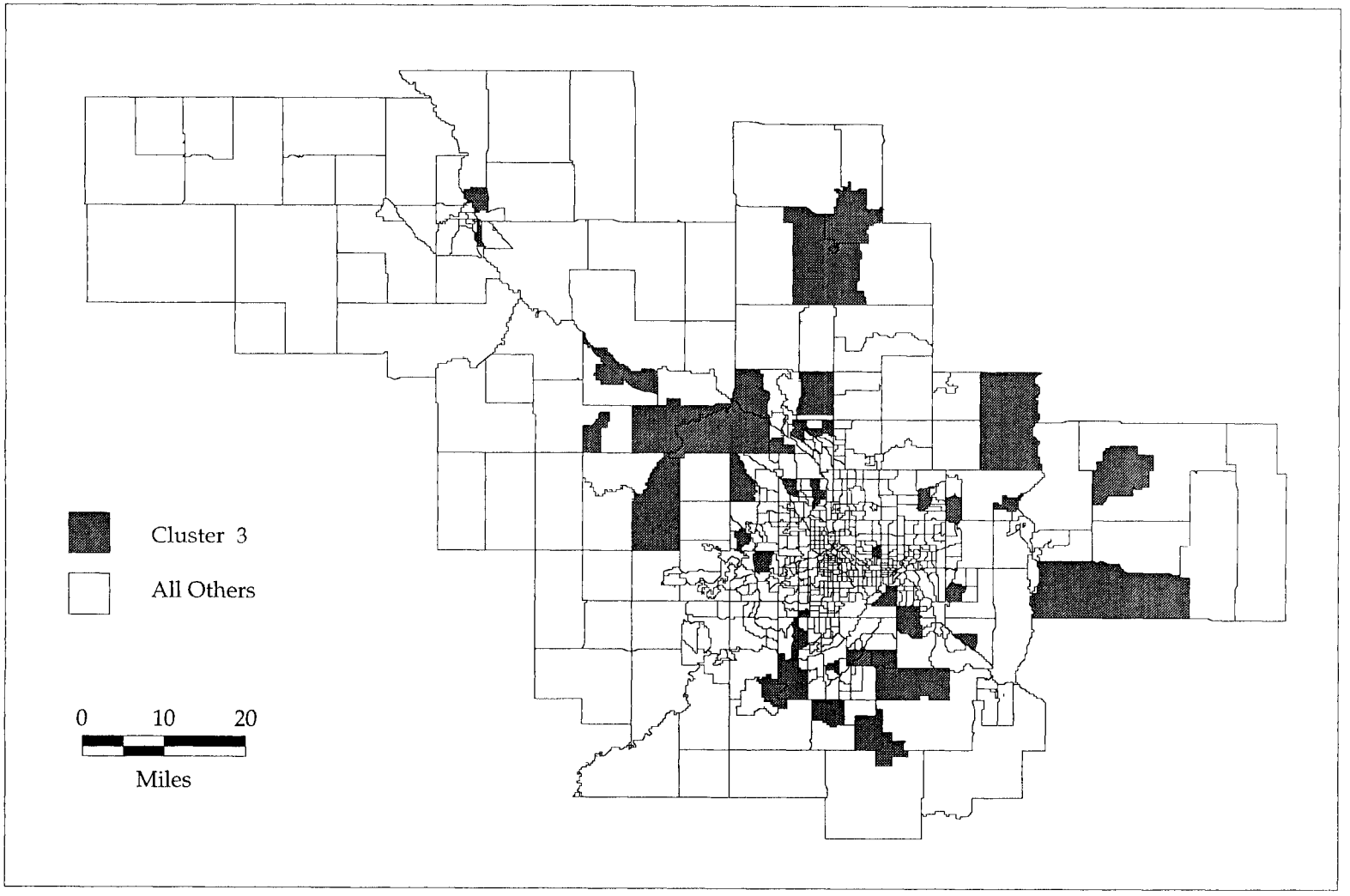

Figure 12. Distribution of Cluster 3 by Census Tract within the Twin Cities - St. Cloud Metropolitan Statistical Areas. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

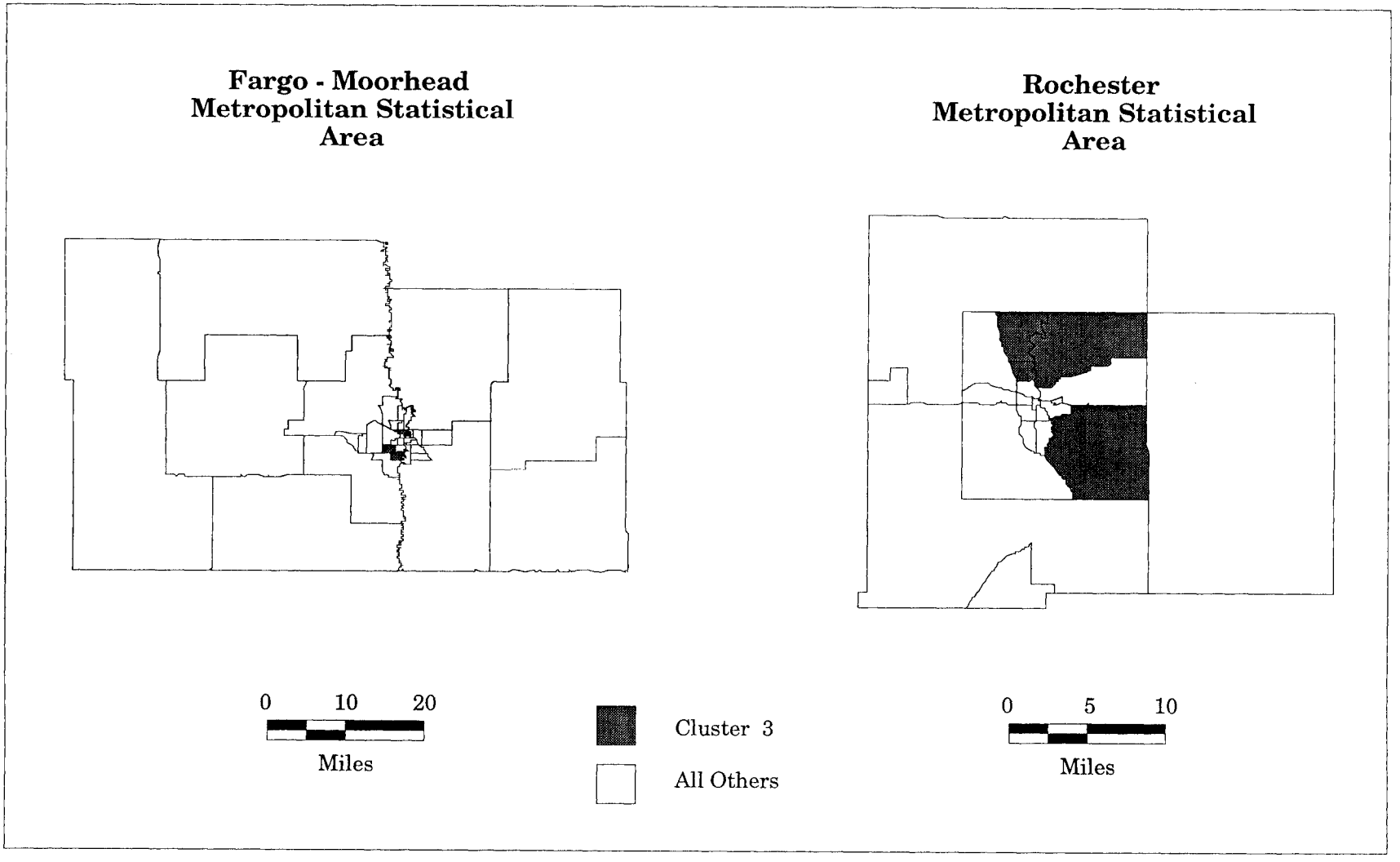

Figure 13. Distribution of Cluster 3 by Census Tract within the Fargo Moorhead MSA and Rochester MSA.
(Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

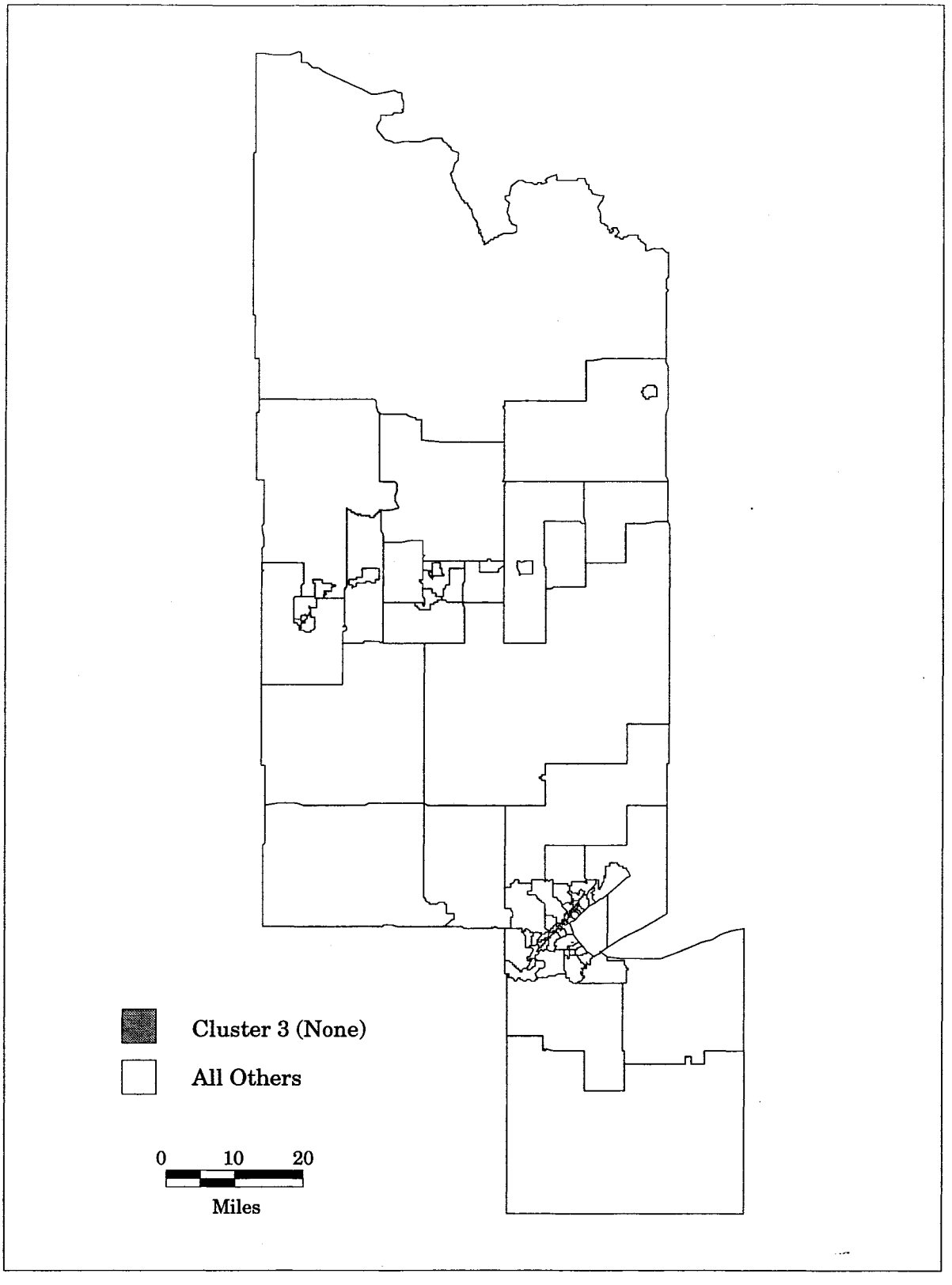

Figure 14. Distribution of Cluster 3 by Census Tract within the Duluth - Superior Metropolitan Statistical Area. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

Table 14. Travel-Related Characteristics, Cluster 4 (402 Minnesota MSA Tracts), 1990

	Within Class		Among Classes		
Variable	**Mean**	**Standard Deviation**	**Maximum**	**Minimum**	**Rank**
Population					
Total	3,301.8	604.95			5
Population Over Age 65					
Total	410.8	221.27			4
Percent	12.4	6.04			2
Commuters Driving Alone to Work					
Total	1,252.1	353.42			5
Percent	76.3	10.26			5
Commuters with Work Journey Duration Over 30 Minutes					
Total	364.1	182.72			5
Percent	22.5	10.51			5
Duration of Journey to Work					
Average, in minutes	19.7	3.87			5
Limited Mobility Population					
Total	10.0	10.87			5
Percent	0.6	0.60			2
Population Below Poverty Level					
Total	293.7	267.92			5
Percent	8.9	7.81			2
Vehicle Ownership					
Total	2,182.9	513.09			5
Average Vehicles per Household	1.7	0.37			5

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

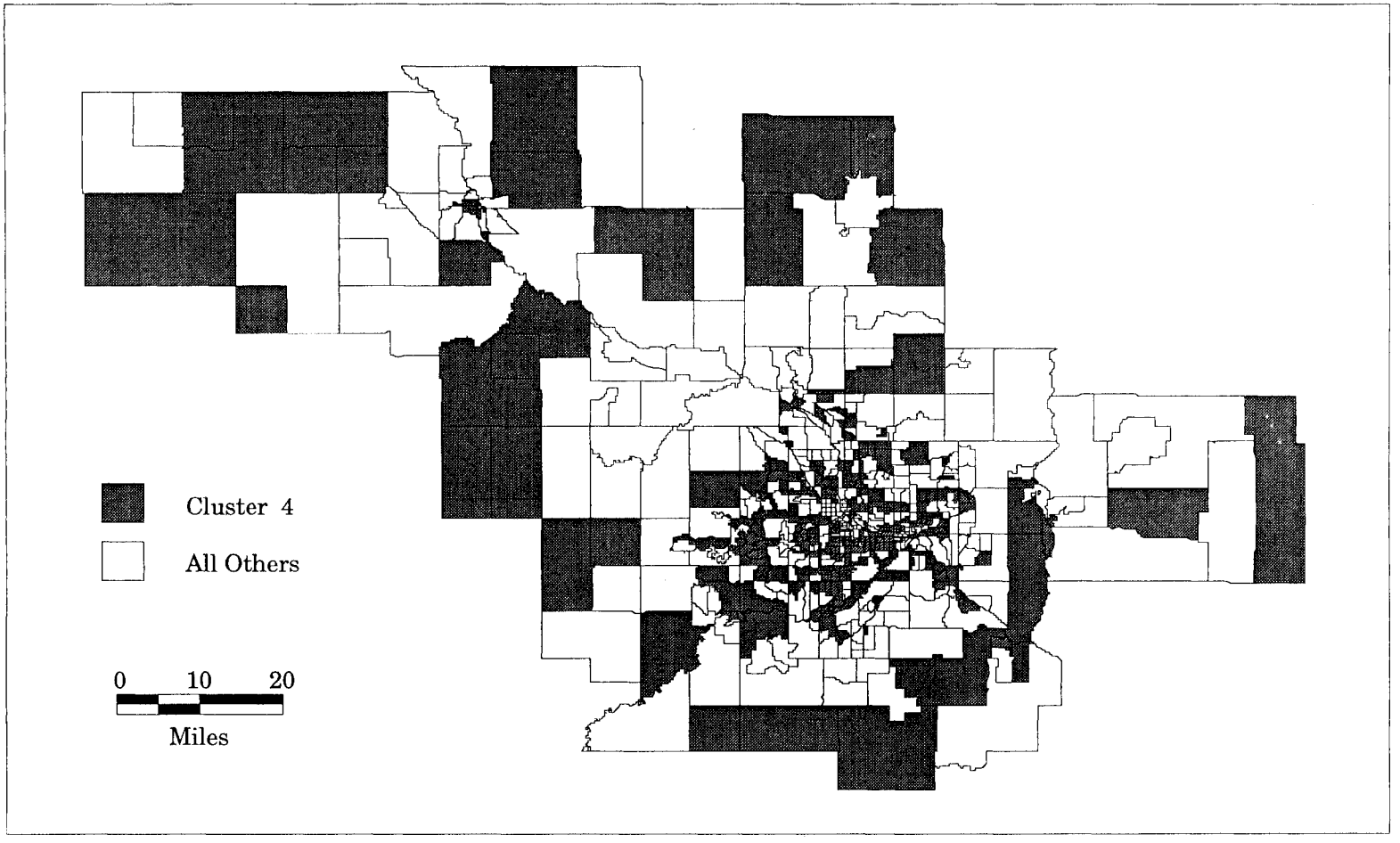

Figure 15. Distribution of Cluster 4 by Census Tract within the Twin Cities - St. Cloud Metropolitan Statistical Areas. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

adjacent exurban areas. The same locational arrangement is present in the St. Cloud MSA, with core tracts and tracts on the outer reaches of the MSA included in the same cluster. The pattern repeats again in the Fargo-Moorhead area, in the Rochester area, and in Duluth-Superior, with core and margin tracts falling within Cluster 4. (Figures 16 and 17)

E. Cluster 5.

The 111 tracts that comprise this cluster display a "middle of the road" quality, somewhat like those in Cluster 4. (Table 15) Tracts in the cluster average 4,906 in population, and a somewhat smaller share of elderly than the average in Cluster 4, but differences on this measure and the others are not pronounced. The most significant points about tract averages in Cluster 5 are the relatively high percentage of persons with mobility limitations, and relatively large number of persons, on the average, living below the poverty level, but the large standard deviation for the poverty measure makes it a less useful discriminator for the cluster than might otherwise be the case.

The Twin Cities and St. Cloud area tracts in Cluster 5 reveal little in the way of an easily interpretable pattern. (Figure 18) The map describes large exurban tracts, as well as others in the inner suburbs and the central cities. The same arrays appear in Fargo-Moorhead and Rochester, with Cluster 5 tracts in the central cities as well as in far flung exurban tracts. (Figure 19) The Duluth-Superior distribution of Cluster 5 tracts duplicates in major outlines the distributional patterns on the other maps, with a scattered assortment of central city tracts plus a few others on on the edges clustered according to factor scores based on transportation-related census measures. (Figure 20)

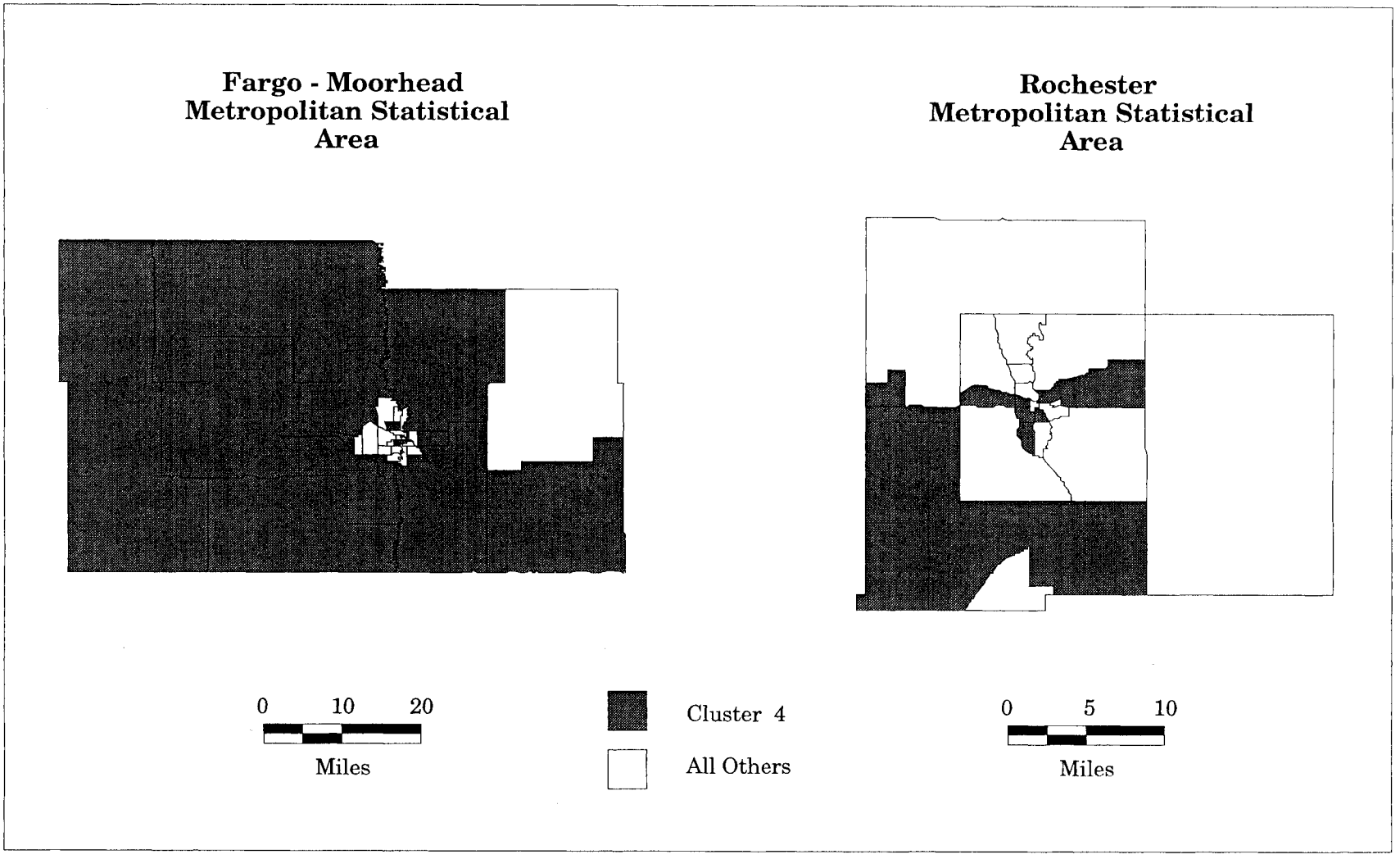

Figure 16. Distribution of Cluster 4 by Census Tract within the Fargo-Moorhead MSA and Rochester MSA.
(Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

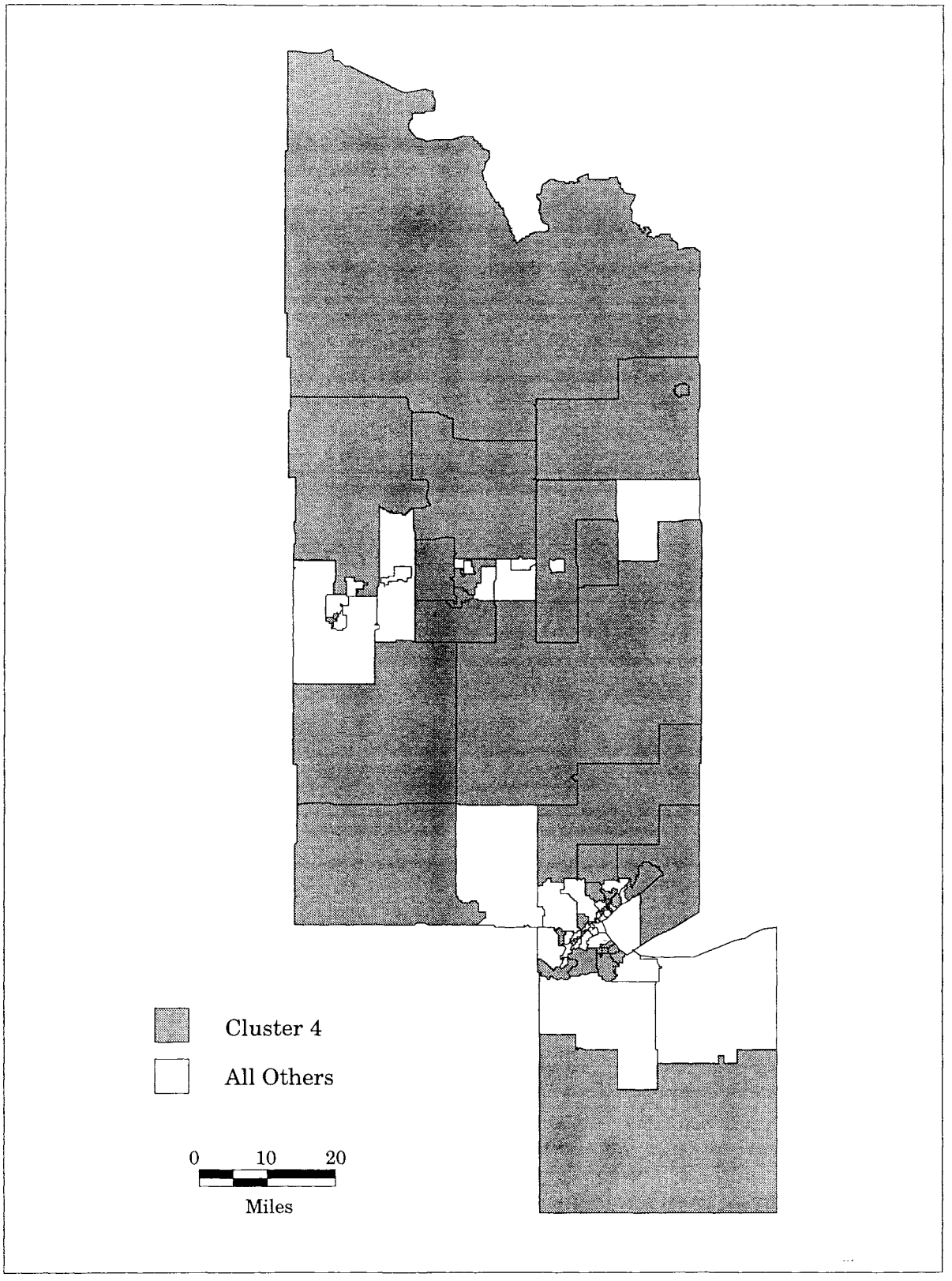

Figure 17. Distribution of Cluster 4 by Census Tract within the Duluth - Superior Metropolitan Statistical Area. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

Table 15. Travel-Related Characteristics, Cluster 5 (111 Minnesota MSA Tracts), 1990

Variable	Within Class		Among Classes		
	Mean	Standard Deviation	Maximum	Minimum	Rank
Population					
Total	4,905.5	430.43			4
Population Over Age 65					
Total	523.8	322.60			2
Percent	10.6	6.44			3
Commuters Driving Alone to Work					
Total	1,902.2	325.51			4
Percent	78.7	9.77			4
Commuters with Work Journey Duration Over 30 Minutes					
Total	571.4	275.60			4
Percent	23.9	11.82			4
Duration of Journey to Work					
Average, in minutes	20.1	4.10			4
Limited Mobility Population					
Total	14.1	14.20			3
Percent	0.6	0.68			2
Population Below Poverty Level					
Total	407.2	399.54			2
Percent	8.0	6.87			3
Vehicle Ownership					
Total	3,237.3	405.09			4
Average Vehicles per Household	1.8	0.31			4

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing (Minnesota), Summary Tape File 3. Calculations by the authors.

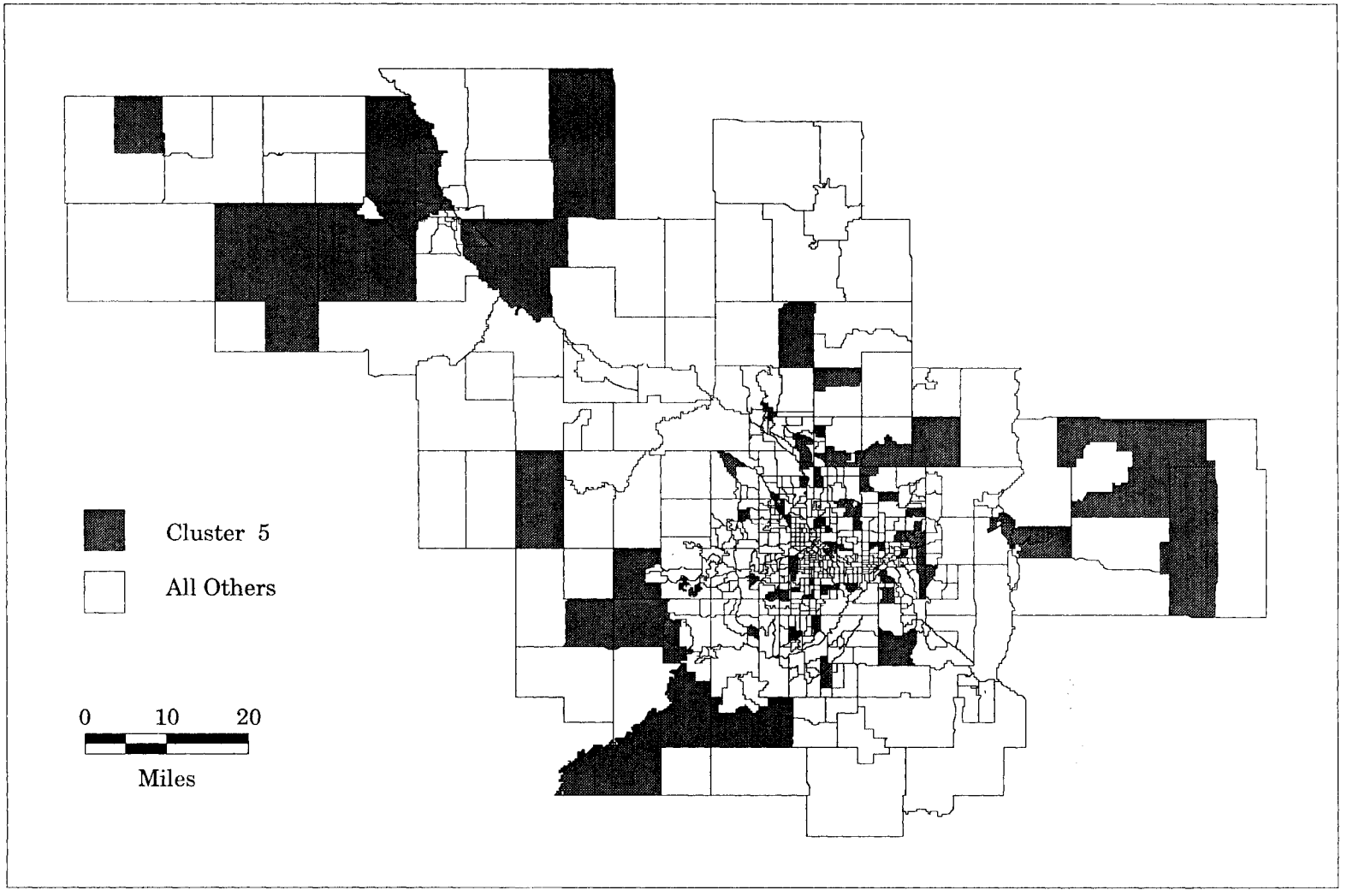

Figure 18. Distribution of Cluster 5 by Census Tract within the Twin Cities - St. Cloud Metropolitan Statistical Areas. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

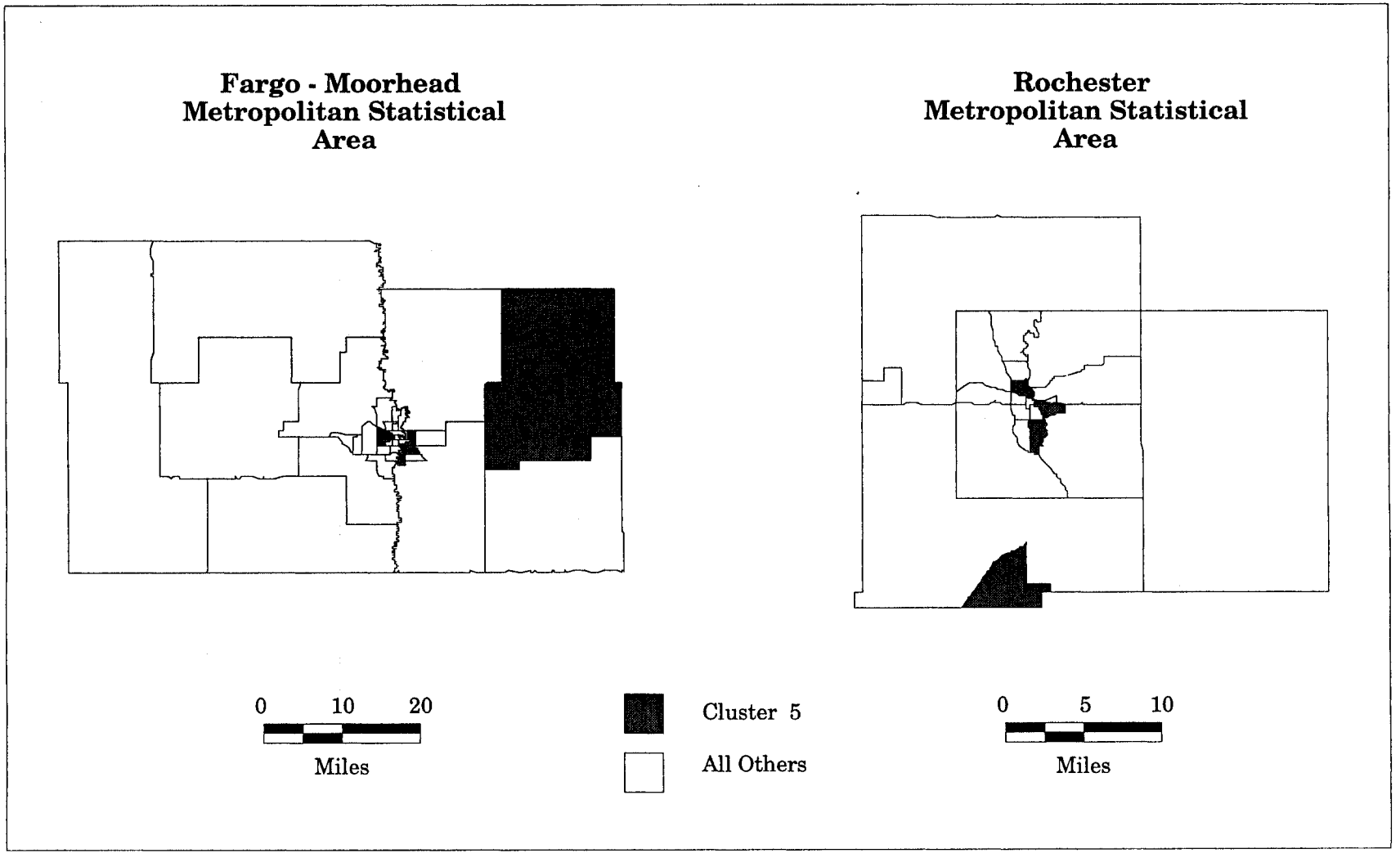

Figure 19. Distribution of Cluster 5 by Census Tract within the Fargo-Moorhead MSA and Rochester MSA.
(Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

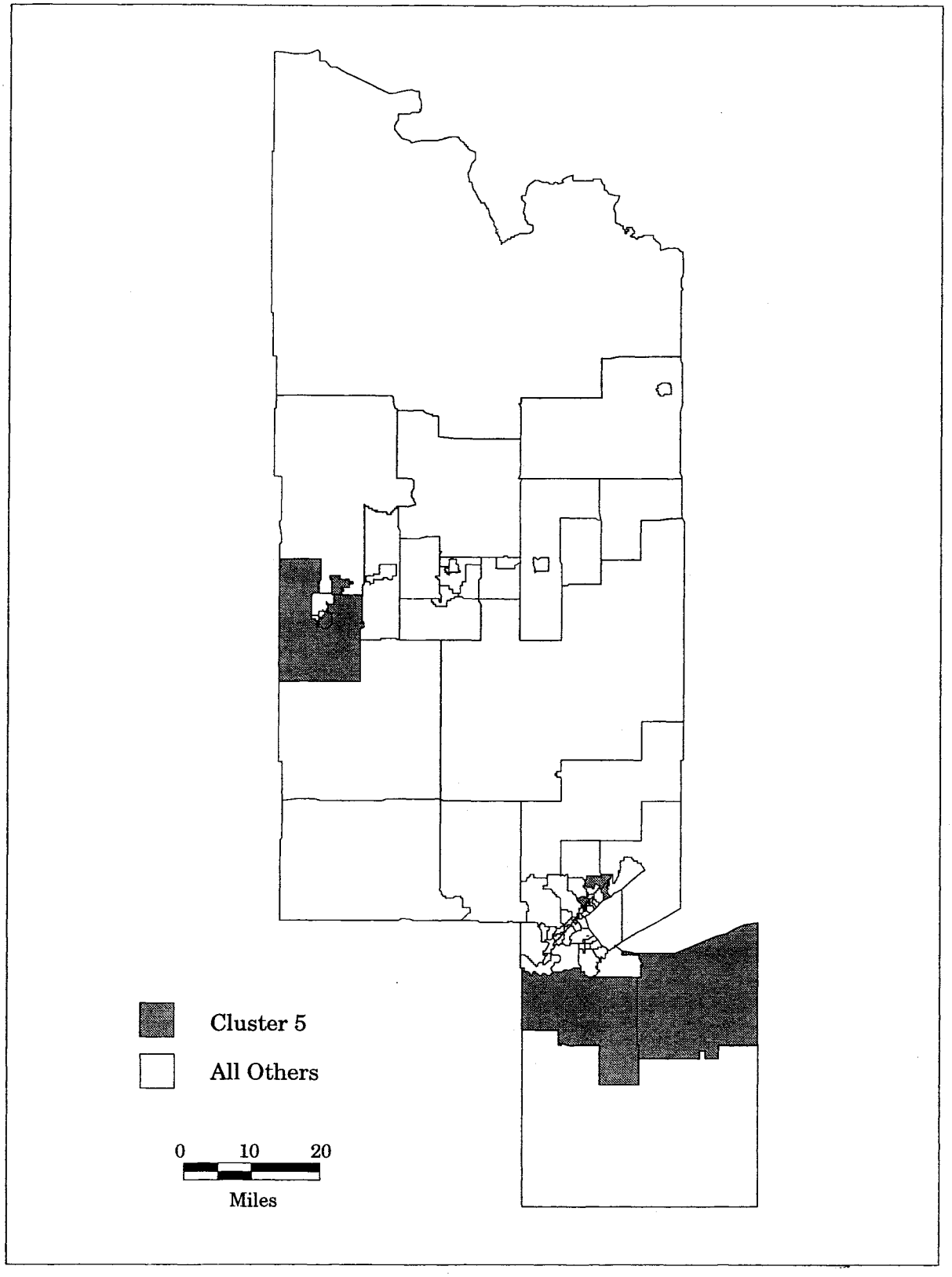

Figure 20. Distribution of Cluster 5 by Census Tract within the Duluth - Superior Metropolitan Statistical Area. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

F. Cluster 6.

The 94 tracts in Cluster 6 are a bit easier to distinguish from the other clusters because, among other things, these tracts have the lowest average of tract poverty rates, the highest average of vehicle ownership rates, although the average of 2.0 is the same as for two other clusters, and average tract population size that is above average. Taken together, tracts in this cluster are younger, faster growing, and in newly developing areas where growth has been recent and large tracts have not had time to subdivide. (Table 16) In the Twin Cities and St. Cloud areas, the tracts in Cluster 6 are almost all in the newly building suburban and exurban areas. Almost none is in the central cities. (Figure 21)

The profile of tracts in Cluster 6 resembles the profile described for tracts in Cluster 1, with the exception of the unusually large populations of tracts in Cluster 1, which set them apart from other tracts in the data set. Had each of the large tracts in Cluster 1 been divided into two tracts, it seems likely that they would have clustered with tracts in Cluster 6.

Essentially the same story repeats in Fargo-Moorhead and in the Rochester areas, with Cluster 6 tracts frequently located near the outer reaches of the MSA. (Figure 22) Although the Duluth-Superior area experienced little growth on its edges during the 1980s, the area contains a small handful of tracts that form part of Cluster 6, and they are again found outside the central cities. (Figure 23)

Table 16. Travel-Related Characteristics, Cluster 6 (94 Minnesota MSA Tracts), 1990

Variable	Within Class		Among Classes		
	Mean	Standard Deviation	Maximum	Minimum	Rank
Population					
Total	5,769.4	425.65			3
Population Over Age 65					
Total	437.2	281.45			5
Percent	7.5	4.75			4
Commuters Driving Alone to Work					
Total	2,549.2	312.95			3
Percent	82.4	3.77			3
Commuters with Work Journey Duration Over 30 Minutes					
Total	838.3	408.84			3
Percent	27.9	14.46			3
Duration of Journey to Work					
Average, in minutes	21.2	4.65			3
Limited Mobility Population					
Total	13.5	10.81			4
Percent	0.4	0.33			4
Population Below Poverty Level					
Total	284.8	193.78		X	6
Percent	4.9	3.10			5
Vehicle Ownership					
Total	4,140.1	314.69			3
Average Vehicles per Household	2.0	0.27	X		1

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing, Summary Tape File 3. Calculations by the authors.

Table 16. Travel-Related Characteristics, Cluster 6 (94 Minnesota MSA Tracts), 1990

	Within Class		Among Classes		
Variable	**Mean**	**Standard Deviation**	**Maximum**	**Minimum**	**Rank**
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Total	13.5	10.81			4
Percent	0.4	0.33			4
Population Below Poverty Level					
Total	284.8	193.78		X	6
Percent	4.9	3.10			5
Vehicle Ownership					
Total	4,140.1	314.69			3
Average Vehicles per Household	2.0	0.27	X		1

Source: U.S. Bureau of the Census, 1990 Census of Population and Housing, Summary Tape File 3. Calculations by the authors.

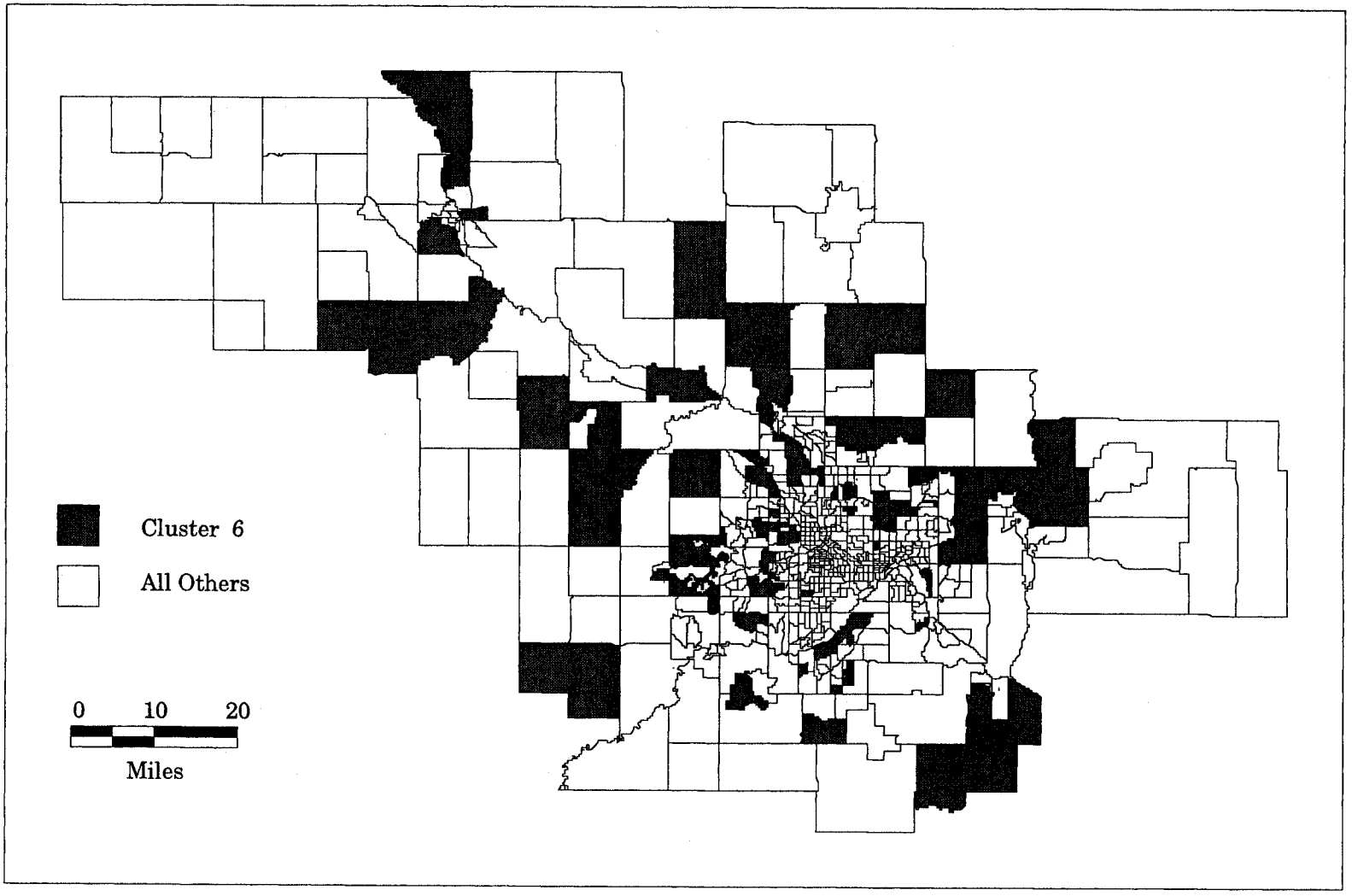

Figure 21. Distribution of Cluster 6 by Census Tract within the Twin Cities - St. Cloud Metropolitan Statistical Areas. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

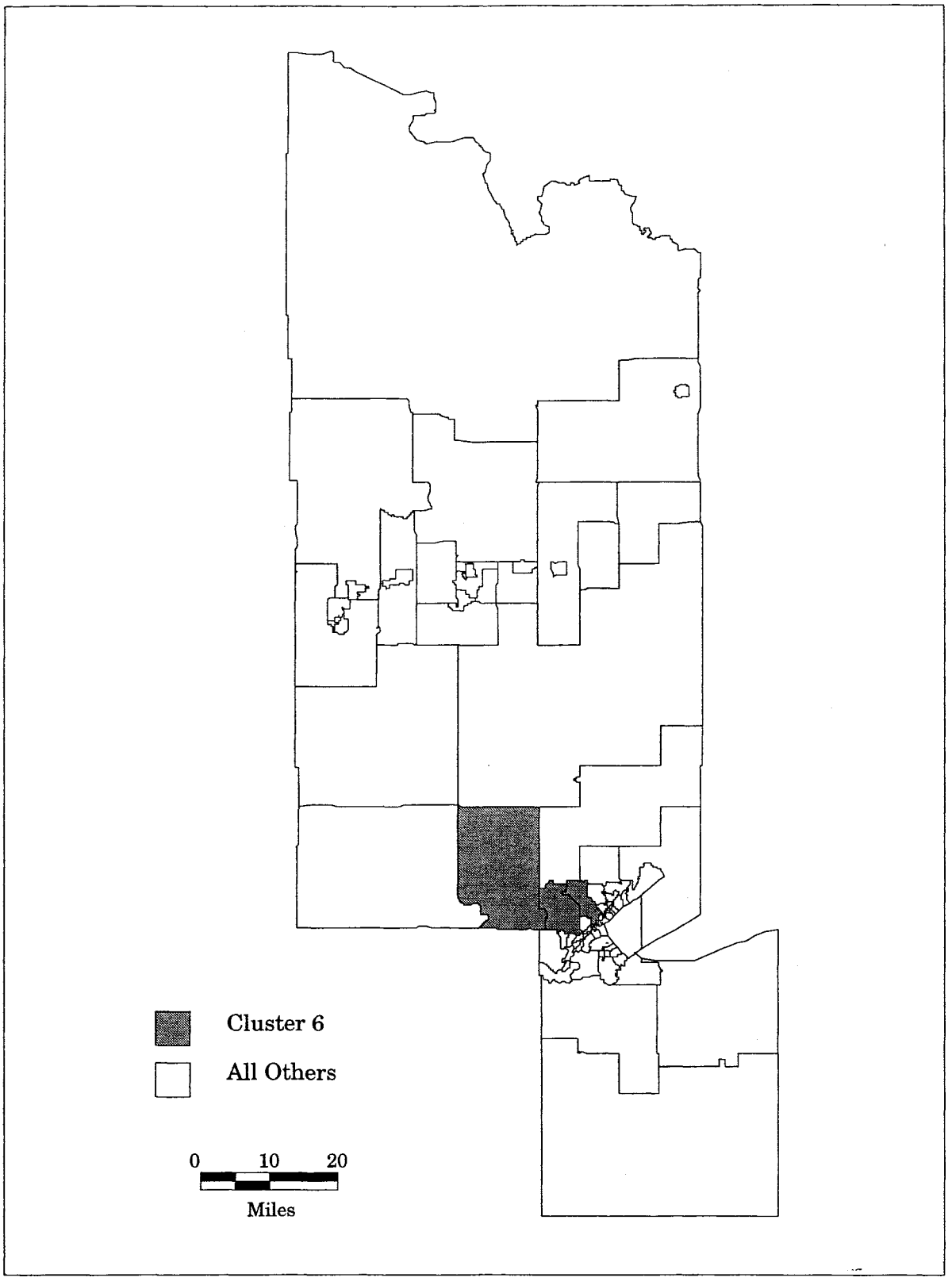

Figure 23. Distribution of Cluster 6 by Census Tract within the Duluth - Superior Metropolitan Statistical Area. (Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Calculations by the authors.)

IX. DISCUSSION AND CONCLUSIONS

We initiated this study of transportation-related measures from the 1990 U.S. Census of Population and Housing for counties and for MSA census tracts in Minnesota in order to investigate and to assess whether those measures could provide some areal classifications that could be useful for transportation planning and management.

A second purpose was to demonstrate the application of some statistical and cartographic procedures (correlation analysis, factor analysis, factor scoring of areal units, classification of areal units using methods of numerical taxonomy, mapping of clusters from the numerical taxonomy).

At the county level it seems difficult to gain any important new insights from a study that includes such widely varying geographical settings as rapidly growing Dakota County, and, say, the northern tier of tourist-retirement communities in Beltrami or Itasca counties. In light of some of the large raw numbers involved, the classification exercise simply exposed differences between metropolitan and nonmetropolitan settings.

Nevertheless, the county-level analysis yielded several interesting results. The maps portray neat, concise statements about the underlying dimensions of travel-related activity throughout the state. What we called the "commuting dimension", for example, reveals the transformation of the settlement fabric within an overwhelmingly automobile-reliant tier of counties surrounding the state's largest metropolitan area, a fact in line with the observation that the concepts of "city", "town", and "farm" have lost much of their precise meaning over the past four decades.

This kind of insight might have been gleaned from simpler maps, such as "share of daily commuters going to an MSA", for example. The advantage of the classification technique used

here is the ability to summarize the combined effects of several variables (share of long-distance commuters, average travel time, number of vehicles per household, etc.) into a single index.

The census tract classifications appear to illustrate the point that relationships between travel activity and socioeconomic characteristics vary considerably for different metropolitan contexts. Moreover, the overall complexity of the classification of census tracts seems to suggest a more heterogeneous settlement fabric than many planners or geographers acknowledge in suburbia or exurbia. Normal practice is to examine differences among small areas such as census tracts or traffic assignment zones by analyzing sample arithmetic means, medians, or other measures of central tendency. It is much less common to investigate statistical variations within small areas and how such variations may influence travel patterns.

So results are mixed. The demonstration purpose has been accomplished, with the results of statistical and cartographic procedures applied to 87 Minnesota counties and to 883 census tracts. The methods work well, but the answer to the initial problem posed appears to be that the transportation-related measures from the 1990 census as analyzed in this study fail to provide much useful insight in the form of areal classifications potentially useful for transportation planning and management.

County-level analysis distinguished among several types of metropolitan area counties around the state, with a residual category of nonmetropolitan counties. This result matches distinctions readily drawn using a variety of different variables, especially population density. The tract-level analysis was able to generate maps of clusters that disclosed a few important distinctions, but most of the map patterns proved to be difficult to interpret. The geographical patterning of two or three of the clusters gave us some insight into substantive questions. For example, the distribution of tracts in Cluster I in Sherburne county appears to pinpoint metropolitan hinterlands being transformed into "metropolitan-style" commutersheds. Elk

River and Eagan emerge in the same cluster, and the fact is that they "feel" similar when we drive through them or consider where their residents work and live.

In both the county-level analysis and in the tract-level analysis, the classification of areal units was carried to the point where six clusters remained. The clusters were mapped and discussed. It is possible that a larger number of clusters might have distinguished more sensitively differences among the areal units. We do not know, because we stopped the grouping procedure with six clusters rather than a larger or smaller number.

The raw data set could be expanded to include additional measures of households or housing characteristics. Additional non-transportation-related measures are known or suspected to be closely correlated with measures that we included in our study. Adding variables that are highly correlated with variables already in the problem adds nothing to the final results. As a demonstration of some potentially useful methods applied to census data for Minnesota, the study provided results. On other grounds, though, its value appears to be limited.

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Appendix A

Factor Analysis of Intercorrelation Matrix for Fourteen Transportation-Related Variables Describing Minnesota's 87 Counties, 1990

Appendix A. Factor Analysis of Intercorrelation Matrix for Fourteen Transportation-Related Variables Describing Minnesota's 87 Counties, 1990.

1. Eigenvalues of the Correlation Matrix: Total = 14 Average = 1

	1	2	3	4	5	6	7
Eigenvalue	7.2246	3.2500	1.0281	0.8952	0.8031	0.4429	0.2512
Difference	3.9747	2.2218	0.1330	0.0920	0.3603	0.1917	0.1840
Proportion	0.5160	0.2321	0.0734	0.0639	0.0574	0.0316	0.0179
Cumulative	0.5160	0.7482	0.8216	0.8856	0.9429	0.9746	0.9925

	8	9	10	11	12	13	14
Eigenvalue	0.0672	0.0235	0.0079	0.0041	0.0020	0.0001	0.0001
Difference	0.0438	0.0156	0.0038	0.0021	0.0018	0.0000	
Proportion	0.0048	0.0017	0.0006	0.0003	0.0001	0.0000	0.0000
Cumulative	0.9973	0.9990	0.9996	0.9998	1.0000	1.0000	1.0000

2. Final Communality Estimates: Total = 13.201055

PERSONS	ELDER	%ELDER	SOLO	%SOLO	LONG	%LONG
0.998036	0.981141	0.669664	0.991672	0.998828	0.960614	0.953421

TIME	MOBLTY	%MOBLTY	POVERTY	%POVERTY	VEHICLES	VEH_HH
0.962410	0.992196	0.989078	0.978365	0.900339	0.995342	0.829950

3. Rotated Factor Pattern

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
PERSONS	0.99274	0.05959	-0.08749	-0.00428	0.03570
ELDER	0.99043	-0.01139	0.00019	0.00577	0.00518
%ELDER	-0.29360	-0.51344	0.54476	-0.10549	-0.10934
SOLO	0.98635	0.06753	-0.11044	-0.00954	0.04403
%SOLO	0.05888	0.13672	-0.08817	-0.00562	0.98431
LONG	0.95286	0.16949	-0.14116	-0.02365	0.05883
XLONG	0.08657	0.95869	-0.11717	-0.11175	0.02489
TIME	0.16685	0.95607	-0.08813	-0.04356	0.10411
MOBLTY	0.99250	0.02850	-0.06109	0.05061	0.00621
%MOBLTY	-0.00021	-0.12716	0.01951	0.98616	-0.00514
POVERTY	0.98780	0.00009	0.04757	0.01822	-0.00439
%POVERTY	-0.13170	-0.19847	0.91588	0.04537	-0.05209
VEHICLES	0.98941	0.06811	-0.09867	-0.00730	0.04452
VEH_HH	-0.31798	0.69416	-0.47995	-0.10282	0.07785

Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Summary Tape File 3. Calculations by the authors.

Appendix B

Factor Scores for Minnesota's 87 Counties, Reporting How Each County Reflects Six Different Patterns of Variation

Appendix B. Factor Scores for Minnesota's 87 Counties, Reporting How Each County Reflects Six Different Patterns of Variation.

FIPS Code	County	FACTOR 1 *Population Mass*	FACTOR 2 *Commuting Tendency*	FACTOR 3 *Socioeconomic Stress*	FACTOR 4 *Mobility Impairment*	FACTOR 5 *Solo Commuting*
27001	Aitkin	-0.16419	0.43788	2.09967	-0.74273	0.22544
27003	Anoka	1.18048	2.0431	-1.54827	-0.29234	0.87213
27005	Becker	-0.09165	0.26045	1.13416	-0.5759	0.4056
27007	Beltrami	0.06805	0.25733	1.93119	0.37314	0.19981
27009	Benton	-0.20235	0.00742	-0.71895	-0.66738	0.9522
27011	Big Stone	-0.33941	-0.74962	0.64105	2.79275	0.51751
27013	Blue Earth	0.09759	-0.06769	0.46999	0.87318	-0.03345
27015	Brown	-0.18265	-1.58177	-1.30528	-0.7938	-0.12383
27017	Carlton	-0.15223	-0.07791	0.1035	-0.472	1.36772
27019	Carver	-0.23806	1.46421	-1.5838	-0.19558	1.05508
27021	Cass	-0.09792	0.85898	2.36477	-0.5616	0.58573
27023	Chippewa	-0.24801	-1.02335	-0.04821	-0.10437	-0.00767
27025	Chisago	-0.31233	2.92165	-0.22558	0.71901	-0.34436
27027	Clay	0.08767	-0.15605	0.15145	1.19007	-0.47906
27029	Clearwater	-0.21644	0.65396	2.17266	-1.35886	-0.35135
27031	Cook	-0.23902	-0.75801	-0.43738	-0.71616	-1.03699
27033	Cottonwood	-0.22974	-1.35063	0.12269	-0.72059	0.04102
27035	Crow Wing	0.01564	-0.4387	0.60268	0.3937	1.61101
27037	Dakota	1.33974	0.61335	-2.03421	-0.30026	1.57335
27039	Dodge	-0.43114	1.08555	-1.18068	0.43169	-0.68268
27041	Douglas	-0.14231	-0.93565	0.12706	-0.57017	1.7978
27043	Faribault	-0.2321	-0.70069	0.0231	-0.13111	-0.08017
27045	Fillmore	-0.16925	0.94921	1.01652	0.22215	-1.28551
27047	Freeborn	-0.15387	-0.95084	-0.45082	0.5076	1.71384
27049	Goodhue	-0.1144	0.2251	-0.69963	0.60767	0.08335
27051	Grant	-0.33493	-0.67532	0.63133	-1.20257	0.47619
27053	Hennepin	7.89606	-0.1886	0.26665	-0.17442	-0.45037
27055	Houston	-0.2731	-0.16895	-0.80122	0.48717	-0.14747
27057	Hubbard	-0.25335	0.12334	0.89436	0.04349	0.59334
27059	Isanti	-0.37055	3.25591	-0.02145	0.06914	0.07416
27061	Itasca	-0.02317	0.37926	0.85284	1.00246	0.92365
27063	Jackson	-0.37432	-0.64401	-0.40556	0.03411	0.65681
27065	Kanabec	-0.2753	1.67184	0.96387	0.58232	-0.69368
27067	Kandiyohi	-0.06118	-0.49414	-0.08954	1.44199	0.69364
27069	Kittson	-0.31768	-0.40043	-0.10035	-0.87502	-1.6444
27071	Koochiching	-0.15457	-0.69084	-0.25453	2.68476	-1.14958
27073	Lac qui Parle	-0.37633	-0.58496	-0.03156	-1.20375	-0.11758
27075	Lake	-0.31245	-0.34452	-0.463	-1.37365	0.64441
27077	Lake of the Woods	-0.25938	0.06412	-0.77063	-1.415	-4.97824
27079	Le Sueur	-0.27664	0.6522	-0.63028	0.10178	-0.32735
27081	Lincoln	-0.28045	-0.12513	0.98064	-0.13248	-1.47897
27083	Lyon	-0.16585	-1.25182	-0.75187	0.13808	-0.08652
27085	McLeod	-0.20862	-0.5083	-1.27459	-0.5487	0.19679

Appendix B. (continued)

		Pop. Mass	*Comm. Tendency*	*Soc. Stress*	*Mobil. Impairment*	*Solo Commuting*
27087	Mahnomen	-0.22251	0.69872	2.68285	-0.42965	-0.03036
27089	Marshall	-0.29467	0.4323	0.26559	-0.36209	-1.37118
27091	Martin	-0.17673	-1.37164	-0.2538	-0.65784	1.01042
27093	Meeker	-0.24441	0.40211	-0.0282	0.3491	0.25691
27095	Mille Lacs	-0.21554	1.14572	0.88353	-0.21863	-0.00228
27097	Morrison	-0.1098	0.82945	0.92904	0.70995	-0.07776
27099	Mower	-0.03079	-0.48539	0.08049	-0.23548	0.67725
27101	Murray	-0.32895	-0.34514	0.16031	-0.53507	-0.47009
27103	Nicollet	-0.23877	-1.00584	-1.72689	-0.39717	-0.22105
27105	Nobles	-0.22067	-0.91453	-0.45925	1.31953	-0.1715
27107	Norman	-0.36215	-0.17025	0.59306	-0.54721	0.82098
27109	Olmsted	0.32796	-0.98161	-1.8187	0.25218	0.32606
27111	Otter Tail	0.017	-0.47701	0.34746	-0.53216	0.83131
27113	Pennington	-0.20713	-0.68724	0.44906	3.29126	0.07453
27115	Pine	-0.18618	1.48326	1.16316	0.63948	0.08964
27117	Pipestone	-0.24515	-0.99023	0.32983	-0.01907	-0.03511
27119	Polk	-0.06828	-0.63895	0.41475	-0.51386	0.92343
27121	Pope	-0.29271	-0.49828	0.51145	-0.7602	0.79205
27123	Ramsey	3.68037	-0.26363	0.57581	0.31939	-0.47981
27125	Red Lake	-0.29904	0.00125	0.61603	-1.26472	-0.14575
27127	Redwood	-0.26164	-0.65496	-0.13561	4.7471	-0.57571
27129	Renville	-0.24862	-0.47126	0.00272	0.21615	-0.41971
27131	Rice	-0.01963	-0.03078	-1.09402	0.27306	-1.26035
27133	Rock	-0.32353	-0.04612	0.0433	-0.98663	-0.24152
27135	Roseau	-0.29874	-0.13264	-1.12621	-0.9998	-2.65789
27137	St. Louis	1.36706	-0.35456	0.96045	-0.26008	-0.3794
27139	Scott	-0.26605	1.70433	-1.94	-0.46585	1.4182
27141	Sherburne	-0.30127	2.68774	-0.81597	0.04954	0.59345
27143	Sibley	-0.34688	0.68105	-0.30802	0.37613	-0.86227
27145	Stearns	0.45665	-0.19823	-0.67678	-0.02398	-0.14028
27147	Steele	-0.24223	-0.9722	-1.6768	0.22672	0.87268
27149	Stevens	-0.22602	-0.83192	0.57287	0.72998	-1.31668
27151	Swift	-0.21631	-0.59832	0.66664	-1.58525	-0.60286
27153	Todd	-0.14693	-0.13758	1.10841	-0.66052	0.73624
27155	Traverse	-0.33568	-1.23388	0.54839	-1.11938	1.15466
27157	Wabasha	-0.30485	1.08679	-0.48535	-0.10934	-0.83952
27159	Wadena	-0.15109	-0.48141	1.83476	0.5685	1.09447
27161	Waseca	-0.30138	-0.47022	-1.03685	0.24576	-0.32871
27163	Washington	0.38877	1.31537	-1.97565	-0.27377	1.16377
27165	Watonwan	-0.25064	-0.82369	-0.43062	0.43306	-1.2497
27167	Wilkin	-0.3757	-0.79259	-0.67898	-0.73552	0.76496
27169	Winona	0.05677	-0.63909	-0.31739	-0.67847	-0.80552
27171	Wright	-0.07416	2.68517	-0.81512	0.03962	0.07863
27173	Yellow Medicine	-0.27002	-0.51099	0.33746	0.01742	-0.75599

Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Summary Tape File 3. Calculations by the authors.

Appendix C

Minnesota's 833 MSA Tracts, Clustered According to Transportation-Related Variables from the 1990 Census

Appendix C. Minnesota's 833 MSA Tracts, Clustered According to Transportation-Related Variables from the 1990 Census.

1. METROPOLITAN AREA TRACT CLASSIFICATION: SUMMARY INFORMATION

	ALL CLUSTERS				CLUSTER 1		CLUSTER 2		CLUSTER 3		CLUSTER 4		CLUSTER 5		CLUSTER 6	
Variable	Total Standard Deviation	Frequency within Standard Deviation	R-Squared	R-Squared/(1-R-Squared)	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Population																
Total	1,853.51	597.47	0.90	8.68	10,139.8	783.93	1,503.2	722.12	7,437.9	638.98	3,301.8	604.95	4,905.5	430.43	5,769.4	425.65
Population Over Age 65																
Total	274.40	252.64	0.16	0.19	325.0	226.14	196.9	173.56	552.4	415.92	410.8	221.27	523.8	322.60	437.2	281.45
Percent	7.91	7.64	0.07	0.08	3.1	1.95	13.1	12.47	7.5	5.68	12.4	6.04	10.6	6.44	7.5	4.75
Commuters Driving Alone to Work																
Total	914.83	339.06	0.86	6.32	4,654.6	553.14	395.3	261.49	3,220.4	447.09	1,252.1	353.42	1,902.2	325.51	2,549.2	312.95
Percent	16.44	13.90	0.29	0.41	85.9	2.74	57.1	25.44	82.9	3.98	76.3	10.26	78.7	9.77	82.4	3.77
Commuters with Work Journey Duration Over 30 Minutes																
Total	391.93	251.24	0.59	1.45	1,776.7	356.81	123.0	92.26	1,093.0	488.07	364.1	182.72	571.4	275.60	838.3	408.84
Percent	11.92	11.45	0.08	0.09	33.2	7.80	17.8	10.61	29.1	14.24	22.5	10.51	23.9	11.82	27.9	14.46
Duration of Journey to Work																
Average, in minutes	4.86	4.61	0.10	0.11	23.4	2.28	16.6	6.37	21.5	4.65	19.7	3.87	20.1	4.10	21.2	4.65
Limited Mobility Population																
Total	12.64	12.29	0.06	0.06	18.6	11.08	7.1	13.28	18.3	16.90	10.0	10.87	14.1	14.20	13.5	10.81
Percent	0.97	0.96	0.03	0.04	0.3	0.19	1.0	1.84	0.4	0.40	0.6	0.96	0.6	0.68	0.4	0.33
Population Below Poverty Level																
Total	323.86	320.59	0.03	0.03	369.5	214.34	347.2	367.94	454.5	496.45	293.7	267.92	407.2	399.54	284.8	193.78
Percent	11.51	10.30	0.20	0.26	3.6	1.99	20.5	18.39	6.1	6.81	8.9	7.81	8.0	6.87	4.9	3.10
Vehicle Ownership																
Total	1,398.39	468.32	0.89	7.97	6,972.8	638.17	740.7	445.58	5,203.9	494.59	2,182.9	513.09	3,237.3	405.09	4,140.1	314.69
Average Vehicles per Household	0.50	0.43	0.27	0.37	2.0	0.10	1.2	0.69	2.0	0.25	1.7	0.37	1.8	0.31	2.0	0.27
Overall	684.65	256.58	0.86	6.16												

Appendix C. (continued)

2. METROPOLITAN AREA TRACT CLASSIFICATION: SUMMARY INFORMATION HIGHLIGHTING MAXIMUM VALUES

	ALL CLUSTERS				CLUSTER 1		CLUSTER 2		CLUSTER 3		CLUSTER 4		CLUSTER 5		CLUSTER 6	
Variable	Total Standard Deviation	Frequency within Standard Deviation	R-Squared	R-Squared/(1-R-Squared)	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Population																
Total	1,853.51	597.47	0.90	8.68	10,139.8	783.93	1,503.2	722.12	7,437.9	638.98	3,301.8	604.95	4,905.5	430.43	5,769.4	425.65
Population Over Age 65																
Total	274.40	252.64	0.16	0.19	325.0	226.14	196.9	173.56	552.4	415.92	410.8	221.27	523.8	322.60	437.2	281.45
Percent	7.91	7.64	0.07	0.08	3.1	1.95	13.1	12.47	7.5	5.68	12.4	6.04	10.6	6.44	7.5	4.75
Commuters Driving Alone to Work																
Total	914.83	339.06	0.86	6.32	4,654.6	553.14	395.3	261.49	3,220.4	447.09	1,252.1	353.42	1,902.2	325.51	2,549.2	312.95
Percent	16.44	13.90	0.29	0.41	85.9	2.74	57.1	25.44	82.9	3.98	76.3	10.26	78.7	9.77	82.4	3.77
Commuters with Work Journey Duration Over 30 Minutes																
Total	391.93	251.24	0.59	1.45	1,776.7	356.81	123.0	92.26	1,093.0	488.07	364.1	182.72	571.4	275.60	838.3	408.84
Percent	11.92	11.45	0.08	0.09	33.2	7.80	17.8	10.61	29.1	14.24	22.5	10.51	23.9	11.82	27.9	14.46
Duration of Journey to Work																
Average, in minutes	4.86	4.61	0.10	0.11	23.4	2.28	16.6	6.37	21.5	4.65	19.7	3.87	20.1	4.10	21.2	4.65
Limited Mobility Population																
Total	12.64	12.29	0.06	0.06	18.6	11.08	7.1	13.28	18.3	16.90	10.0	10.87	14.1	14.20	13.5	10.81
Percent	0.97	0.96	0.03	0.04	0.3	0.19	1.0	1.84	0.4	0.40	0.6	0.60	0.6	0.68	0.4	0.33
Population Below Poverty Level																
Total	323.86	320.59	0.03	0.03	369.5	214.34	347.2	367.94	454.5	496.45	293.7	267.92	407.2	399.54	284.8	193.78
Percent	11.51	10.30	0.20	0.26	3.6	1.99	20.5	18.39	6.1	6.81	8.9	7.81	8.0	6.87	4.9	3.10
Vehicle Ownership																
Total	1,398.39	468.32	0.89	7.97	6,972.8	638.17	740.7	445.58	5,203.9	494.59	2,182.9	513.09	3,237.3	405.09	4,140.1	314.69
Average Vehicles per Household	0.50	0.43	0.27	0.37	2.0	0.10	1.2	0.69	2.0	0.25	1.7	0.37	1.8	0.31	2.0	0.27
Overall	684.65	256.58	0.86	6.16												

3. *METROPOLITAN AREA TRACT CLASSIFICATION: SUMMARY INFORMATION HIGHLIGHTING MINIMUM VALUES*

	ALL CLUSTERS				CLUSTER 1		CLUSTER 2		CLUSTER 3		CLUSTER 4		CLUSTER 5		CLUSTER 6	
Variable	Total Standard Deviation	Frequency within Standard Deviation	R-Squared	R-Squared/(1-R-Squared)	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Population																
Total	1,853.51	597.47	0.90	8.68	10,139.8	783.93	1,503.2	722.12	7,437.9	638.98	3,301.8	604.95	4,905.5	430.43	5,769.4	425.65
Population Over Age 65																
Total	274.40	252.64	0.16	0.19	325.0	226.14	196.9	173.56	552.4	415.92	410.8	221.27	523.8	322.60	437.2	281.45
Percent	7.91	7.64	0.07	0.08	3.1	1.95	13.1	12.47	7.5	5.68	12.4	6.04	10.6	6.44	7.5	4.75
Commuters Driving Alone to Work																
Total	914.83	339.06	0.86	6.32	4,654.6	553.14	395.3	261.49	3,220.4	447.09	1,252.1	353.42	1,902.2	325.51	2,549.2	312.95
Percent	16.44	13.90	0.29	0.41	85.9	2.74	57.1	25.44	82.9	3.98	76.3	10.26	78.7	9.77	82.4	3.77
Commuters with Work Journey Duration Over 30 Minutes																
Total	391.93	251.24	0.59	1.45	1,776.7	356.81	123.0	92.26	1,093.0	488.07	364.1	182.72	571.4	275.60	838.3	408.84
Percent	11.92	11.45	0.08	0.09	33.2	7.80	17.8	10.61	29.1	14.24	22.5	10.51	23.9	11.82	27.9	14.46
Duration of Journey to Work																
Average, in minutes	4.86	4.61	0.10	0.11	23.4	2.28	16.6	6.37	21.5	4.65	19.7	3.87	20.1	4.10	21.2	4.65
Limited Mobility Population																
Total	12.64	12.29	0.06	0.06	18.6	11.08	7.1	13.28	18.3	16.90	10.0	10.87	14.1	14.20	13.5	10.81
Percent	0.97	0.96	0.03	0.04	0.3	0.19	1.0	1.84	0.4	0.40	0.6	0.60	0.6	0.68	0.4	0.33
Population Below Poverty Level																
Total	323.86	320.59	0.03	0.03	369.5	214.34	347.2	367.94	454.5	496.45	293.7	267.92	407.2	399.54	284.8	193.78
Percent	11.51	10.30	0.20	0.26	3.6	1.99	20.5	18.39	6.1	6.81	8.9	7.81	8.0	6.87	4.9	3.10
Vehicle Ownership																
Total	1,398.39	468.32	0.89	7.97	6,972.8	638.17	740.7	445.58	5,203.9	494.59	2,182.9	513.09	3,237.3	405.09	4,140.1	314.69
Average Vehicles per Household	0.50	0.43	0.27	0.37	2.0	0.10	1.2	0.69	2.0	0.25	1.7	0.37	1.8	0.31	2.0	0.27
Overall	684.65	256.58	0.86	6.16												

Data source: U.S. Bureau of the Census, 1990 Census of Population and Housing. Summary Tape File 3. Calculations by the authors.

Appendix D

Statistical Methodology

Appendix D. Statistical Methodology

This study uses the methodology of "numerical taxonomy" to classify Minnesota's counties and census tracts.[1] Sometimes called "cluster analysis," numerical taxonomy refers to a wide range of statistical procedures used to classify objects according to one or more quantitatively-measured attributes. The formal literature on the subject has expanded considerably since the mid-1950s, and along with related techniques (e.g., discriminant analysis) the methods have been used widely in geography and related fields.[2] Today there are dozens of taxonomic procedures in most computer statistical packages, each technique having its own advantages and disadvantages for particular applications.

The general aim of numerical taxonomy is to divide objects into separate groups in such a manner that things in one group are as similar as possible, while remaining as dissimilar as possible from objects in other groups. In practical terms, this means that we are trying to minimize the *within*-group variation and maximize *between*-group variation.

Almost all techniques of numerical taxonomy begin by calculating a measure of similarity between the objects to be classified. Typically, this is accomplished by treating each object as a point, the location of which is defined with reference to axes representing the measured attributes. The similarity of any two objects is defined as the linear distance separating them in this n-dimensional space, where n is the number of measured attributes.

Classification procedures vary widely, but most techniques begin with the same simple operation: the two objects separated by the smallest distance are placed in the same group. The main differences between the various taxonomic procedures lie in how this new, two-object group is treated: are distances to be calculated from each of the points in this group, or from the center of the group? The former approach, known as "single linkage," is the easiest since it requires the calculation of only one matrix of distances between the observations. Procedures which rely on the latter option are part of the family of clustering algorithms called "average linkage." These techniques usually provide better classifications, but they can be costly with large data sets: at each step a new set of distances must be calculated in order to locate the "center" of each group.

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[1]For an excellent overview of the procedures used in this study, see SAS Institute (1985). *SAS User's Guide: Statistics, Version 5 Edition.* Cary, NC: SAS Institute, Inc. The specific procedures used were CLUSTER (pp. 255-315) and FASTCLUS (pp. 377-402). User's guides for more recent versions provide comparable overviews.

[2]The most comprehensive work on numerical taxonomy is Sneath, P. H. A., and R. R. Sokal (1973). *Numerical Taxonomy.* San Francisco: W.H. Freeman. For a detailed examination of the application of taxonomic procedures to geographic problems, see Abler, R. F., J. S. Adams, and P. R. Gould (1971). *Spatial Organization: The Geographer's View of the World.* Englewood Cliffs, N.J.: Prentice-Hall. For an analysis of the procedures as applied to inter-urban topics, see Berry, B. J. L. (1972). *City Classification Handbook: Methods and Applications.* New York: Wiley-Interscience.

Average Linkage and Nearest Centroid Sorting

In this study, we used two approaches to classify places in Minnesota according to transportation and demographic variables. In the first part of the study, we used average linkage techniques to classify Minnesota's 87 counties according to their scores on the five factors extracted from the original set of 14 variables.[3] This procedure yielded a six-category classification, the results of which are summarized in Table 2.

The second part of the study involved a much larger dataset--a total of 833 census tracts. In order to minimize the computing costs required to classify each of these tracts, we relied on a family of algorithms designed to produce results that are basically comparable to average linkage methods, but without computing all of the distances between observations at each step.

The specific routine we used is known a "nearest centroid sorting,"[4] and is available as a separate procedure in any of the recent versions of SAS.[5] Nearest centroid sorting consists of three main steps. First, the reseacher specifies the number of clusters to be calculated; the algorithm then provides initial estimates of the center of each of these groups. These estimates are called cluster *seeds*. Second, each observation is assigned to the nearest seed, forming temporary clusters. In the third step the seeds are re-calculated according to the *actual* means of the variables describing each observation in each cluster. The procedure once again assigns observations to the nearest seed, and the algorithm continues iteratively until there are no changes in the clusters.

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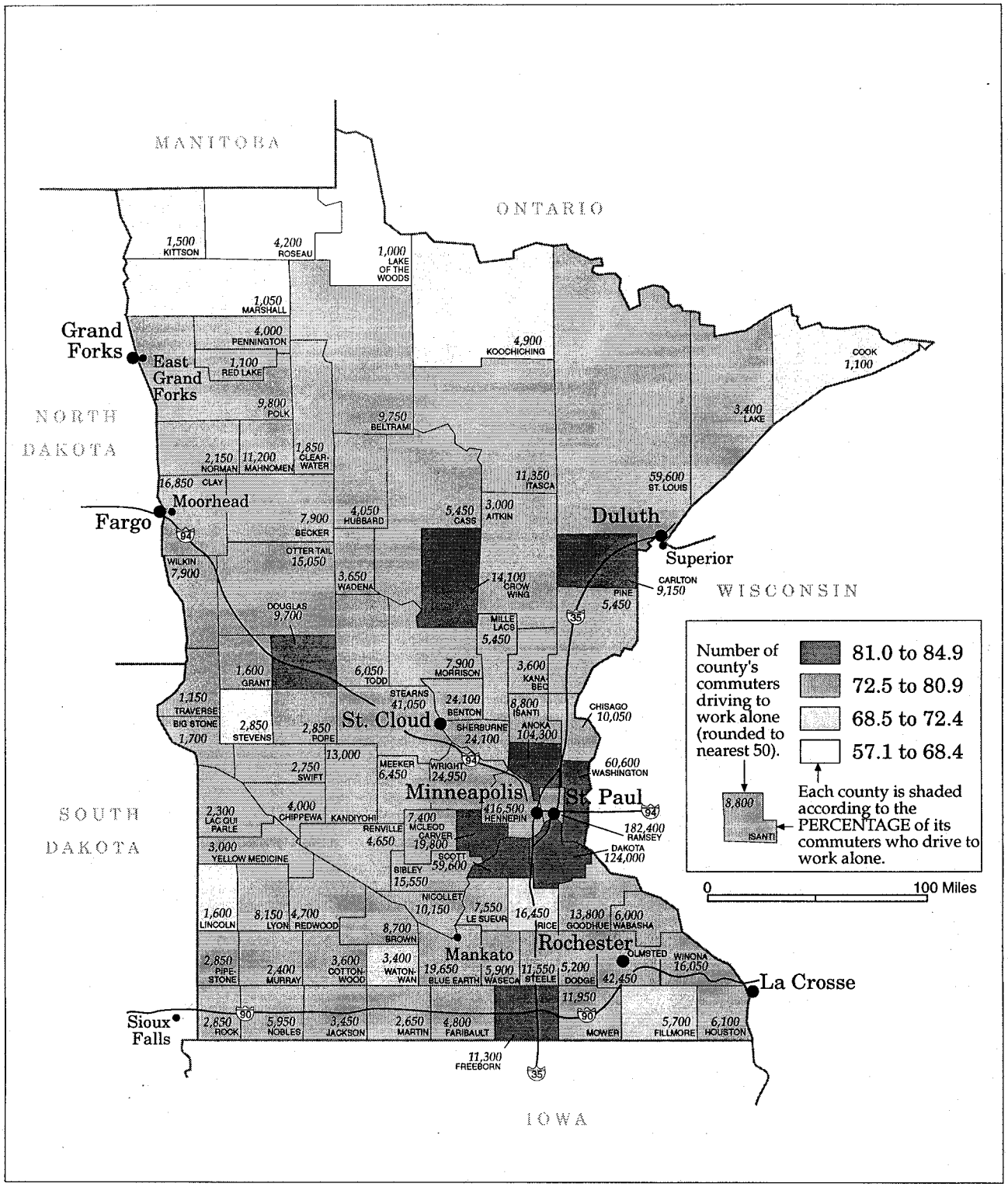
[3]Average linkage techniques were first elaborated by Sokal, R. R., and C. D. AMichener (1958). "A statistical method for evaluating systematic relationships." *University of Kansas Scientific Bulletin* 38, 1409-38. The syntax of the SAS code was "PROC CLUSTER METHOD = AVERAGE; VAR FACTOR1-FACTOR5." For a complete review of the command syntax, see SAS Institute (1985), *op. cit.*, p. 255 ff.

[4]The term "nearest centroid sorting" was first elaborated in Anderberg, M. R. (1973). *Cluster Analysis for Applications*. New York: Academic Press. The algorithm used in recent versions of SAS is based on Hartigan, J. A. (1975). *Clustering Algorithms*. New York: John Wiley & Sons, and MacQueen, J. B. (1967). "Some methods for classification and analysis of multivariate observations." *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability* 1, 281-97.

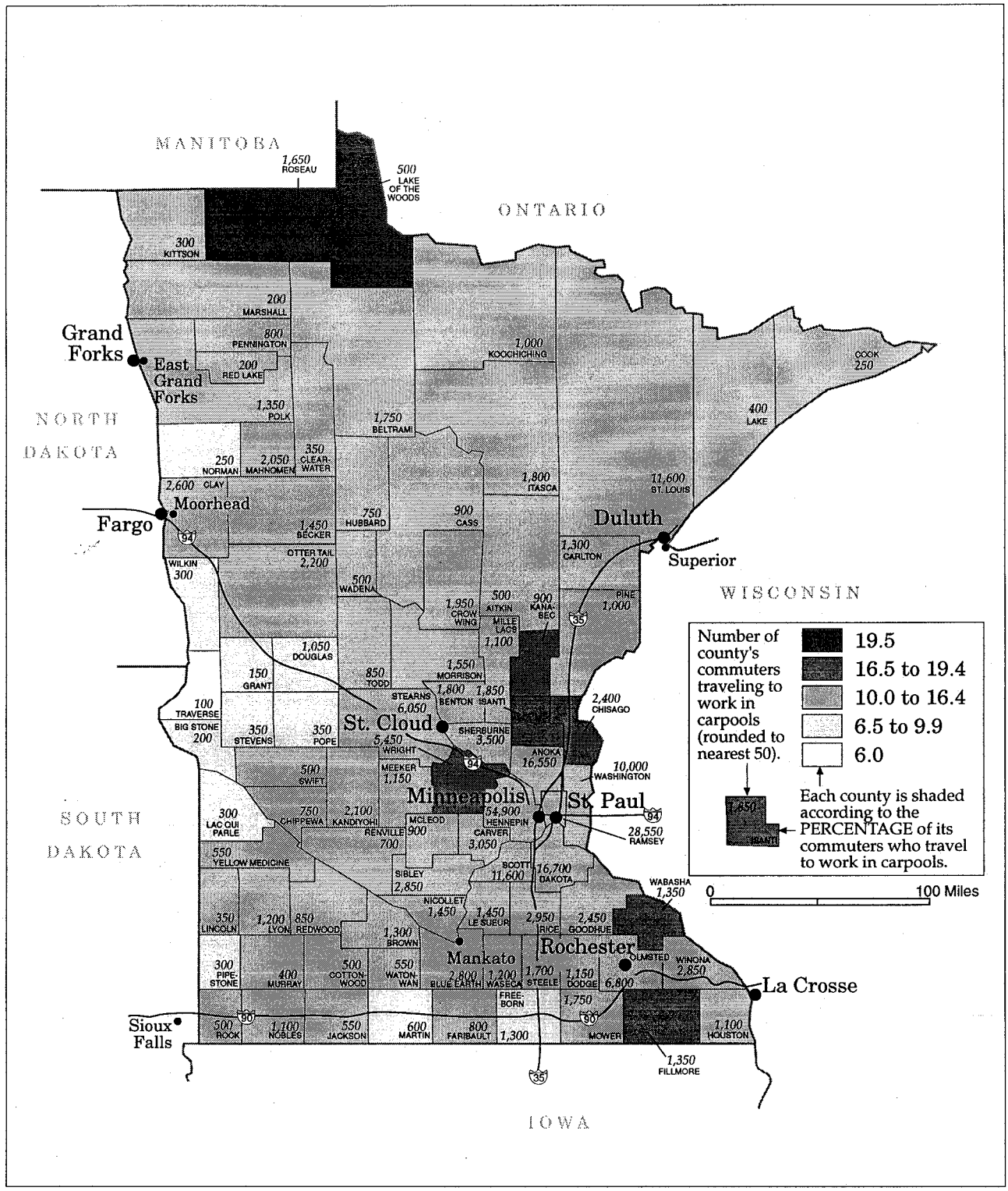
[5]Nearest centroid sorting is the method used in the FASTCLUS procedure. The syntax of the SAS code was "PROC FASTCLUS MAXCLUSTERS=6 REPLACE=FULL; VAR FACTOR1-FACTOR5." See SAS Institute (1985), *op. cit.*, p. 377 ff.

Appendix E

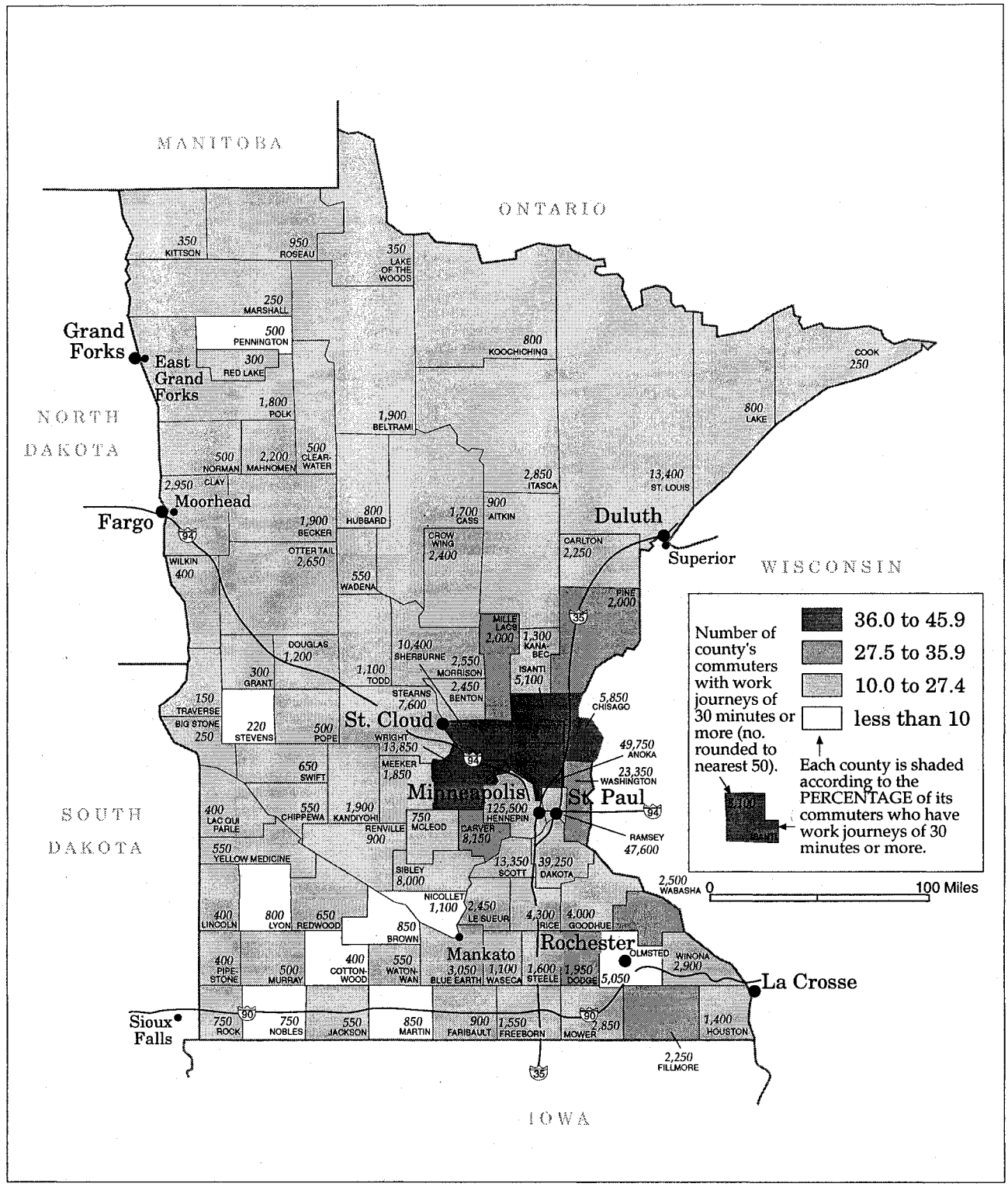
Transportation-Related Measures for Minnesota Counties, 1990: Six Reference Maps



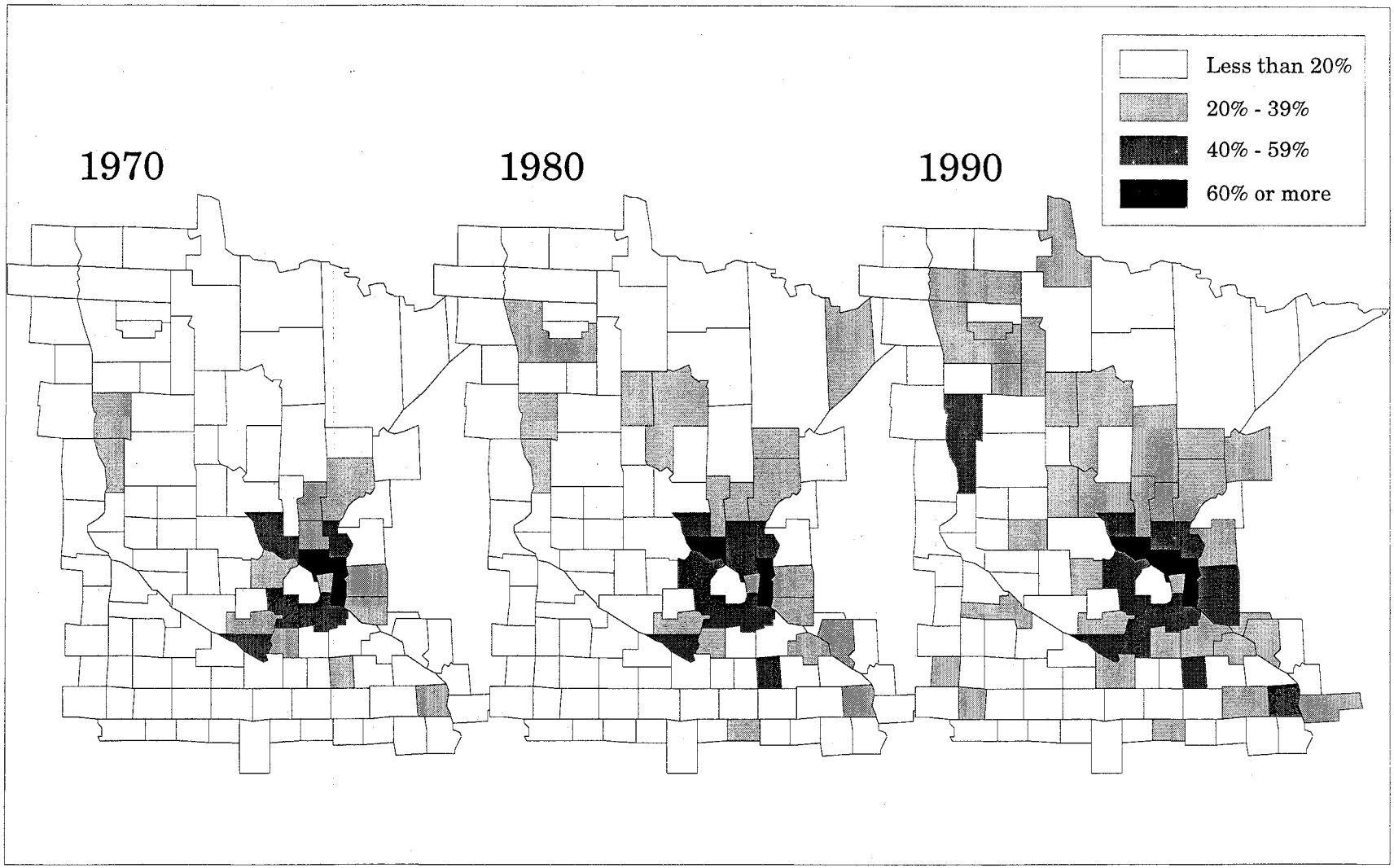
Reference map 1. Commuters Driving to Work Alone, Minnesota Counties, 1990. *(Data Source: U.S. Bureau of the Census, Summary Tape File 3.)*



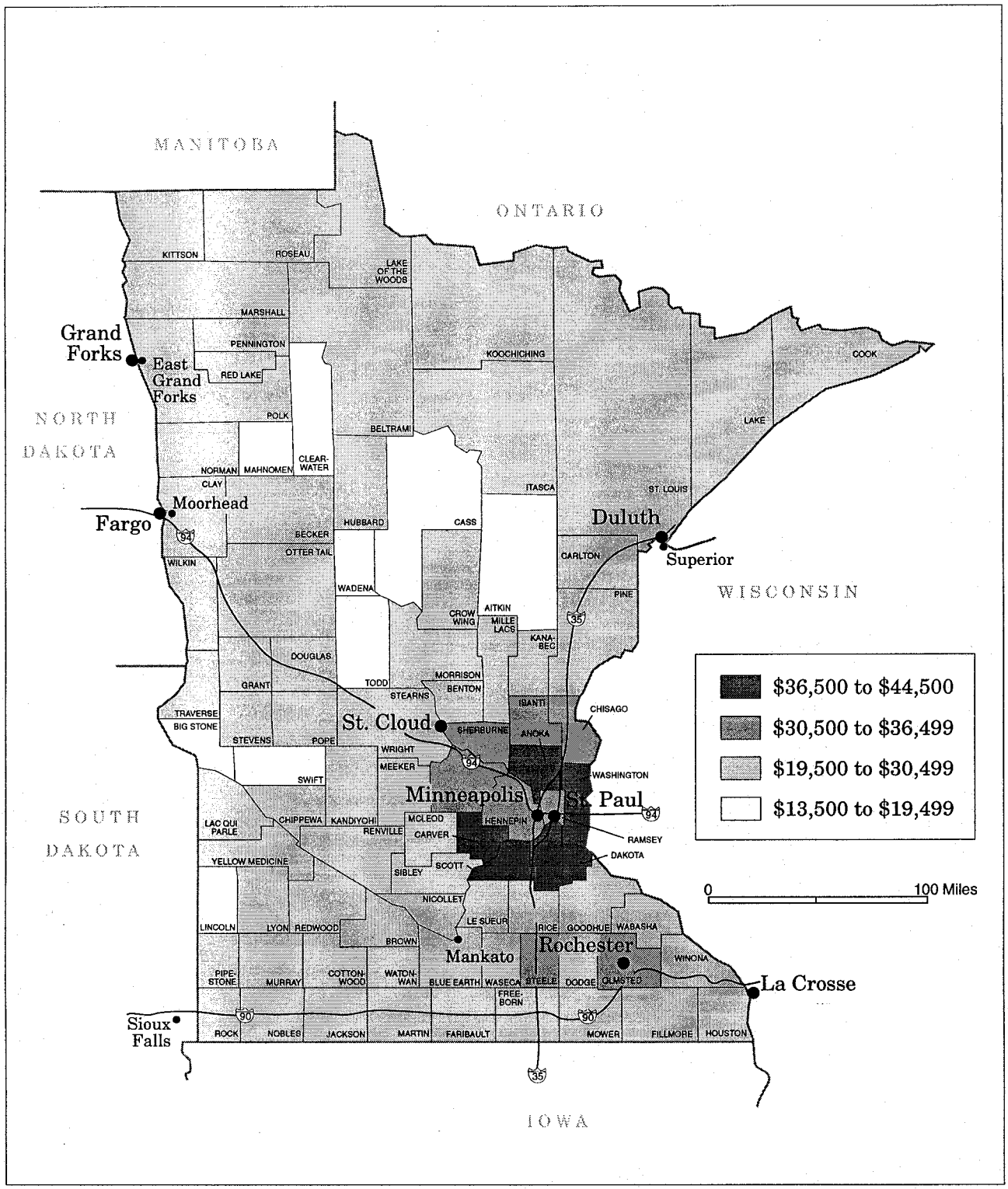
Reference map 2. Commuters Traveling to Work in Carpools, Minnesota Counties, 1990. *(Data Source: U.S. Bureau of the Census, Summary Tape File 3.)*



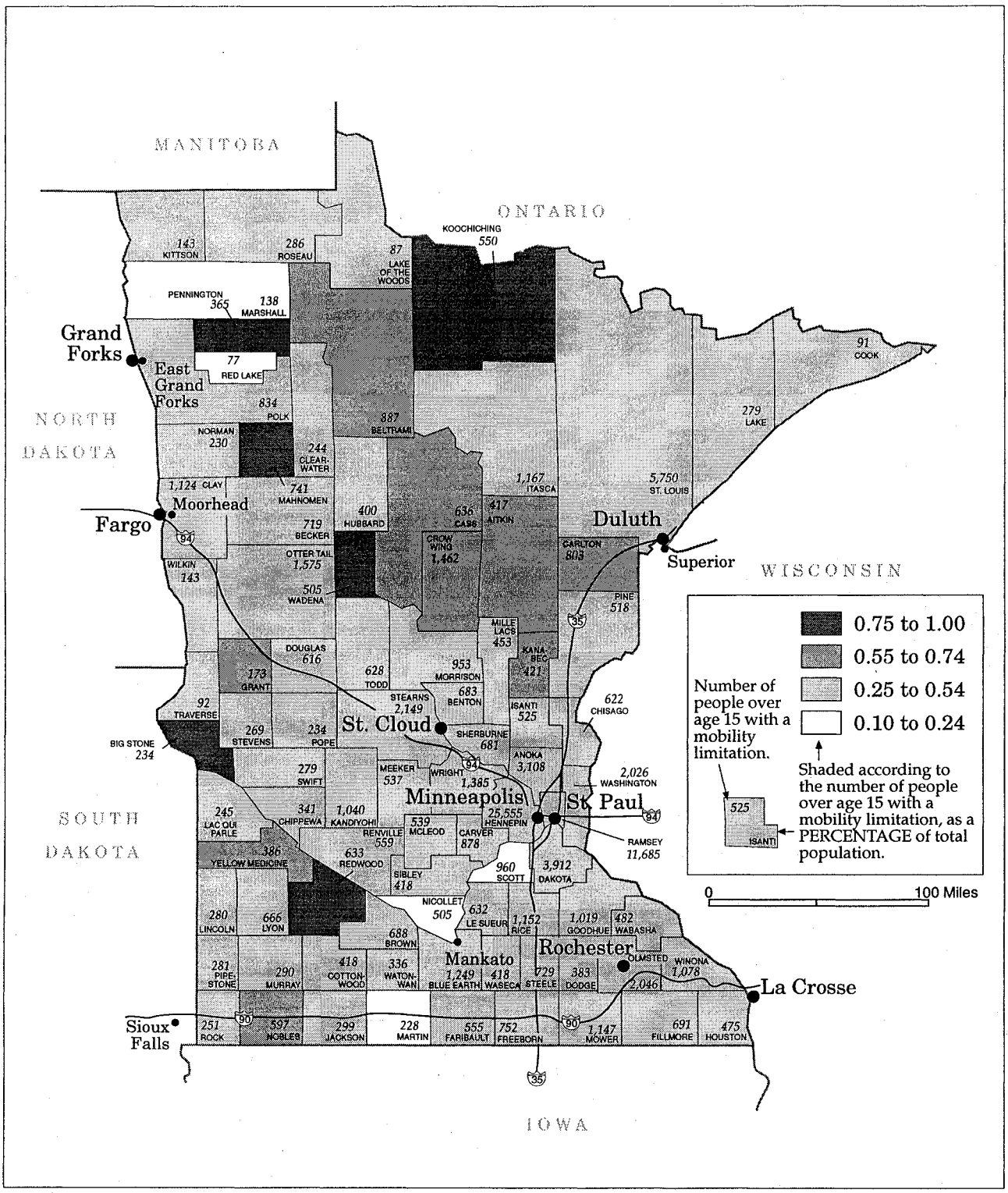
Reference map 3. Commuters with Work Journeys of 30 Minutes or More, Minnesota Counties, 1990. *(Data Source: U.S. Bureau of the Census, Summary Tape File 3.)*



Reference map 4. Percentage of Commuters Working Outside County of Residence, 1970 to 1990. *(Data Source: Special tabulations of U.S. Bureau of the Census Journey-to-Work Frequency Tables, and Bureau of Economic Analysis data.*



Reference map 5. Median Household Income, Minnesota Counties, 1990.
(Data Source: U.S. Bureau of the Census, Summary Tape File 3.)



Reference map 6. Limited Mobility Population, Minnesota Counties, 1990.
(Data Source: U.S. Bureau of the Census, Summary Tape File 3.)

Other Research Reports in This Series:

LONG-DISTANCE COMMUTING IN MINNESOTA

Workers making long daily commutes in the 1950s were understood as those best able to afford amenities normally available outside the "urban core"--that is, the downtown central business district (CBD) plus adjacent transportation-industrial zones and high density residential neighborhoods within "central cities" such as Minneapolis and St. Paul. This report examines characteristics of Minnesota workers residing in Minnesota's metropolitan and non-metropolitan areas who made long duration (more than 30 minutes one way) commutes in 1990, concluding that early metropolitan-based models today lack much if not all of their former applicability.

Minnesota's average commute of 19.1 minutes fell below the national average of 19.7, but more than 450,000 Minnesota workers spent more than 30 minutes commuting each way. Long duration work journeys were not restricted to the stereotypical upper income suburban family. In all geographic categories, the largest group of long duration commuters came from two person households, whose commuting may reflect compromises between two job locations.

In a five county "exurban" (i.e., beyond continuously built-up suburban areas) study area between Minneapolis and St. Cloud, average auto commuting time was the state's highest, at nearly 26 minutes. Blue collar workers reported commuting times longer than professionals. Findings have implications for policy proposals such as highway improvements, toll roads, or new energy taxes.

DATA SOURCES FOR USE IN CONDUCTING TRAVEL BEHAVIOR RESEARCH

This study demonstrates the applicability of two distinct data sources for travel behavior research. Questions relating to reverse-commuting are raised with respect to all working residents, and working residents in low-income households located in Minneapolis.

Census of Population and Housing, 1990 Public Use Microdata Sample (PUMS) and the Twin Cities Metropolitan Council Travel Behavior Inventory (TBI) provide details on aspects of commute and travel patterns. Examining organization and methods of analysis appropriate to determining particular travel-related information presents a unique perspective on the advantages and shortcomings of each data set.

PUMS data provide detailed household and work-journey information. To answer reverse-commuting questions posed in this study, we consider household income, worker occupation, state and Public Use Microdata Area of employment, number of persons in each household, means of transportation used for the journey to work, and work journey duration.

TBI data contain a wealth of information on both the work journey and other trips, but lack the depth of socioeconomic data available in the PUMS file. The value of TBI data in responding to this series of questions lies in the details provided about trip location and purpose.

MODELING COMMUTER FLOWS AMONG LOCAL LABOR MARKETS IN MINNESOTA, 1970-1990

Between 1970 and 1990 the share of Minnesota workers crossing a county boundary on the way to work increased from 12 to 18 percent. This study analyzes this trend by examining commuter flows among labor markets in a 120-county study area encompassing Minnesota and counties in adjacent states.

Statistical models relate commuter flows to demographic and employment conditions. Commuter flows strengthened in the last two decades, becoming more common in declining rural counties and in suburban and exurban areas. Longer work journeys in declining rural areas appear to reflect individual coping strategies as workers seek job opportunities farther afield. The second finding relates geographical variation of commuter flows to underlying changes in the distribution of jobs and residences.

For most types of jobs, employment growth dispersed outward from the cores of metropolitan areas, while in nonmetropolitan counties jobs consolidated in a smaller number of regional centers. Residential development continued to decentralize over the past decades. Together these trends created a network of diffuse regional labor markets in which commuter flows link places with labor deficits to areas with labor surplus in patterns too complex to be modeled solely in terms of aggregate population and housing variables.