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MAXIMIZING THE BENEFITS OF TRANSITWAY INVESTMENT

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Yingling Fan
Nebiyou Y. Tilahun

Humphrey School
of Public Affairs
University of Minnesota

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In the Twin Cities metropolitan area, significant long-range transit planning activities have been ongoing since the late 1990s. By 2030, the region is expected to have a network of fourteen transitways converging on the Minneapolis and St. Paul downtown areas. This project seeks to fully capitalize on the opportunities offered by transitways, by testing forward-looking policy options that enable the effective integration of transit, land use planning, and economic development.

The overarching goal of this research project was twofold: 1) to sensitize and prepare policymakers for risks and rewards of various future land use and transit scenarios; and 2) to develop best practices in regional land use and transit planning for promoting economic growth and social equity.

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Maximizing the Benefits of Transitway Investment

Final Report

Prepared by:

Yingling Fan
Nebiyou Y. Tilahun

Humphrey School of Public Affairs
University of Minnesota

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National advisory panel members:

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- Shawn Escoffery, Surdna Foundation
- Greg LeRoy, Good Jobs First, Washington, DC
- Helen Leung, Living Cities, Washington, DC
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- Eric Muschler, McKnight Foundation
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Executive Summary

Transitways in the Twin Cities region continue to expand, and a network of 14 transitways is planned for 2030. How can the region maximize the return on this investment to improve job accessibility and strengthen the regions economic future? University of Minnesota researchers set out to find the answer.

Economic competitiveness requires connections and accessibility: for a region to be economically competitive, employees with the right skills need to be able to reach appropriate employers in a reasonable time and at an affordable cost. As a result, understanding how to maximize the benefits of transitways requires looking at them in relation to the homes and jobs they serve.

To determine how well transitways connect workers to job opportunitiesand employers to the labor force researchers first identified where the regions greatest opportunities exist. The first step in this process was mapping competitive clustersgeographic groupings of interconnected businesses and organizations that drive regional employment, pay higher wages, and have faster wage growth.

Next, researchers examined the current accessibility of competitive cluster jobs by transit. Some clusters are currently much more accessible by transit than others. For example, access to medical manufacturing jobs is low, while access to office-centered employers such as finance and insurance is higher. In general, the access of Twin Cities employers to the labor force by transit is lower than workers access to jobs; this is reflective of the relatively low density and dispersion of housing in the region.

From an equity perspective, researchers discovered the current system is largely consistent with the needs of the population, offering the greatest access to those with the greatest need. Areas of weakness include locations outside the downtown areas with some of the regions lowest- income populations.

To determine how future transitway plans could affect economic growth in the Twin Cities region, the research team developed and analyzed several different scenarios based on the Metropolitan Councils 2030 population and land-use forecasts. Key findings include:

- The planned future transitway network will improve accessibility to jobs in competitive clusters and to all other jobs in many locations.
- Alternate population and land-use scenarios could further improve accessibility gains of planned transitways:
  - Locating future housing and job development within the I-494/I-694 loop will create additional regional accessibility to jobs.
  - An even more targeted concentration of development near transitway stations leads to even greater gains in job accessibility; these gains benefit low-income populations most.

  - Locating jobs near transitway stations leads to larger increases in accessibility than locating housing near transitway stations.

This study provides several important insights for integrating economic development and land-use policies with planned transitway investment to increase equity, foster further economic growth, and provide greater overall return on investment:

- Not all jobs have the same needs for transit access. Policies that encourage job creation near transitways should take into account the unique location patterns and preferences of each competitive cluster.

- Disadvantaged groups warrant a closer look. Though lower-income families and individuals generally enjoy high levels of transit accessibility, this is largely due to residential concentration near downtowns; additional policy efforts are needed to increase transit accessibility for this population.

- Policies boost impact. Policies that support jobs and housing in and near the core will increase the return on investment in transitways.

- Use transitways as a guide for development. The more development near transitways, the higher the payoff. Development near transitways also produces highest levels of accessibility improvement for the highest-need population.

- Focus on jobs. Not all development has the same impact on accessibilityplacing new jobs near transitways creates greater accessibility gains than placing new housing near transitways.

Chapter 1

Introduction

The Twin Cities metropolitan area has been engaging in significant, long-range transit planning activities since the late 1990s. The Hiawatha light rail, the Northstar commuter rail, the phased implementation of bus rapid transit (BRT) on Cedar Avenue and I-35W, the Central Corridor light rail now under construction, and several other transitways in planning and development stages are all part of this effort. By 2030, the region is expected to have a network of 14 transitways converging on the Minneapolis and St. Paul downtowns as shown in Figure 1.1. This system is expected to significantly improve regional mobility and accessibilityThe Metropolitan Council, which is implementing these changes, also expects the system to enhance regional economic development[1].

These goals require policymakers to consider strategies in which transit and land use changes complement one another as the system is deployed. The nodes of the developing network need both riders and opportunities for the system's impact to be substantial; however, without the right incentives in place, transitways alone may not have sufficient power to attract employers and influence their business development and location decisions. Similarly, the pattern and pace of residential developments may also need incentives to increase the number of people ready to take advantage of transportation improvements. To what extent policy should focus on residences or employment locations is also an open question.

Beyond the overall changes in accessibility the system will generate, to whom these access levels accrue also needs to be examined. The 2030 transitway system is designed to best serve commutes between the central cities and suburban transit stations. The majority of low-income households in the Twin Cities metropolitan area are concentrated in the central cities, while low- and entry-wage jobs are spread throughout the region (Metropolitan Council, 2010). Appropriate land-use changes are needed to ensure existing and planned transitways benefit suburb-to-suburb and inner-city to suburb commuters.

Given these concerns, it is clear the 2030 transitways present both opportunities and challenges for policymakers in the Twin Cities. This research seeks to inform these issues by examining how the planned transitways can complement regional economic development while also addressing equity goals. We approach the problem by first investigating how the current transit system is performing in terms of providing workers access to jobs and employers access to labor in the region. In addition, we look at which employer and worker groups the system is currently serving best. This analysis is then extended to determine how the full 2030 transitway system, once completed, will

[1]Metropolitan Council Chair Susan Haigh, Twin Cities Regional Transitways will Spur Economic Development, http://www.metrocouncil.org/about/chair/2011/chair_May11.htm, accessed Jan 12, 2012

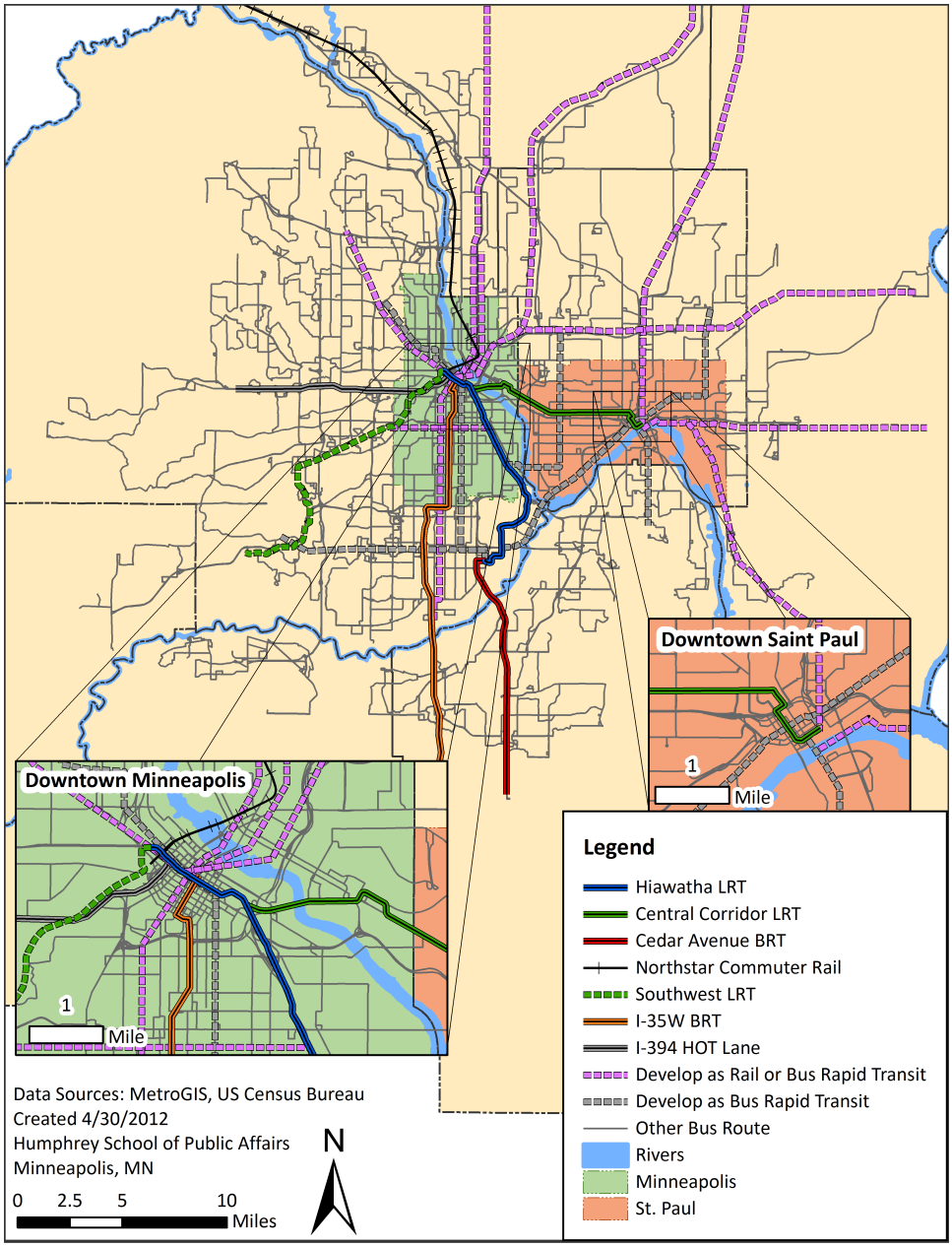

Figure 1.1: The planned 2030 Twin Cities transitway system

serve the forecasted future workers and employers of the region. Finally, different scenarios in which the population and employment locations in the region are shifted are investigated to see if better outcomes in accessibility can be achieved. This is then used as a basis for future policy recommendations.

In tying regional development to transitways, this study employs the concept of competitive clusters to identify those sectors believed to be the engines of regional growth. While the sectors at the forefront of these clusters sometimes require skill specialization from their potential employees, a study of their trading patterns with other sectors in the region shows they have significant trading relationships with less specialized sectors that provide important inputs. In this research, we employ a broader definition of competitive clusters so that each cluster comprises both the exporting sectors (basic sectors at the forefront of the identified clusters) and the less-specialized sectors (non-basic sectors that provide important inputs to the identified exporting sectors in the cluster). By doing so, we ensure the analysis incorporates jobs with a range of skill levels while also focusing on sectors likely to be engines for the regional economy. The study looks at location patterns and current and future accessibility levels to jobs in these clusters.

From the perspective of residents, higher access to competitive cluster employment can have several advantages. Jobs within the competitive clusters pay higher wages relative to the general economy, have faster wage growth, and are marked by higher levels of creativity (Porter, 2003). This means workers are not only able to extract higher wages, but could also benefit from other externalities that arise from having access to newer technologies, working at the forefront of their sector, and developing a new set of contracts. For employers that are part of the competitive clusters, higher transit accessibility could help make them more attractive to a wider labor pool and enable them to attract workers with better skills.

Many states and regions have spent considerable capital fostering different types of clusters. By connecting transitway research with competitive clusters, we also highlight the opportunity to leverage these efforts to enhance transit accessibility. For example, future efforts can proactively incorporate considerations for transit access as they prepare incentive packages for potential employers they are pursuing. Furthermore, the analysis of labor accessibility can be expanded to identify locations where firms can have access to a broad spectrum of the labor force. Existing economic cluster employment locations where transit service is limited are also identified.

The analysis will also more broadly look at all jobs and the extent to which current and future service levels cater to disadvantaged groups whose need for transit service is greatest. In general, access problems are not severe for car owners, while those who don't own cars are largely dependent on transit services. We therefore focus on how current and future changes to the transit system affects the locations with the greatest need for transit service.

This report is organized as follows. Chapter 2 provides a literature review on jobs, land use and transportation, transportation to jobs, and the competitive clusters concept. That is followed in In Chapter 3 where the economic clusters in the Twin Cities region are identified. Chapter 4 looks at the current commute pattern in the region and analyzes the current level of transit accessibility to the clusters identified Chapter 3. The question of labor accessibility from the perspective of employment locations is also investigated. Chapter 5 looks at whether transit access levels provided by the current system are congruent with the needs for transit service in the metropolitan area. Chapter 6 provides an analysis of the future system and investigates how different land-use scenarios can complement the anticipated change in the transitways. Finally, Chapter 7 provides a synthesis of the research. Technical details of the report are provided in the Apppendix.

Chapter 2

Background

2.1 Introduction

This section broadly looks at a number of issues related to two themes in this research: (i) transit, land use and commuting and (ii) competitive clusters. In looking at the first area, we begin with a brief overview of the trends in transit use for work commutes in urban areas. We then move to discussions of land use and transit, and attempts to increase transit use through land use changes. Finally, we look at the market for transit in the context of welfare policy changes and racial inequality, particularly focusing on transportation to jobs. We then move to the second area and review the concept of competitive clusters. Finally, we summarize the literature in these areas and discuss where transit and the concept of competitive clusters intersect.

2.2 Transit and Work Commute

Over the past few decades, the transit mode share for work trips has been declining nationally. US Census data for 1960 shows public transportation mode share for work trips at 12.1% with each decade thereafter showing a marked decline. By 2000, the public transportation mode share stood at 4.7% (U.S. Census Bureau, 2000, 2004). In the same time period, the automobile mode share has risen from 64% to 87.9%[1]. In general, this period has been marked by increasing auto ownership and suburbanization of residences, as well as suburbanization of jobs. These changes have also meant that central cities play a declining role as centers of employment. Data from the 2000 census show 46% of commute trips were suburb to suburb and 9% where central city to suburbs, with both percentages showing an increase from their 1990 levels (Pisarski, 2006). In addition, among workers who lived in Metropolitan Statistical Areas (MSAs), the percentage who worked in a central city fell from 51.9% in 1980 to 50.7% in 1990 and to 46.9% in 2000 (United States Census Bureau, 2001).

In the Minneapolis-St. Paul area, the number of people working in the central cities is even less than the national level - only 29.9% of all workers living in the MSA worked inside a central city in 2000, 68.8% of MSA resident workers worked inside the MSA but outside a central city, while the remaining worked outside of the MSA **?**. Despite these numbers, American Community

[1] cars, trucks and vans -includes single occupant as well as high occupancy vehicles

Survey (ACS) data show that the Minneapolis - St. Paul MSA ranks among the top 15 regions in terms public transportation mode share (McKenzi, 2010). The 2005-2009 5-year ACS estimate for public transportation use among workers 16 years and over is at 4.4% for the MSA, 9.0% for the city of St. Paul and 13.5% for the city of Minneapolis.

In the same time period, congestion costs have risen considerably. TTI's Urban Mobility Report (Schrank et al., 2010) estimates that yearly delay for auto commuters in 2009 was 2.6 times what it was 1982 in very large cities, and 3.4 times as large as 1982 levels in large cities. The estimate for the Twin Cities grew from 6 hours to 43 hours, a more than seven-fold increase. These trends – along with concerns for the environment, health, and energy – have driven policymakers to look for tools to reduce auto dependence, including prescriptions within which transit and land use figure prominently. The next sections will review some of the literature in these areas.

2.3 Land use and Transit

The general patterns of suburban dominance at the expense of central cities, auto dependence, concerns over the environment, congestion and sprawl have led to a host of policy and planning tools to slow or reverse the prevailing trend. One stream of proposals argues a combination of land use interventions to increase residential densities, grid networks and pedestrian friendliness would lead to a moderation of auto use and an increase in transit use. A significant amount of research has shown a relationship between locations that exhibit such built environments and transit mode choice (e.g. Cervero (2007); Cervero and Gorham (1995); Frank and Pivo (1994); Krizek (2003); McNally and Kulkarni (1997); Spillar and Rutherford (1990).)[2]

However, there are the difficulties of teasing out self selection and residential sorting from the effect of land use in affecting choice. Findings by Kitamura et al. (1997) suggest that, while land use factors are correlated with mode share, its role is limited, and modal preferences are better explained by rider's attitudes. Schwanen and Mokhtarian (2005) look at what happens when people's attitudes are at odds with the neighborhoods they live in, and find that the built environment has some influence. The solution they contend is to enable people to sort themselves into neighborhoods that provide choices in line with their attitudes. This view is also reflected in (Cervero, 2007). On the other hand, Pinjari et al. (2007) find that land use variables have a significant effect on mode share even after controlling for sorting effects. For example, they find that higher land use mix contributes positively to transit usage.

Transit Oriented Development (TOD) are proposed as a popular solution for encouraging mixed use, walkable neighborhoods connected to transit that can reduce auto use and combat congestion, as well as revitalize neighborhoods around station areas (Cervero, 2004). Some have shown that more nuanced policies combining transit oriented development with supporting policies could increase transit ridership (Cervero, 1994, 2007). Comparing TOD residents in California that reside within a 1/2 mile of a rail station as compared to those in 1/2-3 miles, Cervero (2007) finds that the former were four times more likely to use transit and six times more likely to use transit than those living within the city limit but outside the 3 mile radius around the station areas.

In reviewing smart growth policies and their connection to transportation, Handy (2005) focuses on four issues, one of which looks at investments in light rail transit systems and their role in increasing density. The evidence suggests that light rail transit systems support density increases

[2]See Ewing and Cervero (2001) for a broad review of studies done prior to 2001.

under specific circumstances and when paired with the right policies. Specifically, she writes that increased densities are possible in "a region that is experiencing significant growth, a system that adds significantly to the accessibility of the locations it serves, station locations in areas where the surrounding land uses are conducive to development, and public sector involvement in the form of supportive land use policies and capital investments" (Handy, 2005).

The role of appropriate policy is also highlighted in a review of the influence Bay Area Rapid Transit (BART) had in shaping land use in Cervero and Landis (1997). The authors find that BART has had significant localized impacts, but that much larger growth in employment and office space has happened in freeway corridors than along the BART corridor. While in some areas the market-driven changes did lead to denser land uses, others had to actively plan and engage in order to capitalize on the existence of BART to develop high-density housing or office space around station areas. Among the policies and actions pursued by regional bodies are the use of tax increment financing, density bonuses, assemblage of irregular parcels into usable tracts, urban renewal grants, equity participation, etc., emphasizing that building rail alone might not bring about the changes needed but that appropriate policy and investment support is needed.

Of course the debate does not end there. Giuliano (1995) argues that land use policies are too indirect to affect meaningful modal changes, and that policy should focus on pricing is argued by Giuliano (1995). Gordon and Richardson (1997) question whether compact cities should actually be a policy goal and provide arguments why they should not. Stopher (2004) argues that public transit systems are unlikely to be the answer for worsening congestion, that there is a niche market for public transport, and that policies should focus on serving this market well rather than trying to increase system-wide ridership.

The combination of high density of workplaces and parking fees make public transport ideal for CBD destined commute trips. A significant market also exists among low-income households that have no vehicles, in addition to people who have consciously decided for environmental or other reasons to use other modes. For this market, transit provides the only access to jobs and economic advancement. The market for jobs will be constrained by the extent of the transportation option available for job searchers to search, find, and maintain employment and as a way to address access inequalities. The following section reviews more closely the connection between transit and jobs focusing on low-income households and welfare recipients.

2.4 Transit and Job Accessibility

There has been considerable work looking at the connection between jobs and transportation spawned by concerns over the idea of spatial mismatch[3] (Kain, 1968, 1992) as well as the changes following the 1996 Personal Responsibility and Work Opportunity Act. The problem of mismatch between home and work location affects many low-income households and welfare recipients. Suburbanizing jobs, fewer skills, industrial decline and low levels of auto ownership have all increased the challenge of finding a job for these groups, while welfare policy changes place urgency on finding gainful employment.

[3]The Spatial Mismatch hypothesis refers to the inability of inner city Black residents to access decentralizing jobs while they are locked into job-poor segregated residential neighborhoods as a result of discriminatory housing practices. For an expanded discussion and review of the Spatial Mismatch literature see Kain (1992) and Ihlanfeldt and Sjoquist (1998).

One area of policy focus to rectify the jobs-housing mismatch problem has been the provision of transportation solutions. These have ranged from transit services targeting job-poor neighborhoods to subsidized auto ownership programs. Though transit plays an important role in providing access to work, its effectiveness varies based on the type of environment it serves. In general, high density places are served well by fixed-route transit services, while challenges increase when dealing with suburban jobs. Results from research on whether transit access itself is important for positive employment outcomes appears mixed. Researchers have shown that transit access is important in explaining average labor participation rates Sanchez (1999); Thakuriah and Metaxatos (2000) find job accessibility by car as well transit to be important for the continued employment of women who have moved from welfare to work. Others find car ownership has a very strong association with moving from welfare to work (Cervero et al., 2002; **?**) while finding the results for transit to be more mixed (Cervero et al., 2002).

The importance of job accessibility as a policy focus area is borne out by studies that show its importance for labor participation (e.g. Sanchez (1999); Thakuriah and Metaxatos (2000)), as well as those that have shown positive association between increasing accessibility and declining welfare usage (e.g. Blumenberg and Ong (1998)). At the federal level, there has been a concerted effort to finance programs that help welfare recipients and low-income persons obtain and maintain employment through the Job Access and Reverse Commute program. Programs included under this umbrella are fixed route transit services and demand response van services, as well as subsidies for car loan programs, each locally targeted and distributed.

However, modal questions about accessibility still persist. Blumenberg and Manville (2004) discuss the strength and weaknesses of transit, van-pool, and car ownership programs and call on policymakers to focus broadly on modal solutions as necessary – including car ownership. Each program has its benefits: fixed route services are most efficient in high-density locations, but face challenges with getting riders close enough to their destinations especially when job densities are low. Van-pool services are relatively much more flexible, though there are organizational costs in setting them up and keeping them operational.While there is broad agreement in the literature that car ownership is the most effective predictor for employment, a variety of factors including costs appear to be prohibitive in making the program broadly available.

It is important to note that previous research on transit and job accessibility has focused on jobs in general or entry-level jobs at most. Given that job opportunities in competitive clusters are often paying better and come with positive externalities, it is important to focus on the role of transit in providing access to jobs in competitive clusters. As far as we are aware, no research exists to date that examines transit and accessibility to jobs in the context of competitive clusters.

2.5 The Cluster Concept

In his 2000 article, Porter states that business clusters remain a feature of most developed economies. This, he argues, is happening even as the traditional reasons for locational aggregation (i.e. closeness to resources and markets) are playing a diminished role in cluster formation as a result of advances in technology and global competition. Porter (2000) defines clusters as "... a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities."

In Porter's view regional competitivenessis a function of the extent to which a knowledge-based

economy is fostered. He divides industries as those that are *factor based*, which rely on resource exploitation; *investment based*, which increase productivity of factor based industries through injection of capital; and *knowledge based*, which thrive on specialized innovation and are able to export their unique products.

Though the idea of Porter's clusters has broad appeal to policymakers, it also has its critics. Martin and Sunley (2003), for example, point to several definitional problems that make the concept ambiguous. The authors question where the industrial and geographic boundaries for Porter's clusters lie, how strong linkages should be, how specialized local concentrations ought (or ought not) to be, and what spatial density defines a cluster, among others. The lack of specificity, they argue, makes empirical identification difficult and has led to a range of approaches to identifying clusters.

In contrast, others (e.g.Benneworth and Henry (2004); Feser (2005)) have accepted that the cluster concept allows for a range of different approaches to empirically determine clusters. Though themselves following a different approach, Feser (2005); Feser et al. (2001), for example, accept Porter's approach as another competing model. Benneworth and Henry (2004) also sees value in the different approaches researchers have used as long as "it creates analyses which draw on multiple perspectives of significance, limitations and boundaries of economic development in particular contexts." They note, however, that the cluster concept is "theoretically immature."

Other approaches include that of Athiyaman and Parkan (2008), who propose an approach that starts from a spatial analysis to confirm the existence of a cluster and follows with an analysis of the specific relationships within clusters. By starting from the geographic side of the question, their approach markedly differs from the approaches of Porter or Feser, whose geographic scale of analysis are often much larger, and clustering is measured for areas relative to nationwide importance.

Though the methods reviewed above share some commonalities, the identification of clusters using Input-Output data takes the idea of connections beyond mere co-location to actual economic activity between firms. It therefore provides the strongest empirical approach to understanding local clusters. More details of these methods is given in Appendix A and summarized in Table 2.1.

2.6 Summary

A number of ideas come out of this review in terms of jobs and transit as well as their importance to the Twin Cities region. One is that properly planned and policy supported developments of transit and residential concentrations, through self selection and to some degree land use induced changes, encourage transit riderships. In this context, fixed-guideway transit can increase transit ridership. When coupled with appropriate policies, areas around transit stop/stations can also capitalize on the existence of a transitway into developing high-density housing that can address modal and possibly environmental concerns. Second is that a market for transit use exists especially to employment locations where job concentrations are high. Generally these tend to be CBDs where high job concentrations are present and where the mix of incentives (e.g. parking costs at destinations) encourage alternative modes. Third is that a market for transit exists where accessibility gains can be targeted and access equity concerns can be addressed. These tend to be places of low auto ownership, high poverty and higher participation of welfare support. For this population, limited accessibility to jobs complicates the disadvantages of finding employment that arise from lack of experience, job skills and job-search skills. Access to an expanded labor market could mean shorter

Table 2.1: Methods of Cluster Identification

	Methods	Data	Comments
Traditional analysis			
Regional competitiveness	Location Quotients Shift-Share Analysis	Employment and employment change over time by sector	Identify export (basic) sectors. Id sectors where regional growth outperforms nation
Competitive clusters			
Porter (2003)	Location Quotients Correlation analysis Case studies	Employment State sectors data	Focuses on traded sectors, perform sector X sector co-location analysis. I-O data used for confirmation
Value Chains			
Feser (2005)	Cluster Analysis	IMPLAN (Input-Output tables)	All sectors used except local serving sectors. Uses I-O tables to derive different trading strengths. Statistical cluster analysis applied to relationship matrix.

searching periods, better choice of jobs, and can lead to economic success.

In regards to economic clustering, there appears to be a consensus that clusters are indeed present in many regions. There exists, however, less agreement on the methods of identifying them. More importantly, the cluster concept appears an important one in the context of regional development, and there exists a dimension of access to labor which directly bears on urban travel. There is, however, no literature that directly connects the cluster concept to urban transportation. There is also little research that looks at whether the clustering phenomenon is present at geographic scales that could easily be served by transit (excluding downtowns). If such clustering is present within specific areas of the metropolitan area, providing higher access to these jobs could benefit both users and the employers that constitute the clusters. If, on the other hand, clustering occurs at the metropolitan or state levels but not enough incentives exist for their formation at smaller geographies, facilitating this process may also prove useful.

In part, the appeal of this project is it goes beyond the transportation dimension of connecting workplaces and homes, and looks at integrated policies that can make transit and transitways in particular work better by pointing out how plausible land use changes could increase access meaningfully. With the competitive clusters idea pointing to the benefits of co-location for industries, we look at how policymakers could strengthen these patterns to make such jobs concentrated and easily accessible. On the other hand, compact transit-oriented developments integrated with future transit plans could also be used to attract workers to residences that can easily access employment centers.

In the following chapter we first identify the competitive clusters in the Twin Cities and map their locations. That is followed in Chapter 4 by an analysis transit job accessibility as it currently stands in the region.

Chapter 3

Competitive Clusters in the Twin Cities Area

3.1 Introduction

In this section we summarize work that has been completed to identify local competitive clusters in the Twin Cities region. Technical details of the analysis are presented in Appendix B. Here we briefly outline the methodology and provide a summary of the clusters and the proportion of regional employment each of these clusters represent. This section also maps the location of the jobs contained in these clusters. Finally, we will show the cumulative distribution of employment in each of these sectors for the metropolitan area.

3.2 Overview of Methodology

Our methodology in identifying competitive clusters in the region adopts many of the methods from Feser (2005), but with significant departures in how we identify and define clusters. Similar to Feser (2005), we use Input-Output data in defining relationships between sectors. This relationship is then coded into binary (0,1) relationships based on the value of the trade volume (in $) between sectors. Once this matrix of relationships is developed, rather than an approach that employs statistical cluster analysis, our approach utilizes network analysis to identifying the relative position of sectors in the Input-Output trading relationships. This approach has the added advantage that sectors no longer have to be grouped to singular clusters but can easily belong to two or more clusters based on their actual trading patterns and therefore allows a more realistic representation of the economy.

The identification of basic clusters uses data from IMPLAN for 2009 for the seven-county area in the Twin Cities and for the nation. The data allows us to tease out two aspects of clusters that are key to their identification. One component is the extent of a sectors prevalence in the region as compared to nationally, and secondly, the inter-relationship that exists among other sectors defining cross-sector relationships. To measure regional concentration location quotients (LQ) were calculated for each of the 369 sectors using total annual receipts (sales) for each sector at the seven county and national levels. This identified a total of 112 sectors (31%) that were basic to the region.

While traditional analysis often ends here, the I-O approach allows for the identification of clusters by looking at the buying and selling patterns between the different sectors. For these

purposes, we isolate the basic sectors for the region and look at the buying/selling relationships among sectors in the region. This analysis allows us to identify the sectors that are most important to the regional economy and serve as anchors to a range of other industries in the region. These sectors buy a significant amount of the output produced by other regional sectors as evidenced in the input-output tables; their presence is essential for the wellbeing of the sectors that depend on them to consume their outputs. In the regional economy of the Twin Cities, nine clusters were identified, each having one central (*anchor*) sector. One advantage of identifying cluster membership using this method is that it allows sectors to appear in different clusters as long as they have substantial trading relationships with the anchor sector. This is in contrast with methods that adopt statistical cluster analysis for the classification of cluster membership, which only allow a sector to be part of one cluster. Details of this analysis are given in Appendix B.

Having identified the anchor sectors, we continue to identify the sectors that have considerable trading relationships with the anchor sectors. This process defines two sets of clusters - one which identifies clusters based on all the sectors that have significant trading relationship with the anchor sectors (which we refer to as the expanded cluster), and a basic cluster that is a subset of the former and only includes the basic sectors in the cluster. The original nine clusters are later consolidated to form five clusters based on the similarity of the sectors involved.

3.3 The Metropolitan Economic Clusters

The consolidated clusters, which we refer to by using the anchor sector that defines them, are as shown in Table 3.1. Percentages in the table refer to the total employment in the regional economy that is captured by the basic and expanded clusters. The sectors in each of the five expanded clusters are given in Appendix B, tables B.4 through B.8.

Some of the largest employers in these clusters include Medtronic, Cardiac Pacemakers Inc., St. Paul Fire & Marine Insurance, TCF Financial Corp., Thomson Reuters, Boston Scientific, Metris Companies, American Diary Queen Corp., and Merrill Corp.

Table 3.1: Anchor Sectors for the Twin Cities Region. Footnote definitions are taken from the Census website.

	Anchor Sector	Percentage of regional employment	
		Basic %	Expanded %
1	Medical equipment manufacturing[1]	4.4	7.0%
2	Management of companies and enterprises[2]	9.1	25%
3	Finance and Insurance[3]	11.1	46.9%
4	Book publishers & Printing Industries [4]	6.2	12.8%
5	Lessors of Non-financial intangible assets[5]	2.5	6.9%

Some sectors are part of more than one clusters. Percentages should not be added.

3.4 Mapping Cluster Locations

Beyond finding the cluster constituents it is important to be able to locate the sectors that are members of each cluster. This allows us to evaluate the extent to which these jobs are accessible to residents of different demographic groups and the extent to which these jobs can be accessed by transit users.

Mapping the constituents of these clusters was done by categorizing an industry list from DUNS (Data Universal Numbering System) which includes a list of businesses, their location, and a primary NAICS code describing the main activity of the firm. These NAICS codes were matched to the categories that were developed by IMPLAN, and each firm is identified as being a part of one of the clusters identified previously. The DUNS data includes 110,325 businesses. Of these Primary NAICS is unclassified for 6456 businesses. All of the businesses outside of these 6456 were successfully mapped to one of the IMPLAN sectors by starting with the most detailed NAICS code available in the DUNS data and dropping one digit until a matching IMPLAN sector was found. Out of the remaining 103,869 firms after removing the unclassified, 73,078 (70%) were identified as belonging to at least one of the expanded clusters which include the non-basic sector. Of these, 17,371 (16.7%) belonged to the sectors that made up the clusters composed of basic sectors alone. Based upon the employment numbers provided in the DUNS data, the expanded cluster constituted 65.7% of the employment among the firms that were successfully categorized, while industries belonging to the basic sector clusters made up 20% of all employment in the successfully categorized firms.

The employment density of each of these clusters are shown in figures 3.1 to 3.5. Total metropolitan job density separated by basic and non-basic employment is given in figure 3.6.

This analysis shows that there are significant differences not only in the size of these clusters but also on where they are located. The downtown areas figure prominently in almost all clusters. Some, like the medical assembly cluster, have a significant suburban footprint as compared to downtown locations. Others clusters, such as those anchored by finance and insurance, have a considerable presence in downtown locations. The overall distribution of employment in the clusters relative to the Minneapolis and St. Paul CBDs respectively is better illustrated in figures 3.7

[1]This cluster combines electro-medical and electro-theraputic equipment manufacturing as well as other medical equipment manufacturing and supplies. Industries in the former primarily engage in manufacturing apparatus such as magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment. The latter includes establishments that make surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, ophthalmic goods, dentures, and orthodontic appliances.

[2]Includes establishments: (1) those that hold the securities of (or other equity interests in) companies and enterprises; (2) those (except government establishments) that administer, oversee, and manage other establishments of the company or enterprise but do not hold the securities of these establishments; and (3) those that both administer, oversee, and manage other establishments of the company or enterprise and hold the securities of (or other equity interests in) these establishments. Those establishments that administer, oversee, and manage normally undertake the strategic or organizational planning and decision making role of the company or enterprise.

[3]Includes establishments engaged in depository services (e.g. Commercial banking, Savings institutions, Credit unions), non-depository services (e.g. consumer lending, real estate credit, loan brokers etc.), as well as insurance companies

[4]The combines the book publishing industries and the printing industries

[5]These are establishments primarily engaged in assigning rights to assets, such as patents, trademarks, brand names, and/or franchise agreements for which a royalty payment or licensing fee is paid to the asset holder.

and 3.8. These figures show the cumulative employment distribution of each cluster as a function of distance from the Minneapolis and St. Paul downtowns respectively.

As can be seen from these figures, clusters that have office-centered anchors such as management, insurance, and finance have a significant amount of their employment close to downtown Minneapolis. In contrast, members of the manufacturing-centered cluster such as medical-equipment manufacturing have much of their employment outside of the downtown area suggesting some level of dispersion. Approximately 20% of employment in finance and insurance as well as management of companies is within the first few miles of the Minneapolis CBD. In contrast, one would have to go out approximately 10 miles from downtown Minneapolis to find 20% of the employment in the medical equipment manufacturing sector.

These patterns, as we will see in the next section, have implications for how accessible jobs in each of these sectors are for metropolitan residents.

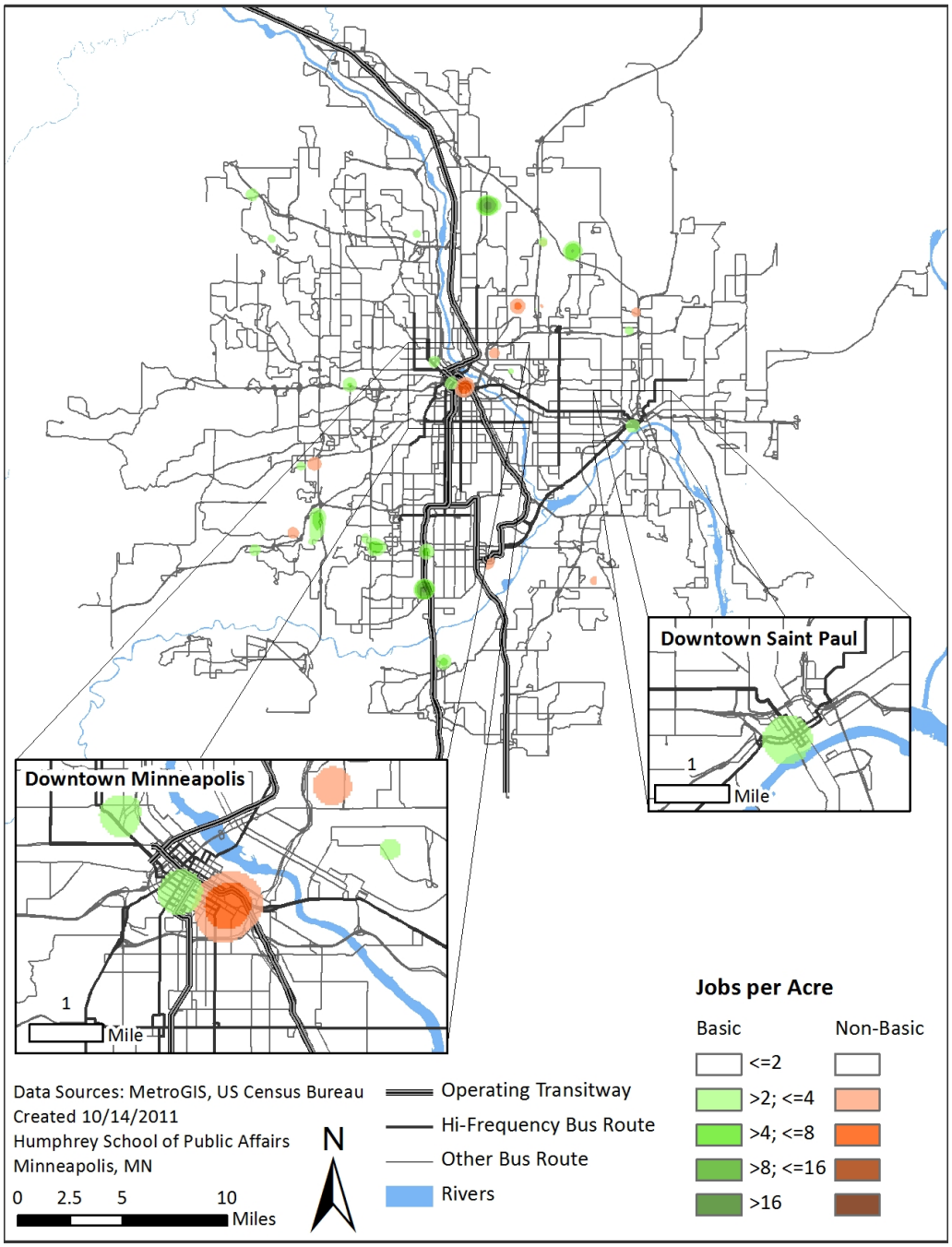

Figure 3.1: Medical equipment and apparatus manufacturing metropolitan job density

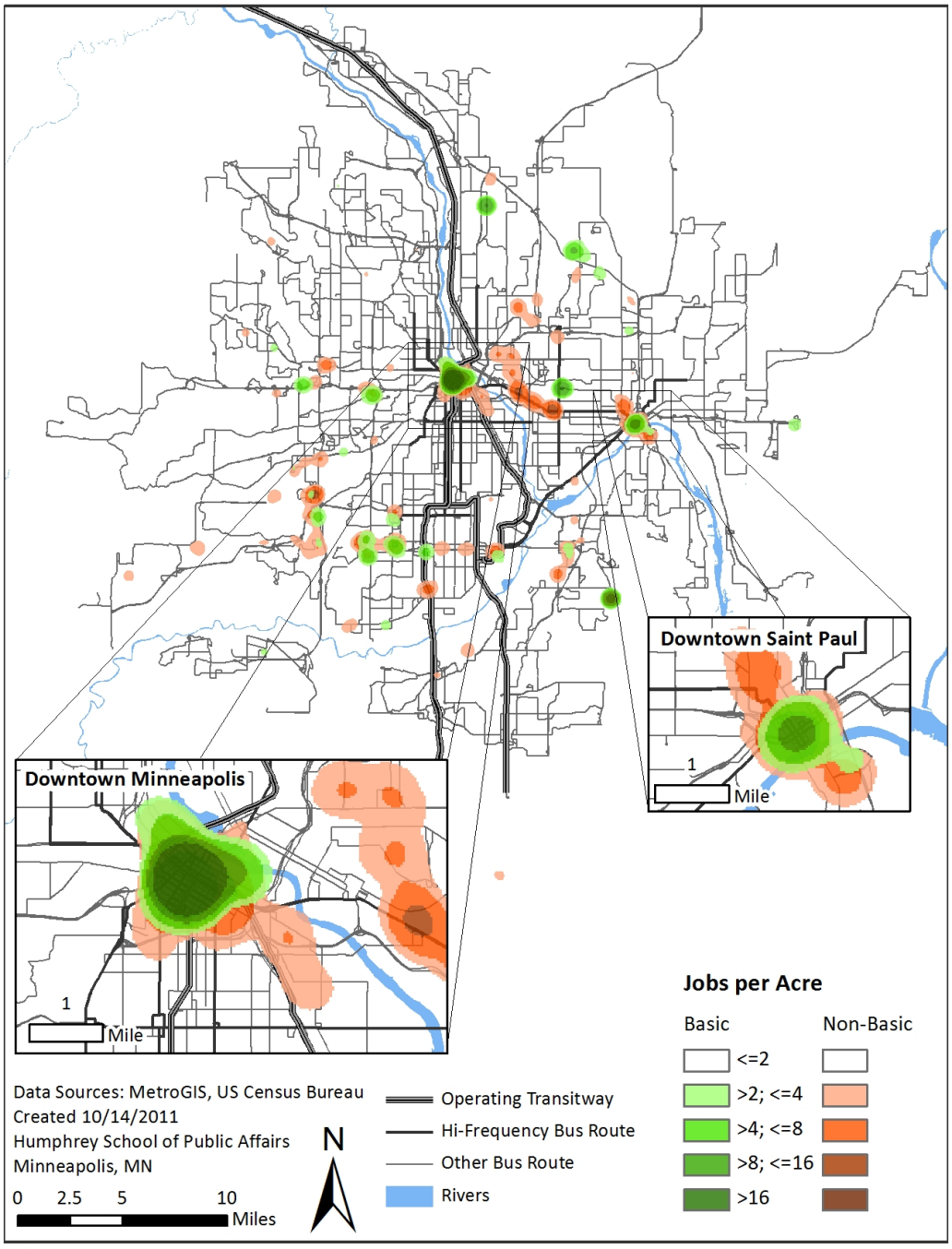

Figure 3.2: Management of companies and enterprises metropolitan job density

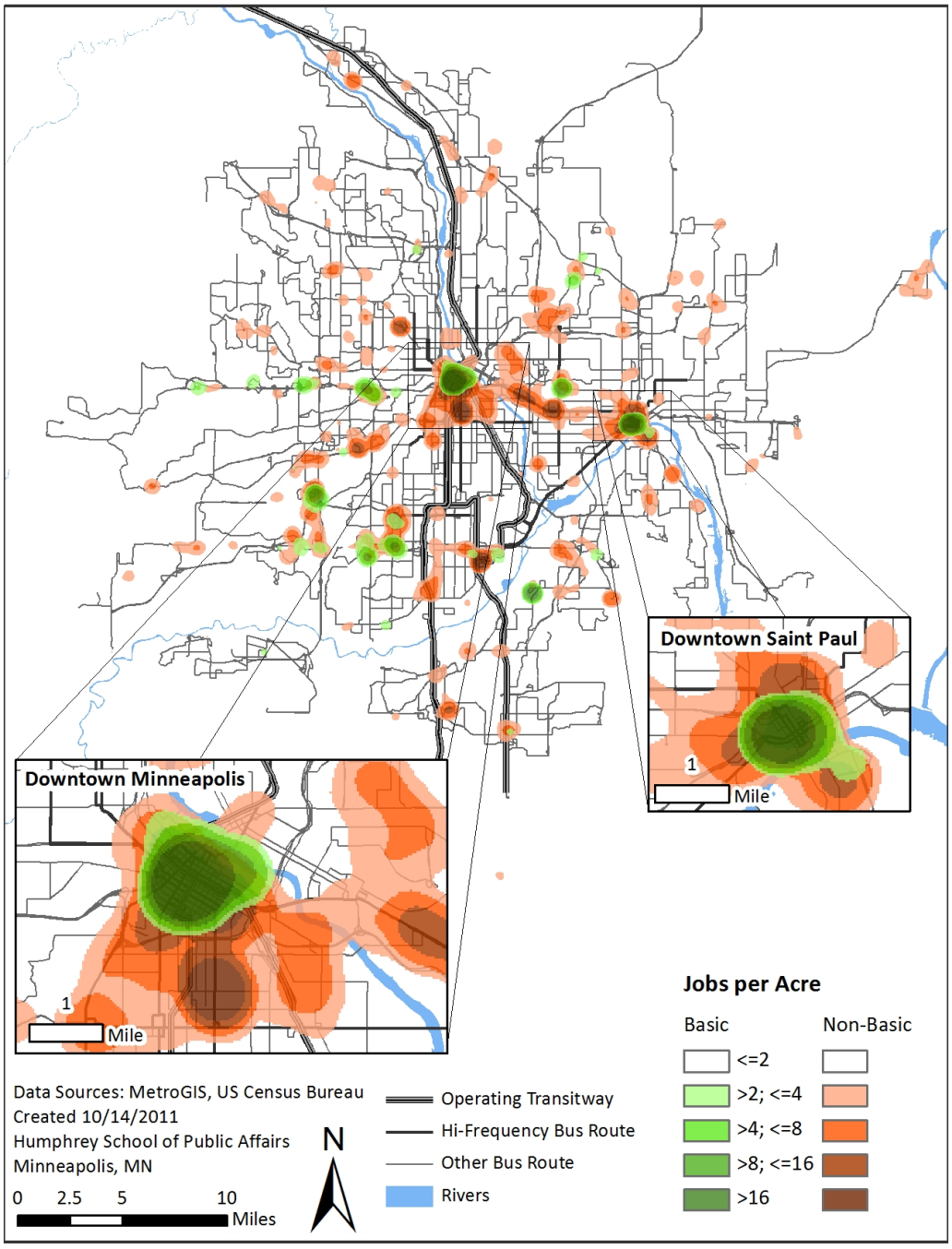

Figure 3.3: Finance and Insurance metropolitan job density

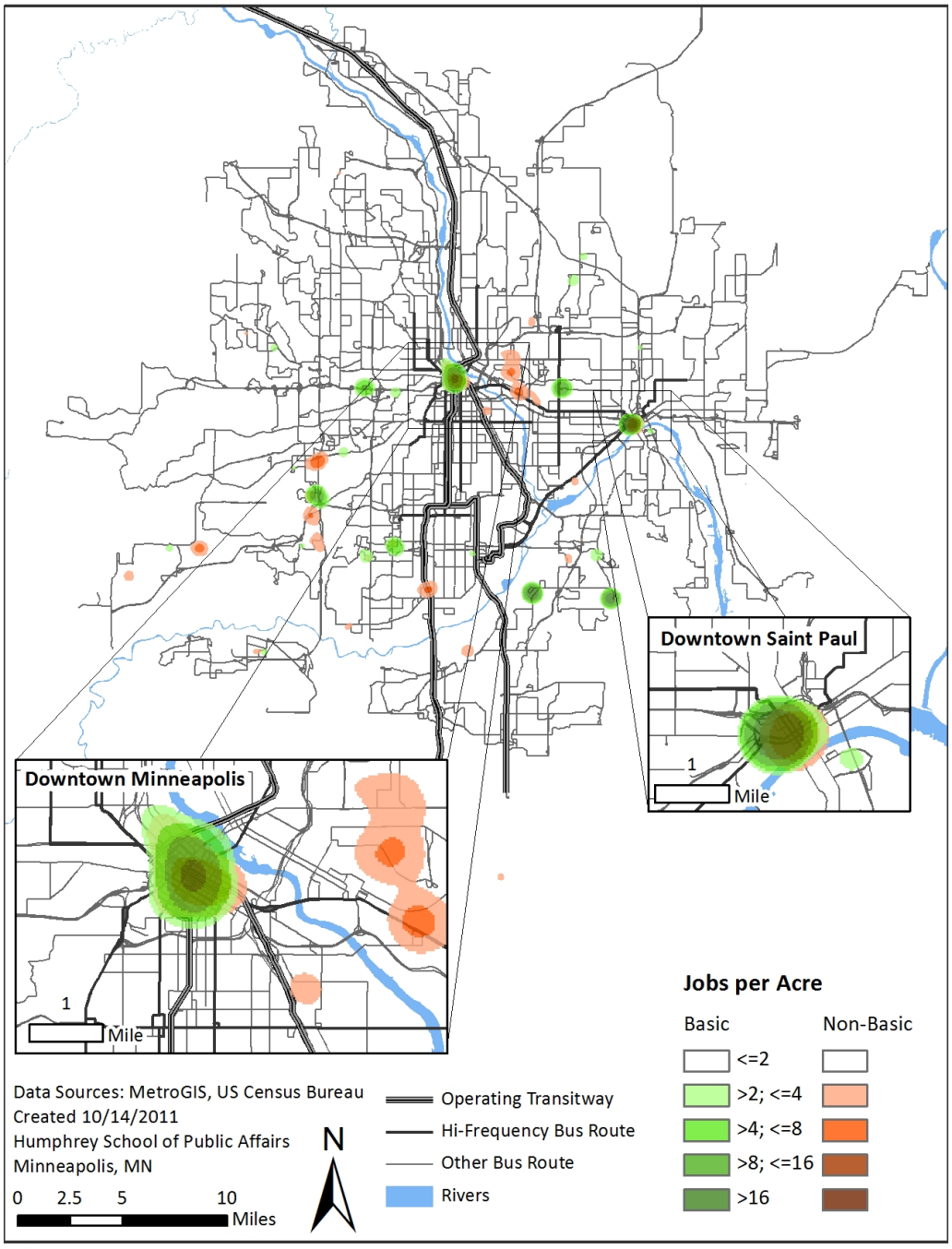

Figure 3.4: Book publishers & Printing industries metropolitan job density

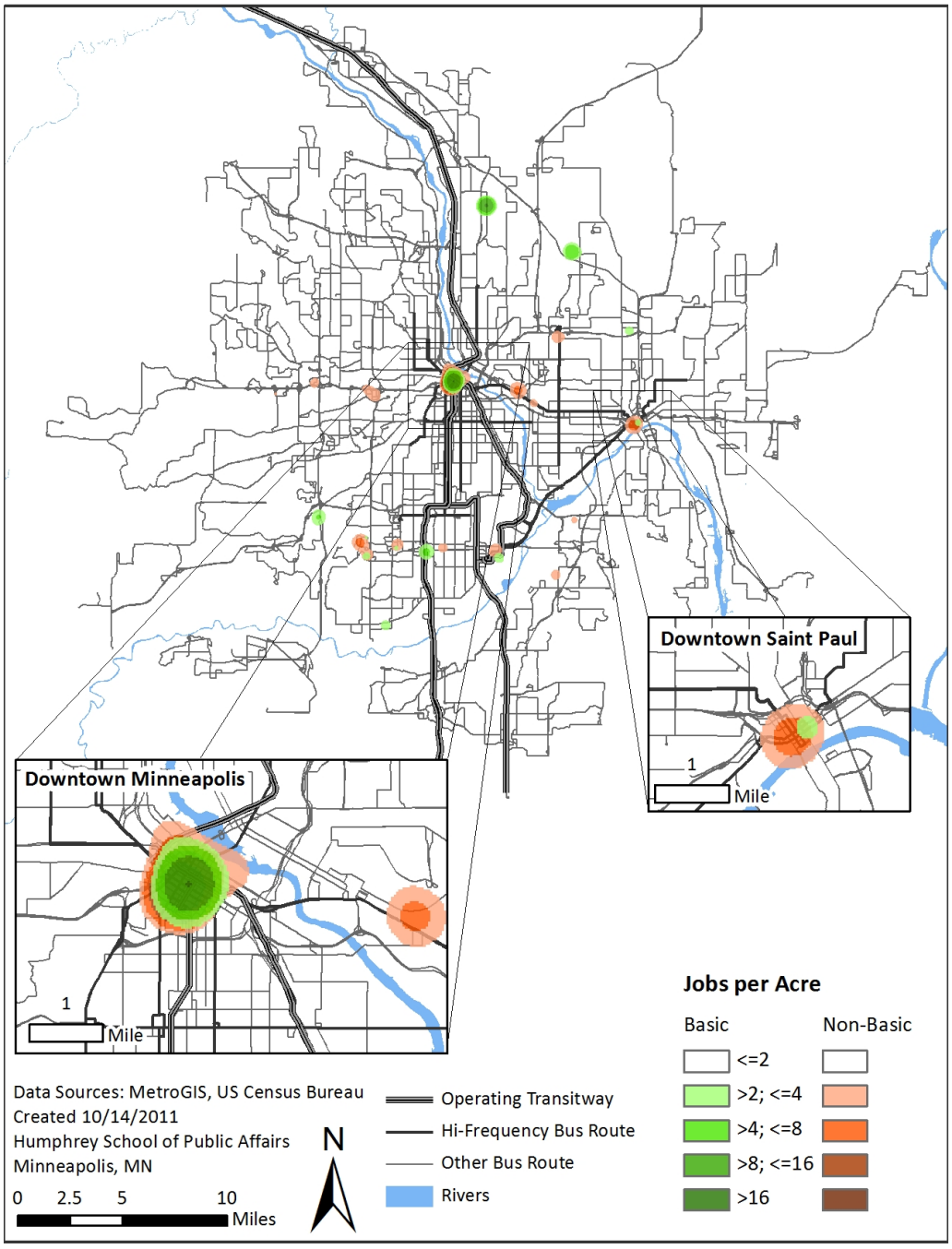

Figure 3.5: Lessors of non-financial intangible assets metropolitan job density

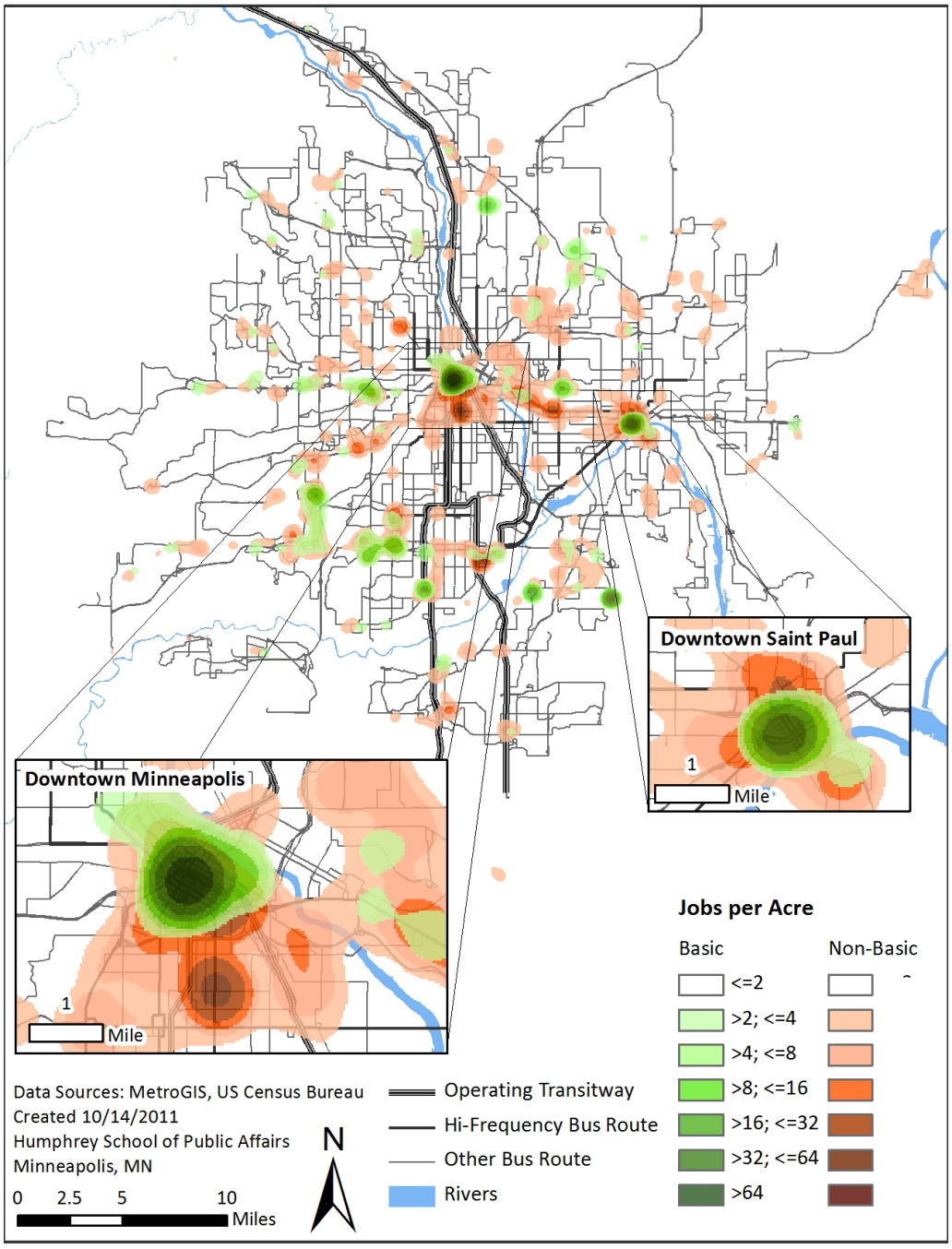

Figure 3.6: Metropolitan jobs density (All jobs)

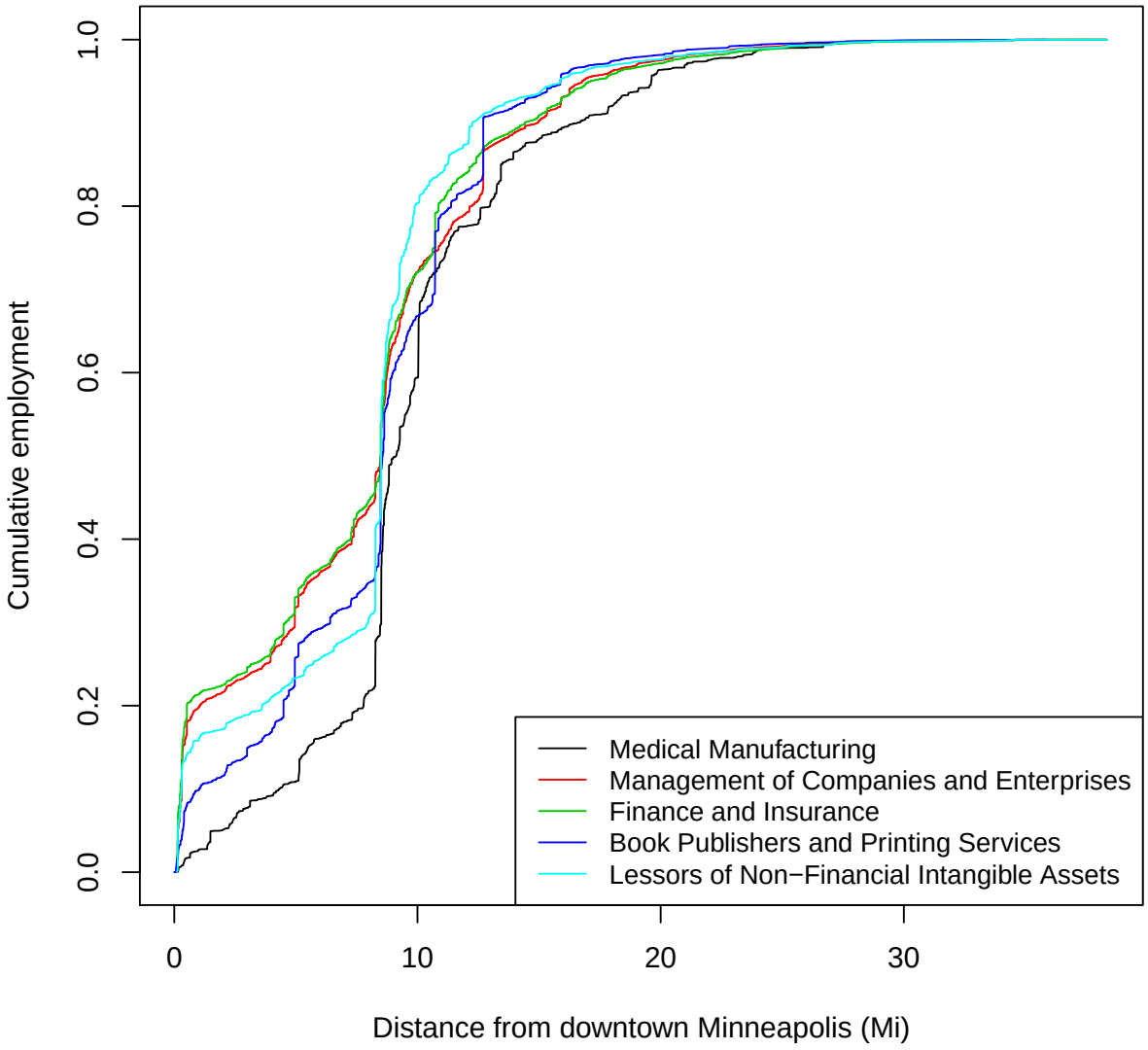

Figure 3.7: Cumulative employment in basic cluster by distance from downtown Minneapolis

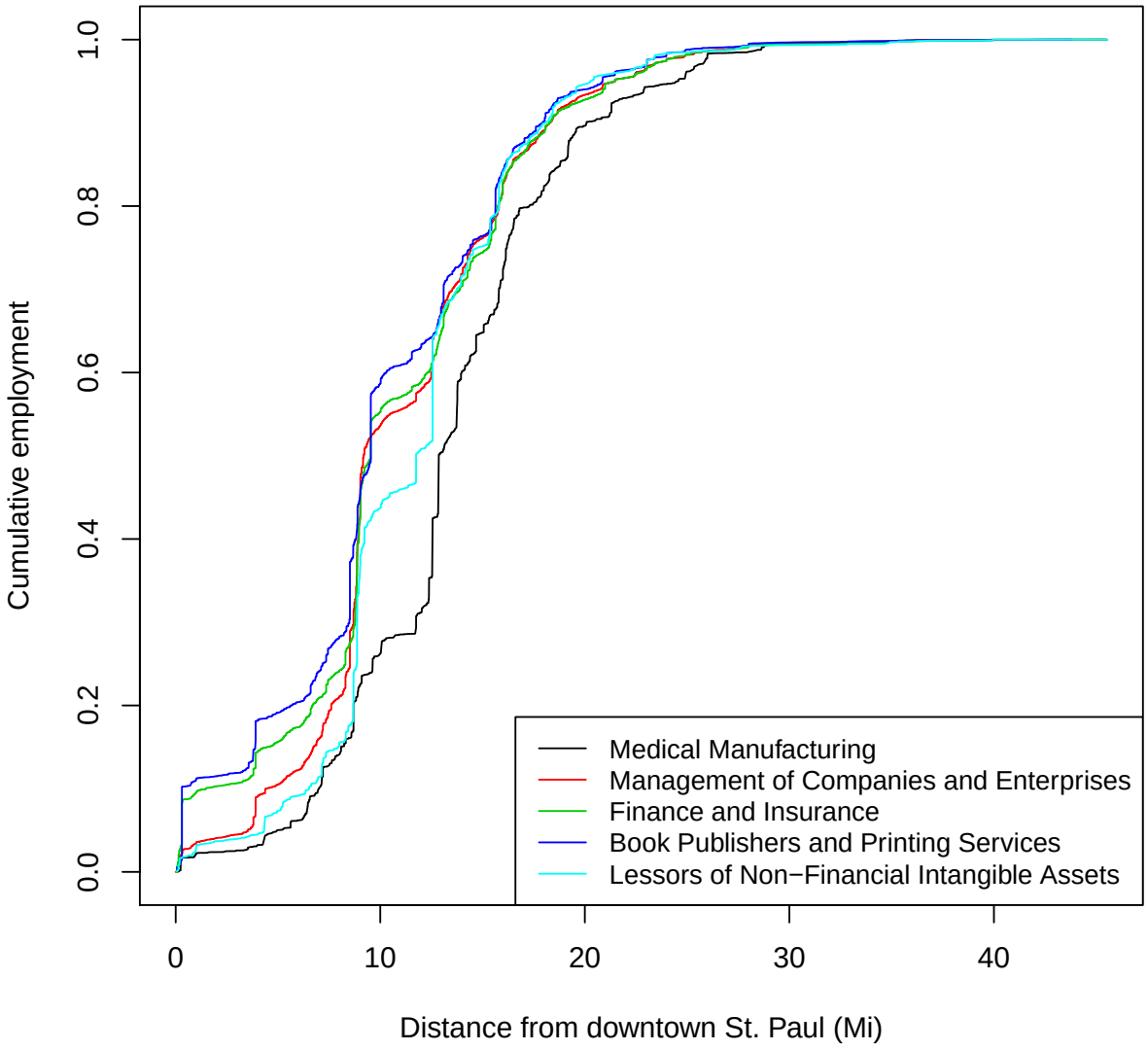

Figure 3.8: Cumulative employment in basic cluster by distance from downtown St. Paul

Chapter 4

Transit Accessibility

4.1 Introduction

In Chapter 3 we identified the competitive economic clusters in the Twin Cities region and looked at the distribution of employment in each of these clusters relative to the central business districts. This chapter builds on these findings by analyzing how accessible each of these clusters are to residents of the metropolitan area. The chapter starts by discussing the regional travel pattern and discusses where workers and their employment are currently located. This is followed by a discussion of accessibility of the cluster jobs discussed in the previous chapter as well as accessibility to all jobs. The question of accessibility is often addressed from the travelers' perspective. In the last section of the chapter, we look at accessibility to labor from each of the metropolitan area destinations.

Accessibility relates to the ease of reaching destinations. The accessibility concept encompasses both mobility, which emphasizes ease of travel in general, as well as the opportunities available at destinations (Handy, 2002; Stopher, 2004). Some level of mobility is a necessity for accessibility, but places with high levels of congestion can still maintain high accessibility as long as opportunities are plentiful. An urban form that enhances regional accessibility by transit, it is argued, can help address issues of increased auto-mobility, including congestion and environmental impacts, by providing a modal alternative. Having good transit accessibility to destinations is especially important for persons without vehicles for whom transit is an important mode. In the cities of Minneapolis and St. Paul for example, 18.8% and 15.2% of occupied households respectively have no vehicles according to 2010 ACS 5-year estimates. Even more concentrated pockets of car-less rates within these cities are not difficult to imagine. For these residents, transit is often the only way to access destinations that are farther out.

In this section we look at how accessible the cluster jobs identified in the last chapter are by transit to residents in different Twin Cities areas.

4.2 Regional Commute Pattern

The regional commute pattern in the metropolitan area was analyzed using the 2009 Longitudinal Employment-Household Dynamics (LEHD) Origin-Destination dataset for private primary jobs. The dataset provides a snapshot of commute patterns of workers in 2009. We aggregate to distance

categories in 5 mile bands from the Minneapolis downtown (0-5mi, 5-10mi, 10-15 mi, 15miles to edges of the 7 county area). The percentage of all workers originating from each band of origins and headed to each destination is given in table 4.1. For example, among workers living in the first 5 miles of Minneapolis, 46.5% also have their primary job in the same 5 miles while about 6.9% work at distances 15 miles or greater from downtown Minneapolis. This 5 mile band contains 12.6% of metropolitan workers.

Table 4.1: Commute Pattern in the Twin Cities Metropolitan Area - All Private Primary Jobs

	Destinations					% of
Origins	0 - 5 mi	5 - 10 mi	10 - 15 mi	15mi - Metro limit	Outside Metro	Metro Workers
0 - 5 mi	46.5	34.1	12.4	3.3	3.6	12.6
5 - 10 mi	28.2	45.2	17.8	4.9	3.9	22.6
10 - 15 mi	20.4	38.1	28	9.4	4.2	24.6
15 - Met. Limits	15	29.9	23.8	25.2	6.2	27.5
Outside 7 county	3.5	7.6	4.8	3.8	80.4	12.7
% of all metro jobs	24.6	38.5	23	13.8	-	

The same table also contains the breakdown of metropolitan jobs in each ring around downtown Minneapolis. The first 5 miles of downtown Minneapolis also contains nearly 25% of the metropolitan jobs. The second, third, and final bands each constitute 38.5%, 23%, and 13.8% of metropolitan jobs. The challenges of serving these different locations by transit becomes very clear from the distribution of jobs. If we assume each each band constitutes a circle (doughnut), the second band is would be three times as large in area as compared with the inner circle. Even though it contains many more jobs than the first circle, the jobs are spread over a much larger area. The 10-15 mile band would be about five times as large as the inner core and has a lower number of jobs and so on. The worker density argument also proceeds in a similar fashion. The second ring, which contains about an additional 10% of the metro workers, has them distributed over an area three times as large.

4.3 Accessibility to Cluster Jobs

Measures of accessibility can range from those that count number of jobs within a given travel time to those that are specified in gravity-like functions and incorporate both attractiveness and a cost of travel. In this section we compare how well transit can access jobs in the seven county metro area, and how that compares to the overall jobs access in the region.

We use two metrics to measure the level of access. One uses the percentage of firms located within a half-mile radius of a high-frequency transit stop.This measure looks at whether the location of jobs is within acceptable walking distance if a person is able to reach the transit stop/station. A second measure is taken from the perspective of residents in each census block. This measure

looks at what percentage of all jobs and cluster jobs are accessible by transit for residents given the currently available transit patterns from their residences.

We analyze accessibility at the census-block level for the metropolitan area. The analysis uses business data business and employment data in the metropolitan area which includes 1,395,383 jobs at 110,325 firms. This data is initially supplemented by findings from Chapter 3 to identify the regional competitive cluster each firm belongs to. This is done by using the firm's NAICS code and matching that to the IMPLAN code for the particular firm.

Based on this analysis, 15.7% of the businesses belong to at least one of the basic clusters, and an additional 50.49% belong to the wider cluster defined around the anchor sectors. Firms in the basic clusters account for 18.9% of the jobs in the DUNS data, and those only in the expanded cluster account for 43% of the jobs in the business data, together covering about 62% of all employment. The remaining firms are either unclassified (5.9%) or their primary NAICS is not identified as having a significant trading relationship with the anchor sectors.

For the accessibility calculation, we sum the total employment as well as employments in each of the basic and expanded clusters and aggregate total employment for the census block that firms are located in. In addition, 2005 data for metropolitan transit travel times from block to block, and location of transit stop/stations is used to measure the accessibility of jobs.

4.3.1 Jobs within a Half-Mile of a Transit Stop

The first analysis measures the percentage of jobs within a half-mile radius of transit stations. We find that upwards of 80% of jobs are located within a half mile of a transit station using all transit stations in the metropolitan region. However, many of theses stations don't have high-frequency service. Narrowing down the list of stations to those served by high-frequency transit service (those with headways of 15 minutes or less), the percentage drops for all clusters. Significantly lower percentages of jobs in the Electromedical Appliances Manufacturing anchored cluster and Book Publishing anchored clusters is noted. Less than 10% of jobs in the medical manufacturing sector are served by such transit. The highest level among basic clusters is measured for those sectors making up the finance and insurance cluster. The summary percentages are given in Table 4.2.

Table 4.2: Percentage of jobs within a half-mile radius of high-frequency transit stop/stations

	Sector	Basic cluster	Expanded cluster
1	Medical manufacturing	9.6	13.8
2	Management of companies	33.8	28.1
3	Finance and Insurance	39.8	29.7
4	Book publishing and Printing	31.0	23.8
5	Lessors of non-financial intangible assets	25.3	30.6

4.3.2 Jobs Accessible within 30 minutes and 60 minutes of Transit Travel Time

We next look at what percentage of jobs are accessible within a 30 minute and 60 minute transit travel time from each of the census blocks in the region using a.m. peak period transit travel times. This analysis is done at the census block level. In this case, all jobs at a destination block are assumed to be reachable if the transit travel time from the origin block (for which access is calculated) is within the 30- or 60-min thresholds, regardless of whether or not the sector falls within a half mile of a transit stop. In effect, this makes our measure a bit more generous than reality, especially for suburban census blocks that are relatively large in size. While the earlier analysis looked at the availability of a transit stops near the employment sectors, this looks at whether service is available to the destinations within reasonable travel times.

The analysis shows that the average transit accessibility to all jobs within 60 minutes in the metro area is 7.1% with some blocks having access to as much as 51.6% of jobs and others having no access to jobs by transit. The average accessibility (in terms of percentage of jobs accessed) to each of the clusters is given in table 4.3.

Table 4.3: Average accessibility by Metro blocks to cluster jobs within 60 and 30 minutes of transit time (expressed in terms of percentage of jobs in cluster)

	Cluster	60 min Basic	60min Expanded	30 min Basic	30 min Expanded
1	Medical manufacturing	3.4%	3.9%	2.4%	2.7%
2	Management of companies	10.9%	8.1%	6.8%	5.2%
3	Finance and Insurance	12.8%	7.4%	8.0%	4.9%
4	Book publishing and Printing	8.3%	6.3%	5.4%	4.1%
5	Lessors of non-financial intangible assets	9.3%	10.0%	5.9%	6.3%
6	All jobs	7.1%		4.7%	

Among the basic clusters the most accessible by transit are those falling under the Finance and Insurance, Management of Companies, followed by Lessors of Non-Financial Assets. The lowest levels of accessibility are calculated to the Medical Manufacturing cluster. Medium levels of accessibility are achieved for jobs in the Book Publishers and Printing services. Intuitively, these findings appear sensible as the highest accessibilities are for the sectors that are most office-centered and likely concentrated in the CBDs.

Relative to all jobs in the region, jobs in the basic cluster generally fare better in terms of access by transit. The average census block accessibility of 7.1% and 4.7% of all jobs are exceeded by all basic cluster access levels except for Medical Manufacturing. For the expanded clusters, average access levels to Medical Manufacturing and Book Publishing and Printing clusters fall below the all jobs access levels. Maps of regional transit accessibility to all jobs as well as jobs in the five clusters at 30 and 60 minutes are given in figures 4.1 to 4.10.

Current access levels are ordered in a manner that reflects the proportion of jobs in the metropolitan area that each cluster makes up. Figures 4.11 and 4.12 each plots the jobs in the cluster as a

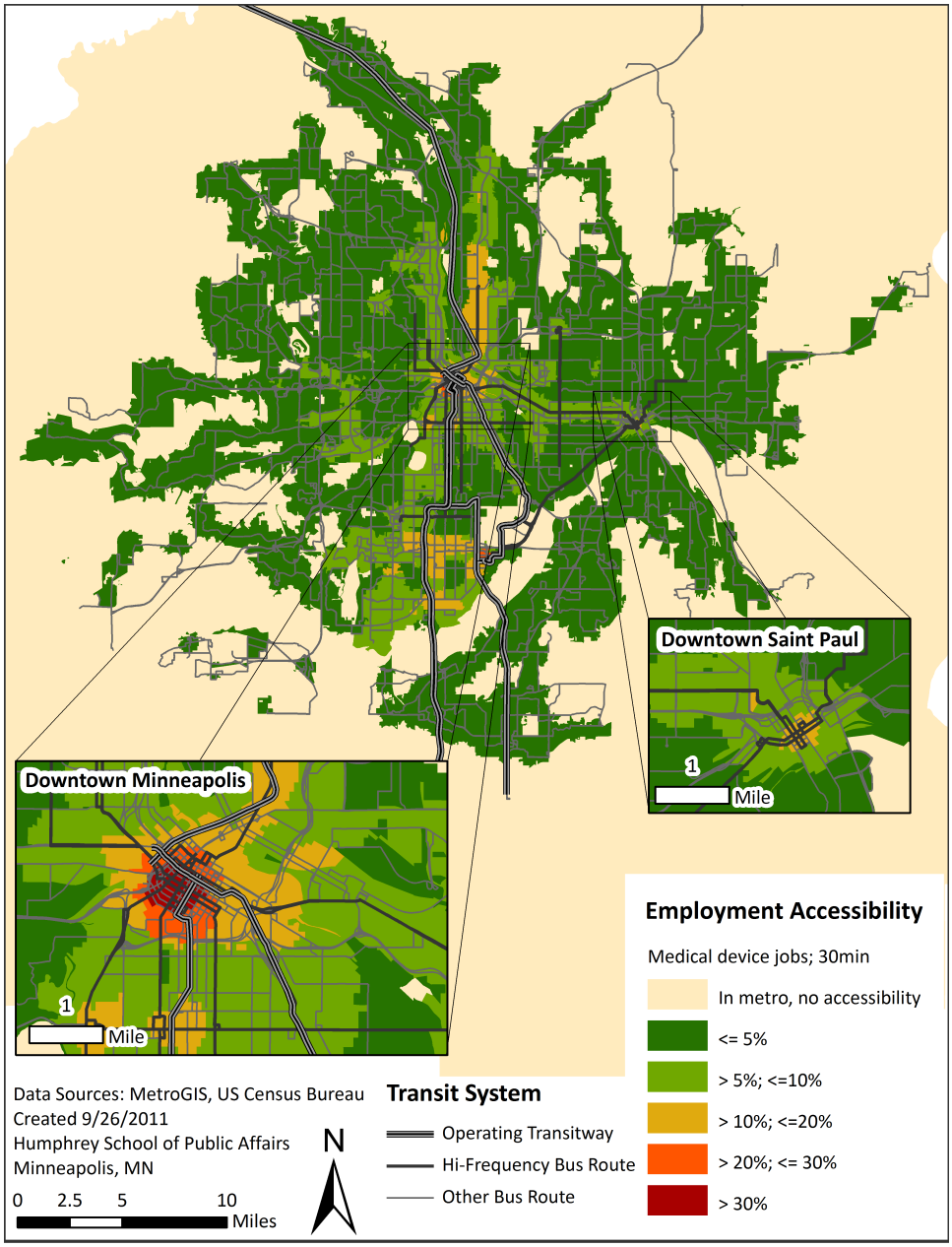

Figure 4.1: Half hour transit accessibility to the Medical Equipment Manufacturing cluster jobs

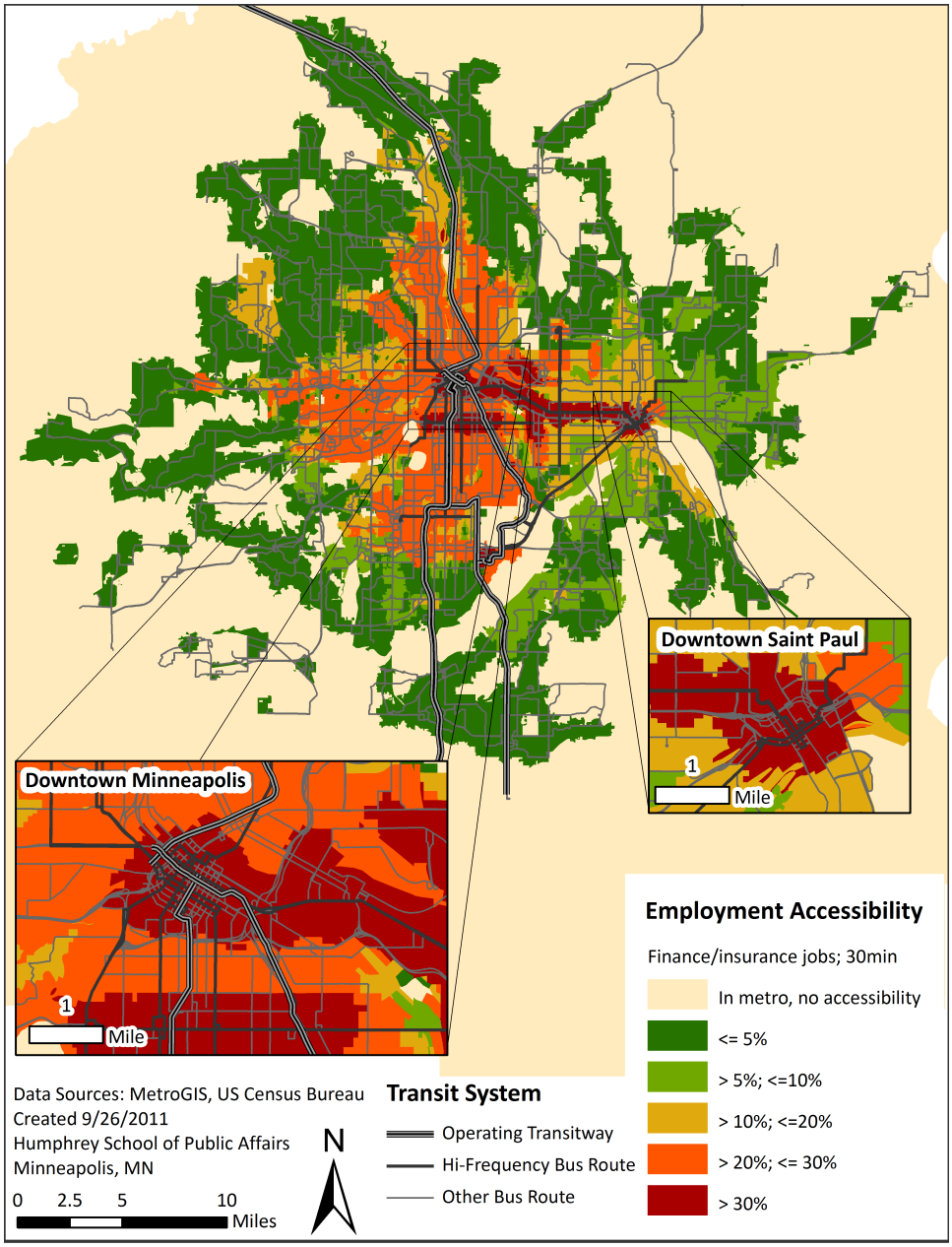

Figure 4.2: Half hour transit accessibility to the Finance and Insurance cluster jobs

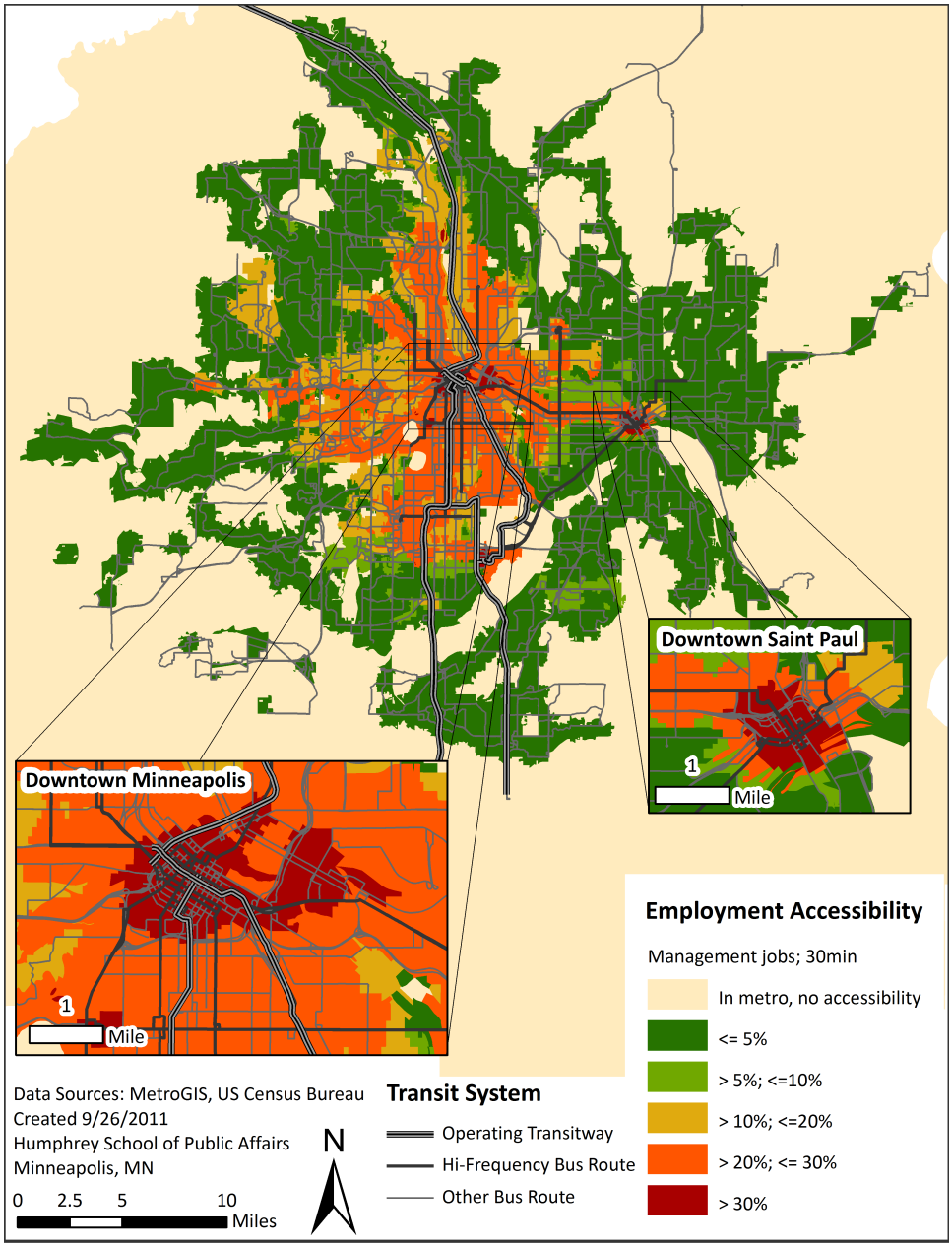

Figure 4.3: Half hour transit accessibility to the Management of Companies cluster jobs

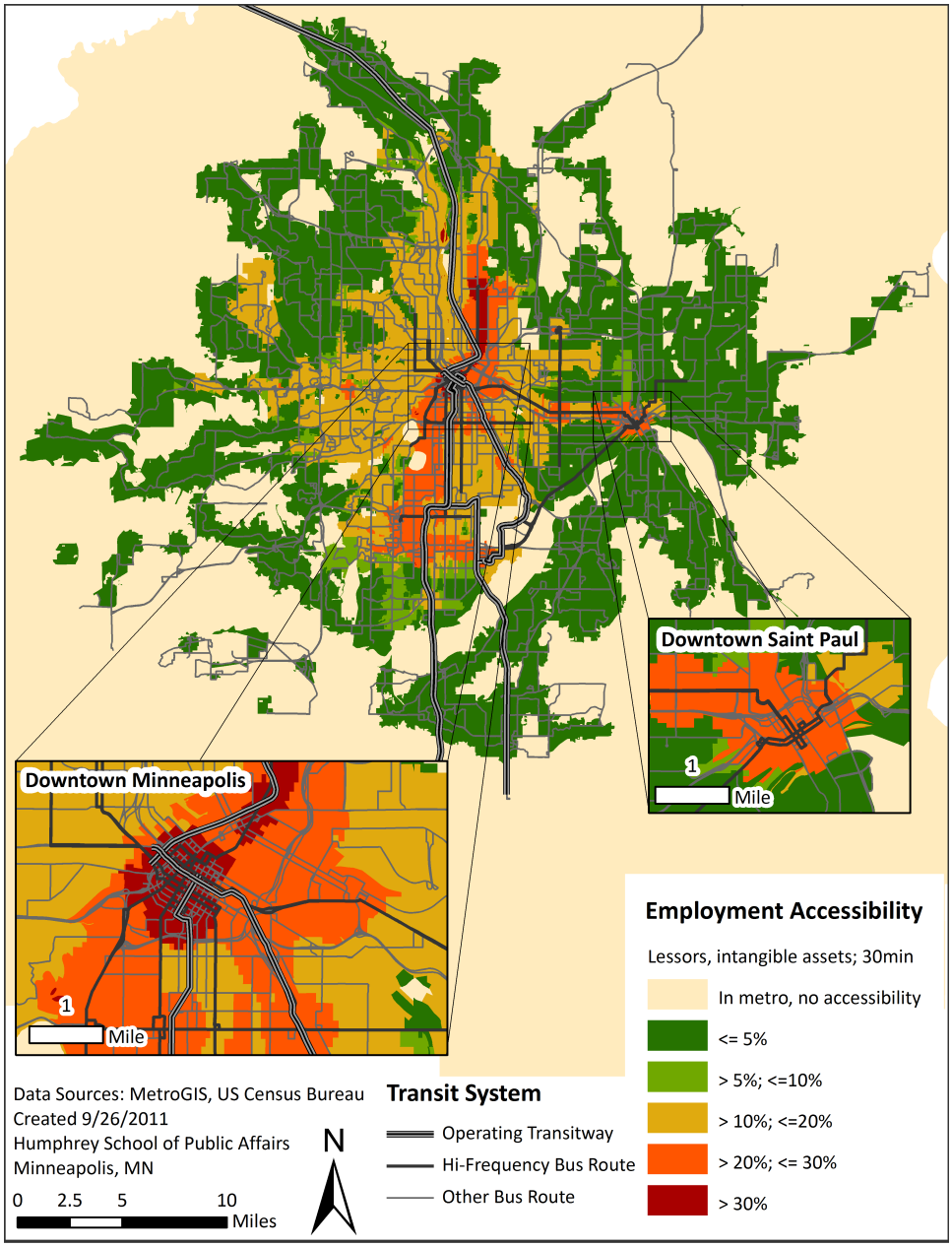

Figure 4.4: Half hour transit accessibility to the Lessors of Intangible Assets cluster jobs

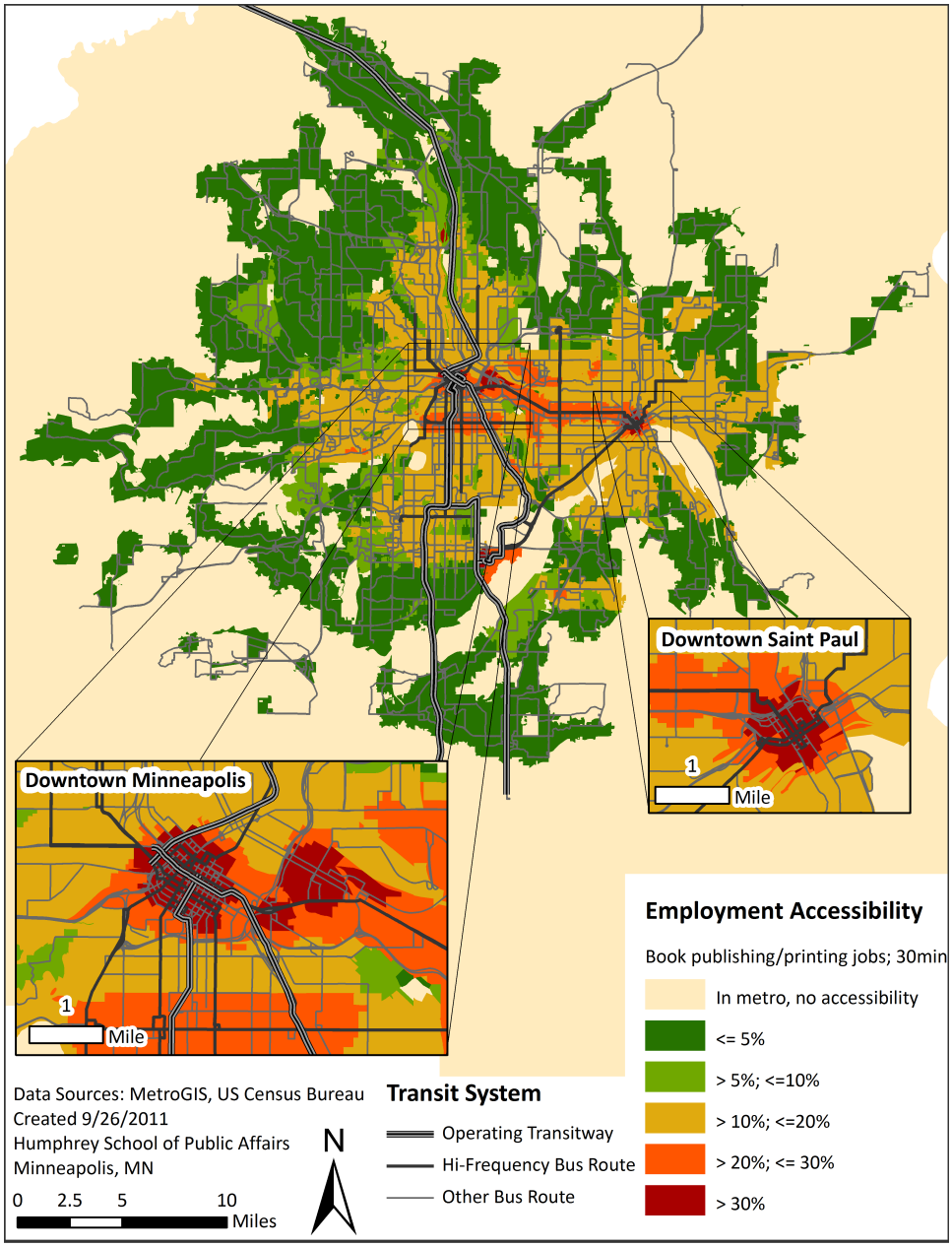

Figure 4.5: Half hour transit accessibility to the Book Publishing and Printing cluster jobs

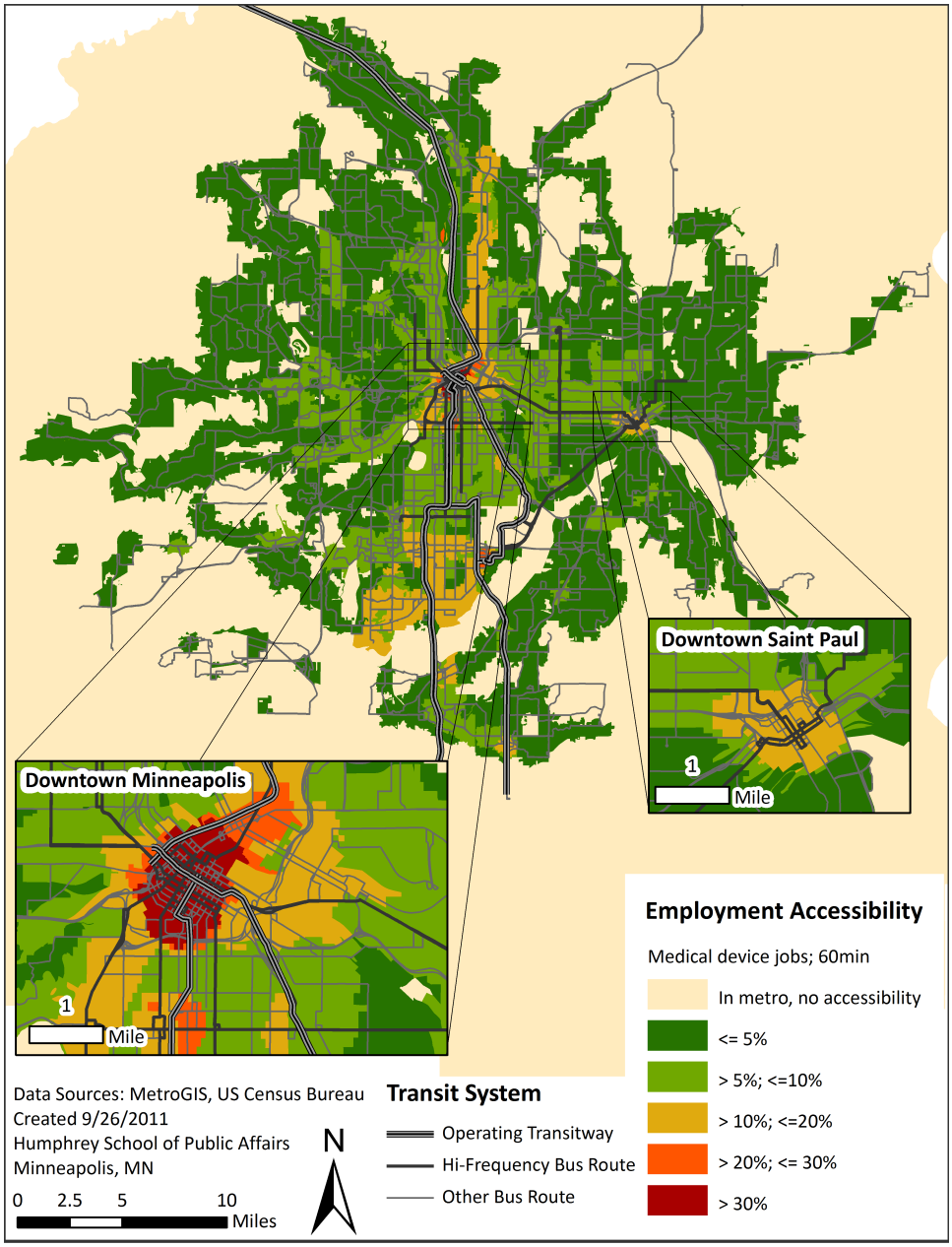

Figure 4.6: One hour transit accessibility to the Medical Equipment Manufacturing cluster jobs

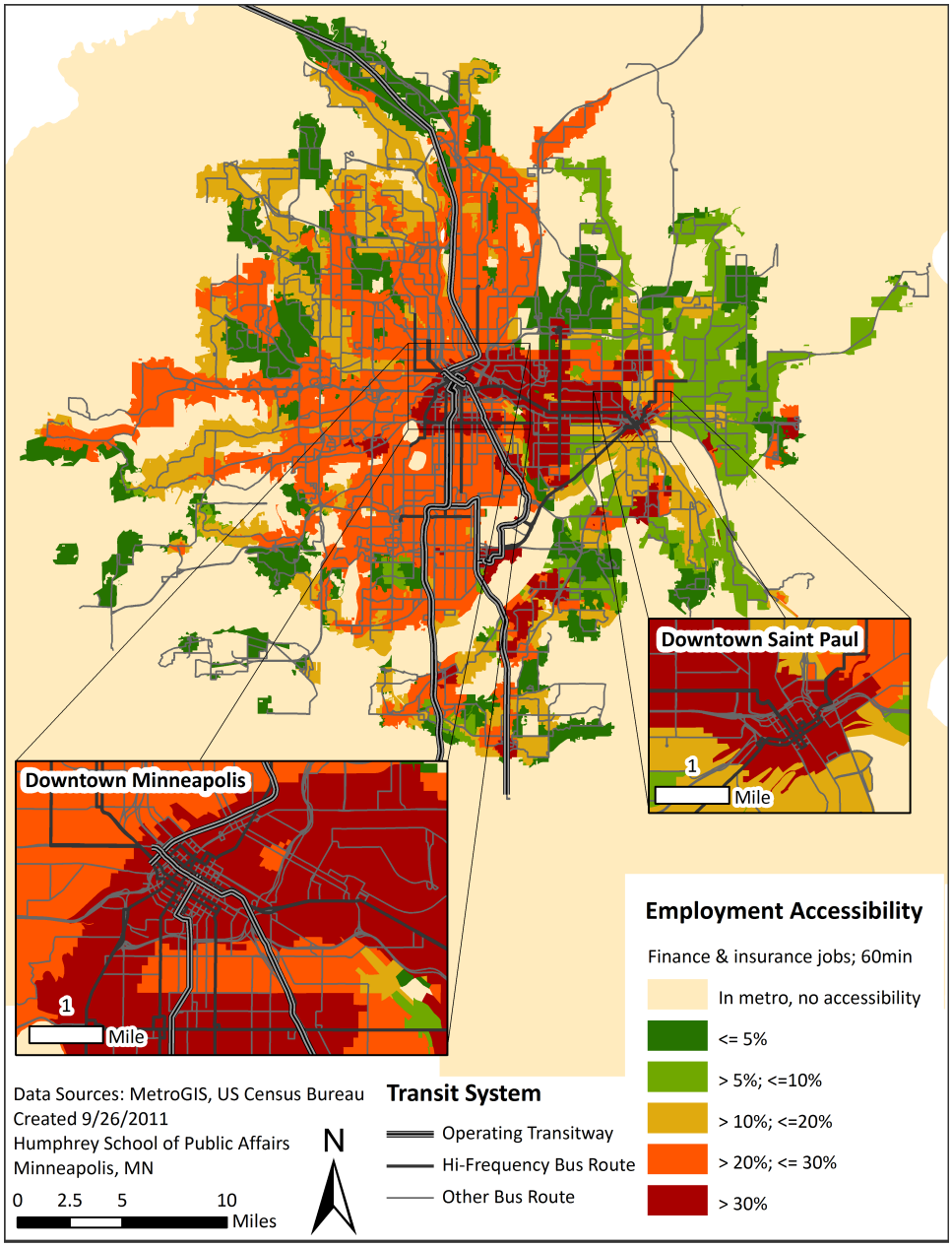

Figure 4.7: One hour transit accessibility to the Finance and Insurance cluster jobs

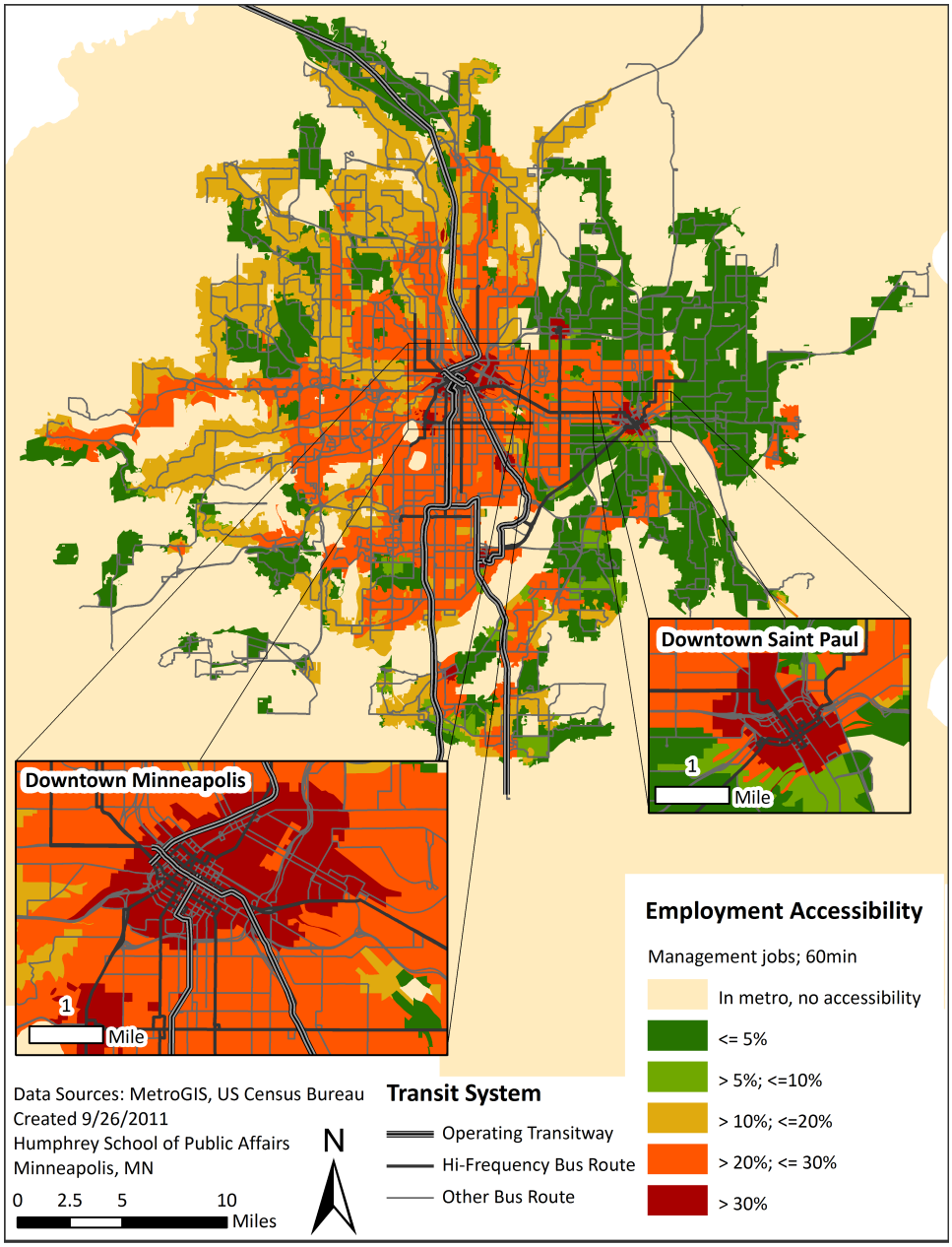

Figure 4.8: One hour transit accessibility to the Management of Companies cluster jobs

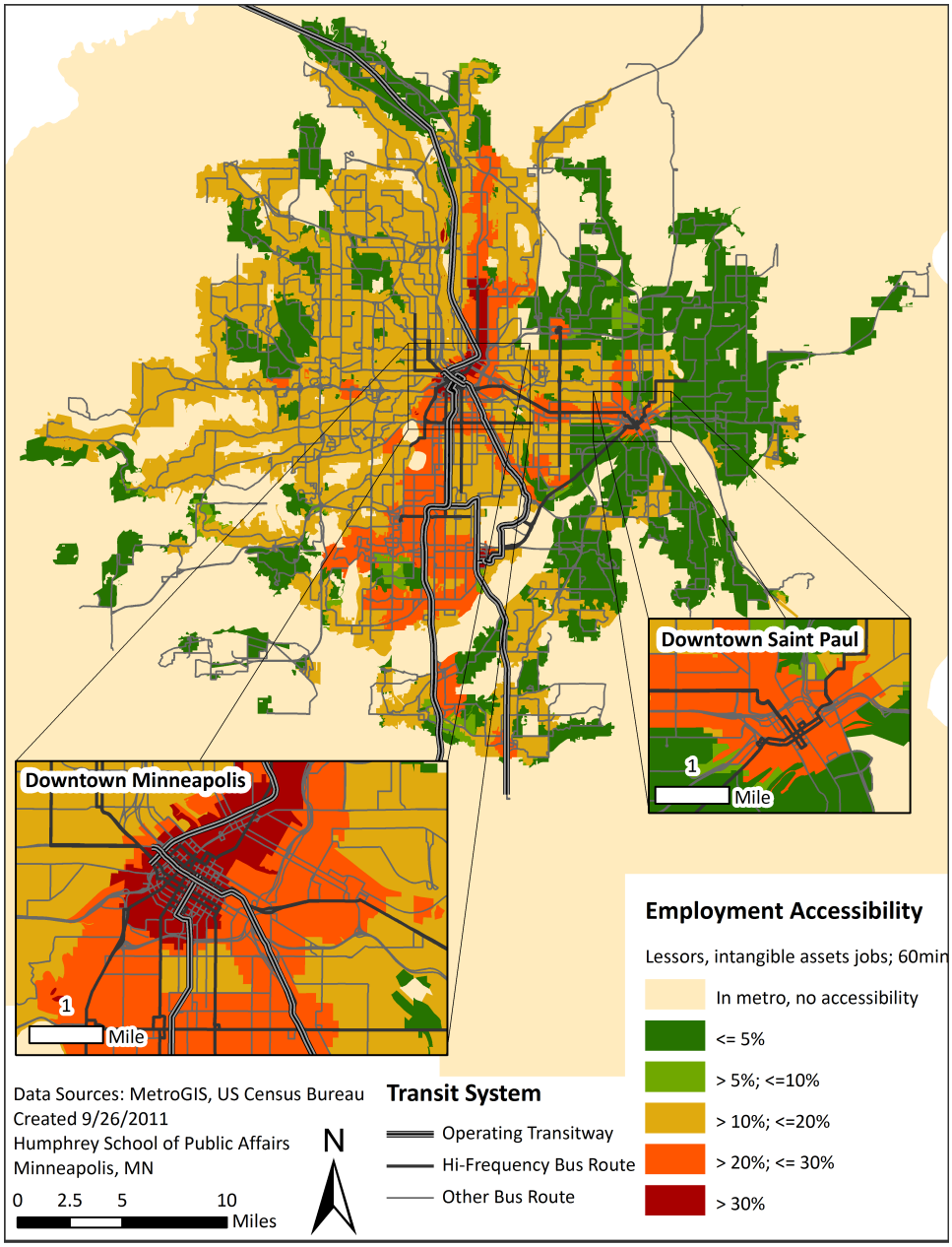

Figure 4.9: One hour transit accessibility to the Lessors of Intangible Assets cluster jobs

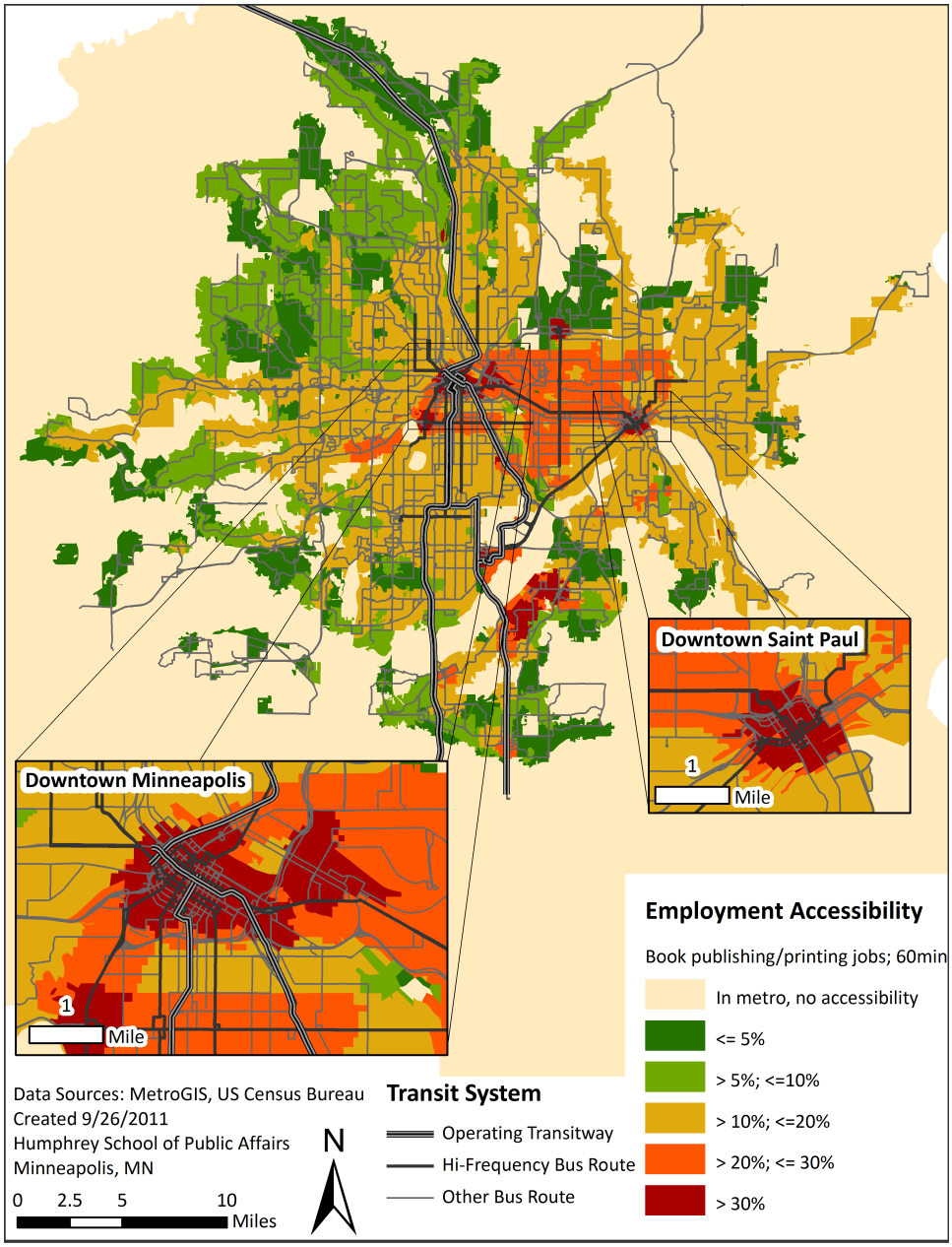

Figure 4.10: One hour transit accessibility to the Book Publishing and Printing cluster jobs

percentage of all the regions job against the average percentage of cluster jobs that are accessible from the different blocks in the metropolitan area.

This pattern changes somewhat when the more expanded cluster is taken into consideration. Clusters around the Finance and Insurance and Management of Companies now make up 46.9% and 25% of all employment. Access to these clusters is, however, lower than that for Lessors of Non-Financial Assets which makes up around 8% of all regional jobs. This arises because both these two anchors have a significantly large number of sectors trading with them, and many of them are spread out in a manner that is not currently well served by transit. The percentage of jobs in each of these sectors that is accessible by transit is higher than those in Medical Manufacturing or Book Publishing and Printing.

4.4 Access to Labor from Employer's Perspective

Thus far, our analysis has focused on accessibility to jobs by transit from the residential perspective. This approach measures the potential for residents to reach jobs around them. Looking at the problem from the employer's perspective, the number of workers that a firm at a given location has access to is more important. However, as the location analysis in Chapter 3 has shown, considerations of labor access are often influenced by the nature of the industry. Those that are manufacturing-centered choose locations that favor easier movement of goods along freeways while those that are mostly office-centered tend to locate in the central business districts. This approach, along with an analysis of the concentration of jobs at the destinations, can show areas where current labor access is limited but which could potentially benefit from being connected to new origins. In addition, it can also highlight areas where current access is reasonably high but where there are a limited number of job opportunities.

This analysis is done both for all workers and low-wage earners. Access levels to workers for firms located in each of the census blocks is calculated using data from LEHD for primary private jobs. For each census block, a list of those origins that can reach it within 30 and 60 minutes are first identified. Then, the number of all workers and low-wage earners at each origin are summed. This gives us the potential total worker pool and low-wage earners that employers at each block group have access to. Figure 4.13 shows the percentage of all workers that firms at a given blockgroup can access in a 30 minute transit travel time. Figure 4.14 shows the same percentage using only low-wage earners.

Both of these figures illustrate how limited transit access by labor is at any given destination outside of the two downtowns. In addition, the maps for all workers and low-wage workers are virtually identical except in a few places. This has implications for the equity dimension of transit which we will see in the next chapter. Overall, few places outside of the downtown cores have access to a substantial amount of labor by transit within a 30 minute travel time. Given that workers are likely to choose lower travel time alternatives when they have an option, the sparse use of transit outside of downtown cores is readily apparent. The access maps also show individuals who are unlikely to have an alternative mode are largely not connected in a better manner to most destinations.

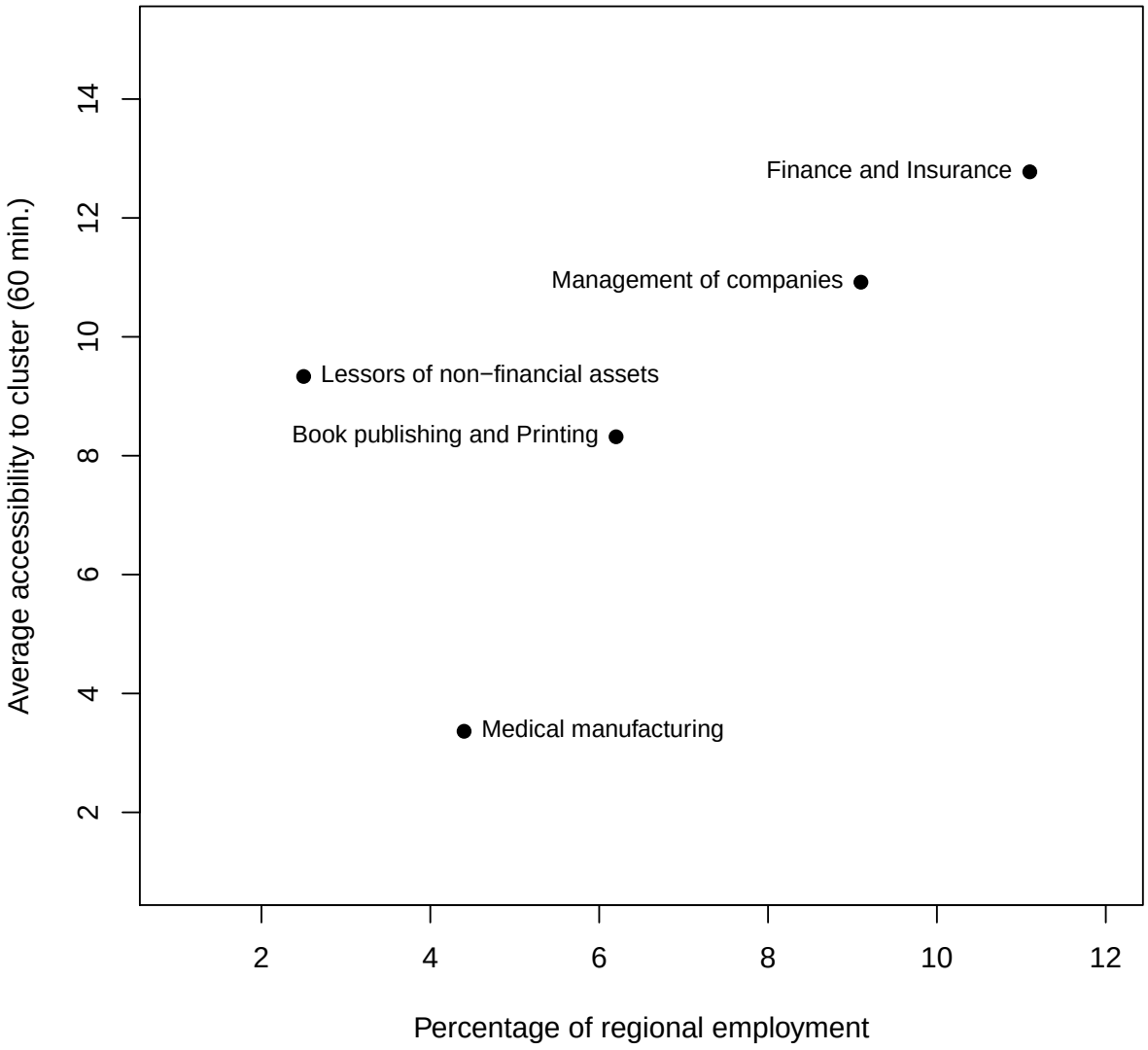

Figure 4.11: Basic cluster jobs as a percentage of all metro jobs and relative accessibility

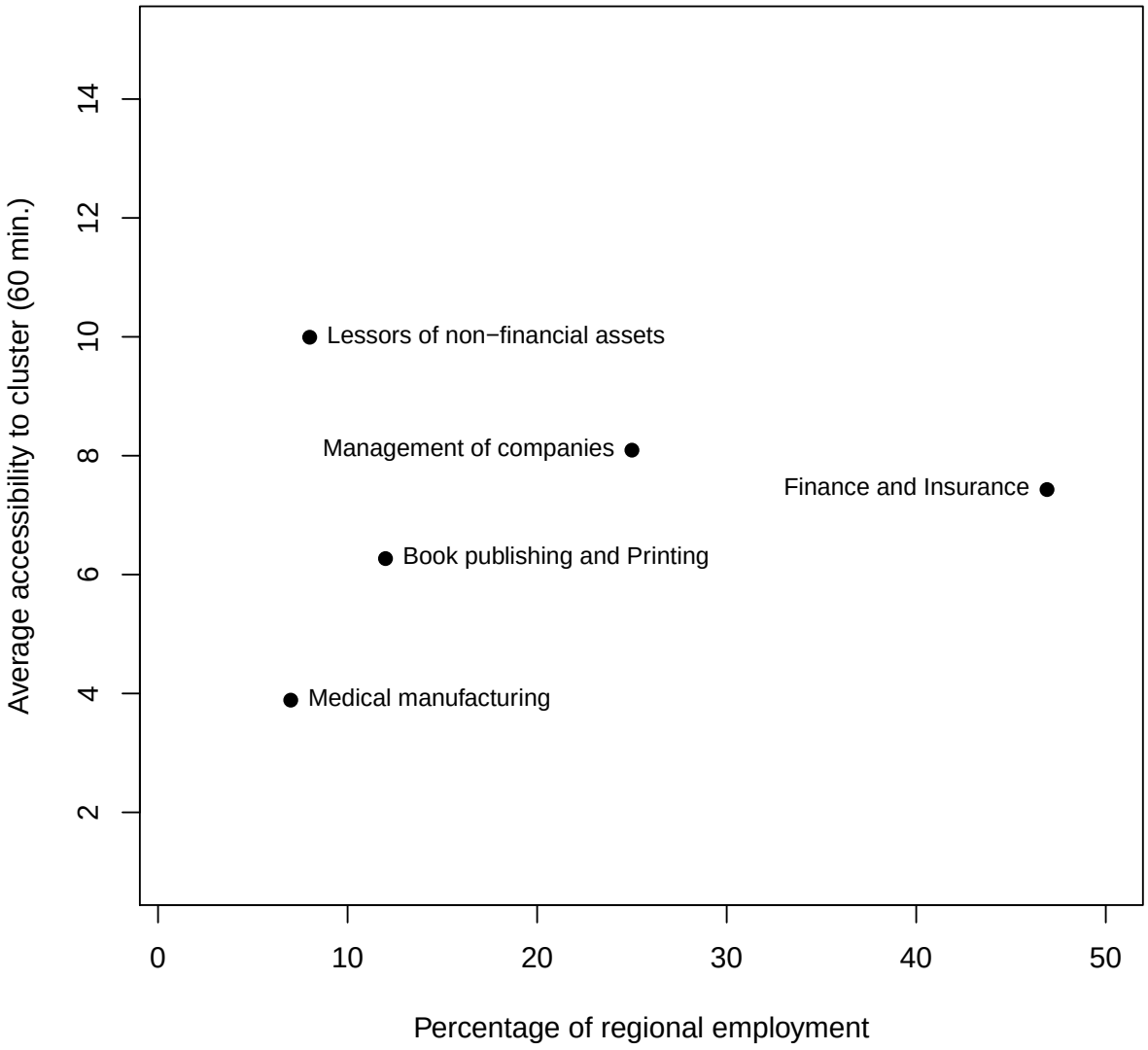

Figure 4.12: Expanded cluster jobs as a percentage of all metro jobs and relative accessibility

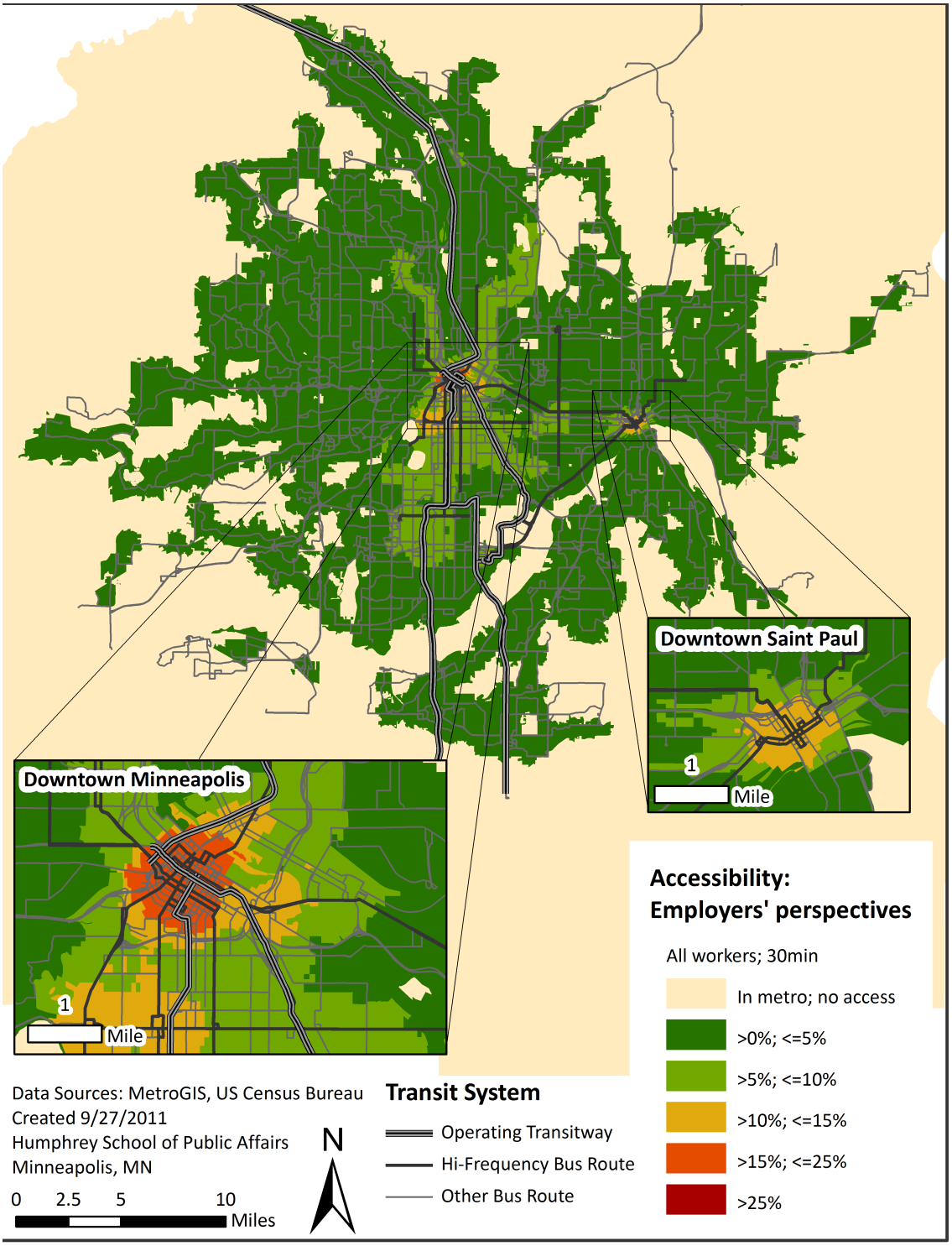

Figure 4.13: Percentage of workers accessible to firms within 30 minutes of transit travel time

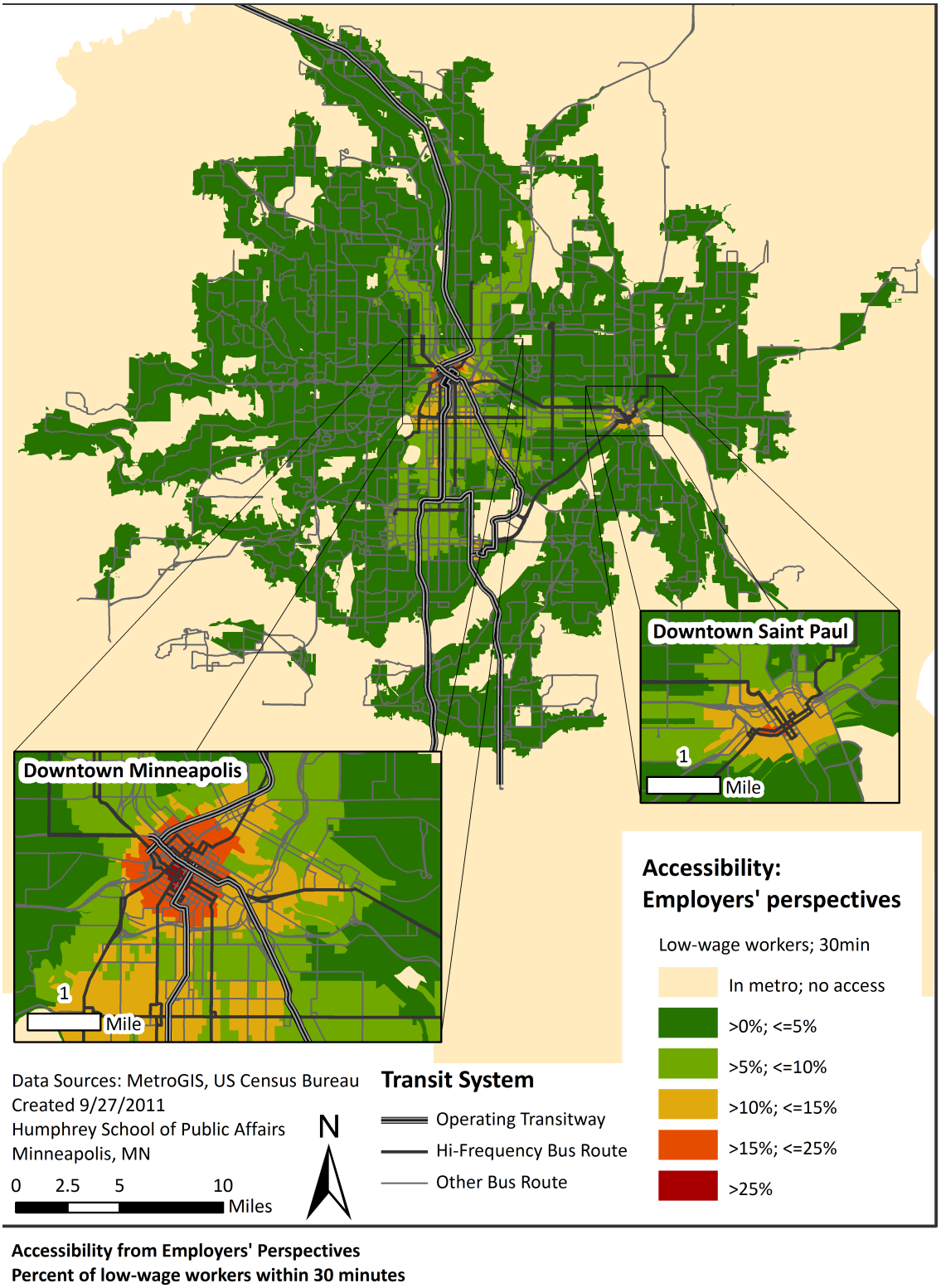

Figure 4.14: Percentage of low-wage workers accessible to firms within one hour of transit travel time

4.5 Summary

This chapter has presented several analysis relating to the current distribution of workers and jobs and the ability to access each from the different metropolitan areas. The analysis of accessibility of cluster jobs presented two results that reinforce one another. First is that there is a significant cluster-to-cluster difference in firm location which affects the proportion of jobs that are served by transit (i.e., that are within a reasonable walking distance of transit stops). For example, the medical-manufacturing cluster has less than 9.6% of its jobs that are within a half mile of a high-frequency transit stop. The inclusion of those non-basic sectors that are suppliers to medical manufacturers increases the proportion of jobs with transit access, indicating that some of the latter are significantly better located to be accessed by transit. Other clusters such as Book Publishing and Printing, Finance and Insurance, and Management of Companies have a relatively larger percentage of their jobs accessible to transit. In these cases, however, the inclusion of the non-basic sectors reduces the percentage of accessible jobs - suggesting that many of the supporting jobs are located away from transit stops.

The second analysis looked at the variation of percentage of jobs that are accessible within a defined threshold of transit travel time. This analysis reinforces the first one by indicating, for example, that access levels to jobs in the Medical Manufacturing sector are very limited as compared to other sectors. For workers, good accessibility to this sector requires either ownership of an automobile, living in the few metropolitan areas where relatively better transit access is possible, or accepting much longer travel times. Other clusters such as finance and insurance do relatively better comparatively in being accessible from many metropolitan areas. Less dramatic, but still considerable differences are also present in other clusters. For example, Book Publishing and Printing is relatively accessible to persons living along the I-94 corridor connecting Minneapolis and St. Paul while it is much less transit accessible for persons living in the northwestern part of the metropolitan area. In addition, as the travel time threshold is expanded from 30 minutes to 1 hour, the percentage of jobs that are accessible for many places rises considerably.

Finally, the analysis looked at the level of access to labor that is possible for firms located in the different parts of the metropolitan area. For most places, transit access levels are small in percentage terms. It is clear that employers' transit accessibility to labor in this region is generally lower than workers' transit accessibility to jobs. This is a reflection of the more dispersed nature of residential locations. Because jobs are relatively more concentrated than residents, there are more places close to areas with job concentration and well-served by transit for job access than places close to areas with residence concentration and well served by transit for labor access. In this scenario, downtowns and places close to the downtowns perform relatively better in terms of access to labor than most places in the metropolitan area.

Chapter 5

Transit Accessibility and Social Equity

5.1 Introduction

The preceding chapters have looked at accessibility as a measure of transit service. Often however, in addition to the level of service provided, the distribution of service is also of interest. Transit service can serve as part of the package of tools aiming to connect those without automobiles to a wider range of opportunities. In this chapter we evaluate how current transit service meets desired accessibility equity goals. This analysis can provide the basis for evaluating how future changes to the transit system could improve the overall distribution of accessibility. The analysis in this section focuses on whether access levels are distributed in a manner that are consistent with desirable equity goals. We look at three dimensions of the distribution of transit access. The first two tie our analysis directly to the need for transit service and the last looks at the association between accessibility levels and socio-economic variables of the metropolitan population.

The first two approaches correspond to the concepts of vertical equity (whether service levels increase with increasing need) and horizontal equity (whether service levels are distributed equally among those with similar needs). However, carving out the population where the *need* is greatest is not trivial. This is especially so since data is available aggregated to larger census geographies which contain some variance in the type of households that occupy them. To overcome this problem, we use income at the blockgroup level as an indicator of need rather than going down to the household level, where data is not available. National statistics show that vehicle ownership is strongly tied to income levels. We use median household income at the blockgroup level for this analysis. This data is taken down to the block level, at whose level the accessibility statistics have been calculated.

5.2 Accessibility and Sociodemographic Indicators of Need

To evaluate the equity of transit access distribution, we divide the population of the metropolitan area into 10 groups each containing roughly 10% of the population. These groupings are created after each block group is sorted by its median household income and cutoffs are set by aggregating the population in 10% increments. This way each quantile includes roughly 10% of the metropolitan population.

The two measures of accessibility are then evaluated by looking at how access is distributed

within each of these groups and across these groups. To the extent median income levels represent need, these distributions tell the story of whether increasing access across groups corresponds with lower incomes as well as whether similar places have very different experiences in terms of accessibility. To the extent lower incomes correspond to higher need for public transportation, this analysis illustrates whether need and accessibility are aligned. Second, within each 10% category, the level of access is analyzed to see if horizontal equity is achieved with a focus on persons falling in the lowest income quantiles.

Figure 5.1 illustrates the distribution of accessibility of all jobs in the metropolitan area for the blockgroups falling in each of the income intervals. The box plot shows the median as a dot, the middle 50% of the accessibility for the blocks contained in a given income quantile is shown by the box and whiskers extend to show the range of the bottom and top 20% of accessibilities. As can be seen, the blocks which contain 10% of the population in the lowest income categories have higher levels of accessibility (measure in percentage of jobs reachable within 30 minutes) as compared with each of the successive higher income quantiles. The pattern suggests that increasing need (to the extent it is reflected by lower incomes) is associated with higher access. The higher income quantiles have an overall lower need and much lower levels of accessibility. Figures for the Basic and Expanded clusters are also very similar.

Figure 5.1, also highlights another aspect of the distribution of accessibility. Within each income quantile, there is substantial variance in the level of access that is provided. This variance is greater especially in the lowest income quantiles where the range of the distribution of accessibility is larger.

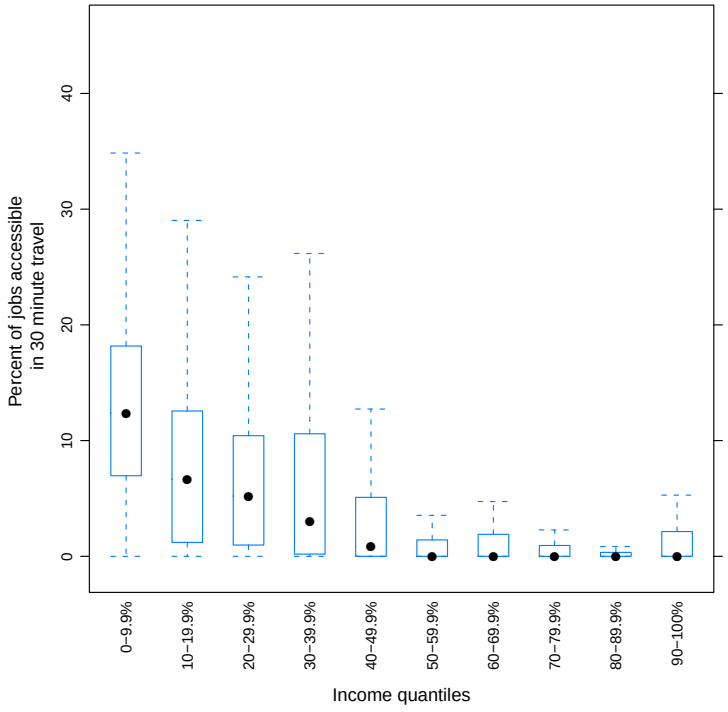

Figure 5.1: Box plot of accessibility to jobs by transit for different residents of the metropolitan area separated by income

The overall trend of increasing accessibility with increasing need is no doubt helped by the concentration of lower income persons within a short distance of downtown Minneapolis. Figure 5.2 illustrates that as income levels increase (and need for transit decreases), so does the distance of the block containing the population from the CBD. For example, for residents who live within 5 miles of downtown Minneapolis, roughly half of them (48%) fall in the lowest 20% income quantile. For residents who live more than 15 miles of downtown Minneapolis, only 4% fall in the lowest 20% income quantile of the region. While on aggregate increasing access appears aligned with need, this trend is confounded by the relationship between the distribution of the lowest income population in the region and distance from the CBD.

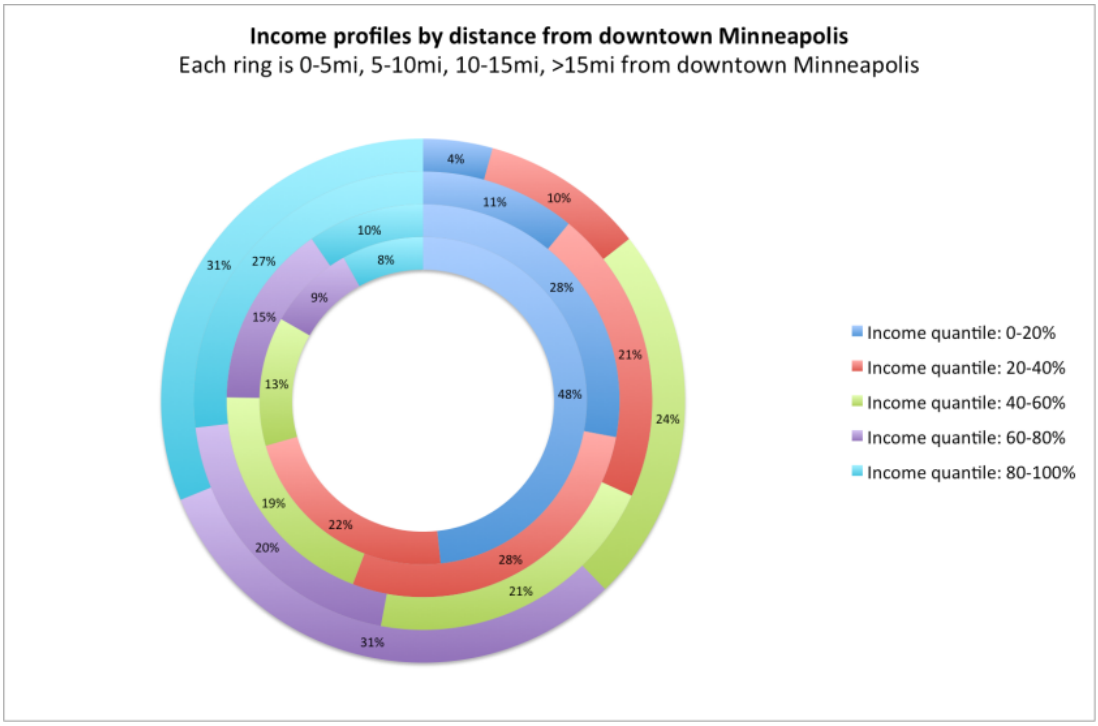

Figure 5.2: Income profiles of the census blocks within metropolitan area separated by distance from downtown Minneapolis

A slightly different plot helps reveal how access levels are distributed if one were to control for distance. By taking several concentric circles of census blocks and looking at the distribution of accessibility within each bin we can compare the extent to which transit accessibility explicitly targets those needing transit access. The four categories used are those blocks within 5 miles, 5-10 miles, 10-15 miles, and greater than 15 miles of the Minneapolis CBD. These accessibility levels are shown in figure 5.3. Once a control for distance is in place, median access levels are relatively insensitive to need as defined by income levels. However, since a large proportion of the lowest-income populations live within the first two rings of the CBD, these populations tend to enjoy the largest accessibility in the region. This is a positive in light of equity goals that seek to address need.

Outside of the 10 mile ring, accessibility levels in general are very low. Still, the lowest income groups especially in the 10-15 mile range enjoy more accessibility than their counterparts though this increase is very limited.

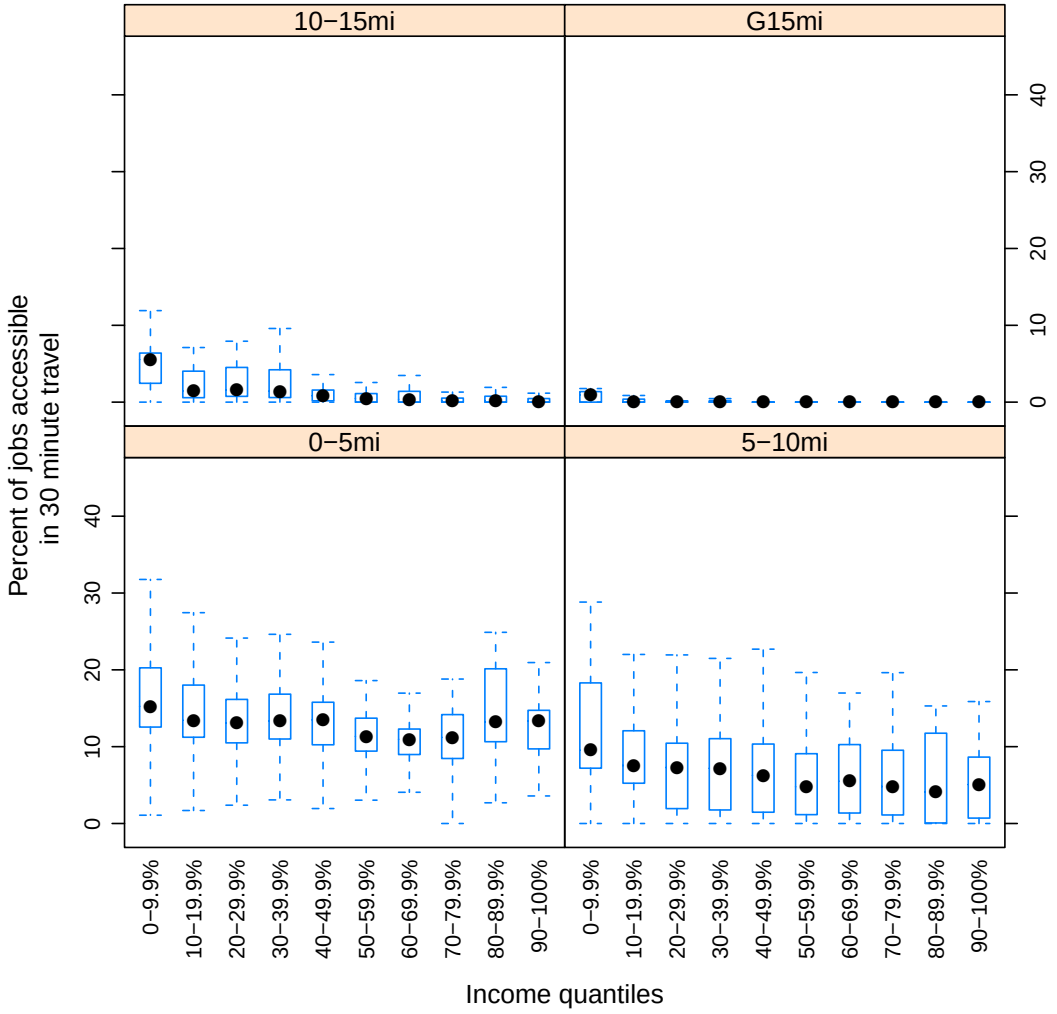

Figure 5.3: Transit accessibility to jobs by income group - separated by distance from downtown Minneapolis

The foregoing analysis points to two competing interpretations of access equity. On the one hand, the aggregate view suggests that access levels correspond to need as measured by income levels. Even given the apparent variance within income levels, the aggregate trend is a positive correlation between lower income and higher transit accessibility to jobs. On the other hand, much of this trend is achieved by virtue of the locations of the lowest income groups, who tend to overwhelmingly live in central cities. Once we control for distance, a much less dramatic relationship between need (income) and accessibility is apparent. Census blocks that have significant differences in need have seemingly limited difference in terms of access levels.

These trends suggest that distance rather than equity considerations dominate the availability of transit. A look at how access levels are distributed within the lowest income groups also supports this observation. Among the 8351 census blocks that make up the residences of the lowest 20% income group, average accessibility levels go from 16.1% for those in the first 5 miles, to 11% in the second five miles, to 3.2% in third 5 miles, and 0.34% in the ring beyond 15 miles from the Minneapolis CBD. These realities are of course complicated by several factors including the lower residential densities that one encounters as distance from CBD increases. But even within the inner rings, opportunities for increasing accessibility are present. For example, nearly a quarter of the census blocks within 0-5 miles and 5-10 mile radius that contain the lowest income groups only have access to 10% or less of the jobs in the metropolitan area. For those on the outer fringes, alternative strategies can be sought.

5.3 Transit access to cluster jobs and socio-demographic groupings of metropolitan residents

The third aspect of the equity analysis compares blockgroup socio-demographic characteristics incorporating racial diversity to look at the distribution of transit accessibility. In doing this comparison, we first apply statistical cluster analysis to group census blockgroups into discrete classes that share similar traits in terms of median incomes at the blockgroup and percentage of non-white population they contain. In general, census blockgroups in the metropolitan area display a negative correlation between these two variables.

Statistical cluster analysis is also applied to the transit accessibility measures for each of the five economic clusters. This analysis separates the census blockgroups into discrete classes ranging from those with a generally high level of transit access to the cluster jobs to those with relatively low levels of access to cluster jobs. These groups were generated for both the basic sector clusters as well as the expanded sector clusters.

The application of cluster analysis on the income and racial mix variables leads to five categories of blockgroups ranging from poorer blockgroups with high minority population concentrations to high-income and low-minority population blockgroups. The cluster analysis based on transit accessibility leads to five relatively distinct clusters of blockgroups for both the Basic and Expanded clusters. In general, blockgroups with low access for the basic cluster also tend to have low access to the expanded cluster (and vice versa). However, there are some limited differences between these two groupings. These two sets of groups that are independently generated based on demographic variables and accessibility variables respectively are then tested for association using χ^2 test of independence.

Figure 5.4 shows a grouping of the metropolitan census blocks based on demographic and

economic variables[1]. Figure 5.5 shows a grouping of census blockgroups based on the similarity of access levels they provide to each of the competitive clusters. Visual inspection of these two maps suggests poorer neighborhoods have relatively higher levels of transit accessibility compared to the wealthier neighborhoods. This is especially true in the central cities of Minneapolis and St. Paul. However, places northwest of Minneapolis that are relatively poorer and contain high levels of minority populations have relatively medium levels of accessibility to cluster jobs. These areas provide opportunities for addressing access equity concerns.

System wide, associations between accessibility and socio-demographic variables are compared using a χ^2 test of independence which looks at whether the accessibility group that a blockgroup falls in is independent of its grouping along income and racial makeup. The test rejects the hypothesis of independence between these two variables (p-value <0.001). Adjusted residuals from the test also reveal that the highest income/low minority census blockgroups tend to be highly associated with blockgroups that have the lowest transit accessibility. On the other hand, the lower income/high minority groups tend to be overly represented among the places with the highest levels of access. These results suggest that given the levels of transit access, its distribution tends to favor the lower-income and more likely transit-dependent demographic, consistent with the findings of the earlier analysis that looked at the population divided by income quantiles. However, as shown in Figures 5.4 and 5.5, these results are not uniform across the board. There are locations with high concentrations of lower-income individuals but where current transit access is rather limited. These locations provide opportunities for creating transit connections and can potentially open doors to new opportunities.

5.4 Summary

This section has looked at how accessibility levels are aligned with the needs of the metropolitan population as measured by income. Overall, we have found a positive association between accessibility and need. However, much of this is a result of the location where the poorer segment of the population lives. Within narrower distance definitions, services do not appear targeted by need but rather by proximity to the dense downtown core. In terms of linking need to transit availability, opportunities are clearly present in the first five miles of downtown as well as outside that core.

The findings from the analysis based on socio-economic similarities and accessibility similarities to the competitive clusters also reveals an overall positive relationship between poorer and high-minority blockgroups and high transit accessibility. The lowest-income/high-minority blockgroups are overly represented among the places with the highest levels of access while the high-income/low-minority census blockgroups are overly represented among the lowest transit accessibility grouping. These trends suggest that the current levels of access on aggregate are at least pointing in the right direction in terms of serving relatively lower-earning households. However, despite the overall positive relationship associating needs to levels of access, blockgroups with low-income and high-minority populations that currently only enjoy medium or lower levels of access to clusters (as well as to all jobs) also exist. As the analysis moves forward into looking at future scenarios, we will explicitly look at how the future transit system may alter accessibility and what implications it may have to accessibility equity.

[1]Data was available at the blockgroup level. All blocks are assigned the group number that their blockgroup fell in

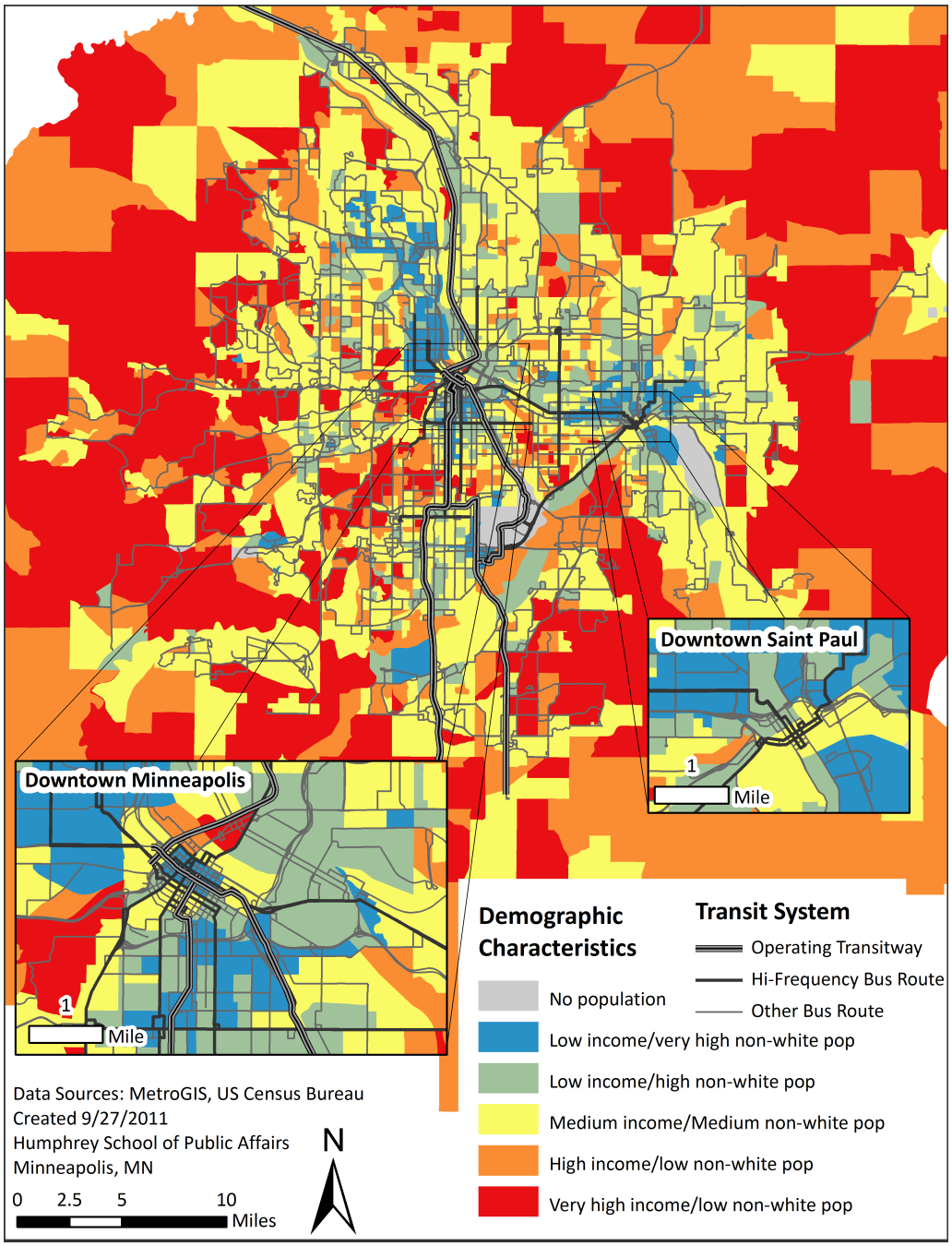

Figure 5.4: Census Blockgroups grouped based on similarities in blockgroup median income and percentage of population that is non-white

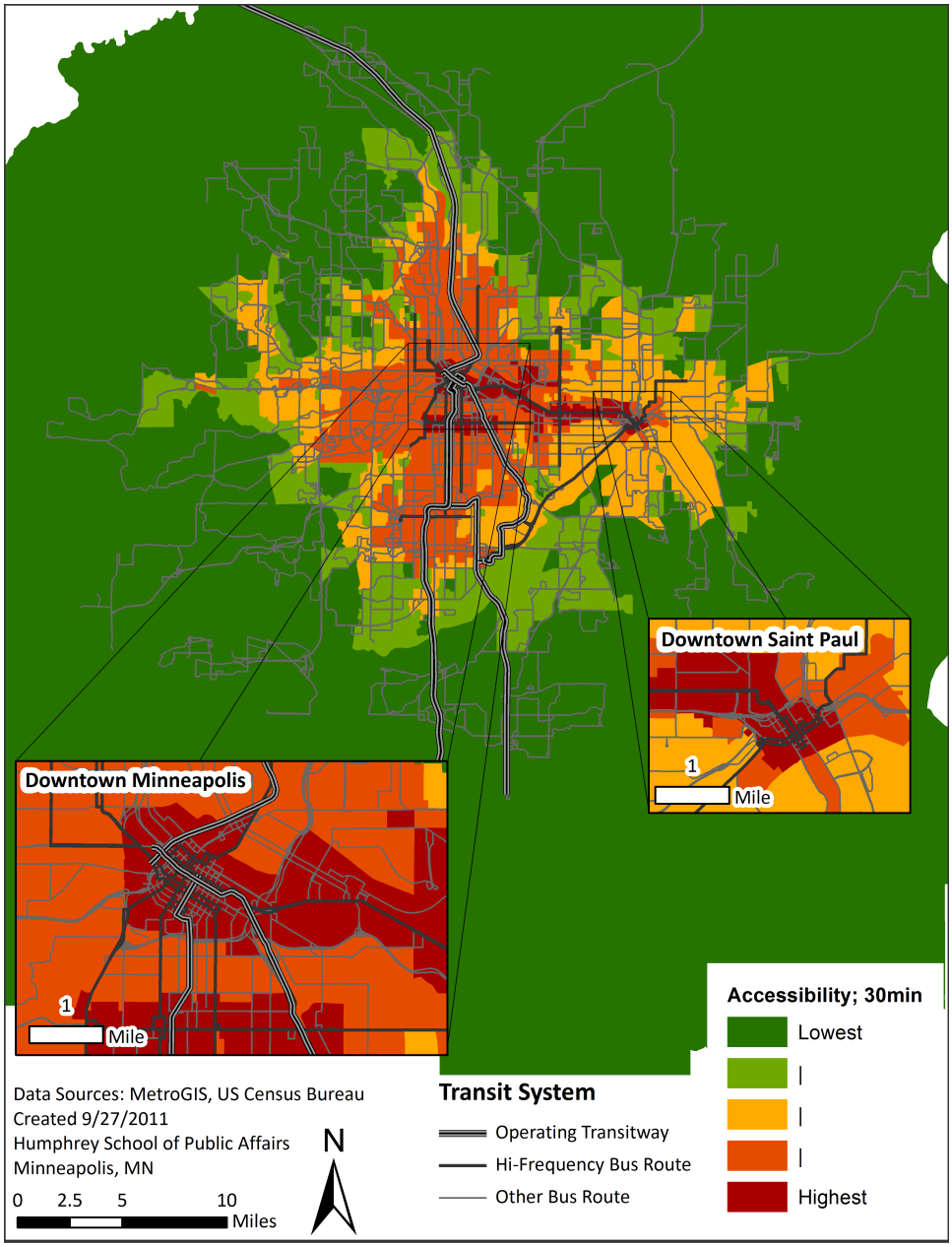

Figure 5.5: Census Blockgroups grouped based on similarities in accessibility to expanded cluster jobs

Chapter 6

2030 Land Use Scenarios

6.1 Introduction

This chapter aims to measure how the 2030 transit system alters the accessibility of the metropolitan region from 2010 levels under the Metropolitan Council's (MC) forecasts of 2030 population and employment at the Traffic Analysis Zone (TAZ) level. In addition, different scenarios under which population and employment distributions in the metropolitan area are altered systematically are tested so that the impact of higher job and population centralization (or decentralization) on regional accessibility can be tested. The aim is to identify the areas of policy focus so that higher gains in regional job accessibility can be realized.

The first section below discusses the different scenarios tested with technical details provided in Appendix C. The accessibility changes from 2010 levels under different scenarios is discussed in the section following. The results demonstrate that different policy focuses will have different payoffs in terms of accessibility gains. Finally, we summarize the results from the chapter.

6.2 The 2030 Scenarios

The 2030 scenarios used in this research depict a wide range of population and employment growth patterns. Besides the MC forecasted 2030 population and employment, alternative population and employment growth patterns are created by simply shifting population and employment from their expected locations to either more concentrated developments in transit corridors or to areas that are on the fringe of the metropolitan area. In the former case, we assume that development in both population and jobs can be made more quickly in transitway corridors. Each Traffic Analysis Zone (TAZ) expected to have a stop for one of the transitway lines is expected to grow at a higher rate than anticipated through different land use policies. Growth at TAZs without transitway stations is lowered but never less than their 2010 level unless the expectation by the MC for that TAZ was a loss of population or jobs. In those cases, we take the expected 2030 population and employment to be the 2030 expected conditions. Alternative growth rates are envisioned for different types of transitways.

In the alternative scenario where development at the fringe is expected, we assume growth in population as well as jobs occurs mainly outside of the I-494/I-694 beltway of the Metropolitan area. This development pattern is similar to alternative scenarios developed by Anderson et al.

(2011). Table 6.1 presents the potential scenarios that will be evaluated.

Table 6.1: Land use scenarios

	Employment		
Population	Growth at Fringe	Stays at 2030 MetCouncil forecast	Centralizes at transitway TAZs
Growth at Fringe	Scenario 1	Scenario 4	Scenario 6
Stays at MC 2030	Scenario 2	Base scenario	Scenario 7
Centralizes at transitway TAZs	Scenario 3	Scenario 5	Scenario 8

Each scenario reallocates jobs to defined locations. Total jobs in the metropolitan area remain at the same level as forecasted by the Metropolitan Council for 2030. Under the different scenarios places along transitway lines can see increased jobs or populations because of land use policies that may be implemented to encourage job and population concentration in these corridors. Also, under these scenarios, the transitway type is expected to effect these predicted growth rates. For example, light-rail transit would be expected to drive more growth than Arterial BRTs than would limited-stop BRT services along the corridors in which they operate. The changes expected at each location also depend on whether or not population/job growth is anticipated in the region. The additional growth at transitway corridors is reduced from the TAZ that expect to see job growth in 2030 making these locations have more moderate population/job growth than anticipated but never lowering it below their 2010 levels. Places that are expected to lose population/jobs are left at their anticipated 2030 levels.

When jobs centralization along transitway corridors is tested, we do not assume that all jobs that are going to be located at transitways TAZs will come due to a decline in suburban growth alone. Instead, job losses are assumed to be spread across all zones that are not on transitway corridors and expect an overall increases in number of jobs between 2010 and 2030. These changes are summarized in Table 6.3.

In each scenario the choice of the additional growth rates in these scenario analysis are aimed to be an achievable goal. Our proposed rates are as given in Table 6.3 with the most optimistic scenario being an additional 10% growth over that forecasted to 2030 for locations where job/population growth is forecasted. The technical details of this analysis are in Appendix C.

6.3 Scenario Analysis

6.3.1 Base analysis

The base analysis is based on the 2010 and 2030 forecasts for jobs and employment that are done by the Metropolitan Council. This forms the basis on which different growth patterns are analyzed. Comparisons are based on a single value - the population-weighted accessibility to metropolitan jobs. In 2010, the population-weighted transit accessibility within 30 minutes was to 117,611 jobs. Through changes in the transit system and expected land use and population shifts, this number is expected to grow by 8,808 jobs to 126,419 jobs. This value is the expected number of jobs accessible within 30 minutes of travel time for a resident of the metropolitan area.

Table 6.2: Expected changes under each scenario

TAZ	Expectation for 2030	Changes under scenario
Base Scenario		
All TAZ	all	2030 forecasts by the MetCouncil
Jobs concentration along transit ways		
Along transitway	all	increase by additional δ_1^*x100 %
Not along transitway	gain jobs	moderate growth than expected (lower limit 2010 jobs)
Not along transitway	lose jobs	remain at forecasted 2030 levels
Population concentration along transit ways		
Along transitway	all	increase by additional δ_2^*x100 %
Not along transitway	gain population	moderate growth than expected (lower limit 2010 population)
Not along transitway	lose population	remain at forecasted 2030 levels
Jobs growth in Suburban locations		
Outside I-694/I-494 beltway	all	increase by additional δ_3^*x100 %
Inside I-694/I-494 beltway	gain jobs	moderate growth than expected (lower limit 2010 jobs)
Inside I-694/I-494 beltway	lose jobs	remain at forecasted 2030 levels
Population growth in Suburban locations		
Outside I-694/I-494 beltway	all	increase by additional δ_4^*x100 %
Inside I-694/I-494 beltway	gain population	moderate growth than expected (lower limit 2010 population)
Inside I-694/I-494 beltway	lose population	remain at forecasted 2030 levels
Population & Job growth inside I-694/I-494 without a focus of Transitways		
All TAZs	lose population	remain at forecasted 2030 levels
Outside I-694/I-494 beltway	gain employment/population	moderate growth than expected (lower limit 2010 population)
Inside I-694/I-494 beltway	gain population	increase by additional δ_5^*x100 %

* δ's depend on transitway type. Aggressive and moderate growth rates will be tested within each scenario. See table 6.3

Table 6.3: Growth rate scenarios

Transitway type crossing TAZ	Growth percentage		
	Low	Med	High
None	0%	0%	0%
Light rail	3%	5%	10%
Arterial BRT	2%	3%	6%
Limited Stop BRT	1%	2%	4%
Commuter Rail	0%	0%	0%
Express Bus	0%	0%	0%

6.3.2 Jobs and Population Centralization

Table 6.4 shows the potential gains from different strategies that may be adopted to direct job and population growth towards the TAZs that will be served by the 2030 network. The None category in the table is the Base 2030 estimates, i.e., the estimates based upon the Metropolitan Council's forecasts. The other categories correspond to population and job growth rates described in Table 6.3.

Clearly the largest gains in population-weighted accessibility comes from a combination of aggressive population and employment centralization towards transitways. This scenario leads to an additional 7% gain in the employment accessibility over the base 2030 estimates (roughly 8700 additional jobs). However, at the tested growth rates, efforts to centralize jobs pay considerably greater dividends than efforts to centralize population. Keeping the 2030 estimates for population and only focusing on an aggressive jobs centralization agenda increases average accessibility by 4.5% or about 5700 additional jobs. On the other hand, focusing on population centralization without jobs centralization (leaving it at expected 2030 levels) would increase the average accessibility by 2.2% (about 2800 jobs), half of the additional jobs that would be accessible from centralizing jobs. Table 6.4 summarizes these results.

Table 6.4: Changes in population-weighted average accessibility in the metropolitan area with centralizing jobs and population

		Employment Centralization			
		None	Low	Moderate	High
Population Centralization	None	126,419	+1.8%	+2.6%	+ 4.5%
	Low	+0.6%	+2.4%	+3.3%	+5.2%
	Moderate	+1.2%	+3.0%	+3.9%	+5.8%
	High	+2.2%	+4.0%	+4.9%	+6.9%

6.3.3 Jobs and Population Decentralization

A similar approach is used to look at alternative scenarios where both employment and population decentralizes more quickly than anticipated under the 2030 Metropolitan Council forecasts. In these case, three levels of decentralization are tested each corresponding to a low (1%), moderate (3%), and high (6%) additional increases for those locations where growth is anticipated and fall outside of the I-494/I-694 ring. These increases in employment and population are offset by reduced rates of growth in zones that are inside the loop and are expected to see growth in employment and population levels, respectively.

Population-weighted average accessibility is also calculated here under different scenarios of low to high growth. Here again employment decentralization would lead to larger and larger loses of accessibility than does population decentralization at the tested rates. Overall, however, the loss of accessibility is not very pronounced as compared to potential gains in the last subsection. Here, under the worst-case scenario of both employment and population decentralizing at an aggressive rate of an additional 6%, the loss in population-weighted accessibility is 1,855 jobs. These results are given in Table 6.5.

Table 6.5: Changes in population-weighted average accessibility in the metropolitan area

		Employment Decentralization			
		None	Small	Moderate	High
Population Decentralization	None	126419	-0.21%	-0.63%	-1.29%
	Small	-0.03%	-0.24%	-0.66%	-1.32%
	Moderate	-0.09%	-0.3%	-0.72%	-1.38%
	High	-0.18%	-0.39%	-0.81%	-1.47%

6.3.4 Job Decentralization and Population Centralization

This option explores what would happen if policies focused on population centralization along transitways but further decentralization was to occur in the location of jobs. The levels of centralization and decentralization are the same as in the above two cases.

Both declines and gains under this scenario are modest. The worst-case scenario in terms of a decline in accessibility happens when population centralization occurs at its lowest rate and job decentralization occurred at its highest rate, which would lead to a a 0.66% drop in population-weighted accessibility. On the other hand, aggressive growth of population along transitways coupled with a low rate of employment decentralization would lead to a 2% increase in expected accessibility. These results are summarized in Table 6.6.

Table 6.6: Changes in population-weighted average accessibility in the metropolitan area: Job Decentralization and Population Centralization

		Employment decentralization			
		None	Small	Moderate	High
Population Centralization	None	126419	-0.21%	-0.63%	-1.29%
	Small	+0.6%	0.43%	0.01%	-0.66%
	Moderate	+1.2%	0.98%	0.56%	-0.11%
	High	+2.2%	2.0%	1.57%	0.89%

6.3.5 Job Centralization and Population Decentralization

This option considers what a policy that focuses on increasing job density along transitways would achieve under different rates of growth while population growth occurs at a higher rate in suburban locations outside the I-494/I-694 loop.

The accessibility calculation shows that in this scenario, population decentralization at the rates tested does not appear to have a large impact on the changes in aggregate accessibility at a given employment centralization rate. At the lowest employment centralization rate, which also has a high population decentralization, the change would be +1.58%, while at the smallest decentralization rate, the accessibility gain is 1.74%. With more aggressive employment centralization, a low population decentralization achieves a 4.5% gain in average accessibility while a high population decentralization achieves a 4.32% gain. These numbers are consistent with the earlier estimates that employment centralization contributes more to overall gains in accessibility (as measured by

the population-weighted average) than does additional centralization of population. Even in situations where population decentralization is occurring, a centralization of jobs is able to overcome the potential losses in accessibility. The results from this scenario are summarized in Table 6.7.

Table 6.7: Changes in population-weighted average accessibility in the metropolitan area: Job Centralization and Population Decentralization

		Employment Centralization			
		None	Small	Moderate	High
Population Decentralization	None	126,419	+1.8%	+2.6%	+ 4.5%
	Small	-0.03%	1.74%	2.60%	4.48%
	Moderate	-0.09%	1.67%	2.54%	4.42%
	High	-0.18%	1.58%	2.45 %	4.32%

6.3.6 Job and Population Centralization without a focus on Transitways

This option considers a scenario where population density increases are focused on the inner cities and inner suburbs without any particular focus on transitways. Low, moderate, and high growth rates are tested whereby TAZs inside the I-494/I-694 loop with anticipated growth from 2010 see additional increases in both employment and population. On the other hand, TAZs outside this beltway with anticipated population and employment growth see modest growth. All TAZs anticipated to see losses in jobs or employment are not affected by this changes.

As one would expect, this scenario leads to increases in accessibility, though in many cases this increase is modest. Under the most ambitious growth rates, an increase of 2.74% is expected when both population and employment are centralized at a high additional rate. When both of these are at the low end, the expected increase is 0.28%. The results are summarized in Table 6.8.

Table 6.8: Changes in population-weighted average accessibility in the metropolitan area: Job Centralization and Population Decentralization

		Employment Centralization			
		None	Small	Moderate	High
Population Centralization	None	126419	+0.23%	+0.69%	+1.24%
	Small	+0.05%	+0.28%	+0.74%	+1.29%
	Moderate	+0.26%	+0.50%	+0.95%	+1.51%
	High	+1.48%	+1.71%	+2.18%	+2.74%

6.4 Accessibility changes in the competitive cluster jobs

In this section, we focus on the competitive clusters in the metropolitan area and look at the anticipated changes in accessibility. The employment numbers for this section comes from the 2005 DUNS data which identifies metropolitan employers, their number of employees, and the primary sector in which they operate. This data is aggregated to the TAZ level to calculate the number of

employees in the basic and expanded clusters defined previously. These are used along with 2010 transit travel times to determine accessibility to these jobs. In calculating the 2030 accessibility, job projections in the basic and expanded clusters needed to be made. For these, the anticipated growth rates for TAZ-level jobs by the metropolitan council is used.

Once again, it is important to note there are inconsistencies between these two data sets (the DUNS and Metropolitan Council data). While the DUNS data provides significant detail about employers including the sector of the industry, the Metropolitan Council data is aggregate employment at the Traffic Analysis Zone. When aggregated the DUNS data contains 23% fewer jobs than the 2010 projections by the Metropolitan council.

The person-weighted average accessibility to metropolitan jobs when using the DUNS data is to 92,626 jobs as compared to 126,419 jobs from the Metropolitan Council data. This difference is exclusively due to differences in the number of jobs in the two data sets. The population figures for both analysis comes from the Metropolitan Council projections and the same transit travel matrix is used.

The accessibility calculations for 2010 and 2030 are as given in table 6.9. As can be seen, if job growth at the TAZ level is consistent with the percentage increases expected in the Metropolitan Council data, with the deployment of the 2030 system, the number of jobs accessible within a 30 minute transit travel time will increase across the board. In terms of percentage increases, higher increases are expected to occur for the Basic cluster (12.2%) and to a smaller extent for the Non-Basic cluster (5.0%). The Expanded cluster, which includes both basic and non-basic cluster jobs will see an increase of 7.5% under these assumptions.

Table 6.9: Metropolitan accessibility to Basic, Non-Basic, and Expanded Cluster jobs in 2010 and 2030

Year	All jobs	Basic cluster	Non-basic cluster	Expanded cluster
2010 (jobs)	92626	20497	37671	58169
2030 (jobs)	99318	22974	39551	62525
Gains	7.2%	12.1%	5.0%	7.5%

6.5 Future Scenarios and Social Equity

The analysis shows that the 2030 transit system will undoubtedly increase levels of job accessibility in the region. Even in the case of population and employment decentralization, population-weighted average accessibility in the region is estimated to increase to 124,560 jobs (=126,419*(1-.0147), see Table 6.5); higher than the 2010 figure of 117,611 jobs. While an increase in average accessibility confirms the positive impact of the 2030 transit system, it is important to know how the accessibility improvements are distributed in space and across income groups. Will the accessibility improvements benefit the socioeconomically disadvantaged in particular?

The analysis shows that both concentrating households and jobs within the I-494/I-694 loop will result in positive increases in regional accessibility to jobs. Figures 6.1 and 6.2 show the changes in accessibility at different locations in the metropolitan area. As can be seen, areas in the center of the metropolitan area largely expect a gain, areas on the suburban fringe without a

direct connection to the transitways will mostly experience relatively small changes in accessibility. This likely suggests greater accessibility improvements for low-income minorities than other population groups, because low-income minorities tend to reside in central city areas. Importantly, the amount of increase in accessibility levels in north Minneapolis neighborhoods is on par with south Minneapolis neighborhoods, as shown in Figure 6.2. This is positive evidence on the social equity impact of the 2030 transit network because north Minneapolis neighborhoods, being areas with concentrated poverty, have relatively lower levels of accessibility in 2010.

Figures 6.3 and 6.4 show the anticipated changes in accessibility by the income profiles of the TAZs in the metropolitan area. As discussed previously, these income quantiles are derived from the 5 year ACS median income estimates for the metropolitan census tracts. Each tract is grouped into the different income quantiles based on its population and median income. Each TAZ is then categorized into the different quantiles based on the tract where its centroid falls. This would mean that though each quantile is approximately 10

Relatively speaking, Figure 6.3 shows a centralizing growth pattern is likely to lead to even better outcomes to the lower-income TAZs as compared to the highest-income TAZs. Changes over the base scenario are not anticipated to be very large for those TAZs where the upper (in terms of income) 50% of the population lives. The same figure shows that under moderate decentralization, the losses in accessibility as compared to the base scenario are not very large for all income groups. Figure 6.4 also illustrates that gains over the 2010 level in the cluster jobs are likely to be positive (on average) to TAZs in all income quantiles, though the gains are small at the top of the income spectrum.

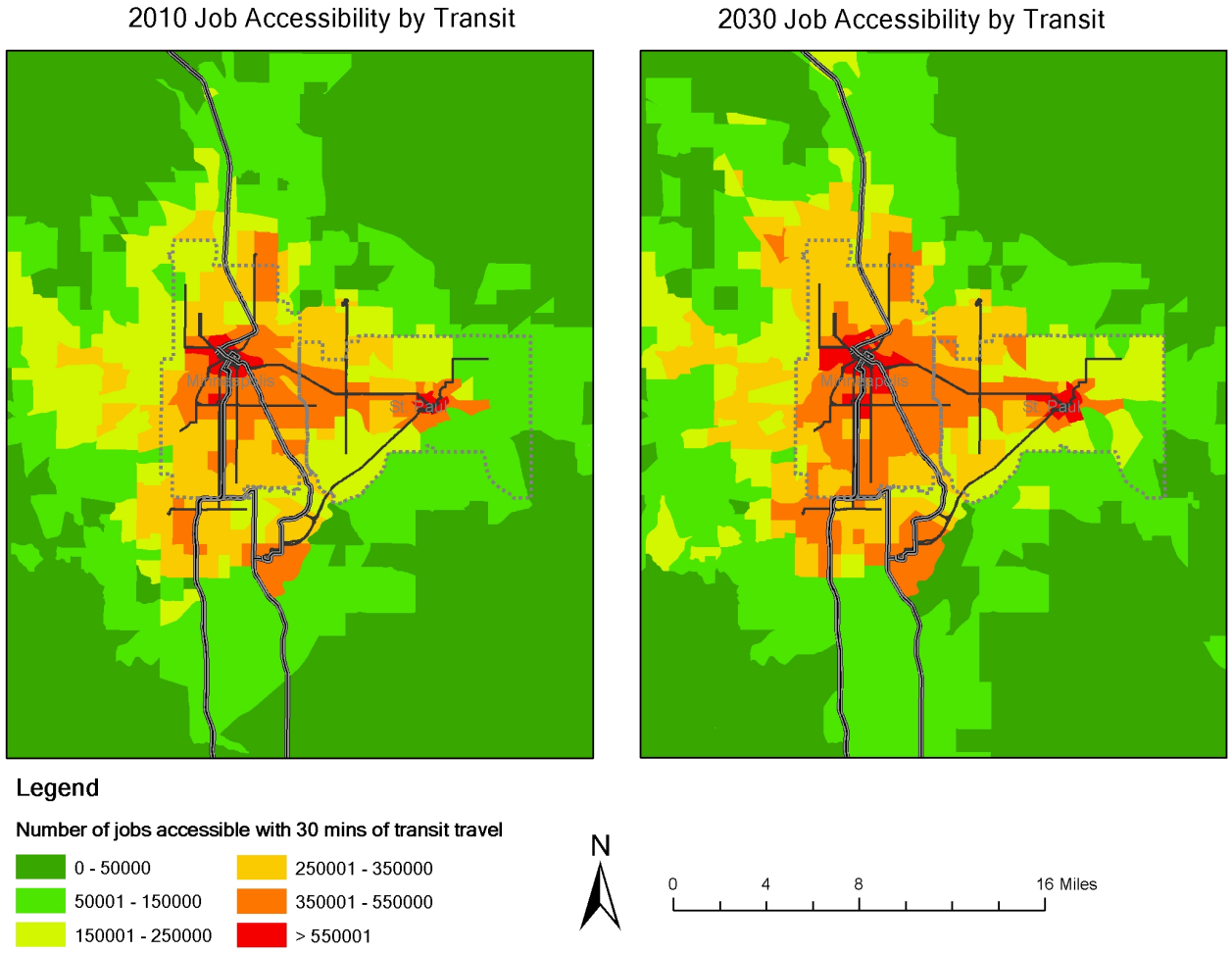

Figure 6.1: Accessibility with in 30 minute travel time to all jobs from 2010 to 2030

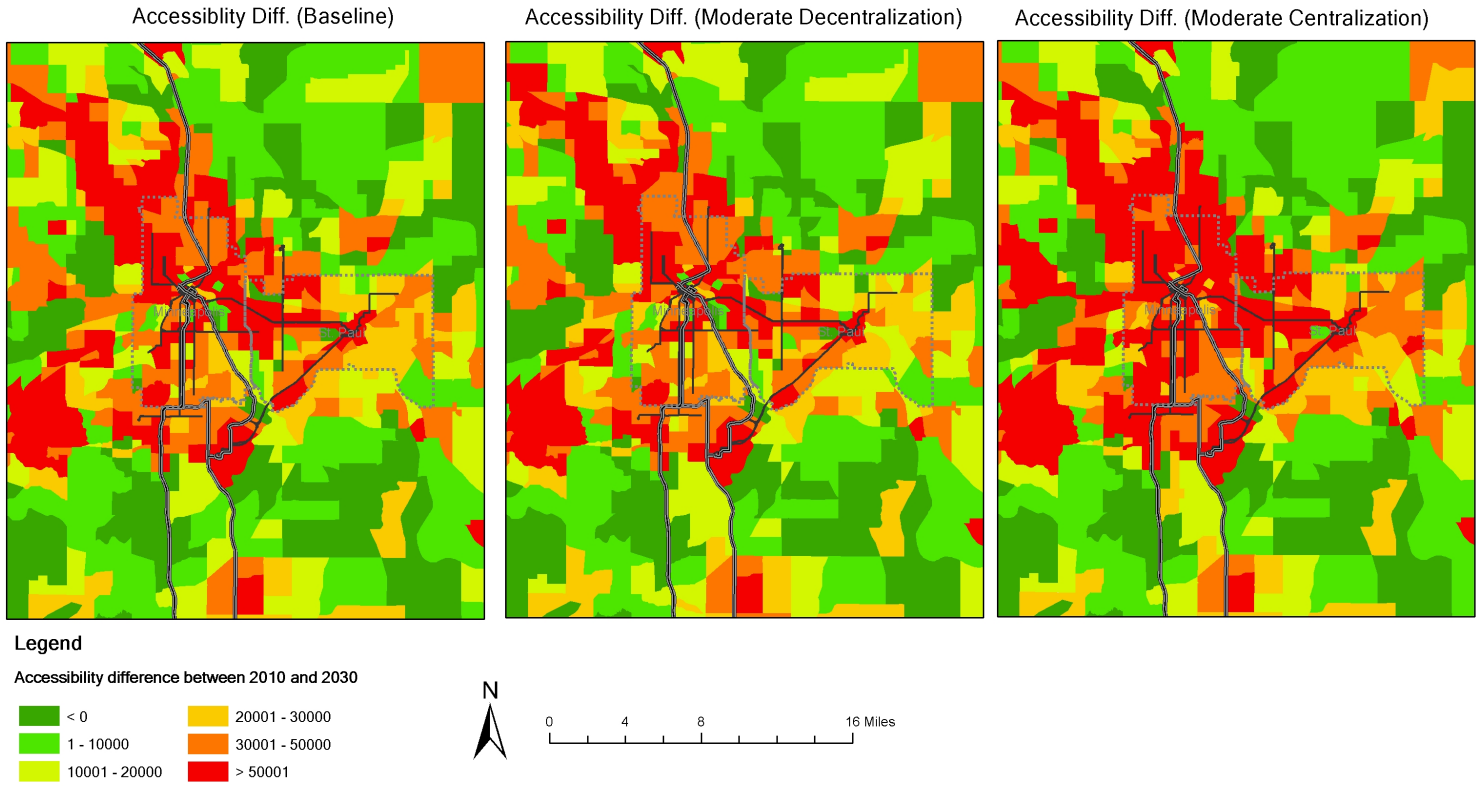

Figure 6.2: Changes in accessibility to all jobs from 2010 to 2030 under the base scenario, moderate centralization and moderate decentralization of jobs

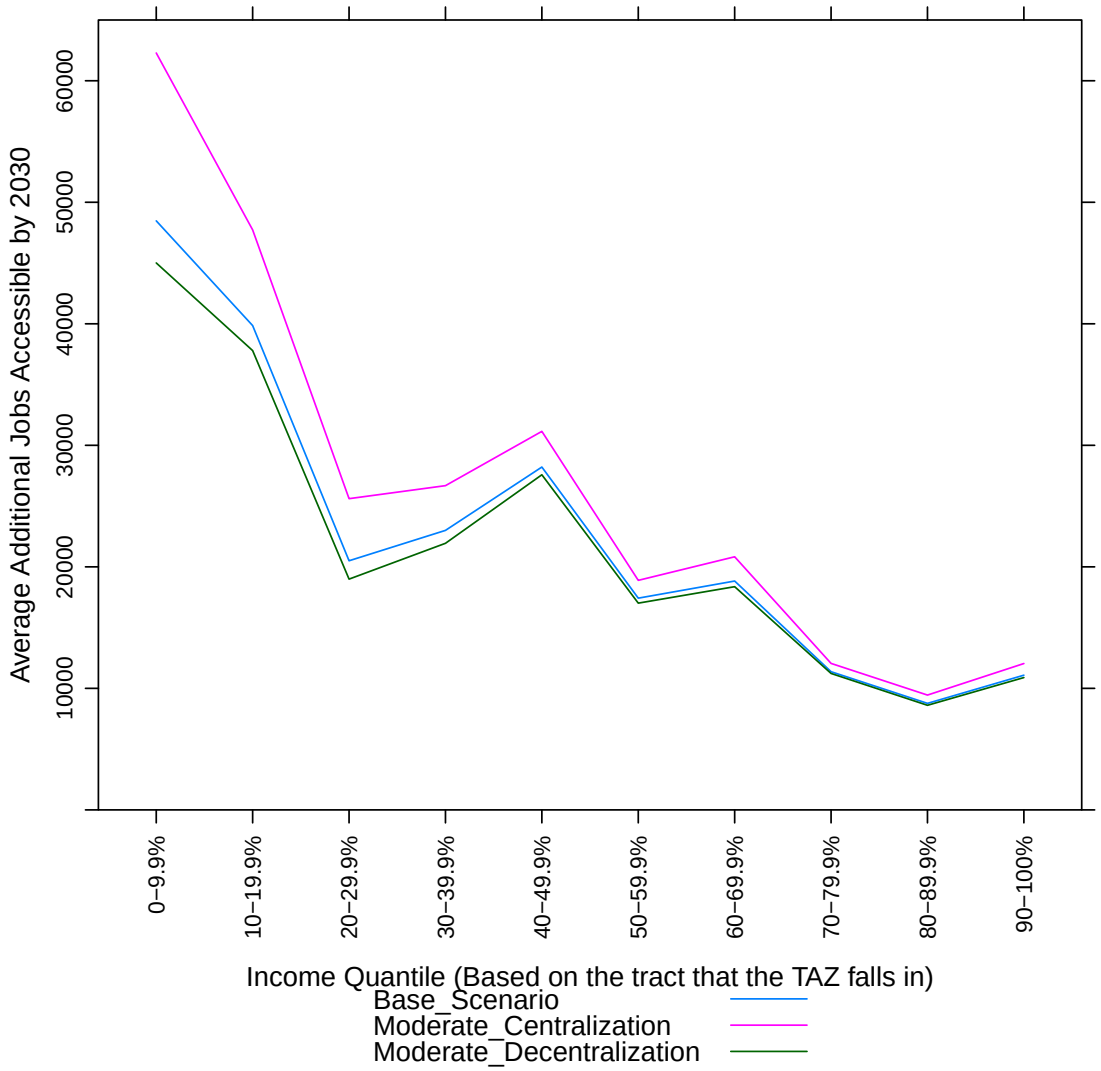

Figure 6.3: Changes in accessibility from 2010 to 2030 by TAZ income characteristics under different scenarios

6.6 Summary

This section has looked at how different types of future development patterns are likely to affect accessibility to jobs in the metropolitan area. Primarily the analysis shows that both concentrating households and jobs within the I-494/I-694 loop will result in positive increases in regional accessibility to jobs. A more targeted concentration along transitway stations will lead to an even greater gain in accessibility. Between the concentration of jobs or concentration of residences, the concentration of jobs to transitway station areas results in a larger gain to regional accessibility than does the concentration of housing. A distributional analysis of the accessibility increases in the region shows the lowest income locations expect the largest average gains in accessibility.

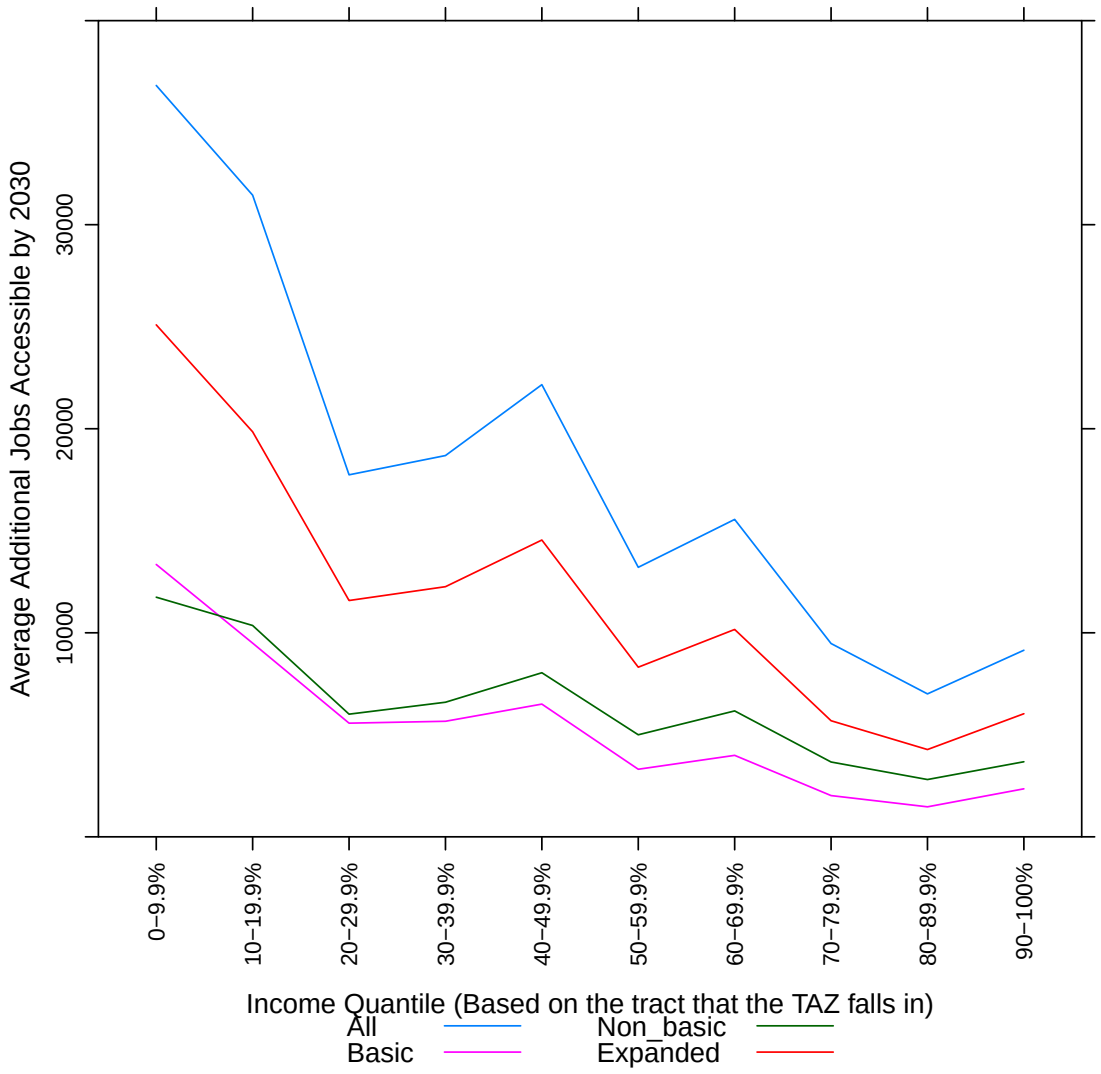

Figure 6.4: Expected changes in accessibility to jobs in the competitive clusters from 2010 to 2030

In addition to changes in accessibility to all jobs, accessibility to metropolitan area competitive cluster jobs is also improved. In particular, Basic cluster jobs see a marked increase in accessibility from 2010 levels with an increase of 12.1%, while the jobs we have termed as non-basic cluster jobs see a moderate increase in accessibility. Overall, access to cluster jobs will be 7.5% higher once the 2030 system is deployed.

Chapter 7

Conclusion

7.1 Synthesis

The Twin Cities area transitway corridors continue to expand. These changes are occurring simultaneously with changes in land use and population shifts. This project has attempted to tie together issues related to transit accessibility, economic development, and equity with a view of enabling better outcomes for the future system.

Our analysis has looked at the economic landscape of the metropolitan area and identified sectors that are important to regional growth. Current accessibility from different parts of the metropolitan area have been evaluated. We have shown that there are varying degrees of access to different types of clusters (sectors) in the metropolitan area. For metro residents who do not have an automobile, this means isolation from some of these opportunities; for others it can mean relatively long travel times. But there are also sectors where levels of access are relatively much better; these tend to be office-centered places of employment such as finance, insurance, and management of companies.

Looking at metropolitan areas as destinations and investigating the level of access to labor reveals that most locations have limited access to labor by transit. Places that tend to do well are the downtowns of the region and neighborhoods immediately around them. This is reflective of the relative density of residences in these locations. On the other hand, limited accessibility to labor from most locations is reflective of the relatively dispersed nature of housing compared with employment locations.

On average, the current system also provides service in a manner consistent with the needs of the populations in the metropolitan area. However, there are opportunities for improvement. Some of the places with the lowest income block groups also experience some of the lowest levels of access in the region. For locations that are more suburban but also constitute some of the lowest-income populations in the region, alternative strategies including demand response services, car sharing, etc. can help address the transit deficit. In fact, such programs may be in place for some of the locations. Our analysis focuses only on fixed route and guideway services, and such programs would not be reflected in the analysis.

Finally, we have analyzed how the future transit system will alter these measured outcomes. Under the basic scenario where population and land use will reflect the forecasts of the regional planning organization, job accessibility levels will be improved for many locations in the metropolitan area. The same is true also for cluster jobs – the subset of the regional sectors considered to be

centers of innovation and primary drivers of the regional economy.

Alternative land use and population (residential) distribution scenarios were developed and tested for the metropolitan region in light of the new transit system. Given limits on the amount of political capital that can be spent in making policy, the aim was to provide guidance on which outcomes were the most desirable. The developed scenarios looked at increasing job concentrations as well as population density along transitways, increasing job and population densities within the inner core of the metropolitan areas, and continued decentralization with growth occurring on the outer fringes of the metropolitan area.

The findings are, as one would expect, that centralization of both population and jobs would lead to better accessibility outcomes on aggregate. Largest payoffs in terms of accessibility gains occur when centralization of both employment and population occurs along transitways. Furthermore, the analysis shows higher accessibly payoffs come from centralizing jobs than come from centralizing residential development.

One of the takeaway messages from this is centralizing jobs and housing needs to be among the priorities of policies that look to take advantage of this investment in infrastructure. In particular, job centralization is key since each job that is added increases the accessibility for all persons for whom transit service to that destination is possible. The method of analysis can also be adopted to rank places that are primarily responsible for the rise in accessibility and to target them for policy intervention.

In all, the lessons can be summarized as follows:

- Focusing on the transitways as guides to where more development should occur leads to higher payoffs
- When centralizing along transitways, jobs centralization has significantly larger payoffs to increasing accessibility than increasing population density

7.2 Future directions

This research has illustrated which goals should be the focus of policy when increasing accessibility is the desired final outcome. The question of which combination of policies will get us there requires further refinement. Strategies will no doubt have to depend on the types of sectors that are to be attracted to different places. As we have illustrated early on in this report, different clusters have different needs for space and mobility of goods that affect their location decisions. Effort must also be spent to ensure that proper commercial/industrial spaces are available for businesses willing to locate near transit.

Another important question is how increased accessibility can be translated into improved employment outcomes especially in areas that experience relatively higher levels of unemployment and poverty. Here lessons from successful models of connecting potential employees to workplaces should be examined. In addition, workforce development strategies targeting businesses and sectors in the identified expanded clusters, job turnover issues and the association with labor market accessibility among entry-level employment, possible circulator transit services between suburban employment clusters and regional transit corridors, are also issues that need further research. The success of these efforts will depend on not just the transportation/land use measures but on the ability of people to use these systems to access economic opportunities.

The 2030 transitways offer many opportunities for connecting home and work, addressing the transit needs of disadvantaged areas, and providing a sustainable transportation mode with lower environmental costs.

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Appendices

Appendix A

Methods of Identifying Clusters

There are a related set of methods that are used to identify clusters in the literature. These methods employ a combination of traditional economic base theory to identify the drivers of a regional economy followed by other extensions that are meant to identify sectors where clustering occurs. Location Quotients often play a significant role in first step to identifying a basic (exporting) sector in a regional economy. In some cases this is done by identifying those sectors that are considered to be local-serving and excluding them from the analysis. Each method then adds an extension that aims to provide additional information on the relationship between the sectors active in regional economies.

One of the ways in which the relationships among the subset of sectors selected for analysis is investigated employs regional Input-Output (I-O) data. These are sometimes used to refine a cluster analysis that has been completed utilizing other methods or to determine value-chains in a regional economy. The I-O data provides input and output exchanges between all industrial sectors at different geographic scales. In the case of Feser (2005) for example, this data is used to determine both vertical (buy/sell relationships) and horizontal linkages (who sources from the same suppliers, and sells to the same buyers).

Other analytical methods such as Shift-Share analysis also help identify the sectors in a regional economy. Here trends in employment are compared with national employment trends, in industry mix, and regional growth in a sector. This method is sectoral and is helpful in identifying the sectors where the region is outstripping the nation in growth/specialization. Different visual methods also help convey this information, including time variables that show changes over a decade.

A.1 Location Quotients

A set of related methods used to identify clusters employ traditional economic base theory to identify the drivers of a regional economy. This method compares location quotients and how they have changed over time. Often employment data is used in these applications since it is readily available. For a given sector in a region, the location quotient of a sector/industry is calculated as follows:

$$LQ_{i,t} = \frac{e_{i,t}/e_t}{E_{i,t}/E_t}$$

Where

Table A.1: Categories based on LQ calculations

	$LQ < 1$	$LQ > 1$
$\Delta LQ > 0$	Weak and growing sectors	Strong and growing sectors
$\Delta LQ < 0$	Weak and declining sectors	Strong and declining sectors

i: is a sector index, and t is time

$e_{i,t}$: refers to regional employment in sector i at time t

e_t: refers to total regional employment in the region at time t

$E_{i,t}$: refers to national employment in sector i at time t

E_t: refers to total national employment in the region at time t

A.2 Growth and The Basic Sector

By looking at the changes over a period of time, the difference in LQ (ΔLQ) provides information on whether the importance of the sector is increasing or declining in the region. The LQ value itself at time t indicates whether or not the sector is *b*asic for the region. Table A.1 provides a summary. Such analysis are in general sectoral.

A.3 Bubble charts

Another technique related to the location quotient method that also tries to provide additional insights into the data is bubble charts. The method is described in Goetz and Shield (2005). These combine wages, job growth, employment size by sector, and industry's location quotient at a given year. Plots are made of wages vs. job growth (between two given years) for each industry sector. This identifies whether a sector is growing, as well as whether it provides high or low wage jobs. The sectors are sized according to the employment size, and colored according to their location quotient, to illustrate whether they are a significant part of the local economy in terms of employment as well as show their importance to the regional economy by comparing them to their national importance (whether it is a basic sector or non-basic sector for the regional economy). Again the spatial dimension of this technique is rather crude. Another step would be necessary to connect labor needs to firms situated in smaller geographies. The method is just as aspatial (aggregated up to regional levels) and also focuses on sectors rather linkages that cut across sectors either vertically or horizontally. It also needs a way to link back sectors to firms or employment zones in smaller geographies. Figures A.1 shows the bubble chart using 2007 and 2008 data for the seven county metropolitan area in the Twin Cities.

A.4 Shift-Share Analysis

Shift-Share analysis is among the traditional measures that compare how a sector is performing by breaking down the changes in employment and attributing the changes to three different com-

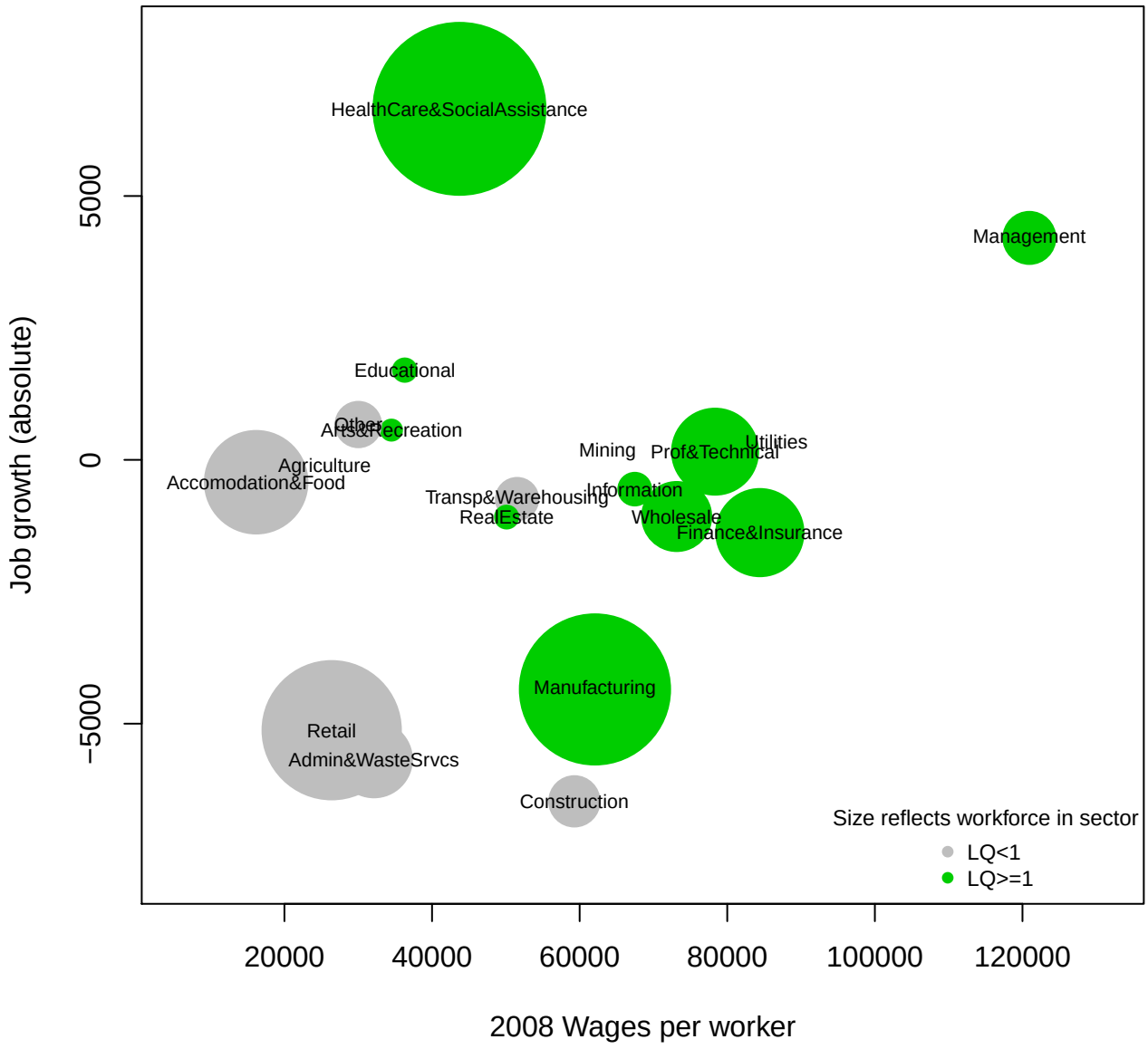

Figure A.1: Sector Growth, Size, Wages, and LQ using 2007 - 2008 data for the seven county area of the Twin Cities

ponents. These components are changes in overall national growth (NS), a shift in industry mix (IM), and the regional growth in the industry (RS). Those sectors with positive RS identify where the region is outperforming national trends.

$$e_{i,t} - e_{i,t-1} = NS + IM + RS$$

$$e_{i,t} - e_{i,t-1} = e_{i,t-1}\left(\left[\frac{E_t}{E_{t-1}} - 1\right] + \left[\frac{E_{i,t}}{E_{i,t-1}} - \frac{E_t}{E_{t-1}}\right] + \left[\frac{e_{i,t}}{e_{i,t-1}} - \frac{E_{i,t}}{E_{i,t-1}}\right]\right)$$

A.5 Porter's Method

Porter's method adopts Location Quotients as a starting point but extends the analysis to look at cross-sector co-location and interaction. Porter (2003) classifies industries into three groups: local industries, which cater to local needs; resource dependent industries, which may export beyond the local region but are located near the resource; and traded industries, which sell their products and services outside of the region. The analysis to group industries into one of these classification, which depends on location quotients, is described in Porter (2003). Focusing on the *traded* and *resource dependent* industries (which are part of the region's base economy), the important players for a region are then shown by plotting their share of national cluster employment ($S_{i,t}$) against the change in share over time (δ).

$$S_{i,t} = \frac{e_{i,t}}{E_{i,t}}$$

$$\delta = S_{i,t} - S_{i,t-1}$$

The *traded sectors* overall make up about a third of all employment nationally. Porter's analysis shows these are highly productive sectors, whose jobs command higher wages, have more rapid wage growth, are highly innovative [using patents per 1000 employees as a proxy] and key to the health of *local sectors* (Porter, 2003).

Though theoretical discussions in Porter's work emphasize linkages that go beyond sectoral definitions or factor requirements, the Location Quotient based analytic framework falls back on traditional measures that breakdown firms based on industries/sectors. Porter (2003) overcomes this limitation by extending the work to include spatial co-location. His analysis focuses on the traded clusters using state level data with four digit SIC codes. Locational correlation is used to identify sectors that co-locate often. Significant correlations were then used to identify groups of industries that are tightly linked. However, due to the analysis framework and the geographic scope, results have to be modified to remove correlations that are deemed spurious (e.g., correlations between industries that have high concentration in few states, but where no industrial linkages were present). This was done through case studies and by consulting Input-Output tables for the national economy. In total, 41 traded clusters with an average of 29 industries each are identified.

A.6 Clusters based in Input-Output Relationships

Input-output relationships have also been used to identify clusters at the national level. Such [buying-selling] relationships, it is argued, are even more important today since most firms have outsourced many activities, and now have to purchase services/goods from others that have specialized in those activities (Stimson et al., 2006). These methods are used for example in Feser (2005); Feser et al. (2001); Feser and Sweeney (2000).

Cluster identification using I-O tables combines Feser (2005)'s methodolgy is as follows: Use the intermediate I-O table (A) (the part that focuses on inter-industry buying and selling) to generate two tables X and Y that show where a sector's inputs come from and who buys its output.

$$x_{ij} = \frac{a_{ij}}{a_{+j}} \qquad\qquad y_{ij} = \frac{a_{ij}}{a_{i+}}$$

Each entry (i, j) of the X and Y' matrices represents the proportion of sector i's output that is bought by sector j, and the proportion of sector i's inputs that came from sector j respectively. Each matrix is symmetric, as is the $I - O$ table.

At this stage, relationships that are not large can be zeroed out in the X and Y' matrices (Feser use only those that supply 2% of inputs (in the X matrix) and those that at least buy 1% of the sector's sales (in the Y' matrix) are retained). In addition, sectors that are categorized as*enabling sectors* are weighed down so that transaction volumes do not dominate the analysis. This is because many sectors get most inputs from a handful of providers. Examples of those that are classified as enabling are wholesales, information, legal services, advertising, finance and insurance. A weighing factor of 0.33 is used to each of the 55 enabling industries in the Feser's analysis.

Four measures are then proposed to measure sector interdependence. Each of these measures (i) the proportion of suppliers shared by two sectors i and j (R_{ij}^{ss}); (ii) the proportion of buyers shared by two sectors i and j(R_{ij}^{bb}); (iii) proportion of buyers of i that are suppliers to j (R_{ij}^{bs}); and (iv)proportion of suppliers to i, that are buyers from j (R_{ij}^{sb}). The first two measures are about horizontal linkages, and the latter two are about vertical linkages.

$$R_{ij}^{ss} = \frac{I_{ij}^{ss}}{U_{ij}^{ss}} \qquad R_{ij}^{bb} = \frac{I_{ij}^{bb}}{U_{ij}^{bb}} \qquad R_{ij}^{bs} = \frac{I_{ij}^{bs}}{U_{ij}^{bs}} \qquad R_{ij}^{sb} = \frac{I_{ij}^{sb}}{U_{ij}^{sb}}$$

where: $\mathrm{I}_{ij}^{ss} = S_i \cap S_j \qquad U_{ij}^{ss} = S_i \cup S_j$
$I_{ij}^{bb} = B_i \cap B_j \qquad U_{ij}^{bb} = B_i \cup B_j$
$I_{ij}^{bs} = B_i \cap S_j \qquad U_{ij}^{bs} = B_i \cup S_j$
$I_{ij}^{sb} = S_i \cap B_j \qquad U_{ij}^{sb} = S_i \cup B_j$
S: Suppliers and B: Buyers

The next step in the analysis creates a new matrix R^{MAX}, which selects the maximum of the four measures. In effect this matrix ignores the type of linkage that exists between the sectors, instead emphasizing the existence of some type of a link. Once this matrix is calculated, the next step is to apply cluster analysis to find groups of sectors that are linked together. This can be accomplished either using the R^{MAX} matrix or by using a threshold to create a 0/1 linkage matrix (for example, at $r_{ij}^{MAX} = .4$). In their analysis, Feser use Ward's hierarchical clustering algorithm on the linkage matrix and determine 45 distinct clusters.

To overcome the problem of sectors only belonging to one cluster, Feser then create a second matrix that represents the average linkage of each sector with all the sectors that belong to a particular cluster. This mean association matrix is *463 sectors X 45 clusters*. Given n sectors in cluster k, the elements of this matrix are calculated as:

$$\bar{r}_{ik} = \frac{\sum_{j \in k} r_{ij}}{n}$$

The most significant linkages are then identified by standardizing the elements of the $\bar{r}_{ik}$ matrix.

$$z_{ik} = \frac{\bar{r}_{ik} - mean(\bar{r}_{ik})}{s.d(\bar{r}_{ik})}$$

For each cluster k, sectors that had $z_{ik} > 2.25$ were then defined as secondary industries. Feser calls this step "fuzzing" the clusters. It is meant to overcome the problems that cluster analysis poses where sectors fall cleanly into only one cluster.

Appendix B

Identifying Competitive Clusters in the Twin Cities Area

B.1 Introduction

In identifying local clusters for the Twin Cities region, we adopt the Feser (2005) approach but with significant departures in how we identify and define clusters. Rather than an approach that employs cluster analysis, our approach here utilizes ideas from social network analysis in identifying the relative position of vertices (sectors) in the Input-Output trading relationships. As we will discuss later, this approach has the added advantage that sectors no longer have to be grouped to singular clusters but can easily belong to two or more clusters based on their actual trading patterns.

The identification of basic clusters uses data from IMPLAN for 2009 for the seven county area in the Twin Cities and for the nation. The Social Accounting Matrix from IMPLAN contains 440 total sectors. The Input-Output data for the Seven County area of Minneapolis-St. Paul includes an industry X industry matrix that contains 386 sectors. These sectors are created by IMPLAN and are groupings of NAICS categories into a smaller set of sectors. For the cluster study in the Twin Cities area we have combined a few of the sectors in to larger components that were reasonable where the IMPLAN NAICS mapping allowed it. For instance, any IMPLAN code that corresponds to the Medical equipment and supplies manufacturing NAICS sector (3391) was recombined to create the a single 'Medical equipment and supplies manufacturing' sector. In the IMPLAN coding this corresponded to five different categories that distinguished for example between surgical and medical instruments and surgical appliance and supplies manufacturing. Similarly all sectors falling under NAICS 62 were aggregated to create the 'Health care and social assistance' category, and all IMPLAN sectors that fell under NAICS 23 were aggregated into a 'Construction' sector. This aggregation reduced the number of sectors to 361 sectors.

The data allows us to tease out two aspects of clusters that are key to their identification. One component is the extent of a sectors prevalence in the region as compared to nationally, and secondly, the inter-relationship that exists among other sectors defining cross-sector relationships. To measure regional concentration location quotients (LQ) were calculated for each of the 369 sectors using total annual receipts (sales) for each sector at the seven county and national levels. This identified a total of 112 sectors (31%) that were basic to the region.

While traditional analysis often ended here, the I-O approach allows for the identification of cross-sector clusters by looking at the buying and selling patterns between the different sectors.

Based on I-O data there are at least five relationships among sectors that we can measure. These are:

1. Direct buying relationships (input sources): These can be defined using the percentage of input (in dollar value) that each sector gets from every other sector. If for example a sector gets at least $p_1\%$ of its input from a given sector, then we can define that a strong connection exists between these two.

2. Direct selling relationships (output sources): These can be defined using the percentage of all outputs from a given sector that are purchased by every other sector. If for example a sector sells at least $p_2\%$ of its output to a particular sector, then a strong connection exists between them.

3. Similar sourcing patterns: If two sectors have $p_3\%$ of their suppliers in common, then they are related.

4. Similar selling patterns: If two sectors have $p_4\%$ of their buyers in common, then they are related.

5. Linkages through intermediary sectors: If two sectors have at least $p_5\%$ firms who buy from one and sell to the other, then they are linked through a value-chain.

Each of these tell a somewhat different story about the relationships among sectors. For instance the input sources (#1 above) helps identify those industries that are key as suppliers of inputs to a large number of firms. Those sectors identified as selling to the most number of sectors at $p1\%$ levels are a key part of the supply chain for most businesses and have special importance in making the business environment work in the region.

A more interesting relationship is defined based on where a significant percentage output for each sector is consumed (#2 above). This relationship of sectors helps identify the anchor sectors around which supplier sectors are clustered. In this case the flows mark the direction of significant output flow from each sector that has few concentrated purchasers. Though each input may not constitute a large percentage of the receiving sector's inputs, the existence of the receiving sector is clearly important to the suppliers.

Relationships defined by 3-5 are more indirect and refer to sectors that share buyers and sellers while not necessarily trading with one another directly. These relationships are important in Feser's methodology which applies statistical cluster analysis to identify groups of sectors (the competitive clusters) based upon the maximal relationship defined between sectors based on all the above five categories.

The approach we outline below also addresses all of these relationships, albeit in a different way. By focusing on the selling relationship alone, we identify the sectors that are most important to the regional economy (anchors). We also study those who form part of the same cluster by having a similar buyer. Those who are important in supply chains are also identified by looking at to what extent they form part of a trading chain among sectors. The next section details the methodology and analysis we followed. Details of this analysis are given in Appendix B

B.2 Analysis

Among the definitions above the output (selling) relationship (#2) provides the most empirically interesting relationships as a basis for defining clusters. The clusters based on inputs are dominated by the whole sale sector, real estate, and management of companies as the important ties between sectors at the 3, 2 or 1% level. Once these three sectors are removed, the inter-relationship between sectors quickly disappears. From a regional analysis perspective the input network that forms around these aggregate sectors is of limited interest since the role of these sectors is not likely to be unique to the region. Though these sectors play an important role in providing inputs for a significant number of other sectors, their presence and size is likely a result of the location decisions of other competitive sectors, rather than the other way around. For these reasons, IMPLAN sectors that correspond to Real Estate and Wholesale have been removed from the analysis. Specifically, the removed sectors correspond to:

IMPLAN 360: Real estate: This includes all sectors in NAICS code 531. These are Lessors of Residential Buildings and Dwellings, Lessors of Nonresidential Buildings (except Miniwarehouses), Lessors of Miniwarehouses and Self-Storage Units, Lessors of Other Real Estate Property, Offices of Real Estate Agents and Brokers, Residential Property Managers, Nonresidential Property Managers, Offices of Real Estate Appraisers, and Other Activities Related to Real Estate.

IMPLAN 319:Whole sale This includes all sectors in NAICS code 42.

The output relationship as described above identifies directed relationships between sectors that sell significant percentage of their total output to particular sectors within the region. For the analysis here, we mark a 2% sale as an important measure of the seller's dependence on the buying sector. The relationship studied here is only limited to the basic sectors identified earlier through the LQ analysis using total sales figures. The relationship among the sectors can be represented in a matrix form that takes the value 1 for sector (i, j) whenever i's sale to j represents 2% or more of i's total sales. Plotted as a network, this relationship looks as shown in figure B.1. As can be seen, many of the sectors identified as basic do not have a single buyer that takes 2% of their output. For some this is because they produce and sell either directly to consumers or government or because they export their products mostly outside of the region. Others may have multiple buyers, none of whom buy at the 2% level.

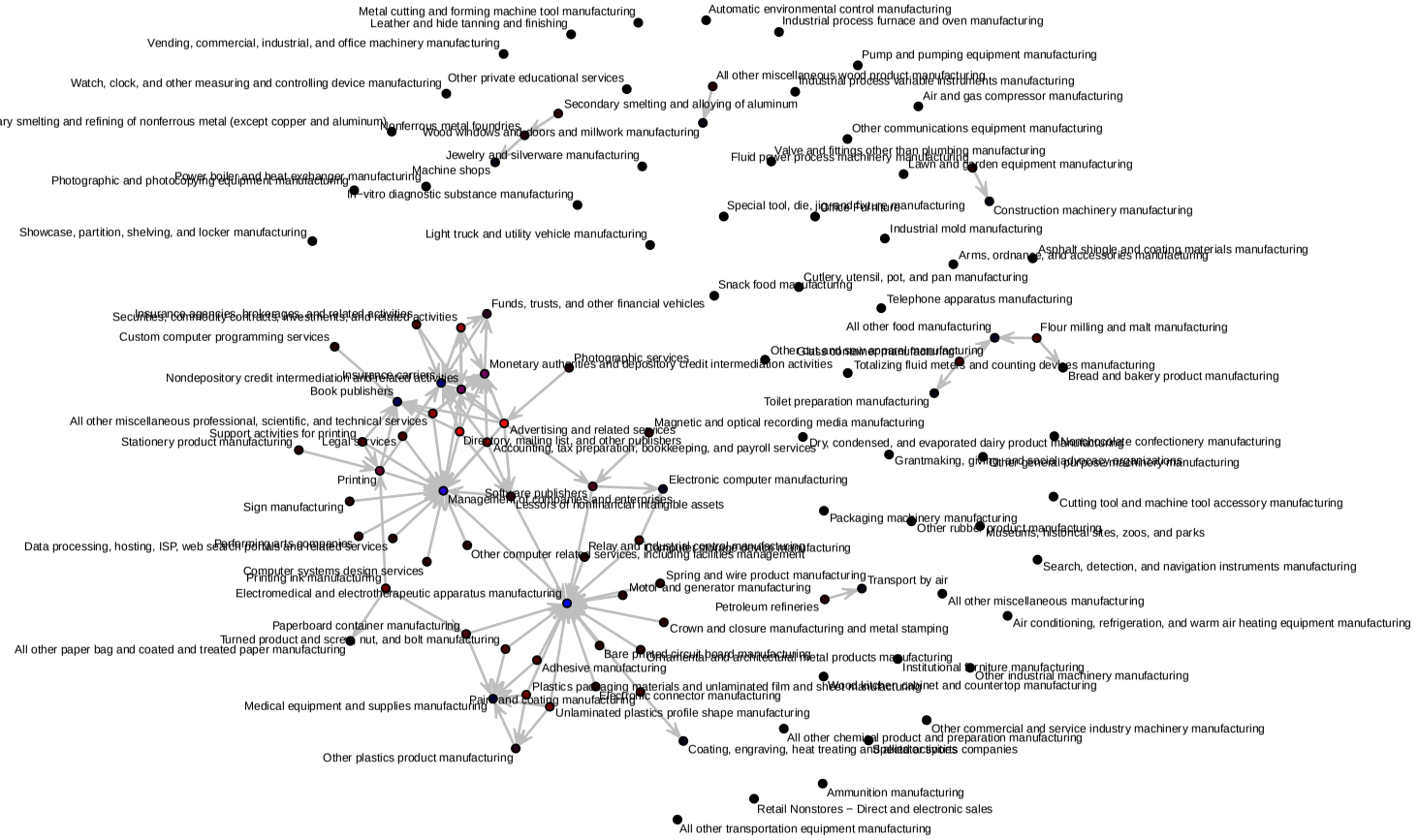

Figure B.1: Output network for basic sectors in the Twin Cities metropolitan area with arrows pointing in the direction of output flow (2% threshold)

In this network, relationships defined at the 2% level are often directed in one direction alone. Several measures of centrality can be applied to this network to understand the roles of different sectors. Here we use measures of degree centrality as well as betweenness, both of which tell us the different roles played by different sectors.

Degree centrality is a measure of the extent to which a vertex is connected to others vertices. In a directed network one may choose to distinguish between in-degree and out-degree. Essentially those sectors with high indegrees are those which buy from multiple sectors. These sectors therefore play an important role in the local economy as many other sectors depend on them to purchase a significant percentage of their outputs. We would call *a*nchor sectors as their success is essential for the well being of the other sectors around them. In the Twin Cities network, there are nine sectors that each have indegrees of three or more. These are listed in table B.1. The most prominent among these is the 'Electromedical and electrotherapeutic apparatus manufacturing' sector which has 17 indegrees (17 sectors selling to it 2% or more of their output). This is closely followed by Management of companies and enterprises at 14, and Insurance carriers at 9. Medical equipment and supplies stands fourth. The largest nine sectors as as shown in figure B.1.

Table B.1: Sectors with highest indegrees

	Sector	In-degree
1	Electromedical and electrotherapeutic apparatus manufacturing	17
2	Management of companies and enterprises	14
3	Insurance carriers	9
4	Medical equipment and supplies manufacturing	6
5	Non-depository credit intermediation and related activities	6
6	Monetary authorities and depository credit intermediation activities	6
7	Book publishers	6
8	Lessors of Non-financial intangible assets	3
9	Printing	3

Sectors that have high out-degrees sell to multiple sectors each buying at the 2% of output level. These sectors provide essential services across sectors and are not highly specialized in catering to singular sectors.Table B.2 presents those sectors with out-degrees of three or more (selling to three or more other sectors each at 2% of output or more). As can be seen, the highest degrees are for Advertising and related services, followed by directory, mailing lists and other publishers, miscellaneous professional, scientific and technical services, and accounting and tax preparation.

A third measure of centrality that helps us identify the sectors involved in supply chains is betweenness centrality. Betweenness is centrality measure that measures how often a vertex if found in the shortest path between other sectors. A vertex (sector) with high betweenness centrality tends to connect other sectors by buying from some sectors and selling to others. The highest betweenness measures in the Twin Cities area are for sectors in the management and financial and credit sectors, as well as printing and software publishers.

Table B.2: Sectors with highest out-degrees

	Sector	Out-degree
1	Printing	3
2	Support activities for printing	3
3	Printing ink manufacturing	3
4	Plastics packaging materials and unlaminated film and sheet manufacturing	3
5	Unlaminated plastics profile shape manufacturing	3
6	Monetary authorities and depository credit intermediation activities	3
7	Non-depository credit intermediation and related activities	3
8	Securities, commodity contracts, investments, and related activities	4
9	Accounting, tax preparation, bookkeeping, and payroll services	4
10	All other miscellaneous professional, scientific, and technical services	4
11	Directory, mailing list, and other publishers	6
12	Advertising and related services	7

Table B.3: Sectors with the highest betweenness centrality

	Sector	Betweenness Centrality
1	Software publishers	4.7
2	Printing	8.0
3	Monetary authorities and depository credit intermediation activities	9.5
4	Advertising and related services	11.0
5	Non-depository credit intermediation and related activities	15.0
6	Management of companies and enterprises	15.7

B.3 Identifying the cluster members

Having identified the anchor sectors, the next step to identify the members of the clusters that have formed around them. This process essentially identifies the basic sectors that sell at the 2% level to the anchor sectors but can also be expanded to identify non-basic sectors that provide employment to workers while depending heavily on the anchor sectors as a buyer of their products. This process defines two sets of clusters - one which forms based on all the sectors that have significant trading relationship with the anchor, and a basic cluster that is a subset of the former and only includes the basic sectors that have significant trading relationship. In defining the wider cluster, the previously removed wholesale and real estate sectors are also included in the analysis. These nine clusters are identified for each of the anchor sectors identified in table B.1.

One advantage of identifying cluster membership using the method outlined here is that it allows sectors to appear in different clusters as long as they have substantial trading with the anchor sector. This is in contrast with methods that adopt statistical cluster analysis for the classification of cluster membership which only allow a sector to be part of one cluster. For example, the Electromedical sector and the Medical Instrument sector share five sectors as members of their

cluster including Adhesive manufacturing, turned product and screw, nut, ad bolt manufacturing, and plastics packaging. Common sectors also exist in book publishing and printing.

Theses clusters were later combined into five for the purposes of the transportation related analysis in this work. The five expanded clusters (which include the non-basic sectors) are given in tables B.4 through B.8.

Table B.4: Medical Manufacturing expanded cluster

	Sector
Anchor	Medical manufacturing
1	Abrasive product manufacturing
2	Adhesive manufacturing
3	All other forging, stamping, and sintering
4	All other misc. electrical equipment and component manufacturing
5	Bare printed circuit board manufacturing
6	Broadwoven fabric mills
7	Communication and energy wire and cable manufacturing
8	Computer storage device manufacturing
9	Copper rolling, drawing, extruding and alloying
10	Crown and closure manufacturing and metal stamping
11	Electronic capacitor, resistor, coil, transformer, and other inductor manuf.
12	Electronic connector manufacturing
13	Fabric coating mills
14	Ferrous metal foundries
15	Health care and social assistance
16	Laminated plastics plate, sheet, and shape manufacturing
17	Lessors of nonfinancial intangible assets
18	Lime and gypsum product manufacturing
19	Management of companies and enterprises
20	Metal and other household furniture manufacturing
21	Motor and generator manufacturing
22	Nonferrous metal rolling, drawing, extruding and alloying
23	Ornamental and architectural metal products manufacturing
24	Other electronic component manufacturing
25	Other plastics product manufacturing
26	Paint and coating manufacturing
27	Paperboard container manufacturing
28	Petrochemical manufacturing
29	Petroleum lubricating oil and grease manufacturing
30	Plastics material and resin manufacturing

	Medical Manufacturing expanded cluster - continued
31	Plastics packaging materials and unlaminated film and sheet manufacturing
32	Power, distribution, and specialty transformer manufacturing
33	Printed circuit assembly (electronic assembly) manufacturing
34	Relay and industrial control manufacturing
35	Scientific research and development services
36	Semiconductor and related device manufacturing
37	Software publishers
38	Specialized design services
39	Speed changer, industrial high-speed drive, and gear manufacturing
40	Spring and wire product manufacturing
41	Textile and fabric finishing mills
42	Transport by truck
43	Turned product and screw, nut, and bolt manufacturing
44	Unlaminated plastics profile shape manufacturing
45	Warehousing and storage

Table B.5: Management of companies and enterprises expanded cluster

	Sector
Anchor	Management of companies and enterprises
1	Accounting, tax preparation, bookkeeping, and payroll services
2	Advertising and related services
3	All other miscellaneous professional, scientific, and technical services
4	Automotive equipment rental and leasing
5	Automotive repair and maintenance, except car washes
6	Business support services
7	Cable and other subscription programming
8	Car washes
9	Civic, social, professional, and similar organizations
10	Commercial and industrial machinery and equipment rental and leasing
11	Commercial and industrial machinery and equipment repair and maintenance
12	Computer systems design services
13	Data processing, hosting, ISP, web search portals and related services
14	Directory, mailing list, and other publishers
15	Electric power generation, transmission, and distribution
16	Electromedical and electrotherapeutic apparatus manufacturing
17	Environmental and other technical consulting services
18	General and consumer goods rental except video tapes and discs
19	Health care and social assistance
20	Independent artists, writers, and performers
21	Legal services
22	Lessors of nonfinancial intangible assets
23	Management, scientific, and technical consulting services
24	Newspaper publishers
25	Nondepository credit intermediation and related activities
26	Office administrative services
27	Other amusement and recreation industries
28	Other computer related services, including facilities management
29	Performing arts companies
30	Periodical publishers

	Management of companies and enterprises - continued
31	Personal and household goods repair and maintenance
32	Printing
33	Promoters of performing arts and sports and agents for public figures
34	Radio and television broadcasting
35	Scientific research and development services
36	Services to buildings and dwellings
37	Sign manufacturing
38	Support activities for printing
39	Telecommunications
40	Travel arrangement and reservation services
41	Wholesale trade businesses

Table B.6: Finance and Insurance expanded cluster

Sector	Role
Anchor	Finance and Insurance carriers
1	Accounting, tax preparation, bookkeeping, and payroll services
2	Advertising and related services
3	All other miscellaneous professional, scientific, and technical services
4	Automotive repair and maintenance, except car washes
5	Business support services
6	Cable and other subscription programming
7	Car washes
8	Civic, social, professional, and similar organizations
9	Commercial and industrial machinery and equipment rental and leasing
10	Commercial and industrial machinery and equipment repair and maintenance
11	Construction and maintenance
12	Directory, mailing list, and other publishers
13	Facilities support services
14	Fitness and recreational sports centers
15	Food services and drinking places
16	Funds, trusts, and other financial vehicles
17	Health care and social assistance
18	Independent artists, writers, and performers
19	Insurance agencies, brokerages, and related activities
20	Investigation and security services
21	Legal services
22	Management of companies and enterprises
23	Newspaper publishers
24	Periodical publishers
25	Personal and household goods repair and maintenance
26	Printing
27	Radio and television broadcasting
28	Real estate establishments
29	Securities, commodity contracts, investments, and related activities
30	Services to buildings and dwellings
31	Specialized design services
32	Transit and ground passenger transportation
33	Travel arrangement and reservation services
34	Wholesale trade businesses

Table B.7: Book publishers and Printing expanded cluster

	Sector
Anchor	Book publishers
1	Advertising and related services
2	All other miscellaneous professional, scientific, and technical services
3	Coated and laminated paper, packaging paper and plastics film manufacturing
4	Couriers and messengers
5	Custom computer programming services
6	Directory, mailing list, and other publishers
7	Insurance carriers
8	Management of companies and enterprises
9	Newspaper publishers
10	Other support services
11	Paper mills
12	Printing ink manufacturing
13	Radio and television broadcasting
14	Sanitary paper product manufacturing
15	Specialized design services
16	Stationery product manufacturing
17	Support activities for printing
18	Warehousing and storage
19	Wet corn milling
20	Wholesale trade businesses

Table B.8: Lessors of non-financial intangible assets expanded cluster

	Sector
Anchor	Lessors of Non-financial intangible assets
1	Accounting, tax preparation, bookkeeping, and payroll services
2	Advertising and related services
3	Business support services
4	Commercial and industrial machinery and equipment repair and maintenance
5	Couriers and messengers
6	Directory, mailing list, and other publishers
7	Electric power generation, transmission, and distribution
8	Electromedical and electrotherapeutic apparatus manufacturing
9	Environmental and other technical consulting services
10	Facilities support services
11	Management of companies and enterprises
12	Management, scientific, and technical consulting services
13	Other information services
14	Radio and television broadcasting

Appendix C

Future Scenario Analysis

C.1 Introduction

This section provides the technical details of the future scenarios developed in chapter 6. As discussed in section 6.2, several land use and residential density scenarios were developed to explore the accessibility outcomes from the 2030 network.

C.2 Technical Details

Technical details of the scenarios are provided in this section.

For each TAZ i, let

$E_{i,j}$: employment in year j at TAZ i (Metropolitan Council numbers)

$P_{i,j}$: population in year j at TAZ i (Metropolitan Council numbers)

γ_i: 1 if transitway has a stop in TAZ, 0 otherwise

δ_{e_i}: 1 if TAZ has positive employment growth, 0 otherwise

δ_{p_i}: 1 if TAZ has positive population growth, 0 otherwise

ρ_i: 1 when TAZ falls outside the I-694/I-494 ring, 0 otherwise

Υ_i: total employment under scenario for TAZ i in 2030

Φ_j: total population under scenario for TAZ i in 2030

Δ: additional employment and population increase fraction - can be 0.02 (2% moderate additional growth) and 0.07 (7% additional growth - ambitious)

C.2.1 Base scenario:

This would be the 2030 estimated land use by the Metropolitan Council.

C.2.2 Concentrating employment along transitways

Step 1: Let TAZs where the transitway stops are located have a more rapid growth than anticipated. Under this scenario, each location with with growth p will instead be assigned $p + \Delta$, where Δ is an achievable amount (on the order of 2 to 10 percent?). This would allow us to test a scenario that may be achievable without being over optimistic about job density.

$$\Upsilon_{i,2030} = \delta_{e_i} * \gamma_i * (\frac{E_{i,2030}}{E_{i,2010}} + \Delta) * E_{2010} \tag{C.1}$$

Step 2: Determine what this total increase amount is:

$$E_d = \sum \delta_{e_i} * \gamma_i * \Upsilon_{i,2030} - \sum \delta_{e_i} * \gamma_i * E_{i,2030} \tag{C.2}$$

Step 3: Calculate the employment size for each TAZ. If TAZ is on transit way, take equation C.1. Otherwise, for each TAZ where the change in employment has been positive and not on the transitway, reduce total employment such that equal number of jobs are removed from each TAZ from the base 2030 scenario:

$$\Upsilon_{i,2030} = \gamma_i * \Upsilon_{i,2030} + (1 - \gamma_i))(E_{i,2030} - \frac{E_d}{\sum(1 - \gamma_i) * \delta_{e_i}}) \tag{C.3}$$

TAZ's where job losses are anticipated remain unaffected.

C.2.3 Concentrating residences along transitways

The same approach can be applied where places with anticipated gains and on transitways gain population more rapidly than anticipated. Places that grow elsewhere grow at a less rapid rate. Places that lose population remain unaffected.

$$\Phi_{i,2030} = \delta_{p_i} * \gamma_i * (\frac{P_{i,2030}}{P_{i,2010}} + \Delta) * E_{2010} \tag{C.4}$$

$$P_d = \sum \delta_{p_i} * \gamma_i * \Phi_{i,2030} - \sum \delta_{p_i} * \gamma_i * P_{i,2030} \tag{C.5}$$

$$\Phi_{i,2030} = \gamma_i * \Phi_{i,2030} + (1 - \gamma_i))(P_{i,2030} - \frac{P_d}{\sum(1 - \gamma_i) * \delta_{p_i}}) \tag{C.6}$$

C.2.4 Rapid employment growth in outer suburbs

This scenario would envision something similar to the Levinson group expansion, but with few modifications. In our case:

- places outside the I-694/494 ring, with employment growth grow more rapidly than expected
- places inside the I-694/494 ring, with employment growth, grow less rapidly than anticipated
- places with negative job growth are not affected

Step 1: Let TAZ's outside the 494/694 ring have a more rapid growth than anticipated. Under this scenario, each location with with growth p will instead be assigned $p + \Delta$ instead

$$\Upsilon_{i,2030} = \delta_{e_i} * \rho_i * (\frac{E_{i,2030}}{E_{i,2010}} + \Delta) * E_{2010} \tag{C.7}$$

Step 2: Determine what this total increase amount is (total amount of jobs redistributed):

$$E_d = \sum \delta_{e_i} * \rho_i * \Upsilon_{i,2030} - \sum \delta_{e_i} * \rho_i * E_{i,2030} \tag{C.8}$$

Step 3: Calculate the employment size for each TAZ. If TAZ is outside of the beltway, take equation C.10. Otherwise, for each TAZ where the change in employment has been positive and is inside the beltway, reduce total employment such that equal number of jobs are removed from each TAZ from the base 2030 scenario:

$$\Upsilon_{i,2030} = \rho_i * \Upsilon_{i,2030} + (1 - \rho_i))(E_{i,2030} - \frac{E_d}{\sum(1 - \rho_i) * \delta_{e_i}}) \tag{C.9}$$

C.2.5 Rapid population growth in outer suburbs

This scenario would be applied similar to the growth of employment in outer suburbs:

$$\Phi_{i,2030} = \delta_{p_i} * \rho_i * (\frac{P_{i,2030}}{P_{i,2010}} + \Delta) * P_{2010} \tag{C.10}$$

Step 2: Determine what this total increase amount is (total amount of population redistributed):

$$P_d = \sum \delta_{p_i} * \rho_i * \Phi_{i,2030} - \sum \delta_{p_i} * \rho_i * P_{i,2030} \tag{C.11}$$

Step 3: Calculate the employment size for each TAZ. If TAZ is outside of the beltway, take equation C.10. Otherwise, for each TAZ where the change in employment has been positive and is inside the beltway, reduce total employment such that equal number of jobs are removed from each TAZ from the base 2030 scenario:

$$\Phi_{i,2030} = \rho_i * \Phi_{i,2030} + (1 - \rho_i))(P_{i,2030} - \frac{P_d}{\sum(1 - \rho_i) * \delta_{p_i}}) \tag{C.12}$$