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Broad Economic Benefits of Freight Transportation Infrastructure Improvement

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UIC UNIVERSITY OF ILLINOIS AT CHICAGO COLLEGE OF URBAN PLANNING & PUBLIC AFFAIRS Urban Transportation Center

Authors:

Kazuya Kawamura, P.S. Sriraj, Cara Bader, Elizabeth Fu, Ethan Halpern-Givens, Jud Murchie - Urban Transportation Center, College of Urban Planning and Public Affairs University of Illinois at Chicago

Peter Lindquist - Department of Geography and Planning, University of Toledo

Principal Investigator:

Kazuya Kawamura

Urban Transportation Center, College of Urban Planning and Public Affairs, University of Illinois at Chicago

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16. Abstract **This project strives to introduce a novel way to quantify the broad re-organization benefits associated with an improvement in the freight infrastructure. Using the approach based on 1) the technique known as Field of Influence, and 2) RAS adjustment of input-output account, the benefits of reducing truck congestion in urban areas are estimated with and without the re-organization effects. Both approaches are applied to various urban areas in the upper Midwest to evaluate their broad applicability and to investigate the relationship between the estimated benefits and the economic structure and size.**			
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EXECUTIVE SUMMARY

ES 1. Study Objective

This study's main objectives are to develop a methodology to estimate the broad economic benefits of improving the efficiency of trucking in urban areas and apply it to the regions with varying economic structure to assess its behavior and applicability. This study seek to complement the efforts by the FHWA to develop the Highway Freight Logistics Reorganization Benefits Estimation Tool ((HDR|HLB Decision Economics Inc. , 2008) that is designed to capture the direct user benefit and also the impacts of reorganization of supply chains. The team at the University of Illinois at Chicago and University of Toledo engaged in the following sub-tasks to accomplish the study objective.

1) Using input-output (I-O) analysis as the base, develop an analytical framework for quantifying broad economic benefits of transportation infrastructure project that can be used with publicly available data

2) Categorize urban areas in the upper Midwest according to their economic structure with respect to the degree of importance that freight-related industries play

3) Conduct a case study involving urban areas with varying economic structure to demonstrate the use of the framework and also to gain policy insights for real-world projects of major significance

4) Gain insights into the broad influence of freight transportation on the economy by examining how the benefits related to freight transportation projects vary across regions and also time

ES 2. Study Approach

The study was conducted with two parallel threads of activities. One set of activities focused on identifying and describing the economic structure of the urban areas in the upper Midwest region (Task 2 above). Of a particular interest is the role that freight sector plays in the economy of each urban area. The analysis, detailed in Chapter 4, first identified industries that are closely linked to truck freight sector through value chain clustering. Then, location quotients were used to quantify the degree of specialization of respective urban areas' economies in those value chain sectors. The second thread of activities, which are discussed in Chapters 5 through 7, focused on the development of a methodology to quantify the impacts of reducing truck congestion through capital programs. Unlike the traditional use of I-O model, which focuses on identifying the multiplier effect of an increase in final demand, our effort strived to capture the benefits associated with the change in the inter-industry purchase of trucking that is expected to result from reduced levels of congestion. RAS method and Field of Influence were used to accomplish this objective.

While it does not directly address productivity effects, it greatly expands the traditional scope of I-O analysis. We apply the methodology to five cities in the upper Midwest region with varying degrees of freight specialization, as determined using the value chain clustering and location quotients, to explore how the structure and size of the economy affect the outcome.

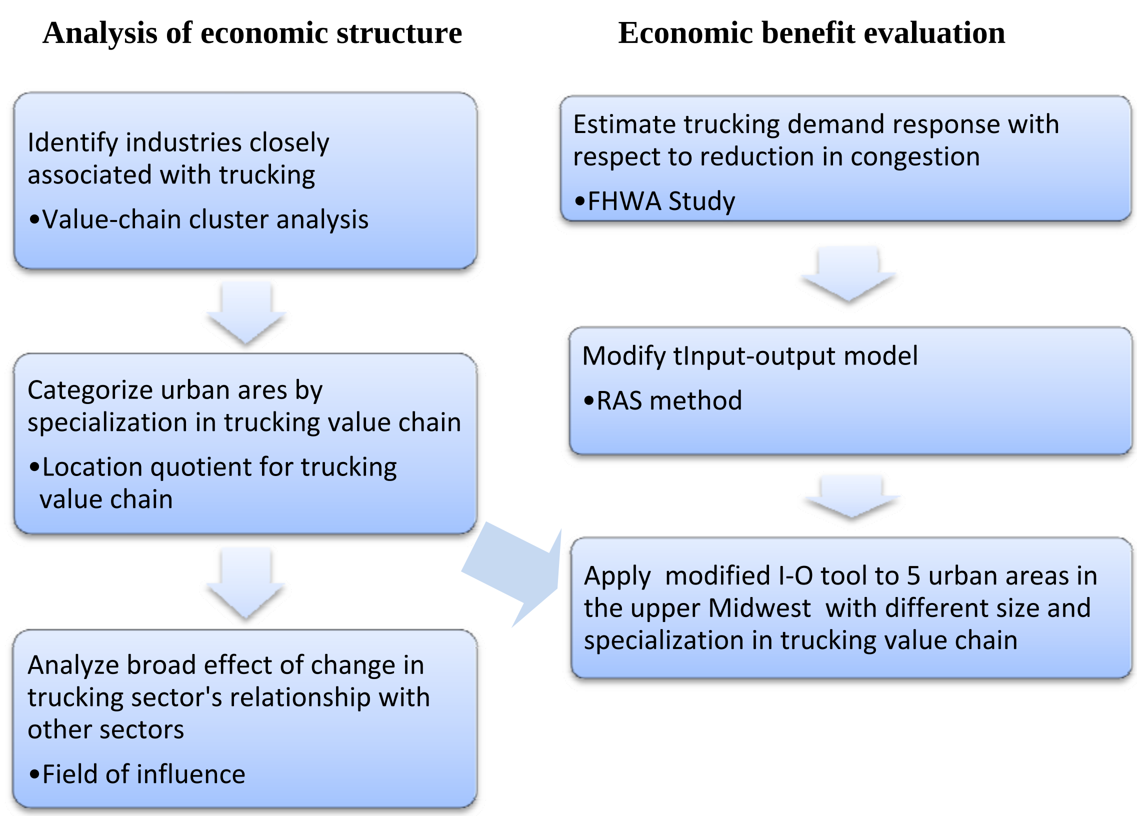

Figure ES-1. Study framework

ES 3. Study Area

The study area for this research encompasses the 10 central U.S. states of the Mid-American Freight Coalition: Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. Figure ES-2 shows the Economic Areas, as defined by the Bureau of Economic Analysis (BEA), contained in those 10 states. When determining the appropriate geography for an I-O model to measure the impacts of transportation investment it is important to capture how infrastructure quality may be different across economic regions but at the same time may impact production processes over a wide geographic area. It is important not to choose an area that is too small because transactions that occur in neighboring counties that make up the external economy will be treated the same as transactions with other states, countries, etc. However, it is a fundamental assumption of this study that infrastructure quality shapes economic structure in different ways in different regions. The BEA's economic areas are meant to capture the relevant regional markets surrounding metropolitan and micropolitan statistical areas. They include one or more economic nodes and surrounding counties related to those nodes. Appendix A lists all of the BEA economic areas and their requisite county components that fall partially or completely within the 10 states region covered in this study.

ES 4. Methodology

Categorization of urban area economies

Using cluster analysis of the I-O accounts, we identified the industries that are most strongly linked with the truck transportation industry in the 10 central states region, in terms of the total dollar value of transactions between the trucking industry and all other industries. Industry sectors in the 10 central states are grouped into primary, secondary, tertiary, and quaternary clusters according to the strength of their relationship with the freight trucking industry.

Figure ES-2. A map of the study area

Then, location quotients are used to evaluate an economic area's specialization in certain industries. This analysis showed that specialization in industries that comprise the most significant value-chain clusters for truck transportation varies across economic areas in the 10 central states. We found that areas such as Louisville, Toledo, and Fort Wayne have high concentrations of industries that are closely linked with trucking. Some areas, such as Detroit, Champaign, and Springfield are highly specialized in industries that purchase services from trucking industries (called "forward linkages" – see Figure ES-4). Meanwhile, Columbus, Wichita, Wausau, and Duluth are specialized in the industries that sell services and commodities to the trucking industry (called "backward linkages" – see Figure ES-5).

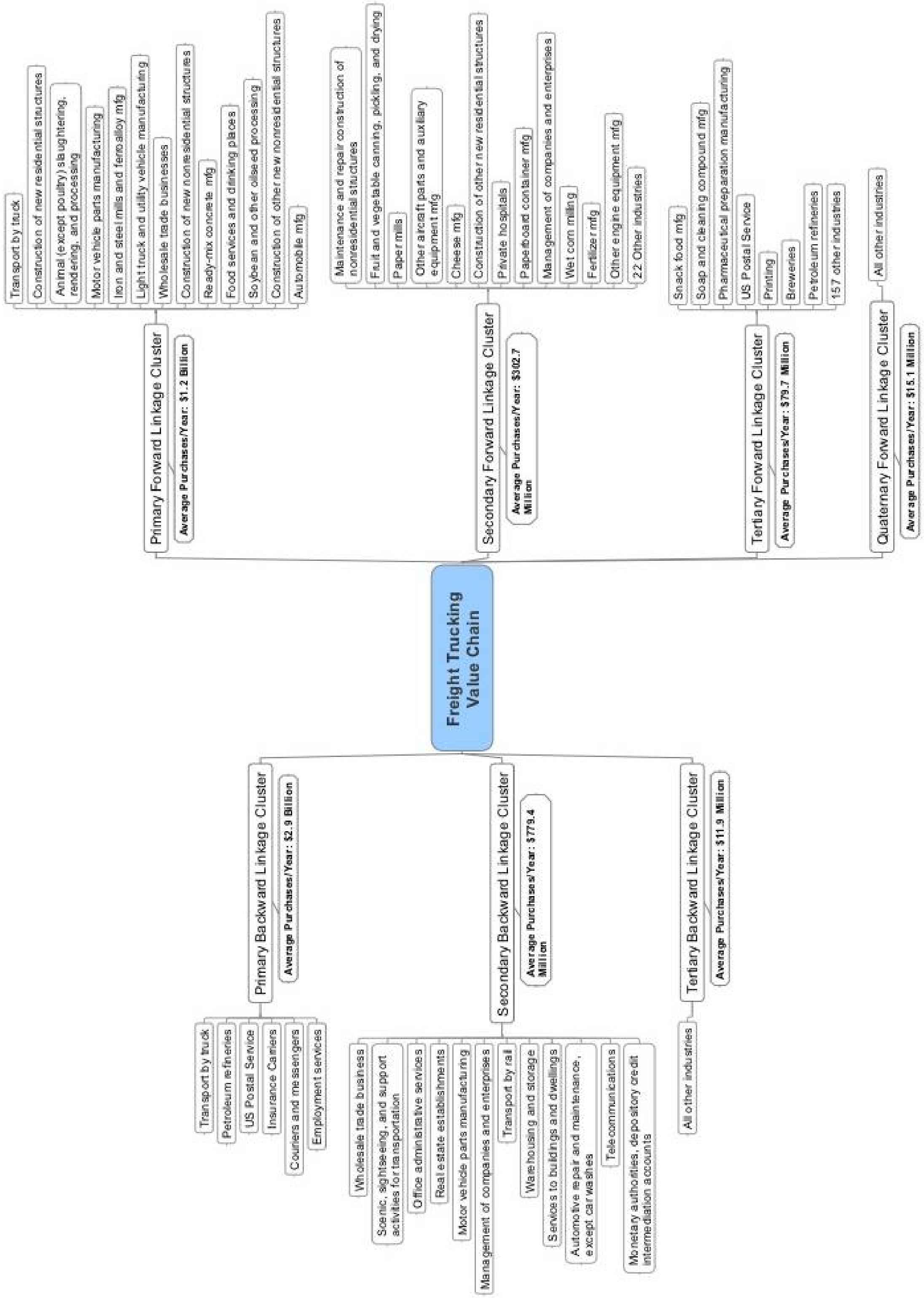

Figure ES-3. Trucking value chain clusters

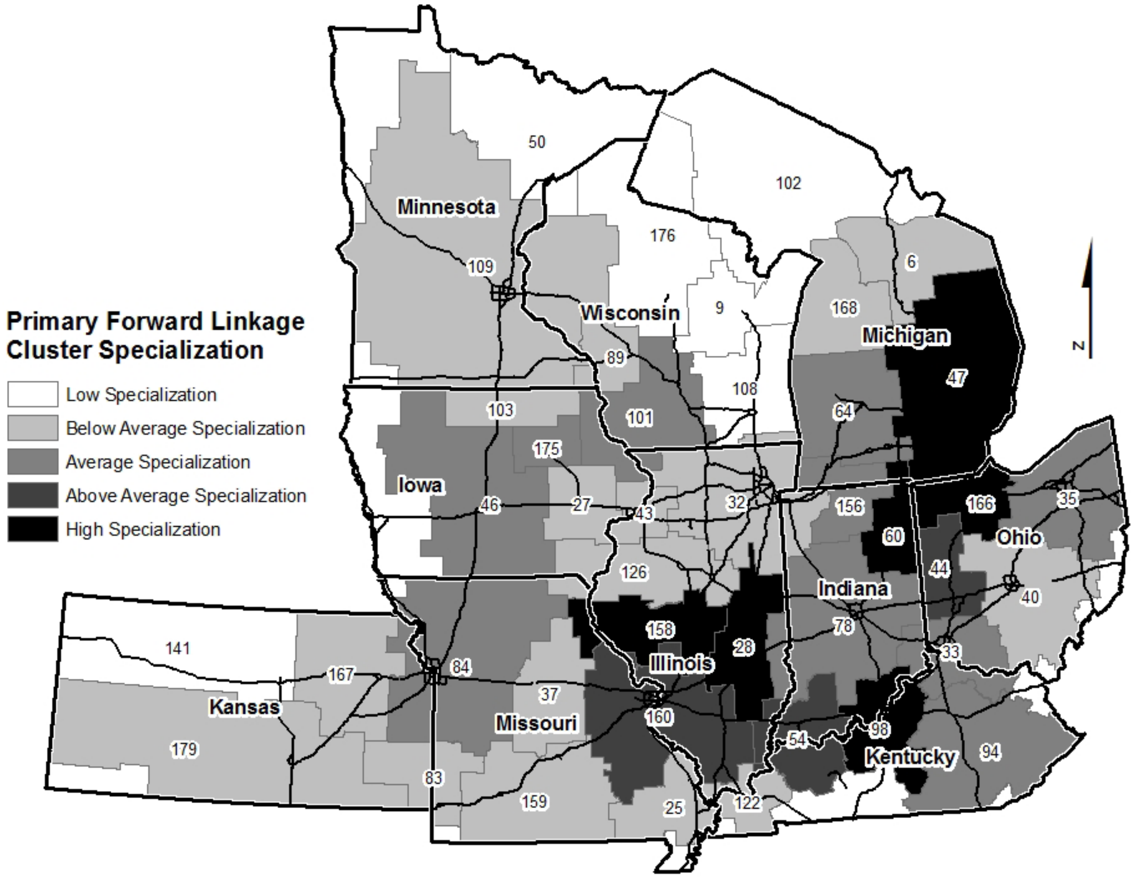

Figure ES-4. Degree of specialization in primary forward linkage clusters

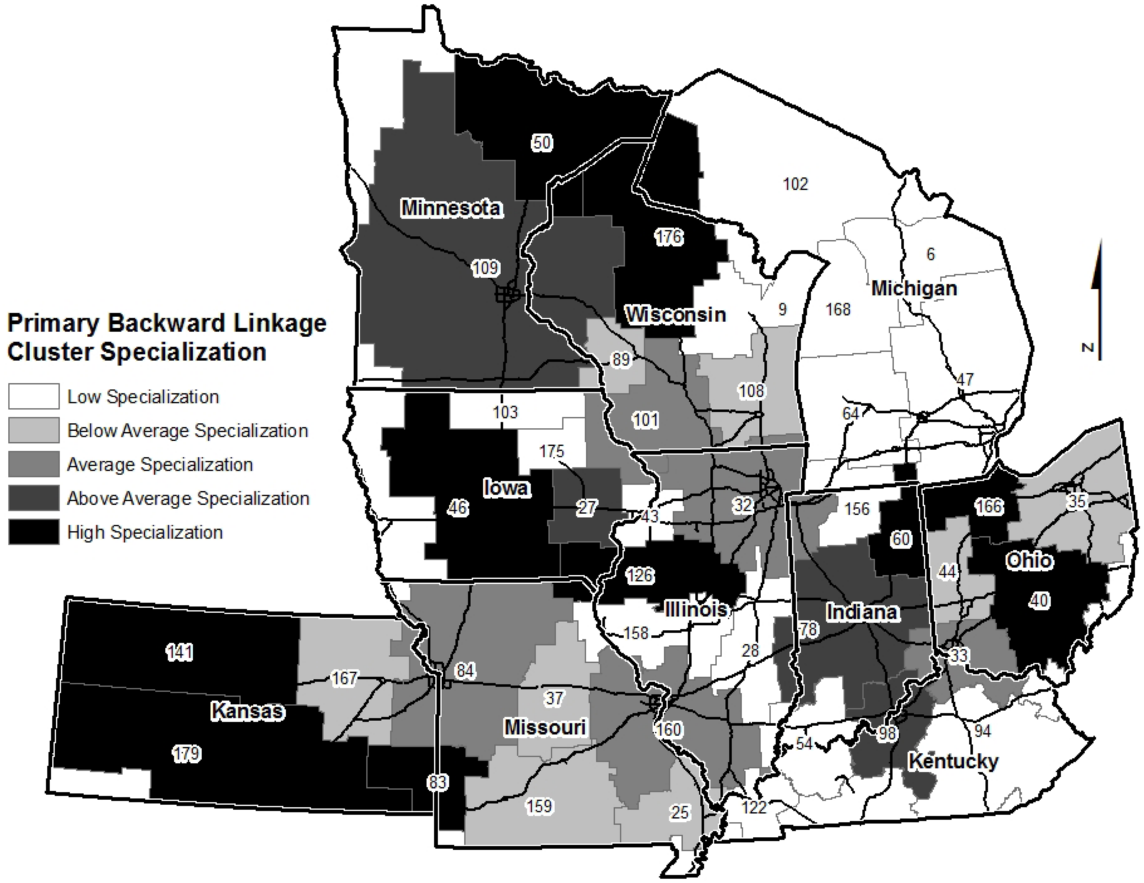

Figure ES-5. Degree of specialization in primary backward linkage clusters

Additionally, we found that no economic areas are highly specialized in the group of industries that are a part of the secondary backward linkage cluster. This suggests that these industries are more evenly distributed throughout the 10 states region. This cluster includes industries that provide general firm support. These industries are primarily local serving, and thus it is less likely that any economic area would contain more of these industries than is necessary to meet the needs of the local economy.

Field of influence

The field of influence represents the change in the Leontief inverse matrix that occurs because of technological change that is represented as one until change in the technological coefficient. Field of Influence was used to evaluate how coefficient change in the truck transportation industry spreads throughout the Leontief inverse matrix in three different economic areas: Chicago-Naperville-Michigan City, IL-IN-WI (EA32), Detroit-Warren-Flint, MI (EA47), and Madison-Baraboo, WI (EA101). An overview of the economic structure of those three areas is provided in Table ES-1.

Table ES-1. Overview of analyzed economic areas

	Chicago	**Detroit**	**Madison**
Total Output	$982,050,219,877	$592,962,114,072	$102,952,332,039
Primary BL Cluster Specialization	Average	Below Average	Average
Secondary BL Cluster Specialization	Above Average	Above Average	Below Average
Primary FL Cluster Specialization	Below Average	High	Average
Secondary FL Cluster Specialization	Below Average	Average	Average

Modified input-output analysis

The I-O analysis, at least the standard set up based on the Leontief's pioneering work and its extensions such as multiplier and impact analyses, cannot serve as the substitute for the microeconomic approach used by the FHWA Tool. This is because I-O analysis estimates the broad economic impacts of a change in the final demand of service or product produced by an industry. In the I-O analysis, the economic structure is exogenously provided by the I-O account. This makes traditional demand-side I-O analysis technique ill-suited for the analysis of improvement in technology or efficiency. Fortunately, there have been numerous efforts to extend the use of the I-O accounts beyond the economic impacts studies of the past.

To link the performance of transportation infrastructure with the freight industry, and thereby I-O tables, we first converted 20% in truck delay reduction into an increase in demand for trucking based on the empirically measured elasticity for freight services caused solely by a delay in reduction on major highway corridors in the central region of the U.S. ((HLB Decision Economics, 2008). An elasticity of 0.0175 was multiplied by a 20% reduction in delay, resulting in a 0.35% increase in demand for freight. This change in demand was then multiplied by the original trucking output to determine the increase in demand. This additional output was then added to the original trucking output to determine the updated trucking output for each economy.

For the amount of delay reduction, we used the 2020 Regional Transportation Plan (RTP) for the Chicago region (Chicago Area Transportation Study, 1998). The plan included 20 capital improvement projects with a price tag of $12.4 billion and was scheduled to be implemented over the course of 23 years. The 2002 plan estimated that the combined effect of those projects would result in a 4.9% reduction in total travel for commercial vehicles, which is translated into a 20% reduction in delay. We used this 20% figure as the benchmark for what can be expected from a set of major capacity improvement projects that are proposed in a typical RTP. Of course, the scale of investment and resulting reduction in congestion vary from region to region. As such, this research should be interpreted strictly as a theoretical study with the goal of demonstrating the feasibility of the proposed analysis method.

The new trucking output served as the element change necessary to create an alternative scenario using the RAS method. The RAS method is a bi-proportional method of adjusting a transaction matrix by introducing or changing at least one new factor. By estimating an increase in demand for trucking associated with a 20% reduction in delay, an alternative direct requirements matrix was constructed. The baseline and alternative direct requirements matrices were then compared to identify the change in each economy. An overview of the analysis approach is graphically shown in Figure ES-6.

This approach was applied to five regional economies that were selected based on the value-chain cluster analysis and the location quotients calculated. The five regional economies selected for analysis are: Toledo, Detroit, Milwaukee, Chicago, and Minneapolis. The analysis measures both the short-term economic impact of investing in freight-dependent economies and the resulting permanent structural shift due to a change in demand. Therefore, both an investment amount (shock) and a change in demand must be assigned to conduct the analysis.

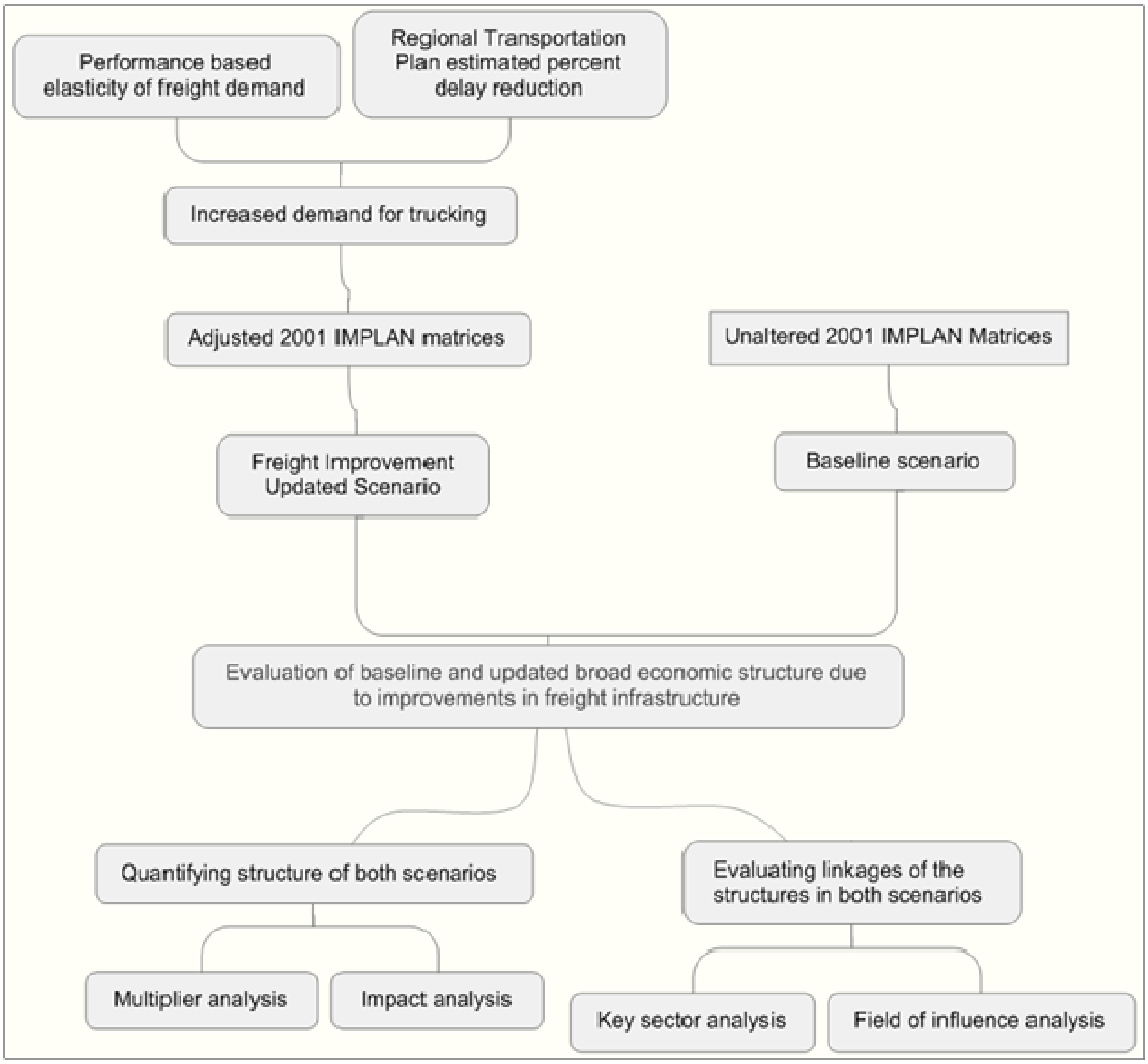

Figure ES-6. Impact analysis framework

Table ES-2. Five urban areas chosen

	2010 GDP ($million)	Specialization in value chain clusters			
		Primary forward	**Secondary forward**	**Primary backward**	**Secondary backward**
Toledo	$26,605	High (1.279)	Average (0.965)	High (1.598)	Below avg. (0.903)
Detroit	$197,773	High (1.377)	Average (0.957)	Low (0.740)	Above avg. (1.220)
Milwaukee	$84,574	Low (0.732)	Above avg. (1.084)	Below avg. (0.848)	Below avg. (0.877)
Minneapolis	$199,596	Below avg. (0.779)	Average (1.016)	Above avg. (1.097)	Average (1.042)
Chicago	$532,331	Below avg. (0.873)	Below avg. (0.864)	Average (1.008)	Above avg. (1.183)

- High Specialization (LQ>=1.25)
- Above Average (1.05<=LQ<1.25
- Average (0.95<=LQ<1.05
- Below Average (0.75<=LQ<0.95)
- Low Specialization (LQ<0.75)

ES 5. Results

Table ES-3 displays a summary of the results of the field of influence analysis. The analysis results confirm that the spread of technological change beginning in the trucking industry would vary between economic areas. However, it also shows that the industries that purchase freight trucking in the largest amounts will not necessarily experience the largest coefficient changes. Also, the relationship between specializations in these industries and coefficient change in mixed. The Chicago region is less specialized in both clusters, but experienced changes very similar to the other regions in the case of the primary linkage cluster. In the secondary linkage cluster the change was greater than Detroit and less than Madison, despite the fact that both economies are more specialized. The analysis showed that coefficient change would be largest in cells indicating backward linkages to trucking, meaning the change in the efficiency of trucking is felt most strongly by the industries that sell services or goods to the trucking industry.

Table ES-3. Summary of Field of Influence analysis results

Region	Location of Largest Change	Specialization in Primary Forward Linkage Cluster	Change Value	Specialization in Secondary Forward Linkage Cluster	Change Value
Chicago	MFG inputs to Trucking	Below Average	0.0091	Below Average	0.0086
Detroit	Trucking-Trucking	High	0.0093	Average	0.0067
Madison	Trucking-Trucking	Average	0.0093	Average	0.0099

Modified I-O analysis produced results that illustrated the limitation of I-O models. One obvious drawback of I-O framework is its inability to simulate changes in price. As such, the simulation of efficiency improvements via an increase in trucking output does not produce expected market response. The analysis showed that improving the efficiency of trucking industry tends to reduce multiplier effects. This result is understandable because transportation is a "derived" demand, meaning that consumption of it does not produce profit or positive utility. Efficient transportation may increase the profitability of firms that consume freight but it does not necessary lead to an increase in the consumption of freight transportation. The policy implication of this finding is that the rationale for investing in infrastructure rests with regional competition. Our analysis indicates that not having efficient freight transportation system does not make damage region's economy on its own. However, if the region is deemed less desirable by the businesses that rely heavily on freight, it would lead to job losses and less competitive economy.

The findings from the analysis, presented in Chapters 5 (Field of Influence) and 7 (modified I-O model) suggest that it is not the case that economic structure in which freight and related industries have a strong presence will likely to benefit from improvement in efficiency in moving freight on trucks. In other words, this study was not able to clearly identify the relationship between technological change (e.g. reduced truck congestion) and cluster membership and freight specialization of Economic Areas. It should be stressed that only three and five urban areas were examined in the Field of Influence and modified I-O analysis, respectively. Therefore, these findings need to be interpreted as preliminary results.

In terms of techniques, a part of the issue is the lack of data to reflect more realistic response in the I-O accounts during the RAS process. Thus, one of the next steps in this line of research is to collect data on changes in inter-industry transaction patterns in response to price change or efficiency improvement. As an alternative of research, conducting the analysis using a CGE or another more sophisticated economic model is likely to provide additional insight.

CHAPTER1. INTRODUCTION

The intimate relationship between freight transportation and the welfare of the economy exists at many levels. For example, based on our own calculation using the Employment Matrix from the Bureau of Labor Statistics (Bureau of Labor Statistics, 2008) , freight transportation is a tremendous job generator for the nation, directly employing 7.8 million people, or 5.8% of the entire workforce in the U.S. In some regions, such as Chicago, freight industry accounts for over 10% of the employment (The Workforce Boards of Metropolitan Chicago, 2005). For many communities that have lost manufacturing jobs over time, freight industry is regarded as the potential economic base for the future.

These figures however, do not capture the true extent of the impact the freight transportation has on the nation's economy. Movement of material is an essential input for the production of numerous products and services. As such, the efficiency with which the goods are transported affects multitude of industries in a variety of ways. As explained in a study published by the FHWA (HDR|HLB Decision Economics Inc. , 2008), there are several dimensions in which the performance of freight transportation affects the economy. They are, first order benefits, or direct benefits to the carriers and shippers from the reduction in the cost of transport, the second order benefits that take into account the changes in the logistics and supply chain management practices, the third order benefits that include the effects associated with the changes in the quality of the products themselves or demand for those products or even an introduction of new products, and finally, the "other effects" that include long-term job and/or income growths.

The key policy insight that is often sought by the decision makers and transportation professionals is whether improving the efficiency of freight transport, mostly through improvements in infrastructure, produce enough economic benefit to justify the investment required. To this end, there have been some notable efforts to develop practical tools to provide insights to the decision makers.

The Highway Freight Logistics Reorganization Benefits Estimation Tool (HDR|HLB Decision Economics Inc. , 2008), developed with a support from the FHWA captures the first and second order benefits associated with investments for infrastructure improvement projects that affect freight flow. The FHWA Tool calculates the first and second order benefits based on the changes in consumer surplus. While it is a useful and to our knowledge the only existing tool that actually estimates the second-order benefits associated with freight, it also has some shortcomings. As described in the report that accompanied the tool, it is not designed to capture the third-order and other types of benefits.

In this study we strive to develop an approach that can capture the propagation of benefits through the inter-industry transactions by using input-output (I-O) framework that has long been used for economic development studies. Since I-O accounts are based on the data collected from actual business transactions, they provide information about the real-world interdependence among industries, GDP (or Gross Regional Product), and final demand. I-O accounts are commercially available at national, state, county, and Zip levels. The data are updated annually. Thus, the I-O analysis can be conducted at various geographical scales and also the data are quite easy to obtain and maintain. Also, I-O analyses capture at least some of the third-order benefits, including the changes in the inter-industry demand for the products and services but not the changes in the geographical allocation of economic activities or innovation.

It should be noted that the I-O analysis, at least the standard set up based on the Leontief's pioneering work (1953), cannot serve as the substitute for the microeconomic approach used by the FHWA Tool. This is because I-O analysis estimates the broad economic impacts of a change in the final demand of service or product produced by an industry. In contrast, the FHWA Tool estimates the change in the total (intermediate and final) demand for trucking and use consumer-surplus to calculate the benefits. Since the FHWA Tool simulates changes in the demand curve itself, it incorporates the change in the economic structure, e.g. the use of trucking as production inputs, into the analysis. In the I-O analysis, the economic structure is exogenously provided by the I-O account. This makes traditional demand-side I-O analysis technique ill-suited for the analysis of improvement in technology or efficiency.

Fortunately, there have been numerous efforts to extend the use of the I-O accounts beyond the economic impacts studies of the past. We will develop a new approach, specifically designed to capture the effect of improvement in the freight sector, by applying some of the I-O based techniques, RAS adjustment of I-O account and Field of Influence analysis. We then apply the approach to different urban areas in the upper Midwest, selected based on their size and economic structure, to assess if different economies respond differently.

Summarizing, the objectives of this research are the following,

1) Using input-output (I-O) analysis as the base, develop an analytical framework for quantifying broad economic benefits of transportation infrastructure project that can be used with publicly available data

2) Categorize urban areas in the upper Midwest according to their economic structure with respect to the degree of importance that freight-related industries play

3) Conduct a case study involving urban areas with varying economic structure to demonstrate the use of the framework and also to gain policy insights for real-world projects of major significance

4) Gain insights into the broad influence of freight transportation on the economy by examining how the benefits related to freight transportation projects vary across regions and also time

This report is organized in the following order. The next chapter presents background on the past studies related to the relationship between infrastructure improvement and productivity, and economic growth. The second half of the chapter will discuss the tools that have been developed to quantify, at project level, economic benefits of improving the efficiency of freight movement. Chapter 3 introduces the overall framework of the study and the key data sets and software that were used. Chapter 4 describes the classification of major urban areas in the upper Midwest region in terms of the degree of specialization/dependence on the clusters of industries that are closely associated with trucking sector. While such analysis is relatively common in the Economic Development profession, we found that application to the freight industry is surprisingly rare. As such, we included an extensive review of theories and techniques behind economic cluster analysis in the hope that this useful tool will be used more often in the future to guide the transportation policy decisions. In Chapter 5, an I-O based technique called Filed of Influence is applied to three urban areas to examine the propagation of the improvement in the efficiency of trucking sector through the rest of the economy. It is followed by the development of an approach that is designed to use a I-O model to simulate the effect of reducing truck delays on the broad spectrum of the economy. Chapter 7 presents the findings from applying the aforementioned approach to five urban areas in the upper Midwest to test various hypotheses related to the relationship between economic structure and expected benefit from reducing truck congestion. The report concludes with the summary of findings and recommendations for future studies in Chapter 8.

CHAPTER 2. BACKGROUND

In this chapter, two threads of research, impacts of infrastructure investment on productivity and the overall economy, and development of tools to quantify the impacts, are reviewed. Further review of literature related to the techniques used for specific tasks of this project, e.g. I-O analysis, will be introduced within the corresponding chapters of this report.

The claim that large scale infrastructure investments cause economic growth has been debated in academic literature, but neither proponents nor critics have developed consistent empirical support (Chandra and Thompson 2000). However, it is clear that incorporating economic impacts of freight-related infrastructure improvements in transportation planning, especially at the regional level, is the exception rather than the rule. Critical infrastructure for freight transportation is often neglected or paid little attention in Regional Transportation Plans (RTPs), because of the inherent difficulty in articulating tangible benefits for taxpayers (Seetharaman, Kawamura and Dev Bhatta 2003).

2.1. Impacts on Productivity

The national economic slowdown in the 1970s and 1980s sparked an interest in the relationship between public infrastructure investment and productivity. The basic approach to capturing this relationship is using the Cobb-Douglas production function. Aschauer (1989) spurred a debate when his uses of a Cobb-Douglas production function found a positive output level with respect to public capital. Using data from 1949 to 1985, he analyzed nonmilitary public capital stock and finds a positive relationship between the ratio of public to private capital stock and total factor productivity. Specifically, he found a 1% increase in the public-private capital stock ratio results in a total factor productivity increase of 0.39% (Aschauer, 1989). Munnell and Cook (1990) further Aschauer's findings and contends that the decline of public infrastructure investment is the reason for labor productivity declines. Among their findings include public capital having a statistically significant impact on private sector output and on the state-level, had a positively significant impact on state's private sector employment. Both Aschauer and Munnell's findings resulted in criticisms. Some researchers argue the specifications used, such as estimated elasticities and implied marginal productivity of public capital as too high (Nadiri & Mamuneasc, 1998). There were also questions about causation and the failure to address how public infrastructure capital and productivity growth could both affect each other (Shirley, 1999) (Nadiri & Mamuneasc, 1998).

Other researchers, including Hulten and Schwab (1984), (1991) and Holtz-Eakin (1994), disagree on the strong results as they found a minimal impact of public capital on productivity gains. Specifically focusing on manufacturing, Hulten and Schwab find support against the notion that the aging public infrastructure is the cause of the decline of manufacturing in the Snowbelt region of the U.S. They use a Hicks-neutral production function which assumes that output is a function of capital, labor, intermediate input, and an augmented value-added technical change. Analyzing the growth rates of these factors between 1951 and 1978, they observed little difference in total factor productivity among all regions in the U.S. Between 1965-73 and 1973-78, total factor productivity was declining in almost every region of the U.S. They found little evidence to suggest that a lack of public investment in the Snowbelt region was negatively affecting the total factor productivity of the manufacturing industry (Hulten & Schwab, 1984). When the pair later expanded their analysis through 1986, they again found that public investment did not significantly explain the success of manufacturing in the Southern and Western regions of the U.S. (Hulten & Schwab, 1991).

Hulten and Schwab's analyses also sparked criticism for failing to directly calculate public infrastructure. In response to Hulten and Schwab's work, Garcia-Mila and McGuire (1992) used a Cobb-Douglas production function that includes public investment inputs to compare the impact of public and private inputs across the entire economy, rather than focusing on the one industry. Garcia-Mila and McGuire includes variables such as capital in structures, capital in equipment, labor, highway capital, and education expenditures for the 48 contiguous states between 1969 and 1983. Their results show highway and education as having a positive correlation with private output, with education having a stronger impact. .

Holtz-Eakin (1994) attempts to reconcile the disparate findings of Hulten and Schwab and Garcia-Mila and McGuire among others on the impacts of public investment on productivity by using controlling for unobserved, state-specific characteristics in the production function.

Using data from the 48 contiguous states between 1969 and 1986, he finds that both on the state and regional level the elasticity for public sector elasticity is approximately zero. Using a similar dataset as Holtz-Eakin, Evans and Karras (1994) investigated the productivity of public investment for a period between 1970 and 1986. They focus on the nonagricultural industries and found that only public investment in education as productive, challenging the extent to which other investments, including infrastructure, are productive. They contend that their study is more robust as it corrects for serial correlation and accounts for endogeneity issues..

The conflicting results noted in this literature review signals that the impact of public investment on public infrastructure is susceptible to the inputs analyzed. Depending on these factors are defined, the results can vary from earlier research suggesting large economic gains to more marginal impacts of later research.

2.2. Impacts on Overall Economy

Chandra and Thompson (2000) suggest that public infrastructure investments, specifically highways, will have a different impact on industries based on proximity to the investment and market orientation. They construct an econometric model to estimate how new highways affect earnings at the county level, after adjusting for intervening factors, using data on new highway construction from 1969 to 1993. They find that highways affect the spatial allocation of economic activity in the region. New highways can encourage economic activity in the counties they pass through, but draw economic activity away from neighboring counties without highway access. This supports the hypothesis that highway projects in rural areas will actually encourage leakages from the local economy and promote location in nearby metro areas. Chandra and Thompson caution against the method of aggregating public capital and industrial activity employed by Holtz-Eakin because it masks the inter-industry dynamics that are altered by infrastructure projects. Although, on aggregate, economic activity may not rise as a result of a highway project, some industries will be positivity affected and other industries may face ambiguous changes (Chandra and Thompson 2000).

2.3. Tools for Estimating Economic Impacts

For a number of years, the Federal Highway Administration (FHWA) has studied the links between transportation improvements and economic performance using macroeconomic, microeconomic, and general equilibrium approaches (HLB Decision Economics 2004). FHWA has sponsored the creation of a tool to refine benefit cost analysis to provide more precise accounting of the benefits of freight transportation projects that documents short-term and long term benefits (HLB Decision Economics 2008).

In the Tool, the benefits of re-organization of the logistics and supply chain, i.e. the second-order benefits, is calculated by the change in the consumer surplus when the demand curve for the trucking is altered after the infrastructure improvement. In contrast, the first-order benefit is calculated from the change in the consumer surplus resulting from the trucking price change along the original (pre-improvement) demand curve. The Tool, which is spreadsheet based, relies on the estimates of the elasticities of demand with respect to the generalized cost of trucking and also trucking rate, obtained from the empirical analysis of data collected for various city-pairs throughout the country (HLB Decision Economics, 2008). Since the analysis found significant differences in the elasticites among the regions, separate sets of estimates were developed for Eastern, Central, and Western parts of the country.

The FHWA Tool calculates the first and second order benefits based on the changes in consumer surplus. While it is a useful and to our knowledge the only existing tool that actually estimates the second-order benefits associated with freight, it also has the following issues.

1. It is not sensitive to the scale of analysis since the elasticity data are available only at very large region levels

2. Elasticity data must be updated periodically to reflect the changes in the freight industry or in the supply chain practices and technology

3. It is not designed to capture the third-order and other types of benefits, and

4. It does not distinguish between in-house and for-hire trucking

In recent years, a proprietary model called TREDIS has incorporated connections between transportation infrastructure improvements and changes in employment and population using empirically observed data (Alstadt, 2012). The analysis, however, is cross-sectional and fails to control for critical exogenous factors such as educational attainment, government investment, infrastructure stock.

There has been a lack of publically accessible tools at the regional scale in evaluating the impacts of freight policy improvements (Seetharaman, Kawamura and Dev Bhatta 2003). Seetharaman, Kawamura, and DevBhatta employ an I-O model to measure the direct and indirect economic impacts expected from implementation of the 2020 Regional Transportation Plan (RTP) for Chicago. However, in this study they note the inability of I-O models to address the fleet composition change that may occur as a result of cost savings. They also point out that under a phased timeline of implementation, the economic structure of the regional economy will be altered and thus later projects may have different impacts than predicted. Also, this study cannot evaluate the impacts on in-house trucking services, which they note are significant components of the freight trucking industry.

CHAPTER 3. STUDY FRAMEWORK

3.1 Study Components

This study's main objectives are to develop a methodology to estimate the benefit of improving freight transportation and apply it to the regions with varying economic structure to compare and explore the outcomes. As such, the study was conducted with two parallel threads of activities, as shown in Figure 1. One set of activities focused on identifying and describing the economic structure of the urban areas in the upper Midwest region. Of a particular interest is the role that freight sector plays in the economy of each urban area. The analysis, detailed in Chapter 4, first identified industries that are closely linked to truck freight sector through value chain clustering. Then, location quotients were used to quantify the degree of specialization of respective urban areas' economies in those value chain sectors. The second thread of activities, which are discussed in Chapter 5,6 and 7, focuses on the development of a methodology to quantify the impacts of reducing truck congestion through capital programs. Unlike the traditional use of I-O model, which focuses on identifying the multiplier effect of an increase in final demand, our effort strived to capture the benefits associated with the change in the inter-industry purchase of trucking that is expected to result from reduced levels of congestion. While it does not directly address productivity effects, it greatly expands the traditional scope of I-O analysis. We apply the methodology to cities in the upper Midwest region with varying degrees of freight specialization, as determined using the value chain clustering and location quotients, to explore how the structure and size of the economy affect the outcome.

3.2 Study Area

The study area for this study encompasses the 10 central U.S. states of the Mid-American Freight Coalition: Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. Figure 2 shows the Economic Areas, as defined by the Bureau of Economic Analysis (BEA), contained in those 10 states. When determining the appropriate geography for an I-O model to measure the impacts of transportation investment it is important to capture how infrastructure quality may be different across economic regions but at the same time may impact production processes over a wide geographic area.

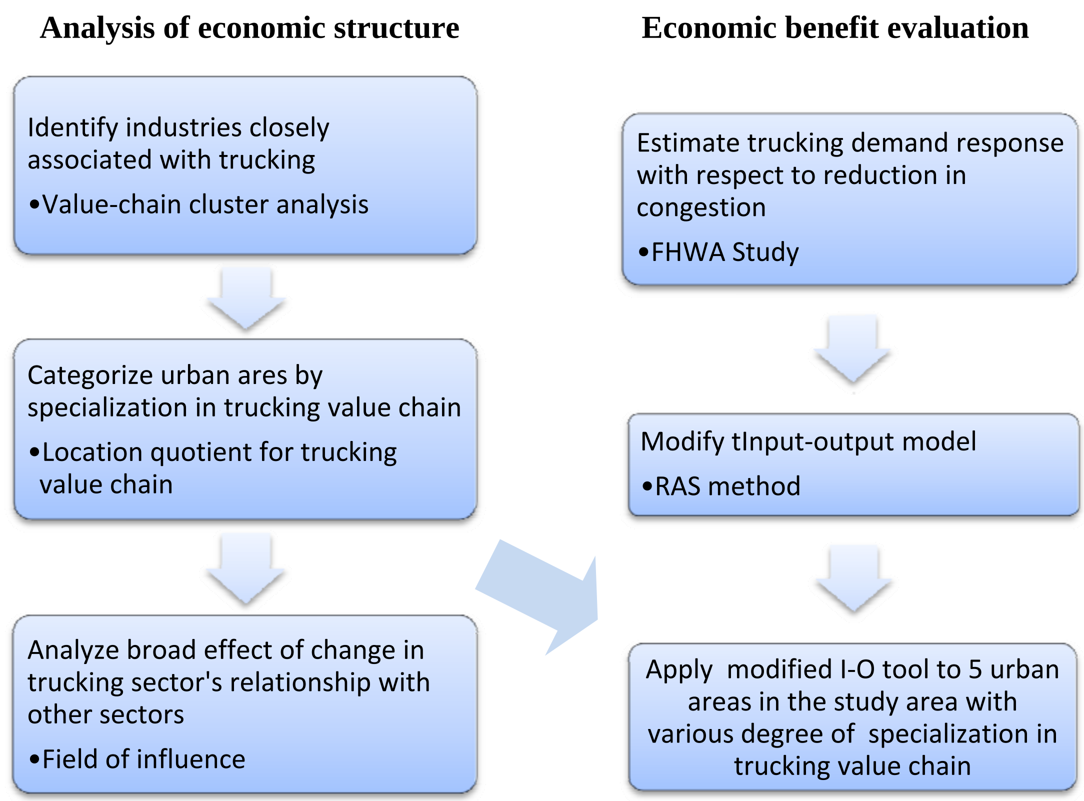

Figure 1. Study framework

It is important not to choose an area that is too small because transactions that occur in neighboring counties that make up the external economy will be treated the same as transactions with other states, countries, etc. However, it is a fundamental assumption of this study that infrastructure quality shapes economic structure in different ways in different regions. This assumption is supported by the FHWA's calculation of separate freight transportation elasticities for the west, central, and eastern regions (HLB Decision Economics, 2008). The most recent definition of economic areas was released in 2004 and was based upon commuting patterns in the 2000 Census, redefined metropolitan and micropolitan statistical areas from the Office of

Management and Budget, and newspaper circulation data. For a detailed explanation of the criteria for determining economic areas refer to Johnson and Kort(2004).

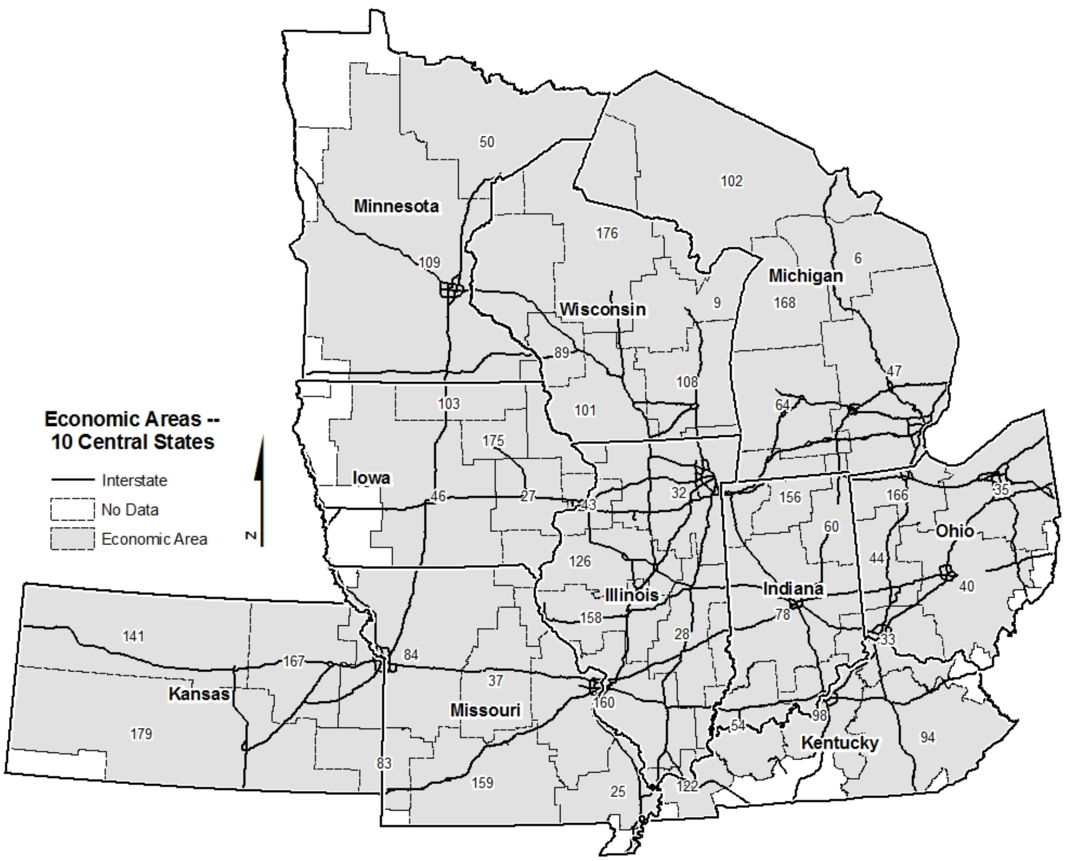

Figure 2. A map of the study area

The BEA's economic areas are meant to capture the relevant regional markets surrounding metropolitan and micropolitan statistical areas. They include one or more economic nodes and surrounding counties related to those nodes.

Appendix A lists all of the BEA economic areas and their requisite county components that fall partially or completely within the 10 states region covered in this study. The economic areas are divided between those that are included in the analysis and those that are not. In most cases, an economic area was excluded from the study because a significant portion of it fell outside the 10 states region and thus data was not available.

3.3. Data

The main data set used in this study are I-O accounts. I-O analysis was pioneered by Wassily Leontief (1939) and has since become one of the most widely applied methods in economics. Leontief sought to develop a Tableau Économique based on the work of François Quesnay (1759) that would show inter-industry interactions in the U.S. economy in order to diagram how expenditures travelled through the economy. Leontief relied on Quesnay's model of the French economy as well as the work of Leon Walras(1874) toward a general equilibrium model of economics using production coefficients to construct linear equations of input and output (Stone 1986). The first official table of the U.S. was released in the early 1950's (Leontief, 1951) using data from 1939.

Miller and Blair (1985) cite the fundamental purpose of the I-O model as to enable analysis of the interdependence of industries in an economy. The heart of the model is a transactions table (also called the inter-industry transactions matrix) based on expenditure and revenue accounting principles. The table is an NxN matrix based on N industries in the economy. Each row of the table lists the outputs (credits/sales) of each industry separated into recipient industries. Each column lists the inputs (debits/purchases) used by the industry in production separated by source industry. Therefore each row describes the distribution of a producer's output throughout the economy and each column describes the inputs required for an industry to produce. Additional columns outside the transactions table, referred to as final demand vectors, list sales from each industry to markets outside the industrial production structure such as consumer purchases, private investment, government, and export. Additional rows account for non industrial inputs to production such as employee compensation, government services, capital/interest payments, land/rent, and profit and are often referred to as value added or payments sectors.

The I-O table is a system of double-entry bookkeeping (Miernyk 1965). For each industry, represented in the rows of the table, all of the receipts from sales are paid out in order to purchase goods and services from other industries as factors to production. These purchases are represented in the column entries. After allowing for inventory changes, the total gross output of each industry is equal to the total purchases, or outlays, made by the industry. The basic I-O model is constructed using observed economic data, for a specific region, usually the nation, over a specific time period, usually one year, and must be divisible into producing industries of similar goods (Miller and Blair 1985). Industry divisions are also commonly referred to as sectors. Although industries generally refer to firms producing similar products and sectors refer to the kind of market that firms serve, both terms are malleable and context specific. The I-O table can be set up to reflect industrial or sectoral aggregation and the terms are often used interchangeably.

In a one period I-O model, each column represents the cost function for the represented industry (Leontief 1939). A fundamental assumption of the I-O framework is that inter-industry purchases, such as from industry i to industry j, are dependent solely on the total output of industry j (Miller & Blair, 1985). The value of purchases from industry i to industry j relative to total purchases by industry j is called the technical coefficient. The technical coefficient indicates the dollar value of purchases from industry i that is necessary for industry j to produce one dollar's worth of output. The inter-industry transactions matrix is transformed into a technical coefficients matrix by dividing each cell by its respective column total. This is also called the direct requirements matrix. The Leontief system assumes technical coefficients are unchanging, returns to scale are constant, and sectors use inputs in fixed proportions (Miller & Blair, 1985). Represented industries employ a uniform production process and do not alter the process based on scale, supply constraints, or price changes.

For this study, we used the I-O information extracted from the IMPLAN IMPLAN (IMpact analysis for PLANning) software released by Minnesota Implan Group (MIG) Inc. All industry data were first extracted from the Industry-by-Industry Transactions Report and the Industry Output Outlay Summary Report under the 440 Industry aggregation scheme employed by IMPLAN. Since our analysis is conducted at the BEA economic area level, the IMPLAN data, which are provided at the county level, needed to be processed to match the geographic scale of the analysis. The county level data files were aggregated into one large model using IMPLAN to provide the data for cluster analysis. The county level data files were then re-aggregated into models for each of the Bureau of Economic Analysis' economic areas that are located within the 10 central states outlined previously.

CHAPTER 4: COMPARISON OF TRUCKING INDUSTRY VALUE CHAIN ACROSS URBAN AREAS

In this chapter, our effort to categorize and compare different economic areas within the study area using quantitative measures is described. The framework described here uses clustering techniques and location quotients to categorize urban areas by the degree of dependence on and use of truck freight sector. Clustering is used to identify industry sectors that are strongly connected with trucking industry. Then, location quotients are used to measure the relative importance/weight that those industries occupy within the economy of each of the 43 economic areas in the upper Midwest. Finally, Field of Influence analysis is applied to Chicago, Detroit, and Madison to analyze how the change in a technical coefficient involving the freight sector propagates across the economy.

The work described in this chapter in itself provides useful insights into the structure of the economies of the cities in the upper Midwest. In Chapter 6, an approach for quantifying the impacts of reducing truck congestion using the I-O model will be applied to some of the urban areas examined in this chapter to explore if economic structure, especially specialization in freight or freight-heavy sectors, and size affects the benefit associated with reducing truck congestion through infrastructure projects.

4.1. Literature Review

4.1.1. Industry clustering

Industry cluster analysis has been defined as "the systematic identification and documentation of key groups of interdependent businesses in an economy" (Feser & Luger, 2003). However, it is difficult to advocate for one uniform definition of industry cluster analysis because the field does not represent a unified theory. Rather, a variety of old and new theories of the interrelationships between economic actors and the implications of these patterns for economic growth and development provide the impetus for a wide variety of industry cluster studies (Feser 1998). Industry cluster principles are often used in tandem with traditional development schemes to improve the effectiveness of implementation of existing policy. All cluster policies are focused on the related goals of resource targeting and resource leveraging. Industry cluster analysis is used by policymakers to identify targets for scarce development resources in order to leverage these resources through synergies, positive externalities, and increasing returns believed to exist within the clusters (Feser 1998).

It is important to note the distinction between economic clustering, based on inter-firm linkages in economic space, and geographic clustering, based on the co-location of firms in geographic space. Geographic clusters of firms are often referred to as industrial complexes (Feser, Sweeney and Renski 2005). Perroux (1950) first theorized abstract economic space as the nonspatial sphere containing a field of forces in which relations between firms, buyers and suppliers takes place. He found no little reason to suggest why economic relationships need depend on physical proximity, and found linkages to exist when economically justified regardless of spatial location.

Perroux's theory of growth poles is an important component of contemporary industry cluster theory. He emphasizes a focus on propulsive industries. Propulsive industries will dominate other sectors because of large size, market power, and role as lead innovators (Perroux 1998). Perroux argues that propulsive industries are poles of growth that attract, focus, and direct other resources similar to the way that end-market industries drive behavior throughout the value chain. Perroux views the economy as unbalanced, and thus innovations and counter-innovations occur along different poles. Propulsive industries will transfer growth pulses through the demand for intermediate goods. They become diffusers of process and product innovations because of market power and the ability to demand innovation. It is the organization of industries and firms along different poles of growth that provide the organizing structure of economic space.

Feser and Luger (2003) argue that as a mode of inquiry, industry cluster analysis is flexible. Studies can be tailored to a wide variety of cluster definitions, scales, and data sources. However, this flexibility can be manipulated into meaninglessness if studies are designed to seek pre-determined results. It is therefore very important to account for methodology when performing industry cluster analysis so that results can be recreated and objectively judged.

Industry clusters can be defined on the basis of surveys of expert opinion, geographic location, or I-O data among other methods, and also combinations of the above (Feser 2005). Feser and Bergman (1999) argue that the framing of a policy problem provides a set of restrictions on the way a cluster may be defined. Therefore, it is important to choose a methodology and data source given the task at hand and available resources.

4.1.2. Clustering statistics

Cluster analysis, throughout statistics, is a generic name for a variety of methods that can be used to create classifications of similar entities. The clustering method is a multivariate statistical procedure that starts with a data set containing information about the entities to be clustered and attempts to reorganize those entities into relatively homogenous groups (Aldenderfer and Blashfield 1984). The development of clustering methods came largely from the biological sciences. Sokal and Sneath's book *Principles of Numerical Taxonomy* (1963) is the primary foundational text, but the development of high speed computers and the importance of scientific classification have contributed to the expansion of the literature in the last 50 years (Aldenderfer and Blashfield 1984).

Five basic steps characterize a cluster analysis, according to Aldenderfer and Blashfield (1984): (1) selection of a sample to be clustered; (2) definition of a set of variables, *n*, which measure the entities in the sample; (3) computation of the similarities among the entities; (4) use of a cluster analysis method to create groups of similar entities; and (5) validation of the resulting cluster solution. Additionally, similarity measures can be divided into four groups: (1) correlation coefficients, (2) distance measures, (3) association coefficients, and (4) probabilistic similarity measures. However, only correlation and distance measures have been used consistently in the social sciences.

Choosing the variable is the most important step of a cluster analysis, and variables should be chosen within the context of an explicitly stated theory (Aldenderfer and Blashfield 1984). There are many clustering methods that can be used to create groups of similar entities. Since this work is not meant for statisticians, each of these are not explained in depth here. However, the seven major families of clustering methods presented in Aldenderfer and

Blashfield are discussed, and further exploration of their text is recommended for detailed explanation of the strengths and weaknesses of each method: (1) hierarchical agglomerative, (2) hierarchical divisive, (3) iterative partitioning, (4) density search, (5) factor analytic, (6) clumping, and (7) graph theoretic. This study will employ a hierarchical agglomerative clustering method, which will be explained and addressed later.

Aldenderfer and Blashfield offered cautions about statistical cluster analysis that mirror the arguments of Feser and Luger (2003) about industry cluster analysis. They argue that most cluster methods are simple procedures that are not supported by extensive bodies of statistical reasoning. Since most cluster methods have evolved from within particular disciplines they are bound by the biases of those disciplines. Additionally, different clustering methods can produce different results based on the same data set. Finally, although the strategy of cluster analysis is structure-seeking, the operation of cluster analysis is structure-imposing. This final argument is equivalent to the common statistical adage that correlation does not equal causation, or in the case of this study that the definition of a cluster as a set of industries does not mean that that those industries will always interact within a given economic space (Feser, Renski, & Koo, 2008). This problem of cluster analysis makes validation of a clustering solution difficult. There is no statistical consensus on the proper "null hypothesis" for a clustering solution, meaning that they way to test whether or not there is actually no structure present in the data is not yet clear. This is because statistical clustering is done through a set of specific algorithms that impose structure from the variables presented. The intuitive null hypothesis would be to not use the algorithm, but that would also negate the finding of clusters.

4.1.3. Clustering using Input-Output

The goal of industry cluster analysis is to allow policy officials to gain unique insight into the basic features of their regional economy by focusing on industry linkages and interdependence among firms (Bergman and Feser 1999). I-O accounts are one of the few measures of inter-firm relationships available to analysts at wide geographic scale (Feser, 1998). Additionally, the focus on buyer-supplier relationships that I-O matrices provides allows for analysis that documents trade flows among many, some unexpected, industries (Roelandt, et al. 1999).

The I-O framework also offers the ability to study innovations in groups of industries. Perroux suggests that innovations are not only clustered in time, as theorized by Schumpeter (1934), but also in economic space (Perroux, 1998). Technological advances establish paths for innovation to travel throughout economic space through the adoption of learning processes in economically linked industries.

Feser, Bergman, and colleagues have developed a method of identifying industry clusters based on a set of inter-industry benchmarks derived from I-O data. They have taken into account previous attempts to identify national clusters of industries through I-O linkages that were undertaken in the 1970s (Streit, 1969); (Roepke, Adams, & Wiseman, 1974); (Czamanski, 1974). Through this method they advocate for the identification of trading linkages at a region larger in scale than the one at study, and then using these benchmarks to analyze the industrial mix and competitive advantage of specific regions (Bergman & Feser, 1999); (Feser & Bergman, 2000); (Feser, Sweeney, & Renski, 2005); (Feser, Renski, & Koo, 2008). They advocate the multi-scaled approach in order to reveal gaps in supplier chains at the local level that are evident only when considering larger geographies.

4.1.4. Value-Chain clusters

Industry cluster analysis has many different typologies. Roelandt et al. (1999) have suggested a typology based on a range of possible levels of analysis. At the national level, clusters are conceived as over-arching industry groups that are linked within the marcroeconomy. Aroche-Reyes (2001) employed this typology when identifying national industrial clusters through graph theoretic methods based on national I-O data. Other relevant types at this level include the examination of general innovation processes and patterns of industrial specialization. Clusters at the industry (or meso) level are based on the extended value chains revealed through patterns of inter-industry and intra-industry linkages. Studies of cluster-specific technology adoption, such as this study, and best-practice benchmarking as discussed in the previous section, represent studies of this meso level. At the firm (or micro) level, clusters are conceived of as a few linking firms or a limited number of firms co-located in geographic space. Micro level analysis includes needs assessments, chain analysis, and design of business development programs.

This study will define industry clusters based on the value-chain. Value-chain clusters can take two different forms. In the first form, matrices **X** and **Y'** contain information about the intermediate purchasing patterns of all industries. Feser (2005) explains:

> "A cell in a given column vector in **X** reports the ratio of purchases by column industry *j* from row industry *i* to total intermediate purchases by industry *j*, or *j*'s intermediate input purchasing pattern. A cell in a given column vector **Y'** reports the ratio of sales of row industry *i* to column industry *j* to total intermediate sales by industry, or *i*'s intermediate selling pattern."

Correlation procedures are then applied to **X** and **Y'** to identify sectors that may be a part of common value chains (Czamanski 1974). Feser and Bergman (2000) then apply factor analysis to the Czamanski correlations to identify value chains. In this case, the clusters revealed are based solely on the inherent purchasing pattern evident in the I-O matrix.

In the second form, the central industry in the cluster is defined by the analyst, and clustering methods are applied upon measures of backward linkages (inputs purchased from other industries) and forward linkages (outputs sold to other industries) derived from the I-O transactions table (Peters, 2001). Peters, in his study of the information technology value chain in the State of Missouri, employed a centroid hierarchical agglomerative cluster method to determine backward and forward linkage clusters. In this method, the clusters actually represent groups of industries that the central industry sells to or purchases from in similar intensities. Industries that do not interact with the central industry will not be present in the analysis at all.

The first method attempts to group value chains based on the broad economic structure based in an I-O table, while the second method attempts to organize one specific value chain, perhaps already targeted by a local economic development authority, based on the intensity of purchases reflected in an I-O table. In either case, understanding the other industries present in an extended value chain can aid firms in making location decisions and can assist local economic developers in targeting efforts.

Analysts often try to link industry cluster analysis with measures of local specialization in order to assist industry targeting policies and attract firms to locate within a given region. Peters (2001) linked extended value chain cluster analysis with a mapping of specialization in value chain industries in order to link the “who” in the value chain with the “where.” Similarly, the G-statistic has been used to identify counties that have high concentrations of industries within a given value chain an also border counties with activity in the value chain (Feser, Sweeney, & Renski, 2005). The G-statistic is based on standard deviations of economic activity as well as employment shares.

4.1.5. Linkage analysis

There is a general consensus that linkages between sectors in an economy are important for economic growth as first theorized by Perroux,; however, the process by which these key linkages are identified is still contentious (Sonis, Guilhoto, et al. 1995). The objective of linkage analysis is to quantify the impacts of a change in one sector on other related sectors (Kawamura, Sriraj and Lindquist 2009). This work was first pioneered by Hirschman (1958) and Rasmussen (1958). Rasmussen’s initial work identified key sectors in the economic structure based on the presence of above average forward and backward linkages. Although they are not without challenge, the indices developed by Hirschman and Rasmussen are a part of generally accepted procedures for identifying key sectors within the economy (Sonis, Guilhoto, et al. 1995). Key sector analysis of linkages has been widely used because it is one of the few ways to analyze forward linkages within I-O analysis. Additionally, the model is relatively straightforward and easy to construct when an I-O model is model is available (Nazara, et al. 2003).

Linkage analysis has been an important part of understanding how technological changes, and more specifically innovation, are transmitted across the economy. Change in technological coefficients of I-O tables over time was initially believed to be due to errors in measurement, but change induced by technology, changing markets, economic structure change, and the general effects of growth and development can all also be causes of coefficient change (Sonis and Hewings 2009). Two types of innovation could cause technical coefficient change. Process innovation implies that the same amount of inputs yield an increased amount of output in a given process. Reducing congestion can be categorized in this group as trucks will be able to deliver the same amount of goods with less hours and miles of trucking operation. Product innovation means that each sector produces the same amount of output with less input of the innovated product (Dietzenbacher 2000). Each of these would imply that the ratio of an industry’s purchase of a good relative to total purchases would change. The effects of new technology on interdependence in an economic system can occur along two dimensions: (1) sectoral interaction through product purchases, and (2) spillovers to other countries/regions (van der Linden and Oosterhaven 1995).

Linkage analysis has been criticized on the basis that it cannot account for other critical elements of economic growth such as constraints on production, international comparative advantage, balance of payments, institutional and policy settings, technological and skill endowments, income distribution, and final demand structure (Lenzen 2003). Although I-O tables reflect the current technology used in the economic structure, they do not explain how this technology came to be (Dietzenbacher 2000), and thus linkage analysis is better viewed as a descriptive rather than empirical or predictive tool. However, the clear link between understanding the transmission of technological change through linkages and the improvement of general equilibrium models has made further study a pressing need (Sonis and Hewings 2009).

4.2. Data and Tools

4.2.1. Transaction data

The data used to calculate location quotients for this study are the total dollar value of output by industry. These data were drawn from the Industry Output Outlay Summary Report in IMPLAN. The report was exported from IMPLAN models of each of the EAs included in the study and a model of the 10 central states as a whole. These data were used because they were readily available from the IMPLAN reports necessary for other parts of this study. Employment or income data is most often used to calculate location quotients. Using these types of data, it is possible to determine specialization of the workforce. In this study output data are used because it is only necessary to determine the areas in which each cluster represents a more or less significant portion of the local economy. Output by industry is available at every geography level represented in this study and is fairly easily to manipulate in order to achieve the general information this study seeks. In cases where more concrete comparisons to local employment and income are necessary, it would be prudent to use employment or income data available from the Bureau of Labor Statistics or evident in additional reports from IMPLAN models.

4.2.2. Geographic Information Systems data

Geospatial vector data are displayed in ArcGIS from a shapefile. These shapefiles show the coverage of specific data across space. For this study, the shapefile that depicts the EAs present in the 10 central states is derived from existing data provided by U.S. Census Bureau TIGER/Line® Shapefiles. TIGER/Line® Shapefiles depicting spatial coverage at the county level for the 10 central states were joined with a list of EA membership at the county level provided by the BEA. These data were used to create a visual representation of the economic areas that was subsequently joined with location quotient data calculated in the study. All TIGER/Line® data were projected to the 1983 State Plan Coordinate System Iowa North coordinate system. Any distortion inherent in this coordinate system does not affect any outcome of this study.

The widespread use of I-O analysis has been facilitated by the development of a number of easy to obtain software programs that enable model building and analysis. This study employed two such tools, discussed below. Additionally, statistical packages, SPSS and Stata as well as ArcGIS 10 were used to process and analyze data.

4.2.3. IMPLAN

We used IMPLAN (IMpact analysis for PLANning) software released by Minnesota Implan Group (MIG) Inc. to build the models necessary to perform the analysis described. IMPLAN offers proprietary software that allows the user to construct I-O models without advanced knowledge of economic theory and national economic accounting principles (MIG Inc 2010). The advanced user is able to customize the model and edit certain assumptions, such as regional purchase coefficients that are the fraction of commodity purchases that occur within the region. IMPLAN offers the ability to export reports of model components for further analysis and can construct single region or multi-regional models. While the software is geared toward performing economic impact analysis, MIG Inc. also offers I-O account data for purchase at the county and state level that are compiled from a wide variety of sources including the Bureau of Labor Statistics, Bureau of Economic Analysis, and U.S. Census (MIG Inc 2010). The most recent release of IMPLAN software is Version 3.0, which was employed for this study.

A benefit of the IMPLAN software, compared to other programs available, is the ability for the advanced user to view and modify model parameters. This allows for the customization of the model based on known elements of a project that may differ from standard model assumptions. IMPLAN also offers a user-friendly interface with many options for data organization and reporting at the disaggregated NAICS level or by 440 sector designations developed by IMPLAN.

4.2.4. PyIO

PyIO, pronounced pai-o, is a Python module for I-O analysis developed and released by the Regional Economics Applications Laboratory (REAL) at the University of Illinois Urbana-Champaign. The most recent public release is PyIO 2.0, which employs a graphic user interface over a base of Python codes that perform computations on I-O tables. The software does not provide the capability to assemble or generate an I-O table. Version 2.2 was employed in this study and was obtained directly from REAL. The program only reads information from an ASCII text file, and can output to text or Microsoft Excel documents. PyIO can calculate the Leontief inverse matrix, perform impact analysis, and perform RAS adjustment on an I-O matrix. Also, the software conducts push-pull, field of influence, key sector, multiplier product matrix, and decomposition analysis. The purpose of these techniques is presented succinctly in the PyIO manual (Nazara, et al. 2003). The PyIO software is free as is the Python computer programming language it is built on. This makes it more accessible to low income users and communities. Future versions of PyIO are anticipated to include clustering methods.

4.3. Value Chain Clustering

This study employs a Ward's hierarchical agglomerative clustering method using Chebychev's distance measure to reveal forward and backward linkage industry clusters.

Specialization in industries contained within the clusters is compared across economic areas of the 10 states region using location quotients and maps. Finally, a field of influence analysis is performed to evaluate the diffusion of technological change within the truck transportation industry across I-O models of the economic areas of Chicago, Detroit, and Madison.

Every cluster analysis contains a group of similar steps: (1) selection of a sample to be clustered, (2) definition of a set of variables that measures the entities in the sample, (3) computation of the similarities among the entities, (4) use of a cluster analysis method to create groups of similar entities, and (5) validation of the resulting cluster solution. In this section, methodologies applied in each step are discussed in detail.

4.3.1.. Cluster sample

Value chain clusters for the freight truck transportation industry are calculated based on industry to industry transactions data in 2007. The sample area is the 10 central states of Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio and Wisconsin. The region was chosen for two reasons: data availability and the regional variability of the relationship of freight to the rest of the economy. First, the aggregate 10 central states region is the largest geography at which county level data was available. Second, the FHWA Benefit/Cost study of freight transportation indicated that elasticities of demand for freight, which affect the size of freight trucking purchases in an industry production function, vary between the west, central, and east regions of the U.S. (HLB Decision Economics 2008).

This suggests that although the common reference economy for an I-O study is the nation as a whole, it is more appropriate to compare economic areas in the central region to an aggregate measure of the central region rather than the nation as a whole. An I-O model of the 10 central states was constructed using IMPLAN at the University of Toledo, and the Industry-by-Industry Transactions Report was provided for analysis in this study.

4.3.2. Clustering variable

The variable to be clustered is the total dollar value of the transaction between two industries. Backward linkage clusters are calculated based on the column transactions of

IMPLAN Industry Code 335, transport by truck. Column transactions represent the dollar value of the truck transportation industry's intermediate input purchases from every other industry represented in the economy. Forward linkage clusters are calculated based on the row transactions of industry 335, transport by truck. Row transactions represent the dollar value of truck transportation sold to all other industries in the economy. In order to ease interpretation and validation of the cluster solution the transaction values were standardized. Standardization of variables is a common practice for cluster studies and has been found in multiple studies to have a negligible impact on the cluster solution reached (Aldenderfer and Blashfield 1984).

Transaction values were standardized to range from zero to one by transforming them into trading linkage ratios using the same method employed by Feser, Renski, and Koo (2008):

$$X_{i355} = \frac{a_{i335}}{a_{+335}}$$

$$Y_{i355} = \frac{a_{335j}}{a_{335+}}$$

Where, the value x_{i335} is the ratio of purchases of industry 335 from industry i to total intermediate purchases by industry 335, and the value y_{335j} is the ratio of sales of industry 335 to industry j to total intermediate sales by industry 335.

The clustering algorithm was performed on a vector of x_{i335} representing backward linkages from sector 335, and a vector of y_{335j} representing forward linkages, evident through transactions, from sector 335. The variable a represents total dollar values. These vectors were entered as separate column variables in SPSS. Each vector was accompanied by a column of variable labels indicating the industry other than freight trucking in the trade linkage ratio.

4.3.3. Similarity measure and cluster analysis method

SPSS performs steps three and four of the cluster method described by Aldenderfer and Blashfield in tandem. This study employs Ward's hierarchical agglomerative clustering algorithm in SPSS using Chebychev's distance measure. These features are available under the "Classify" option of the "Analyze" menu in PASW Statistics 18. The hierarchical agglomerative method begins under the assumption that every case is an independent cluster. An N×N similarity matrix is constructed that describes the similarity (or difference) between each case and every other case to be considered for clustering.

Distance measures are technically measures of dissimilarity; two identical points are a distance of zero apart. Distance measures are a similarity measure in reverse scale. The values of distance measures have no absolute meaning. Distance measures have a tendency to be influenced by “elevation differences,” especially in the case of variables with large size differences and standard deviations (Aldenderfer & Blashfield, 1984). Since the transactions used in this study feature large size differences, it is appropriate to standardize the variables.

The most popular distance is squared Euclidian distance, which is appropriate for centroid, median, or Ward’s method of clustering (Aldenderfer and Blashfield 1984). The distance between two cases is the sum of the squared differences between all values of the clustering variables. In this study, only one variable is used for the determination of the cluster, therefore the distance measure is the squared distance between two cases. Euclidian distance places a heavier weight on the differences between two cases, which is not necessary for this study because the cases already show a high variability.

This study employs Chebychev’s distance measure. This distance measure is appropriate when using centroid, median or Ward’s method of clustering. The distance between two cases is the maximum absolute distance between all of the values of the clustering variables. In this case, transactions are the only variable used to determine clusters, so the distance is the absolute difference between two cases. Algorithms for both squared Euclidian and Chebychev’s distances are included in Appendix B.

The hierarchical clustering method proceeds by finding the two most similar cases in the similarity matrix and merging them to form a cluster. The method continues for N-1 steps until all cases are merged into one large cluster. Different clustering methods vary by the linkage rules used to compare clusters to each other as the process moves along. The most conceptually simple linkage rule is single linkage. A new candidate can be combined into a cluster under single linkage if the candidate shares the highest available similarity, or lowest dissimilarity, with any existing member of the cluster. The hierarchical method produces non-overlapping clusters, meaning each case is a member of only one cluster. As the process proceeds each cluster can be subsumed as a member of a larger cluster at a higher level of similarity. The results can be expressed as a dendrogram, or tree diagram, that displays the hierarchical structure of the clustering method against the similarity value at which two clusters are merged. Aldenderfer and Blashfield note that hierarchical methods only take one pass at the data, and are thus sensitive to the way the data are ordered. Clustering solutions can be altered by reordering data within the similarity matrix, and results are not stable if cases are dropped. These issues are especially important when dealing with small samples.

Single linkage, average linkage, and Ward's method are widely popular linkage rules. Single linkage measures are not affected by any data transformations because they maintain the relative ordering of values in the similarity matrix. However single linkage tends to produce long elongated clusters.

Average linkage rules calculate an average of the similarity of the case under consideration to all existing members of the cluster; this average is used to determine whether or not the case with join the cluster. The centroid and median methods are a variant on the average linkage rule that are most commonly used. The centroid method calculates the center of gravity of the two cases considered (either a cluster and a single case or two existing clusters). The similarity/difference between the two clusters is calculated based on the similarity/difference between their respective centroids. The median method is identical to the centroid method, but additional weight is placed on the cluster size. Centroid and median methods tend to find compact and hyperspherical clusters of similar cases (Peters, 2001).

Ward's method uses an analysis of variance approach to analyze the distance between two considered cases. This method is designed to find the minimum variance within clusters; it works by joining groups or cases that result in a minimum increase in the within group sum of squares. The method has been regarded as highly efficient, but tending to create small clusters (StatSoft 2008). Wards method has been criticized because the clusters found are ordered in terms of elevation. However this issue can be addressed by minimizing the distance between variables. This study compensates for this by standardizing the variables and using a metric that does not place a weight on distance. Additionally, this is not a strong factor for this study because the clusters are meant to illustrate an elevation in the form of intensity of purchase.

The approach used for this study was modeled after the strategy proposed in Peters (Peters, 2001). Peters uses a centroid hierarchical analysis method with Chebychev distance. Four separate groups of hierarchical agglomerative clustering methods were applied to the transaction data in this study: centroid method with squared Euclidian distance, centroid method with Chebychev distance, Ward's method with squared Euclidian distance, and Ward's method with Chebychev distance. The results of each method were similar but not identical. The results tended to vary along the generalizations of each distance measure and linkage rule outlined above. Ward's method using Chebychev distance provided results that were the most clear and easy to interpret. This will be discussed in the next section.

4.3.4. Validating cluster solution

The fifth step of the cluster analysis is concerned with validating the resulting cluster solution. This is a conceptually difficult step for a number of reasons. First, as described previously, there is a lack of an agreed upon null hypothesis for statistically evaluating a cluster solution. The clustering method and distance measure chosen perform a series of algorithms on the variables that create clusters as opposed to finding them; the action of the cluster analysis intends to be structure seeking but it is actually structure imposing. The process of performing a cluster analysis creates the structure within the data, it is therefore impossible to then evaluate the case that there is no inherent structure in the data.

However, given this limitation, there are a number of techniques used to determine the appropriate number of clusters formed in the analysis. All hierarchical methods begin with N individual clusters and end with 1 cluster of N cases after N-1 stages. In order to determine the number of clusters that can be appropriately assumed to exist within the data, the analyst needs to determine the stage of the clustering process at which a critical loss of information occurs.

Loss of information can be shown in three separate ways using fusion coefficients. The fusion coefficient is the similarity (or dissimilarity) measure at which two clusters are joined. This value is listed in the agglomeration schedule output of SPSS as "Coefficients." Each of these methods is exemplified in Peters (2001) and Aldenderfer and Blashfield(1984) and will be used when discussing the clustering solution reached in this study.

First, fusion coefficients are shown in the dendrogram of clustering stages. Each individual case is shown as a branch at the top of the tree; the fusion coefficient of the linkage between two cases is displayed as the height of the split between branches on the tree. The first stages of the clustering process will feature mergers of highly similar cases into larger branches at low fusion coefficients. The change in fusion coefficient with each merger is relatively small, and the individual branches are relatively short. A substantial loss of information occurs when the two clusters that were merged with relatively low fusion coefficients are merged with a relatively high fusion coefficient. This is shown through long branches on the dendrogram because two internally similar but externally dissimilar clusters between are being merged. This tends to happen towards the trunk of the tree. To determine the appropriate number of clusters using the dendrogram, the analyst needs to look for a large jump in the length of the branches of the tree. Mergers that happen before this jump are pruned into a cluster. Clusters must be pruned at one elevation, or fusion coefficient, across the board. The analyst cannot pick and chose from sub-clusters that occur below the fusion coefficient. It is important to note that this strategy is heuristic and is biased by the needs and opinions of the interpreter as to the "correct" structure of the data (Aldenderfer & Blashfield, 1984). However, using the dendrogram is the most popular method of determining the cluster solution because it easy to interpret for a broader audience.

Another heuristic method for determining a cluster solution is to graph the stage of the cluster analysis, and thus the number of clusters implied by the stage, against the fusion coefficient with the values of the fusion coefficient on the y-axis and the number of clusters on the x axis. The point at which the graph is essentially flat shows when significant loss of information is no longer occurring. However, this process is also subjective based on the interpreter's choice between beginning to flatten and essentially flat.

Finally, another subjective procedure for determining the cluster solution is to examine the fusion coefficients in a list and look for a significant "jump" in the value (Aldenderfer & Blashfield, 1984). This process can be aided by listing the change in the fusion coefficient, or loss of information, next to the fusion coefficient. Once again, a jump implies that two relatively dissimilar clusters have been merged. The number of clusters prior to the jump is the most likely solution. However, there are many variations in the value of the fusion coefficient that occur, and it can be difficult for the analyst to tell which jump is "correct."

Peters (2001) puts forth an additional objective method for validating the cluster solution. He conducts an analysis of variance using the number of cases in each cluster, the mean non-standardized value of cases within the cluster, and the standard deviation of non-standardized values within the cluster. He uses this information to statistically demonstrate that the input cases for each cluster are significantly different. Although this is a statistically valid way of proving the cluster solution, it is a given in this study that the mean values of the clusters will be significantly different and the members of the clusters will be of different value intensities.

4.4. Economic Area Specialization in Value Chain Clusters

Individual economic areas are compared using location quotients in order to evaluate the economic areas' specialization in industries that are significant in the value chain for freight truck transportation. Location quotients measure concentration of a given industry, or group of industries, in the study economy compared to a reference economy. The same reference economy used to calculate the clusters, the 10 central states, is used as the reference economy to calculate location quotients. The formula for a location quotient is as follows:

$$LQ_{EA} = \frac{\left(\frac{\text{CLUSTER OUTPUT}_{EA}}{\text{TOTAL OUTPUT}_{EA}}\right)}{\left(\frac{\text{CLUSTER OUTPUT}_{10States}}{\text{TOTAL OUTPUT}_{10States}}\right)}$$

The numerator is the share of total output in the economic area that comes from the industries cluster, and the denominator is the share of total output in the 10 states region that comes from the industries within the cluster. The location quotients are grouped into five categories that denote different ranges. These categories are organized as follows:

High Specialization:	$LQ \geq 1.25$
Above Average Specialization:	$1.05 \leq LQ < 1.25$
Average Specialization:	$0.95 \leq LQ < 1.05$
Below Average Specialization:	$0.75 \leq LQ < 0.95$
Low Specialization:	$LQ < 0.75$

The location quotients for each EA and each cluster of industries are joined to spatial depiction of the EA in ArcGIS. This information is used to create a map of each EA's specialization level displayed by category for each cluster group. The specializations are symbolized in grayscale.

4.5. Findings

4.5.1. Value chain clusters for truck transportation

The value chain clusters for truck transportation are groups of industries that purchase freight truck transportation (i.e. forward linkage) and industries that the truck transportation industry purchases goods from (i.e. backward linkage). These industries are clustered based on the total dollar value of their purchases. Industries with similar values of purchase are group together in a cluster according the Ward's hierarchical agglomerative clustering method using Chebychev's distance measure as outlined in the previous section. Backward linkage clusters are comprised of groups of industries that the truck transportation industry purchases goods from (inputs to trucking) in statistically similar amounts, as determined by the clustering method. Forward linkage clusters are comprised of groups of industries that purchase truck transportation (destinations of trucking output) in statistically similar amounts.

4.5.1.1. Backward linkage clusters

Industries with backward linkages to truck transportation provide the goods and services necessary for the truck transportation industry to operate. The values of input provided to truck transportation, industry 335 in the IMPLAN code, were taken from the industry column of the inter-industry transactions matrix for the 10 Midwest states. These values were used in the clustering method previously described to achieve the following solution.

The results of the clustering method suggest the presence of three distinct clusters. The industries present in each cluster and the total dollar value of input purchases by truck transportation are listed in Table 1.

Table 1. Backward linkage industry clusters

Cluster	Industry Code	Industry	Purchases
1	335	Transport by truck	$3,712,680,886
1	115	Petroleum refineries	$3,419,000,750
1	427	US Postal Service	$3,317,860,229
1	357	Insurance carriers	$2,668,872,979
1	339	Couriers and messengers	$2,415,738,616
1	382	Employment services	$1,948,090,447
2	319	Wholesale trade businesses	$1,126,914,277
2	338	Scenic, sightseeing, and support activities for transportation	$1,020,802,518
2	384	Office administrative services	$935,417,734
2	360	Real estate establishments	$906,928,089
2	283	Motor vehicle parts manufacturing	$900,130,758
2	381	Management of companies and enterprises	$899,705,652
2	333	Transport by rail	$841,848,938
2	340	Warehousing and storage	$704,773,531
2	388	Services to buildings and dwellings	$564,890,467
2	414	Automotive repair and maintenance, except car washes	$514,020,147
2	351	Telecommunications	$480,365,334
2	354	Monetary authorities, depository credit intermediation acts.	$457,186,186
3	---	ALL OTHER INDUSTRIES	$4,726,962,833

The three cluster solution is validated by examination of the fusion coefficients along the agglomeration schedule (Table 2) and a chart (Figure 3) of the fusion coefficients plotted against the number of clusters implied at the final stages of the clustering method. The table shows a significant jump in the loss of information moving from the three cluster solution to the two cluster solution. The loss of information is measured by the change in the fusion coefficient between stages. This suggests that the three cluster solution is appropriate. The graph shows that a noticeable flattening of the fusion coefficient line begins after the three cluster solution, indicating minimal loss of information beyond three clusters.

Table 2. Backward linkage clusters - list of fusion coefficients

Stage	Clusters	Fusion Coefficient	Loss of Information
415	1	0.949	0.492

414	2	0.457	0.211
413	3	0.246	0.063
412	4	0.183	0.042
411	5	0.141	0.034
410	6	0.107	0.028
409	7	0.079	0.012
408	8	0.067	0.01
407	9	0.057	0.007
406	10	0.05	0.05

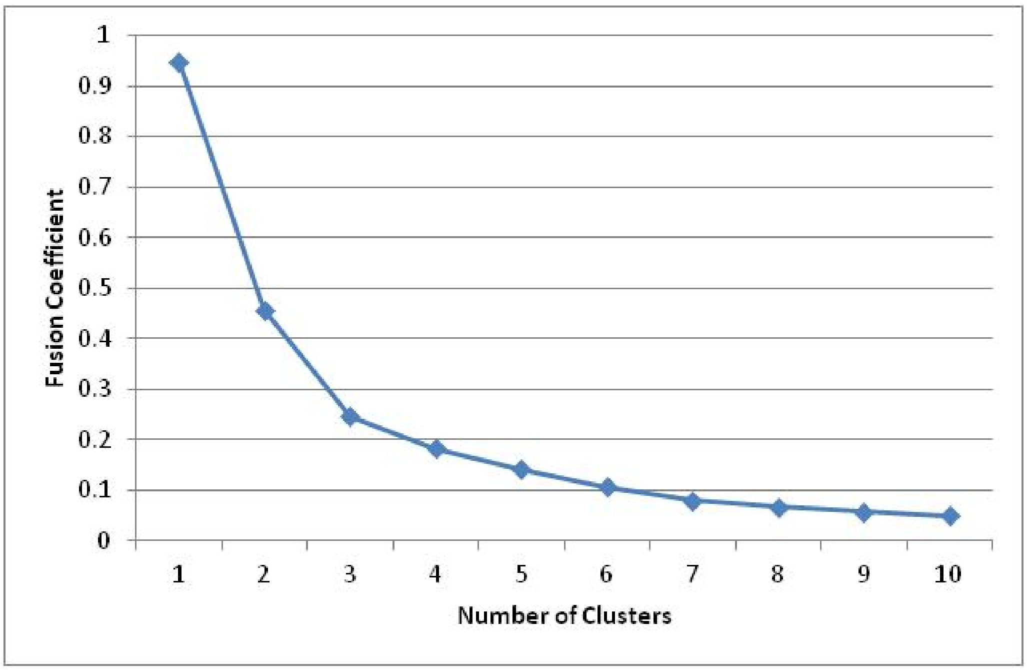

Figure 3. Backward linkage clusters fusion coefficient curve

Table 3 shows the results of an analysis of variance (ANOVA) F-test on the clustering solution. The results show that the input variable, the value of purchases, is significantly different between the three clusters. Therefore the differences in purchase values that exist between the clusters can be viewed as statistically significant. This allows us to interpret the cluster result as depicting industries that supply the truck transportation industry in significantly different intensities.

Table 3 ANOVA results – backward linkage clusters

F = 3431.360 p = 0.000			
Cluster	**N**	**Mean**	**Standard Deviation**
1	6	$2,913,707,318	677842520.7
2	12	$779,415,303	227206137.3
3	398	$11,876,791	35425924.57

The first cluster contains industries that can be described as providing primary inputs to truck transportation. These six industries supply the highest dollar value of inputs to freight trucking (average sales $2.9 billion). The second cluster contains industries that can be described as providing secondary inputs to truck transportation. These industries supply goods in significant amounts, but not as intensely as the primary input suppliers (average sales $779.4 million).The third cluster contains industries that can be described as providing tertiary inputs to truck transportation. These are the industries that truck transportation purchases inputs from in the least amounts per year (average sales $11.9 million). There are 398 industries in this cluster. The truck transportation industry does not purchase any inputs from many of these industries. The industries in the primary and secondary inputs clusters are listed in Table 4**.**

Table 4. Primary, secondary and tertiary input cluster industries

Cluster	Industries	Average Sales per year
Primary	Transport by truck, petroleum refineries, US Postal Service, Insurance carriers, couriers and messengers, employment services	$2,913,707,318
Secondary	Wholesale trade business, scenic sightseeing and support activities for transportation, office administrative services, real estate establishments, motor vehicle parts manufacturing, management of companies and enterprises, transport by rail, warehousing and storage, services to buildings and dwellings, automotive repair and maintenance, telecommunications, monetary authorities and depository intermediary activities	$779,415,303
Tertiary	All other industries	$11,876,791

The primary inputs cluster contains industries that supply the greatest dollar value of inputs to truck transportation. Most of these industries would be anticipated to supply a high value of inputs to transport by truck including the industry itself, petroleum refiners, insurance carriers, and employment services. Intra-industry transactions represent the highest total dollar value of transactions in this cluster. This is likely due to subcontracting relationships that characterize many elements of the trucking industry. Many firms contract with individual owner-operators to fulfill needs. Perhaps surprising is the significant role of the U.S. Postal Service and couriers and messengers industries. The relationship between trucking and the U.S. Postal Service is not entirely clear. It is likely that many trucking firms use the Postal Service to fulfill small (samples, proofs, drop shipments, etc) and less-than-truckload rush deliveries via the U.S. Postal Service. Firms such as California Trucking Companies take this approach (California Trucking Companies 2011). Also, trucking firms that engage in long term contracts with clients and handle many aspects of logistics may require the services of the U.S. Postal Service or other parcel carriers to forward deliveries out of service range (or internationally). The presence of the couriers and messengers industry in this cluster may be because firms classified in this industry (according to IMPLAN) may actually produce trucking services as a secondary commodity. This is a shortcoming of the assumption of I-O analysis that all firms in an industry produce one product uniformly. In reality, some firms produce commodities that could be representative of more than one industry, but I-O models constructed by industry will assign the total value of a firm's production to only one industry category, regardless of how many different types of commodities the firm produces.

The secondary inputs cluster contains industries that supply a large amount of inputs to truck transportation. Significant industries include wholesale trade business, real estate establishments, motor vehicle parts manufacturing, transport by rail, warehousing and storage, and automotive repair and maintenance, telecommunications, and monetary authorities. These industries are not surprising taking into consideration the needs of the trucking industry. Wholesale and warehousing and scenic and sightseeing transportation are the highest value industries in this cluster. Although wholesaling and warehousing represent significant partners with freight, this industry may be artificially inflated by the IMPLAN aggregation scheme. IMPLAN sectors are not aggregated to represent similar levels of detail between general sectors in the economy. In the case of manufacturing, the IMPLAN aggregation scheme goes into great detail in dividing industries based on specialized product orientation, but in the case of wholesale and warehousing, a wide variety of industries with different orientations are grouped into one category. Therefore, the wholesale and warehousing ranks highly because it is a large sector, in terms of categorization, and a large supplier to trucking. The scenic and sightseeing and support activities for transportation industry is significant because it includes various support industries for trucking, by definition, and likely includes many firms that produce trucking services as a secondary commodity.

The tertiary inputs cluster contains industries that provide a very small to moderate amount of inputs to trucking. The industries with the largest input values in this cluster are management and technical consulting, accounting and bookkeeping, and investigation and security services.

4.5.1.2. Forward linkage clusters

Industries with forward linkages to truck transportation are those industries to which truck transportation sells its service (output). These industries use truck transportation as an input in the production process. Forward linkages are measured in this study using the total dollar value of transactions in the truck transportation, industry 335, row of the inter-industry transactions matrix for the 10 central states I-O model.

The results of the clustering method suggest four distinct clusters. The industries present in each cluster and the total dollar value of purchases of truck transportation output are listed in Table 5. Many more industries purchase truck transportation in significant amounts than is the case for backward linkages; because of this the clusters suggested are larger and more diverse.

The four cluster solution is validated by examination of the fusion coefficients along the agglomeration schedule Table 6 and a chart (Figure 4) of the fusion coefficients plotted against the number of clusters implied at the final stages of the clustering method. The data values used to determine the clustering method are more similar in the case of forward linkage clusters; every industry purchases some service from truck transportation. This relative decrease in variability makes the distinction between a three cluster and a four cluster solution somewhat more subjective; the implications of this are thoroughly covered in the methods section.

In the case of the forward linkage clusters, the change in the loss of information is more subtle, but there is a jump that occurs when moving from the four cluster solution to the three cluster solution. This indicates that the four cluster solution is appropriate. A jump is also evident between the three cluster solution and the two cluster solution. The four cluster solution was chosen in order to present more disaggregated information to provide reference for other analysts. Although this introduces some element of bias, in this case the clustering solution is not meant to indicate that there is a structural barrier between the clusters. These clusters are meant to provide analytical categories about the significance of purchases of truck transportation from industries within the economy. The chart of the fusion coefficients indicates that change in the fusion coefficients is more tapered in the forward linkage clusters. This chart also validates the four cluster solution because the move from five clusters to four is relatively flat, and the move from four clusters to three is noticeably steeper. Once again, this is a subjective distinction.

Table 5 Forward linkage cluster industries

Cluster	Industry Code	Industry	Purchases
1	335	Transport by truck	$3,712,680,886
1	37	Construction of new residential permanent site single- and multi-family structures	$1,901,212,509
1	59	Animal (except poultry) slaughtering, rendering, and processing	$1,552,918,867
1	283	Motor vehicle parts manufacturing	$1,286,830,134
1	170	Iron and steel mills and ferroalloy manufacturing	$1,239,966,308
1	277	Light truck and utility vehicle manufacturing	$1,128,062,584
1	319	Wholesale trade businesses	$975,499,871
1	34	Construction of new nonresidential commercial and health care structures	$825,791,336
1	161	Ready-mix concrete manufacturing	$822,488,974
1	413	Food services and drinking places	$745,577,642
1	45	Soybean and other oilseed processing	$677,834,133
1	36	Construction of other new nonresidential structures	$596,675,523
1	276	Automobile manufacturing	$558,914,051
2	39	Maintenance and repair construction of nonresidential structures	$469,566,351
2	54	Fruit and vegetable canning, pickling, and drying	$436,161,259
2	105	Paper mills	$433,774,338
2	286	Other aircraft parts and auxiliary equipment manufacturing	$430,839,221
2	56	Cheese manufacturing	$409,261,685
2	38	Construction of other new residential structures	$402,629,238
2	397	Private hospitals	$393,164,029

2	107	Paperboard container manufacturing	$375,873,841
2	381	Management of companies and enterprises	$370,588,560
2	44	Wet corn milling	$353,744,201
2	130	Fertilizer manufacturing	$353,440,074
2	225	Other engine equipment manufacturing	$351,649,269
2	361	Imputed rental activity for owner-occupied dwellings	$317,813,107
2	126	Other basic organic chemical manufacturing	$314,064,885
2	320	Retail Stores - Motor vehicle and parts	$295,167,362
2	2	Grain farming	$291,654,160
2	55	Fluid milk and butter manufacturing	$276,550,336
2	99	Wood windows and doors and millwork manufacturing	$275,533,698
2	127	Plastics material and resin manufacturing	$272,233,853
2	394	Offices of physicians, dentists, and other health practitioners	$269,537,853
2	329	Retail Stores - General merchandise	$253,005,664
Forward Linkage Cluster Industries (continued)			
Cluster	**Industry Code**	**Industry**	**Purchases**
2	42	Other animal food manufacturing	$250,789,693
2	164	Lime and gypsum product manufacturing	$243,262,065
2	149	Other plastics product manufacturing	$243,145,706
2	216	Air conditioning, refrigeration, and warm air heating equipment manufacturing	$237,840,257
2	11	Cattle ranching and farming	$235,526,460
2	70	Soft drink and ice manufacturing	$235,044,940
2	171	Steel product manufacturing from purchased steel	$232,888,271
2	414	Automotive repair and maintenance, except car washes	$232,063,654
2	324	Retail Stores - Food and beverage	$218,019,415
2	31	Electric power generation, transmission, and distribution	$212,698,769
2	136	Paint and coating manufacturing	$205,551,872
2	432	Other state and local government enterprises	$199,597,334
2	41	Dog and cat food manufacturing	$198,091,166
3		N/A	
4		ALL OTHER INDUSTRIES	

Table 6: Forward linkage clusters – list of fusion coefficients

Stage	Number of Clusters	Fusion Coefficient	Loss of Information
430	1	.711	0.255
429	2	.456	0.113
428	3	.343	0.083
427	4	.260	0.054
426	5	.206	0.040
425	6	.166	0.030
424	7	.136	0.020
423	8	.116	0.015
422	9	.101	0.013
421	10	.088	0.013

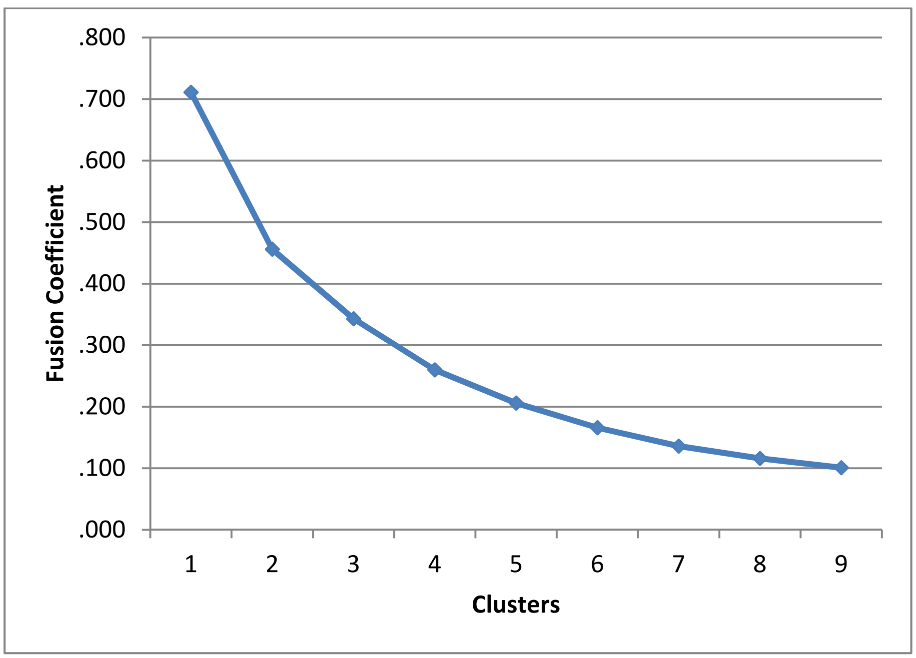

Figure 4. Forward linkage clusters fusion coefficient curve

An ANOVA F-test on the four cluster solution shows that the differences of the input variable, purchases of truck transportation output, are statistically significant. This suggests that the clusters are significantly different. Table 7 shows the ANOVA results.

Table 7. ANOVA results – forward linkage clusters

F = 312.769 p = 0.000			
Cluster	**N**	**Mean**	**Standard Deviation**
1	13	$1,232,650,217	842484655.4
2	34	$302,669,782	80149855.81
3	160	$79,738,302	38610771.56
4	224	$15,090,721	10178309.53

Table 8 contains a list of industries in the primary and secondary linkage clusters and the top ten industries in the tertiary linkage cluster. The first cluster contains the industries that represent the primary forward linkages of the transport by truck industry. This group purchases the highest amount of freight trucking per year (average purchases $1.2 billion) and contains 13 industries. The second cluster contains industries that have secondary forward linkages to truck transportation. These 34 industries purchase significantly more trucking than the industries in the tertiary cluster per year (average purchases $302.7 million). The third cluster contains industries that have tertiary forward linkages to truck transportation. These industries purchase a moderate amount of transportation by truck (average purchases $79.7 million), and there are 160 industries in this cluster. The fourth cluster contains 224 industries that have quaternary forward linkages to trucking. Industries in this cluster purchase the smallest amount of truck transportation per year (average purchases $15.1 million).

Table 8 Primary, secondary, tertiary, and quaternary forward linkage clusters

Cluster	**Industries**	**Average Purchases per Year**
Primary	Transport by truck, construction of new residential structures, animal (except poultry) slaughtering/processing, motor vehicle parts manufacturing (mfg), iron and steel mills, light truck and utility vehicle mfg, wholesale trade business, construction of new nonresidential structures, ready-mix concrete mfg, food services and drinking places, soybean and other oilseed processing, automobile mfg,	$1.2 billion
Secondary	Maintenance and repair construction – nonresidential, fruit and vegetable canning, paper mills, other aircraft parts and auxiliary equipment mfg, cheese mfg, construction of other new residential structures, private hospitals, paperboard container mfg, management of companies and enterprises, wet corn milling, fertilizer mfg, other engine equipment mfg, imputed rental activity for owner-occupied dwellings, other basic organic chemical mfg, retail stores- motor vehicle and parts, grain farming, fluid milk and butter mfg, wood windows/doors/millwork mfg, plastics material and resin mfg, offices of physicians/dentists/health practitioners,	$302.7 million

	retail stores – general merchandise, other animal food mfg, lime and gypsum product mfg, other plastics mfg, air conditioning/refrigeration/warm air equipment mfg, cattle ranching and farming, soft drink and ice manufacturing, steel product mfg from purchased steel, automotive repair and maintenance, retail stores – food and beverage, electric power generation/transmission/distribution, paint and coating mfg, other state and local government enterprises, dog and cat food mfg	
Tertiary	Top Ten: Snack food mfg, soap and cleaning compound mfg, pharmaceutical preparation mfg, US Postal Service, printing, breweries, petroleum refineries, poultry processing, construction machinery mfg, broom/brush/mop manufacturing (160 industries total)	$79.7 million
Quaternary	ALL OTHER INDUSTRIES (224 industries total)	$15.1 million

The primary forward linkage cluster contains the most substantial purchasers of trucking output. These are the industries that purchase trucking output most intensely. The most significant output recipient is the trucking industry itself. However, agriculture, automobile manufacturing, construction, and food distribution industries are also represented within the cluster. Once again, intra-industry transactions are the highest value because of the subcontracting relationships that characterize the freight industry. Owner-operators sell their services, which is output by a small firm in itself, to other firms in the trucking industry. The other industries in this cluster are not surprising; they represent firms that would likely need trucking to transport products to other firms or retail outlets.

The secondary forward linkage cluster contains industries that purchase significant amounts of trucking output; these industries are also intense users of freight trucking but less so than the first cluster. Additional industries from the sectors represented in the primary cluster are prevalent. However, aircraft manufacturers, paper milling, retail stores, chemical manufacturing, and state and local government enterprises are also represented. Some industries in this cluster may not produce bulky or heavy goods that require large amounts of freight, but rather produce higher dollar value or value added goods. Chemical manufacturing and offices of physicians/dentists/health practitioners represent this type of industries. This study represents linkages using dollar value of transactions; therefore industries that produce relatively more expensive goods or high value added goods are implicitly weighted relatively higher.

The tertiary forward linkage cluster contains industries that purchase a moderate amount of truck transportation per year. This cluster is much larger and more diverse than the previous two clusters; the industries within the cluster do not use freight truck transportation as intensely as the industries within the first two clusters. Other freight transportation industries (air, rail, etc.), chemical and pharmaceutical manufacturing, breweries and distilleries, the U.S. Postal service, metal manufacturing, dairy, and many specialized manufacturing industries are members of this cluster.

The quaternary forward linkage cluster contains industries that purchase a modest amount transport by truck. This is the largest cluster; it contains 226 industries. These industries use truck transportation as an input with the least intensity compared to industries in the other three clusters.

It is important to note that these clusters describe the industries that the trucking industry is most dependent on in terms of supplying inputs and demanding trucking services. The variable used to create the clusters relates total transactions between trucking and an industry, relative to the total purchases (or sales) of the trucking industry. Therefore, inclusion of these industries in the clusters does not necessarily indicate that trucking is a critical component of that industry's inputs requirements or sales. This clustering analysis revealed the industries that are highly linked to trucking in terms of trucking's needs and sales. Including an additional variable into the clustering method that measures the significance of a transaction between trucking an another industry compared to that industries total input spending or total sales would also indicate that industry's relative dependence on trucking as an input or a demand source. This is discussed more in the conclusion.

The industry clusters that have been identified through their backward and/or forward linkages with the trucking sector, are referred to as "value chain clusters", following Peters' approach (Peters, 2001). Value chain clusters represent industries that are connected with the trucking industry through purchasing or selling of services and commodities. Figure 5 displays the value chain for truck transportation based on volume of purchases. In the next step, we will examine each of the BEA economic areas in the data set in terms of the specialization/concentration of their economies in the value-chain clusters for trucking.

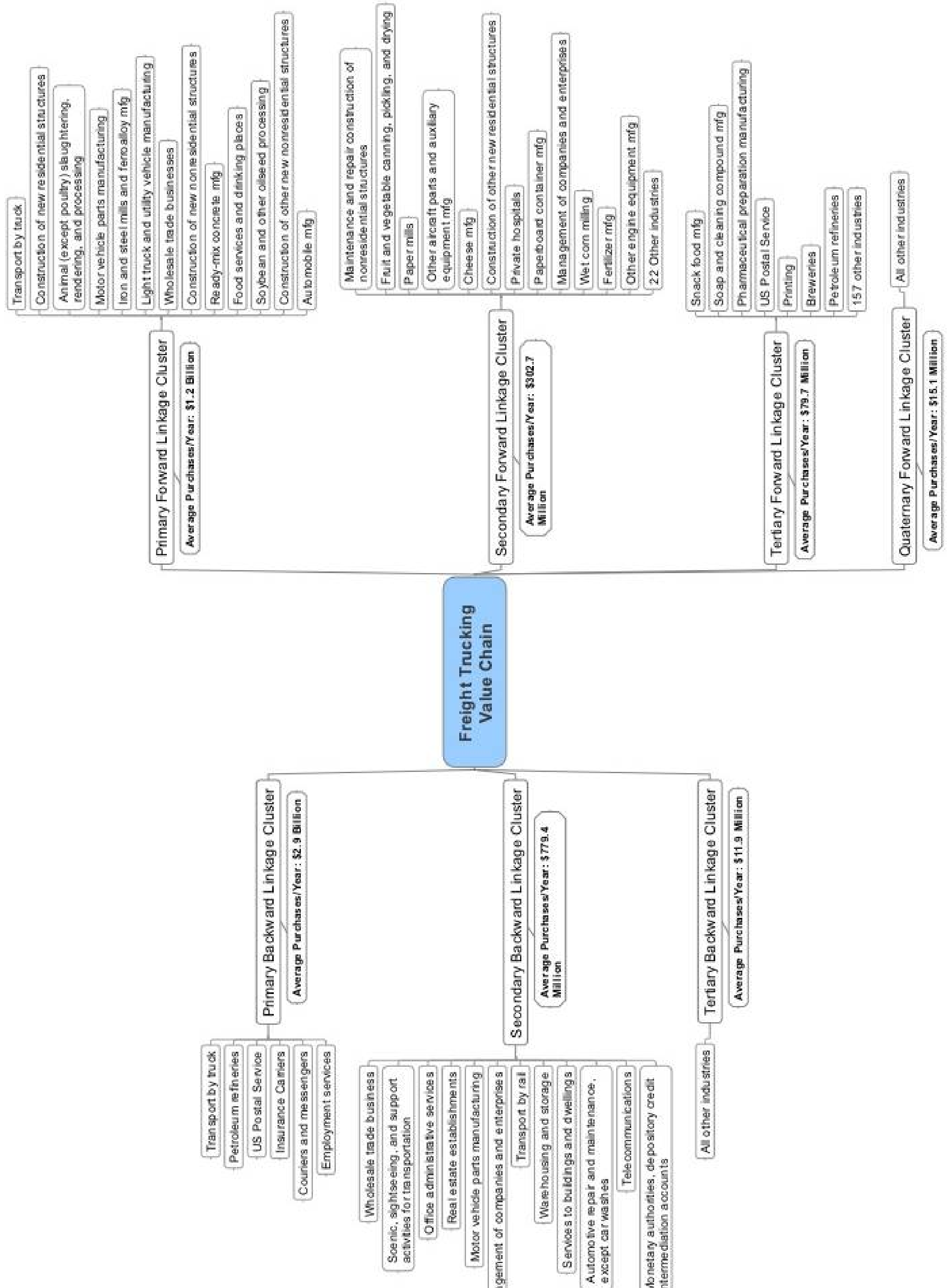

Figure 5. Value-Chain for freight trucking

4.5.2. Specializations of economic areas

The economic structure of each economic area (EA) in the 10 central states region varies based on the industries present in each economy. Economic structure also varies because of concentration in certain economic activities or industries within an EA compared other areas. Location quotients are calculated in order to evaluate how different EAs within the 10 states region are more or less specialized in industries that are significantly involved in the value chain for truck transportation. The industries in the primary and secondary forward and backward linkage clusters are aggregated into one sector representing the entire cluster. This enables evaluation of an economic area's specialization in the most important industries along the value chain as a whole. Although the tertiary forward linkage cluster represents a group of industries that purchase a moderate amount of trucking and may be important in individual EAs, the cluster was excluded for ease of aggregation and interpretation. It is easier to compare specialization in a reasonably small group of industries jointly; specializations across economic areas are more difficult to interpret because of the large number of industries in the tertiary forward linkage cluster.

Location quotients are calculated based on the total output of industries within the cluster. The total share of total output in cluster industries in each of 43 economic areas is compared to the share of total output in cluster industries in the 10 states region in total. Table 9 lists the location quotient of each economic area in each of the primary and secondary linkage clusters.

Table 9. Location quotients by economic area

EA	Name (Abv.)	Primary Forward	Secondary Forward	Primary Backward	Secondary Backward
10 States	10 States	1.000	1.000	1.000	1.000
32	Chicago	0.873	0.864	1.008	1.183
47	Detroit	1.377	0.957	0.740	1.220
109	Minneapolis	0.779	1.016	1.097	1.042
35	Cleveland	0.990	1.048	0.768	0.990
160	St. Louis	1.096	0.982	1.033	1.020
78	Indianapolis	1.028	0.993	1.099	0.992
84	Kansas City	1.005	0.791	1.029	1.220
108	Milwaukee	0.732	1.084	0.848	0.877

40	Columbus	0.920	1.033	1.290	1.016
33	Cincinnati	0.957	1.091	0.969	1.154
9	Appleton	0.396	0.691	0.511	0.336
64	Grand Rapids	0.955	1.007	0.658	1.084
98	Louisville	1.446	0.881	1.244	0.847
46	Des Moines	1.010	1.037	1.634	0.908
44	Dayton	1.070	1.055	0.897	0.880
101	Madison	1.010	1.003	1.030	0.782
179	Wichita	0.808	0.994	1.997	0.653
166	Toledo	1.279	0.965	1.598	0.903
94	Lexington	1.043	0.952	0.710	0.886
156	South Bend	0.997	0.857	0.411	0.755
126	Peoria	0.788	1.229	1.294	0.702
54	Evansville	1.199	1.066	0.703	0.656
60	Fort Wayne	1.361	0.824	1.392	0.939
158	Springfield, IL	1.605	1.059	0.730	0.591
159	Springfield, MO	0.860	1.271	0.891	0.855
27	Cedar Rapids	0.899	1.078	1.182	0.623
176	Wausau	0.735	1.495	1.386	0.568
43	Davenport	0.872	1.392	0.646	0.929
28	Champaign	1.265	1.130	0.738	0.900
167	Topeka	0.810	1.219	0.947	0.806
37	Columbia	0.900	1.179	0.840	0.835
50	Duluth	0.544	1.251	1.717	0.582
83	Joplin	0.829	1.353	1.279	0.617
25	Cape Girardeau	0.786	1.293	0.886	0.654
89	La Cross	0.778	1.560	0.800	0.768
102	Marinette	0.715	1.308	0.420	0.679
175	Waterloo	1.032	1.086	0.544	0.664
168	Traverse City	0.860	1.175	0.523	0.777
122	Paducah	0.819	1.411	0.531	0.590
141	Salina	0.698	1.348	1.303	0.725
103	Mason City	0.825	1.073	0.574	0.638
6	Alpena	0.789	1.083	0.314	0.831

For the purpose of this analysis, these location quotients (LQ) are divided into indices of specialization as follows:

High Specialization: $LQ \geq 1.25$

Above Average Specialization: $1.05 \leq LQ < 1.25$

Average Specialization: $0.95 \leq LQ < 1.05$

Below Average Specialization: $0.75 \leq LQ < 0.95$

Low Specialization: $LQ < 0.75$

Figure 6 depicts specialization in the primary backward linkage cluster industries across all economic areas within the 10 states. This is the group of industries that truck transportation purchases inputs from most intensely. The economic areas that are most highly specialized in the industries that comprise the primary input cluster are Fort Wayne, Toledo, Columbus, Wausau, Duluth, Des Moines, Peoria, Salina, Wichita, and Joplin. The economic area with the highest location quotient is Wichita (1.997); therefore Wichita is the most specialized in industries that represent the primary backward linkages of trucking. It can be argued that an infrastructure investment will have some effect on the pattern of backward linkages. For example, since Wichita is the most specialized in these industries, it is possible that the impacts on primary backward linkage industries, relative to the size of the economic area, would be larger in the Wichita economic area than any other area in the 10 central states.

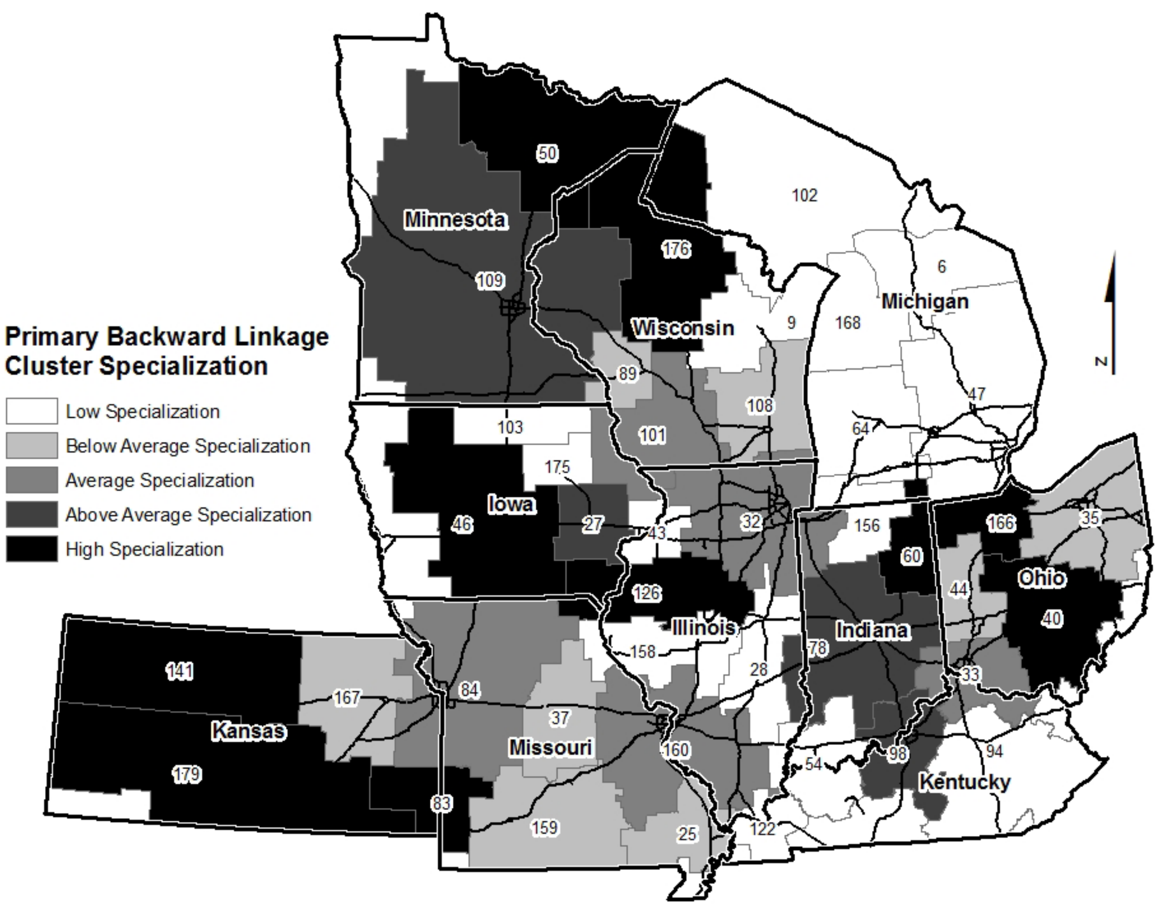

Figure 6. Primary backward linkage cluster specialization

Figure 7 shows specialization in industries that comprise the secondary backward linkage cluster across all economic areas in the 10 states region. Truck transportation purchases a significant amount of inputs from the industries within this cluster. None of the EAs are highly specialized in secondary input industries. This does not mean that these industries are not present in individual EAs, but rather these industries are more evenly distributed across the region. The secondary backward linkage cluster features a number of service industries: office administration, management services, telecommunications, automotive repair, and services to business and dwelling. These industries are primarily local serving in nature, so it is to be expected that they would be more equally distributed across the 10 state region than other clusters that feature a higher number of export oriented industries. Economic areas that are specialized above average levels are Detroit, Grand Rapids, Chicago, Cincinnati, and Kansas City.

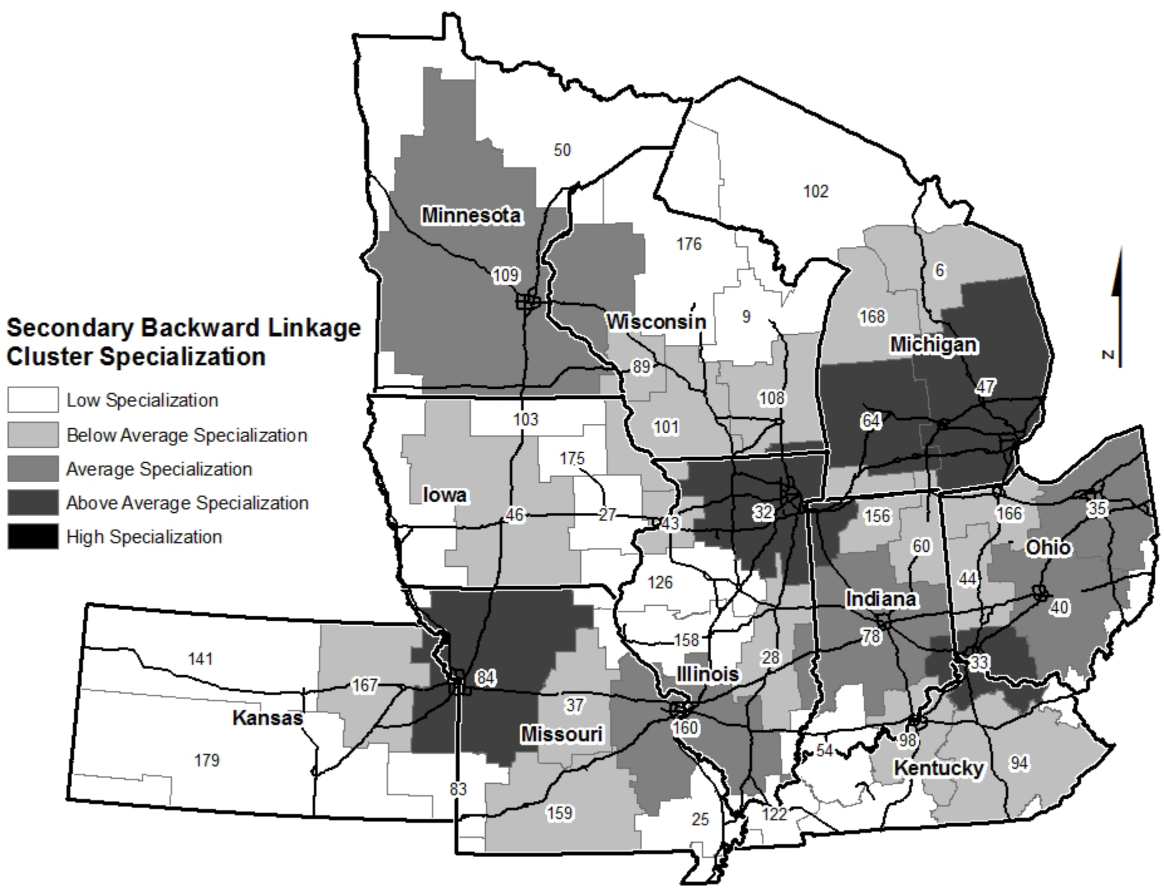

Figure 7. Secondary backward linkage cluster specialization

Figure 8 shows specialization in industries in the primary forward linkage cluster across all of the economic areas in the 10 states. These are the industries are the largest purchasers of truck transportation output. The economic areas that highly specialized in this group of industries are Detroit, Toledo, Fort Wayne, Louisville, Champaign, and Springfield (IL). An infrastructure project has the potential to make truck transportation cheaper or more efficient, especially for industries in the primary forward linkage cluster. It can be argued that economic areas that are specialized in these industries will become more competitive as a result of infrastructure investments because of the savings to important industries. A local economic developer or policy analyst can argue that infrastructure investments in Detroit, Toledo, Fort Wayne, etc. will have higher relative impacts in terms of significance to the local economy because their economies feature a larger concentration of industries that purchase large amounts of freight.

Figure 9 shows the specialization in industries that comprise the secondary forward linkage cluster across all economic areas in the 10 states region. These industries purchase a substantial amount of freight trucking per year. The economic areas that are highly specialized in the secondary forward linkage cluster are Marinette, Wausau, La Crosse, Davenport, Paducah, Cape Girardeau, Springfield (MO), Joplin, and Salina. It can be theorized that infrastructure improvements in these economic areas will improve the competitiveness of the economy as a whole because they would improve access for industries in the secondary forward linkage cluster to cheaper or more efficient trucking.

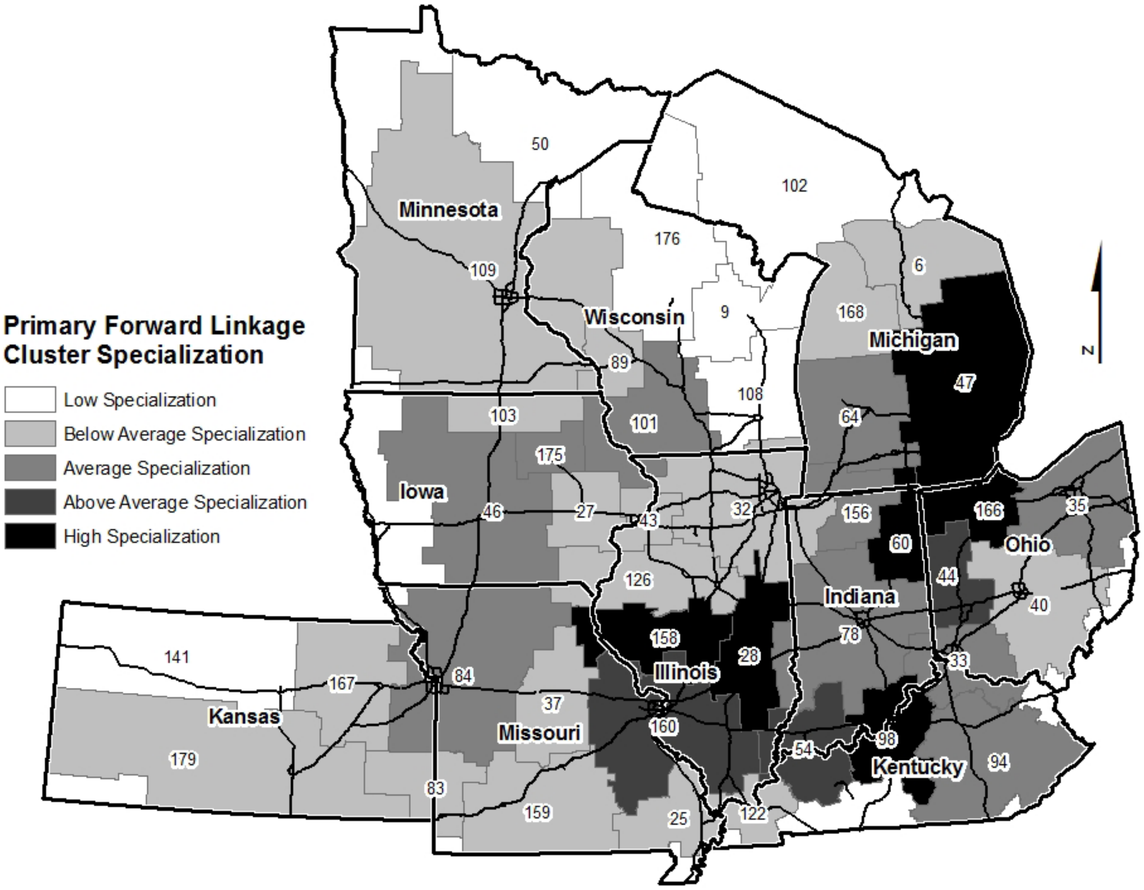

Figure 8. Primary forward linkage cluster specialization

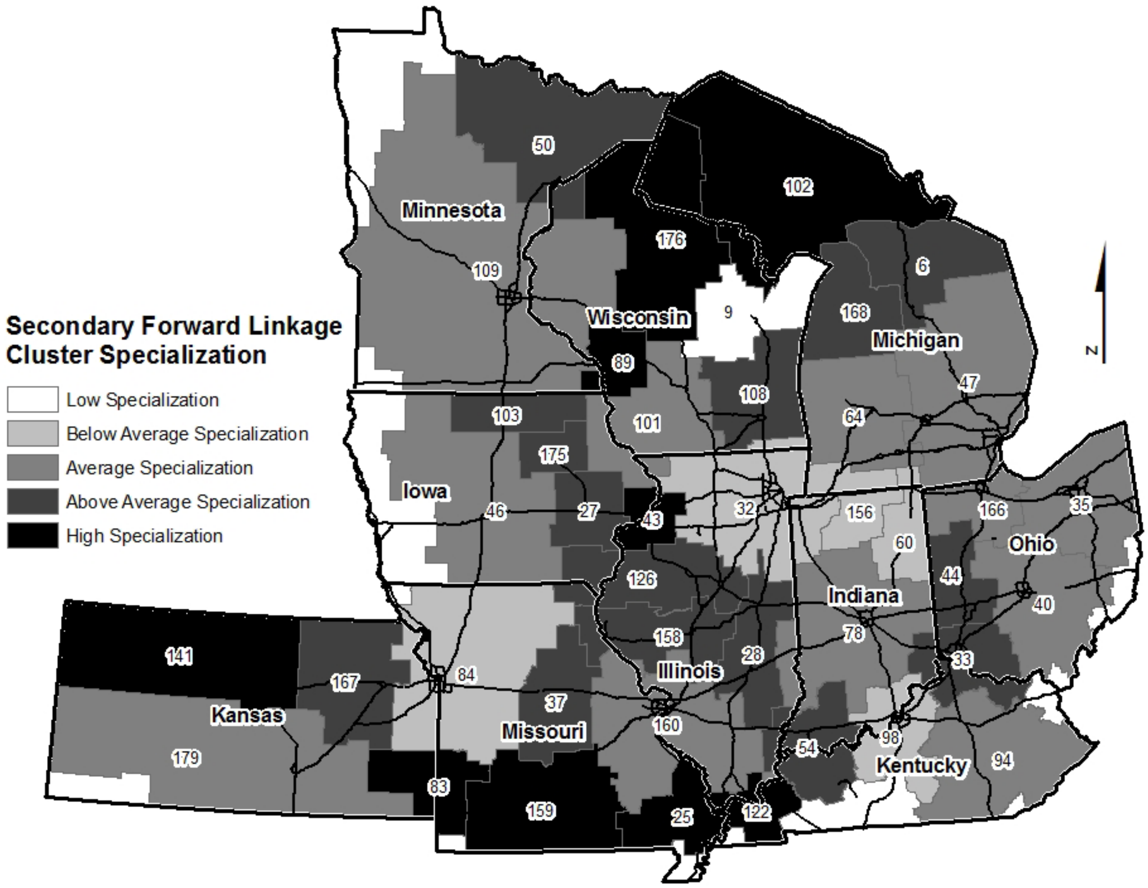

Figure 9. Secondary forward linkage cluster specialization

It is important to note that these location quotients do not take into account the overall size of the trucking industry within the region beyond its inclusion in the appropriate clusters. In the case of the economic areas that have smaller economies, in terms of total dollar value of output, it is likely that the trucking industry is much smaller than in economic areas that represent large economies. However, if the trucking industry is a relatively large part of the small economy, it is considered highly specialized under this methodology. Introducing a mechanism to adjust the location quotients based on the total size of the trucking industry within the economic area would better account for this variation.

Using location quotients also removes the weight that total economic size places on the significance of some industries. Even though some economic areas are highly specialized in certain clusters, those clusters may produce less total output than a less specialized economic area if the less specialized area is much larger. For example, the Chicago economic area is specialized below average in both the primary and secondary forward linkage clusters. However, it is very likely that the Chicago region produces higher values of total output in these clusters than Springfield (IL) or Salina, which are both highly specialized, because the total economic size of the Chicago region is much larger than Springfield or Salina. Additionally, the Chicago economy is much more diverse, and it is less likely for any industry to be significantly specialized in a diverse economy. Therefore, location quotients indicate where the industries that will be highly affected by infrastructure investments, cluster members, represent a relatively more substantial portion of the economy in terms of local economic size and not total contribution to the 10 states region.

Also, this metric does not reveal any information about the number of employees within each of these industries or the total wages earned by employees. In the case where understanding specialization on the basis of regional jobs is most important, location quotients should be recalculated using a measure of total employment or income by sector. However, the purpose of the location quotients for this study is to contribute to the understanding of the impacts of truck transportation infrastructure projects on the industries that are significant in the value chain. These location quotients do provide an indication as to how economic structure of varies across the 10 states region. This indicator of structure is used to compare how technical coefficient change, as a result of the infrastructure project, is diffused throughout the local economy.

4.6. Discussion

This chapter has identified the industries that are most strongly linked with the truck transportation industry in the 10 central states region, in terms of the total dollar value of transactions between the trucking industry and all other industries. Industry sectors in the 10 central states are grouped into primary, secondary, tertiary, and quaternary clusters according to the strength of their relationship with the freight trucking industry. The validity of these clusters using a Ward's hierarchical cluster analysis is heuristically and statistically verified.

Members of the primary and secondary clusters represent the most significant trading partners with the freight industry either through purchasing of trucking services or provision of inputs. These industries are likely to experience the third order benefits, those accrued because of technological innovation or industrial reorganization, or an improvement in freight transportation infrastructure. A change in the efficiency and technology of the freight trucking industry will have the greatest effects on these industries. Although this study does not put forth a method to quantify the value of these third order benefits, it does point toward the industries that will experience these benefits.

Industries in the primary and secondary backward linkage clusters represent the industries from which freight trucking purchases a relatively high amount of inputs. Members of these clusters include firms that supply services necessary to firm operations (insurance, payroll, etc), firms that supply essential parts toward the production of freight trucking (motor vehicle parts, petroleum, motor vehicle repair, etc), and firms that may exhibit subcontracting relationships with trucking or engage in the production of trucking service as a secondary commodity (U.S. Postal Service, couriers and messengers, scenic and sightseeing transport). Further research is necessary to clarify the nature of linkages between freight trucking and the firms in the latter category. In the case of the U.S. Postal Service, it seems as though trucking firms may have subcontracting relationships with the postal service to fulfill small (such as samples) or rush less-than-truckload with contracted clients. Couriers and messengers and scenic and sightseeing firms may have tight purchasing relationships with trucking because many firms in this category carry goods as a secondary product. This is a weakness of the industry-by-industry approach of I-O analysis because it assumes that all firms in an industry category purchase the same product. However, many firms produce a primary product type, but also engage in auxiliary production of complementary goods that are described by other industries.

Industries in the primary and secondary forward linkage clusters are industries that purchase high values of trucking relative to the trucking industry's total dollar value of output. Intra-industry transactions represent the highest value of transaction within the primary cluster. This is due to subcontracting relationships that characterize the trucking industry. Agricultural, construction, and mechanical parts manufacturing industries are also well represented members of these clusters. There do not appear to be any surprise industries in the primary and secondary forward linkage clusters. However, the nature of the I-O framework does implicitly weigh transactions with industries that produce expensive or high value added good relatively higher.

Location quotients are used to evaluate an economic area's specialization in certain industries. This analysis shows that specialization in industries that comprise the most significant value-chain clusters for truck transportation varies across economic areas in the 10 central states. No economic area is highly specialized in the industries of all four strongly linked clusters. Additionally, no economic areas are highly specialized in the group of industries that are a part of the secondary backward linkage cluster. This suggests that these industries are more evenly distributed throughout the 10 states region. This cluster does include industries that provide general firm support. These industries are primarily local serving, and thus it is less likely that any economic area would contain more of these industries than is necessary to meet the needs of the local economy.

Theoretically speaking, areas that are already specialized in important industries along the value chain would receive relatively higher benefits from an infrastructure improvement in relation to their economy as a whole. This is especially true in areas specialized in forward linkage clusters because an infrastructure improvement would reduce costs to those industries and contribute to the competitiveness of a cluster of industries that contribute to the region's economic base. In the long term, this might lead to improvements in resource utilization and/or innovations. Specialization means that those industries represent a relatively higher proportion of the total dollar value of output of that economic area compared to the 10 states region.

However, it may be deceptive to use location quotients to compare the impacts on economic areas of different size. Economic areas that have larger, in terms of dollar value, and more diversified economies are less likely to be specialized in any group of industries because the total size of the economy is much larger. It is possible that industries that are members of clusters produce more output in a large economy that is less specialized than a small economy that is specialized. Therefore, from the perspective of the 10 states region, it could be possible to elicit larger dollar value of third order benefit by investing in a larger economy even though it is less specialized. Location quotients do offer the ability for a local economic developer or policy maker to argue that an infrastructure investment would produce a larger relative impact for a small economy. Location quotients allow a local decision maker to show that money spent on transport has the potential to produce benefits for a small economy that drastically effect competitiveness rather than benefits that are larger in total dollar value, but less important for economic development and strength. However, this analysis also illustrates the “Catch-22” of location quotients and industry targeting. It is easy to argue for local boosterism for any type of industry or any potential project under this justification.

CHAPTER 5 FIELD OF INFLUENCE

5.1 Background

Field of influence analysis was developed by Michael Sonis and Geoffery Hewings to help evaluate the impact of a change from one sector to the rest of the economy by measuring the impacts of a change in an inter-industry relationship on the remaining sectors, which would be reflected in the Leontief inverse matrix (Sonis and Hewings 1991). The field of influence represents the change in the Leontief inverse matrix that occurs because of technological change that is represented as one until change in the technological coefficient. It is important to note that the amount of change in field of influence analysis is not important, as it is scalable; the important variable in field of influence analysis is the location of change (Sonis and Hewings 2009).

Since the field of influence, when multiplied by the rational fraction function of the change in the Leontief inverse, and added to the original Leontief inverse, the results will be the new Leontief inverse matrix caused by a change in the direct requirement matrix. The first order field of influence formula is included below. *F[(j, i)]* is the first order field of influence.

$A\left[a_{ij}\right] = Direct\ requirement\ matrix$
$E\left[e_{ij}\right] = A\ Matrix\ containing\ changes\ to\ direct\ requirement\ matrix$
$B\left[b_{ij}\right] = Leontief\ inverse\ matrix = (I - A)^{-1}$
$B'\left[b'_{ij}\right] = Leontief\ inverse\ matrix\ after\ change\ in\ direct\ requirement\ matrix$
$= (i - A - E)^{-1}$

$$B' = B\ \frac{1}{Q(E)}\left(\sum_{k=1 i \neq is,}^{n} \sum_{j \neq js} F_{k}{e_{j1}}_{i1} \cdots e_{jkik}\right)$$

$Where\ Q(E) = the\ ratio\ the\ determinants\ of\ B, B', F_k.$
$Field\ of\ influence\ first\ order\ is\ given\ as$

$$F[i,j] = \begin{pmatrix} b_{1i} \\ \cdot \\ \cdot \\ \cdot \\ b_{ni} \end{pmatrix} \begin{pmatrix} b_{j1} & \cdot & \cdot & \cdot & b_{jn} \end{pmatrix}$$

Several authors have pointed out that field of influence analysis is useful as a complement to other linkage analysis techniques, such as key sector analysis (Parré, Alves and Sordi 2002) (Sonis, Guilhoto, et al. 1995). Similar to key sector analysis, the field of influence approach helps to identify specific opportunities for greater than average potential. However, field of influence analysis provides this linkage for specific relationships rather than the sector generally (Parré, Alves and Sordi 2002).

The field of influence analysis is performed on I-O models of Chicago-Naperville-Michigan City, IL-IN-WI (EA 32), Detroit-Warren-Flint, MI (EA47), and Madison-Baraboo, WI (EA101). The inter-industry transactions, total output, value added and final demand values were taken from the Industry-by-Industry Transactions report and the Industry Output Outlay Summary produced by IMPLAN.

In order to ease the viewing of the results, PyIO to aggregate the I-O models into 21 sectors. However, the economic structure, and industries present, in all three economic areas varies, and so a new aggregation scheme must be developed for each model. In the case where an industry that is a part of the primary or secondary forward linkage cluster falls within the range of another sector, it is excluded from that sector. Each industry is counted only once. Also, forward linkage clusters are only included for the purpose of this field of influence analysis because there is overlap among industries in forward and backward linkage clusters; therefore, the backward linkage clusters cannot be aggregated because the same industry would have to be included in multiple clusters, which violates the I-O model. Finally, truck transportation is included as its own sector, apart from the clusters, in order to isolate the effect of a change in only trucking technology.

The field of influence is performed in the aggregated I-O table in PyIO. This study evaluates a change in intra-industry technology between the truck transportation row and truck transportation column, cell (10, 10). Currently, PyIO is capable of calculating only the first order field of influence, i.e. change in one cell of a direct requirements table. The result of the field of influence analysis is a matrix that depicts the incremental change in the Leontief inverse matrix due to a scalar change in the cell specified. The new Leontief inverse coefficient can be calculated by adding the incremental change of the field of influence output to the original Leontief inverse coefficient.

5.2. Field of Influence Analysis

So far, this study has shown that certain industries have stronger links, on the basis of the total dollar value of purchases, to the truck transportation industries than others. These industries are included in the primary and secondary forward and backward linkage clusters. Furthermore, individual economies within a region differ in economic structure. In this case, we have focused on specialization in industries within the clusters. Differences in economic structure were represented graphically earlier in the document, but are also evident in I-O models. This section will evaluate how coefficient change in the truck transportation industry spreads throughout the Leontief inverse matrix in three different economic areas: Chicago-Naperville-Michigan City, IL-IN-WI (EA32), Detroit-Warren-Flint, MI (EA47), and Madison-Baraboo, WI (EA101). Figure 10 highlights these economic areas in the greater 10 states region.

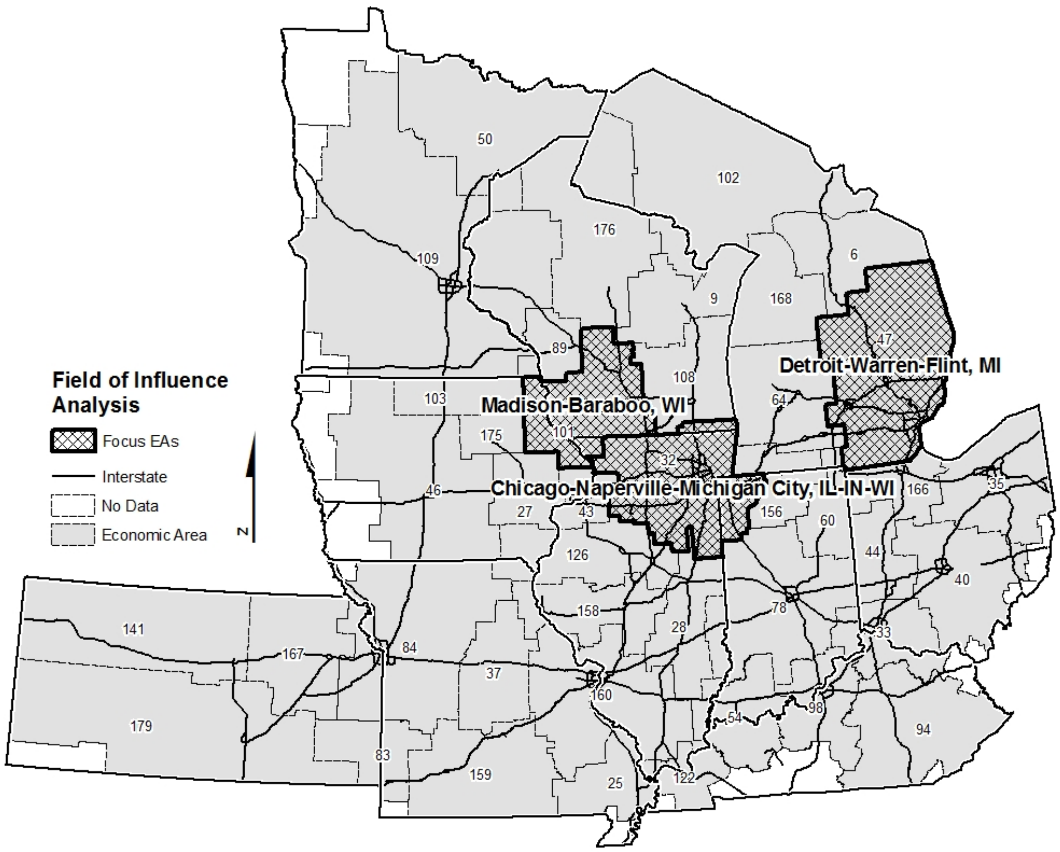

Figure 10. Focus areas of field of influence analysis

The Chicago economic area produced approximately $982 billion in output in 2007. It is specialized below average levels for the 10 state region in both forward linkage clusters. The Chicago economy is more diverse than either Detroit or Madison, and has a strong relationship between manufacturing and trucking. The Detroit economic area produced approximately $593 billion in output in 2007. It is highly specialized in industries in the primary forward linkage cluster. The Detroit economy has traditionally been very concentrated in manufacturing industries, especially relating to automotive production. The Madison economic area produced approximately $103 billion in total output in 2007. It is not particularly specialized in industries in the forward linkage clusters. The presence of these industries in the Madison economic area resembles the proportions seen on average in the 10 central states. The Madison economy has a higher level of agricultural activity than either Chicago or Detroit. Table 10 summarizes the economic characteristics of the three economic areas for the purpose of this study.

Table 10. Overview of analyzed economic areas

	Chicago	Detroit	Madison
Total Output	$982,050,219,877	$592,962,114,072	$102,952,332,039
Primary BL Cluster Specialization	Average	Below Average	Average
Secondary BL Cluster Specialization	Above Average	Above Average	Below Average
Primary FL Cluster Specialization	Below Average	High	Average
Secondary FL Cluster Specialization	Below Average	Average	Average

It is expected that the field of influence results will differ in the three regions because of the differences in economic structure described above. Also, it is expected that the Leontief inverse changes will be largest in the primary and secondary linkage clusters because they represent the strongest ties to the freight trucking industry. However, because some industries are present in both forward linkage clusters and backward linkage clusters, only the backward linkage clusters are represented in the I-O models. Double counting an industry within the model would bias the results towards that industry. The truck transportation industry has been left out of the primary backward linkage cluster in order to isolate its individual effect on the rest of the economy.

The field of influence analysis is performed for a change in technical coefficient in the truck transportation column and the truck transportation row. This cell describes the intra-industry transactions between trucking such as fleet organization purchases and subcontracting relationships. This cell was chosen because the industry interacts with itself in the largest dollar value, and this is the industry's most significant link. Also, the spread of technological innovation that occurs as a result of an improvement in transportation infrastructure will begin with a change in efficiency of the freight trucking industry. The best way to represent this would be to alter the coefficient in every cell of the truck transportation row. Since this is not yet possible with the available software, the product innovation is symbolized as beginning with coefficient change in the cell representing intra-industry transactions. The field of influence analysis assumes an initial scalar coefficient change, so the cell chosen will show a change greater than unit change. An example of the technological change that is represented by altering this cell would be a fleet composition change that occurs within trucking firms as a result of an infrastructure improvement. Modeling this scenario was directly cited as a shortcoming of the FHWA tool.

Table 11 shows the results of a field of influence analysis performed on a model of the Chicago economic area. The cells that show an above average change are shaded in gray, and the top ten cell changes are outlined in black. The largest change occurs in the trucking-to-trucking cell, where the field of influence was performed (1.1006). This makes sense as the largest change because choosing this cell implicitly hypothesizes that it has strong links with the rest of the economy. The value of "1" is assumed as a part of the field of influence analysis. The largest residual change is actually shown in the cell relating the trucking industry's purchase of general manufacturing goods (not a part of the linkage clusters). All of the largest cell changes are in the column of trucking, indicating that coefficient change is spread more strongly through backward linkages. Also, the changes in Transportation & Warehousing, Finance & Insurance, and Administrative Services are all larger than the changes experienced to either of the backward linkage clusters. Although the coefficients depicting the cluster industries' purchase of truck transportation does show above average change, it is not in the top ten values. Also, stronger change is experienced in the trucking industry's purchase of goods from the secondary backward linkage cluster. That may be due to overlap between industries in the forward and backward linkage clusters.

Table 12 shows the results of the field of influence analysis performed on the Detroit economic area using the same shading criteria previously employed. Once again, the above average values fall exclusively in the column and row of the trucking industry. In this case, the largest residual change is within the trucking industry. The top ten values are contained within the same cells as the Chicago region. The magnitude of the changes, however, is smaller in the Detroit model compared to Chicago. Detroit is more specialized than Chicago in the industries of the forward linkage clusters. The region is highly specialized in the primary forward linkage cluster, and the magnitude of this change in the Detroit region (0.093) is larger than Chicago (0.091). However, this difference is very small. Also, Chicago is specialized below average in industries in the secondary forward linkage cluster. The magnitude of coefficient change for this sector's purchase of freight in the Chicago region (.0086) is larger than Detroit (.0067), which is more specialized. This may be because the Chicago economy is larger, even though it is less specialized.

Table 13 shows the results of the field of influence analysis performed on the Madison economic area. The same shading criteria are used. The locations of change observed are similar to the fields of influence in Chicago and Detroit. The largest cell change is the intra-industry trucking value. However, this magnitude is smaller than either Detroit or Chicago. In all three economies, the column values of the trucking industry show the largest changes. This indicates that technological change in trucking spreads to a greater through backward linkages in these regions. The Madison economic area is specialized at average levels in the industries that are a part of the primary and secondary backward linkage cluster. Coefficient change in the primary cluster is the same as in the Detroit model (0.0093) and greater than Chicago. Change in the secondary cluster coefficient was greater in the Madison model (0.0099) than in either Detroit or Chicago. Madison is the only region where one of the top ten change values is in a row cell. This occurs in the cell indicating the Agriculture, Forestry, and Hunting industries' purchases of freight. Madison has a much higher proportion of economic activity in these industries compared to either Chicago or Detroit.

Table 11. Changes in Leontief inverse matrix – Chicago

FIELD OF INFLUENCE ANALYSIS - TRUCK TRANSPORTATION TO TRUCK TRANSPORTATION - EA32 (CHICAGO)																					
Sector	Primary Forward Linkages Cluster	Secondary Fwd Linkages Cluster	Agr, Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Retail	Transportation & Warehousing	Truck Transportation	Information	Finance and Insurance	Real Estate & Rental	Professional, Sci, & Tech Services	Administrative and Waste Services	Educational Services	Health & Social Services	Arts, Entertainmt, and Rec	Accomodation and Food Services	Other Services	Government & Non NAICS
Primary Forward Linkages Cluster	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Secondary Forward Linkages Cluster	0.0004	0.0004	0.0003	0.0001	0.0007	0.0005	0.0006	0.0003	0.0003	**0.0526**	0.0002	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0004
Ag, Forestry, Fishing & Hunting	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0085	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001
Mining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Utilities	0.0003	0.0003	0.0002	0.0001	0.0005	0.0004	0.0004	0.0003	0.0003	**0.0387**	0.0002	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0003
Construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Manufacturing	0.0009	0.0008	0.0005	0.0003	0.0014	0.0011	0.0012	0.0007	0.0007	**0.1072**	0.0005	0.0001	0.0001	0.0003	0.0004	0.0004	0.0004	0.0006	0.0004	0.0006	0.0008
Retail	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0046	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transportation & Warehousing	0.0006	0.0006	0.0004	0.0002	0.0009	0.0007	0.0008	0.0005	0.0005	**0.0716**	0.0003	0.0001	0.0001	0.0002	0.0002	0.0003	0.0003	0.0004	0.0002	0.0004	0.0005
Truck Transportation	0.0091	0.0086	0.0056	0.0029	0.0145	0.0115	0.0123	0.0072	0.0073	**1.1006**	0.0048	0.0015	0.0013	0.0031	0.0036	0.0041	0.0041	0.0065	0.0037	0.0060	0.0077
Information	0.0002	0.0002	0.0001	0.0001	0.0003	0.0002	0.0002	0.0001	0.0001	0.0219	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
Finance and Insurance	0.0007	0.0007	0.0004	0.0002	0.0011	0.0009	0.0010	0.0006	0.0006	**0.0871**	0.0004	0.0001	0.0001	0.0002	0.0003	0.0003	0.0003	0.0005	0.0003	0.0005	0.0006
Real Estate & Rental	0.0003	0.0003	0.0002	0.0001	0.0005	0.0004	0.0004	0.0002	0.0002	**0.0375**	0.0002	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0003
Professional, Sci, & Tech Services	0.0004	0.0004	0.0002	0.0001	0.0006	0.0005	0.0005	0.0003	0.0003	**0.0456**	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003
Administrative and Waste Services	0.0006	0.0006	0.0004	0.0002	0.0010	0.0008	0.0008	0.0005	0.0005	**0.0733**	0.0003	0.0001	0.0001	0.0002	0.0002	0.0003	0.0003	0.0004	0.0002	0.0004	0.0005
Educational Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Health & Social Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Arts, Entertainment, and Recreation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Accomodation and Food Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other Services	0.0004	0.0004	0.0002	0.0001	0.0006	0.0005	0.0005	0.0003	0.0003	**0.0462**	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003
Government & Non NAICS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 12. Changes in Leontief inverse matrix - Detroit

FIELD OF INFLUENCE ANALYSIS - TRUCKING TO TRUCKING - EA47 (DETROIT)

Sector	Primary Forward Linkages	Secondary Forward Linkages	Ag, Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Retail	Transportation & Warehousing	Truck Transportation	Information	Finance and Insurance	Real Estate & Rental	Professional, Sci, & Tech Services	Administrative and Waste Services	Educational Services	Health & Social Services	Arts, Entertainment, and Recreation	Accomodation and Food Services	Other Services	Government & Non NAICS
Primary Forward Linkages Cluster	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Secondary Forward Linkages Cluster	0.0004	0.0003	0.0003	0.0001	0.0005	0.0004	0.0004	0.0002	0.0002	**0.0433**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
Ag, Forestry, Fishing & Hunting	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Utilities	0.0003	0.0002	0.0003	0.0001	0.0004	0.0003	0.0003	0.0002	0.0002	**0.0386**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
Construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Manufacturing	0.0004	0.0003	0.0003	0.0001	0.0004	0.0004	0.0004	0.0002	0.0002	**0.0409**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
Retail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transportation & Warehousing	0.0005	0.0004	0.0005	0.0001	0.0007	0.0006	0.0006	0.0004	0.0003	**0.0636**	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003
Truck Transportation	0.0093	0.0067	0.0082	0.0022	0.0114	0.0096	0.0096	0.0061	0.0049	**1.0854**	0.0035	0.0011	0.0009	0.0023	0.0026	0.0038	0.0032	0.0047	0.0031	0.0058	0.0054
Information	0.0001	0.0001	0.0001	0.0000	0.0002	0.0001	0.0001	0.0001	0.0001	0.0152	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0001
Finance and Insurance	0.0005	0.0004	0.0004	0.0001	0.0006	0.0005	0.0005	0.0003	0.0003	**0.0593**	0.0002	0.0001	0.0000	0.0001	0.0001	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003
Real Estate & Rental	0.0003	0.0002	0.0002	0.0001	0.0003	0.0003	0.0003	0.0002	0.0001	**0.0324**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002
Professional, Sci, & Tech Services	0.0003	0.0002	0.0003	0.0001	0.0004	0.0003	0.0003	0.0002	0.0002	**0.0356**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
Administrative and Waste Services	0.0006	0.0004	0.0005	0.0001	0.0007	0.0006	0.0006	0.0004	0.0003	**0.0669**	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0002	0.0004	0.0003
Educational Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Health & Social Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Arts, Entertainment, and Recreation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Accomodation and Food Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other Services	0.0004	0.0003	0.0004	0.0001	0.0006	0.0005	0.0005	0.0003	0.0002	**0.0526**	0.0002	0.0001	0.0000	0.0001	0.0001	0.0002	0.0002	0.0002	0.0001	0.0003	0.0003
Government & Non NAICS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 13. Changes in Leontief inverse matrix – Madison

FIELD OF INFLUENCE ANALYSIS - TRUCKING TO TRUCKING - EA101 (MADISON)																					
Sector	Primary Forward Linkages	Secondary Forward Linkages	Ag, Forestry, Fishing & Hunting	Mining	Utilities	Construction	Manufacturing	Retail	Transportation & Warehousing	Truck Transportation	Information	Finance and Insurance	Real Estate & Rental	Professional, Sci, & Tech Svcs	Administrative and Waste Services	Educational Services	Health & Social Services	Arts, Entertainment, and Recreation	Accomodation and Food Services	Other Services	Government & Non NAICS
Primary Forward Linkages Cluster	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Secondary Forward Linkages Cluster	0.0003	0.0003	0.0004	0.0001	0.0003	0.0002	0.0003	0.0001	0.0001	**0.0303**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001
Ag, Forestry, Fishing & Hunting	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Utilities	0.0002	0.0002	0.0003	0.0000	0.0002	0.0001	0.0002	0.0001	0.0001	**0.0196**	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Manufacturing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Retail	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0045	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transportation & Warehousing	0.0003	0.0003	0.0005	0.0001	0.0004	0.0002	0.0003	0.0002	0.0002	**0.0361**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0002
Truck Transportation	0.0093	0.0099	**0.0148**	0.0020	0.0106	0.0074	0.0092	0.0047	0.0047	**1.0752**	0.0028	0.0008	0.0010	0.0021	0.0028	0.0037	0.0028	0.0055	0.0030	0.0044	0.0050
Information	0.0001	0.0001	0.0002	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0140	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001
Finance and Insurance	0.0005	0.0005	0.0008	0.0001	0.0006	0.0004	0.0005	0.0003	0.0003	**0.0591**	0.0002	0.0000	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0003
Real Estate & Rental	0.0002	0.0002	0.0002	0.0000	0.0002	0.0001	0.0002	0.0001	0.0001	**0.0176**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0001
Professional, Sci, & Tech Svcs	0.0002	0.0002	0.0002	0.0000	0.0002	0.0001	0.0002	0.0001	0.0001	**0.0176**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0001
Administrative and Waste Services	0.0003	0.0004	0.0005	0.0001	0.0004	0.0003	0.0003	0.0002	0.0002	**0.0391**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
Educational Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Health & Social Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Arts, Entertainment, and Recreation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Accomodation and Food Services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other Services	0.0004	0.0004	0.0006	0.0001	0.0004	0.0003	0.0004	0.0002	0.0002	**0.0456**	0.0001	0.0000	0.0000	0.0001	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0002
Government & Non NAICS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 14 displays a summary of the results of the field of influence analysis that are most significant for this study. The analysis results confirm the hypothesis that the spread of technological change beginning in the trucking industry would vary between economic areas. However, it also shows that the industries that purchase freight trucking in the largest amounts will not necessarily experience the largest coefficient changes. Also, the relationship between specializations in these industries and coefficient change in mixed. The Chicago region is less specialized in both clusters, but experienced changes very similar to the other regions in the case of the primary linkage cluster. In the secondary linkage cluster the change was greater than Detroit and less than Madison, despite the fact that both economies are more specialized.

Table 14. Summary of Field of Influence analysis results

Region	Location of Largest Change	Specialization in Primary Forward Linkage Cluster	Change Value	Specialization in Secondary Forward Linkage Cluster	Change Value
Chicago	MFG inputs to Trucking	Below Average	0.0091	Below Average	0.0086
Detroit	Trucking-Trucking	High	0.0093	Average	0.0067
Madison	Trucking-Trucking	Average	0.0093	Average	0.0099

The analysis showed that coefficient change would be largest in cells indicating backward linkages to trucking. This is somewhat problematic because quantifying the third order benefits of trucking for industries that represent forward linkages is more important. A cheaper and more efficient trucking service has the potential to improve the competitiveness of these industries in a region. However, this is the nature of using I-O analysis to measure transaction based linkages. Backward linkages are often more evident through transactions, but forward linkages include the social and institutional relationships that I-O analysis ignores.

5.3 Conclusions

Field of influence analysis offers the opportunity to quantify the third order benefits of infrastructure improvements. The Federal Highway Administration has already shown that infrastructure investments will alter the production process of industries in the short term using their Cost/Benefit Analysis tool. Field of influence analysis extends this evaluation to the medium to long term by modeling the spread of coefficient change throughout the entire economy as evident by changes in the Leontief inverse (total requirements) matrix.

Regional field of influence allows the economic developer or policy analysts to compare how the total impacts of an improvement in trucking technology, or efficiency, will vary by region and industry. Our findings, summarized in Table 14, show that change in technology in the trucking-to-trucking cell of the I-O model (akin to a reorganization of the kind of subcontracting relationships in trucking due to increased efficiency) will change the value of the total requirement coefficient in the primary forward linkage cluster by 0.0091 in Chicago and 0.0093 in both Detroit and Madison. This means that if trucking technology were to change due to an improvement project, an increase in final demand for trucking by one dollar in either Detroit or Madison will include industries in the primary forward linkage cluster demanding 0.02 cents more per dollar of freight than industries in the primary forward linkage cluster of Chicago.

In general, the changes in the direct requirement matrices across study areas are generally small: most changes are only observable at the fourth decimal level or smaller. The broad implication of these small changes is that Trucking is either relatively inelastic or, so efficient in its current state that reducing delay by 20% has only minimal impact. Whichever the cause, this suggests infrastructure projects aiming to improve the efficiency of Trucking are unlikely to be justified using I-O alone.

CHAPTER 6: DEVELOPMENT OF ECONOMIC IMPACT ESTIMATION TOOL

In this chapter, development of a methodology to use I-O model to simulate the effect of infrastructure improvements and associated reduction in truck congestion is discussed. The chapter includes a review of basic concepts of I-O analysis and related techniques. Chapter 6 describes the application of the approach described in this chapter to five urban areas in the upper Midwest.

6.1. Literature Review

Developed by Wassily Leontief in the 1930s, I-O analysis is a framework that analyzes the interdependence of industries within a given economy. At its core, I-O refers to a system of linear equations that describe the distribution of an industry's product throughout an economy (Miller & Blair, 1985**.** Though I-O accounting of inter-industry transactions existed long before Leontief, his formalization of the body of work has led to the methodology being referred to the Leontief model and ultimately resulted in Leontief receiving a Nobel Prize in Economic Science in 1973.

I-O focuses primarily on the business spending component of the non-basic sector and tracks how inter-industry production linkages lead to more or less regional income for each unit of final sales for regional goods and services. The total product of an economy is the combined value of all the final products produced in a given year. The total output is all sales in year. Total output is larger than total product because it includes the inter-industry sales of inputs to production. Final sales, rather, are representative of demand for final products (Bendavid-Val, 1991)**.**

I-O **(**I-O**)** separates an economy into groups, firms that sell and firms that buy. These firms are then employed in three matrices: the transaction matrix, the direct requirement matrix, and the total requirements matrix. The basis of Leontief's method is the I-O, or transaction table. The transaction matrix, the upper left section of the I-O table, includes all the transaction data between buyers and sellers in an economy. The table shows how the output of each industry is distributed among other industries and sectors of the economy, while simultaneously showing the inputs to each industry from other industries and sectors. Essentially, it is the summary of all inter-industry transactions in a specified economy, be it national, regional, or even local.

The transactions are presented in monetary terms for the period of time the study is being conducted (typically years). To the right of the transaction matrix is the final demand section of the I-O table. This section includes columns covering exports, government purchases, and households, among others. Reading the transaction table is relatively straightforward. When reading it horizontally, the values in the row indicate the sales made by that particular industry to each industry. Conversely, when read vertically, it provides the purchases made by a given industry from all other industries. In this capacity, the transaction matrix captures the inputs and outputs for each industry in a specified economy.

The direct requirements matrix is also known as the technical coefficient matrix, the a-matrix, and the direct coefficients. It represents the amount of additional input a given sector requires from supplying sectors to produce one additional dollar of output. It is calculated by dividing each cell in the sector column by that sectors adjusted gross output.

The total requirements matrix stems from the direct requirements table and reflects the total purchases of direct and indirect inputs required throughout an economy per unit of output sold to final purchasers by intermediate suppliers. In other words, where the direct requirements matrix indicates the additional inputs needed for one unit of output, the total requirements matrix also includes the increased inputs needed by the intermediate suppliers. In this capacity, the total requirements matrix includes all the direct and indirect requirements for each industry.

6.1.1. Input-output analysis in transport

Most quantitative analyses of the economic effects of transportation projects are limited to user benefits and environmental impacts. Economic impact tools, such as I-O, are rarely used to measure investments in transportation systems, despite being used in measuring other infrastructure projects. Central problem in the I-O framework is the ability to simulate productivity changes directly, so converting travel time savings into a change in demand from increased productivity is necessary (Seetharaman, Kawamura, & Dev Bhatta, 2003).

Traditional methods, notably benefit-cost analysis, focus only on direct impacts (aka time and cost savings) and are limited by not considering the broader role of transportation in the economy. I-O is accessible, more affordable and offers complementary understanding of the industries affected by public investments in transportation. Perhaps of greatest value to transportation, is that I-O is grounded in technical, measurable relationships of production and bridges the gap between economists, managers and engineers

An economic development impact is typically measured by an area's level of activity in employment, income, quality of life, and economic stability over time. These impacts are typically measure by changes in economic output, gross regional product, personal income, or employment, among others. Each of these measurement criteria can reflect the sum of direct effects on business growth (firms directly affected by change), indirect effects on business growth (suppliers of directly affected firms) and induced economic growth (re-spending of increase in worker income).The sum of all these represents the total economic effect (Wang & Charles, 2010).

6.1.2. Regional input-output analysis

There are two basic features of a regional economy that influence the characteristics of a regional I-O study versus a national one. First, the structure of a production in any one region may be similar or significantly different than that recorded in a national I-O table. This is especially true with small or highly specialized economies, as any one industry may represent a significant amount of the overall economy. Conversely, in large, diverse economies, the structure of production is likely to be more reflective of the national structure.

Second, the smaller an area, the more likely its economy is dependent on trade with external economies. In this capacity, a greater portion of its spending is transferred to outside economies than in larger economies, something known in economic base as leakage. In other words, smaller economies are unlikely to be entirely self-sustaining and are thereby forced to purchase from outside their borders to satisfy demand. While multiplier analysis is discussed in further detail below, generally speaking, the larger the amount of leakage, the lower the multiplier in any given economy (Miller & Blair, 1985), (Stone R. , 1986), (Giarratani, Mady, & Socher, 1976).

6.1.3. Impact analysis

Impact analysis is used to measure the effects of a hypothetical change on an economy. It is frequently used as a way to compare various scenarios of how an economic shock will impact an economy. The baseline model, typically the current state, is compared with one or more updated models depending on the number of scenarios being assessed. The analysis is conducted using a change in demand for at least one sector that is then multiplied by the respective cells in the total requirements matrix (Miernyk, 1965), (Halpern-Givens, 2010). Impact is most appropriately used to measure short-term effects of a project. Therefore, it is commonly used to measure the impact of projects that are construction heavy (i.e. Infrastructure projects, Airports, Ports, etc), or those that have a finite time span.

6.1.4. Multiplier analysis

Multiplier analysis originated with Keynes, who built upon the work of R.S. Kahn. Keynes noted that were an economy to experience an injection of income, consumer spending would rise, although less than the amount of new income. As consumers spent, the amount spent became another's new income, of which a lesser amount was then re-spent. This cycle then continues with each round being smaller than the round before. Keynes pointed out that if the marginal propensity to consume could be measured, the income multiplier could also be measured. While Keynes developed the concept of the aggregated multiplier, it is relatively limited in shedding insight on the more detailed impact on individual industries and sectors (Miernyk 1965).

The most common types of multipliers are those that estimate the effects of the exogenous changes on output, income or employment. Output multipliers represent the total value of production in all sectors of the economy that is necessary in order to satisfy a dollar's worth of final demand for a given sector. It is the ratio of the direct and indirect effect to the initial effect alone. The larger the output multiplier, the larger the impact of each additional dollar spent in a sector. Income multipliers measure the impact of final-demand spending changes into household income changes, while employment multipliers measure the connection between output and employment in an industry (Miller and Blair 1985).

6.1.5. Input-Output techniques and extensions

In the more than 75 years since Wassily Leontief formalized I-O analysis, numerous new techniques and extensions have been developed. While these methods have been used to address earlier concerns about I-O analysis, they also offer analysts a more expansive set of tools for measuring conducting economic impact analysis. Dietzenbacher and Lahr (2001) credit these tools, along with the increases in computing power, to be central to the increased interest in I-O analysis over the last twenty years. Specific to this research, two such techniques are of interest: RAS updating and Linkage Analysis.

6.1.5.1. RAS updating

The RAS method, or bi-proportional method, is a commonly used method of updating and balancing I-O tables. The method is an iterative process by which a change in final demand is reallocated throughout a transaction table (Nazara, Guo, Hewings, & Dridi, 2003). First, the change(s) is portioned vertically, in the sector column the initial change takes place. Next, the changes in each cell of the sector column(s) are then allocated horizontally, across the direct inputs to the affected sector. Finally, the impact to each horizontal sector is then allocated across each of the vertical sectors again, completing the update (Miller & Blair, 1985).

The RAS method is a mathematical tool to update tables based on an exogenous change. The updated table is therefore limited by the quality of the information used to calculate the change. Despite this limitation, however, Planting and Guo (Planting & Guo, 2002) note that the results are as relevant as more complicated methods, perhaps explaining its popularity for regionalizing national I-O tables. Due to the inherent limitations in the data required for I-O analysis (availability, cost, lags, etc.), RAS is a particularly useful tool as constructing a new table is rarely feasible.

6.1.5.2. Linkage analysis

The objective of linkage analysis is to quantify how change in one industry affects another (Kawamura, Sriraj and Lindquist 2009). Building off the work of Hirschman (1958) and Rasmussen (1958), indices of linkage have become part of the generally accepted methods for indentifying key industries in an economy. While linkage analysis is not without criticism, it continues to be widely used and discussed in economic impact literature (Sonis, Guilhoto, et al. 1995).

Of significant importance for this research is Rasmussen's work on forward and backward linkages within an economy. Backward linkages refer to the way a given industry changes purchasing behavior as economic conditions change. Conversely, forward linkages refer to how industries purchasing goods and services from an industry change when the economy is stimulated. In short, backward linkages represent inputs to a given industry, while forward linkages represent the industry's output. Although not without challenge, the indices developed by Hirschman and Rasmussen are generally accepted tools for identifying key sectors within the economy.

It is widely agreed that linkages among industries in a given economy act as catalysts for economic growth. This agreement stems from a consensus that economic change is often stimulated by a small number of industries at first, though the overall economy may grow over time. Where there is less agreement, however, is how to identify these important linkages (Sonis, Guilhoto, et al. 1995).

6.1.6. Assumptions and criticisms of input-output

Models typically simplify actual processes and therefore require assumptions to be made. While these assumptions are necessary for the model to have demonstrative power, they must be understood to appropriately understand and interpret the results of the analysis. With I-O, the following are several assumptions of significant importance.

First, I-O models are usually static. They represent snapshots of an economy at a specified time and thereby assume transactions between industries do not change with total demand. In this capacity, the basic model is unable to measure technological change because production functions are fixed. In addition, there are no constraints on supply when adapting to final demand increases and returns to scale are constant.

Second, the model is designed around backward linkages. It considers how a good is produced, not the results of what happened after its production. While it may be used to measure changes in iron and steel inputs improve the rail infrastructure, it does not to measure how the resulting change in demand for rail will impact auto or airline purchasing behavior.

Additional assumptions of I-O include the model being constructed from a demand-side perspective, meaning supply-side shocks are difficult to measure. Additionally, the framework assumes all products in a given sector are produced in the same manner. In this way, the model does not allow for differing technologies being used within the same sector.

While many of the criticisms of I-O stem from the above limitations, others relate to interpreting the results. For example, Oosterhaven and Stelder (2002) criticize the use of multipliers because of their tendency to exaggerate. They argue multiplier analysis can be used to show each and every sector is more important than its own share of the total employment. Using an illustration of the Dutch transportation sector, they show that conducting a multiplier analysis for each sector will result in, when aggregating the results, that the economy is much larger than its actual size. As Oosterhaven and Stelder demonstrate, multipliers have problems which should be understood before using them as the sole justification for a policy decision.

Similarly, impact analysis is frequently criticized because it typically generates positive results. Because of this, impact analysis impact analysis can be used to justify almost any projects. Recognizing this weakness, the Federal Highway Administration's Economic Analysis Primer mandates using both impact and multiplier analysis methods in conjunction with other tools, such as Benefit-Cost Analysis, to obtain a broader understanding of the full impact of infrastructure projects.

Another criticism is that the model is unable to allow for substitution in production. In this way the model is limited because it ignores how advances in technology or increased efficiency drive firms to substitute inputs. As shown in the case study by Halpern-Givens (2010), the change in truck transportation demand as a result of reduced delay was introduced into the model using the RAS method. As described above, RAS balances a matrix using an iterative process of spreading out the increased output. This ignores the way that the more efficient transportation sector can induce substitution by purchasers towards an improved good of greater magnitude than the current production would suggest.

6.1.7. Current trends

I-O analysis has evolved to address many contemporary issues beyond economic accounts. One of the most common extensions of the I-O model has been to link economic activity with pollution costs. Leontief (1970) first added columns to the transactions table containing the costs of pollution treatment. Lenzen (2003) has used I-O to isolate sectors in the Australian economy that have above-average environmental impacts including pollution, resource depletion, and ecosystem degradation. Stone (1986) also highlights the use of I-O models to track the distribution of income, model the capital account and balance sheet to reflect the flow of funds and wealth, model world trade between regions of economic activity, and model social demographic characteristics.

Researchers also use I-O analysis in a dynamic environment to examine structural change in the economy over time. Leontief first formulated the dynamic I-O model in 1953 ((Leontief, 1953). The dynamic I-O environment has been used by Idenburg and Wilting (2000) to study the impacts of technology related innovations from 1980 to 1997 on sectoral production, natural resource use, and emissions in the Dutch economy. Wilting, Faber, and Idenburg (2008) extended this model to survey and account data though 2000 and used it to make production projections into 2030. Beyers (2001) analyzed succeeding regional I-O models in order to evaluate structural economic change in Washington State.

Others have attempted to address the question of substitution within input output frameworks caused by price and technology change. Peterson (1974) used the case of fuel choices in Britain in order to estimate the importance of relative cost on consumer and firm demand. His model attempted to introduce a two-stage process of firm behavior that acknowledges desire to use a bundle of inputs and calibration of specific demand for inputs based on a price index. Dutchin and Lange (1995) used a combination of dynamic I-O and general equilibrium modeling in order to introduce the possibility of substitution as a part of technology choice. They attempted to understand how cost savings to the firm and the adoption of new technologies by other firms influence a firm's choice to adopt new technology. Their model created independent price vectors to reflect old technology, new technology with full adoption, and new technology only adopted by the firm and analyses cost savings according to these different scenarios.

6.2. Analysis Methods

6.2.1. Input-Output analysis

I-O analysis is a common tool used to evaluate the economic impact of various plans, projects and developments. In the I-O analysis, the relationship between the final demand for a product (or service) and the total output of that product (or service) is written as

$X = BY$

where,

X = Total output matrix

Y = Final demand

A = direct requirement matrix (also referred to as the technical coefficient matrix, the technology matrix, the a-matrix and the direct coefficients)

$B = (I-A)^{-1}$ = Leontief inverse

Under this formulation, to perform an impact analysis, a change in the final demand, Y, is multiplied to determine the increase in the total output, X.

6.2.2. RAS method

The I-O analysis, at least the standard set up based on the Leontief's pioneering work and its extensions such as multiplier and impact analyses, cannot serve as the substitute for the microeconomic approach used by the FHWA Tool. This is because I-O analysis estimates the broad economic impacts of a change in the final demand of service or product produced by an industry. In the I-O analysis, the economic structure is exogenously provided by the I-O account.

This makes traditional demand-side I-O analysis technique ill-suited for the analysis of improvement in technology or efficiency. Fortunately, there have been numerous efforts to extend the use of the I-O accounts beyond the economic impacts studies of the past.

In this study, we use the RAS method, sometimes referred to as the Ratio Allocation System or the bi-proportional method to make adjustments to the I-O tables to reflect changes in the economic structure, which can result from transportation infrastructure improvements. While bi-proportional adjustment technique has been used at least since 1930's, including transportation studies, Stone is generally credit with establishing the application within the I-O framework (Planting & Guo, 2002). Today, it is a widely used method for the updating and balancing of I-O tables. The method is an iterative process of row and column adjustments that attempts to balance a given table. The iteration is conducted using the following formula.

$$A^t = [R][A^0][S]$$

Applied to the following

$$\sum_j^n r_i\, x_{ij}^0 s_j = u_i^t \text{and } \sum_i^n r_i\, x_{ij}^0 s_j = v_j^t$$

[R] and [S] are diagonal matrices from row- and column-oriented multipliers represented by $r_i$and s_j. $A^t$is the updated direct requirement matrix and A^0 is the original direct requirement matrix. $x_{ij}^0$is intermediate demand for I commodity and j industry. $u_i^t$is the total intermediate output vector and v_j^t is the intermediate input vector (Jalili, 1998). A modified RAS method exists in which known inter-industry cells may be replaced with a zero before the calculation and replaced with the known value following the procedure (Miller & Blair, 1985).

Because the RAS method is a mechanical tool to update I-O tables, there has been significant discussion of the validity of the technique. The quality of data used to update I-O tables is a determining factor in the validity of results. One example of such is analysis conducted by Lecomber in 1969 and 1975. The 1969 article *RAS Projections and When Two or More Matrices are Known* found significant error; however, by 1975 Lecomber published *A Critique of Adjusting, Updating and Projecting Matrices*, in which he found that the method was able to produce much more accurate results when expert information had been incorporated using the modified RAS system (Planting & Guo, 2002).

One widely accepted notion about the RAS method is that the results are as relevant as other more complex methods such as quadratic or linear programming. The RAS technique is used widely to regionalize national I-O tables and update benchmark tables using limited new data. Regional I-O analysis tools such as IMPLAN and REMI also incorporates RAS technique in their model.

6.2.3. Impacts of travel time reduction on trucking demand

While infrastructure improvements can benefit movements of freight in many dimensions, for this study, we use delay reduction as a performance measurement of freight. However, in order to quantify economic impacts of delay, or more precisely a reduction in delay resulting from a transportation infrastructure improvement project, information on how changes in delay affect freight industry activities is needed. A multi-modal freight demand model can be used to estimate the demand change associated with congestion. However, recognizing that this is an exploratory study to test the feasibility of the proposed framework, we opted to use a simpler approach based on an empirical study by the Federal Highway Administration.

A 2008 report published by the Federal Highway Administration found an elasticity of 0.0175 for freight services caused solely by a delay reduction on major highway corridors in the central region. In this case, “central region” is defined as 18 transportation corridors dispersed throughout 12 states (HDR|HLB Decision Economics Inc., 2008). In application this figure means that if delay in the central region decreased by 10 percent, then demand for trucking would increase by a rate of 0.175 percent. Since this figure is based on the longitudinal observations of the relationship between trucking activity and congestion levels along 30 major corridors in the United States, it is considered to capture the long-run responses, i.e. first, second and third order benefits. There is also an increase in demand for freight services as prices decrease.

The elasticity of trucking demand with respect to delay provides a needed connection between the performance of transportation infrastructure and the freight industry economy, and thus the I-O accounts. The study framework, shown in Figure 11 , develops two sets of I-O account, with and without a delay reduction.

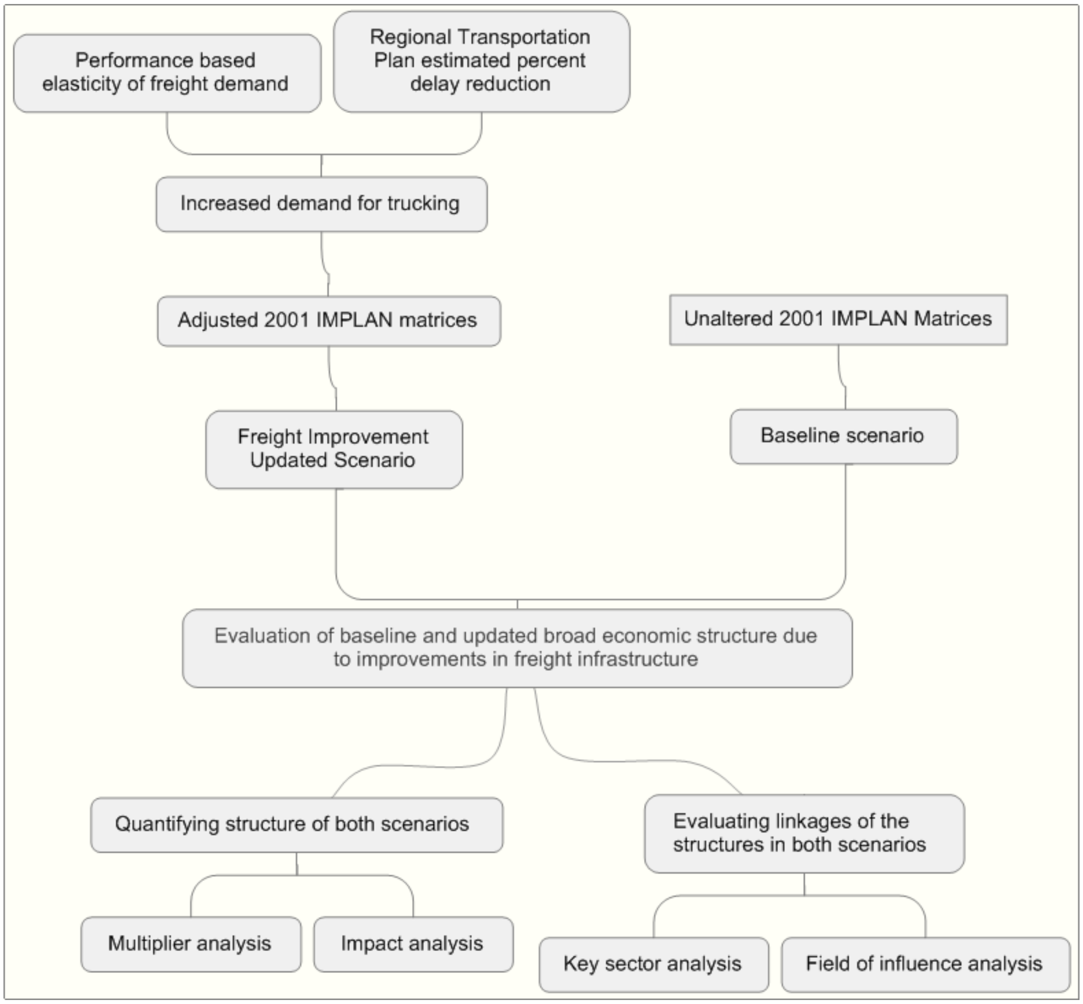

Figure 11. Impact analysis framework

For the amount of delay reduction, we used the 2020 Regional Transportation Plan (RTP) for the Chicago region (Chicago Area Transportation Study, 1998). The plan included 20 capital improvement projects with a price tag of $12.4 billion and was scheduled to be implemented over the course of 23 years. The 2002 plan estimated that the combined effect of those project would result in a 4.9% reduction in total travel for commercial vehicles, which is translated into a 20% reduction in delay. We used this 20% figure as the benchmark for what can be expected from a set of major capacity improvement projects that are proposed in a typical RTPs. Of course, the scale of investment and resulting reduction in congestion vary from region to region. As such, this research should be interpreted strictly as a theoretical study with the goal of demonstrating the feasibility of the proposed analysis method. Using I-O analysis and extensions will help to gain a stronger understanding of the many impacts that result from improvement to freight infrastructure.

6.2.4. Accounting for reduced truck congestion in I-O analysis

To link the performance of transportation infrastructure with the freight industry, and thereby I-O tables, the analysis used the FHWA elasticity figure for freight services caused solely by a delay in reduction on major highway corridors in the central region of the U.S.

An elasticity of 0.0175 was multiplied by a 20% reduction in delay, resulting in a 0.35% increase in demand for freight. This change in demand was then multiplied by the original trucking output for each study area to determine the increase in demand. This additional output was then added to the original trucking output to determine the updated trucking output for each economy.

The new trucking output served as the element change necessary to create an alternative scenario using the RAS method. As discussed previously, the RAS method is a bi-proportional method of adjusting a transaction matrix by introducing or changing at least one new factor. By estimating an increase in demand for trucking associated with a 20% reduction in delay, an alternative direct requirements matrix was constructed. The baseline and alternative direct requirements matrices for each study area were then compared to identify the change in each economy.

The RAS method can be used to adjust the I-O accounts to reflect the structural changes in the economy as a reaction to reduction in delay. However, in order to understand the implications of those changes with regard to policy and planning issues, it is necessary to employ analysis techniques that can extract relevant information from I-O accounts. Impact and multiplier analyses were uses toward this end. Following section provides a brief overview of those analysis techniques.

6.2.5. Multiplier and impact analysis

The most common application of I-O accounts in transportation planning is multiplier or impact analyses, which are briefly introduced below.

Output multipliers are useful to determine the effects of money spent on output. Output multipliers are calculated as the column total of the Leontief inverse matrix, or

$$O_j = \sum_{i=1}^{n} b_{ij}$$

where the each element of Leontief inverse is given as b_{ij} and the output multiplier for industry j is given as O_j . The greater the output multiplier the greater the impact of each subsequent dollar spent in that sector.

Impact analysis is a common method for evaluating the effects that a hypothetical change will have on the economy. Impact is measured in terms of final demand, Y. Impact analysis will require an estimate of change in the final demand for at least one sector. Essentially, impact analysis estimates the impact on the total economic output by multiplying a given change in the final demand by the multiplier for corresponding industry.

Impact analysis is now a commonly used tool by professionals. One important note about impact analysis is that it is based on output, but often the largest change is due to construction or other short-lived event with a finite time span. Generally speaking, impact analysis is not a tool for long-term projections. Projecting over a short period is one criticism with impact analysis. A second problem with impact analysis is that generally the results are positive, more often than not to illustrate the benefit of a given project. This can be problematic because it may obscure alternative uses for funds or comparisons between different projects. However, impact analysis is a common and useful tool when the implications are understood.

Since impact analysis requires a "shock", or a change in the final demand, a roadway resurfacing project that was a part of the American Recover and Reinvestment Act (ARRA) Projects was chosen. Specifically, a project to improve the sections of Kennedy Expressway from East River Road to I-94 in the Chicago region with a total cost of $16.07 million dollars,$14.22 million from the federal funds, was used as the benchmark project that provided the demand increase for the construction sector. For different urban areas with vastly varying size of economy, the size of the shock needs to be scaled. The procedure used to scale the shock is described in the next chapter.

CHAPTER 7 ECONOMIC STRUCTURE AND ECONOMIC IMPACTS OF FREIGHT INFRASTRUCTURE IMPROVEMENT

7.1. Introduction

This chapter expands and integrates the analysis and methodology discussed in Chapters 4 and 5. Specifically, it applies the I-O methodology from Chapter 6 to five regional economic areas with varying levels of freight specialization areas, as identified in value-chain analysis in Chapter 4. The objective is to gain insights into the broad influence of freight transportation on the economy by examining how the benefits related to freight transportation projects vary across different regional economies. Differently, does freight specialization translate into broader economic impact when making infrastructure investments?

7.1.1. Research questions

This chapter tests four primary hypotheses. Each is designed to be testable and shed light onto the role freight plays in regional economies. Essentially, they are natural extensions of the findings in Chapters 4 and 5. They are also designed to be particularly useful for policymakers seeking to understand the immediate and long-run effects of investing scare resources.

The first two hypotheses, H1 and H2, build on the value-chain and freight-dependent economy work in Chapter 4. They are:

H1: Investing in the infrastructure of highly freight specialized economies has larger returns than investing in the infrastructure of less freight dependent economies.

H2: Freight specialization plays a larger role in determining the impact of freight investment than does the overall size of an economy.

These hypotheses address the role of freight specialization and the overall size of an economy in determining the short-term economic impact of investments in freight infrastructure. They are short-term in nature, considering the short-term effect of resources spent on reducing freight congestion. The hypotheses assume a more efficient freight sector is associated with higher levels of productivity.

The second set of hypotheses, H3 and H4, look at the permanent structural effect of making the freight sector more efficient. They are:

> *H3: Improving freight efficiency by reducing trucking delay reduces the output of the overall regional economy*
>
> *H4: Freight specialization has less an impact on the industries impacted by freight investment than does the overall structure of an economy*

H3 and H4 tie Chapters 4 and 5 together by considering how differences in the composition of regional economies result in varying effects of freight investment. In other words, it studies whether the impact of freight investment affects each economy differently, depending on their respective economic structure. The expectation is that freight is intimately connected to so many industries that the effects of freight investment will be felt throughout the entire economy, rather than be limited only to the linkages identified in Chapter 4.

7.2. Analysis Methods

This chapter applies the I-O methodology in Chapter 6 to five regional economies with varying levels of freight dependency, as identified in Chapter 4. As such, the primary analysis methods for this section are discussed in greater detail in earlier chapters. This section therefore discusses how and why each of the five study areas were selected, the assumptions and calculations made regarding the level of freight investment, and how specific methods were used to test each of the four hypotheses described above. The data used are the same 2007 IMPLAN data used in Chapter 4.

7.2.1. Selecting the study areas

To perform this analysis, five regional economies were selected using the value-chain cluster analysis and the location quotients calculated in Chapter 4. The value-chain analysis in Chapter 4 identified industries with forward and backward linkages to the freight industry. Forward linkages represent industries freight sells to, while backward linkages represents industries freight purchases from. The value-chain analysis then grouped forward and backward linkages into primary and secondary linkages, reflecting the relationship to freight.

Location quotients for the four linkage categories – Primary Forward, Secondary Forward, Primary Backward, and Secondary Backward – were then calculated for the major economic areas in the 10-state region. Location quotients are used to demonstrate the degree to which an economy specializes in one or more industries. Using a baseline, in this case the 10-state Midwest, the composition of various regional economies is measured against the whole. A location quotient of 1 is indicative of average specialization and the farther above or below 1 a location quotient is, the higher or lower the degree of specialization the regional economy has in a particular industry.

The five regional economies selected for analysis are:

Toledo

Toledo has the highest degree of freight specialization, being highly specialized in both primary forward and primary backward industries. Of the five economies, Toledo is also the smallest of the five economies in terms of GDP. Toledo is an interesting case because it is both small in terms of GDP and highly specialized in freight.

Detroit

Detroit is the most highly specialized in primary forward linkages, with the location quotient of 1.377, meaning its purchases of freight relative to its economy is higher than any of the four other study areas. Given its role as an auto manufacturing hub, this makes intuitive sense as vehicles manufactured in the region are shipped far and wide. Detroit is also the least specialized of the five study areas in terms of the purchases made by its freight sector from other sectors (location quotient = 0.740). Detroit should thereby provide insights into the role forward and backward linkages play in a large economy.

Milwaukee

Milwaukee has the lowest freight specialization of the five study areas, falling below the 10 state average in three of the four linkage categories. Milwaukee is the least specialized in primary forward linkages of any study area and is below average in both primary and secondary backward linkages. Including Milwaukee serves as a contrast to more specialized areas such as a

Toledo and Detroit. Further, being the second smallest of the five economies, Milwaukee may also offer insight into the effect of an economy's size on freight investment.

Minneapolis

Of the five study areas, Minneapolis is most closely aligned with the 10-state average for freight specialization. Below average in primary forward linkages and slightly above average in primary backward linkages, it is average in both forward and backward secondary linkages. The Minneapolis economy is roughly the same size as Detroit, twice the size of Milwaukee, and less than 40% the size of Chicago.

Chicago

Chicago is the largest economy in the 10-state region, being larger than the four other economies combined. Chicago is below average in each forward linkage category and average and above average in backward linkages respectively. Chicago is included to offer insight into the degree by which fright influences a large diverse economy in comparison to smaller economies such as Toledo or Milwaukee. Table 15 compares the size and also the truck value chain clustering of the five urban areas.

Table 15. Five urban areas chosen

	2010 GDP ($million)	**Specialization in value chain clusters**			
		Primary forward	**Secondary forward**	**Primary backward**	**Secondary backward**
Toledo	$26,605	High (1.279)	Average (0.965)	High (1.598)	Below avg. (0.903)
Detroit	$197,773	High (1.377)	Average (0.957)	Low (0.740)	Above avg. (1.220)
Milwaukee	$84,574	Low (0.732)	Above avg. (1.084)	Below avg. (0.848)	Below avg. (0.877)
Minneapolis	$199,596	Below avg. (0.779)	Average (1.016)	Above avg. (1.097)	Average (1.042)
Chicago	$532,331	Below avg. (0.873)	Below avg. (0.864)	Average (1.008)	Above avg. (1.183)

- High Specialization (LQ>=1.25)
- Above Average (1.05<=LQ<1.25
- Average (0.95<=LQ<1.05
- Below Average (0.75<=LQ<0.95)
- Low Specialization (LQ<0.75)

Once the five study areas were selected, the methodology described in Chapter 6 was applied. The analysis measures both the short-term economic impact of investing in freight-dependent economies and the resulting permanent structural shift due to a change in demand. Therefore, both an investment amount (shock) and a change in demand must be assigned to conduct the analysis.

7.2.2. Input-Output analysis

7.2.2.1. PyIO RAS: changing demand

The change in demand is calculated in the same manner as described by Halpern-Givens. To link the performance of transportation infrastructure with the freight industry, and thereby I-O tables, the analysis used the FHWA elasticity figure for freight services caused solely by a delay in reduction on major highway corridors in the central region of the U.S.

As shown in Table 16, an elasticity of 0.0175 was multiplied by a 20% reduction in delay, resulting in a 0.35% increase in demand for freight. This change in demand was then multiplied by the original trucking output for each study area to determine the increase in demand. This additional output was then added to the original trucking output to determine the updated trucking output for each economy.

The new trucking output served as the element change necessary to create an alternative scenario using the RAS method. As discussed previously, the RAS method is a bi-proportional method of adjusting a transaction matrix by introducing or changing at least one new factor. By estimating an increase in demand for trucking associated with a 20% reduction in delay, an alternative direct requirements matrix was constructed. The baseline and alternative direct requirements matrices for each study area were then compared to identify the change in each economy.

Table 16. Calculating increase in trucking demand

City	Total Trucking Output	Increased Demand	NewTrucking Output	Total New Trucking Output
Chicago	$ 11,664,950,195	0.0035	40,827,326	11,705,777,521
Detroit	$ 5,500,931,641	0.0035	19,253,261	5,520,184,901
Milwaukee	$ 2,504,122,559	0.0035	8,764,429	2,512,886,988
Minneapolis	$ 5,643,534,668	0.0035	19,752,371	5,663,287,039
Toledo	$ 1,266,327,881	0.0035	4,432,148	1,270,760,028

7.2.2.2. PyIO impact and multiplier analysis: defining the shock

In order to analyze the impact of an investment on an economy, the amount to invest and the industry to invest in must be chosen. As noted earlier, the $14.22 million investment in the construction industry in the Chicago region was selected as the benchmark for the shock. The benchmark amount of the shock for Chicago was normalized for each economy by calculating the ratio of the shock on the overall size of Chicago's trucking sector and applying it to the other study areas (Table 17). Though regional GDP could have been selected instead of the size of the trucking sector, total trucking was selected because the size of an investment in freight infrastructure is likely to depend more on size of the freight sector than the overall regional economy. For example, total trucking output in Toledo is nearly 5% of the overall GDP compared to the other regions where trucking is less than 3%. Were a more generic measure such as GDP used for Toledo, it would significantly reduce the shock to Toledo, despite it being the most highly specialized of the study areas.

Table 17. Normalized shock to construction Sector

City	Total Trucking Output	Shock to Construction Sector
Chicago	$ 11,664,950,195	$ 14,220,000
Detroit	$ 5,500,931,641	$ 6,705,836
Milwaukee	$ 2,504,122,559	$ 3,052,617
Minneapolis	$ 5,643,534,668	$ 6,879,675
Toledo	$ 1,266,327,881	$ 1,543,700

7.2.2.3. Testing the hypotheses

The methodology in Chapter 6 provides an apt foundation for testing the hypotheses described earlier in this chapter. Impact analysis is used to assess the short-term effect of investing in the construction industry across economies with varying levels of freight specialization and differing GDPs. The results of the impact analysis will help to answer H1, H2, and H3.

To test H4 and the long-term and structural changes resulting from making the freight sector more efficient, the direct requirements matrices for each study must be updated using the RAS method and then compared. To shed additional light on all the hypotheses, impact analysis on both the baseline and updated scenarios is performed.

Hypotheses	Test
H1: Investing in the infrastructure of highly freight specialized economies has larger returns than investing in the infrastructure of less freight dependent economies.	Impact Analysis
H2: Freight specialization plays a larger role in determining the impact of freight investment than does the overall size of an economy.	Impact Analysis
H3: Improving freight efficiency by reducing trucking delay reduces the output of the overall regional economy	Impact Analysis and comparing baseline and RAS-adjusted scenarios
H4: Freight specialization has less an impact on the industries impacted by freight investment than does the overall structure of an economy.	Comparing the direct requirements matrices for the baseline and RAS-adjusted scenarios

7.3. Results

7.3.1. Changes in I-O tables

The changes in the I-O tables, included in full detail in Appendix C, are presented in three ways. The first looks at aggregate industry changes, meaning total increases or decreases in purchases and/or sales for each of the 21 industries. Second, a more detailed look at the Trucking sector highlights shifts in individual industry behavior. Third, at the most granular level, changes in the composition of inter-industry transactions as each industry adjusts to changes in demand are discussed.

Though the changes are small – noticeable at four decimals or more – they are observable and do offer some interesting trends. The high-level findings can be summarized as follows:

- Limited overlap occurred across study areas, with positive changes spread across a broader range of industries than negative changes
- Sales (outputs) by Trucking declined in all 21 industries and across all five study areas.
- Each of the ten largest positive transaction changes between industries occurred in either Toledo or Milwaukee, with no overlap in the affected transactions between the two study areas. Conversely, the ten largest negative transaction changes between industries were spread across five study areas and had considerable overlap across the study areas.

7.3.1.1. Industry-Level findings

At the industry level, ten different industries were identified among the top three increasing their purchases. Only one, Accommodation and Food Services, was identified in three of the five study areas; being a top three impact in Chicago, Milwaukee and Minneapolis (see Table 18). Overlap across two study areas only occurred with three other industries, while six distinct industries were identified in only a single location. Of the five study areas, Milwaukee and Minneapolis were most closely aligned, overlapping in two of the top three industries.

Table 18. Industries experiencing top 3 increases in purchasing

Positive Change in Total Purchases	
Accommodation and Food Services	Chicago, Milwaukee, Minneapolis
Health and Human Services	Milwaukee, Minneapolis
Administrative and Waste Services	Detroit, Toledo
Mining	Chicago, Detroit
Industries identified in one area	6
Total industries identified in Top 3	10

Positive changes in total sales had even less overlap, with eleven industries identified among the top three increasing sales (Table 19). No industries were found among the top three positive changes in three or more study areas. Three industries were found in two study areas, with sales increases in Educational Services, Construction, and Mining. Chicago and Detroit overlap in two top three industries.

Table 19. Industries experiencing top 3 increases in total sales

Top 3 Positive Change in Total Sales (Outputs)	
Educational Services	Chicago, Detroit
Construction	Detroit, Milwaukee
Mining	Milwaukee, Toledo
Industries identified in a single area	8
Total industries identified in Top 3	11

In general, the negative change to purchasing was more consistent across study areas than the positive changes. As shown in Table 20, seven industries were identified among the top three negative changes to purchasing. A decline in Truck Transportation purchases was among the top three in all five study areas. Finance and Insurance was among the three largest negative changes in Milwaukee, Minneapolis and Toledo. Four of the five study areas shared at least two of the top three changes. Chicago was the only study area with one overlapping industry, that being Truck Transportation.

Table 20. Industries experiencing top 3 decreases in total purchases

Negative Change in Total Purchases	
Truck Transportation	ALL
Finance and Insurance	Milwaukee, Minneapolis, Toledo
Professional, Scientific, and Technical Services	Detroit, Toledo
Industries in one area	4
Total industries identified in Top 3	7

Seven industries were identified among the top three decreases in sales (Table 21). Negative changes in Transportation and Warehousing were found in all study areas except Milwaukee. Finance and Insurance and Manufacturing were each identified in three locations. Minneapolis and Toledo had the most overlap, overlapping on each of the top three industries. Chicago also had considerable overlap, sharing two of the top three industries with both Detroit and Minneapolis. Milwaukee was the only city to have a single industry of overlap.

Table 21. Industries experiencing top 3 decreases in total sales

Negative Change in Total Sales	
Transportation and Warehousing	Chicago, Detroit, Minneapolis, Toledo
Finance and Insurance	Milwaukee, Minneapolis, Toledo
Manufacturing	Chicago, Minneapolis, Toledo
Management of Companies	Chicago, Detroit
Industries in one area	3
Total industries identified in Top 3	7

7.3.1.2. Trucking sector findings

While changes varied widely at the aggregate level, the normalized purchasing and sales changes across study areas are more similar when considering the impact to the trucking sector (Table 22). For starters, not a single study area experienced a positive change in Trucking sales, meaning the RAS update reduced Trucking sales across all industries. In addition, only five unique industries were identified, resulting in considerable overlap across the negatively affected industries in each study area.

Transportation and Warehousing experienced a top three decline in all five study areas, while Other Services did so in all but Chicago. Further, declines in Manufacturing were shared by Chicago, Minneapolis and Toledo, while Management of Companies was identified in Chicago and Detroit. The only stand-alone industry identified among the top three in any study area was the Finance and Insurance industry in Milwaukee.

Changes in trucking purchases were also more consistent than evidenced at the aggregate industry level above, though not as much as on the sales side. Seven different industries were identified among the top three negative impacts across study areas. Of these, purchases from Truck Transportation itself saw the largest decline in all five economies. Purchases from Construction, and Government and Non-NAICS, were identified in three study areas each. Detroit and Milwaukee shared each of the top three industries, while Chicago, Minneapolis, and Toledo had only declines Truck Transportation in common.

Increases in trucking purchases varied more widely. Nine different industries were identified among the top three positive impacts to each study area, with five being identified in only a single economy. The Agriculture, Forestry, Fishing, and Hunting and Accommodation and Food Services industries were among the largest positive changes in three of the five study areas. None of the study areas overlapped with more than one industry, however.

Table 22. Changes in trucking sector sales (outputs) and purchases (inputs)

Industry	Chicago		Minneapolis		Detroit		Milwaukee		Toledo	
	Change in Total Purchases (Inputs)	Change in Total Sales (Outputs)	Change in Total Purchases (Inputs)	Change in Total Sales (Outputs)	Change in Total Purchases (Inputs)	Change in Total Sales (Outputs)	Change in Total Purchases (Inputs)	Change in Total Sales (Outputs)	Change in Total Purchases (Inputs)	Change in Total Sales (Outputs)
Agriculture, Forestry, Fishing & Hunting	-0.0000082	-0.0000063	0.0000004	-0.0000005	0.0000000	-0.0000064	0.0000436	-0.0000027	0.0000719	0.0000158
Mining	0.0000112	-0.0000404	0.0000000	-0.0000004	0.0000222	-0.0000024	0.0000000	0.0000527	-0.0000200	0.0000122
Utilities	-0.0000033	-0.0000228	0.0000012	-0.0000112	0.0000057	-0.0000092	-0.0000048	-0.0000197	-0.0000390	-0.0000551
Construction	-0.0000086	-0.0000111	0.0000026	-0.0000134	-0.0000033	0.0000038	-0.0000865	0.0000180	-0.0000094	-0.0000246
Manufacturing	-0.0003381	-0.0004058	0.0000005	-0.0002407	0.0000014	-0.0001404	-0.0000063	-0.0001076	-0.0000022	-0.0002630
Wholesale Trade	-0.0000096	-0.0001122	-0.0000035	-0.0000555	0.0000019	-0.0000279	0.0001291	-0.0000191	-0.0000027	0.0000134
Retail	-0.0000001	-0.0000238	0.0000019	-0.0000249	-0.0000036	-0.0000201	0.0000118	-0.0000228	0.0000098	-0.0000120
Transportation and Warehousing	0.0000033	-0.0002065	-0.0000021	-0.0001922	-0.0000040	-0.0001815	-0.0000310	-0.0001216	-0.0000508	-0.0001922
Information	-0.0000013	-0.0000269	-0.0000019	-0.0000237	0.0000007	-0.0000243	0.0000260	0.0000125	0.0000401	-0.0000320
Finance and Insurance	-0.0000024	-0.0001675	-0.0000182	-0.0001774	-0.0000019	-0.0001051	-0.0002104	-0.0005776	-0.0002040	-0.0002865
Real Estate & Rental	-0.0000083	-0.0000832	0.0000006	-0.0000602	0.0000002	-0.0000514	-0.0000159	-0.0001517	0.0000082	-0.0000777
Professional, Scientific, & Technical Services	0.0000049	-0.0000684	0.0000008	-0.0000395	-0.0000069	-0.0000420	-0.0000666	0.0000425	-0.0001275	-0.0000739
Management of Companies	-0.0000013	-0.0001830	-0.0000041	-0.0001467	0.0000002	-0.0001676	0.0000194	-0.0001250	0.0000185	-0.0001195
Administrative and Waste Services	-0.0000033	0.0000000	-0.0000089	-0.0000001	0.0000076	0.0000002	-0.0002495	-0.0000024	0.0001329	0.0000021
Educational Services	-0.0000073	0.0000010	-0.0000036	-0.0000019	0.0000042	0.0000009	0.0000367	0.0000125	0.0000366	0.0000094
Health and Social Services	-0.0000019	-0.0000912	0.0000039	-0.0000426	-0.0000047	-0.0000734	0.0000600	-0.0001399	-0.0000260	0.0000101
Arts, Entertainment, and Recreation	-0.0000021	-0.0000015	0.0000000	-0.0000001	0.0000000	-0.0000001	0.0000512	0.0000103	0.0000000	0.0000006
Accommodation and Food Services	0.0000087	-0.0000026	0.0000105	0.0000020	0.0000038	-0.0000033	0.0000761	-0.0000168	-0.0000808	0.0000071
Other Services	0.0000024	-0.0001503	0.0000015	-0.0001770	-0.0000036	-0.0001674	0.0000180	-0.0001133	-0.0000340	-0.0001286
Government & Non NAICS	-0.0000059	-0.0000071	-0.0000196	-0.0000065	-0.0000109	-0.0000061	-0.0002100	-0.0000221	-0.0000114	-0.0000005
Truck Transportation	-0.0014036	-0.0001652	-0.0013323	-0.0001577	-0.0011655	-0.0001327	-0.0010099	-0.0001249	-0.0009959	-0.0000903
Top 3 Positive Change										
Top 3 Negative Change										

7.3.1.3. Transaction level findings

Across the five study areas, each of the ten largest normalized positive changes is in either Milwaukee or Toledo (Table 23). In Milwaukee, inter-industry Mining purchases experienced the largest increase of any sector. Purchases by the Wholesale Trade industry from the Professional Services and Technical Services, Wholesale Trade, and Transportation and Warehousing industries account for three of the five largest positive changes. In Toledo, Administrative and Waste Services and Agriculture, Forestry, Fishing, and Hunting purchases account for 4 of the top 5 increases in purchasing.

Table 23. Ten largest inter-industry transaction increases

Ten Largest Transaction Increases			
Study Area	Sellers	Buyers	Change
Toledo	Health and Social Services	Administrative and Waste Services	0.0000419
Milwaukee	Mining	Mining	0.0000357
Milwaukee	Professional, Scientific, & Technical Services	Wholesale Trade	0.0000208
Milwaukee	Wholesale Trade	Wholesale Trade	0.0000198
Toledo	Manufacturing	Agriculture, Forestry, Fishing & Hunting	0.0000185
Milwaukee	Information	Information	0.0000165
Toledo	Management of Companies	Administrative and Waste Services	0.0000164
Toledo	Agriculture, Forestry, Fishing & Hunting	Agriculture, Forestry, Fishing & Hunting	0.0000153
Milwaukee	Transportation and Warehousing	Wholesale Trade	0.0000150
Toledo	Information	Information	0.0000145

Differing from the positive changes, the ten largest negative changes in inter-industry transactions are spread across all five study areas (Table 24). Overall, Truck Transportation purchases from Manufacturing in Chicago, Minneapolis and Toledo account for the three largest declines. Truck Transportation purchases from Transportation and Warehousing is the largest decline in Detroit, while Inter-industry purchases in the Finance and Insurance industry is the largest decline in Milwaukee.

Table 24. Ten largest inter-industry transaction decreases

Ten Largest Transaction Decreases			
Study Area	Sellers	Buyers	Change
Chicago	Manufacturing	Truck Transportation	-0.0002884
Minneapolis	Manufacturing	Truck Transportation	-0.0002405
Toledo	Manufacturing	Truck Transportation	-0.0002405
Chicago	Transportation and Warehousing	Truck Transportation	-0.0002001
Minneapolis	Transportation and Warehousing	Truck Transportation	-0.0001930
Detroit	Transportation and Warehousing	Truck Transportation	-0.0001832
Milwaukee	Finance and Insurance	Finance and Insurance	-0.0001789
Chicago	Management of Companies	Truck Transportation	-0.0001782
Minneapolis	Other Services	Truck Transportation	-0.0001750
Toledo	Transportation and Warehousing	Truck Transportation	-0.0001729

7.3.2. Impact analysis

The results of the impact analysis suggest size plays a larger role than freight specialization in determining the impact of a shock. The first component of the impact analysis measures the impact of the construction shock on the baseline scenarios of each study area. The shock had the largest impact in Chicago, with the total impact being more than $21.5 million, or 52% larger than the $14.2 million investment (Table 25) . Minneapolis experienced the second largest increase, nearly 42% greater than the shock. Somewhat interestingly, Detroit experienced less than half the total impact of Minneapolis, despite having a nearly identical GDP. Toledo and Milwaukee, the most and least specialized economies, experienced relatively similar returns at 30% and 26 %, respectively.

Table 25. Ratio of baseline impacts to shock

City	% Change
Chicago	52.2%
Minneapolis	41.7%
Toledo	30.1%
Milwaukee	26.4%
Detroit	20.1%

As shown in the previous section by the change in direct requirement matrices, the effect of a large-scale infrastructure project on each study can shift the economic structure of a region. In turn, the structural shift of an economy can alter the impact of a given project. To consider these effects, impact analysis was conducted for the RAS updated scenarios for each of the five study areas.

In comparison to the baseline scenario, shocking the construction industry in the more efficient freight economy resulted in a lower total output than the less efficient baseline model (Table 26). Measuring the change as a percentage of the baseline impact, Milwaukee experienced the largest negative change, nearly five times that of Minneapolis, the smallest.

Table 26. Impacts of change as percentage of baseline impact

Study Area	% Change
Milwaukee	-0.0103%
Chicago	-0.0077%
Toledo	-0.0024%
Detroit	-0.0019%
Minneapolis	-0.0019%

Only a handful of industries experienced increases from the baseline to the more efficient trucking sector scenario (Table 27). No industry in Chicago experienced a positive change. Minneapolis saw only the Mining sector increase, while Detroit's Wholesale Trade industry grew. Toledo had the most positive changes, with six, while Milwaukee had three. Mining was the largest positive change in all three study areas, with Educational Services being second in both Milwaukee and Toledo.

Table 27. Largest positive industry changes from baseline to updated scenarios

Rank	Chicago	Detroit	Milwaukee	Minneapolis	Toledo
1.	N/A	Wholesale Trade	Mining	Mining	Mining
2.	N/A	N/A	Educational Svc.	N/A	Educational Svc.
3.	N/A	N/A	Construction	N/A	Wholesale Trade

Of industries experiencing negative change, Transportation and Warehousing was identified in four of the five study areas, making it the most frequently identified industry (Table 28) . Along with Finance and Insurance, it was also the industry with the largest negative change in two of the five study areas. Agriculture, Forestry, Fishing and Hunting was a top three negative change in three study areas, while Truck Transportation was among the three largest declines in Detroit and Minneapolis.

Table 28. Largest negative industry change from baseline to updated scearios

Rank	Chicago	Detroit	Milwaukee	Minneapolis	Toledo
1.	Agriculture, Forestry, Fishing & Hunting	Transportation & Warehousing	Finance and Insurance	Transportation & Warehousing	Finance and Insurance
2.	Professional, Scientific, & Technical Svc.	Truck Transportation	Agriculture, Forestry, Fishing & Hunting	Truck Transportation	Utilities
3.	Transportation & Warehousing	Agriculture, Forestry, Fishing & Hunting	Government & Non-NAICS	Educational Services	Transportation & Warehousing

7.3.3. Multipliers

As previously discussed, multiplier analysis is based on the Leontief inverse matrix, which is calculated using the direct requirements matrix. It is clear that the structural change will directly impact the multiplier analysis. However, changes in multipliers are generally small. Despite being small, they demonstrate, the structural impact to the economy is observable.

Multipliers are presented in two ways: percentage change, and absolute change. The percentage change results display which industries experienced the largest impact. The absolute change is presented to demonstrate the relative magnitude of the change from the baseline scenario to the more efficient one. Absolute change allows policymakers to understand if the change is large enough to alter the industry in which to invest the funds. For example, were the construction industry to have the largest multiplier in the baseline scenario, policymakers would be encouraged to invest in construction-heavy projects to maximize the impact. If the change in demand increases the multiplier in the manufacturing industry enough to be larger than the construction multiplier, policymakers will want to know as it suggests a change in policy.

The percentage change results are presented in Table 29 below. The smallest cities, Milwaukee and Toledo, experienced the most positive changes in multipliers with eight and six respectively. Wholesale Trade in Milwaukee and Administrative and Waste Services in Toledo had the largest positive changes in multipliers of 0.012%. Of the industries experiencing the most positive changes to multipliers, only Administrative and Waste Services was found in more than one study area (Detroit and Toledo).

The vast majority of industries across all five study areas experienced lower multipliers in the updated scenario. Chicago and Minneapolis experienced negative changes to multipliers in all industries. Unlike the positive changes, industries with negative changes to multipliers varied less across study areas. Truck Transportation again experienced the largest decline in each of the five economies. Construction, Finance and Insurance, and Government and non-NAICS were also found in more than one study area.

Table 30 below ranks industries according to their respective multipliers. The multipliers in each column are ranked on a spectrum from dark green (largest multiplier) to dark orange (smallest multiplier). If the shading of a given industry varies from the baseline to the updated scenario in a study area, it indicates the impact of the 20% reduction in delay has impacted the economy significantly enough to alter policy decisions.

As Table 30 shows, little variation occurs across study areas. Finance and Insurance has the largest multiplier in all five study areas while Utilities have the smallest. Similarly, while the magnitude of multipliers changed, as demonstrated in the percentage change table above, the magnitudes of the changes were not large enough to alter any industry in relation to others. In short, across all 21 sectors and each of the five study areas, a 20% reduction in delay does not impact an economy enough to change policy decision criteria.

The key findings of the multiplier analysis are consistent with the results of the impact analysis and the changes in the direct requirements matrix. The trucking sector and trucking related industries experience the largest impacts and positive changes vary across more industries than do negative impacts. Additionally, the smallest economies experience the most positive changes, suggesting the size of an impact plays a large role in determining impact. Ultimately, however, despite these directional findings, the magnitude of the 20% reduction in delay is not large enough to change the multipliers of each industry in relation to each other.

Table 29. Percentage changes to multipliers

Baseline and Updated Output Multipliers	Chicago			Detroit			Milwaukee			Minneapolis			Toledo		
Industry	Baseline Scenario	Updated Scenario	% Change	Baseline Scenario	Updated Scenario	% Change	Baseline Scenario	Updated Scenario	% Change	Baseline Scenario	Updated Scenario	% Change	Baseline Scenario	Updated Scenario	% Change
Agriculture, Forestry, Fishing & Hunting	1.5479	1.5478	-0.006%	1.4036	1.4036	-0.0011812%	1.3574	1.3575	0.002409%	1.4727	1.4727	-0.002%	1.2935	1.2935	0.005272%
Mining	1.4304	1.4303	-0.001%	1.4311	1.4311	0.0012128%	1.3754	1.3754	-0.003899%	1.4837	1.4836	-0.003%	1.2208	1.2207	-0.003385%
Utilities	1.3070	1.3070	-0.002%	1.1963	1.1963	0.0002975%	1.1403	1.1402	-0.002113%	1.1580	1.1580	-0.001%	1.1343	1.1343	-0.004921%
Construction	1.5221	1.5220	-0.008%	1.4355	1.4355	-0.0018918%	1.4061	1.4060	-0.010124%	1.5087	1.5087	-0.002%	1.3015	1.3014	-0.002426%
Manufacturing	1.5547	1.5541	-0.040%	1.4169	1.4169	-0.0011735%	1.4015	1.4014	-0.002373%	1.4836	1.4835	-0.002%	1.2177	1.2177	-0.002035%
Wholesale Trade	1.4362	1.4361	-0.003%	1.3646	1.3646	-0.0003318%	1.3400	1.3401	0.011845%	1.3858	1.3858	-0.001%	1.2361	1.2361	-0.001615%
Retail	1.3938	1.3938	-0.002%	1.3413	1.3413	-0.0011502%	1.3036	1.3036	-0.000908%	1.3458	1.3458	-0.001%	1.2033	1.2033	-0.000401%
Transportation and Warehousing	1.5904	1.5903	-0.005%	1.3841	1.3841	-0.0009920%	1.3252	1.3251	-0.005607%	1.4537	1.4537	-0.001%	1.3114	1.3114	-0.006237%
Information	1.5999	1.5999	-0.002%	1.4926	1.4926	-0.0003235%	1.4795	1.4795	0.001220%	1.5511	1.5511	-0.001%	1.2760	1.2761	0.003560%
Finance and Insurance	1.6975	1.6975	-0.001%	1.5835	1.5835	-0.0003358%	1.5772	1.5768	-0.027874%	1.5951	1.5950	-0.003%	1.4173	1.4170	-0.024469%
Real Estate & Rental	1.4396	1.4396	-0.002%	1.3743	1.3743	-0.0002616%	1.3519	1.3519	-0.003414%	1.4113	1.4113	-0.001%	1.2264	1.2264	0.000129%
Professional, Scientific, & Technical Services	1.5138	1.5138	-0.001%	1.4343	1.4343	-0.0010926%	1.4242	1.4240	-0.008268%	1.4542	1.4542	-0.001%	1.2719	1.2718	-0.013193%
Management of Companies	1.4735	1.4735	-0.002%	1.3603	1.3603	-0.0002914%	1.3669	1.3669	0.000461%	1.4503	1.4503	-0.001%	1.2822	1.2822	0.001081%
Administrative and Waste Services	1.4991	1.4991	-0.002%	1.4592	1.4592	0.0002763%	1.3498	1.3495	-0.025761%	1.4845	1.4844	-0.002%	1.2568	1.2569	0.012472%
Educational Services	1.4420	1.4420	-0.003%	1.3651	1.3651	0.0000148%	1.3292	1.3292	0.002573%	1.3747	1.3747	-0.001%	1.2205	1.2205	0.002749%
Health and Social Services	1.3846	1.3846	-0.001%	1.3071	1.3071	-0.0007028%	1.3125	1.3125	0.002997%	1.3427	1.3427	0.000%	1.1937	1.1937	-0.004102%
Arts, Entertainment, and Recreation	1.4785	1.4785	-0.002%	1.4218	1.4218	-0.0005409%	1.4498	1.4498	0.003171%	1.4711	1.4711	-0.001%	1.2813	1.2813	-0.001195%
Accommodation and Food Services	1.5176	1.5176	-0.003%	1.4474	1.4474	-0.0003763%	1.4506	1.4507	0.005538%	1.5245	1.5245	0.000%	1.2755	1.2754	-0.009294%
Other Services	1.4857	1.4857	-0.002%	1.4050	1.4050	-0.0010891%	1.3824	1.3823	-0.001119%	1.4541	1.4541	-0.001%	1.2731	1.2731	-0.005063%
Government & Non NAICS	1.6413	1.6412	-0.006%	1.4651	1.4650	-0.0018902%	1.4835	1.4831	-0.023061%	1.4804	1.4804	-0.003%	1.4252	1.4251	-0.002503%
Truck Transportation	1.6233	1.6210	-0.144%	1.4845	1.4828	-0.1158421%	1.4053	1.4038	-0.105980%	1.5557	1.5537	-0.133%	1.3916	1.3903	-0.096309%
Total Positive Changes			0			4			8			0			6
Total Negative Changes			21			17			13			21			15

Table 30. Relative changes in multipliers

Baseline and Updated Output Multipliers	Chicago		Detroit		Milwaukee		Minneapolis		Toledo	
Industry	Baseline Scenario	Updated Scenario	Baseline Scenario	Updated Scenario	Baseline Scenario	Updated Scenario	Baseline Scenario	Updated Scenario	Baseline Scenario	Updated Scenario
Agriculture, Forestry, Fishing & Hunting	1.5479	1.5478	1.4086	1.4086	1.3574	1.3575	1.4727	1.4727	1.2935	1.2935
Mining	1.4304	1.4303	1.4311	1.4311	1.3754	1.3754	1.4337	1.4335	1.2203	1.2207
Utilities	1.3070	1.3070	1.1963	1.1963	1.1403	1.1402	1.1580	1.1580	1.1343	1.1343
Construction	1.5221	1.5220	1.4355	1.4355	1.4061	1.4060	1.5087	1.5087	1.3015	1.3014
Manufacturing	1.5547	1.5541	1.4169	1.4169	1.4015	1.4014	1.4335	1.4335	1.2177	1.2177
Wholesale Trade	1.4362	1.4361	1.3646	1.3646	1.3400	1.3401	1.3858	1.3858	1.2361	1.2361
Retail	1.3538	1.3538	1.3413	1.3413	1.3086	1.3085	1.3453	1.3453	1.2033	1.2033
Transportation and Warehousing	1.5904	1.5903	1.3841	1.3841	1.3252	1.3251	1.4537	1.4537	1.3114	1.3114
Information	1.5995	1.5995	1.4926	1.4926	1.4795	1.4795	1.5511	1.5511	1.2760	1.2761
Finance and Insurance	1.6575	1.6575	1.5835	1.5835	1.5772	1.5763	1.5951	1.5950	1.4173	1.4170
Real Estate & Rental	1.4396	1.4396	1.3743	1.3743	1.3519	1.3519	1.4113	1.4113	1.2264	1.2264
Professional, Scientific, & Technical Services	1.5138	1.5138	1.4343	1.4343	1.4242	1.4240	1.4542	1.4542	1.2713	1.2713
Management of Companies	1.4735	1.4735	1.3603	1.3603	1.3569	1.3563	1.4503	1.4503	1.2822	1.2822
Administrative and Waste Services	1.4991	1.4991	1.4582	1.4582	1.3498	1.3495	1.4845	1.4844	1.2568	1.2569
Educational Services	1.4420	1.4420	1.3651	1.3651	1.3292	1.3292	1.3747	1.3747	1.2205	1.2205
Health and Social Services	1.3846	1.3846	1.3071	1.3071	1.3125	1.3125	1.3427	1.3427	1.1937	1.1937
Arts, Entertainment, and Recreation	1.4785	1.4785	1.4218	1.4218	1.4498	1.4498	1.4711	1.4711	1.2813	1.2813
Accommodation and Food Services	1.5176	1.5176	1.4474	1.4474	1.4506	1.4507	1.5245	1.5245	1.2755	1.2754
Other Services	1.4857	1.4857	1.4060	1.4060	1.3824	1.3823	1.4541	1.4541	1.2731	1.2731
Government & Non NAICS	1.6413	1.6412	1.4651	1.4650	1.4385	1.4381	1.4304	1.4304	1.4252	1.4251
Truck Transportation	1.6233	1.6210	1.4845	1.4828	1.4063	1.4033	1.5557	1.5537	1.3915	1.3903
Total Positive Changes		0		4		3		0		6
Total Negative Changes		21		17		13		21		15

7.4. Conclusions

7.4.1 Hypothesis evaluation

The objective of this analysis was to gain insights about the broad relationship between freight investment and regional economies. To do so, four hypotheses were tested, with the results presented in the previous section. This section summarizes those findings as they related to each of the four hypotheses, and discusses conclusions and possible extension of the research.

H1: Investing in the infrastructure of highly freight specialized economies has larger returns than investing in the infrastructure of less freight dependent economies.

The findings of the impact analysis reject H1. As Table 25 shows, the most specialized freight economy, Toledo (30%), had only slightly higher returns than the least specialized economy, Milwaukee (26%). In this vein, the economies with the most average freight specialization, Chicago and Minneapolis, experienced the largest percentage increase in returns as a result of the construction industry shock. With Toledo being the most specialized economy, if H1 were correct, Toledo should have the highest returns of any study area.

While demand for freight may be inelastic with respect to congestion over the short term, firms will likely change behavior and adjust over the long term. This explanation is not testable in this type of study, as I-O analysis is largely limited for use short-term impact studies. Additionally, I-O analysis does not allow for substitution effects, longitudinal changes over time, or third-order benefits. Therefore, alternative methods, such as Computational General Equilibrium (CGE) modeling, are likely more appropriate for measuring such longer-term changes.

H2: Freight specialization plays a larger role in determining the impact of freight investment than does the overall size of an economy.

The results also reject H2. Toledo and Milwaukee experienced similar effects of a shock to the construction sector. If H2 were correct, Milwaukee, being the least freight specialized economy, and Toledo, being the most highly specialized economy, should have more distinct differences. Further, the most average economies of the study areas, Chicago and Minneapolis, should not have experienced the largest returns.

The results can be explained, in part, using the multiplier analysis and the concept of leakage. I-O modeling is designed to show how much spending, and subsequent re-spending, is conducted within an economic area. Chicago's multipliers are significantly larger than Toledo's in both the baseline and updated scenarios. This means that a dollar spent in Chicago "multiplies" throughout the Chicago economy more times than a dollar spent in Toledo does in Toledo. Chicago, being a large, highly sophisticated and diverse economy produces more locally than a smaller, more specialized economy like Toledo. Because of this, it follows that transportation investment projects in large diverse economies will likely have a greater impact than similar projects in small and specialized economies.

H3: Improving freight efficiency by reducing trucking delay reduces the output of the overall regional economy

The findings confirm H3. The updated model in each of the five study areas experienced a lower total output than the baseline model. Further supporting the finding that the size of an economy plays a significant role in determining the impact of an investment project, the larger economies of Chicago and Minneapolis experienced negative changes in the multipliers for all industries. Conversely, the smallest economies, Milwaukee and Toledo, experienced most positive changes in multipliers.

These results may indicate delay creates friction in the trucking sector that requires a larger output than is necessary in a more efficient model. Reducing delay thereby allows firms to benefit from economies of scale and ship more with less. Another explanation could be that fewer delays in freight increases leakage as firms can purchase freight from further away, potentially outside the regional economy.

In addition, these findings highlight the limitation of this analysis. While the trucking sector experiences a lower output, I-O is unable to show the broader or longitudinal shifts over time. While I-O effectively demonstrated varying short-term impacts and that a structural change occurs, it is limited in showing what additional impact might occur due to the increase in efficiency and the corresponding shift in demand. These additional effects are sometimes referred to as third-order impacts, as they are in addition to the direct and indirect benefits of the investment. It is entirely possible that these third-order impacts might offset the reduced output due to increased trucking efficiency.

H4: A high degree of freight specialization has less impact on the industries affected by freight investment than does the overall structure of an economy

The results also support H4. The five study areas were chosen for their unique economic structures and the limited overlap across industries affected by the shock and change in demand support H4. With the exception of the top negatively impacted purchasing industries, little overlap occurred across study areas. Positive change was identified by 10 different purchasing industries and 11 selling industries. Conversely, negative changes were found in five unique purchasing industries and nine selling industries, much less variance.

It should be noted that these results are interpreted strictly within the context of the analysis heretofore described in this chapter. The most critical aspect of the research is that it utilized I-O model to conduct analysis. It is possible, even likely, that the insensitivity of economic impacts of freight infrastructure improvement with respect to economic structure that we have found can partially attributed to the assumptions employed in I-O models and also the limitation of the RAS adjustment technique. As such, some of the findings presented in this chapter do not agree with the findings from the Field of Influence analysis described in Chapter 5.

CHAPTER 8: SUMMARY

In the work described in Chapter 4, 43 Economic Areas, defined by the Bureau of Economic Analysis, were evaluated and categorized based on their economic structure with regards to relative concentration of economic activities in "truck value chain" industries, which were identified from a clustering exercise using I-O accounts. This analysis showed a great deal of variation across the 10 states in terms of the degree of specialization in industries that are included in value-chain clusters for truck transportation. We found that there is no economic area that is highly specialized in the industries of all four strongly linked clusters, i.e. forward linkage primary, forward linkage secondary, backward linkage primary, and backward linkage secondary. Also, we found that no economic areas are highly specialized in the group of industries that are a part of the secondary backward linkage cluster. Since location quotient measures relative concentration of economic activities, this finding suggests that these industries, that provide inputs to the trucking sector, are more evenly distributed throughout the 10 states region.

The Field of Influence results are useful in comparing where infrastructure investments are likely to have the largest total effects. Policy analysts can use the new Leontief inverse matrix after a field of influence analysis to calculate new industry multipliers. Since the assumed change of a field of influence is scalar, it would not represent a multiplier change because of a specific project, but rather it would should how sensitive total industry multipliers are to a change in trucking technology. This would allow analysts and economic developers to compare the potential magnitude of third order benefits between regions, because all spending that requires inter-industry purchases, and thus is multiplied throughout the economy, will have changed due to trucking technology change.

The findings from the analysis, presented in Chapters 5 (Field of Influence) and 7 (modified I-O model) suggest that it is not the case that economic structure in which freight and related industries have a strong presence will likely to benefit from improvement in efficiency in moving freight on trucks. In other words, this study was not able to clearly identify the relationship between technological change (e.g. reduced truck congestion) and cluster membership and freight specialization of Economic Areas. It should be stressed that only three and five urban areas were examined in the Field of Influence and modified I-O analysis, respectively. Therefore, these findings need to be interpreted as preliminary results.

Based on the limited observations, the field of influence showed that the industries that possess the strongest forward linkages to truck transportation were not the industries that were most significantly affected, which indicates that the benefits of improvement in trucking propagates through the economy in some, yet identified manner. This could be due to a number of reasons. First, this study has shown that regional differences in economic structure matter greatly. Regional differences may prevent a clear correlation between cluster membership and the magnitude of technological change as seen in the field of influence from emerging. Also, the forward linkage clusters are focused on the industries that are most important and significant in relation to the transportation industry. Although an industry may purchase a significant amount of truck transportation, relative to the truck transportation industry, this may be a relatively insignificant portion of the total purchases in that industry. Also, it should be remembered that I-O accounts only capture monetary transactions between the industries, while benefits of reducing truck congestion are more likely to be distributed according to the ton-miles of trucking business purchased by the firms.

Modified I-O analysis produced results that illustrated the limitation of I-O models. One obvious drawback of I-O framework is its inability to simulate changes in price. As such, the simulation of efficiency improvements via an increase in trucking output does not produce expected market response. The analysis showed that improving the efficiency of trucking industry tends to reduce multiplier effects. This result is understandable because transportation is a "derived" demand, meaning that consumption of it does not produce profit or positive utility. Efficient transportation may increase the profitability of firms that consume freight but it does not necessary lead to an increase in the consumption of freight transportation. The policy implication of this finding is that the rationale for investing in infrastructure rests with regional competition. Our analysis indicates that not having efficient freight transportation system does not make damage region's economy on its own. However, if the region is deemed less desirable by the businesses that rely heavily on freight, it would lead to job losses and less competitive economy.

In terms of techniques, a part of the issue is the lack of data to reflect more realistic response in the I-O accounts during the RAS process. Thus, one of the next steps in this line of research is to collect data on changes in inter-industry transaction patterns in response to price change or efficiency improvement. As an alternative of research, conducting the analysis using a CGE or another more sophisticated economic model is likely to provide additional insight.

APPENDIX A

EA ID	EA Name	Counties Included in the EA
EAs included in this study:		
006	Alpena, MI	Michigan: Alpena, Antrim, Charlevoix, Cheboygan, Crawford, Emmet, Montmorency, Oscoda, Ostego, Presque Isle, Roscommon.
009	Appleton-Oshkosh-Neenah, WI	Wisconsin: Brown, Calumet, Door, Kewaunee, Menominee, Oconto, Outagamie, Shawano, Waupaca, Waushara, Winnebago.
025	Cape Girardeau-Jackson, MO-IL	Illinois: Alexander, Pulaski; Missouri: Bollinger, Butler, Cape Girardeau, Carter, Mississippi, New Madrid, Perry, Ripley, Scott, Stoddard, Wayne.
027	Cedar Rapids, IA	Iowa: Benton, Cedar, Iowa, Johnson, Jones, Keokuk, Linn, Louisa, Muscatine, Washington.
028	Champaign-Urbana, IL	Illinois: Champaign, Clay, Coles, Cumberland, Douglas, Effingham, Fayette, Ford, Jasper, Moultrie, Piatt, Richland, Shelby, Vermilion, Wayne.
032	Chicago-Naperville-Michigan City, IL-IN-WI	Illinois: Boone, Bureau, Carroll, Cook, DeKalb, DuPage, Grundy, Iroquois, Kane, Kankakee, Kendall, Lake, LaSalle, Lee, Livingston, McHenry, Ogle, Putnam, Stephenson, Will, Winnebago; Indiana: Jasper, Lake, LaPorte, Newton, Porter; Wisconsin: Kenosha.
033	Cincinnati-Middletown-Wilmington, OH-KY-IN	Indiana: Dearborn, Franklin, Ohio, Ripley, Switzerland; Kentucky: Boone, Bracken, Campbell, Fleming, Gallatin, Grant, Kenton, Lewis, Mason, Owen, Pendleton; Ohio: Adams, Brown, Butler, Clermont, Clinton, Hamilton, Highland, Warren.
035	Cleveland-Akron-Elyria, OH	Ohio: Ashland, Ashtabula, Carroll, Columbiana, Crawford, Cuyahoga, Erie, Geauga, Harrison, Holmes, Huron, Lake, Lorain, Mahoning, Medina, Portage, Richland, Stark, Summit, Trumbull, Tuscarawas, Wayne; Pennsylvania: Mercer.[a]
037	Columbia, MO	Missouri: Audrain, Boone, Callaway, Camden, Cole, Cooper, Howard, Maries, Miller, Moniteau, Monroe, Morgan, Osage, Randolph, Shelby.
040	Columbus-Marion-Chillicothe, OH	Ohio: Athens, Coshocton, Delaware, Fairfield, Fayette, Franklin, Gallia, Guernsey, Hardin, Hocking, Jackson, Knox, Licking, Logan, Madison, Marion, Meigs, Morgan, Morrow, Muskingum, Noble, Perry, Pickaway, Pike, Ross, Scioto, Union, Vinton; West Virginia: Mason.[b]
043	Davenport-Moline-Rock Island, IA-IL	Illinois: Henry, Mercer, Rock Island, Whiteside; Iowa: Clinton, Scott.
044	Dayton-Springfield-Greenville, OH	Ohio: Allen, Auglaize, Champaign, Clark, Darke, Greene, Mercer, Miami, Montgomery, Preble, Putnam, Shelby, Van Wert.
046	Des Moines-Newton-Pella, IA	Iowa: Adair, Adams, Appanoose, Boone, Buena Vista, Calhoun, Carroll, Cherokee, Clarke, Clay, Crawford, Dallas, Davis, Decatur, Dickinson, Emmet, Franklin, Greene, Guthrie, Hamilton, Hardin, Humboldt, Ida, Jasper, Lucas, Madison, Mahaska, Marion, Marshall, Monroe, Palo Alto, Pocahontas, Polk, Poweshiek, Ringgold, Sac, Story, Tama, Union, Wapello, Warren, Wayne, Webster, Wright.
047	Detroit-Warren-Flint, MI	Michigan: Alcona, Arenac, Bay, Clare, Clinton, Eaton, Genesee, Gladwin, Gratiot, Hillsdale, Huron, Ingham, Iosco, Isabella, Jackson, Lapeer, Lenawee, Livingston, Macomb, Midland, Monroe, Oakland, Ogemaw, Saginaw, St. Clair, Sanilac, Shiawassee, Tuscola, Washtenaw, Wayne.
050	Duluth, MN-WI	Minnesota: Carlton, Cook, Itasca, Koochiching, Lake, St. Louis; Wisconsin: Douglas.
054	Evansville, IN-KY	Illinois: Edwards, Gallatin, Wabash, White; Indiana: Daviess, Dubois, Gibson, Martin, Perry, Pike, Posey, Spencer, Vanderburgh, Warrick; Kentucky: Daviess, Hancock, Henderson, Hopkins, McLean, Muhlenberg, Ohio, Union, Webster.
060	Fort Wayne-Huntington-Auburn, IN	Indiana: Adams, Allen, Blackford, DeKalb, Grant, Huntington, Jay, Noble, Steuben, Wabash, Wells, Whitley; Michigan: Branch.
064	Grand Rapids-Muskegon-Holland, MI	Michigan: Allegan, Barry, Calhoun, Ionia, Kalamazoo, Kent, Mecosta, Montcalm, Muskegon, Newaygo, Oceana, Ottawa, Van Buren.
BEA Economic Areas (continued)		
EA ID	**EA Name**	**Counties Included in the EA**
078	Indianapolis-	Illinois: Clark, Crawford, Edgar, Lawrence; Indiana: Bartholomew, Benton, Boone, Brown,

	Anderson-Columbus, IN	Carroll, Cass, Clay, Clinton, Decatur, Delaware, Fayette, Fountain, Greene, Hamilton, Hancock, Hendricks, Henry, Howard, Jackson, Jennings, Johnson, Knox, Lawrence, Madison, Marion, Miami, Monroe, Montgomery, Morgan, Orange, Owen, Parke, Putnam, Randolph, Rush, Shelby, Sullivan, Tippecanoe, Tipton, Union, Vermillion, Vigo, Warren, Wayne, White.
083	Joplin, MO	Kansas: Allen, Bourbon, Cherokee, Crawford, Neosho, Wilson, Woodson; Missouri: Barton, Cedar, Jasper, Newton, Vernon; Oklahoma: Ottawa.[b]
084	Kansas City-Overland Park-Kansas City, MO-KS	Kansas: Anderson, Atchison, Doniphan, Douglas, Franklin, Johnson, Leavenworth, Linn, Miami, Wyandotte; Missouri: Adair, Andrew, Bates, Benton, Buchanan, Caldwell, Carroll, Cass, Chariton, Clay, Clinton, Daviess, DeKalb, Gentry, Grundy, Harrison, Henry, Holt, Jackson, Johnson, Knox, Lafayette, Linn, Livingston, Macon, Mercer, Nodaway, Pettis, Platte, Putnam, Ray, St. Clair, Saline, Schuyler, Sullivan, Worth.
089	La Crosse, WI-MN	Minnesota: Houston; Wisconsin: Jackson, La Crosse, Monroe, Trempealeau, Vernon.
094	Lexington-Fayette-Frankfort-Richmond, KY	Kentucky: Anderson, Bath, Bourbon, Boyle, Breathitt, Casey, Clark, Clay, Clinton, Cumberland, Elliot, Estill, Fayette, Floyd, Franklin, Garrard, Harlan, Harrison, Jackson, Jessamine, Johnson, Knott, Knox, Laurel, Lee, Leslie, Letcher, Lincoln, McCreary, Madison, Magoffin, Martin, Menifee, Mercer, Montgomery, Morgan, Nicholas, Owsley, Perry, Pike, Powell, Pulaski, Robertson, Rockcastle, Rowan, Russell, Scott, Washington, Wayne, Whitley, Wolfe, Woodford; West Virginia: Mingo. [b]
098	Louisville-Elizabethtown-Scottsburg, KY-IN	Indiana: Clarke, Crawford, Floyd, Harrison, Jefferson, Scott, Washington; Kentucky: Adair, Breckinridge, Bullitt, Carroll, Grayson, Green, Hardin, Henry, Jefferson, Larue, Marion, Meade, Nelson, Oldham, Shelby, Spencer, Taylor, Trimble.
101	Madison-Baraboo, WI	Illinois: Jo Daviess; Iowa: Allamakee, Clayton, Delaware, Dubuque, Jackson; Wisconsin: Adams, Columbia, Crawford, Dane, Grant, Green, Iowa, Juneau, Lafayette, Marquette, Richland, Rock, Sauk.
102	Marinette, WI-MI	Michigan: Alger, Baraga, Chippewa, Delta, Dickinson, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Schoolcraft; Wisconsin: Florence, Marinette.
103	Mason City, IA	Iowa: Cerro Gordo, Chickasaw, Floyd, Hancock, Howard, Kossuth, Mitchell, Winnebago, Winneshiek, Worth.
108	Milwaukee-Racine-Waukesha, WI	Wisconsin: Dodge, Fond du Lac, Green Lake, Jefferson, Manitowoc, Milwaukee, Ozaukee, Racine, Sheboygan, Walworth, Washington, Waukesha.
109	Minneapolis-St. Paul-St. Cloud, MN-WI	Minnesota: Aitkin, Anoka, Becker, Beltrami, Benton, Big Stone, Blue Earth, Brown, Carver, Cass, Chippewa, Chisago, Clearwater, Cottonwood, Crow Wing, Dakota, Dodge, Douglas, Faribault, Fillmore, Freeborn, Goodhue, Grant, Hennepin, Hubbard, Isanti, Jackson, Kanabec, Kandiyohi, Lac qui Parle, Le Sueur, Lincoln, Lyon, McLeod, Mahnomen, Martin, Meeker, Mille Lacs, Morrison, Mower, Murray, Nicollet, Olmsted, Otter Tail, Pine, Pope, Ramsey, Redwood, Renville, Rice, Scott, Sherburne, Sibley, Stearns, Steele, Stevens, Swift, Todd, Traverse, Wabasha, Wadena, Waseca, Washington, Watonwan, Winona, Wright, Yellow Medicine; South Dakota: Grant,[b] Marshall,[b] Roberts;[b] Wisconsin: Barron, Buffalo, Burnett, Chippewa, Dunn, Eau Claire, Pepin, Pierce, Polk, Rusk, St. Croix, Sawyer, Washburn.
122	Paducah, KY-IL	Illinois: Massac, Pope; Kentucky: Ballard, Caldwell, Calloway, Carlisle, Crittenden, Graves, Livingston, Lyon, McCracken, Marshall.
126	Peoria-Canton, IL	Illinois: De Witt, Fulton, Hancock, Henderson, Knox, McDonough, McLean, Marshall, Mason, Peoria, Stark, Tazewell, Warren, Woodford; Iowa: Des Moines, Henry, Jefferson, Lee, Van Buren; Missouri: Clark, Scotland.
141	Salina, KS	Kansas: Cheyenne, Cloud, Decatur, Ellis, Ellsworth, Gove, Graham, Jewell, Lincoln, Logan, Mitchell, Norton, Osborne, Ottawa, Phillips, Rawlins, Republic, Rooks, Russell, Saline, Sheridan, Sherman, Smith, Thomas, Trego, Wallace.
156	South Bend-Mishawaka, IN-MI	Indiana: Elkhart, Fulton, Kosciusko, Lagrange, Marshall, Pulaski, St. Joseph, Starke; Michigan: Berrien, Cass, St. Joseph.
158	Springfield, IL	Illinois: Adams, Brown, Cass, Christian, Greene, Logan, Macon, Menard, Montgomery, Morgan, Pike, Sangamon, Schuyler, Scott; Missouri: Lewis, Marion, Ralls.
159	Springfield, MO	Arkansas: Baxter,[b] Boone,[b] Carroll,[b] Marion,[b] Newton;[b] Missouri: Barry, Christian, Dade, Dallas, Bent, Douglas, Greene, Hickory, Howell, Laclede, Lawrence, Oregon, Ozark, Phelps, Polk, Pulaski, Shannon, Stone, Taney, Texas, Webster, Wright.
		BEA Economic Areas (continued)
EA ID	**EA Name**	**Counties Included in the EA**
160	St. Louis-St. Charles-	Illinois: Bond, Calhoun, Clinton, Franklin, Hamilton, Hardin, Jackson, Jefferson, Jersey,

	Farmington, MO-IL	Johnson, Macoupin, Madison, Marion, Monroe, Perry, Randolph, St. Clair, Saline, Union, Washington, Williamson; Missouri: Crawford, Franklin, Gasconade, Iron, Jefferson, Lincoln, Madison, Montgomery, Pike, Reynolds, St. Charles, Ste. Genevieve, St. Francois, St. Louis, Warren, Washington, St. Louis (Independent City).
166	Toledo-Fremont, OH	Ohio: Defiance, Fulton, Hancock, Henry, Lucas, Ottawa, Paulding, Sandusky, Seneca, Williams, Wood, Wyandot.
167	Topeka, KS	Kansas: Brown, Chase, Clay, Coffey, Dickinson, Geary, Jackson, Jefferson, Lyon, Marshall, Morris, Nemaha, Osage, Pottawatomie, Riley, Shawnee, Wabaunsee, Washington.
168	Traverse City, MI	Michigan: Benzie, Grand Traverse, Kalkaska, Lake, Leelanau, Manistee, Mason, Missaukee, Osceola, Wexford.
175	Waterloo-Cedar Falls, IA	Iowa: Black Hawk, Bremer, Buchanan, Butler, Fayette, Grundy.
176	Wausau-Merrill, WI	Michigan: Gogebic, Ontonagon; Wisconsin: Ashland, Bayfield, Clark, Forest, Iron, Langlade, Lincoln, Marathon, Oneida, Portage, Price, Taylor, Vilas, Wood.
179	Wichita-Winfield, KS	Kansas: Barber, Barton, Butler, Chautauqua, Clark, Comanche, Cowley, Edwards, Elk, Finney, Ford, Grant, Gray, Greeley, Greenwood, Hamilton, Harper, Harvey, Haskell, Hodgeman, Kearny, Kingman, Kiowa, Labette, Lane, McPherson, Marion, Montgomery, Ness, Pawnee, Pratt, Reno, Rice, Rush, Scott, Sedgwick, Stafford, Stanton, Sumner, Wichita; Oklahoma: Kay.[b]
***EAs excluded from this study*:**		
029	Charleston, WV	Kentucky: Boyd, Carter, Greenup, Lawrence; Ohio: Lawrence, Washington; West Virginia: Boone, Braxton, Cabell, Calhoun, Clay, Fayette, Gilmer, Greenbrier, Jackson, Kanawha, Lincoln, Logan, Nicholas, Pleasants, Pocahontas, Putnam, Raleigh, Randolph, Ritchie, Roane, Summers, Tucker, Wayne, Webster, Wirt, Wood, Wyoming.
055	Fargo-Wahpeton, ND-MN	Minnesota: Clay, Norman, Wilkin; North Dakota: Barnes, Cass, Dickey, Foster, Griggs, LaMoure, Ransom, Richland, Sargent, Sheridan, Stutsman, Wells.
057	Fayetteville-Springdale-Rogers, AR-MO	Arkansas: Benton, Madison Washington; Missouri: McDonald; Oklahoma: Adair, Delaware.
063	Grand Forks, ND-MN	Minnesota: Kittson, Lake of the Woods, Marshall, Pennington, Polk, Red Lake, Roseau; North Dakota: Benson, Cavalier, Eddy, Grand Forks, Nelson, Pembina, Ramsey, Steele, Traill, Walsh.
082	Jonesboro, AR	Arkansas: Clay, Craighead, Greene, Lawrence, Mississippi, Poinsett, Randolph; Missouri: Dunklin, Pemiscot.
116	Nashville-Davidson-Murfresboro-Columbia, TN	Kentucky: Allen, Barren, Butler, Christian, Edmonson, Hart, Logan, Metcalfe, Monroe, Simpson, Todd, Trigg, Warren; Tennessee: Bedford, Cannon, Cheatham, Clay, Coffee, Cumberland, Davidson, DeKalb, Dickson, Fentress, Franklin, Giles, Grundy, Hickman, Houston, Humphreys, Jackson, Lawrence, Lewis, Macon, Marshall, Maury, Montgomery, Moore, Overton, Perry, Pickett, Putnam, Robertson, Rutherford, Smith, Stewart, Sumner, Trousdale, Van Buren, Warren, Wayne, White, Williamson, Wilson.
119	Oklahoma City-Shawnee, OK	Kansas: Meade, Morton, Seward, Stevens; Oklahoma: Alfalfa, Beaver, Beckham, Blaine, Caddo, Canadian, Carter, Cimarron, Cleveland, Coal, Comanche, Cotton, Custer, Dewey, Ellis, Garfield, Garvin, Grady, Grant, Greer, Harmon, Harper, Hughes, Jackson, Jefferson, Johnston, Kingfisher, Kiowa, Lincoln, Logan, Love, McClain, Major, Marshall, Murray, Oklahoma, Pontotoc, Pottawatomie, Roger Mills, Seminole, Stephens, Texas, Tillman, Washita, Woods, Woodward; Texas: Sherman.
120	Omaha-Council Bluffs-Fremont, NE-IA	Iowa: Audubon, Cass, Fremont, Harrison, Mills, Montgomery, Page, Pottawattamie, Shelby, Taylor; Missouri: Atchison; Nebraska: Boone, Burt, Butler, Cass, Colfax, Cuming, Dodge, Douglas, Nance, Platte, Polk, Sarpy, Saunders, Washington.
129	Pittsburgh-New Castle, PA	Ohio: Belmont, Jefferson, Monroe; Pennsylvania: Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Washington, Westmoreland; West Virginia: Brooke, Hancock, Marshall, Ohio, Tyler, Wetzel.
154	Sioux City-Vermillion, IA-NE-SD	Iowa: Monona, O'Brien, Osceola, Plymouth, Sioux, Woodbury; Nebraska: Antelope, Boyd, Cedar Dakota, Dixon, Holt, Knox, Madison, Pierce, Stanton, Thurston, Wayne, Wheeler; South Dakota: Bon Homme, Clay, Union, Yankton.

BEA Economic Areas (continued)

EA ID	EA Name	Counties Included in the EA
155	Sioux Falls, SD	Iowa: Lyon; Minnesota: Nobles, Pipestone, Rock; South Dakota: Aurora, Beadle, Brookings, Brule, Buffalo, Charles Mix, Clark, Codington, Davison, Day Deuel, Douglas, Hamlin, Hand,

		Hanson, Hughes, Hutchinson, Hyde, Jerauld, Jones, Kingsbury, Lake, Lincoln, Lyman, McCook, Miner, Minnehaha, Moody, Sanborn, Stanley, Sully, Turner.

[a] **Data for this county were available, and the county was included in the EA.**
[b] **Data for this county were not available. This county was excluded from the EA for the purpose of this study.**

APPENDIX B

Distance Measures

1. Squared Euclidian Distance

Squared Euclidian distance between cases x_i and x_j is defined as:

$d_{ij}^2 = \sum_{k=1}(x_{ik} - x_{jk})^2$where x_{ik} is the value of the k^{th} variable for the i^{th} case. The distance between two cases is the sum of the squared differences between the values of all k clustering variables.

2. Chebychev Distance

Chebychev distance between cases x_i and x_j is defined as:

$$d_{ij} = \max_k |x_i - x_j|$$

where $\max_k$ is the maximum of the absolute difference between cases i and j across all k clustering variables.

<u>Ward's Method</u>

The within-groups sum of squares, or error sum of squares (ESS) is:

$$ESS = x_i^2 - \frac{1}{n(\sum x_i)^2}$$

where x_i is the score of the i^{th} case.

APPENDIX C

Top 10 Positive and Negative Changes to Direct Requirements Matrix

Top 10 Positively Impacted Industries

Chicago			Detroit			Milwaukee			Minneapolis			Toledo		
Sellers	Buyers	Change	Sellers	Buyers	Change	Sellers	Buyers	Change	Sellers	Buyers	Change	Sellers	Buyers	Change
Professional, Scientific, & Technical Services	Mining	0.0000027	Construction	Mining	0.0000057	Mining	Mining	0.0000357	Manufacturing	Accommodation and Food Services	0.0000023	Health and Social Services	Administrative and Waste Services	0.0000419
Real Estate & Rental	Professional, Scientific, & Technical Services	0.0000025	Real Estate & Rental	Mining	0.0000036	Professional, Scientific, & Technical Services	Wholesale Trade	0.0000208	Health and Social Services	Accommodation and Food Services	0.0000018	Manufacturing	Agriculture, Forestry, Fishing & Hunting	0.0000185
Real Estate & Rental	Mining	0.0000023	Wholesale Trade	Manufacturing	0.0000025	Wholesale Trade	Wholesale Trade	0.0000198	Health and Social Services	Health and Social Services	0.0000015	Management of Companies	Administrative and Waste Services	0.0000164
Information	Professional, Scientific, & Technical Services	0.0000019	Health and Social Services	Mining	0.0000021	Information	Information	0.0000165	Manufacturing	Construction	0.0000012	Agriculture, Forestry, Fishing & Hunting	Agriculture, Forestry, Fishing & Hunting	0.0000153
Manufacturing	Accommodation and Food Services	0.0000017	Wholesale Trade	Agriculture, Forestry, Fishing & Hunting	0.0000020	Transportation and Warehousing	Wholesale Trade	0.0000150	Professional, Scientific, & Technical Services	Accommodation and Food Services	0.0000012	Information	Information	0.0000145
Transportation and Warehousing	Transportation and Warehousing	0.0000015	Utilities	Mining	0.0000019	Other Services	Wholesale Trade	0.0000140	Health and Social Services	Retail	0.0000009	Health and Social Services	Agriculture, Forestry, Fishing & Hunting	0.0000143
Construction	Mining	0.0000014	Wholesale Trade	Wholesale Trade	0.0000019	Real Estate & Rental	Wholesale Trade	0.0000139	Finance and Insurance	Health and Social Services	0.0000008	Real Estate & Rental	Administrative and Waste Services	0.0000124
Manufacturing	Mining	0.0000014	Wholesale Trade	Accommodation and Food Services	0.0000019	Construction	Health and Social Services	0.0000136	Wholesale Trade	Accommodation and Food Services	0.0000008	Other Services	Administrative and Waste Services	0.0000110
Professional, Scientific, & Technical Services	Accommodation and Food Services	0.0000013	Manufacturing	Mining	0.0000018	Professional, Scientific, & Technical Services	Accommodation and Food Services	0.0000136	Agriculture, Forestry, Fishing & Hunting	Health and Social Services	0.0000007	Educational Services	Educational Services	0.0000090
Real Estate & Rental	Accommodation and Food Services	0.0000012	Transportation and Warehousing	Utilities	0.0000017	Management of Companies	Wholesale Trade	0.0000134	Professional, Scientific, & Technical Services	Mining	0.0000007	Government & Non NAICS	Administrative and Waste Services	0.0000084

Top 10 Negatively Impacted Industries

Chicago			Detroit			Milwaukee			Minneapolis			Toledo		
Sellers	Buyers	Change	Sellers	Buyers	Change	Sellers	Buyers	Change	Sellers	Buyers	Change	Sellers	Buyers	Change
Manufacturing	Truck Transportation	-0.0002884	Transportation and Warehousing	Truck Transportation	-0.0001832	Finance and Insurance	Finance and Insurance	-0.0001789	Manufacturing	Truck Transportation	-0.0002405	Manufacturing	Truck Transportation	-0.0002405
Transportation and Warehousing	Truck Transportation	-0.0002001	Other Services	Truck Transportation	-0.0001704	Health and Social Services	Administrative and Waste Services	-0.0000756	Transportation and Warehousing	Truck Transportation	-0.0001930	Transportation and Warehousing	Truck Transportation	-0.0001729
Management of Companies	Truck Transportation	-0.0001782	Management of Companies	Truck Transportation	-0.0001700	Finance and Insurance	Government & Non NAICS	-0.0000498	Other Services	Truck Transportation	-0.0001750	Finance and Insurance	Finance and Insurance	-0.0001431
Truck Transportation	Truck Transportation	-0.0001547	Manufacturing	Truck Transportation	-0.0001413	Real Estate & Rental	Government & Non NAICS	-0.0000503	Truck Transportation	Truck Transportation	-0.0001566	Other Services	Truck Transportation	-0.0001343
Other Services	Truck Transportation	-0.0001485	Truck Transportation	Truck Transportation	-0.0001324	Wholesale Trade	Truck Transportation	-0.0000463	Finance and Insurance	Truck Transportation	-0.0001558	Management of Companies	Truck Transportation	-0.0001265
Finance and Insurance	Truck Transportation	-0.0001476	Finance and Insurance	Truck Transportation	-0.0001124	Transportation and Warehousing	Truck Transportation	-0.0001601	Management of Companies	Truck Transportation	-0.0001446	Truck Transportation	Truck Transportation	-0.0001006
Manufacturing	Manufacturing	-0.0001152	Health and Social Services	Truck Transportation	-0.0000539	Finance and Insurance	Truck Transportation	-0.0001613	Wholesale Trade	Truck Transportation	-0.0000551	Finance and Insurance	Truck Transportation	-0.0000689
Real Estate & Rental	Truck Transportation	-0.0000578	Real Estate & Rental	Truck Transportation	-0.0000523	Management of Companies	Truck Transportation	-0.0001465	Real Estate & Rental	Truck Transportation	-0.0000518	Real Estate & Rental	Professional, Scientific, & Technical Services	-0.0000384
Health and Social Services	Truck Transportation	-0.0000541	Wholesale Trade	Truck Transportation	-0.0000440	Other Services	Truck Transportation	-0.0001614	Health and Social Services	Truck Transportation	-0.0000471	Information	Professional, Scientific, & Technical Services	-0.0000280
Wholesale Trade	Truck Transportation	-0.0000525	Professional, Scientific, & Technical Services	Truck Transportation	-0.0000366	Truck Transportation	Truck Transportation	-0.0001278	Professional, Scientific, & Technical Services	Truck Transportation	-0.0000430	Wholesale Trade	Truck Transportation	-0.0000263

CFIRE

University of Wisconsin-Madison
Department of Civil and Environmental Engineering
1410 Engineering Drive, Room 270
Madison, WI 53706
Phone: 608-263-3175
Fax: 608-263-2512
cfire.wistrans.org