Evaluating the Economic Impact of Freight Investment in Unique Economies Using Input-Output

BY

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THESIS

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SUMMARY

This research investigates the economic impact transportation infrastructure investments have on distinct economies. Using Input-Output analysis, it compares five Midwestern economies with varying levels of freight specialization. The primary objective and contribution of this thesis is to provide insight about how the impact of freight transportation projects varies across different regional economies. As the research is designed to assist policymakers in making better-informed decisions when allocating scarce resources, the most significant finding is that a significant reduction in freight delay has minimal impact on policy decisions. Therefore, additional tools should be used to gain further insight into the impact of such projects.

1. INTRODUCTION

The primary objective and contribution of this thesis is to provide insight about how the impact of freight transportation projects varies across different regional economies. It does this by applying input-output methodology to five regional economic areas of distinct size and level of freight specialization. The research is designed to assist policymakers in making better-informed decisions when allocating scarce resources.

1.1 HYPOTHESES

This thesis tests four primary hypotheses that are natural extensions from Halpern-Givens and Bader. Each is designed to be testable and to shed light on the role freight plays in regional economies.

The first two hypotheses, H1 and H2, build on the value-chain and freight-dependent-economy work of Bader. Together they 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. H1 and H2 are short-term in nature, considering the effect of resources spent on reducing freight congestion. The hypotheses assume a more efficient freight sector is associated with higher levels of productivity. Despite this, the expectation is that the size of an economy determines the overall impact of a freight investment more so than the economy's degree of freight specialization.

> *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.*

The second set of hypotheses, H3 and H4, refer more directly to the research of Halpern-Givens. While H1 and H2 focus on the near-term economic impact of an investment made in freight dependent economies, H3 and H4 look at the permanent structural effect of making the freight sector more efficient.

H3 extends the finding of Halpern-Givens that the economic impact of reducing trucking delay resulted in a less productive economy than in the less efficient baseline model. Though the difference was slight, economic theory generally suggests higher efficiencies lead to more productive economies. Because the finding is somewhat counter intuitive, this analysis tests this finding across five study areas. The objective is to explore whether the finding is limited to the case study or if it has broader implications.

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

Finally, H4 ties the theses 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 by Bader.

> *H4: Freight specialization has less an impact on the industries impacted by freight investment than does the overall structure of an economy*

2. LITERATURE REVIEW

This research investigates the economic impact transportation infrastructure investments have on distinct economies. Using Input-Output analysis, it compares five Midwestern economies with varying levels of freight specialization. The review of the literature thereby proceeds as follows: (1) discussion of the literature pertaining to transportation and economic development; (2) a summary of the work of Halpern-Givens (2010) and Bader (2011); (3) an overview of the input-output technique and the extensions used in this study.

2.1 Economic Impact of Infrastructure Investment

Freight transportation has a broad effect on the nation's economy because it is an essential input in the production process. In this capacity, investments made to improve freight transportation are likely to have far-reaching effects across a given economy. A common question asked by researchers is, however, whether freight transportation itself drives economic growth or whether it is one of a number of necessary conditions required to grow an economy.

Generally speaking, the literature distinguishes between two broad economic impacts of transportation - direct and indirect. Dr. Jean-Paul Rodrigue (Rodrigue, Comtois, & Slack, 2009) defines direct impacts as those related to accessibility change where transportation enables larger markets and enables to save time and costs. Indirect Impacts related to economic multiplier effects where the price of commodities, goods or services drop and/or their variety increases. In short, direct impacts reduce costs of transportation, whereas indirect impacts affect costs of and demand for other sectors as well.

Recognizing the broad role of transportation, it is frequently argued that policies which increase mobility (motor vehicle travel) are also good for Economic Development. Policymakers cite the following studies, among many others, as economic justification for investing in transportation infrastructure.

Keeler and Ying (1988) found the rapid growth of highway infrastructure in the U.S. from 1950 to 1973 had a strong positive effect on productivity growth in trucking. Their findings suggest the increase in trucking productivity from the highway system covered as much as 44% of the overall cost of total highway investment during the period. Building on this, Garcia-Mila and McGuire found spending on highways is associated with an increase in state output. Similarly, Pozdena (Pozdena, 2009) finds greater spending on oil is correlated with GDP growth.

Work by Chandra and Thompson finds geographic location of highways appears to influence the composition of firms. Their results show that highways affect the spatial arrangement of economic activity in the counties highways pass through and those adjacent them. Initial findings suggest the improved transportation results in a positive impact on the local economy. When the economic effects of adjacent counties are considered, however, the research suggests the increase in one county's economic health is associated with the decrease in another (Chandra & Thompson, 2000).

Adelheid Holl (Holl, 2006) finds that benefits of transportation infrastructure improvements go beyond direct impacts of reduced travel time and cost savings to the industries mentioned by Rodrigue and Bader. Analyzing the manufacturing sector in Spain, Holl finds transportation provides additional benefits for logistic reorganization, market expansion, and wider supplier access, among others. In short, transportation may be more important because it

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has become less expensive, permitting new types of production. This recognition suggests transportation analysis take into account the way firms use different types of transportation. Though these studies show increased vehicle travel and GDP growth often move in the same direction, little evidence suggests the relationship is a causal one.

Rodrigue argues that transportation itself, however, is not a sufficient causal condition for development. The lack of transportation, however, is likely a constraint on development. He argues the outcome of transportation improvements is typically a more efficient division of production, geographic specialization in transportation is likely to lead to comparative advantage in transportation-related industries. Such industries directly linked to freight include freighters, managers, shippers, while indirectly related industries might include insurance, finance, packaging, handling, travel agencies, transit operators, among others (Rodrigue, Comtois, & Slack, 2009) (Bader, 2011).

Building on this, O'Fallen (O'Fallon, 2003) finds little evidence of the relationship in the short-term and argues infrastructure investment on its own, cannot grow the economy. She finds the investment must be made in places where the appropriate economic conditions, structure, or need exists. Litman adds that increases in VMT do increase economic development, but they are dependent on whether the increase is production oriented or consumer/recreationally oriented. Perhaps most significantly, Holtz-Eakin (Holtz-Eakin, 1994) shows that when the effective controls are included in the analysis, the evidence does not support the relationship between public-sector capital and private-sector productivity.

In short, the large body of research on the relationship of transportation and the economy agrees there is a relationship between transportation and economic growth. Whether the

relationship is causal, however, has yet to be demonstrated. Work by Keeler and Ying, Garcia-Mila and McGuire, Pozdena, Chandra and Thompson, and Holl show strong correlation exists. Conversely, studies by Rodrigue, O'Fallen, Litman, and Holtz-Eakin argue transportation infrastructure can support growth where the right conditions exist, but has only limited impact when such conditions do not exist.

2.2 Input-Output Analysis

Developed by Wassily Leontief in the 1930s, Input-Output analysis is a framework that analyzes the interdependence of industries within a given economy. At its core, Input-Output refers to a system of linear equations that describe the distribution of an industry's product throughout an economy (Miller & Blair, 1985). Though Input-Output 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 (Miller & Blair, 1985).

Input-Output 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).

Input-Output 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 (Bendavid-Val, 1991), (Miller & Blair, 1985), (Miernyk, The Elements of Input-Output Analysis, 1965).

The basis of Leontief's method is the input-output, or transaction table. The transaction matrix, the upper left section of the Input-Output 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 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. Immediately below the transaction matrix is the income section, where household wages, corporate earnings and taxes paid to governments are shown. Finally, the bottom right quadrant covers non-market transfers such as gifts, savings, and intergovernmental transfers, 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.

2.2.1 Input-Output in Transportation

Most quantitative analyses of the economic effects of transportation projects are limited to user benefits and environmental impacts. Economic impact tools, such as Input-Output, are rarely used to measure investments in transportation systems, despite being used in measuring other infrastructure projects. A central problem in the Input-Output 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 do not consider the broader role of transportation in the economy. Input-Output 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 Input-Output is grounded in technical, measurable relationships of production and bridges the gap between economists, managers and engineers

Economic development impacts are typically measured by indicators only loosely connected to transportation, such as an area's level of activity in employment, income, quality of life, or economic stability over time. These impacts are typically evaluated by changes in economic output, gross regional product, personal income, or employment, among others. Each of these 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 these three criteria represents the total economic effect (Wang & Charles, Application of the Input-Output Model to the Analysis of the Economic Impacts of Transport Infrastructure Investment in Australia, 2010).

In order to apply economic development tools such as Input-Output analysis to transportation projects requires the conversion of traditional transportation metrics into metrics used in economic development. This research uses an elasticity rate to bridge this gap. Following the methodology of Halpern-Givens (Halpern-Givens, 2010), this research uses an elasticity rate for delay reduction, a common transportation metric, to calculate a change in demand and, ultimately, a change in total economic output, a typical economic development metric.

2.2.2 Regional Input-Output Analysis

There are two basic features of a regional economy that influence the characteristics of a regional input-output 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 input-output

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.

2.2.3 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 (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.

2.2.4 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, The Elements of Input-Output Analysis, 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 & Blair, 1985).

2.2.5 Input-Output Techniques and Extensions

In the more than 75 years since Wassily Leontief formalized Input-Output analysis, numerous new techniques and extensions have been developed. While these methods have been used to address earlier concerns about input-output 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 input-output analysis over the last twenty years. Specific to this research, two such techniques are of interest: RAS updating and Linkage Analysis.

2.2.6 RAS Updating

The RAS method, or bi-proportional method, is a commonly used method of updating and balancing Input-Output 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 (Guo, Lawson, & Planting, 2002) note that the results are as relevant as more complicated methods, perhaps explaining its popularity for regionalizing national input-output tables. Due to the inherent limitations in the data required for input-output analysis (availability, cost, lags, etc.), RAS is a particularly useful tool as constructing a new table is rarely feasible (Halpern-Givens, 2010). In this analysis, RAS is used to create a new scenario based on a change in demand resulting from reduced freight delay.

2.2.7 Linkage Analysis

The objective of linkage analysis is to quantify how change in one industry affects another (Kawamura, Sriraj, & 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, Hewings, & Martins, 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 (Bader, 2011).

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, Hewings, & Martins, 1995).

2.2.8 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 Input-Output, the following are several assumptions of significant importance.

First, input output models are 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 the model assumes returns to scale are constant (Halpern-Givens, 2010).

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 (Bader, 2011).

Additional assumptions of Input-Output 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 (Bader, 2011) (Halpern-Givens, 2010).

While many of the criticisms of Input-Output stem from the above limitations, others relate to interpreting the results. For example, Oosterhaven and Stelder criticize the use of multipliers because of their tendency to exaggerate (Oosterhaven & Stelder, 2002). 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 (US Department of Transportation, 2003).

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 (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. As Bader (Bader, 2011) points out, 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.

2.3 Halpern-Givens and Bader

As this thesis applies the methodology of Halpern-Givens (Halpern-Givens, 2010) to the analysis of Bader (Bader, 2011), a brief introduction to their work as it relates to this thesis is important.

In his 2010 thesis, Ethan Halpern-Givens applied input-output analysis to consider the impact of transportation infrastructure investment. While Input-Output analysis has long been used in economic development analysis, its use in transportation is much less developed. His work applied Input-Output analysis to measure both the short-term impact analysis and the longer-term structural change to the Chicago economy by reducing trucking delay by investing in trucking infrastructure. To create an alternative scenario to the baseline, he used the RAS method to generate one with a more efficient trucking sector resulting in a 20% reduction in freight delay.

Halpern-Givens looked at the differences in both the short-term economic impacts of an investment in freight infrastructure, as well as the permanent structural shift resulting from the change in demand due to reduced delay. In the short-term, he found the more efficient trucking economy to experience a slightly smaller economic impact as a result of the shock than the baseline economy. This finding is specifically tested across the five study areas in this thesis. Similarly, the more efficient economy had a smaller total output than the baseline scenario, perhaps suggesting the freight sector is relatively inelastic. As the findings of Halpern-Givens appear somewhat counter-intuitive, it is worth noting that a key limitation of Input-Output analysis is that it does not account for third-order, longitudinal, or substitution effects, any of which may offset the slight decline in total output.

In her 2011 thesis, Cara Bader sought to identify key relationships in the transportation sector using value-chain and cluster analysis. She identified industries with forward and backward linkages to transportation, distinguishing between those with primary linkages (direct) and secondary linkages (indirect). She then groups these industries together and, using location quotients, ranks economic areas within the 10-state Midwest by their degree of freight specialization. It is from these rankings that the five economic areas in this analysis were selected.

3. ANALYSIS TOOLS AND DATA

3.1 Analysis Tools

3.1.1 Stata

Stata is an integrated statistical package offering tools for data analysis, data management, and graphics commonly used in social science research. Stata 11 was used for this analysis to aggregate the Input-Output tables from 400+ sectors into 21 for each of the five study areas. This was done to mimic the aggregation used in the previous research of Ethan Halpern-Givens (2010).

3.1.2 PyIO

PyIO is a free Input-Output module, written in Python, developed and released by the Regional Economics Applications Laboratory (REAL) at the University of Illinois Urbana Champaign. PyIO 2.0 was used in this study. The software does not have the ability to generate an input-output table, so it must be provided by the user via an ASCII text file. PyIO presents the results on screen, though it is also able to export the files to Microsoft Excel. PyIO was used in this study to perform impact analysis, multiplier analysis and RAS adjustments. In addition, PyIO can create the Leontief inverse matrix and run push-pull, field of influence, key-sector, and decomposition analysis (Nazara, Guo, Hewings, & Dridi, 2003).

3.2 Data

3.2.1 Input-Output Accounts

The primary data for this research are county-level input-output accounts from IMPLAN for the 10 central U.S. states of the Mid-American Freight Coalition: Illinois, Indiana, Iowa, Kansas,

Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. Using IMPLAN, the county-level files were aggregated into one large model by Cara Bader, for use in her 2011 research. She then re-aggregated the county-level files into models for each of the Bureau of Economic Analysis' (BEA) economic areas that are located in the 10-state region. In each of these models, the data used in this study were derived from the Industry-by-Industry Transaction Report and Industry Output Outlay Summary Report.

Under licensing restrictions imposed by IMPLAN, personal access to the models and source data was not possible for this study, so only the data output provide by the reports was analyzed. The Department of Geography and Planning at the University of Toledo generously provided the data used in this research. All industry data were provided to Ms. Bader under the 440 Industry aggregation scheme employed by IMPLAN. Appendix A lists the 440 industries present in the 2007 IMPLAN Sector Scheme. The industry output totals for the economic areas included in this research were used by Ms. Bader to calculate the location quotients used to identify the five study areas selected for this research.

3.2.2 Economic Areas

Five distinct Economic Areas, as defined by the BEA, are analyzed in this research. Economic Areas are intended to capture the relevant regional markets surrounding metropolitan and micropolitan statistical areas. The BEA's definition of Economic Areas represents the largest geography level used for economic statistics provided by the federal government based on economic linkages. Appendix B lists each of the five BEA Economic Areas included in this research, along with the counties included.

3.2.3 Federal Highway Administration Performance Elasticity

This research uses an elasticity rate identified in the HLB Decision Economics Inc (HLB) research performed on behalf of the Federal Highway Administration. HLB found that reducing delay time typically led to an increased demand for trucking services. The rate used in this study is for the central region. The elasticity rate for the region is 0.0175, significantly larger than the eastern (0.0076) and western regions (0.0070). HLB attributes this to the high level of manufacturing in the central region, which is a primary consumer of freight services. The region's geographic nature as a corridor through which freight passes through is also likely to contribute. The central region elasticity of 0.0175 is used in this thesis to calculate the increased demand in trucking resulting from a reduction in delay for purposes of updating the transaction table using the RAS method.

4. METHODS

This thesis applies the Input-Output methodology used by Ethan Halpern-Givens (2010) to five regional economies with varying levels of freight dependency using the rankings of Cara Bader (2011). This section 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.

4.1 Selecting the Study Areas

To perform this analysis, five regional economies were selected using the value-chain analysis and the location quotients calculated in Bader's 2010 work. Her analysis 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 1.00 is indicative of average specialization and the farther above or below 1.00 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 vary in size and freight specialization (Figure 1). They are:

Toledo: Small and Specialized. 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 included both because it is both small in terms of GDP and highly specialized in freight. In addition, because of its close proximity to the much larger Detroit, Toledo may have interesting findings as a satellite economy.

Detroit: Bi-Polar. Detroit is the most highly specialized in primary forward linkages (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 and parts 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 (0.740).Detroit should thereby provide insights into the role forward and backward linkages play in a large economy.

Milwaukee: The Least Specialized. 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: The Median. 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: Big and Balanced. 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.

Figure 1: The Five Study Areas

	2010 GDP (In Millions $)	Primary Forward	Secondary Forward	Primary Backward	Secondary Backward
Toledo	$26,605	High Specialization (1.279)	Average (0.965)	High Specialization (1.598)	Below Average (0.903)
Detroit	$197,773	High Specialization (1.377)	Average (0.957)	Low Specialization (0.740)	Above Average (1.220)
Milwaukee	$84,574	Low Specialization (0.732)	Above Average (1.084)	Below Average (0.848)	Below Average (0.877)
Minneapolis	$199,596	Below Average (0.779)	Average (1.016)	Above Average (1.097)	Average (1.042)
Chicago	$532,331	Below Average (0.873)	Below Average (0.864)	Average (1.008)	Above Average (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)

4.2 Input-Output Analysis

Once the five study areas were selected, the Input-Output methodology of Halpern-Givens was applied. This began by using the RAS method to create two scenarios, a baseline and one with a more-efficient trucking sector, and then performing impact and multiplier analysis using PyIO. The analysis requires both an investment amount (shock) and a change in demand to be assigned, of which the methodology of each is discussed below.

4.2.1 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 Input-Output 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 Figure 2, 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. Similar to Halpern-Givens, 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.

Figure 2: Calculating Increased 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

4.2.2 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. Following Halpern-Given's methodology, the $14.22

million investment in the construction industry from the Chicago case study was selected as the

baseline shock. Though any industry could have been chosen, construction was selected for two

reasons. First, it is the same industry used in the methodology in Halpern-Givens and thereby

keeps the methodology consistent. Second, while an investment in freight infrastructure may be

made in multiple sectors, construction is likely to be among the top sectors in any analysis.

Whether investing in new train lines, ports, rail-yards, highways, intermodal hubs, or elsewhere,

the construction industry will be among the largest beneficiaries.

After selecting the baseline amount of the shock for Chicago, the shock 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 (Figure 3). 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.

Figure 3: Determining the 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

4.2.3 Aggregation

After the scenarios were created and the shocks determined, Stata was used to aggregate the data from 400+ sectors to the 21 used by Halpern Givens (2010). Each Industry-by-Industry Transactions Report was converted into.csv file and imported into Stata. A simple program was written in Stata to aggregate the data, with the results being exported into Excel. Excel pivot-tables were then used to transform the Stata file into a 21X21 transaction matrix. A similar process was then performed using the Output-Outlay Summary Report, which provided the total output, final demand, and value-added information required by PyIO. The transaction table was then combined with the total output, final demand, and value-added data in a text file formatted for use with PyIO.

<u>4.2.4 Testing the Hypotheses</u>

The methodology described above provides an apt foundation for testing the hypotheses described at the beginning of this thesis. Impact and multiplier 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 provides findings specific to 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. Figure 4 below summarizes the tests used to test each hypothesis.

Figure 4: Hypotheses and Tests

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.	Conduct Impact and Multiplier Analysis on each study area
H2: Freight specialization plays a larger role in determining the impact of freight investment than does the overall size of an economy.	Conduct Impact and Multiplier Analysis on each study area
H3: Improving freight efficiency by reducing trucking delay reduces the output of the overall regional economy	Conduct Impact and Multiplier Analysis and compare baseline and RAS-adjusted scenarios
H4: The industries impacted by freight investment vary depending on the structure of each economy.	Comparing the direct requirements matrices for the baseline and RAS-adjusted scenarios

5. RESULTS

5.1 RAS Update Changes in I-O tables

The changes in the Input-Output tables 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 (TABLE X). 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 shifts in demand are discussed. It should be noted that all results are the normalized impact to each economy, allowing for comparison across the five study areas.

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 the Trucking sector 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.

5.1.1 Industry-Level Findings

At the industry level, limited overlap occurred across study areas, with ten different
industries 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 (Figure 5). Overlap across two study areas only occurred
with three other industries, while six distinct industries were identified in only a single economic
area. Of the five study areas, Milwaukee and Minneapolis were most closely aligned,
overlapping in two of the top three positively impacted industries.

Figure 5: Industries Experiencing Top 3 Increases in Total Purchases

Top 3 Positive Change in Total Purchases (Inputs)	
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 a single area	6
Total industries identified in Top 3	10

Positive changes in total sales had even less overlap, with eleven industries were
identified among the top three increasing sales (outputs). No industries were found among the
top three positive changes in three or more study areas (Figure 6). 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.

Figure 6: 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. Seven industries were identified among the top three negative changes to purchasing (Figure 7). 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.

Figure 7: Industries Experiencing Top 3 Decreases in Total Purchases

Negative Change in Total Purchases (inputs)	
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

Only six industries were identified among the top five decreases in sales (Figure 8). 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.

Figure 8: Industries Experiencing Top 3 Decreases in Total Sales

Negative Change in Total Sales (outputs)	
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

5.1.2 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 (Figure 9). 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 (Figure 9). 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.

Figure 9: 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	-0.0001111	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										

5.1.3 Inter-Industry Transaction Level Findings

Across the 5 study areas, each of the ten largest normalized positive changes is in either Milwaukee or Toledo (Figure 10)). 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.

Figure 10: The Ten Largest Inter-Industry Transaction Increases

Study Area	Sellers	Buyers	Change
	Ten Largest Transaction Increases		
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 (Figure 11). 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.

Figure 11: The Ten Largest Inter-Industry Transaction Decreases

Study Area	Sellers	Buyers	Change
	Ten Largest Transaction Decreases		
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

5.2 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 (Figure 12). 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.

Figure 12: Ratio of Baseline Impact 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 (Figure 13). Measuring the change as a percentage of the baseline impact, Milwaukee experienced the largest negative change, nearly five times that of Minneapolis, the smallest. These findings support those of the Halpern-Givens (2010), further suggesting metrics other than total economic output should be considered when evaluating such infrastructure investments.

Figure 13: Impact 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 (Figure 14). 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.

Figure 14: The 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 (Figure 15). 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.

Figure 15: The Largest Negative Industry Changes from Baseline to Updated Scenarios

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

5.3 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. The results shown in Table X show this; 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 Figure 16 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.

Figure 16: 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	0.003660%
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	0.005588%	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	-0.005068%
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	-0.002603%
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	

Figure 17 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 Figure 17 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 5 study areas, a 20% reduction in delay does not impact an economy enough to change policy decision criteria.

Figure 17: 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	1.4036	1.4036	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	1.4837	1.4836	1.2208	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	1.4836	1.4835	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	1.3938	1.3938	1.3413	1.3413	1.3036	1.3036	1.3458	1.3458	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	1.5999	1.5999	1.4926	1.4926	1.4795	1.4795	1.5511	1.5511	1.2760	1.2761
Finance and Insurance	1.6975	1.6975	1.5835	1.5835	1.5772	1.5768	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	1.2719	1.2718
Management of Companies	1.4735	1.4735	1.3603	1.3603	1.3669	1.3669	1.4503	1.4503	1.2822	1.2822
Administrative and Waste Services	1.4991	1.4991	1.4592	1.4592	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	1.4050	1.4050	1.3824	1.3823	1.4541	1.4541	1.2731	1.2731
Government & Non NAICS	1.6413	1.6412	1.4651	1.4650	1.4835	1.4831	1.4804	1.4804	1.4252	1.4251
Truck Transportation	1.6233	1.6210	1.4845	1.4828	1.4053	1.4038	1.5557	1.5537	1.3916	1.3903
Total Positive Changes		0		4		8		0		6
Total Negative Changes		21		17		13		21		15

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.

6. CONCLUSIONS

6.1 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 X shows on page Y, 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.

At least two things might explain these findings. First, the freight sector is a derived demand sector and making it cheaper does little to change demand for freight. The FHWA elasticity figure used in this analysis supports this, with only a 0.0175% elasticity for freight in the central U.S. Lower transportation costs, however, are likely to reduce prices to consumers in a wide range of areas, as reducing the cost of freight lowers the cost of doing business for many different industries.

An additional explanation builds on the above. While freight may be inelastic 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 Input-Output analysis is largely limited for use short-term impact studies. Additionally, Input-Output analysis does not allow for substitution effects, longitudinal changes over time, or third-order benefits. Therefore, alternative methods, such as Computational General Equilibrium 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. Input-output modeling is designed to show how much spending, and subsequent re-spending, is conducted within an economic area. The multipliers shown in Table X demonstrate this. 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 and the initial findings from Halpern-Given's case study. 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, Input-Output 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. As shown in Tables X and X, positive change was identified by 10 different purchasing industries and 11 selling industries. Conversely, Tables Y and Z show negative changes in 5 unique purchasing industries and 9 selling industries, much less variance.

6.2 Weaknesses, Limitations, and Extensions

There are a number of limitations, and corresponding extensions, of this research that can be grouped into three buckets: methodological assumptions, Input-Output limitations, and spatial.

6.2.1 Methodological Limitations and Extensions

Methodological limitations are those stemming from assumptions made in conducting the analysis. Four assumptions of note, the associated weaknesses or limitations, and possible extensions are discussed below.

- The arbitrary nature of shocking the construction sector is limited in the information it provides. Despite being sector most likely to be shocked for infrastructure projects, were the shock to another sector, it would like change the results of the impact analysis. Sensitivity analysis could be performed using various sectors to gain insights into the significance of this limitation.

- Another limitation is the assumption that elasticity is constant across each of the five study areas. Due to limitations in the data, only regional elasticity rates are available for the change in demand as a response to reduction in delay. Were elasticity rates available at the economic area level, the analysis could be run again and the magnitudes of the results are likely to change. Such an analysis might compare economies in the eastern or western regions using the corresponding HLB elasticity rates. Such an analysis is unlikely to change the directional findings, due to the relative inelasticity of the freight sector. While the magnitude of the impacts will change, it is unlikely to alter the conclusions of this research.

- The analysis also assumes each of the five regional economies is independent of the others. Given each are located in the mid-western region and several are within close proximity to each other – Milwaukee to Chicago, Toledo to Detroit – full independence is unlikely. Data limitations prevented incorporating such analysis in this research; though extending the research to cover larger regional economies may generate interesting findings.

- Finally, the aggregation scheme for this analysis is also a limitation. Freight, especially trucking, is an industry that is connected to so many sectors that a more disaggregated analysis will likely provide further insight into the specific impacts of freight on the

economy. For example, many sectors have large trucking components – Retail, Construction, Mining, Wholesale Trade, etc. – that are not observed at the aggregated level. A more disaggregated analysis is likely to reveal components of these industries that are significantly impacted by reducing delay by 20%. It is very likely that the largest impacts, especially at the transaction level, are likely to change in such an analysis

6.2.2 Input-Output Limitations and Extensions

As with all tools of analysis, Input-Output has its limitations. While many of these are discussed in the literature review and throughout the analysis, several are worth noting here.

- Input-Output analysis is not designed to provide longitudinal impacts, substitution effects, third-order benefits, or any changes in supply or demand due to price changes. For example, this analysis is unable to account for economic impacts stemming from a more efficient trucking sector. While elasticity numbers were used to connect more efficient trucking to a shift in demand, the analysis is unable to provide information about how changes to costs of production play out throughout the economy. This is significant because the analysis shows a more efficient trucking sector results in a lower economic output (total sales), but it usable to show how that efficiency translates into larger profits and how those profits are spent. Such an increase in profits and how they are spent may very well offset the reduction in trucking output. Conducting the analysis using a CGE or another more sophisticated economic model is likely to provide additional insight.

- Another limitation of this research is the use of the RAS method to create the alternative scenario. The RAS method iteratively spreads the increase in trucking output across an economy such that the sectors with the largest connections to trucking experience the

largest change. Doing so ignores how changes in demand impact price and the how that would translate into structural shifts that is different than the purely mathematical RAS allocation. A possible extension would be to compare scenarios generated using the RAS method and several using alternative methods that incorporate the impact of price change or cost reductions. Such an analysis would require a more sophisticated tool, such as CGE, and would be subject to the limitations of those tools (i.e. accessibility, cost, expertise, etc.).

6.2.3 Spatial Limitations and Extensions

In addition to the above limitations and extensions, further research might explore the spatial and geographic dimensions of the research. For example, this analysis ignores the potential influence of geographic location on shifting transportation activities from less central to more central locations. Further analysis might consider the proximity of Toledo (highly specialized) and Milwaukee (low specialization) to much larger urban centers – Detroit and Chicago, respectively.

Transporting goods from Milwaukee to the East must go through Chicago, perhaps reducing Milwaukee's level of specialization. Similarly, transporting manufactured goods from Detroit to the rest of the country is likely to go through Toledo, perhaps having the reverse effect. The results of the analysis, however, found them experiencing similar results in various tests. Extensions of this research might look at the relationship between similar cities and how firm behavior shifts between the largest cities such as Chicago and Detroit and close-proximity cities such as Toledo and Milwaukee, when transportation investments are made.

Another geographic extension might consider the macro-level impact as inter-regional shifts based on transportation investment occur. An interesting research question might consider how the economic output of the Midwest shifts when an infrastructure investment makes the trucking sector in Toledo more efficient. As Table X shows, Toledo experiences an increase in Mining sales when trucking becomes more efficient. What this analysis does not do is indicate whether than increase in Mining is due to new mining in Ohio or whether the shipment of commodities mined in Michigan are being shipped to Toledo rather than Detroit. In this capacity, understanding the macro-picture may prove useful to policy makers when assessing how to allocate resources among economic areas in the same state or region.

6.3 Policy Implications

As this is planning research, it is important to connect the findings to policy decisions. The most significant finding is that a significant reduction in freight delay (20%) has minimal impact on policy decisions. Therefore, additional costs and benefits should be considered to gain further insight into the impact of such projects.

Another conclusion is that Input-Output analysis should not be used as the sole tool to justify infrastructure investments. One reason is that it shows regional economic output to decline as freight efficiency improves. Much of this is likely due to limitations of the tool to capture third-order benefits or the impact of price changes. As such, alternative methods designed to consider such impacts should be used in tandem with Input Output.

Lastly, size matters more than the degree of freight specialization in determining the impact of freight investment. While the freight sector has broad reach throughout an economy,

larger and non-freight dependent economies such as Chicago and Minneapolis experience less

leakage than freight-specialized economies such as Toledo and Detroit. This again highlights a

limitation of Input-Output, as it is biased towards larger economies.

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