Measuring the Economic Costs of Urban Traffic Congestion to Business

by

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ABSTRACT

This paper provides key findings from NCHRP Study 2-21, which examined how urban traffic congestion imposes economic costs within metropolitan areas. Specifically, the study applied data from Chicago and Philadelphia to examine how various producers of economic goods and services are sensitive to congestion, through its impacts on business costs, productivity and output levels. The data analysis showed that sensitivity to traffic congestion varies by industry sector, and is attributable to differences in each industry sector's mix of required inputs and hence its reliance on access to skilled labor, access to specialized inputs and access to a large, transportation-based market area. Statistical analysis models were applied with the local data to demonstrate how congestion effectively shrinks business market areas and reduces the "agglomeration economies" of businesses operating in large urban areas, thus raising production costs. Overall, this research illustrates how it is possible to estimate the economic implications of congestion, an approach that may in the future be applied for benefit-cost analysis of urban congestion reduction strategies or for development of congestion pricing strategies. The analysis also shows how congestion reduction strategies can induce additional traffic as a result of economic benefits.

OVERVIEW

While it is clear that increasing traffic congestion does impose costs upon travelers and affect broader business operations, it has been difficult to develop and apply empirical measures of the extent of those economic costs. This paper describes a new modeling approach for analyzing how urban traffic congestion affects businesses and metropolitan-wide economic activity, based on results of NCHRP project 2-21. The paper is organized into five parts: (a) background on the nature of the analysis problem, (b) general approach for analyzing congestion costs, (c) calibration of statistical analysis models, (d) application of scenarios to assess the nature of congestion impacts, and (e) conclusions.

BACKGROUND

Defining Congestion.

Traffic congestion is defined as a condition of traffic delay (i.e., when traffic flow is slowed below reasonable speeds) because the number of vehicles trying to use a road exceeds the design capacity of the traffic network to handle it. Traffic congestion is widely viewed as a growing problem in many urban areas because the overall volume of vehicular traffic in many areas (as reflected by aggregate measures of vehicle-miles or vehicle-kilometers of travel) continues to grow faster than the overall capacity of the transportation system. The resulting traffic slow-downs can have a wide range of negative impacts on people and on the business economy, including impacts on air quality (due to additional vehicle emissions), quality of life (due to personal time delays), and business activity (due to the additional costs and reduced service areas for workforce, supplier and customer markets). This study focuses specifically on the latter type of impact -- how roadway traffic congestion affects the economy, in terms of business costs, productivity and output.

Motivation.

In many metropolitan areas, there are increasing concerns about how the growth of traffic congestion may adversely affect the area's economy (business sales and income), and concerns about the relative return-on-investment associated with alternative projects or policies to address those problems. Unfortunately, the severity and pattern of congestion, as well as the effectiveness of alternative projects or policies to address it, can vary widely from area to area. That can depend on the size and layout of the metropolitan area, its available transportation options and the nature of its traffic generators.

Similarly, there is no single rule of thumb for the economic cost of worsening congestion or the economic benefit of congestion reduction, for that can also differ depending on the area's specific economic profile, as well as its unique pattern of congestion. All of these issues need to be addressed first, before there can be truly meaningful efforts to examine the benefit-cost ratio or return-on-investment of alternative congestion reduction strategies. This was the motivation for the National Cooperative Highway Research Program to fund a study of the economic implications of urban traffic congestion. This paper describes key findings from that larger report [1].

Prior Research on Congestion Impacts.

There have been prior attempts to estimate the economic impacts of congestion through business surveys, including most notably NCHRP Project 2-17(5) [2]. The problem is that such prior attempts found that business managers do not explicitly track the costs of congestion, and hence seldom make any specific attribution of their business costs to congested roads. There are several reasons why they do not do so:

- <u>Hypothetical Nature of Scenarios</u>. Business staff have difficulty predicting their hypothetical responses to what they perceive to be non-realistic scenarios. For a business manager operating in an area of traffic congestion, the existing conditions (including longer commutes, higher costs of parking, and longer delivery times) may be viewed as a pervasive phenomenon or otherwise accepted as part of the cost of doing business. Many people in urban businesses cannot estimate the cost of congestion to their business since they cannot imagine how different the business would be under the purely hypothetical situation in which such congestion is not present.
- <u>Self-Selection Bias</u>: Only survivors can be interviewed. A survey of businesses in congested areas will only include the existing businesses, since any business that could not survive in a congested area would have already closed up or moved out. Hence the remaining businesses tend to be those that are not adversely affected by congestion. This includes offices that are not highly dependent on truck deliveries or in-store shopper visits. It also includes businesses that have the ability to minimize congestion impacts on their operations through flexible scheduling, reliance on internet or telecommunications activities, or use of transit alternatives.
- <u>Differential Sensitivity.</u> Some businesses thrive in high density business districts, and their staff cannot easily distinguish the advantage of density from the disadvantage of congestion delay. For some types of businesses (e.g., offices of banking, finance and business service companies, and restaurants serving them), there can be productivity benefits associated with agglomeration – locating together in high-density business districts, which offset the higher travel and parking costs of doing business in those areas.

For those types of businesses (which typically have low needs for incoming or outgoing freight deliveries), congestion may not even be recognized as a major problem.

Objective of this Study.

Learning from the results of prior research, we examined the economic implications of congestion not by surveying businesses, but rather by using an empirical analysis approach which examines the many aspects of congestion-related costs incurred by different types of business operations in different types of urban settings. We then used statistical analysis of existing business and travel patterns to infer the business productivity loss associated with congestion.

Given the complexity of the problem and the limitations of available data, our study does not provide the final word on economic costs of congestion. Rather, it represents a starting point – showing the many facets of congestion impacts on businesses and local economies, illustrating the types of data necessary to document those costs, and demonstrating how analysis can be carried out and ultimately improved.

GENERAL APPROACH

Recognizing Different Types of Congestion Costs.

To develop an approach for assessing the economic implications of congestion, we start with a typology of the different forms of congestion-related economic impacts, and then identify the common features of how they affect business.

- Travel Cost. At the most basic level, increasing congestion backups mean that some trips on the road system – whether by car, truck and bus – will entail longer travel times for riders and higher vehicle operating costs for vehicle operators. The added time and expense for drivers and passengers are the key components of travel system efficiency measures covered in traditional engineering-based benefit-cost studies. Values can draw upon a wealth of past research on the value of time, travel time reliability factors, vehicle operating expenses and congestion-related accident costs [3], [4], [5], [6]. (See Table 1.)
- Additional Business Operating Costs. Traffic congestion can impose additional costs to businesses associated with freight and service deliveries. For instance, delay in delivering time-sensitive freight can in some cases impose additional inventory costs, logistics costs, reliability costs or just-in-time processing costs onto businesses that ship or receive the products. The recognition of these additional business costs is also consistent with a growing view that it is the freight shippers and receivers, rather than the truck drivers, who are the true "users" of freight transportation systems. Values for these costs can draw upon an emerging body of research in the fields of logistics and just-in-time scheduling [7], [8], [9]. In addition, there is also a body of research indicating that businesses end up absorbing spatial differences in costs of worker commuting within competitive urban labor markets [10], [11].
- Productivity. Over and above the effects of congestion on travel cost and additional business operating expenses, congestion can have further business productivity impacts. Generally, congestion can reduce the size of business labor market areas, customer delivery market areas and/or shopper market areas that can be served or accessed within a limited window of reasonable travel time. This reduction in effective "market reach" can reduce worker access to jobs and shopper access to stores. From the viewpoint of affected businesses, it can reduce their access to specialized labor or material inputs as

well as the scale of their customer markets. There is a growing body of modeling research examining the size of these market scale and accessibility factors [12], [13], [14], [15].

Recognizing Business Responses to Congestion.

There can be a variety of ways in which businesses can respond to these changes. Faced with a change in access or costs of obtaining specialized labor or specialized material inputs, some businesses may shift their product mix. Others may compensate by changing their technology mix of labor and capital inputs. Still others may reduce the size of delivery areas, change their delivery scheduling or pricing policies, or compensate by reducing the number of daily deliveries made per driver. Others may adjust to serve smaller or more specialized markets for workers, suppliers and customers [8], [16], [17]. However, all of these adjustments can still leave a remaining loss of business productivity associated with reduced "economies of scale" in their business operations.

The key aspect of this typology of business impacts is that we recognize that different types of businesses are likely to be affected and compensate for congestion in different ways. This means that various types of businesses may have different "production functions" representing how they use workers and materials to produce and delivery their products and services. These production functions affect the extent to which various types of businesses are affected by congestion. At the aggregate urban level, then, the economic impacts of congestion can thus vary depending on the spatial pattern of where congestion occurs and the mix of businesses in those areas.

Developing a Statistical Modeling Approach.

While reported perceptions of individual business managers are an unreliable means of assessing economic impacts of congestion, it is possible to apply statistical analysis methods to identify the nature of business sensitivity to congestion. This can be done through economic modeling which relates observed business location patterns to spatial differences in relative costs of market access for labor and materials, including worker commuting and business product/service delivery costs. This approach recognizes that changes in travel times due to congestion can differentially affect business costs in different industries, and different locations within urban regions.

An important element of the economic model approach for this study is the concept of differentiation among inputs. This differentiation represents the preference that businesses have for a choice among inputs, including specialized labor and specialized materials used in the production or provision of the products and services they provide. A higher degree of differentiation in the inputs that a firm uses allows the firm to choose a combination of inputs that best suits their needs and maximizes their profits. When congestion causes a decrease in access, firms may have to pay a higher cost to attract and retain their current mix of suppliers or workforce, or else substitute closer suppliers and workers who do not have the special characteristics they desire. In other words, congestion can reduce the diversity of choices for available inputs so that a firm must settle for an inferior substitute. When access increases, as when congestion decreases, a firm can potentially realize a benefit in access to superior goods. The production function model captures this effect.

Another central concept in this approach is that businesses can adjust to changes in cost arising from greater or lesser access to diverse inputs. These potential adjustments are embodied in production functions, and in particular, a term called the elasticity of technical substitution among inputs. The elasticity of technical substitution refers to the importance of variety in goods and services supplied by various industries to all firms within a particular region. Firms that value differentiation more can realize a productivity gain by tapping into a larger market for their inputs. Those that do not are relatively indifferent to the larger market afforded by increased transportation access. Industries providing more variety tend to have a lower elasticity of substitution. This means that those businesses seek inputs from a wide geographic area and are willing to pay for the higher transportation costs for those inputs. On the other hand, industries supplying less specialized inputs tend to have a higher elasticity of substitution. Such firms get inputs from wherever it is convenient nearby and are less willing to pay additional transportation costs for their inputs.

However, it is known that businesses do not have to just absorb added costs of freight shipping or worker commuting caused by congestion. Rather, they have some ability to adjust to those cost changes. Thus, the introduction of realistic production functions can help to better calculate the true cost effects of congestion on business. The production function recognizes that one employee is not a perfect substitute for another employee even if they are in the same occupation. It also recognizes that the product or service of one supplier may not be a perfect substitute for that offered by another potential supplier. Therefore, employers will be able to enhance productivity by selecting the most appropriate possible suppliers and employees for their needs. It then follows that the larger the area from which businesses can draw suppliers and workers, the easier and less expensive is the task of selecting the optimal mix.

STATISTICAL MODEL CALIBRATION

Concept of Production Function Models.

The research team conducted extensive data assembly and statistical model analysis for the Chicago and Philadelphia metropolitan areas. The analysis models were developed to examine the degree of sensitivity of various types of business activity to the costs of transporting products and costs of worker commuting. A "production function" related observed levels of business activity in various parts of the urban areas to spatial differences in relative costs of market access for labor and materials. A key element of the analysis was an explicit recognition that while businesses incur a variety of costs associated with congestion, they do have some ability to adjust levels of activity and trade off among labor and material inputs. The introduction of realistic "production functions" can recognize that fact and help to better portray the true costs of congestion on business.

Development of Data Sets.

The first step in the calibration of statistical models was to obtain detailed data on patterns of business locations and origin-destination patterns of commuting trips, truck trips and other business travel patterns by traffic activity zone. There were 1,669 zones in the Chicago region and 1,510 zones in the Philadelphia area. The commuting trip patterns (origin- destination matrices and trip lengths) were differentiated by occupation and the truck trip patterns were differentiated by industry. (See Figures 1 and 2).

Calculation of Direct Costs.

Additional data measured the value of travel time and operating costs for commuting and truck trips by origin-destination pair. These values were based on available information on how the pattern of business inventory, logistics, reliability and production process costs differ by type of business, type of worker occupation, type of commodity shipped and type of vehicle. Table 2 summarizes calculated values used in our study to represent composite values of shipping costs, reliability costs and shipment values associated with delivery delay for different types of delivered products. Table 3 summarizes the calculated costs of commuting for different occupation groups.

Specification of a Production Function Model.

A multiple regression analysis was conducted to statistically develop coefficients which estimate differences in levels of business activity in urban zones (the dependent variable) as a function of various factors (independent variables), including differences in relative costs of accessing labor (commuting costs) and materials (delivery costs) from those zones. Three basic facts underlie our economic modeling approach:

- Business Market Size. The observable location pattern of businesses reflects the fact that some types of business have a few large establishments serving a wide area, while other types of businesses have many small establishments each serving a smaller local area. These patterns reflect the fact that different types of businesses have different worker (occupation) and supply (commodity) needs, as well as different product/service delivery markets. In effect, these patterns reflect the degree of specialization of the different types of businesses in terms of workers and products.
- Business Production Processes. The degree to which different types of business incur productivity losses from traffic congestion depends on how congestion affects their direct travel-related costs, their production costs, and their ability to adjust to smaller markets (which in turn reflects the extent to which they depend on access to specialized workers or materials).
- Business Mix. The mix of businesses in downtown business districts, outlying industrial areas and bedroom communities are very different – reflecting their different needs for access to specialized worker skills, specialized materials or specialized markets.

These relationships mean that congestion can cause not only changes in the direct cost of production, but also additional changes in accessibility to specialized inputs. By increasing transportation costs, congestion thus changes the distribution of shipments and trips as it reduces access to specialized workers and customer markets.

In contrast, policies or investments that reduce congestion can lead to additional reduction of business operating costs as firms are now able to utilize labor that more specifically meets their production needs, and serve broader customer markets. Effects of congestion reduction on productivity may thus come from improved access to broader worker and customer markets, as well as from logistic and scheduling efficiencies, and scale economies.

To illustrate the methodology for this study, elasticities of technical substitution among various types of labor, capital and intermediate inputs were estimated through regression models, using a “Cobb-Douglas” formulation. This is a simplified production function in which the elasticities of substitution (for specific product types and worker occupations) are assumed to be constant, and there is a consistent relationship between percentage changes in prices and demand. Future studies may adopt more sophisticated formulations.

The statistical model parameters thus indicated the “elasticity of substitution” among product inputs and reflected the extent to which firms purchase supplies which are specialized as opposed to basic commodities. In general, the more that the materials purchased are not specialized, the more firms can substitute closer suppliers when costs of obtaining products from more distant suppliers increase, as would occur with rising congestion. These elasticity parameters thus indicated the extent to which businesses can adjust in order to offset congestion costs.

Model Parameters –Elasticities of Substitution.

The technique used to estimate the elasticity of substitution parameters was maximum likelihood, which finds the parameters most likely to produce the observed number of trips in each zone and for each industry. All these coefficient estimates had a high degree of statistical accuracy and significance, as reflected by low standard deviations. The actual estimation and application of regression coefficients (production model parameters) are the subject of considerable discussion in the full NCHRP report. Key findings are shown in Tables 4 and 5, and are summarized below:

High Elasticity. A high elasticity of substitution occurs when the supplier market is homogeneous (i.e., with little difference in quality or function of product), so that buyers are very willing to switch suppliers to save cost. For a purely homogenous commodity in a market with competing suppliers, a one percent increase in product cost for one supplier would lead to a 100 percent loss of sales to lower cost competitors.

In the truck (freight delivery) models, the highest elasticity of substitution among inputs was found to occur for agricultural commodities. In the worker commuting models, the highest elasticity of substitution was found to occur for service occupations, private household (e.g., maid) occupations and clerical occupations. For these categories of business products and worker occupations, the models indicate that businesses are more concerned with lower cost than with finding specialized materials and worker skills, and tend to seek more local sources rather than pay additional transportation costs associated with congestion.

Low Elasticity. A low elasticity of substitution occurs when the supplier market is differentiated (in terms of product quality and specialized function), and buyers value access to that differentiated market. In that case, buyers are less willing to switch suppliers due only to a change in product cost. In a fully differentiated product market, every supplier is unique, so individual producers do not lose sales if the price of their product rises.

In the truck (freight delivery) models, the lowest elasticity of substitution among inputs was found to occur for manufactured products, since those goods tend to be highly differentiated. In the worker commuting models, the lowest elasticity of substitution was found to occur for executives and managers, precision production occupations and transportation and material moving occupations. For these categories of business products and worker occupations, the models indicate that businesses seek a broader market area to obtain specialized materials and worker skills and, in the face of congestion, will pay a premium to reach them.

Interpretation of Model Coefficients

In general, the calibrated models for Chicago and Philadelphia yielded consistent results:

Industry Differences in Congestion Costs. The results for both areas showed that industries with broader worker requirements and higher levels of truck shipping absorb higher costs associated with congestion. They also benefit most from congestion reduction.

Industry Sensitivity to Congestion Costs. The production function models also showed that firms with lower-skilled labor requirements or non-specialized (commodity) input requirements tend to be hurt relatively less by congestion (and benefit relatively less from congestion reduction) than those with requirements for highly-skilled labor or highly-specialized material inputs.

Effect on Travel Patterns. The models confirmed that congestion does reduce the agglomeration benefits of urban areas by reducing access to specialized labor and delivery markets, while businesses adjust with shorter trip lengths. Conversely, congestion reduction can provide greater benefits to businesses associated with access to broader labor and delivery markets.

Economies of Scale. The models also illustrated how traffic congestion has the effect of nullifying some of the agglomeration benefits of operating businesses in larger urban areas. The labor cost model, for instance, indicated that doubling the effective labor market size leads to an average 6.5% increase in business productivity.

ILLUSTRATIVE CONGESTION SCENARIOS

The actual economic impacts of traffic congestion can differ by metropolitan area, depending on its economic profile and business location pattern. The case study areas examined here also illustrate how congestion impacts can differ depending on the nature of the congestion scenario. While it was beyond the scope of this study to define or investigate the effectiveness of any particular transportation policies or strategies, some hypothetical scenarios were created to illustrate how they different forms of congestion timing and location can differentially affect business activity and costs. They were: (Scenario #1)a 6% reduction in truck delivery delays in the downtown business district; (Scenario #2) a 6% reduction in truck delivery delays in a central city industrial zone outside of downtown; (Scenario #3)a 10% reduction in worker commuting delays region-wide, and (Scenario #4) a 50% reduction in commuting delays only for an outlying residential area. Key findings are summarized as follows:

Distribution of Impacts. The biggest savings from reductions in truck delivery delays were associated with service industries. The economic impacts were also dramatically different depending on where the congestion occurred. When the congestion reduction for trucking was centered on the downtown business district of both cities, the economic benefit were largely concentrated on those businesses located downtown. That is because many of those downtown businesses are service oriented, relying on incoming deliveries of supplies but with relatively modest movements of outgoing truck deliveries to other parts of the metropolitan area. In contrast, when the congestion reduction was centered around an older industrial area in both cities, then the economic benefits were widely distributed amongst industries and business locations throughout the metropolitan area. That is because the directly-affected businesses had a high level of outgoing truck shipments, serving broad industries and locations – from the downtown to outlying fringe areas.

The economic impacts associated with worker access were also dramatically different depending on where the congestion occurred. When congestion reduction was evenly distributed region-wide, the economic benefit was still largest for those businesses located on the periphery of the metropolitan area. That is because there tend to be longer travel distances for workers and incoming deliveries coming into those businesses, and hence they are most highly affected by increases or decreases in congestion costs. In contrast, when the congestion reduction was centered around an area with many skilled and educated workers, the economic benefit was broadly distributed among locations throughout the metropolitan area. It was also greatest for types of businesses employing executives and precision-skilled workers.

Overall Magnitude of Impacts. All four scenarios represent some form of reduction in either commuting delays or truck delivery delays, and their impacts are summarized in Tables 6 and 7. Two variations of the models were run. In the "fixed production" version of the models, commuting and truck delivery distances were assumed to be fixed. In the "flexible production" version, the elasticities of technical substitution were used to estimate additional impacts associated with changes in access to labor and delivery markets, and their productivity benefits. These results indicate that if we allow for flexible production functions (i.e., substitution among different workers and materials), then a decrease in congestion can lead to an increase in business productivity that is greater than the mere savings obtained if production was fixed (in which the exact same suppliers and workers were used). That is because a decrease in congestion can allow urban businesses to access a broader pool of differentiated supplier products and worker skills. This access to broader markets is an economic benefit that also shows up as an induced increase in vehicle-miles of travel.

While the percentage magnitude of these impacts appear to be small, the actual dollar magnitudes are very significant. For the truck delivery scenarios (#1 and #2), the annual changes in business costs were respectively $252 - 272 million for Chicago and $23 – 100 million for Philadelphia. For the worker commuting scenarios (#3 and #4), the annual changes in business costs were respectively up to $350 million for Chicago and $200 million for Philadelphia.

A recent study of urban congestion published by the Texas Transportation Institute (TTI) has estimated that total congestion costs in the Chicago and Philadelphia urbanized areas total $4.1 and $1.3 billion annually [18]. The estimation of congestion scenarios in this study are not comparable to the TTI study because of different methods. Our study used localized urban travel demand forecasting models that incorporated population and employment patterns and simulated changes in trip tables and vehicle routing in response to congestion changes, whereas the TTI study used the roadway database of the Highway Performance Monitoring System (HPMS). While the forecasting models (used in this study) are sensitive to changes in travel costs, they do not provide the coverage of VMT on minor roads that is captured by the HPMS. Our study also used differential values of time that varied by worker occupation and industry type for deliveries, as opposed to the flat values used in the TTI study. Finally, our study focused only on commuting and truck delivery trips, and did not cover shopping, recreational and personal business trips. However, the partial results emerging from this study imply costs of congestion that are potentially higher, but clearly still within the same order of magnitude, as those reported in the TTI analysis.

CONCLUSIONS

Contribution of this Study

More Complete Measurement. The most important aspect of this study is that it attempts to achieve a more complete representation of the real monetary cost of congestion to local or regional economies than the mere accounting of traveler expense and time. This includes the incorporation of additional productivity costs associated with travel time variability, worker time availability, freight inventory and logistics/scheduling, just-in-time production processes, and economies of market access.

Link to Productivity Studies. The study also incorporates a concept of production functions that attempt to recognize the ability of businesses to sometimes substitute among inputs (and workers) to some degree, as they adjust to the higher costs of travel. This effect is of particular note, for it helps to reconcile transportation impact analysis methods with more aggregate studies of the relationship between business productivity and transportation investment. While some of the specific numbers generated in this study are affected by model assumptions, the analysis does provide insight into the ways in which travel time reduction can induced traffic growth.

Scale Economies. The economic analysis further demonstrates how congestion can effectively shrink business market areas and reduce the scale economies (agglomeration benefits) of operating in large urban areas.

Application for Policy Testing. The product of this study is a demonstration of a general approach that can be applied for broader analysis of the economic costs of congestion around the country. The model results show that a congestion alleviation strategy that explicitly considers impacts to firms in terms of their costs of doing business can provide a fuller picture of the trade-offs among alternative investments than a traditional comparison based merely on traveler costs.

Remaining Needs

This study is also useful in identifying needs for further research. They include:

(1) Assessing the costs and traffic impacts of alternative congestion reduction strategies. This study focused on developing ways to measure congestion impacts, and thus relied on simplified, hypothetical scenarios to test those measurement techniques. Future studies need to examine the costs or efficacy of specific transportation policies and strategies to mitigate congestion in different types of land use and economic settings.

(2) Measuring congestion impacts for additional classes of trips. This study focused on measuring economic impacts of congestion for local truck delivery costs and workforce-related costs. Future studies need to also examine impacts on personal trips and shopping trips, and that requires inter-zonal data on their trip patterns and trip lengths.

(3) Obtaining greater detail on truck movements. This study utilized detailed origin-destination data on commuting patterns (from Census journey-to-work statistics), and less detailed information available on truck movements. Future studies need to obtain more detailed information on industry and commodity breakdown for products as well as data on truck trips with external origins or destinations, plus deliveries of products and services via car, van and light delivery vehicle.

(4) Testing measurement methods for additional metropolitan areas. This study involved substantial effort working with two metropolitan planning organizations to obtain and derive inter-zonal data on trip patterns for specific trip purposes, industries and occupations. Now that the methodology has been demonstrated to be feasible, further testing is needed to establish the level of consistency in statistical relationships among a broader range of metropolitan areas.

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LIST OF TABLES AND FIGURES

Table 1. Value of ~~One Hour of~~ Travel Time by Benefit Category and Vehicle Type

$ per Person-Hour	Vehicle Class						
Category	Small Auto	Medium Auto	4-Tire Truck	6-Tire Truck	3-4 Axle Truck	4-Axle Comb.	5-Axle Comb.
On-the-Clock							
Labor/Fringe	26.27	26.27	8.02	21.88	18.22	21.95	21.95
Vehicle	1.72	2.02	2.18	3.08	8.80	7.42	7.98
Inventory	0.00	0.00	0.00	0.00	0.00	1.65	1.65
Total	27.99	28.29	20.20	24.96	27.02	31.02	31.58
Other Trips							
Percentage of Miles	90%	59%	0%	0%	0%	0%	0%
Value	12.78	12.78	--	--	--	--	--
Weighted Average	14.30	14.33	15.08	25.27	27.91	31.64	32.25

Source: Federal Highway Administration, The Highway Economic Requirement System (updated 3/97).

Table 2. Calculated Shipping Delay Costs, by Industry

Delivered Product	Direct User Cost (per hr.)	Reliability Cost (per minutes of delay squared)	Value of Shipment
Agriculture	$25.07	$7.00	$16,764.55
Mining	$25.04	$0.83	$5,469.32
Manufacturing	$25.66	$11.20	$34,681.55
Service/Other	$0.00	$0.00	$135.00

Source: calculated by NCHRP #2-21 project team, based on literature review.

Table 3. Calculated Commuting Delay Costs, by Occupation

Occupation	Average Hourly Wage
Precision Production and Crafts	$16.20
Transport and Material Moving	$15.08
Executive, Admin, Managerial	$21.90
Technicians	$17.40
Machine Operators	$12.25
Protective Services	$9.79
Helpers and Laborers	$11.03
Sales Occupations	$15.65
Professional Occupations	$22.39
Clerical Occupations	$12.64
Private Household Occupations	$ 4.57

Source: Calculated by NCHRP #2-21 project team, based on literature review.

Table 4. Estimated Elasticity of Substitution for Material Inputs, by Industry

Delivered Product	Coefficient of Substitution	Standard Deviation
Chicago		
Agriculture	14.51*	0.42
Mining	4.62*	0.28
Manufacturing	7.44*	0.05
Service/Other	10.61*	0.01
Philadelphia		
Agriculture	15.00*	0.33
Mining	10.10*	0.21
Manufacturing	6.81*	0.01

** Statistically significant at the 99 percent confidence level.*

Table 5. Elasticity of Substitution Coefficients for Labor, by Occupation

Occupation Category (Chicago)	Coefficient of Substitution	Standard Deviation
Precision Production, Craft, Repair	11.27*	0.017
Transportation and Material Moving	11.35*	0.028
Executive, Administrative, Managerial	12.25*	0.016
Technician and Related Support	12.83*	0.031
Machine Operators, Assemblers, Inspectors	13.04*	0.024
Protective Services	13.21*	0.043
Handlers, Cleaners, Helpers, Laborers	13.75*	0.031
Sales	13.05*	0.018
Professional Specialty	14.57*	0.018
Administrative Support	14.66*	0.016
Private Household Services	16.02*	0.140
Services (excl. household and protective)	16.49*	0.024

** Statistically significant at the 99 percent confidence level.*

Table 6. Impact of Scenarios Affecting Commuting Trips Only

	Current (Base Case)	Percent Change Due to Scenario: With Fixed Production	Percent Change Due to Scenario: With Flexible Production
Scenario: 10 Percent Constant Region-Wide Reduction in Commuting Time			
<u>A. Chicago Region</u>			
VMT / Day	35.8 million	0.00%	+1.75%
Commuting Cost / Day	$47.0 million	-3.41%	-1.7%5
Total Labor Cost / Day	$382.3 million	-0.42%	-0.42%
<u>B. Philadelphia Region</u>			
VMT / Day	29.9 million	0.00%	+1.12%
Commuting Cost / Day	$41.8 million	-2.21%	-1.41%
Total Labor Cost / Day	$300.2 million	-0.31%	-0.31%
Scenario: 50 Percent Decrease in Vehicular Travel Time Only for One Sub-Area			
<u>A. Chicago Region</u> (Congestion Change only on Lake County Commuters			
VMT / Day	35.8 million	0.00%	+0.63%
Commuting Cost / Day	$47.0 million	-0.94%	-0.51%
Total Labor Cost / Day	$382.3 million	-0.12%	-0.12%
<u>B. Philadelphia Region</u> (Congestion Change only on Chester Commuters)			
VMT /Day	29.9 million	0.00%	+0.05%
Commuting Cost / Day	$41.8 million	-0.07%	-0.04%
Total Labor Cost / Day	$300.2 million	-0.01%	-0.01%

Table 7. Impact of Scenarios Affecting Truck Delivery Trips Only

	Percent Change Due to Scenario	
	With Fixed Production	**With Flexible Production**
Scenario: 6 Percent Reduction in Delivery Cost for CBD Only		
A. Chicago Region		
VMT		+0.5932%
Productivity		+0.3630%
Total Input Cost	-0.0099%	-0.0107%
B. Philadelphia Region		
VMT		+0.727%
Productivity		+0.884%
Total Input Cost	-0.013%	-0.014%
Scenario: 6 Percent Reduction in Delivery Cost for Industrial Corridor Only		
A. Chicago Region (Congestion Change only on Part of Cook Co. South of CBD)		
VMT		+0.3970%
Productivity		-0.1746%
Total Input Cost	-0.0095%	-0.0099%
B. Philadelphia Region (Congestion Change only on Area Around Chester, PA)		
VMT		+0.0926%
Productivity		-0.0088%
Total Input Cost	-0.0029%	-0.0031%

Figure 1. Commuting Trip Length, by Occupation (Chicago Area)

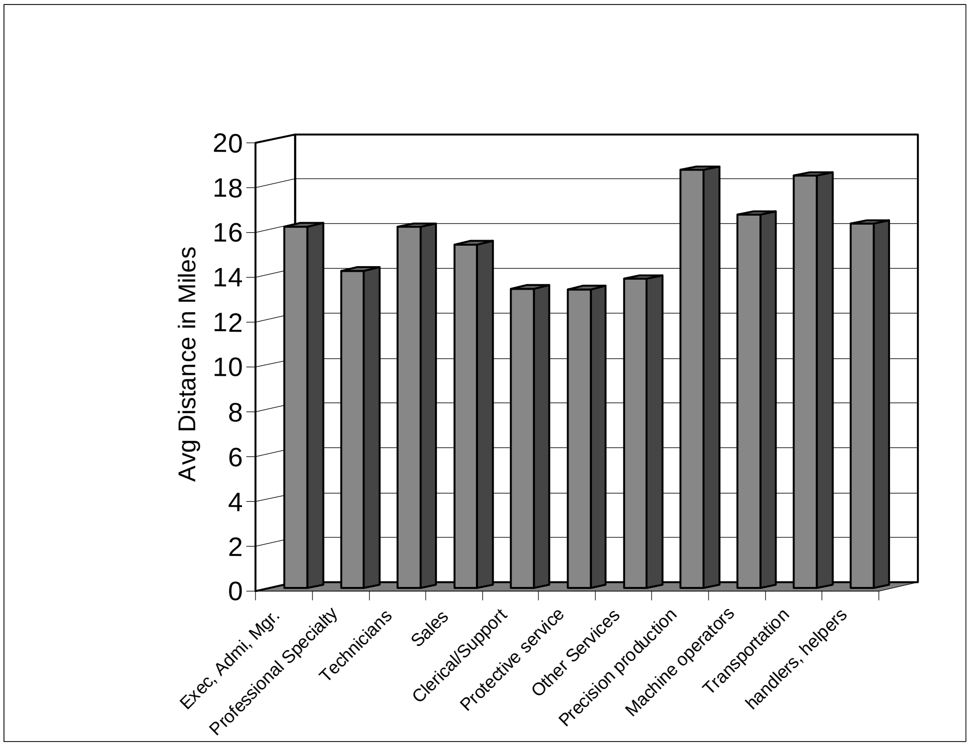

Figure 2. Location Pattern of Jobs by Industry in the Chicago Area