U.S. Department of Transportation

Federal Highway Administration

FREIGHT TRANSPORTATION

Improvements and the Economy

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Executive Summary

Despite the wealth of information on transportation's contribution to the economy, debate continues on the linkages between transportation improvements and economic performance and the relative strength of these links. Focusing on freight transportation, this report summarizes the results of the Federal Highway Administration's (FHWA's) work on the economic benefits of transportation improvements. In addition to this summary, two analytical reports are included as appendices: 1) Economic Effects of Transportation: The Freight Story; and 2) Transportation Infrastructure, Freight Services Sector and Economic Growth: A Synopsis.

Three methods—macroeconomic and microeconomic research and general equilibrium approaches—have been employed to study the linkages between transportation and the economy. Each of these is discussed in this report.

- Macroeconomic research focuses on the broad link between transportation spending and U.S. Gross Domestic Product (GDP). FHWA-sponsored research in the 1990s on the effects of highway investment definitively determined that highway capital contributes to economic growth and productivity, although the effect was greater in the 1950s and 1960s when the Interstate highway system was being built.

- Microeconomic research, particularly benefit-cost analysis (BCA), evaluates the effects of transportation improvements on individual firms, such as cost savings and service improvements. Accordingly, BCA has become an important tool for assessing the benefits of transportation investments. Traditional BCA, however, does not capture all the benefits of highway investments, particularly those realized by shippers, such as faster and more reliable delivery.

- General equilibrium approaches focus on measuring the benefits of transportation improvements gained from regional specialization and technological changes. The use of this method to analyze linkages between transportation improvements and the economy is still relatively new.

Decisionmakers need detailed information and analytical tools to prioritize projects and determine spending levels. Since many decisions on transportation investments are made at the local level, FHWA's Office of Freight Management and Operations is working on refining BCA to provide a fuller accounting of the benefits of transportation investments for freight movement. To date, only the benefits to carriers have been counted, ignoring the benefits to shippers. This new research documents a range of short-term (first-order) and long-term (second-order) benefits for both carriers and shippers. First-order benefits are immediate cost reductions to carriers and shippers in terms of reduced transit times and reliability. Second-order benefits include efficiency improvements and further cost reductions. These benefits result from improvements in logistics and supply chain management and changes in a firm's output or location. Additional research was conducted to develop a benefit-cost model that could provide more accurate estimates of the benefits of freight improvements. Development of this tool will be a major gain in analytical capability, helping decisionmakers conduct both project planning and assessment in a manner that recognizes more explicitly the unique contributions that transportation improvements make to a region's economy, particularly those that move freight more efficiently.

FREIGHT TRANSPORTATION IMPROVEMENTS AND THE ECONOMY

Billions of dollars are spent annually to maintain and improve the highway system to benefit passenger and freight transportation. To understand the relationship between highway investments and national economic goals, the Federal Highway Administration (FHWA) sponsors economic research. This summary report focuses on recent research efforts by the Office of Freight Management and Operations to refine benefit-cost analysis (BCA) to provide a more realistic accounting of the benefits of transportation investments. As background information, the report also highlights past FHWA-sponsored macroeconomic research and briefly discusses General Equilibrium Approaches (GEA), another method for analyzing the linkage between transportation and the economy. The report begins by describing the challenges facing freight transportation today.

Freight Transportation: Today's Challenge

The volume of freight has grown significantly over the past few decades. Between 1975 and 1997, domestic intercity tons of freight grew by about 60 percent, with the air and trucking modes experiencing the fastest growth (Eno 2002). In 1998, the transportation network moved 15 billion tons of goods valued at more than $9 trillion (1998 dollars). Freight volumes are expected to increase by another 70 percent by 2020 according to the Freight Analysis Framework (FAF), a comprehensive database and policy analysis tool. Likewise, the value of goods moved is expected to increase from $9 trillion in 1998 to nearly $30 trillion (1998 dollars) in 2020. Moreover, international trade is forecast to grow faster than domestic trade (USDOT FHWA 2002a). In 2001, U.S. international merchandise trade accounted for 22 percent of GDP (USDOT BTS 2003).

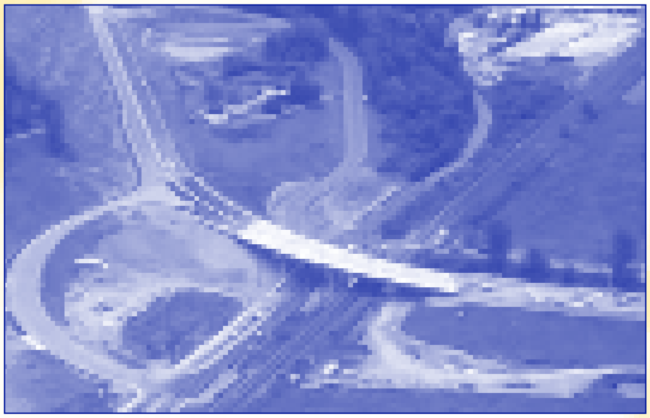
The way in which goods are moved has evolved as well. Businesses and individuals now demand more flexible and timely service, increasing the importance of an efficient and reliable freight transportation system. Research on trucking has shown that shippers and carriers value transit time in the range of $25 to $200 per hour, depending on the product being carried. The value of reliability (i.e., the cost of unexpected delay) for trucks is another 50 percent to 250 percent higher. (USDOT FHWA 2002c). Another trend is the increasing use of intermodal transportation to move freight. The rise in intermodalism emphasizes the importance of infrastructure that connects different modes, especially at international gateways or where modes converge at transfer points. Consequently, not only is the condition and performance of each modal network important, but so too is how different modes fit together to provide a continuous transportation system.

The growth in freight movement is placing enormous pressure on an already congested highway system. Between 1980 and 2002, truck travel grew by more than 90 percent while lane-miles of public roads increased by only 5 percent. No slowdown in freight transportation growth is in sight. FAF estimates that the percentage of urban Interstates carrying 10,000 or more trucks will increase from 27 percent in 1998 to 69 percent in 2020 (USDOT FHWA 2002a).

To close the gap between demand and capacity, new public investments are needed. Investments are likely to include a mix of approaches, including adding new capacity, improving existing infrastructure, streamlining operations, and using intelligent transportation system (ITS) technologies to provide real-time travel information or gateways clearances to enhance the performance of vehicles and operators.

Because of significant growth in freight on an increasingly congested network, decisionmakers in the public sector are giving more attention to the effects of congestion on freight transportation and the need for freight-specific investments. The Alameda Corridor project in California is a recent and highly visible example of a freight-specific investment that also significantly improved passenger traffic. The 20-mile corridor that extends from downtown Los Angeles to the Ports of Los Angeles and Long Beach was often choked with traffic impeded at rail crossings by rail lines that snaked across the roadway at grade. The project eliminated 200 highway-rail grade crossings, widened Alameda Street, and improved traffic signal controls to reduce traffic delays, enhance safety, improve rail operations, and minimize truck drayage in and around the Ports of Los Angeles and Long Beach. These improvements are expected to eliminate an estimated 15,000 hours of delay per day for vehicles that used to wait for trains to pass (ACTA 2002).

Other freight projects under development include the FAST (Freight Action Strategy for Everett-Seattle-Tacoma) Corridor serving the Ports of Everett, Seattle, and Tacoma; the Portway and Port Inland Distribution Network serving the Port of New York and New Jersey; and the Chicago Regional Environmental and Transportation Efficiency (CREATE) project. The CREATE project will eliminate 25 rail-highway crossings and 6 rail-rail grade crossings and improve rail connections and crossovers in 5 rail corridors traversing the region. Expected benefits include a decrease in local highway delay and its associated costs to motorists, a reduction in rail commuter time, and a decrease in highway-rail grade crossing accidents (AAR 2003). All of these projects illustrate the use of multimodal freight services to address the mutual interests of freight and the community.



FAST Corridor project: New highway bridge over railroad near Tacoma.
Source: FAST

Attention is also being placed on investments in new ITS freight technologies, such as the Electronic Freight Manifest (EFM) system. In operational tests at the Chicago O'Hare International Airport and New York City-JFK International Airport, EFM reduced the time spent on processing manifests and transferring loads from one mode to another by 56 percent to 100 percent. Furthermore, processing drivers at air cargo facilities was two to four times faster than the manual, paper-based system. The time saved resulted in estimated cost savings per shipment of $1.50 to $3.50, depending on the kind of business (USDOT FHWA 2003a). On top of the economic benefits, the EFM system enhanced security through the use of biometrics and smart cards to document and control access to cargo.

Significant public funding will be required to build and maintain transportation infrastructure and invest in new technologies. Investment analysis is an important part of developing future strategies for closing the gap between freight demand and transportation capacity. However, investment analysis must be supplemented with more fundamental information on the relationship between freight transportation investment and the country's Gross Domestic Product (GDP). Quite rightly, policymakers, taxpayers, and investors need clear information to help define the appropriate level of spending to maximize transportation system productivity and public benefits. To do this, decisionmakers must have high-quality data and analytical tools. FHWA's research on the linkage between transportation improvements and the economy is aimed at giving decisionmakers the information and tools needed to invest wisely and prioritize future projects.

Understanding the Links Between Transportation and the Economy

Despite the wealth of information that economic research has provided, debate continues on the linkages between transportation improvements and economic performance and the relative strength of these links. Disagreements over the ways in which the two are linked and over how to measure the effects are at the center of the debate. Three broad methods have been employed to study these linkages: macroeconomic and microeconomic research and General Equilibrium Approaches.

A large amount of FHWA-sponsored work focused on the macroeconomic benefits of transportation investments, usually measured by how these investments would affect GDP. This work, particularly that of Nadiri and Mamuneas, is discussed briefly in Box A. Although useful in understanding the overall effects, macroeconomic studies do not shed light on the mechanisms by which investments lead to benefits. For example, macroeconomic research does not tell us how building a road improves industrial productivity or how it affects a specific area.

Box A: Macroeconomic Research

Most macroeconomic studies have shown a positive association between infrastructure investment and economic growth. However, the degree to which the economy is stimulated is the subject of much analysis. Some of the early work in the United States (Aschauer 1989, Munnell 1990) focused on public investment in infrastructure of all types (transportation, water, and wastewater treatment) and found very large rates of return. This work came under criticism by other economists (Hulten and Schwab 1991). In particular, other researchers argued that the rates of return on public investment were implausibly high and the causation found between public investment and productivity growth might be spurious or even run in the opposite direction. To address these and other concerns, FHWA sponsored new research in the 1990s by M. Ishaq Nadiri and Theofanis Mamuneas.

Nadiri and Mamuneas (1996) measured the contribution of highway capital to private sector productivity. Estimating the effect of public highway investment on the economy between 1950 and 1989, they found that total highway capital does contribute to economic growth and productivity at industry and national economy levels, although the contribution is more modest than suggested by earlier studies (Aschauer 1989, Munnell 1990) and can vary over time. Nadiri and Mamuneas found that the return on investment was highest during the 1950s and 1960s when there was a shortage of highway capital stock and the Interstate Highway System was under construction. The rate of return declined in the late 1960s as the network was completed. In the 1970s and 1980s, increasing shares of annual highway investment went to maintenance; the rates of return approached levels close to that of private investment. This suggested an adequate supply of highway capital in the aggregate.

Further research by Nadiri and Mamuneas (1996 and 1998) confirmed the role of transportation investments in economic growth. Simply put, more and better roads reduce the cost of production in most industries at a given level of output by making it faster and cheaper to obtain parts and raw materials and to get finished products to market. Moreover, lower costs lead to lower prices and greater demand, which translate to a growth in output. Nadiri and Mamuneas concluded that the road-improvement program has been an enormous success with large benefits to society.

Two other points are worth bearing in mind, however. First, these results are for total highway spending. Nadiri and Mamuneas' research shows that rates of return on non-local highways, such as the Interstate Highway System, are approximately 5 percent to 7 percent higher. Second, the rates of return calculated by Nadiri and Mamuneas are for the producers of goods and services as a whole. They do not include the benefits that accrue to consumers who also use highways when they commute to work or make trips to the grocery store, for example. Since these types of trips account for a large share of highway usage, benefits are likely to be quite large. More research is needed to capture these benefits and integrate them with the work that has already been done (USDOT FHWA 1998).

Microeconomic research has been conducted to determine the benefits of transportation improvements to individual firms. Microeconomic studies, which typically use a benefit-cost analysis framework, are useful in assessing individual projects, but they underestimate the overall effects of transportation investments by ignoring the benefits that accrue to shippers from cost savings and service improvements. FHWA sponsored research to improve benefit-cost analysis so that it can take these factors into account.

General Equilibrium Approaches are another way of analyzing the economic effects of transportation improvements. GEA focuses on the role transportation improvements play in bringing about economic growth through regional specialization and technological changes. These analytical approaches are briefly discussed in Box B.

Box B: General Equilibrium Approaches

General Equilibrium Approaches (GEA) are another way of analyzing the economic effects of transportation improvements. GEA focuses on measuring the benefits of transportation gained from regional specialization and technological changes. GEA also highlights the importance of geography in determining the effects of transportation improvements by emphasizing the notion that the benefits of a transportation infrastructure project will not be the same in different places or at different times. These benefits typically are not captured by either macroeconomic or microeconomic studies. In recent years, researchers have examined GEA to draw out its implications for analyzing transportation improvements (Appendix B).

Regional Specialization

One of the main benefits of transportation is that it enables regional specialization in the production of goods. Because each region has a different mix of attributes, such as natural resources and labor skills, the ability to efficiently grow or manufacture products will vary. Moreover, when a region specializes in producing a few products, it can produce them in greater quantities at a lower cost. The benefits of regional specialization, however, go only as far as the reduction in production costs outweighs transportation costs. Hence, these benefits depend on the cost and quality of transportation. As transportation becomes cheaper and more reliable, trade will increase. Change in the demand for transportation is a good indicator of the benefits of regional specialization.

Theoretically, benefit-cost analysis can capture the benefits of trade. In practice, this is a difficult proposition because benefit-cost calculations are made before project implementation. This requires an analyst to predict the effects of the project on trade, which is made even more difficult by the fact that some changes may occur over a long period of time. Therefore, an initial step in assessing the effects of transportation improvements on the economy through gains from regional specialization is to conduct a series of benefit-cost analyses on past projects. To study the full effects, analyses might be made several years or even decades after a project is completed.

Although useful, regional specialization does not explain some aspects of trade. In many cases, similar products are traded between regions and countries with comparable endowments. For example, Canada and the United States, two countries similar in many ways, trade a large number of automobiles and automotive components with shipments going in both directions. Another general equilibrium approach, known as the "New Economic Geography" explains trade as a result of economies of scale and product differentiation rather than differences in endowments. Trade allows producers to reach broader markets for goods that may differ only slightly from those of their competitors. Larger markets mean economies of scale for producers. Moreover, trade in goods that differ in subtle ways gives consumers a wider variety of products from which to choose. Today's seemingly endless variety of automobiles and electronics allows consumers to pick products that closely match their needs, thereby maximizing their utility.

Product variety also suggests that today's economy is not one in which goods are completely interchangeable—a key component of what economists call perfect competition. When products are not perfect substitutes, producers maintain some power to control demand and to retain more of the gain from cost reductions. Benefit-cost analysis measures only the benefits of transportation improvements to consumers, missing the benefits to producers. Researchers have found that benefit-cost analysis underestimates the benefits of transportation improvements by 10 percent to 40 percent.

Box B (continued)

Other research done under the rubric of the New Economic Geography focuses on the effects of transportation improvements in different contexts, such as location (geography) and level of development. This work emphasizes the idea that what works well in one place at a particular time may not work well in another place or at another time. Moreover, the New Economic Geography suggests that conventional benefit-cost analysis tends to underestimate overall benefits because of synergistic (or network) gains. Benefits from two improvements made together often lead to greater gains than the sum of the benefits from two projects made separately.

Development and Use of New Technologies and Processes (Technological Shifts)

History shows that improved transportation services have spurred major changes in agriculture and manufacturing and regional growth. The building of canals and railroads in the 19th century, for example, opened up large parts of the United States to agricultural production. In the process, large-scale production and specialization brought about transformations in production technologies and, therefore, productivity. New technologies employed in transportation can also lead to broad changes. The use of telecommunications and information technologies in freight transportation has improved the ability to coordinate shipments over long distances, lowering costs, and thereby shaping global production systems in which inputs and components are sourced internationally.

Although it is generally accepted that improvements in transportation can spur technological change and vice versa, it is difficult to predict what the effects will be, how long they will take to manifest, and how they will affect different places. Nevertheless, research should continue with a view to informing public policy debates on the links between transportation, technology, and the economy.

Microeconomic Research: FHWA's Benefit-Cost Analysis Study

Microeconomic studies focus on the effects of transportation improvements on the economy from the perspective of individual firms. Typically these effects are measured using BCA. Benefits are either the extra profits earned by firms due to lower costs, the lower costs passed on to consumers as lower prices, or a combination of the two. Benefits may be offset, to some degree, by the negative effects of increases in transportation services, such as more air pollution. These negative effects, referred to as "external" costs, are typically borne by society as a whole. BCA considers external costs when measuring the effects of transportation improvements.

To date, however, benefit-cost analyses of transportation investments, usually highway improvements, have not captured all the benefits derived from improvements in freight transportation. Models attempting to capture the benefits of highway investment to trucking have tended to parallel studies of passenger travel. The result has been that the benefits of a better road network for freight transportation are assumed to be limited to the carrier, the actual road user. These benefits are reduced travel time, decreased operating costs, and reduced costs related to crashes. Benefits to the shipper of a better road network, such as faster and more reliable delivery, are not fully accounted for in this approach.

Phase I: Documenting Benefits

Microeconomic research, sponsored by FHWA's Office of Freight Management and Operations, has been conducted to provide a fuller accounting of the benefits of transportation investment. Phase I of this research documented a range of short-term (first-order) and long-term (second-order) benefits, which are discussed below. This report does not discuss third-order benefits, such as improved and new products, that derive from improvements in logistics and supply chain management (USDOT FHWA 2002b). Phase II of the research involved estimating these benefits across

Box C: Polaroid and Ford Motor Company

Both Polaroid and Ford Motor Company have taken advantage of improvements in transportation speed and reliability by reorganizing their logistics to boost their competitive position. Polaroid centralized inventories in Europe by substituting transportation for warehousing, closing a number of warehouses in the process. The annual net savings were $6.9 million from less warehousing personnel, lower inventory carrying costs, and lower insurance premiums on the remaining warehouses among other savings. Other unquantified benefits were also realized such as a discount on consolidated shipments to centralized warehouses (USDOT FHWA 2002b).

Ford Motor Company reorganized its logistics by changing the way it distributes vehicles to its dealers. Traditionally, assembly plants would ship finished passenger vehicles directly to dealers, but only when a sufficient quantity of orders had been received to fill an entire railcar or truck. To shorten the average delivery time from the assembly plant to the dealer from 72 days to a goal of 15 days, Ford created what it calls "national mixing centers." These centers, located in Chicago, IL; Shelbyville, KY; Kansas City, MO; and Fostoria, OH, act as distribution centers by receiving all types of vehicles from assembly plants and then re-shipping the correct number and type of vehicles to the dealer. The mixing center distributes vehicles by rail or truck to dealers. It is estimated that a vehicle will be held at a mixing center for less than 24 hours before being shipped to a dealer (USDOT FHWA 2002b).

30 freight-significant corridors using readily available data (USDOT FHWA 2003b).

First-Order Benefits of Transportation Investments

A reduction in transportation costs to individual firms is the most obvious microeconomic benefit of transportation investments. Highway improvements reduce costs for two reasons. First, as the network expands, the density of its links increases. This makes point-to-point trips less circuitous, thereby reducing transport distances. Second, the addition of new roads, the expansion of existing ones, or operational improvements such as incident management or ITS deployment, may decrease congestion and travel times in some places. In either case, the amount of transportation input per unit of production—measured in vehicles-miles and vehicle-hours—goes down. Hence, costs are reduced, and productivity is improved.

In addition to reducing costs by decreasing transit-time, improved reliability is an important benefit of highway investment. Improved reliability allows firms to realistically predict the amount of buffer-time in the delivery of goods. (Buffer-time is the amount of time a carrier builds into a trip to reduce the risk of being late.) A reliable buffer-time also allows firms to reduce inventories and the costs associated with storing goods at various stages of the production cycle, a feature of just-in-time delivery. This is a major benefit since nearly 28 percent of production in the United States is based on just-in-time delivery (AASHTO 2002). One implication of just-in-time delivery systems is that inventory reductions are achieved at a cost of consuming more transportation services. At the system level, this means that more trucks are on the road at any given time, leading to more congestion.

Second-Order Benefits of Transportation Investments

Second-order benefits of transportation investments include improved efficiencies and further cost reductions resulting from a firm's ability to consolidate production and warehousing facilities (Box C). By consolidating, firms can take advantage of economies of scale and lower costs associated with fewer facilities. Consolidation, however, leads to an increase in the average length of haul. Trip length increases overall because shipments that were transported to and from the closed facilities must now be moved to and from the remaining facilities that are farther away. Thus, economies of scale are achieved only at the cost of more transportation services. As noted earlier, at the system level, this means more traffic on our roadways. Transportation improvements also increase the range of possible locations for manufacturing plants and distribution facilities, another second-order benefit. In some cases, transportation investments may make it possible for firms to improve their productivity by clustering facilities in a certain place. This is known as agglomeration economies. In other cases, transportation improvements may allow a firm to reduce its land costs by choosing a low rent location away from dense activity centers.

Furthermore, transportation improvements may enhance productivity by adding value to the output of either the shipper or the carrier. For example, fresh fish is worth more than frozen or processed fish. Transportation improvements that make it possible to deliver fresh fish to markets in relatively short timeframes expand markets to locations where the product has a higher value. Other commodities that can be produced only in a limited number of places are similarly enhanced by cheaper and more reliable transportation, such as mineral water from a specific location. Value is also added by technologies, such as the EFM system noted earlier, that allow carriers to provide real-time tracking information about a shipment. Such information enhances a shipment's value to a client in many ways, including the ability to more accurately schedule other resources involved in the production, receiving, or distribution processes.

Dell Computer

Dell Computer's on-line sale of custom-configured computers is one of the foremost examples of the use of just-in-time delivery and its effects on the production process. Using just-in-time delivery of components and tight inventory control, Dell is able to ship a customized computer within 36 hours of receipt of the order. This system allows Dell to reduce parts inventory from an industry norm of 75 days to 100 days to just 6.6 days, decreasing its inventory costs dramatically (USDOT FHWA 2002b).

Phase II: Turning Concepts into an Analytical Tool

Based on the theoretical work discussed above, FHWA sponsored additional research to enhance the measurement of benefits arising from transportation investments. The main thrust of this work was to develop an analytical model using readily available data to estimate the causal links among highway performance, truck freight rates, and shippers' demand for highway freight transportation. Data on truck traffic, truck freight rates, congestion levels, and economic activity levels in 30 selected freight-significant corridors were used to estimate the value that both carriers and shippers place on improved highway performance. The model was designed to quantify first-order and second-order benefits detailed in phase I of the research.

The analysis estimated the demand for highway freight movement in relation to highway performance while accounting for the effects of other more dominant factors such as the overall level of economic activity, labor rates, and fuel costs. Researchers used truck vehicle-miles traveled in each corridor to measure demand and the volume-to-capacity ratio to measure highway performance. Posted trucking rates for less-than-truckload (LTL) companies were used in a cross-sectional analysis, and trucking rates from a rate bureau were used for a time-series analysis.

Although there were some challenges along the way, the modeling did provide a statistically valid range of estimates of the relationship between the demand for trucking and highway performance. At the high end of the range, the model estimated that a 10 percent decrease in congestion increased the demand for trucking by about 1 percent, other things being equal.

The availability of data and concerns about data quality were among the challenges encountered in the development of the model. For example, only LTL rates were available for the cross-sectional analysis. And, in some of the corridors, data contained large, inexplicable variations in congestion estimates. Moreover, in some cases, the researchers found it very difficult to account for all the factors that explain freight rates and demand for trucking. When trying to explain the variation in freight rates, for instance, the researchers could not successfully control for the fact that the most intense competition among trucking companies, usually leading to lower trucking rates, often occurs in the most highly traveled and congested corridors.

Despite these problems, the benefit-cost analysis model enabled an estimation of the full benefits of highway improvements. As noted previously, current models are deficient in that they take into account only those benefits that accrue to carriers. They do not take into account benefits to the owners (shippers) of the freight being transported by trucks. Yet, as the examples of Dell, Ford, and Polaroid show, shippers do benefit substantially. A statistically valid estimate of shippers' demand for highway carriage provides a relatively simple means for adjusting the results from existing models to reflect the full benefits of highway improvements. Preliminary results of the phase II research suggest that the benefits found in current benefit-cost models should be increased by about 15 percent to account for these newly measured effects (USDOT FHWA 2003b).

It is important to note that an improved benefit-cost analysis model will also enable an evaluation of an increase in highway performance regardless of whether it is brought about by infrastructure investments, ITS improvements, or some other means. As long as the increase in performance could be measured accurately, BCA would serve as an effective tool in evaluating the benefits of transportation improvements.

Alameda Corridor: The 10-mile Mid-Corridor Trench is the centerpiece of a project that eliminates conflicts at more than 200 highway-rail grade crossings. Source: Alameda Corridor Transportation Authority

Conclusion

FHWA's research into the economic effects of investments in transportation will continue to focus on providing a more accurate, more detailed, and broader perspective on the benefits attributable to highway system improvements and the possible economic costs of system deterioration. Although valuable insights have been gained, additional research is needed. Current plans are to develop an improved benefit-cost analytical model that will provide better estimates of the benefits of improvements. The development of an improved model will be a major gain in analytical capability. Such a tool has the potential to help decisionmakers conduct both project planning and assessment in a manner that better recognizes the unique contributions of freight transportation to a region's economy.

Although improving benefit-cost analytical models will provide much-needed help in assessing the links between transportation and the economy, it is not the only answer. Benefit-cost analysis should be supplemented with insights from other analytical perspectives. These include macroeconomic modeling, transportation and industry case studies, and new approaches, such as GEA, that are sensitive to the economic and geographical context of new transportation investments and their effects. Pursuing several analytical approaches also reduces the chance of missing significant characteristics of, and changes in, systems as complex and dynamic as transportation and the economy.

Making good investment choices for the transportation system will be critical to enhancing America's economic productivity and global connectivity. Over the past 25 years, goods movement has grown dramatically in size and complexity. Increased freight volumes are already straining the system and are expected to continue to grow. The transportation system will have to adapt to this growth, requiring, in many cases, substantial government investment. A better understanding of the linkage between transportation investments and the economy will help decisionmakers select the most cost-effective investments and prioritize freight projects for future consideration. The introduction of a more comprehensive understanding of transportation benefits into traditional economic analysis is greatly needed, and FHWA continues to work toward that end.

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Appendices

Economic Effects of Transportation: The Freight Story

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Summary

This report describes the linkages between freight transportation and the economy. It is written with a broad audience in mind—an audience that is comprised predominantly of non-economists. It draws on the technical concepts that have been constructed under the Freight Benefit-Cost Analysis (BCA) Study that is being sponsored by the Federal Highway Administration (FHWA)—see the adjacent exhibit.[1]

Improvements in freight carriage can be expected to have important economic effects. Lower costs or better service, or both, in freight movement have a positive effect on all firms engaged in the production, distribution, trade and/or retail sale of physical goods. Reducing the per-mile cost of goods carriage means that any production or distribution facility can serve a wider market area, with potential gains from scale efficiencies. It also means a factory can draw supplies from a wider area with potential gains in terms of the cost and/or quality of parts and materials coming to the factory.

Managers of businesses are paying ever closer attention to efficiency in goods movement and tighter control of inventory and the whole supply chain. Logistics costs comprise transportation costs, costs of owning and operating warehouses, ordering costs, and carrying costs of inventory (principally interest and insurance). In recent years, trucking costs have been falling and reliability has been

FHWA's Freight BCA Study

The goal of the Freight BCA Study—which is being conducted by ICF Consulting and HLB Decision-Economics under subcontract to AECOM—is to develop a benefit-cost analysis framework that captures the full extent of the economic impacts of changes to the freight transportation system, including benefits associated with business reorganization. To date, FHWA's Freight BCA Study has included the following.

1. *A comprehensive review of literature on the economic impacts of transportation investments, covering over 170 articles, books, reports, and/or papers on the subject. The product of this component is a "Compilation of the Literature" report that describes the salient findings most relevant to freight transportation.*
2. *The development of a microeconomic framework for assessing the comprehensive impacts of changes in the freight system. The framework is presented in a White Paper titled "Benefit-Cost Analysis of Highway Improvements in Relation to Freight Transportation: Microeconomic Framework". The framework is briefly described in this report (at the end of Section 1).*
3. *A report that 1) describes the linkages between freight transport improvements and economic productivity and 2) presents the microeconomic framework in a manner that is accessible to non-economists.*
4. *A meta-analysis of the relationship between logistics costs and freight transportation demand. The purpose of the meta-analysis is to support the application of the microeconomic framework by producing single estimates of elasticities that characterize dynamic economic interactions between demand and costs in a road freight transportation system.*

[1] Readers interested in obtaining copies of the various reports that have been developed (to date) under FHWA's Freight BCA Study can visit http://www.ops.fhwa.dot.gov/freight/.

improving. Businesses have tended to respond by buying more transportation and using it to reduce the other components of logistics costs (e.g., through fewer warehouses or lower inventories). As we shall see, the tendency of managers to respond this way to lower costs and/or improved quality of freight transportation is a fundamental source of the economic benefits stemming from improvements in the freight transportation system.

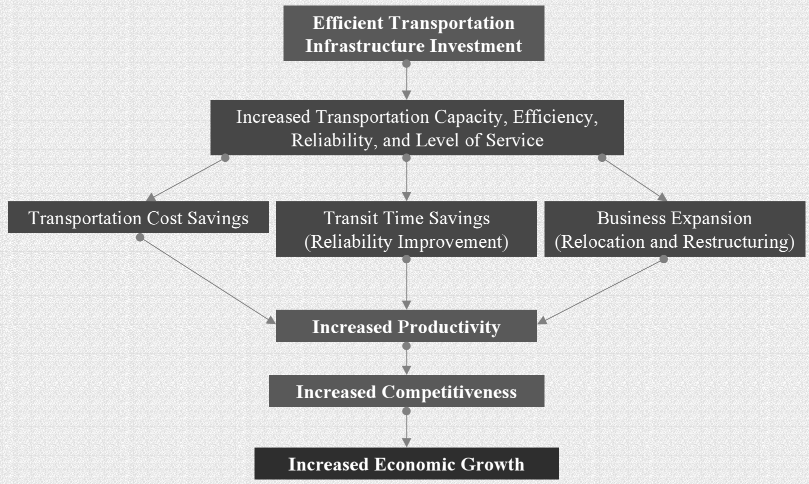
This report describes how an efficient and reliable freight transportation system helps to generate improvements in economic productivity. Using findings from FHWA's Freight BCA Study, the underlying linkages between freight transport and the economy are reviewed first. Then, the types of factors that drive the efficiency and reliability of freight transportation are discussed. Emphasis is placed on events that have led to significant improvements in truck and rail transport—events that have provided the foundation for the benefits that can be generated via business reorganization. Finally, the detrimental effects of worsening congestion on the productivity of the freight system are reviewed. The speed and reliability of the freight system can be expected to worsen as vehicle traffic grows and congestion increases. Such a development could force shippers and carriers into costly redesign and restructuring of their systems with higher logistics costs and a consequent drop in productivity. Improvement in the performance of the freight system, with concomitant gains in national productivity, will require significant gains in the battle against congestion.

1. Freight Transportation and the Economy: A Description of the Linkages

The American economy can grow and deliver improved living standards through one of two means, more workers or more productivity. With an aging population and net birth rates in decline, the nation is heavily dependent on productivity growth to achieve its economic goals. Transportation investment is important because its principal influence is on productivity.

Exhibit 1 illustrates how investments in transportation infrastructure can lead to generative effects[2] and growth in the national economy. Although improvements in passenger transportation have important economic ramifications, freight transportation enhancements that reduce the costs of moving goods (and services) to and from markets are critical to economic expansion. This is because the movement of goods is what economists term a factor input in the production of goods. Much like labor and capital, transportation costs affect directly the price of goods and services and the profits of producers. Consequently, investments that reduce the cost of moving goods to and from markets (via improvements in reliability, transit times, service levels, etc.) can help to increase and sustain economic growth. In effect, the efficiency and reliability of the freight transportation system affects economic productivity, and many economists would argue that productivity is the most important determinant of economic performance.

Exhibit 1: Transportation and the Economy



1.1 Overview of Linkages

Improved freight transportation systems reduce costs for delivery of goods and services; they also support faster, more reliable transportation from one place to another. These, in turn, reduce the costs of collecting inputs and delivering products to markets in several ways: less driver time on the road thus lower labor costs; increased trip miles per time period per vehicle and thus smaller vehicle fleet needed for the same amount of work ("freight efficiency"); lower vehicle repair and operating costs; and improved transportation reliability.

[2] Generative effects are those that increase income by using resources more effectively and/or by using resources previously underutilized.

The first three work directly to reduce total product costs. Improved transportation reliability works to reduce production costs via reductions in inventories of inputs, spare parts, and/or finished goods.

Cost reductions that are realized enhance the competitive position of enterprises with access to the improved freight facility or system. Expanded demand can generate economies of scale and improved productivity as enterprises take advantage of these market opportunities—thus inducing another round of cost reduction.

Beyond lower dollar costs to shippers, reductions in transit time and/or increases in schedule reliability can be expected to also have significant impacts. These gains in terms of time allow firms to manage their inventories and supply chains more efficiently. Increased reliability, for example, reduces the requirement for “buffer” stocks, inventory held to protect against delivery failure. Lower transit times reduce some costs (e.g., drivers’ wages for a given trip length). Further, as with lower dollar costs, less time for a move extends the “reach” of a factory or warehouse.

Exhibit 2: *The logistics director of a national specialty retailer described this issue. He said he preferred to restock fast-moving goods on a next-day basis to make more space available for other products. But he said transportation cost kept him from doing this unless the stock turned over fast enough to justify truckload shipments. Otherwise, the higher transportation cost means a narrower, less attractive product range in a store.*

In this manner, better freight movement lets a firm serve customers better or at lower cost or both. One example is the variety of products that can be stocked in a retail store. The more space that is required to maintain inventory of fast-moving items, the less space there is available for items that turn over at a lower rate. Yet a wider product line is more attractive to customers. The more frequently the fast-moving items can be replenished, the more space is available for slower-moving items. And frequency of replenishment depends, in part, on transport costs (see Exhibit 2 directly above).

Exhibit 3: Dell Computer on-line sales of custom-made computers—*In 1996 Dell Computer launched its “on-line” store. Customers use the Internet to order computers made to their own specifications. Upon receipt, an on-line order is broken down to individual components. Components are either ordered for JIT delivery on very short notice or drawn from small stocks that are replenished on a JIT basis. From receipt of order to shipping the assembled computer with software loaded and tested takes about 36 hours. The JIT parts system allowed Dell to reduce parts inventory from an industry norm of 75 to 100 days to 6.6 days.*

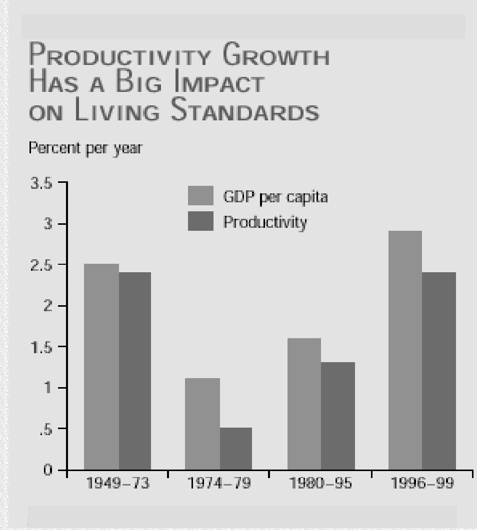
Improvements in the freight transportation system have made it possible for innovative producers to provide a high level of service to retail customers while holding inventories at low levels. One of the best examples of this is the system of on-line ordering of custom configured computers combined with just-in-time (JIT) delivery of components and tight control of inventory developed by Dell Computer (see Exhibit 3). The JIT system provides a high level of customer service with a dramatic reduction in inventory levels and costs.

Innovation like JIT would not be possible without a combination of quality freight transportation services with sophisticated electronic communications systems. Improvements in these areas have impacted positively our standard of living and strengthened our economy by extending and improving the reach of businesses to markets and supplies.

1.2 Improvements in Logistics and Effects on Industry Productivity

From the discussion above, we see that it is not just a longer reach to supplies and markets that matters but also a better reach. As freight transport becomes faster and more reliable, hence more predictable, the flow of goods and the stocking of goods can be managed more efficiently. In other words, we see improvement in logistics. These improvements can increase productivity in manufacturing and distribution in many ways, and productivity improvements affect the economy (see Exhibit 4).

Exhibit 4: Productivity and Economic Performance—*Productivity growth is important because it is the main determinant of changes in our standard of living. Note how growth in Gross Domestic Product (GDP) per capita tends to rise and fall in conjunction with growth in labor productivity.*



As a technical concept in economic theory, productivity has more than one definition. But all the definitions embrace, one way or another, the notion of getting more output, or product, from available resources. An increase in productivity reflects more efficient use of the labor, capital, materials, and so forth that are available to society at any given time. Production can always be increased if more resources can be found, but the supply of resources at any particular time is always limited. Productivity gains allow us to enjoy more or better goods and services with the resources we have.

Improvement in logistics is about improvement in transportation and about more efficient management of inventory. Customers expect many kinds of goods to be available when they want them. When a person walks into a store or calls a catalogue house, that person wants to get the desired item and walk away with it or be assured by the catalogue company that it will be sent on the way directly. If the item is not in stock, both the retailer and the customer have a problem. The customer has to go to another store, or come back another time on an extra trip, or be told the item is on back order. Either way, the customer accepts a delay, goes to another retailer, or chooses something other than the preferred item. The retailer loses business. The same model applies to businesses buying supplies; it is costly to a business if it cannot obtain supplies when needed.

Businesses deal with this problem by carrying inventory. The whole purpose of holding inventory is to lower the probability that a firm will have to turn away a buyer for lack of stock or have to stop production for lack of parts or other supplies. But inventory is costly. Capital must be used to hold it, warehouse or store space has to be used to store it, and insurance must be carried to cover the risk of loss or damage. All of these costs are reduced if inventory can be reduced. Inventory held in retail stores or warehouses can be reduced if replenishment is fast and reliable.

For manufacturers and distributors of goods, there is a constant tension between the pressure to have enough stock to satisfy customers and the pressure to reduce the cost of carrying inventory. Businesses often find that improved freight transportation provides a way to accommodate these conflicting pressures. And, when inventory costs can be reduced while maintaining or improving the level of customer service, that is an increase in productivity.

In many cases, firms actually find that spending more on transportation is profitable because there are offsetting reductions in inventory costs. But this can only be the case with an efficient and reliable transportation system. Firms that analyze their costs carefully sometimes find that inventory can be reduced and the number of warehouses reduced without loss of customer service by using more transportation and using it more effectively. Such changes in a firm's logistics set-up are sometimes referred to as a "reorganization effect." The reorganization effect occurs when a firm's managers decide that time-cost reductions, and other savings from freight improvements, are sufficient, for example, to increase length of haul and reduce the number of the firm's warehouses (see Exhibit 5). In this way, a firm takes advantage of reduced freight costs to realize scale economies in its warehouses and reduce inventory. The firm spends more on freight carriage, but the intended result is a reduction in total logistics costs.

Exhibit 5: How do Firms React to Improvements in Freight Transportation?

- Firms reduce stocking points, increase JIT processes, and increase shipping distances
- Firms react to reduced late-shipping-delays, valued highly by shippers, by investing more in logistics
- Inter-industry trading patterns are affected

There are good examples of cases where logistics reorganization, supported by a good transportation system, leads to lower total logistics costs and also to improved customer service. In the late 1980s, Polaroid, for example, decided to centralize its European inventories by buying more transportation and using fewer warehouses; a large number of warehouses were, in fact, closed. Polaroid's action resulted with: 1) estimated annual gross savings of $6.9 million and 2) net annual savings of $6.3 million after subtracting $0.6 million per year for increased costs resulting from computer system maintenance and increased warehouse personnel at headquarters (see Exhibit 6 on the following page).

When service can be improved while costs are cut, that is truly a gain in productivity. And the gains realized by Polaroid could not have been achieved without an efficient and reliable freight system in place.

Exhibit 6: Polaroid's Cost Savings from Reorganization—The Break-Down

- *warehousing personnel—$2.5 million;*
- *inventory carrying costs—$2.2 million;*
- *warehouse rental costs—$1.0 million;*
- *facilities and offices—$0.6 million;*
- *internal transportation between dealers and subsidiaries—$0.5 million; and*
- *insurance premiums—$0.1 million.*

Besides the savings that Polaroid could quantify, there were other gains that were not measured. Prior to centralizing inventory, 69 percent of orders could not be filled at the location that received them, so that items were backordered until they could be filled from other locations. This required significant internal transportation among dealers and subsidiaries to reposition inventory. Polaroid also achieved freight-cost savings based on volume discounts for consolidated (truckload) shipments to centralized warehouses.

Similarly, Ford Motor Company found a way to reduce transportation costs and inventory costs and improve service to its dealers by exploiting the lower cost of rail shipment of finished vehicles and introducing a new distribution system that sped the movement of vehicles from factories to dealers. Ford instituted a system of "mixing centers," essentially distribution centers, with predominantly rail shipment from factories to mixing centers and the final leg to the dealer by rail and highway or all highway according to the circumstances (see Exhibit 7). Ford's goal was to reduce order delivery times from 72 to 15 days from receipt of dealer order. The mixing centers replaced a system in which various types of vehicles ordered by a particular dealer were held at an assembly plant until there were enough vehicles for that dealer to fill an entire rail car (ten to twenty vehicles, depending on their size) or truck (five to ten vehicles, depending on their size). When a rail car or truck could be filled, the shipment moved to the dealer. Under the new system, each assembly plant ships daily to the mixing centers.

Exhibit 7: Ford's Mixing Centers-- *Ford created four national mixing centers at Chicago; Shelbyville, Kentucky; Kansas City, Missouri; and Fostoria, Ohio.*

At the mixing centers, vehicles are sorted and recombined to meet actual orders from dealers and moved on by rail or highway. Vehicles are held at the mixing center only as long as is needed for sorting and transloading, usually eight to 24 hours.

Through a major restructuring of its logistics operations and facilities, Ford was able to reduce both transportation and inventory costs while improving service to its customers. This resulted in an increase in productivity, and it required efficient and reliable freight systems, both rail and highway.

These cases, including that of Dell in the previous sub-section, illustrate a point that is at the heart of the freight story—businesses will increase expenditure on freight transportation, buy more freight service, and thereby achieve a reduction in total logistics costs because of savings in inventory and warehouses. And this is done in ways that improve customer service as well as reduce cost. Perhaps a central point is that firms are alert for opportunities to improve their logistics systems and will act when they find the price and quality of transportation that makes it feasible to do so.

These gains in logistics are gains in productivity. They may occur when a firm responds to a freight improvement, or, for whatever reason, analyzes its logistics arrangements and discovers that it is not taking full advantage of the freight transportation system's capabilities. Either way, these productivity gains will not occur unless a firm's management perceives that the freight system is robust and reliable enough to support its plans. These gains certainly will not occur if a firm's managers perceive that the quality of the freight system (as defined by speed and reliability) is deteriorating or will deteriorate (see Exhibit 8). This is the link between the quality of the freight system and national productivity gains.

Exhibit 8: Some Findings from Interviews with Shippers and Carriers—*As part of FHWA's Freight BCA Study, twenty-one interviews have been conducted with shippers and carriers. This is some of what they show.*

Current service is good

- ➞ On-time rates often over 95%

Firms frequently revisit their logistics arrangements

- ➞ Of 13 shippers, 5 changed or were about to change logistics

Firms concerned if highway conditions get worse

Businesses revisit logistics under a variety of business pressures (cost and customer service)

- ➞ Freight-transport improvements affect the outcome of industry re-organizations
- ➞ Shippers revisit logistics in response to business pressures

1.3 The Business Reorganization Effect

We have seen that a good freight-transportation system allows and stimulates logistics improvements that, in turn, raise the productivity of businesses and, thus, the productivity of the nation. When the productivity of the nation is increased, the national economic welfare is enhanced; we are able to produce more or better goods and services than would otherwise have been the case.

While these concepts are intuitively valid, the analytical work to provide definite quantitative information on the link between improved freight transportation and national welfare is just beginning. Benefit-cost models have been developed for evaluation of highway investments, but none of them accords proper treatment to the benefits of freight improvements.[3] This is because the link between improved freight transportation and national welfare is complex; and hinges on how the cost of doing business is affected by improvements in freight transport and, in turn, how cost reductions translate into productivity gains in the economy.

In particular, previous models do not account for the benefits to the owners of the cargo and all they can mean in terms of more efficient logistics and greater productivity in manufacturing. Not treating the effects of road improvement (for example) on the owners of the cargo moving over the road is a major omission. Valuing a reduction in truck travel time (referred to as "transit time" for freight) only by the saving in drivers' wages

[3] In general, the sponsors and authors of these models have been heavily focused on user benefits for highway passengers and have not given thorough consideration to the economics of freight movement. In the standard models, the treatment of trucks is parallel to that of passenger cars. Benefits are reckoned on the basis of reduced travel time, reduced operating costs, and reduced costs from accidents, all in terms of benefit to the owner of the truck.

implicitly assumes there is no benefit to the shipper from getting goods to their destination more quickly. But it clearly must make at least some difference to the shipper if cargo is delivered earlier than it otherwise would be. This would mean, for example, that a larger number of warehouses could be reached in a day's drive from a factory, and a larger number of customers could be reached in a day's drive from a warehouse. As we have already noted, these extensions of the reach of a manufacturing or stocking facility can lead to gains from scale efficiencies and, possibly, provide opportunities for reducing total inventory.

The following classification scheme for benefits and other effects should facilitate understanding of the benefits associated with improvements in freight transportation.

Effects of Improved Freight Transportation	
First-order Benefits	Immediate cost reductions to carriers and shippers, including gains to shippers from reduced transit times[4] and increased reliability.
Second-order Benefits	Reorganization-effect gains from improvements in logistics[5]. Quantity of firms' outputs changes; quality of output does not change.[6]
Third-order Benefits	Gains from additional reorganization effects such as improved products, new products, or some other change.
Other Effects	Effects that are not considered as benefits according to the strict rules of benefit-cost analysis, but may still be of considerable interest to policy-makers. These could include, among other things, increases in regional employment or increases in rate of growth of regional income.

FHWA's Freight BCA Study focuses on the first and second-order benefits of improved freight transportation. It looks at demand for freight carriage from the viewpoint of the consumer of freight transportation (i.e., the shipper). A shipper's response to the change in freight-movement cost is determined by the conditions of its demand for freight transportation. A shipper's demand for freight transportation reflects both the market's

[4] Carrier effects include reduced vehicle operating times and reduced costs through optimal routing and fleet configuration. Transit times may affect shipper in-transit costs such as for spoilage, and scheduling costs such as for inter-modal transfer delays and port clearance. These effects are non-linear and may vary by commodity and mode of transport.

[5] Improvements include rationalized inventory, stock location, network, and service levels for shippers.

[6] In the first-order case, nothing changes for shippers except the cost of freight movement (including time cost). They continue to ship the same volume of goods the same distance between the same points. Their costs are less, but they make no response to the cost reduction other than to keep the extra income thus realized. In order to estimate the first-order benefits, it is necessary to find the value of the time-cost reductions and then add this amount to those that are calculated in a standard analysis—reductions in operating costs, cost savings from reductions in accidents, and drivers' wages—all assuming no change in volumes or distances shipped.

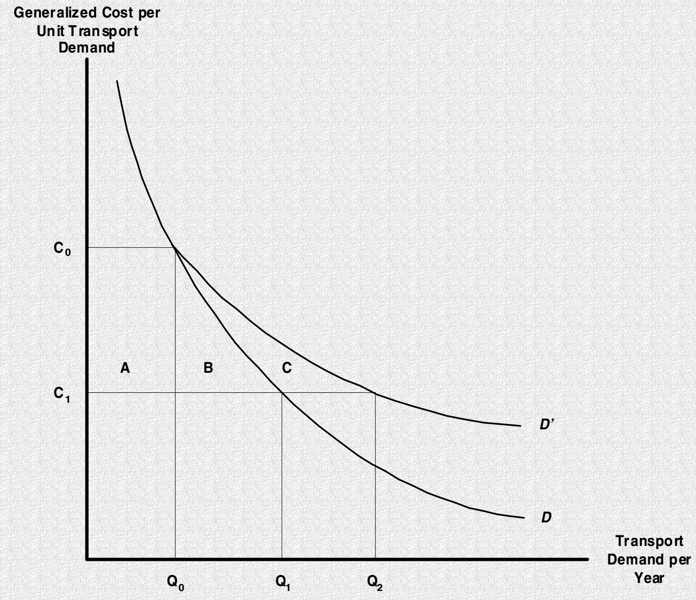
In the second-order case, firms respond to the cost reduction. They may reduce prices to gain additional revenue by selling more goods; they may ship longer distances; they may close some warehouses; they may do some combinations of these things; or they may do something else altogether. Cost reductions of a certain magnitude occur; firms respond in ways that lead to both greater output and lower cost per unit of output.

demand for the firm's products and the way in which it uses freight transportation as an input to its production and/or distribution processes.

As developed under the Freight BCA Study and presented in Exhibit 9, the shipper's demand curve for freight transportation takes two forms, D_0 and D_1. D_0 shows a shipper's demand for freight transportation before an improvement to the freight system (in particular a highway improvement). The new curve, D_1, shows the change in demand that follows the improvement. The shipper's reaction to the cost reduction can be thought of as occurring in three phases. In the very short run, the shipper makes no response and continues to buy the same number of vehicle miles of freight, VM_0. The benefit to the shipper is the area A, the cost reduction with the existing volume of freight. In the next phase of response, the shipper takes advantage of the lower cost and buys more freight movement, VM_1. This adds the area B to the benefit. But this still reflects the shipper's original demand curve, D_0. The shipper has not made any changes in the firm's basic logistics.

Exhibit 9: How the Business Reorganization Effect Can be Captured Under a Benefit-Cost Framework—*The shipper's demand curve reflects the benefits the shipper gets from buying freight transportation. The cost the shipper is willing to incur to obtain freight transportation is what managers believe the freight movement is worth to the firm. They will not incur a cost higher than what they think it is worth (although they will willingly take it at a lower cost if that is possible). Thus, the change in the demand curve reflects the greater benefits the shipper can get from the freight-carriage improvement, once the firm has reorganized its logistics set-up.*

A freight improvement's full benefit is reflected in the sum of areas A, B, and C.

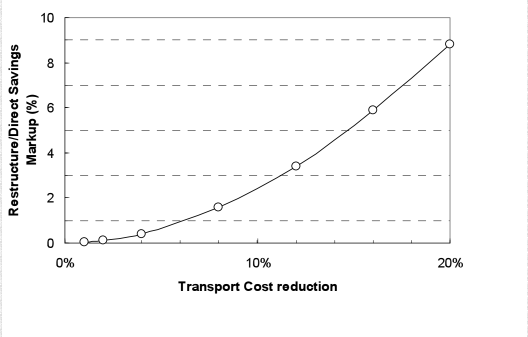


But, after managers have had time to consider the cost reduction, they may, as already noted, make changes in their logistics. This is when the shipper's demand for transportation would change, and there would be the new freight transportation demand curve, D_1. The additional benefit from the reorganization is area C, the area between the old and new demand curves. The freight improvement's full benefit is reflected in the sum of areas A, B, and C.[7]

[7] Note that, as shown in "Benefit-Cost Analysis of Highway Improvements in Relation to Freight Transportation: Microeconomic Framework", this captures all benefits without double counting.

Although the extent of logistics reorganizations is not well known, case studies and interviews conducted under the Freight BCA Study have confirmed that it can and does occur. With the best parameter estimates to date (albeit based on limited data), the mark-up factor for reorganization over conventional benefits follows the pattern shown in Exhibit 10.

Exhibit 10: Mark-up Factor for Reorganization Over Conventional Benefits—*For any level of transport cost reduction, a risk analysis allows us to assign a probability range to the dependent variables. For instance, based on assumed ranges of uncertainty in parameters and with a 20% transport cost reduction, the analysis shows that we can be confident at the 90% level that the true mark-up factor is between 7.5% and 10%.*



It is reasonable to expect that the mark-up factor will level off as transport cost reductions increase.

2. Trends in Freight Transportation

Based on the above, we now can see how improvements in freight transportation generate economic benefits that can improve the productivity of the national economy. In particular, an efficient and reliable freight system is a necessary condition for ensuring that transport costs remain low and foster increases in productivity. The following question remains, however: what affects the reliability and efficiency of the freight system?

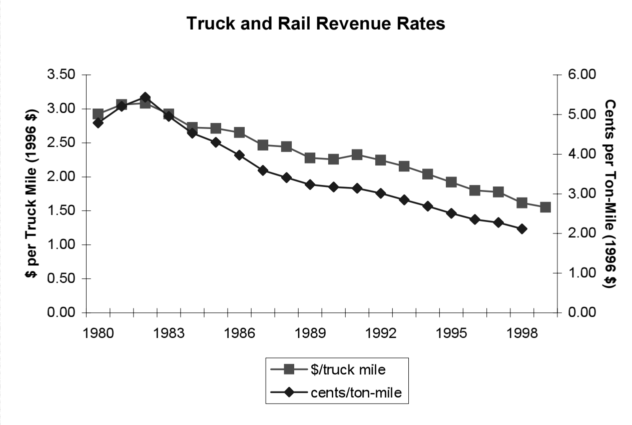
In this Section, we will develop a picture of changes in the freight system and how well it has been performing—keeping in mind that the performance of the freight system is important since it not only affects economic productivity, but is itself a function of public policy. We will look briefly at the history of freight transportation since deregulation, recent trends in investment in freight transportation, especially highway freight, and consider the implications of investment trends.

2.1 Historic Perspective on Freight Transportation in the Post-deregulation Period

Changes in transportation and logistics, and especially changes in the trucking industry, came about as a consequence of trucking deregulation (Motor Carrier Act of 1980) and partial rail deregulation (Staggers Rail Act of 1980). Deregulation led to declines in trucking rates (see Exhibit 11), and, more importantly, a new, responsive, and flexible trucking industry emerged that has become more sophisticated in its operations and has made possible much of the improvement in the logistics system that has subsequently evolved.

Exhibit 11: Deregulation led to a decrease in trucking rates.

The fact that deregulation led to a striking decline in truck rates is shown below. After adjusting for inflation, revenue per truck-mile in 1999 was approximately 53% of the 1980 level. We see a similar pattern for rail rates. Revenue per ton-mile in 1998 was just over 44% of the figure for 1980.



The elimination of regulatory barriers to entry, and particularly the requirement for route and commodity-specific operating authority, permitted the rise of efficient truckload (TL) operations. Prior to deregulation, some TL firms existed, but the regulatory barriers kept them out of any significant markets. The less-than-truckload (LTL) firms were, for most practical purposes, the trucking industry. Insulated from competitive pressures, they generally offered one-size-fits-all service. There were no contracts for specific bundles of services and few arrangements for truckload pick-up and delivery at customer-specified times. And, of course, there was little door-to-door truckload service.

Things changed when TL carriers could approach shippers and offer door-to-door services, tailored to customer specifications, at rates much lower than those demanded by the LTL firms. It was this development that allowed guaranteed just-in time (JIT) deliveries and all the other features that brought the evolution of advanced logistics systems and supply-chain management (see Exhibit 12A). And, as we have seen, improvements in logistics generate business reorganization effects that help to enhance productivity.

More specifically, the phenomenon of lower freight rates and better service led to substitution of transportation spending for inventory spending. As shown in Exhibit 12B, actual spending on freight transport was rising much faster than inventory costs—businesses took advantage of cheaper and better freight transport to restrain growth in their inventory costs.

As businesses substituted transportation spending for inventory spending, and the business reorganization effect began to take a foothold, the demand for trucking services increased significantly. In particular, since 1990 (10 years post-deregulation) growth in trucking ton-miles has accelerated significantly (see Exhibit 13, below) and at a faster

Exhibit 12A: The advent of TL carriers allowed for significant efficiency improvements in logistics systems.

The increased efficiency of the logistics system is manifest in the reduction of logistics cost as a share of Gross Domestic Product (GDP). Total logistics costs peaked as a share of GDP at 16.0 percent in 1981. By 1992 the share had dropped to 10.1 percent and has since remained close to that level over the last few years, being at 9.9 percent in 1999. This trend is shown in below.

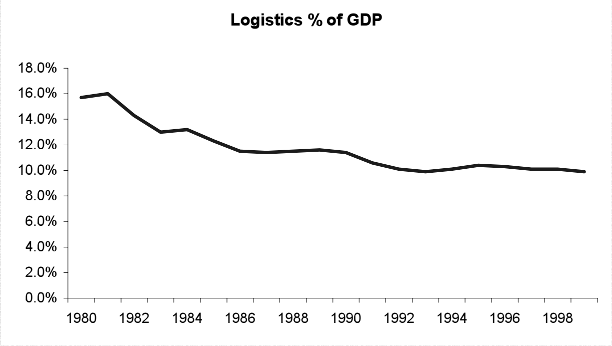
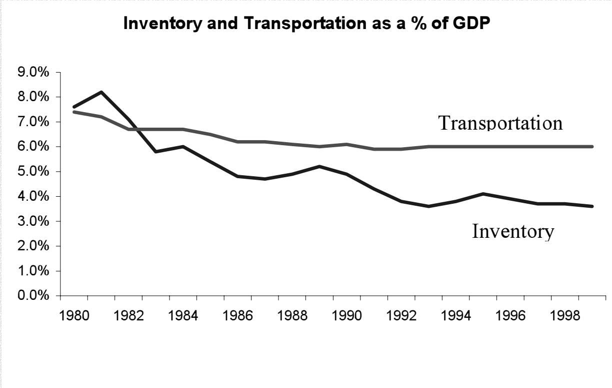


Exhibit 12B: Firms began to substitute transportation spending for inventory spending.

Relative to GDP, freight costs were at 7.4 percent in 1980 and have fallen since. Since 1988 the national freight bill has been an almost constant share, 6.1 or 6.0 percent, of GDP while the relative share of inventory costs has continued to fall—from a post-1980 high of 8.2 percent in 1981 to 3.6 percent in 1999.



rate than GDP, but in line with growth rates in manufacturing.[8]

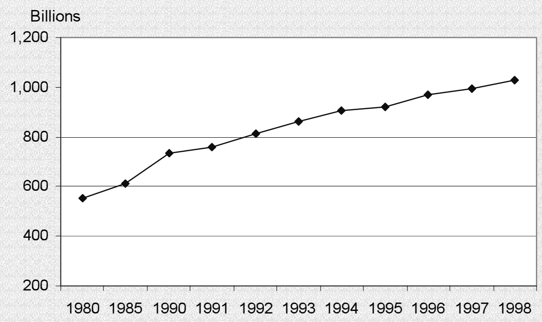
As with the development of TL carriers, the growth of intermodal rail traffic has improved the freight system's efficiency. In 1980, the Interstate Commerce Commission exempted intermodal rail transport from all economic regulation without waiting for the Staggers Act. Railroads could quote whatever rates they thought best and were free to enter into contracts with customers. (Before 1980 contracts were not allowed.)

As a result, while total rail tonnage has grown slowly since 1980 (an average of 0.6 percent per year from 1980 to 1998), intermodal traffic (measured by number of trailers and containers moved by rail) has increased an average of 6.0 percent per year over the same period. The attraction of lower rail rates is part of the reason for this rapid growth. But the ability to develop contracts in which railroads could tailor service to the specific requirements of large customers was also important.

Exhibit 13: The demand for trucking services has grown rapidly in the 1990s, partly reflecting the business reorganization effect.

During the first decade following deregulation (1980 to 1990), intercity ton-miles grew at an average annual rate of 2.8 percent per year, somewhat slower than the 3.2 percent rate experienced during the pre-deregulation decade. Ton-miles between 1990 and 1998 grew at an annual rate of 4.3 percent, faster than GDP's growth of 3.0 percent, but in line with manufacturing growth.

Intercity Trucking Ton-Miles



Intermodal freight transport has generated benefits that have further fostered productivity growth in manufacturing and the overall economy. For instance, the benefits of low-cost double-stack service were fully realized because the trans-Pacific container lines were able to contract with rail carriers for fast and reliable service—service that adheres to the

[8] The following table shows the annual growth in ton-miles compared with manufacturing growth. The two growth rates are virtually the same over the period 1980-1998. It should be noted, however, that, in the last few years, growth in highway freight ton-miles has fallen somewhat below growth in manufacturing output.

	1980-1990	1990-1998
Annual Growth in Intercity Trucking Ton-Miles	2.8%	4.3%
Annual Growth in Manufacturing	2.7%	4.3%

Longer truck hauls (which partly determine ton-mileage) reflect, in part, the greater "reach" of factories and warehouses as businesses have reorganized and optimized their logistics arrangement in light of improved performance of the freight system. On the other hand, lighter products and packing materials may have restrained the growth of tonnage relative to production. This explains why trucking ton-miles has not grown at a faster rate than manufacturing output.

precise schedules set by the steamship companies. Because of this, and because of competition between railroads, large volumes of imported consumer goods move speedily and reliably from West-coast ports to the Midwest at low rates (e.g., railroads are hauling containers from Los Angeles to Chicago at a rate of 30 cents a mile, while the average truckload rate is currently somewhat in excess of $1.00 a mile). Freight service of this quality and price allows major distributors and retailers to keep a tight rein on their logistics costs to the benefit of their customers and the overall economy.

TL carriers and intermodal transportation services exemplify the types of changes that have led to improvements in the reliability and quality of this nation’s freight system. As shippers have changed their logistics practices to take advantage of a more flexible and demand-responsive freight system, carriers have also improved their operations—as suggested by the development of TL and intermodal services. Improvements in trucking productivity, for example, are important to ensure that efficiency gains in the freight system are sustainable. So, how has productivity in the trucking industry fared since deregulation?

Exhibit 14: Productivity Trends in the Trucking Industry

Based on available sources, labor productivity improved significantly from 1975 to the mid-1990s, but appears to have leveled off and may be possibly declining. The chart below presents two labor productivity indexes: one from the Bureau of Labor Statistics (BLS) and the other a calculation using ton-miles and BLS labor data.

Trends in Trucking Labor Productivity

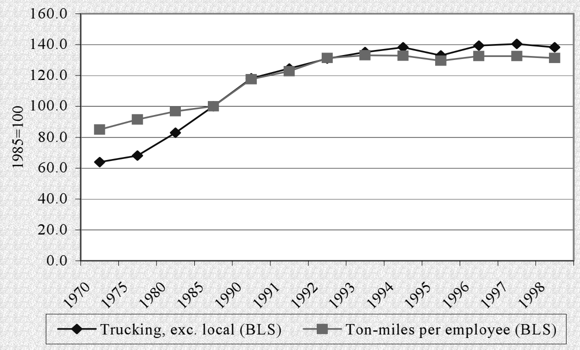


Exhibit 14 shows the recent trends in trucking labor productivity. The flattening, and even recent decline, in productivity suggests that the trucking industry may have difficulty in meeting short-term transportation demands from the manufacturing and service sectors over the next several years.[9] If that occurs, productivity losses in the transportation sector can lead to higher intermediate costs to the manufacturing sector in the form of increased operating costs. This, in turn, can exert downward pressure on manufacturing productivity, as transportation and warehousing costs rise relative to output. In the longer term, decreases in manufacturing productivity result in an overall weakening of the U.S. economy.

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[9] Note that it is possible that quality improvements (e.g., on-time performance) are not fully reflected in the BLS measure for labor productivity. That measures uses inflation-adjusted revenue as the measure of trucking output.

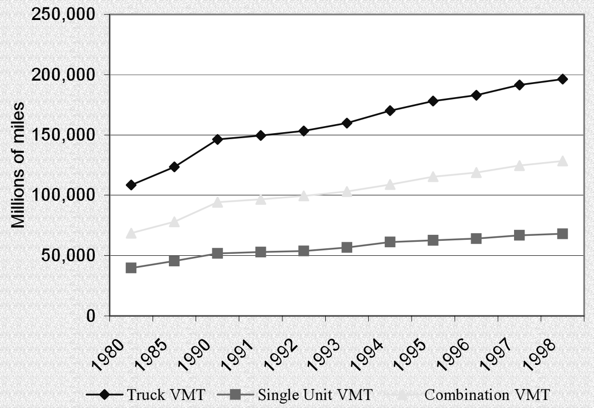
Although there has been a recent decline, capital (equipment) utilization has also improved since deregulation. The average length of haul has increased and the number of trips made by the average tractor-trailer combination has also increased over the last two decades. More trips, and more miles per trip, means the average combination vehicle is moving more ton-miles.

2.2 Freight Productivity and System Performance

It is not entirely clear what has caused the slowdown in the productivity of the trucking industry. Labor productivity is affected by various factors including traffic congestion, the reliability of the transportation system, regulation (such as the hours of service rule and size and weight regulations), and the availability of qualified and experienced drivers or operators. However, although deregulation has led to important efficiency gains in carrier services and logistics practices, increasing traffic levels on our nation's highways may be beginning to take their toll on the productivity of the freight system (see Exhibit 15).

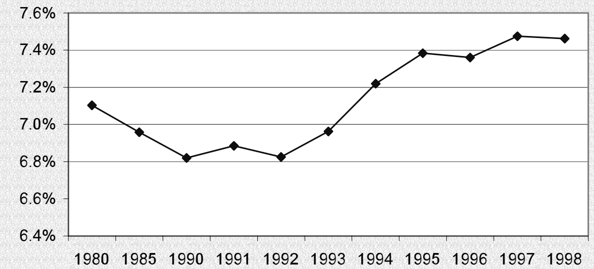
Exhibit 15: Growth in Truck Traffic

Growth in truck vehicle-miles accelerated in the 1990-1998 period by an average annual compound growth rate of 3.8 percent from 3.0 percent experienced during the 1980s. Combination truck vehicle-miles have grown at a faster rate than single-unit truck vehicle miles, reflecting an increasing average length of haul.



Even more striking is the fact that the share of truck VMT to total VMT has markedly increased in recent years. The share of truck VMT rose rapidly between 1993 and 1995 and appears to be leveling off at 7.5% of total highway VMT.

Share of Truck VMT



The impact of increasing traffic levels on the quality and reliability of freight transportation can be magnified if concomitant investments in our highways, ports, railroads, and intermodal facilities do not keep pace—in economics jargon, if the supply of infrastructure does not keep pace with increases in demand, the cost of moving freight will increase. Have we been investing enough on our nation's highways to ensure that the productivity of the freight sector is maintained?

Exhibit 16A (below) shows the trend in highway investment since 1980, adjusted for inflation. The amounts shown are capital outlays on State-administered highways.[10] The annual growth rate in investment over this period was 4.0 percent, compared to inflation-adjusted growth in GDP of

[10] State roads were chosen so as to leave out the local network that is less important for line-haul freight movement.

3.2 percent per year.[11] Although capital outlays on highways have grown steadily since 1980 and outpaced growth in GDP, highway congestion has worsened significantly over this same period, as shown in Exhibit 16B.[12]

Exhibit 16A: Highway Investment Since 1980

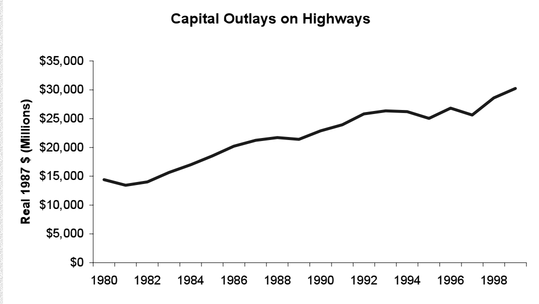
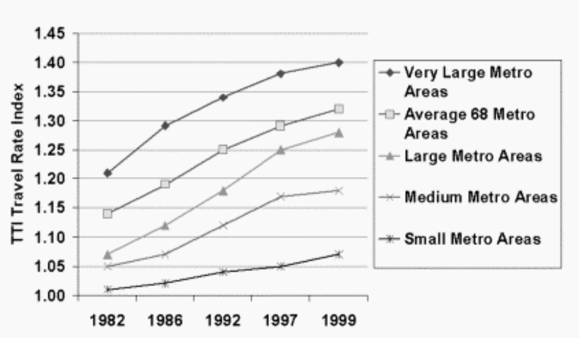


Exhibit 16B: Travel Rate Congestion Index

Congestion has increased rapidly since 1980, as both passengers and freight compete to improve mobility and productivity.



Congestion is especially problematic for freight transportation. As noted earlier, evidence gathered in discussions with shippers and carriers indicates that shippers have been getting a high level of highway-freight service. Those shippers that demand it have obtained a high degree of schedule reliability (e.g., deliveries consistently arriving in time windows of 15 or fewer minutes even on runs of ten hours or longer). Whole systems of inventory control and supply-chain management have been built around the expectation that this kind of reliability is a permanent feature of freight service. Also, siting of warehouses and terminals has been based on current levels of speed and reliability on the highway network. All of these features of total logistics system are important for national productivity and welfare, and all could be threatened if the reliability of the highway system continues to deteriorate.[13]

Specifically, logistics costs are shown to be highly dependent on both transit time and transit time variability, which are directly affected by congestion. The sensitivity to transit times increases significantly for higher values of variability. The same can be said for service levels. The relationships between estimated total logistics costs and transit time and variability are illustrated in Exhibit 17 (below).

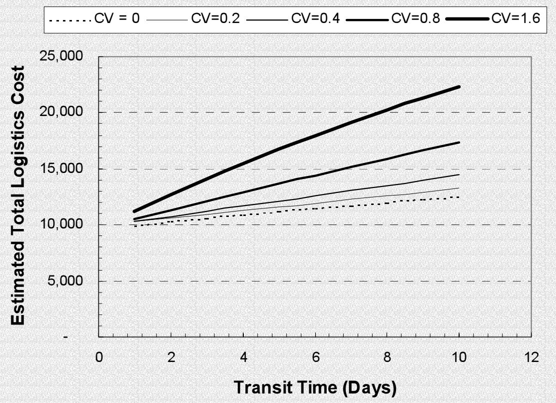
[11] In this same period, railroad capital expenditures grew relatively slowly, at an annual rate of 1.0 percent after adjusting for inflation. This is slightly faster than the growth of rail tonnage in the same period (0.6 percent per year).

[12] The TTI travel rate congestion index measures how much longer it takes you to make trip in a congested peak travel period (e.g., 8AM or 9AM) compared to an uncongested off-peak period (e.g., midday or late night). In 1982, it took about 20 percent more time to make a trip in a very large metropolitan area during the peak period. In 1997, it took over 40 percent more time.

[13] Note that the share of truck VMT to total VMT on the nation's highways has increased markedly in recent years. Consequently, increases in delay resulting from congestion have had an increasing impact on the productivity of trucking.

Non-recurrent, or unanticipated, congestion is even more problematic to the productivity of the freight transport system. Congestion contributes not only to making transit times longer, but also more unpredictable. This unpredictability can hinder JIT inventory management and even hinder some production processes. As a result, shippers attach a dollar value to predictability and speed. A study by HLB Decision-Economics indicated that carriers on average value savings in transit time at between $144 – $192 per hour. Savings in non-scheduled delay were valued at $371 per hour. In addition to value-of-time savings, there would also be vehicle operating cost savings from more efficient and reliable speeds. Although these results are based on a small sample, they indicate the magnitude of savings that can be generated by improving the performance of the highway system (which can be measured by congestion levels). It is interesting to note that time late was valued at roughly twice the rate of transit time.[14]

Exhibit 17: Minimum Logistics Cost Versus Transit Time for Various Levels of Reliability*



Lower logistics costs are achieved principally through smaller safety stocks. Improvements in achievable service levels are also made possible by a reliable and fast transportation system.

* Transit time reliability is expressed using the coefficient of variation CV. CV is defined as the ratio of the standard deviation to the mean.

Consequently, reduced transit time variability (which can be generated by decreases in congestion) allows for gains in scheduling and routing of transport resources. Increased competitiveness as a result of improved service levels may translate into higher sales and increased demand for both products and transport services.

2.3 Implications of Investment and Performance Trends

In commenting on the condition of the system, shippers and carriers tend to stress two themes. One is that they are, to a large degree, satisfied with the highway network as it now performs. They have designed their schedules and logistics systems around the current level of performance. But many of these people also emphasize that they would have a low level of tolerance for any deterioration in performance. For instance, there are choke points and problem areas, areas where speeds are markedly lower than in the rest of the country.

[14] The value of direct time savings in freight transportation provides a lower bound for the overall value of such time savings from a total logistics perspective. As a logistics input, transportation efficiency gains might alter the optimal balance between inventory holdings, warehousing and transportation. In the long run, some firms may be able to utilize improved transportation delivery to reduce safety stocks, improve service levels and lessen warehousing needs. A business reorganization effect could reduce total logistics costs well beyond the value of direct time savings.

In the absence of improvements, the speed and reliability of the freight system can be expected to worsen as vehicle traffic grows and congestion increases. Such a development could force shippers and carriers into costly redesign and restructuring of their systems with higher logistics costs and a consequent drop in productivity. It is reasonable to suppose that, if such costs are to be minimized, the current level of investment must be, at least, maintained. However, improvement in the performance of the freight system, with concomitant gains in national productivity, will require gains in the battle against congestion.

Take, for example, the impact that congestion has on productivity growth stemming from information technology. Economic research is proving what has been suspected for a few years—that the sustained economic expansion of the late 1990s reflects a powerful link between information technology and the growth rate in U.S. productivity. [15] The link is important because more than 80 percent of any improvement in people's real incomes and living standards can come only from productivity growth.[16] Productivity growth due to advanced logistics in the freight transportation sector is a microcosm of the IT revolution.

Exhibit 18 (below) illustrates how the relationship between IT-productivity growth in the economy at-large is mirrored in the freight transportation sector. Innovation in information technology facilitates development of new products in robotics, just-in-time inventory control programs, networked dispatching, real-time schedule management, and other manifestations of intelligent production and transportation logistics. When manufacturers and transportation firms invest in such products, their labor productivity improves (as proven by Stiroh) and peoples' real wages improve accordingly. And, since capital investment itself triggers faster technological advance, a circle is established which drives the rate of growth higher still.[17]

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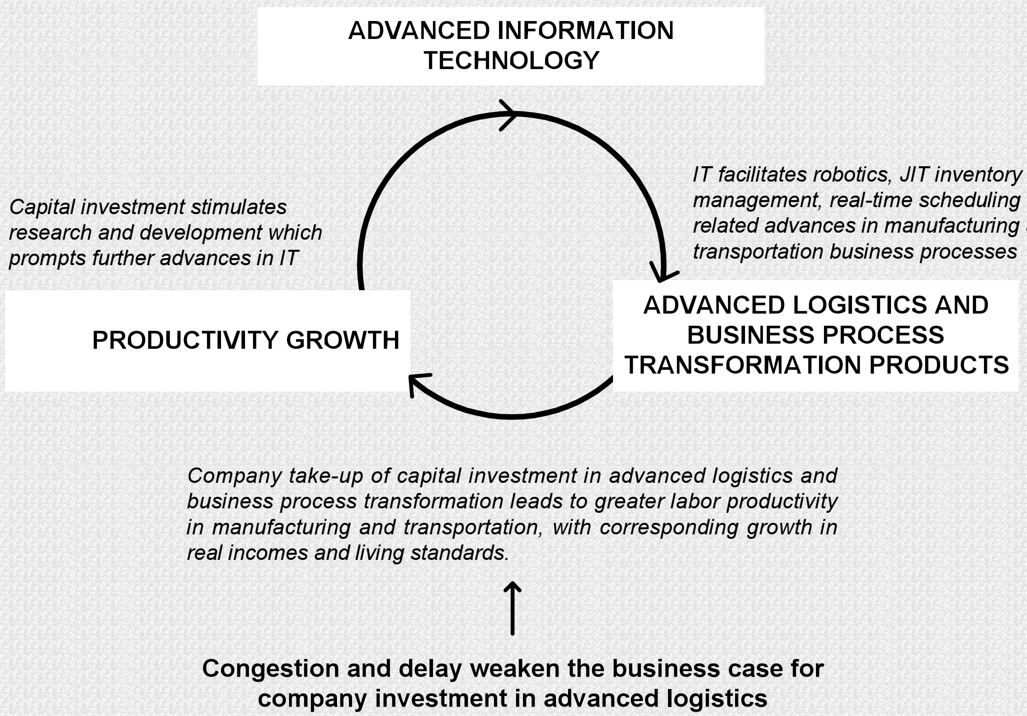
[15] Kevin J. Stiroh of the Federal Reserve Bank of New York reports that IT-intensive industries experience significantly larger productivity gains than other industries and a wide variety of his econometric tests show a strong correlation between IT capital deepening and productivity growth. Stiroh's results indicate that virtually all of the aggregate productivity acceleration of the late 90s is due to industries that either produce IT or use it intensively, with essentially no contribution from industries that are less involved in the IT revolution. From *Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?* Federal Reserve Bank of New York, January 12, 2001

[16] Dale W. Jorgenson, *Information Technology and the U.S. Economy,* The American Economic Review, March 2001

[17] David Lewis, *The Role of Public Infrastructure in the 21st Century,* Special Report 220, Transportation Research Board, National Research Council, 1988

Exhibit 18: The relationship between IT-productivity growth in the economy at-large is mirrored in the freight transportation sector.



But linkages can be weakened, even severed, by congestion and delay on the nation's highways. It is one thing for new robotics and intelligent logistics products to come on the market; it is quite another for manufacturing and transportation firms to invest in them. Such investment is costly. Threats to the effectiveness of such products are threats to the business case for investing in them. Widespread testimonials are not at hand, but analytic and anecdotal evidence indicates that congestion and delay is viewed in some sectors as a barrier to obtaining satisfactory pay-back from investment in just-in-time logistical products. Take-up of advanced logistics may be waning already, in part due to the economic slowdown, but also to mounting congestion in some strategic corridors around the country.

3. Future Growth in Freight Transportation

As discussed in earlier sections of this report, an efficient and reliable freight transportation system helps to sustain growth in economic productivity. However, recent trends in the performance of the highway system, as measured by congestion and system reliability, likely have adversely impacted the system's productivity. As congestion has worsened, system reliability has been compromised. Moreover, decreases in carrier productivity, can lead to increases in the relative cost of moving goods, dampening growth in the economy.

It can be argued that the problems that are generated by congestion will be difficult to mitigate because of projected growth in the demand for highway travel and concomitant constraints in the development of additional highway infrastructure (e.g., constraints stemming from funding availability, environmental considerations, community opposition, etc.). For instance, the Federal Highway Administration (FHWA) estimates that by 2020 freight volume in the US will nearly double in some sectors (see Exhibit 19). Consequently, maintaining (not to mention improving) the productivity of our freight transportation system will be challenging.

Exhibit 19: *According to a recent FHWA presentation, US domestic freight traffic is expected to grow by 2.9 percent by 2020. "Freight Trends/Issues, Multimodal System Flows and Forecasts, and Policy Implications" shows that US domestic freight will rise by 3.4 percent between 1998 and 2010, and another 2.4 percent from 2010 to 2020. US international freight traffic is expected to grow by 3.4 percent between 1998 and 2020, including an increase of US/Canada traffic by 3.1 percent, US/Mexico traffic by 3.5 percent. In 1998, domestic and international US freight traffic totaled approximately 9.8 billion tons and $9.1 trillion.*

The private sector's ability to generate the types of economic benefits that stem from productivity increases depends on how well our transportation facilities are maintained, operated, or expanded (for highways, these activities fall predominantly within the responsibility of the public sector). Likewise, through regulation and investment decisions, public policy affects the manner in which shippers and carriers operate and make logistics decisions.

However, transportation policy and planning is not as robust as it should be in relation to the freight sector. For instance, project analysis tools do not appropriately recognize how and why infrastructure design and capacity problems drive down the productivity of freight transportation and drive up the cost of industrial production. Likewise, transportation planners and decision-makers cannot anticipate readily how infrastructure improvements would make freight carriers, their industrial customers, and the economy at large better off. With a significant portion of the focus of transportation policy and planning shifting to freight-related matters, filling the planning gap is essential.

Clearly, highway investments that increase capacity and/or speed and reduce accidents will improve the performance of trucks, as will improvements in operations planning. Improvements in intermodal connections will also have an effect. Furthermore, Intelligent Transportation Systems (ITS) can be particularly important, especially when they reduce incident-based congestion. It is clear that transportation agencies at all levels of government can bring about improvement in highway freight-carriage. For instance,

- Targeted capacity expansion projects that alleviate high-frequency bottlenecks in the freight system can improve transit time variability.

- Freight planning can help to make sure that freight movement needs are appropriately considered by decision-makers by providing state and local transportation planners with the necessary tools to better account for the impacts of alternative investments on the efficiency of the freight system.

- Programs that strive to improve operations planning (or the interaction of planning and operations functions within a transportation agency) can improve system performance.

- ITS deployment can enhance the efficiency of the highway system through operational improvements, better user information, and incident management (which is particularly problematic from the perspective of system reliability).

- Federal grant programs that provide financing mechanisms for freight transportation improvements can help to generate the types of investments needed to improve the productivity of the freight system.

In a nutshell, future (and to some extent current) challenges will center on 1) squeezing as much efficiency as possible out of available transportation resources (in particular infrastructure) and 2) finding scarce resources to implement efficiency-enhancing programs and projects.

Transportation Infrastructure, Freight Services Sector and Economic Growth: A Synopsis

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Introduction

The U. S. Department of Transportation, Federal Highway Administration (FHWA) has had a long interest in gaining a clear understanding of the nature of linkages between transport infrastructure investments and economic growth and performance.

Several factors underlie this continuing interest of FHWA. First, FHWA directly and indirectly invests significant amounts in highway infrastructure each year, and needs to know that these investments are justified by rational decision criteria. Second, FHWA is committed by the Department's Strategic Plan to promote the nation's economic growth and economic competitiveness in the way it conducts its investment and non-investment activities. To accomplish this strategic mission, FHWA clearly needs knowledge on the nature and scope of the relationships between the provision of highway investments and economic growth and performance. An important dimension of these economic impacts relates to the impacts of transport investments on the performance of the rapidly evolving freight services sector, whose improved productivity in turn enhances the productivity of the overall economy.

Research aimed at improving our understanding of these linkages between transport infrastructure, the freight services sector, and economic performance can potentially address a range of issues:

- What is the nature and magnitude of the relationship between transport investments and the performance of the freight services sector, of other economic sectors, and indeed of the overall economy? What effects does transport public capital have on the productivity of labor and capital? What is the willingness to pay on the part of a private sector firm or industry for an additional increase in transport public capital? How robust are these relationships when the transport infrastructure investments are made in different contexts—say a link completion in a core region vs. a road in a peripheral region, or an investment in a growth period vs. in a declining era, etc.? To what degree does transport investment influence economic growth and to what extent is it in turn an outcome of economic growth?

- Since the convergence of transport policy reforms (particularly the new economic incentives and competition created by transport deregulation and liberalization in recent years) and novel transport and information technologies have promoted major productivity-enhancing service and process innovations in the freight services sector, a further question arises: what is the role played by transport public investments in promoting such structural changes as the reorganization of the logistical processes, which may augment productivity both in the transport service sectors and in the many transport-using sectors in the economy? In other words, what are the multiple and complex linkages between public investments in transport, the freight services sector and economic performance?

- Yet, our current understanding of these transport-economy linkages derives largely from models of aggregate relationships between transport and the economy. How should we open such 'black box' models? How do we characterize and analyze the economic mechanisms by which improvements in transport infrastructure and freight services course through the national and regional economies? As freight transport cost-service improvements promote market expansion and integration, what interactive changes occur in labor, land, and product markets within and between various economic sectors? How do these interactions turn out in the world of 'The New Economic Geography' with its increasing returns and imperfectly competitive markets? How can we trace the general equilibrium responses rippling through the economy, integrating under the stimulus of transport infrastructure improvements? What implications follow from this analysis for assessing transport's role in the nation's economic competitiveness?

This document is a synopsis of a larger White Paper that surveys and assesses current knowledge on these multiple and complex linkages among transport infrastructure investments, the freight services sector, and economic performance, as viewed from the perspective of the issues raised above.

The Freight Services Sector: Technical Change, Evolution and Contribution to the Economy

Two attributes characterize the crux of the evolution of the U.S. freight services sector in recent decades. First, the *quantitative change,* is reflected by the continuous growth in the volume and distance of freight moved—both of which have promoted spatial integration and robust growth of the American economy. In a broad sense, the American economy has become less freight intensive. Declines in the ratio of freight tons to GDP reflect the growing importance of services relative to goods producing industries and the shift from commodities production to diversified goods with higher ratios of value to weight. Until about 1980, ton-miles grew at a much faster rate than tons (although still declining in ratio to GDP) as the U.S. economy became more spatially integrated and firms sought more distant markets. This effect appears to have been played out by 1980, however, after which tons and ton-miles grew at roughly the same rate. However, it would be a mistake to interpret these trends as meaning that freight is becoming less important. The *value* of goods shipped per dollar of GDP continues to expand, so the trends in tons and ton-miles reflect economic shifts away from low value commodities rather than a decreasing dependence on the movement of goods within the U.S. economy, which is getting more globally organized.[i]

The second attribute is a broad *qualitative change* in the last two decades in the *nature and scope of services* the freight services industry offers to transport-using firms. As transport deregulation and liberalization policies in the U.S. in the last two decades have provided supportive economic incentives and a competitive environment, freight services firms have adopted many *enabling and space-shrinking* technologies of transport and communications. The resulting technical innovations have had two types of effects: first, these technologies have lowered sharply transport costs of various modes (Figures 1b and 1c).

Figure 1a. Difference Between International Fares (U.S. - Foreign) and U.S. Domestic Fares Adjusted for Distance, Selected Years, 1978-1996.

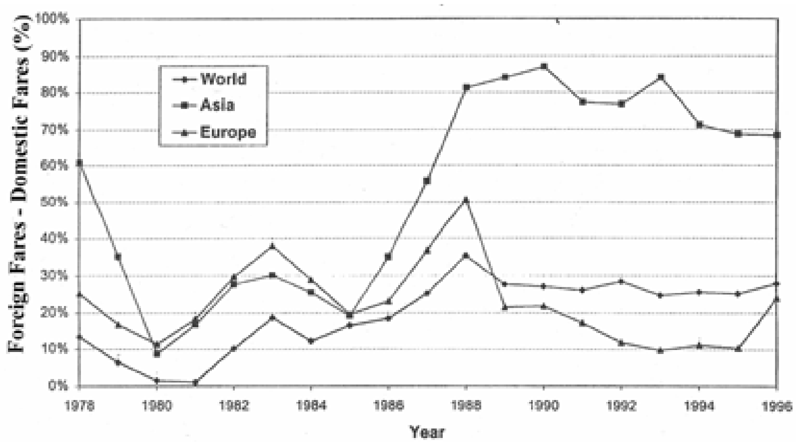


Figure 1b. Operating Costs of Less Than Truckload and Truckload Carriers, 1988-1995 (1995 dollars per vehicle-mile)

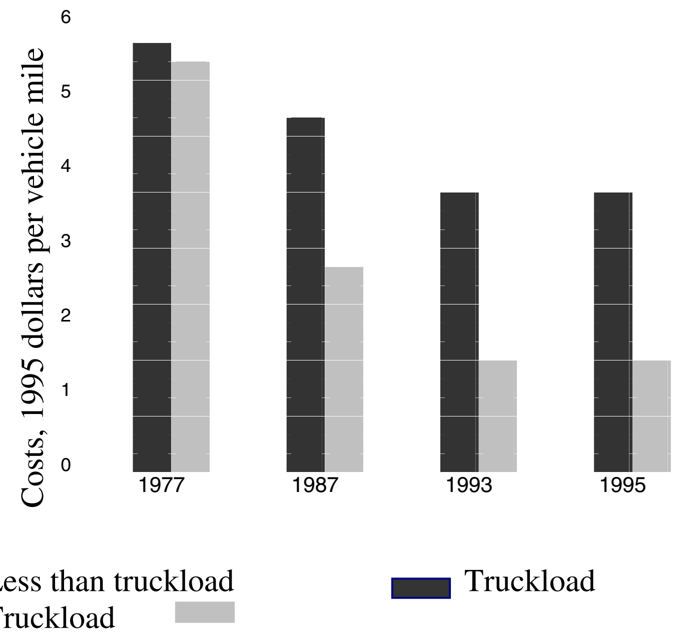
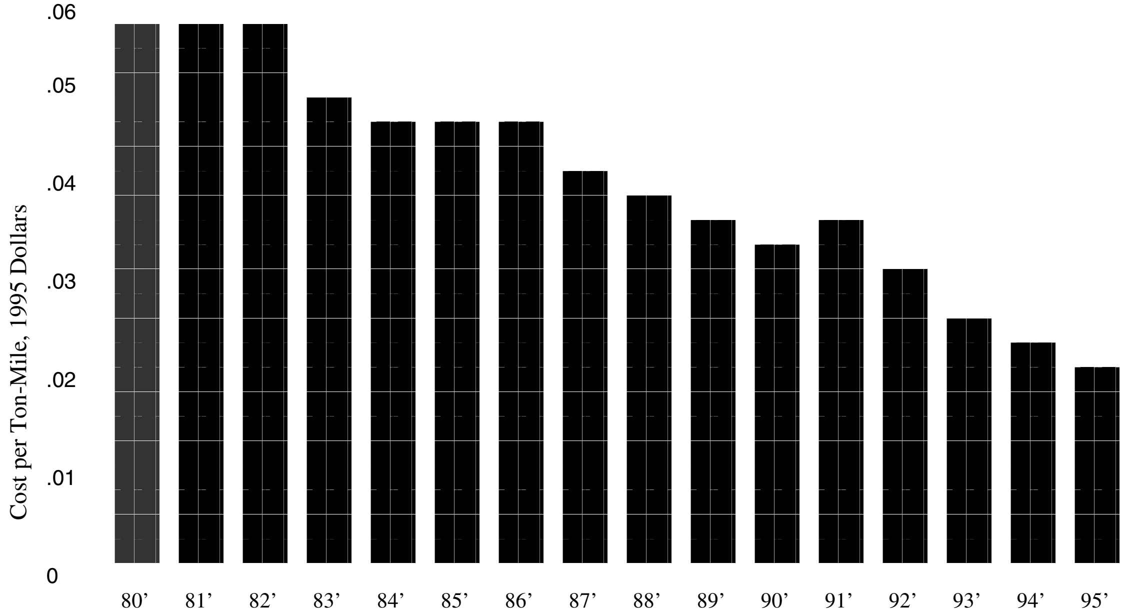


Figure 1c. Railroad Operating Costs per Revenue Ton-Mile, 1980-1995 (1995 Dollars)



Source: Morrison and Winston, 1999

Second, these new information technologies (IT) have yielded a variety of transport *service and process* innovations, which have made possible improvements in the transport logistics process and its fruitful reorganization. Firms in all industries have undergone a logistical revolution whereby inventories are thinner and production and transportation activities are more highly coordinated. As freight-consuming firms make these changes they place ever greater demands on freight service firms to deliver goods in narrower time windows and to provide services in support of more precise logistical management. In response, freight service firms offer a) process changes, such as *better management systems* (improved vehicle utilization, handling systems, etc.) and *product flow rescheduling* (use of JIT, quick response system, etc.). These process changes reflect improving efficiency and, through changing load factors and carrying capacity, influence the total level of goods transport; service changes, such as *realignment of supply chains* (new patterns of sourcing, vertical disintegration of production value chains, changing markets); and *refashioning of the logistical systems* (the spatial concentration of inventories and production).

These new services provided by freight firms represent not only reliability and timeliness but also flexibility and new modes of operation for customer firms--thereby offering the manufacturing and service industry customers system-wide cost reduction and additional *production value and strategic comparative advantage.*

The major consequences of the logistical improvements promoted by transport infrastructure investments occur in the various freight transport service-using sectors—primary, manufacturing, and service sectors — which make up the larger economy. How do the cost reductions and service enhancements in the freight sector provide benefits to various industries producing goods and services? What are the mechanisms and interacting pathways by which the logistics improvements course through the different transport-using economic sectors and improve the overall performance of the economy? How do we measure the economic benefits of transport investments?

Different Approaches to Measuring the Economic Benefits of Transport

It is part of conventional wisdom that transport investments are a crucial factor in economic growth, and in the transformation of regions and cities. The contribution of transport investments to the growth and development of the U.S. economy in the last two centuries has been noted extensively -- first the canals, then the railroads stimulating the agricultural development of the Midwest, then the transcontinental railroad linking the two coasts and helping alter the distribution of population and economic activity by around 1900, and finally the auto and the Interstate System transforming the urban landscapes shaped earlier by the streetcar.[ii] Similarly, the World Bank, which has funded $50 Billion in a large number of transport projects in recent decades in developing countries, estimates an average annual rate of return of 22% for all transport projects—as compared to a 15% rate of return for projects in all sectors.[iii]

In spite of these and other impressive inferences on transport's impacts on overall economic performance from economic history and from transport project appraisals, there has been a continuing debate (among planners, policy types, and academics) between those who hold that transport investments are crucial to economic growth at the regional and national levels and those that maintain an opposite view, suggesting that there is limited evidence of a causal connection between transport improvements and economic performance. Part of the debate swirls around the *magnitude or size* of transport's economic impact as well.

This debate is complicated by the absence of a received analytical wisdom that can settle these issues. Instead, there is a large body of analytical studies on transport-economy linkages, which vary widely in the scope of the issues they consider, in their technical sophistication, and in the rigor of their results. A high proportion of the studies focus on the aggregate contribution of transport infrastructure to the larger economy, usually measured by Gross Domestic Product (GDP) or Personal Income. Others emphasize the direct cost savings to firms from transport improvements as well as the indirect impacts of the cost and time savings in the form of gains from logistical reorganization. Finally, there is a nascent analytical concern with capturing explicitly the 'network' or general equilibrium effects of transport improvements on the various transport-using sectors in the broader economy. This emerging approach attempts the delineation of the various economic processes and mechanisms involved in translating transport improvements (via labor, and product markets and technical and organizational changes) into the wide-ranging economic impacts in the larger economy.

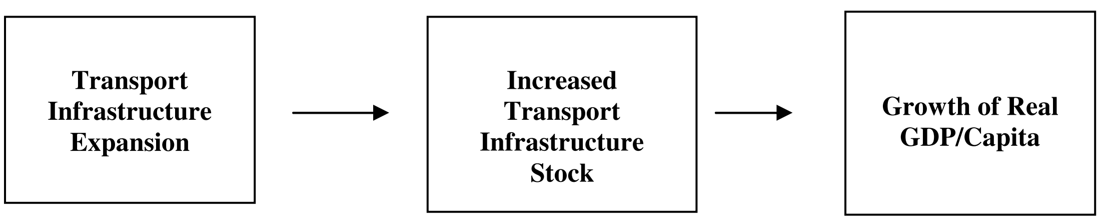
For the purposes of this paper, three broad approaches can be recognized in the available knowledgebase on transport-economy linkages. They are:

* Macroeconomic Models
* Microeconomic Models (including gains from logistics reorganization), and
* Models of General Equilibrium Effects.

Macroeconomic Models

The greatest proportion of analytical effort on the transport-economy linkages is represented by Macroeconomic modeling. The thrust of this approach is to relate the investments in transport infrastructure to GDP (Gross Domestic Product) in the economy. It views infrastructure as a direct injection to the economy and introduced typically as a factor of production additional to the traditional factors of capital and labor in a production function (Figure 2). In this form, it is possible to observe *whether and to what degree* infrastructure increases the level of economic output and enhances the productivity of private capital. Such positive economic relationships have been observed in most studies—both in the U.S. and abroad over the last two decades -- though the *magnitude* of the relationships between infrastructure investments and economic output varies widely across studies.

Figure 2. Infrastructure and Economic Growth
(a la Mera, Aschauer, Nadiri*, et al*)



Since the pioneering application of macroeconomic modeling to an estimation of transport-economy linkages by Koichi Mera (1973) in Japan, there has emerged a significant body of empirical work in the field as applied to U.S., Japan, India, Sweden, U. K., Germany, France, and Mexico. Despite a broad agreement among the studies in the U. S. and abroad on the *positive* contribution of transport infrastructure to the overall economy, there has been debate about the *magnitude* of this contribution. Some studies make dramatic claims about transport's contribution to American economic growth[iv], while most studies in the U.S. and elsewhere infer more modest but variable contributions of transport infrastructure to economic productivity.

The consequent debate in the early 1990s about the magnitude of the economic impact of transport has had two salutary effects. First, a careful inspection and analysis of the differences among the empirical studies in this field – in terms of their model structures, in the statistical methods used, in their variable measurement concepts, and in their data – has led to broad acceptance of a positive and modest economic impact of transport infrastructure (Table 1).

Table 1. Summary of Output and Cost Elasticities of Highway and Other Public Capital in Various Countries

Country	Sample	Infrastructure Measure	Elasticity Range
United States	aggregate (ts) states (xs) states (ts/xs) regions, trucking industry (ts/xs)	public capital public capital highway capital highway capital	output: 0.05 to 0.39 output: 0.19 to 0.26 output: 0.04 to 0.15 cost: 0.044 to -0.07
Japan	regions (ts/xs)	transportation & communication infrastructure	output: 0.35 to 0.42
United Kingdom	aggregate (ts)	public capital	cost: negative, statistically significant
France	regions (xs)	public capital	output: positive, statistically significant
Germany	industry (ts/xs)	public capital, highway capital	cost: negative, statistically significant
India	aggregate (ts), states (xs)	economic infrastructure: roads, rail, electric capacity	cost: -0.01 to -0.47
Mexico	national, 26 industries	transportation, communication & electricity, public capital	returns to public capital: 5.4% - 7.3%

Note: ts=time series; xs = cross section

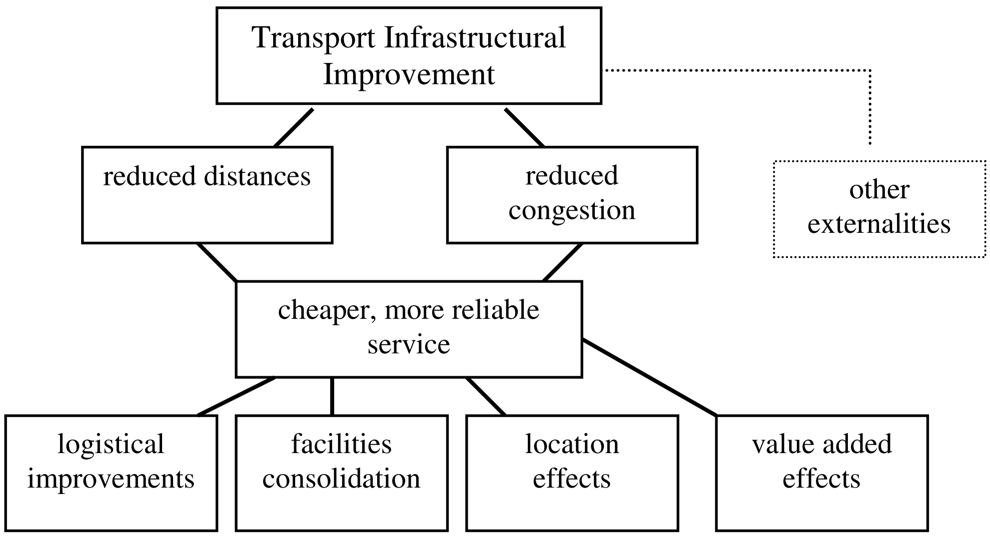
Second, a recent sophisticated study by Nadiri and Mamuneas (1996), that has addressed the methodological deficiencies of some earlier studies, has provided results on disaggregate impacts of transport infrastructure, which are widely well received. This study has made robust estimates of cost elasticities, marginal benefits of highway capital, and the contribution of highway capital to productivity growth for each of 35 industries in the U.S. economy. The rich framework developed in this study is helpful for posing a variety of related policy issues such as the willingness for a private sector to pay for an additional unit of transport infrastructure and the optimality of transport infrastructure.

Two major deficiencies remain with the macroeconomic approach. First, a major deficiency of the macroeconomic research is that it does not take into account the *network* character of roads or other transport modes. The productivity-enhancing impact of transport infrastructure depends on *the spatial, temporal, and development stage* of the network.[v] Second, the specification of impacts of transport infrastructure on production factors (labor, capital, and other factors) in macroeconomic models is too aggregate to be more than a 'black box'. This black box needs to be unbundled. Transport infrastructure improvements, as noted below, impact on labor and other factor markets and on product markets in complex ways with positive and negative feedback loops--in the context of spatial agglomeration and potential innovation stimuli. The net outcomes of these complex mechanisms, namely the general equilibrium effects, are *uncertain and contextual.* Further research from the macroeconomic perspective must be complemented by an analysis from the general equilibrium view.

Microeconomic Benefits

Investments in transportation infrastructure can lead to better or cheaper freight services, which in turn lead to increased productivity of individual firms. We refer to these effects collectively as microeconomic benefits. Cost Benefit Analysis (CBA) is the conventional means of assessing microeconomic benefits. In this section we describe the different forms that microeconomic benefits can take and discuss how and to what extent they may be captured by CBA.

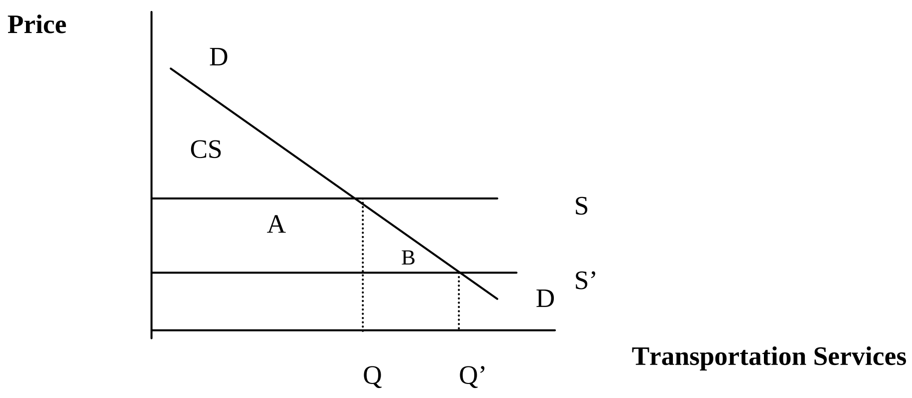
Figure 3. Microeconomic Impacts



The first and most obvious of these benefits is the reduction in inbound and outbound transportation costs. Highway infrastructure improvements – which may include additions of new roads, expansion or improvement of existing roads, and expansion of effective capacity though implementation of ITS – reduce costs for two reasons (Figure 3). First, as the network expands the density of its links increases, making point-to-point trips less circuitous and thereby reducing distances. Second, addition of new roads and capacity expansions on existing roads may decrease congestion and thereby travel times. Either way, the amount of transportation input per unit of production–measured in the first case in vehicle miles and in the second case in vehicle hours –goes down, hence an improvement in productivity.

CBA assesses such benefits according to the theoretical framework described in Figure 4. Here the horizontal supply function S is the constant cost of the transportation service[vi], and the downward sloping demand function D, is the amount users are willing to purchase at various prices. The difference between D and S (up to the amount Q, which is the equilibrium level of services consumed) is called the consumer surplus (CS). This is a measure of social benefit because it is the difference between what consumers actually pay and what they are willing to pay.

Figure 4



Now suppose that an investment in transportation infrastructure reduces the cost of the services, as demonstrated by the downward shift of the supply function from S to S'. The increase in CS is the sum of the areas A (the benefit of reduced cost for Q) and B (the consumer surplus on the increase in services consumed from Q to Q' due to the cost reduction). This is the way CBA measures the user benefit arising from an infrastructure improvement.[vii]

It is important note here that CBA functions under the assumption that all benefits accrue to the consumer of transportation services. If the service provider has monopoly power, some of that benefit may be appropriated in the form of excess profits. Conventional CBA does not have a mechanism for calculating the value of such a producer surplus.[viii]

Given the assumption of perfect competition, the CBA framework can be extended in a number of ways. For example, if there is a negative externality associated with level of service consumed, the net benefit may be calculated as the user benefit minus the increase in the externality. If the transportation infrastructure in question is subject to congestion, the supply function S is increasing with Q, implying a reduction in CS for higher levels of service consumption.[ix]

Microeconomic benefits can, however, take a number of forms that are not easily captured in the conventional CBA framework. We discuss four here: logistical adjustments, consolidation of facilities, location effects and value added effects (Figure 3).

Logistical Adjustments

Logistics costs are the costs of assembling inputs at the production site and distributing output to the ultimate consumer. In addition to transportation costs, they include the cost of procuring and dispatching goods and the cost of carrying inventory. In recent decades, manufacturing, wholesaling and retailing industries have undergone a “logistical revolution” whose outcome has been substantial reductions in typical carrying costs (insurance, interest, and warehousing costs) achieved by reducing typical inventory levels. This is the essence of the “just-in-time” inventory principal.

The reduction in inventories is achieved by receiving and dispatching a larger number of smaller shipments. In order to reduce the possibility of stock shortfalls, shipments must arrive within fairly narrow time windows. Thus, inventory reductions are achieved at the cost of consuming more transportation services, both in a quantitative sense (more vehicle shipments) and a qualitative sense (more reliable delivery times.) Thus we have a substitution relationship between inventory-related inputs and transportation inputs.[x]

It therefore stands to reason that if an investment in infrastructure results in a decline in transportation costs, firms will reduce their inventory carrying costs by using more and better transportation services.[xi] But the benefit of the improved infrastructure to the firm will come not in the form of reduced transportation costs per unit of output, but rather in the form of reduced inventory carrying cost. How can we capture such a benefit in the CBA framework? (We return to this question shortly.)

Consolidation of Facilities

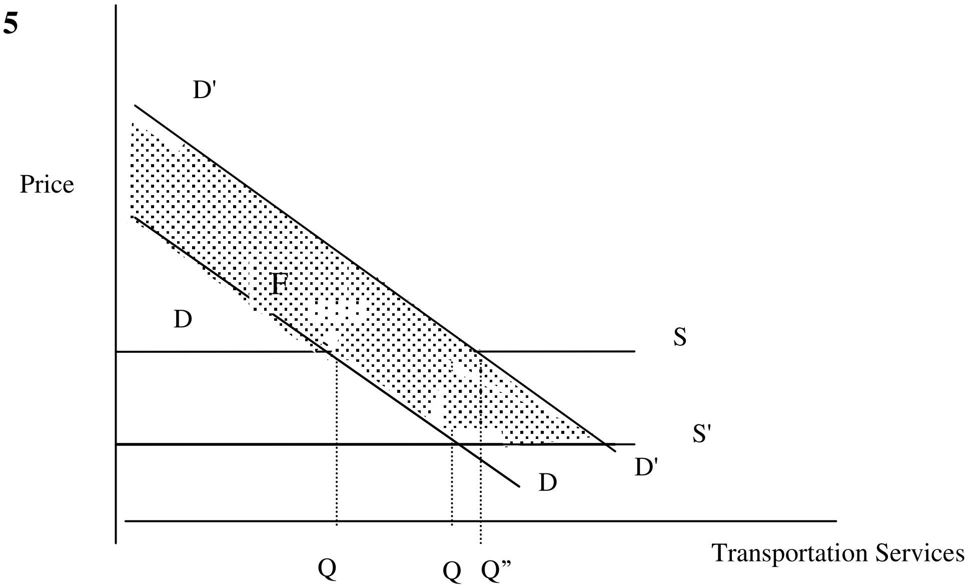
Falling transportation costs due to improved infrastructure can also make it possible for firms to concentrate production or distribution operations into a smaller number of facilities. Imagine a national wholesaler with ten warehouses scattered around the country. If the firm were able to consolidate its operations into a few locations, it could benefit from scale economies and save warehouse costs. However, consolidation would imply that the average length of shipments would be longer, thus scale economies are achieved only at the cost of more transportation services.

Again, it stands to reason that if transportation costs go down, firms will have an incentive to consolidate facilities.[xii] Thus, the benefits of the improved infrastructure will be realized in terms of savings in non-transportation costs.

Incorporating Logistical Savings and Consolidations in CBA

It is not at first clear that the conventional CBA framework as shown in Figure 4 can capture the benefits accruing from logistical adjustments and facilities consolidation because it does not reflect changes in inputs other than transportation. Since in either case non-transportation costs are reduced by increasing the consumption of transportation inputs, however, they can be captured by the effect of an outward shift in the demand function from D to D’ as shown in Figure 5. The story is as follows. If logistical practices and the number of facilities are held fixed, a reduction in cost from S to S’ leads to an increase in transportation services consumed from Q to Q’. If firms are able to make changes to logistical practices or consolidate facilities, there is a further increase from Q' to Q''. The increase in benefits now has two components: The areas A and B from Figure 4 and the area F shown in Figure 5. The latter captures the benefits of savings in non-transportation inputs.[xiii]

Figure 5



Location Effects

There are a number of ways that improvements in transportation infrastructure may contribute to productivity growth through mechanisms that involve the location choice of the firm.[xiv] For example, infrastructure investments promote productivity when firms are able to take advantage of *agglomeration economies* – essentially the efficiency benefits of locating in large clusters.[xv] Naturally, the benefits of agglomeration are at some point offset by the costs of congestion. In this sense, major investments in infrastructure that offset congestion within, as opposed to between production centers, expand the potential for agglomeration.

Expansion of transportation infrastructure – especially the Interstate Highway system – has increased the range of possible locations for producers of goods and services. "Greenfield" production sites located at the periphery of metropolitan areas or in rural areas have been sought by many producers to economize on land costs. Thus, just as firms are able to reduce inventory- carrying costs by increasing their use of transportation services, firms choosing peripheral locations along highways reduce land costs while consuming more transportation services.

It may seem contradictory to argue that transportation infrastructure promotes productivity on the one hand by allowing firms to cluster together in cities and on the other by allowing firms to spread out into the periphery. But this must be viewed in light of the fact that different firms benefit from different locations.[xvi]

For new, innovative products, acquiring appropriate labor skills, developing product innovations, and market penetration are the key concerns, so firms do best in urban core locations. For more established goods and services, implementing process innovations, and economizing on the cost of inputs such as labor and land are the main competitive strategies, so firms do best in the periphery. *The main point is that a transportation system that provides sufficient capacity and connectivity benefits all firms by expanding the range of locations from which they can choose.*

Transportation and Value Added

So far we have discussed the microeconomic benefits of transportation system improvements in terms of cost reduction. Cost reductions translate into productivity enhancements and therefore they can explain much of the impact of transportation infrastructure on productivity growth as observed in the macroeconomic literature.

Another way that transportation infrastructure can enhance productivity is by *adding value* to the output of either the freight using firms or the transportation service provider. Take fresh fish as an example. The best way to add value to a fish is do nothing to it – except get it to the consumer quickly. Fresh fish is worth more than salted, frozen, or otherwise processed fish. Improvements in transportation service that make it possible to get a fish from Maine to St. Louis in less than 24 hours after it is caught are a major source of productivity enhancement. The justification for interpreting this as a case of adding value, rather than just reducing costs, is that the fish can only be produced in one or a few places and may have a scarcity value elsewhere. Thus, transportation makes it possible for the fish-producing firm not only to expand markets but to reach markets where its output has a higher value than in its local market.

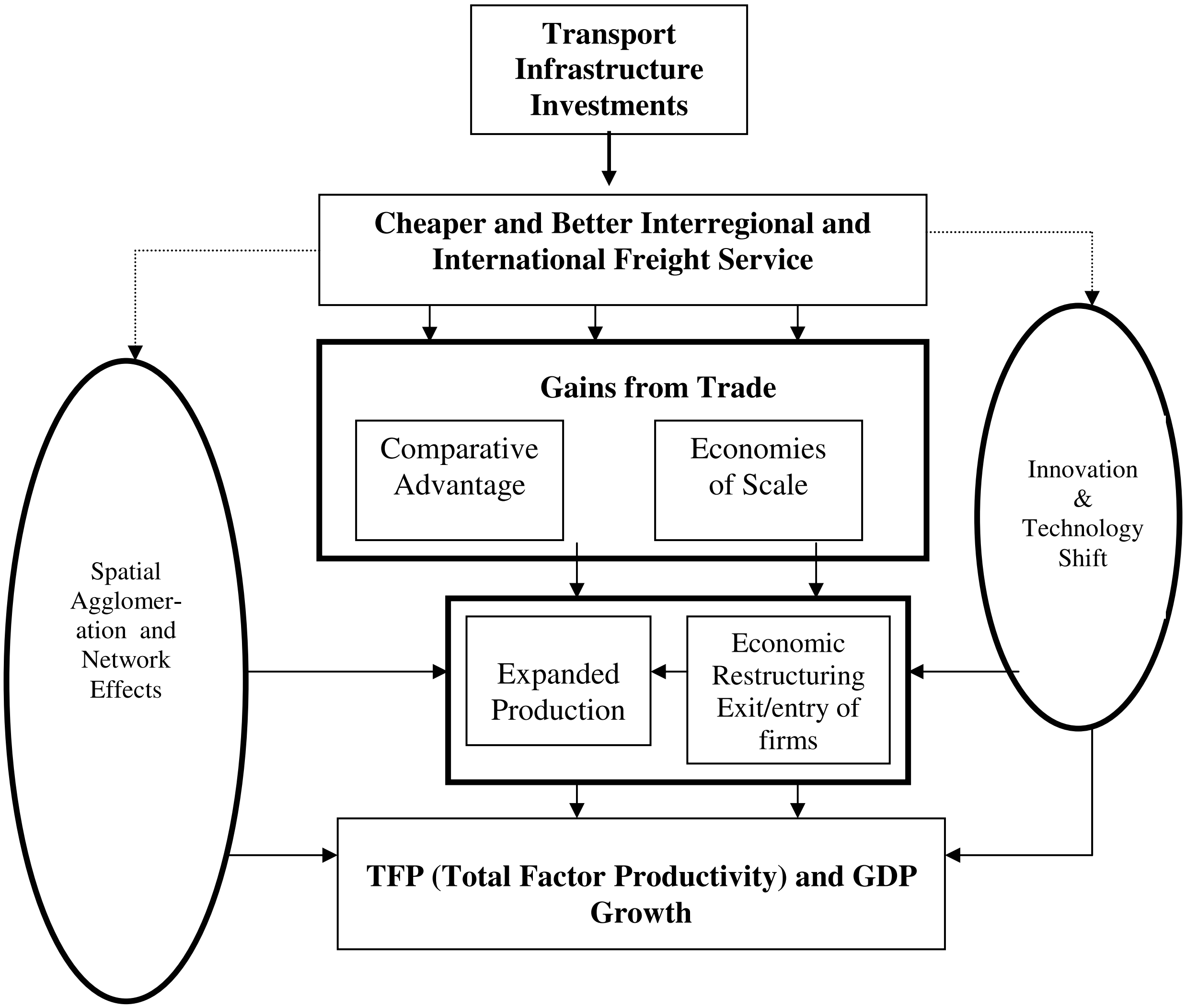
As another example, consider a machine that is used in a production process. The firm that uses the machine will pay more for it if they can be certain that it will never be out of service for more than a few hours. The firm that produces the machine will able to make such a guarantee – and therefore charge a higher price – if they know that it will be possible to ship necessary parts to the machines location if there is ever a breakdown. Thus the availability of high-quality transportation service increases the value of that machine.

Improved infrastructure can also add value to the services of transportation providers. For example, higher capacity and implementation of ITS infrastructure can help trucking firms deliver goods not only cheaper but also within narrower time windows. They can also provide real time tracking information and a high level of flexibility regarding the volume, location and frequency of shipments. All of this makes the service more valuable to the client.[xvii]

General Equilibrium Benefits

We now turn to those benefits from improvements to transportation infrastructure that cannot be assessed at the level of the individual firm. General equilibrium benefits occur when cost reductions or improvements in transportation services result in a redistribution of resources across firms and regions in such a way as to increase aggregate productivity. An important question here is whether CBA can adequately capture the general equilibrium benefits of infrastructure investment.

Figure 6. General Equilibrium Effects



General equilibrium benefits arise in the form of *gains from trade*. One of the main historical consequences of improved transportation services has been a shift from a regime of economic autarky, whereby each region or nation produces a wide variety of goods to satisfy its own demands, to one of specialization and trade, whereby each region or nation concentrates its productive resources on a smaller number of goods and services and trades in order to satisfy it full range of demands.

This may yield economic benefits for two reasons. First, different regions have different resource endowments, which make them most efficient at producing different things. If each region specializes in those things it can produce most efficiently, overall productivity is enhanced. Second, even if all regions are similarly endowed, specialization implies that each region produces fewer goods, but more of each good it produces. Thus, economies of scale are realized. These two explanations for gains from trade are associated with two streams of economic theory—the theory of comparative advantage and the "new economic geography"—each of which has something interesting to say about the effects of improved transportation.

Comparative Advantage

The theory of comparative advantage has its roots in the 19th century when the British economist David Ricardo argued against the "corn laws" which restricted imports of agricultural commodities into Great Britain. Corn law supporters argued that there could be no possible economic justification for importing grain since British agriculture was at least as efficient as agriculture in countries from which cheap imports originated. Ricardo countered that even if Britain had a small efficiency edge on other countries in agricultural production, it had a very large efficiency advantage in manufacturing production. Since there were fixed amounts of labor and capital resources available in Britain, British agricultural production had a high opportunity cost because it diverted resources from more lucrative manufacturing production. Thus even though Britain had an absolute advantage over its potential trading partners in both agriculture and manufacturing, it had a comparative advantage only in manufacturing. British agriculture was at a comparative disadvantage because of its high opportunity cost. Therefore, if foreign grain were imported and resources were transferred from agriculture to manufacturing, both Britain and its trading partners would be better off.

Ricardo's ideas have been refined by modern economists,[xviii] but the basic message is the same: all trading partners are better off if they specialize in those things in which they have comparative advantage than if they seek to achieve self sufficiency by producing a large variety of goods. Note that this is a *general equilibrium* benefit in that it does not arise due to improved productivity in individual production units, but rather from a redistribution of production that leads to higher aggregate productivity. An important caveat to this, however, is that gains from trade can only be realized to the extent that they exceed the transportation costs needed to achieve them. Therefore one of the most important benefits of improved transportation infrastructure arises from its role in enabling gains from trade.

The theory of comparative advantage has been the major economic argument in favor of liberalizing international trade. One might assume therefore that economic benefits in the form of gains from trade arise primarily from investments in infrastructure built mainly for international trade: international shipping and air facilities, international bridges, facilities for rapid border clearance etc. In fact, recent experience shows that such infrastructure, along with complementary institutional changes, is critical to the success of regional economic integration initiatives (Lakshmanan Subramanian, Anderson and Leautier, 2001.) The role of infrastructure in trade creation, however, extends more broadly to the national infrastructure system, since domestic transportation is needed to bring export goods to international gateways.[xix]

More importantly, the notion that transportation infrastructure yields economic benefits that come in the form of gains from trade applies just as well to domestic trade as to international trade – especially in an economy as large and diverse as ours. The United States economy is a *multiregional* economy comprising a set of distinct but highly integrated economic regions, each with a system of urban centers and resource hinterlands. In such a national economy the theory of comparative advantage applies just as well as it does in, say, Europe where differentiated regional economies exist within national frontiers.

The railroads, the inland and coastal waterways, and the National Highway System provide the critical links that make regional specialization and interregional trade possible. Evidence of the increasing specialization over the second half of the twentieth century is found in the fact that ton-miles of freight grew more rapidly than tons of freight, especially in the period for 1960 to 1980 (see Table 1). Under systems of autarky and regional specialization, the same number of tons might be shipped, but the average distance of shipment would be much greater in the latter. Thus growth in the average distance over which a ton of freight is shipped is consistent with increasing regional specialization and interregional trade.

What implication does this have for assessing the benefits of transportation investments? Any project that makes interregional trade easier and cheaper results in improved efficiency (and thereby reduced costs) for those goods that are shipped interregionally. At first blush it might seem that CBA, with an apparently partial equilibrium orientation, will miss this benefit. However, under of conditions of perfect competition the increase in trade will occur up to the point where the cost reduction from specialization and trade is just offset by the transportation cost. Thus, the benefits derived from increased travel captures the gains from trade.

This argument is fine from a theoretical perspective, but it suffers somewhat in the implementation. CBA is normally applied *ex ante* – that is the calculation is made before the infrastructure investment is made. (Otherwise it would be of little use as a decision tool.) This means that the analyst must *predict* the increase in the demand for transportation services in order to calculate growth in consumer surplus. Accurate predictions of the full range of economic integrations that may occur after the addition of a major infrastructure improvement is a challenging requirement that is seldom met in applied CBA. Not only would changes in aggregate trade flows need to be predicted, but since this is a relatively long-term phenomenon the timing of the changes must be estimated in order to conduct appropriate discounting.[xx]

An initial step toward assessing the magnitude of gains from trade attributable to infrastructure investments would be to conduct a series of *ex post* cost benefit analyses where the observed trade impacts are measured some years or decades after an improvement is made. This *ex post* approach would serve both as a means of assessing the magnitude of the benefits from highway construction that arise due to growth in interregional trade and as a means of comparing benefits calculated after the fact to those found in *ex ante* CBA studies for the same projects.

The New Economic Geography

Comparative advantage essentially says that gains from trade arise out of diversity across nations. But many of the most important trade relations occur between places that are in fact very similar, such as the United States and Canada or states within the European Community. Furthermore, in many bilateral trade partnerships, goods in the same industry group flow in both directions across the border. Such intra-industry trade is again inconsistent with the theory of comparative advantage, which envisions only exchanges of dissimilar goods.

In light of the inability of comparative advantage to explain some important trends in trade, a new analytical framework called the "new economic geography" has emerged. Where the theory of comparative advantage is driven by variations in endowments, the new economic geography is driven by *scale economies*. The crux of this theory is that even if all regions have identical endowments, if each region specializes in unique goods that it supplies to all other regions, it will achieve higher productivity though economies of scale.
Naturally the theory is more complicated than this.[xxi] It is based in a model where product variety is the critical component of competition so that all firms produce distinct but substitutable goods. Consumers' utility functions are defined in such a way that they prefer to consume a variety of goods rather than to concentrate their production on a small number of goods. Thus goods are imperfect substitutes. This means that each firm has some degree of monopoly power and can therefore set its price above its marginal cost. The cost structure for each firm includes a fixed component and a constant marginal cost, which results in a downward sloping average cost function indicative of scale economies.

By opening up trade, producers in each region are able to reach broader markets for their unique goods, allowing them to move down their average cost curves and earn greater profits. Naturally this market expansion effect is limited by interregional transportation costs so any reduction in transportation costs yields increased trade benefits.[xxii] The model also integrates consumer demand and labor markets.

While a fuller explanation of the theory is provided in section IV of the paper, a few of its advantages are worth noting. By stressing the role of product differentiation, it brings theory more in line with modern economies, where homogeneous commodities play shrinking roles. Product differentiation naturally leads to imperfect competition and the inclusion of scale economies permits a formal treatment of spatial phenomena such as agglomeration economies and regional wage differences. Most importantly from our perspective, the inclusion of space naturally leads to a more central role for transportation.

A recent study commissioned by the Standing Advisory Committee on Trunk Road Assessment in the United Kingdom illustrates some of the new insights that can be gained by applying the analytical framework of the new economic geography to questions of transportation investment.[xxiii] The authors developed a computable general equilibrium

(CGE) model based on hypothetical data and parameters incorporating the principals of monopolistic competition as described above. It includes two or more regions, each with endowments of two primary inputs: immobile capital and labor, which is mobile in the long run. Equilibrium wage rates are determined at the regional level. Each region includes some competitive and some monopolistically competitive industries and input-output parameters describe the linkages among industries in terms of intermediate goods flows. Since firms will enter any monopolistically competitive industry where excess profits are being earned, expansion will occur in industries and regions whose profits expand due to a change in transportation costs.

Because of the multiregional structure of the simulation, it was possible to identify circumstances where reductions in transportation costs would have differential regional impacts. For example, the hypothetical simulations illustrated that:

- Lower transportation costs lead to greater regional specialization;
- Reducing transportation costs along two routes simultaneously yields benefits that are greater than the sum of benefits when they are lowered independently;
- Transport cost reductions that have positive benefits in aggregate may have negative effects on some regions; and
- Reduction in transportation cost may reduce or increase interregional wage differences, depending upon the context.

The report also asked the question: Is CBA an accurate method for evaluating transportation infrastructure investments when the industries that consume transportation services are monopolistically, rather than perfectly, competitive? Their answer was no, for two reasons. The first we have already discussed: under imperfectly competitive markets, certain types of benefits are hidden from conventional measurement of CBA. The second reason is perhaps less evident: in a world of imperfect competition and scale economies, certain general equilibrium effects are too small to be ignored. In each of the simulations conducted with the model, the authors compared the general equilibrium benefits to those that would be calculated using conventional CBA and found the latter to underestimate benefits by wide margins. (How to interpret the size of these margins is an open question, however, given the hypothetical nature of the simulations.)

These results have a variety of implications. For one thing, they reinforce the message that in an imperfectly competitive world, conventional CBA analysis tends to underestimate benefits of transportation investments. They also show that specific transport cost reductions can have spatially variable impacts and that reductions that are beneficial in the aggregate can be detrimental to certain places – a result that economic historians will hardly find surprising! More generally, they illustrate the point we made earlier that the benefits accruing from an infrastructure investment depend on the *context* within which the investment is set.

But what is the implication for the evaluation of individual projects? The importance of context as highlighted in these results suggests that is unlikely that a simple one-size-fits-all framework can identify all the potential benefits and costs of non-marginal infrastructure projects. Is it therefore necessary to abandon CBA and adopt more complex and flexible CGE models as the standard framework?

To answer this, we must be mindful of the fact that both the theoretical and especially the empirical development of these models is in its infancy. CGE models as they exist today are complex and data hungry, so promising benefits from hypothetical simulations don't necessary imply that working empirical models can be developed.

The most prudent course is therefore to continue using CBA – including the most current methods to adjust for externalities, demand shifts etc. – as an initial quantitative estimate of the efficiency of any project, but to follow up with more qualitative analyses to determine whether the CBA results are likely to underestimate or overestimate true net benefits. In these more qualitative analyses, the types of issues pointed out in the new economic geography should be given special attention.

Technology Shifts

There have been times in history when expanded freight services have made radical changes in the structure of production possible. For example, the development first of canals and later of railroads made it possible for huge areas of the central lowlands of the U.S. to be developed for specialized agriculture serving a national market. To a degree this fits into the standard comparative advantage argument described above, except that rather than a shift from autarky to specialization it involved the creation of new economic regions whose growth was driven from an early stage primarily by export commodities. Furthermore, it involved a fundamental transformation of production technologies, achieving much higher productivities through specialization and large-scale production. It can be argued that a host of improvements in agricultural technology were induced, at least in part, by the expanded market opportunities made possible by freight improvements.

Another example is the industrial revolution in textile production that occurred on a global scale in the 19th century. In this case, improved freight carriage made it possible to develop a production system that required the movement of material inputs of cotton from production region (US South, Egypt, India) to production centers in England and New England. Thus, unlike the example above where freight made it possible for a specialized production region to reach broader markets, in this case freight made it possible for widely separated but complementary regions to be integrated into a specialized production system. Again, this story has elements of comparative advantage, but it involves a fundamental shift in technology made possible by improved freight. The key issue is this, while both comparative advantage and the new economic geography assume production technologies which are exogenous and fixed, historical examples suggest that new trade opportunities have at times given rise to technological shifts, resulting in an endogenous change in the production technology.

The two historical examples illustrate the role that freight improvements play in fundamental shifts in technology. It is likely that freight improvements provide opportunities for more marginal shifts on an ongoing basis. For example, the interstate system not only allowed producers to seek out locations with lower land costs, but also allowed them to implement more space-intensive technologies to enhance efficiency. Reductions in the cost of global trade due to innovations such as containerization set the stage for a general transformation to global production systems whereby inputs and components are sourced internationally.

While it is almost impossible to predict technology shifts, a lot could be learned from *ex post* empirical studies that attempt to identify them. Case studies of industries that have undergone rapid transformations in production technologies or logistical organization could seek to determine whether technological progress was either enabled or spurred on by new or improved freight transportation options. Such studies need not be limited to goods producing industries, but could also include large-scale retail operations that are currently in a phase of rapid technological transformation.

Lessons Learned

Freight transportation continues to play a critical role in the U.S. economy. In recent years this role has been reinforced by qualitative changes in the nature and scope of freight services offered. Not only have the costs of freight services declined, but firms in the freight service sector now offer a broader range of enhanced services allowing freight-using firms more flexibility to restructure their logistical and production activities, and thereby achieve non-transportation cost reductions. This is in large part the outcome of novel applications of IT in the freight service sector and continued public investment in transportation infrastructure. Given its central role in the development of the highway network, FHWA has a critical interest in a better understanding of the role of transport investments in enabling freight service firms to achieve these logistical improvements and related efficiencies, which not only enhance these firms' productivity, but also that of transport using firms in the larger economy.

Prior to the seminal work of Koichi Mera in the 1970's, assessments of the economic impacts of investments in transportation infrastructure were limited to appraisals of individual projects. Such appraisals provided relatively little insight into the broader role that transportation infrastructure plays in aggregate economic growth and productivity. Despite variations in data, methods, and the magnitude of the effects they uncovered, the sequence of macroeconomic analyses conducted in the U.S. and abroad over the past twenty-five years has identified a persistent, positive influence of transportation investments on aggregate economic performance.

While it is important to know that highway and other transportation investment programs are conferring economic benefits, macroeconomic studies tell us relatively little about the actual mechanisms through which these benefits arise. Policy formulation must address not only the question of whether to invest in infrastructure, but also the question of which among an array of potential projects will yield the greatest economic return. In order to answer this second question, it is necessary to open up the "black box" of macroeconomic studies and attribute economic benefits to specific mechanisms that may vary across projects due to location, network relationships, and other contextual factors.

In this paper we have looked at the underlying mechanisms from two perspectives: the microeconomic (partial equilibrium) perspective and the general equilibrium perspective. From the microeconomic perspective, individual firms benefit from cheaper, better, and faster freight services – benefits that can be captured in a conventional CBA framework. But cheaper and better transportation services may lead to savings in non-transportation inputs as well. For example, presented with lower transportation costs producers may choose to reduce inventories or consolidate facilities, even if it means consuming more transportation services. Important work is underway to incorporate these types of effects into CBA calculations.[xxiv] There are still other possible benefits that, to date, have not been incorporated into the CBA model. For one thing, improved infrastructure increases the locational flexibility of firms, which in turn can lead to a variety of efficiency improvements. Also, there are a number of ways in which improved infrastructure allows firms to *add value* – this includes both providers of transportation services and freight-consuming producers of other goods and services.

The general equilibrium perspective highlights a different kind of benefits from improved transportation. These benefits arise from economy-wide adjustments and redistributions. The key notion here is *gains from trade*, whereby aggregate efficiency is enhanced when cheaper or better transportation promotes interregional and international specialization and trade. The theory of comparative advantage tells us that producers and consumers are better off when each region specializes in those goods and services it can produce most effectively. High quality, affordable transportation makes this possible. The "new economic geography" shows that in the presence of scale economies and imperfect markets, reduced transportation costs can lead to a host of economic transformations that yield aggregate economic benefits. One of the most important lessons from this emerging line of theory is that the impacts of transportation improvements are *context dependent*. So, for example, the outcome of a new corridor connecting two regions depends on such things as the state of the pre-existing transportation network; the relative size, wage level, and state of economic development of the two regions; and the degree of type and competition of markets functioning in both regions. Clearly, if this is the case, economic assessments must incorporate a broader range of interrelationships and data than is typical in current practice.

Beyond conventional gains from trade, better transportation can also lead to major shifts in technology that bring about improvements in aggregate efficiency. Specialized commercial agriculture, the industrial revolution, and the globalization of production all represent technological transformations that would not have been possible without non-marginal improvements in transportation systems. Smaller, more incremental technological shifts most probably arise with each successive boost in transportation performance.

With the exception of the direct cost and time savings that are captured in conventional CBA, our ability to measure any of the main categories of benefits described here is relatively poor. Many of the impacts we describe have only been derived from theory or demonstrated by means of hypothetical simulation. Some experts, while conceding that a broad range of indirect benefits may exist, argue that the values of these benefits are probably small and therefore conventional CBA is sufficient.[xxv] Others counter that once you abandon assumptions of perfect competition and constant returns to scale, indirect effects can be cumulative and large.[xxvi]

Given our degree of uncertainty about many of these benefits, research along two avenues is warranted. The first is the expansion of our analytical toolbox to include a broader range of economic mechanisms. This includes further elaboration of CBA to capture the effects of logistical transformation, productivity-enhancing location shifts, and value-added effects. It also includes the development of more comprehensive frameworks such as CGE (Computable General Equilibrium) models. While the application of these models to transportation analysis is still a nascent field, a lot can be learned from operational models that are currently applied to international trade, tax policy and a number of other fields.

The second avenue of research comprises *ex post* assessment of major infrastructure projects and programs. By means of a more historical perspective we can ask a number of critical questions such as: To what extent did improved infrastructure lead to increased specialization and expansion of markets? How do freight service firms take advantage of improved infrastructure to offer cheaper and better services? What logistical, technological and locational innovations followed in the years after the project's completion? How did such economic adjustments translate into higher productivities and incomes? Naturally, such assessments must be more than just case studies; they must apply appropriate analytical methods to identify those economic changes that can be attributed to the infrastructure improvement from those that would have occurred without it.

Such a research program is ambitious, but its payoffs may be great. Its goal will be to create both a better understanding of the role of transportation in the economy and better analytical capacity to support more informed decisions about transportation infrastructure decisions in the future, and an increased capacity to serve the Department of Transportation Strategic missions of improving the national economy and national competitiveness.

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[i] National Transportation Statistics, BTS, USDOT
[ii] e.g. Fishlow, 1965; BTS, 1995
[iii] Eno, 1997
[iv] Aschaeur, 1989; Munnel, 1990
[v] The problem is elaborated upon in the more detailed white paper of which this paper is a synopsis.
[vi] The cost includes tolls and users costs of labor, fuel, capital depreciation etc. The user costs may be a function of distance, travel time, or both.
[vii] The user benefit is approximated by the "rule of half": ½ (S-S')(Q+Q'). This general procedure is repeated for personal transportation users as well as freight transportation users and the sum of freight and personal benefits are weighed against the project cost.
[viii] This sort of market distortion is not limited to the case where there is imperfect competition in the market for transportation services. The same applies if there is a monopolist in a freight consuming goods or service market. Benefits of investments in transportation infrastructure may be assessed from the perspective of derived demand for transportation services. Venables and Gasiorek (1999) have shown that in such cases CBA underestimates benefits.
[ix] These extensions are explained further in the companion paper.
[x] A good theoretical treatment of total logistics cost minimization is found in McCann, 1988. The idea of a substitution relationship between transportation inputs and other inputs is due to HLB, 2001.
[xi] In support of this idea, there is recent empirical evidence that expenditures on highway infrastructure has a negative effect on inventory levels at the state level (Shirley and Winston, 2001.)
[xii] Empirical studies in the United States (Hickling, 1995) and the United Kingdom (McKinnon and Woodburn, 1996) indicate an important trend toward cost savings through facilities consolidation, although neither can demonstrate a direct causal link with transportation costs.
[xiii] This approach, which is expanded upon in the companion paper, was introduced in HLB 2001, which also presents potential means of calculating the value of F.
[xiv] This runs counter to the conventional wisdom whereby location shifts should not be counted among the benefits of highway infrastructure. That argument is correct so far as the shifts simply reflect transfers of identical production activities from one location to another. But the spatial shifts described here are productivity enhancing and in therefore they produce real benefits.
[xv] The notion of agglomeration economies has long been used by geographers as a conceptual tool to explain the emergence of cities, and has gained empirical support from recent econometric studies that attribute significant productivity benefits to economic agglomeration (Ciccone and Hall, 1996.)
[xvi] The product life-cycle model (Vernon, 1966) argues that products and the industries that produce them pass through stages in their histories over which their main business requirements evolve.
[xvii] In assessing these benefits, care must be taken to avoid double counting – for example, the increase in the value of a trucking firm's services may be equivalent to the logistics cost savings of its client
[xviii] The modern version of the theory of comparative advantage is known as the Heckscher – Ohlin – Samuelson framework (Findlay, 1995.)
[xix] For example, a recent study by the Bureau of Transportation shows that 10.4% of U.S. freight movements over domestic road and rail infrastructure are ultimately to support international trade.
[xx] Some attempts have been made to incorporate competitive business expansion impacts into CBA (Weisbrod and Treyz, 1998) but they are rather *ad hoc* and generally only applied to changes in output for a single region or cluster of regions.
[xxi] The basic model exploits the analytical breakthrough of Dixit and Stiglitz (1977) who incorporated scale economies into a general equilibrium model assuming a monopolistically competitive market structure. A good overview is found in Fujita, Krugman and Venables 1999.
[xxii] In the long run, however, more firms – each providing a unique product variety – will enter any market where profits are being earned. The presence of more firms shifts the demand curves of all preexisting firms downward until excess profits are exhausted. Thus it is entry of new firms that brings about an equilibrium.
[xxiii] Venables and Gasiorek, 1999.
[xxiv] Lewis 1991; HLB 1995, 2001.
[xxv] See for example Mackie and Nellthorp, 2001
[xxvi] Venables and Gasiorek, 1999.

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15. Supplementary Notes

16. Abstract

This report summarizes the results of the Federal Highway Administration's (FHWA's) work on the economic benefits of transportation improvements using macroeconomic, microeconomic, and general equilibrium approaches. Detailed information is provided on recent microeconomic research focused on improving benefit-cost analysis (BCA) of freight transportation improvements. FHWA's Office of Freight Management and Operations sponsored this research. In addition to the summary, two analytical reports are included as appendices: 1) *Economic Effects of Transportation: The Freight Story*; and 2) *Transportation Infrastructure, Freight Services Sector and Economic Growth: A Synopsis*.

The BCA research was conducted to improve estimation of the benefits of transportation improvements. In current BCA only the benefits to transportation carriers are counted ignoring the benefits to shippers. The research was conducted in two phases.

Phase I of FHWA's research documented a range of short-term (first-order) and long-term (second-order) benefits to both carriers and shippers. First-order benefits include a reduction in transportation costs to individual firms due to decreases in transit time. Second-order benefits include efficiency improvements and further cost reductions, resulting from improvements in logistics and supply chain management and changes in a firm's output or location.

Phase II focused on developing an analytical model using readily available data to estimate the links among highway performance, truck freight rates, and shippers' demand for highway freight transportation. The model was designed to quantify first-order and second-order benefits detailed in phase I of the research. Preliminary results of Phase II research suggest that the benefits found in current benefit-cost models should be increased by about 15 percent to account for these newly measured effects.

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