

# **Freight Benefit/Cost Study**

## **Capturing the Full benefits of Freight Transportation Improvements: A Non-Technical Review of Linkages and the Benefit-Cost Analysis Framework**

(Final Report)

*Presented to:*

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## 1. INTRODUCTION

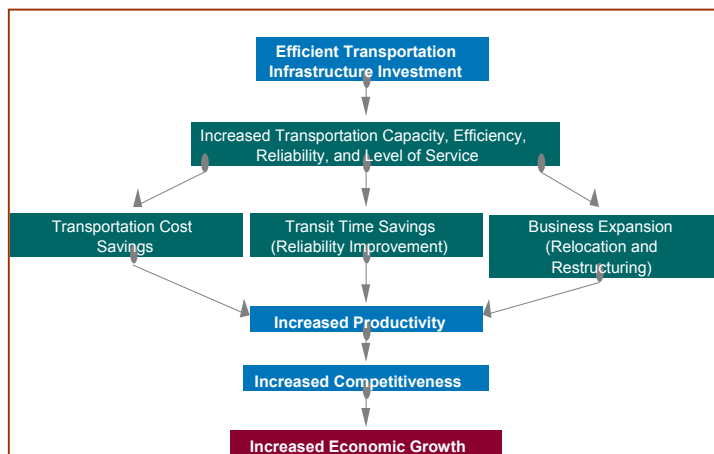
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Transportation policy and planning is not as robust as it should be in relation to the freight sector. The Federal Highway Administration's policy and planning institutions and tools do not appropriately recognize how and why infrastructure design and capacity problems drive down the productivity of freight transportation and drive up the cost of industrial production. Likewise, FHWA 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.

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 production, distribution, trade and/or retail sale of physical goods. Reducing 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.

Beyond lower dollar costs to shippers, reductions in transit time and/or increases in schedule reliability will 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

Exhibit 1: Transportation and the Economy



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.

In these several ways, freight improvements can spread reductions in cost and gains in productivity through all the economic sectors that produce or distribute goods (see Exhibit 1). Improvement in highway-freight carriage is one of the ways that government can make a truly valuable contribution to the efficiency of the American economy. While this may seem obvious, the impacts of freight-transportation improvements have been neglected, or been given scant attention, both in the scholarly literature on social benefits of highway improvements and in more general discussion.

Regardless of what scholars are writing about, 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 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 in this way to lower costs and/or improved quality of freight transportation is a fundamental source of benefits from improvements in freight carriage.

The programs of FHWA can contribute to improvements in goods movement in several ways. Clearly, highway investments that increase capacity and/or speed and reduce crashes will improve the performance of trucks. Improvements in intermodal connections will also have an effect. Intelligent Transportation System improvements can be particularly important, especially when they reduce incident-based congestion. It is clear that FHWA has a considerable capacity to bring about improvement in highway freight-carriage. It is entirely appropriate, then, that FHWA seek to measure the benefits generated by such improvements.

The most significant effort to date to study effects of highway improvement on costs and productivity of U.S. businesses is the work by Professor Ishaq Nadiri of New York University, sponsored by FHWA. Nadiri's work showed those effects to be significant. But his analysis is concerned with the impact of all highway improvements (on a fairly high-level system) on all businesses. It is not focused on freight movement as such. Freight carriage is clearly one of the effects that Nadiri captures, but not the only one, since improvements in highway passenger travel also have effects on business performance. In any event, Nadiri's work does not provide a basis for estimating benefits of future improvements in highway freight-movement. An entirely different approach is needed, one founded on the precepts of benefit-cost analysis, which is designed to estimate benefits of proposed investments.

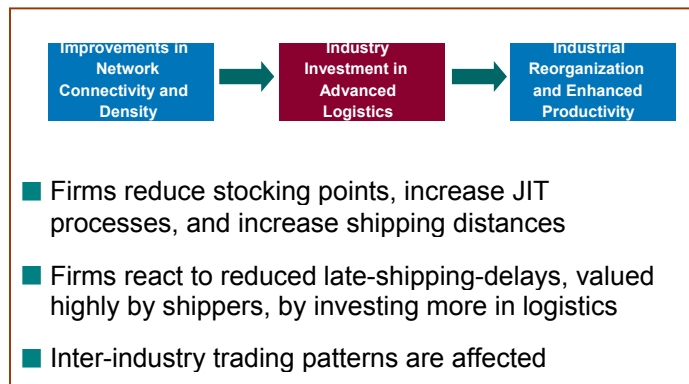
A number of benefit-cost models have been developed for evaluation of highway investments, but none of them accords proper treatment to the benefits of freight improvements. In general, the sponsors and authors of these models have been heavily focused on user benefits for highway passengers and truck operators 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. Where cost of travel time for a car is based on value of time for the occupants, cost of travel time for a truck is based on drivers' wages. In other words, the benefit valuation is based entirely on reduction in cost to the owner of the truck—in the freight context, the benefits estimated are the benefits to the carrier. But any effects on the owner of the cargo—the shipper—are not explicit or may not be fully accounted for in this approach.

Not treating the effects of road improvement 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 implicitly assumes there is no benefit to the shipper from getting goods to their destination more quickly. Yet 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.

Improvements in reliability can have effects similar to those of transit-time reductions and also allow tighter control of delivery schedules and inventories all along the supply chain. Reliability effects are usually thought to be stronger than transit-time effects alone,

Exhibit 2: How do Firms React to Improvements in Freight Transportation?



according to previous work done by HLB Decision Economics.<sup>1</sup> We can include both effects in the overall term, “time-cost reduction.” When time-cost reductions are strong enough, they can lead to additional efficiency gains through the “reorganization effect.” The reorganization effect occurs when a firm’s managers decide that time-cost reductions, and other savings from freight improvements, are sufficient to increase length of haul and reduce the number of the firm’s warehouses (see Exhibit 2). 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 result is a reduction in total logistics costs. The objective of this study is to capture the benefits of freight improvements in the standard benefit-cost methodology. The insights discussed above provide the basis for an analytic framework that can bring the full benefits of freight improvements into the benefit-cost calculation.

This paper presents the conceptual framework that has been developed for this purpose. We can build on the conceptual framework to develop a method that is analytically robust, will yield useful, quantitative results, and will stand up under critical economic



review. The material in this paper is presented in five sections—this introduction and four following sections:

- Section 2: Illustration of Linkages—This section explains and discusses business managers' increasing focus on reducing logistics costs while improving service to customers. Three case histories are presented that provide some insight on the ways in which businesses reorganize their logistics operations.
- Section 3: Framework for Economic Analysis—Here we present the economic concepts that will be used to estimate benefits of freight improvements and shows how those concepts provide a usable framework for the analysis. The concepts are defined and explained so as to be accessible to non-economists.
- Section 4: Estimating Quantitative Values for Benefits—In this section, we set out the approach, and related economic concepts, that will allow us to use the framework to develop quantitative values for benefits of freight improvements. The material is presented in a manner that makes it understandable for non-economists.
- Section 5: Summary and Next Steps—This section summarizes the analytical framework and the quantitative approach and identifies the next steps the study team must take to develop valid, usable estimates of benefits of freight-transportation improvements.

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<sup>1</sup> NCHRP 2-17(4) “*Measuring the Relationship between Freight Transportation and Industry Productivity*”, Final Report, HLB Decision Economics Inc., June 1995.

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## **2. ILLUSTRATION OF LINKAGES**

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The purpose of this section is to provide the reader with some specific examples of the things businesses do when they reorganize and restructure their logistics operations and the kinds of savings and other benefits that they realize. In the first part we give some sense of the evolution of business thinking about logistics over the last few decades; in the next part we offer three short case histories of logistics reorganization carried out by major corporations: Polaroid Camera, Dell Computer, and Ford Motor Company.

### **2.1 The Business World's View of Logistics: Trends and Developments**

Since the end of World War II, American businesses have given ever closer attention to reducing costs and improving performance of their logistics operations. Freight carriage, inventories, warehouses, and related facilities and operations have come under intense scrutiny as managers have realized both the potential for savings and for improved service to customers.

In the 1960s, for example, air lines promoted air freight on the basis of savings that shippers of high-value merchandise could achieve through reductions in inventory, warehousing, and materials-handling costs by switching from ground modes to more expensive, but much faster, air transport. Many shippers found that, in fact, they could spend more on transportation but achieve a reduction in total logistics costs. Essentially, they found that the money spent for reduced transit time and increased reliability was returned to them in lower costs for the other elements of their logistics operations. Reduction in time costs also provided benefits for customers and expanded sales for businesses. Markets for perishables such as fresh fruits, vegetables, and cut flowers were hugely expanded as air transport extended the reach of producers and distributors of these goods.

Throughout the 1960s business managers and analysts spoke of “physical distribution” when referring to the logistics operations and facilities that supported the movement of finished goods along the chain from manufacturers to wholesalers to retailers. Inbound

movement of materials and components was seen as a separate subject and was referred to in the literature as “physical supply.” This curious distinction vanished in the 1970s, and all of these activities and issues came under the single label of “logistics,” presumably borrowed from military parlance.

Concern with finding the least-cost combination of logistics components has long since spread beyond the distribution of perishable and other very high-value merchandise to virtually all physical products that must be stored and shipped. The concept of trading expenditure for increased speed and reliability against expenditure for inventory levels, number and size of warehouses, and related costs has been well established for some time. Exploiting reductions in time cost to achieve lower total logistics costs and improved customer service is the essence of the business response to freight improvement that we need to examine in this study.

In general, freight transportation costs have been declining in real terms because of deregulation and the trucking-industry changes it spurred and because of technology and infrastructure improvements. At the same time, inventory and warehousing costs have been increasing. The distinct trend has been to spend more on transportation and realize offsetting reductions in other logistics costs. As transportation costs have decreased relative to inventory and warehousing costs it has become common place to substitute transportation for inventory and warehousing to reduce total logistics costs. One result has been a decline in logistics costs as a relative share of the total costs of business.

Businesses are particularly aware of highway improvements that reduce transit time and increase reliability. Among other things, increased reliability reduces the amount of inventory that must be maintained as a buffer against the risk of late or missed deliveries. Decreases in transit time allow for greater productivity of drivers and extend the reach of a factory or warehouse. The effective market reach of a warehouse, for example, is often defined by the *round trip* that can be completed in one day (in ten hours or less under current maximum hours of service rules). Decreases in transit time enable greater distances to be covered and/or more stops to be made, enlarging the market served by the warehouse. While we write here in terms of distinct effects of speed increases and

reliability increases, there is some evidence that business managers view these in a combined way. A speed increase is of limited value, for example, if reliability is low.

In thinking about business reactions to freight improvements, it is important to bear in mind that there is a distinct element of “lumpiness” in the ways that firms can respond. Changing the number, size, and location of warehouses, for example, cannot be done in a gradual and continuous fashion. Such actions may require major investments; businesses’ discretion in making changes may also be time constrained by factors such as the terms of leases. Thus, business responses may lag well behind freight improvements in time. It is also the case that there will be a minimum gain, or threshold, in terms of cost reduction and time improvement that managers must see before they make major responses to a freight improvement.

## **2.2 Case Histories of Logistics Reorganizations**

### **2.2.1 Polaroid**

In the late 1980s Polaroid decided to centralize its European inventories by substituting transportation for warehousing; a large number of warehouses were closed. Estimated annual gross savings were \$6.9 million, broken down as follows:

1. warehousing personnel—\$2.5 million;
2. inventory carrying costs—\$2.2 million;
3. warehouse rental costs—\$1.0 million;
4. facilities and offices—\$0.6 million;
5. internal transportation between dealers and subsidiaries—\$0.5 million; and
6. insurance premiums—\$0.1 million.

Net annual savings were \$6.3 million after subtracting \$0.6 million per year for increased costs resulting from computer system maintenance and increased warehouse personnel at headquarters. A capital investment of \$3.0 million for new computer equipment was required.

Besides these 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 unspecified freight cost savings based on volume discounts for consolidated (truckload) shipments to centralized warehouses as well as reduced freight rates that reflected truck cost savings from reduction of border crossing inefficiencies.

### **2.2.2 Dell Computer**

In 1996 Dell Computer launched its “on-line” store. Customers were able to choose their own computer configurations and to receive 24-hour support on line. When an on-line order is received, the configuration of the desired computer is immediately transmitted to the manufacturing group. Using a specification sheet the order is broken down to individual components. Components are either ordered for just-in-time (JIT) delivery on very short notice or drawn from relatively small stocks that are replenished on a JIT basis. The computer is assembled by a production team and then shifted to software loading where it is tested for between four to eight hours. The entire process from receipt of order to shipping requires about 36 hours. Dell would not be able to achieve this combination of rapid response and low level of inventory without a very high level of freight service from United Parcel Service (UPS) under a comprehensive contract covering all inbound movements of parts, in addition to a sophisticated, computer-based communications system.

The on-line store concept was a revolutionary precedent for the computer industry that had been dominated by manufacturers with complex supply chains and relatively large inventories of parts and computers. By building to order and outsourcing most components, Dell gained a major cost advantage by greatly reducing parts inventories and virtually eliminating stocks of finished machines. Dell effectively became little more than an assembly and shipping company.

The JIT system for parts delivery allows Dell to reduce inventory of components from an industry norm of 75 to 100 days to 6.6 days. Suppliers are integrated into Dell's on-line ordering and procurement system resulting in a span of fifteen minutes for most suppliers between receipt of order and shipment to Dell's assembly plant. Shippers of monitors, for example, receive an e-mail giving the day a customer's order is to be shipped, and the monitor is delivered on that day. Dell estimates that they save \$30 per monitor by virtually eliminating inventory.

Dell's build-to-order approach is of particular significance in an industry characterized by continuous innovation and introduction of new products. Since prices of components decline rapidly in response to continuous innovation, Dell derives a cost advantage from the fact that most components are not bought until an order is received.

The Dell JIT system of procurement and on-line ordering typifies the virtual substitution of transportation and communications for inventory. It would not be possible without the availability of very high-quality freight transportation services.

### **2.2.3 Ford Motor Company**

Ford presents another example of using communication and transportation improvements to establish closer links to the customer and reduce inventory. The transportation-improvement stimulus came from cost and service gains realized from sharply increased use of rail service. Railroads went from moving very few new vehicles from assembly plants to a dominant share (over 80 percent) of this market. For example, in 1980 railroads handled 342,000 carloads of vehicles compared to 609,000 carloads in 1990. Since 1990 annual movements of finished vehicles have increased to nearly 900,000. This is a case in which a shipper reorganized its logistics to exploit fully the financial advantages of a low-cost mode while improving service to customers.

Several trends have favored increased use of rail movements of finished automobiles and light trucks in the U.S.

- Domestic vehicle production has grown largely as a result of foreign transplants and resulting decreases in imports with a more recent shift to exports.

- The mixture of new vehicles shipped has changed in the direction of more light trucks, which tends to favor rail for shipments from factories because the cubic-space requirements of light trucks and sport utility recreational vehicles are better met by rail cars.
- North American assembly plants, with the exception of recent rail served expansions in Mexico, have remained relatively concentrated in the Midwest and southern Ontario at rail-competitive distances from major coastal markets.

The Big Three did not respond to the service characteristics of rail shipment in any substantial way until 1997. Commencing in 1997 both Ford and GM announced sweeping changes in how new vehicles were to be distributed from assembly plants to domestic markets. Ford moved to implement a “regional mixing center” concept.

The stated reasons for the changes in distribution of finished automobiles were to reduce the costs of inventories and transportation and improve services and sales to dealers and customers. Ford was seeking to reduce order delivery time for new vehicles from 72 days to 30 days by 1997 and then to 15 days by 1999. Chrysler has announced similar objectives to deliver all orders within 28 days and sold orders within 16 days. GM has already established 24-hour delivery for its Cadillac line by creating ten regional distribution centers from which dealer orders can be filled in 24 hours.

Ford has created four national mixing centers at Chicago; Shelbyville, Kentucky; Kansas City, Missouri; and Fostoria, Ohio. Ford has an exclusive contract with Norfolk Southern Railway under which NS constructs and operates these sites. Each mixing center performs the function of a logistics distribution center by creating an assortment of vehicles that can be shipped to dealers in full rail cars or trucks to destination markets.

The mixing centers replace a push distribution system in which dealer orders for different lines of vehicles were accumulated at particular assembly plants until a sufficient quantity existed to fill an entire rail car (ten to twenty vehicles, depending on size) or truck (five to ten vehicles, depending on size) for shipment to the local market. Instead of waiting for sufficient dealer orders to fill rail cars and trucks, each assembly plant will make daily shipments to the mixing centers. The mixing centers will receive shipments from

different assembly plants. Rail cars and trucks will be unloaded and reloaded with a unique assortment for destination markets, reflecting orders by local area dealers. Vehicles will normally be held at the mixing center only as long as necessary for transloading. It is estimated that vehicles will be received at the mixing centers, unloaded, reloaded and shipped within eight to 24 hours.

The properties acquired for the Ford mixing centers range in size from 300 to 700 acres. The actual property to be used for automobile distribution will vary from 125 to 180 acres, averaging about 150 acres. The remaining acreage will be held as a combination of buffer or for other developments. It is anticipated that other manufacturers will also use the mixing centers as one mechanism to lower throughput costs. In some instances the development costs have been substantial. For example, NS has purchased nearly 700 acres at Shelbyville, KY to develop a 125-acre mixing facility for Ford. Ideally, about 300 to 400 acres would have been acquired but several large parcels had to be acquired in their entirety, necessitating a total land acquisition expense of nearly \$10 million. The Shelbyville center has parking spaces for nearly 3,000 vehicles and employs nearly 200 persons. The Ford distribution center concept has been adopted to achieve economies of transportation time by maximizing trainload and truckload movements of vehicles from all plants to the centers and from centers to local markets.

The four Ford mixing centers will handle over 3.2 million new vehicles a year. The mixing center concept also appears to have achieved substantial transportation cost savings for Ford. Exclusive rail access to each center was put out for competitive bid among three railroads. NS was the low bidder and serves all four sites. As a result NS can expect to handle almost all of Ford's business in these markets albeit at a substantial discount.

Through a major restructuring of its logistics operations and facilities, Ford was able both to reduce transportation costs and inventory costs while improving service to its customers.



## **2.3 Summary**

Two of these cases, Polaroid and Dell, illustrate a point that is at the heart of our analytical framework—that 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. Ford found savings in both freight costs and other logistics costs. The auto maker responded to the stimulus of improved rail service by switching to a lower-priced mode and using it more efficiently to cut inventory costs and reduce the time required to respond to customers' orders. Perhaps the central point is that real-world firms are alert for opportunities to improve their logistics systems and will act when they find the price and quality of transportation makes it feasible to do so.

In the following section, we see how this readiness to respond to better transportation can be expressed in formal economic logic and how the degree of business response becomes the keystone of our analytic framework.

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### **3. FRAMEWORK FOR ECONOMIC ANALYSIS**

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Standard approaches to highway benefit-cost analysis do not include the full stream of benefits specific to freight carriage (e.g., benefits stemming from business reorganization effects). A standard analysis of a highway investment takes account of benefits to immediate highway users: time savings, reduction in operating costs, and reduction in accident costs. Benefits from savings in truck travel time are calculated with an estimate of the average wage of the drivers. In the context of freight benefits, these are benefits to the owner of the truck (the carrier), but they do not include benefits to the owner of cargo (the shipper).

Costs of truck operation do not, however, provide a sufficient means of estimating the value of time in freight carriage; the impact on the shipper must be included as well. In industries with relatively high logistics costs, the greater share of gains from freight improvement may well go to the shipper rather than the carrier. Time-cost reductions—reductions in transit time and increases in reliability—have substantial value for shippers. These values need to be estimated and added to the benefits treated in the standard analysis in a manner that appropriately deals with potential double counting issues.

But that is, by no means, the whole story of bringing freight into the benefit-cost framework. There are significant effects of freight improvements beyond the immediate cost reductions for carriers and shippers. Improvements in the freight-movement system may allow companies to change their modes of operation in ways that lead to further gains in productivity. In a paper written over thirty years ago, Herbert Mohring and Harold Williamson referred to this as the “reorganization effect.” Improved transportation may let firms realize economies of density or scale, for example, by building bigger plants, warehouses, or stores, because a single facility can serve, or draw supplies from, a larger area owing to better transportation.

Much of a firm’s response to transportation-cost reduction will be reorganization of its logistics. It will respond to the lower costs by moving goods longer distances, using fewer warehouses, and carrying less inventory for a given level of sales. It will buy more

transportation and realize gains from improved logistics. But firms can make other changes in the ways they do things; lower costs might lead to product improvements, for example. We need to be clear about the different kinds of effects that may flow from freight-transportation improvement; they have to be treated differently in the analysis. The following classification scheme is helpful.

<b>Table 1: Effects of Improved Freight Transportation</b>	
First-order Benefits	Immediate cost reductions to carriers and shippers, including gains to shippers from reduced transit times <sup>2</sup> and increased reliability.
Second-order Benefits	Reorganization-effect gains from improvements in logistics <sup>3</sup> . Quantity of firms' outputs changes; quality of output does not change.
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.

The first part of the Freight BCA Study is concerned with the first and second-order benefits of improved freight transportation. At this stage, we are, thus, concerned with immediate cost reductions, including time-cost reductions for shippers, and with reorganization-effect improvements in logistics. The challenge is to bring the first and second-order benefits together in such a way that they are fully counted, but nothing is counted twice.

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-

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<sup>2</sup> 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.

<sup>3</sup> Improvements include rationalized inventory, stock location, network, and service levels for shippers.

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. The first-order case, taken by itself, is an unrealistic scenario. In the real world, a firm would make some kind of response to any noticeable cost reduction. We make the conceptual separation between the first and second-order cases because it helps us follow the path of causality and because it helps us fit these phenomena into the economic concepts of supply and demand. Cost reductions of a certain magnitude occur; firms respond in ways that lead to both greater output and lower cost per unit of output.

We look 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 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.

The conditions of demand are embedded in a curve or equation called a "demand curve." In our context, the curve shows the amount of freight transportation a firm will buy at various levels of freight cost, including time costs. The demand curve in Exhibit 4 takes two forms,  $D_0$  and  $D_1$ .  $D_0$  shows the firm's demand for freight transportation before the improvement takes place. The new curve,  $D_1$ , shows the change in demand that follows the improvement. But the change in demand is not immediate; it reflects a firm's response to the cost reduction, a response that will occur over some considerable period of time

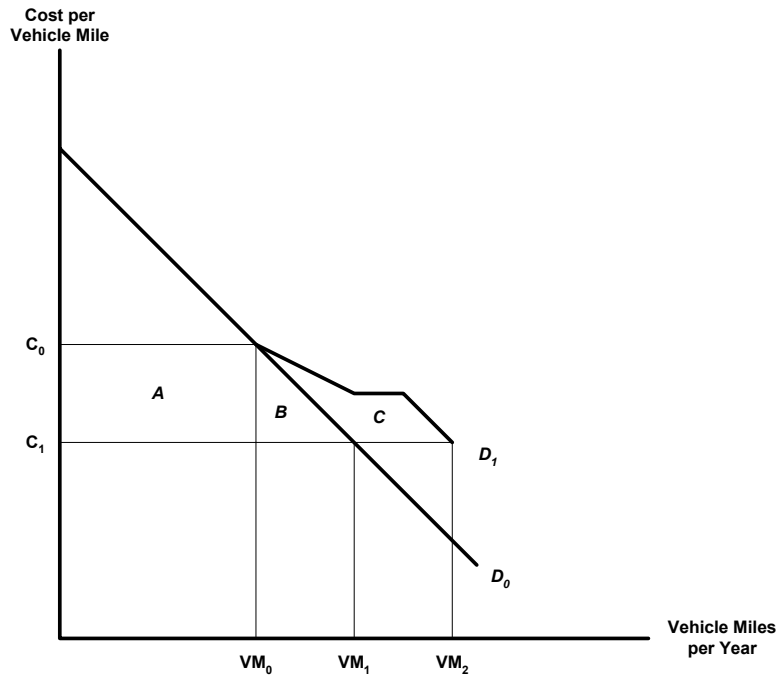


Exhibit 3: Demand Curve for Transportation

Recall that a shipper's demand for freight transportation reflects both the market's demand for the firm's products and the way it uses freight transportation as an input. The market demand for the products is not affected by the freight improvement, nor, at the first instance, is the way the firm uses freight transportation. The way a shipper uses freight transportation refers to its basic logistical arrangements, especially number and location of warehouses. The shipper's reaction to the cost reduction can be thought of as occurring in three phases, as illustrated in Exhibit 3.

Exhibit 3 shows the cost reduction from  $C_0$  to  $C_1$  on the vertical axis. 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 logistical arrangements.

But, after managers have had time to consider the cost reduction, they may, as already noted, make changes in their basic logistical arrangements. 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. This captures all benefits with no double counting.

The meaning of the shift in the demand curve requires some additional explanation. 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.

An important extension of this point is that the full benefit to the shipper is also the full benefit to society, as defined by the strict canons of benefit-cost analysis.<sup>4</sup> This is because consumers' demand for the shipper's product is embedded in the shipper's demand for inputs, including freight transportation. If, for example, the shipper makes gizmos, the social benefits from gizmo consumption are reflected in the shipper's demand for all the

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<sup>4</sup> All the benefits we are considering under the first and second-order cases count as social benefits by the strictest rules, providing there is no double counting. As the classification of effects in Exhibit 3 shows, there are a number of effects that may be of interest to citizens and to decision makers but are not benefits to society as reckoned by economic theory. As the table shows, such effects might include regional redistribution of income, regional employment effects, impacts on land values, or other effects. These effects might be shifts of benefits from one group to another, or they might be other reflections of the benefits already counted in the strict framework. In technical economic language, the benefits in A+B+C account for all the benefits to society from the freight improvement. This point is demonstrated mathematically in a paper by Herbert Mohring and Harold Williamson, published in 1969. That paper and the argument it presents are discussed in technical terms in the White Paper on the analytical framework that accompanies this paper.

inputs necessary to make gizmos.<sup>5</sup> Whatever benefits are realized by gizmo consumers are captured in the gains to the shipper, as measured by the combination of the reduction in costs (area A) and the increase in the shipper's consumer surplus (areas B and C).<sup>6</sup> (Please note that what is being measured here is not the increase in the shipper's profits. That is something different.)

Note that most of the discussion here is in terms of one firm buying freight carriage. The economic concepts set out here will apply with equal validity to many firms—all the firms, for example, affected by a freight-transportation improvement. We have developed a sound conceptual framework for the Freight BCA. We need a method for estimating the actual values that go with these theoretical constructs.

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<sup>5</sup> When we refer to “social benefits” here, it should be understood that we refer to the *gross* benefits of the freight improvement without subtracting costs to arrive at a net figure. Our underlying theoretical argument says there are no external benefits, all benefits are captured in the shippers' demand curves. When, in a later stage, we address costs, we will definitely find external costs that have to be added to the calculation.

<sup>6</sup> The economic concept of consumers' surplus reflects the fact that the total amount consumers pay for a particular good or service is less than what that good or service is actually worth to them. Different people will place a different value on a good. But, generally speaking, sellers are unable to discriminate among buyers according to their different values. The price prevailing in a market reflects the value placed on a good by that consumer (or consumers) who, among those who are buying, places the least value on that good, the “marginal consumer.” Others buying would be willing to pay more. For these consumers, there is a surplus, the difference between the price they pay and the actual value to them. See Appendix A for more on consumers' surplus.

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## **4. ESTIMATING QUANTITATIVE VALUES FOR BENEFITS**

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In the previous section, we explained that the shift in a shipper's demand for freight transportation would be the conceptual basis for estimating the benefits from a freight improvement. With the theoretical foundation in place, we turn to the problem of estimating actual values. It is one thing to build a framework of abstract reasoning on a demand curve as a theoretical construct; it is quite another thing to develop an empirical estimate of a demand curve or of a shift in a demand curve.

The approach that we have chosen to this empirical problem is based on a mathematical relationship that economists call "elasticity" of demand. If you know the price at which a good or service is actually being sold, and the quantity that is being sold at that price, and you know the elasticity of demand, then you have a great deal of information about the demand curve. For our purposes, elasticity of demand has two virtues: it provides useful information on demand, and therefore on benefits; and it may be feasible to estimate it.

Elasticity may be thought of as a measure of responsiveness. Elasticity of demand has to do with the response of demand for a good to a change in the price of that good (or service)—more precisely, it is a relationship between a change in price and the associated change in quantity sold.<sup>7</sup> Elasticity may be applied to other economic phenomena. Economists often investigate elasticity of costs, for example, with respect to other variables that may be of interest.

For our purpose of benefits estimation, we are concerned with the elasticity of demand for freight transportation with respect to the cost of freight transportation, cost including time costs. (The full mathematical argument in support of this point is set out in the White Paper, and there is no need to repeat it here.) The value of this elasticity can be known from the values of two other, related elasticities. One is about how shippers'

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<sup>7</sup> An elasticity is a ratio of percentages. In general, one speaks of the elasticity of  $y$  with respect to  $x$  when one is interested in the response of  $y$  to a change in  $x$ . The elasticity is the ratio of the percentage change in  $y$  to the percentage change in  $x$ .



demand for freight transportation responds to changes in time costs—elasticity of demand with respect to time costs. The other is about how shippers' logistics costs respond to changes in time costs—elasticity of logistics costs with respect to time costs.<sup>8</sup>

Intuitively, it seems reasonable that the response of shippers' demand and shippers' logistics costs to changes in time costs should be key factors in estimating benefits, and the mathematical argument in the White Paper demonstrates this point. Further, there is some prior experience in trying to estimate elasticity of cost with respect to time cost. As part of work done under NCHRP 2-17(4) [2], HLB Decision Economics developed a method for estimating the elasticity of logistics costs with respect to time costs. It appears feasible that the same method could be used for estimating elasticity of demand for freight transportation with respect to time costs.

The method used in 2-17(4) [2] was essentially one of very detailed interviews with representatives of a number of firms, the representatives being executives with close knowledge of their firms' logistics arrangements and likely investment strategies in the face of falling costs of freight carriage. The degree of time cost reduction—reduction in transit time and gain in reliability—required to cause a firm to make the investments required to reduce the number of its warehouses and increase their size is the most critical piece of information required for estimating both elasticity of logistics costs and elasticity of freight-transport demand with respect to time costs. Obtaining this information in sufficient detail and for a large enough sample of firms is probably the most challenging task confronting the team as we move forward into the data-gathering effort.

A number of other data items are also essential for this effort. The following is a partial enumeration of the most important information needs.

- Direct time-cost savings, from transit-time savings and increased reliability, due to highway improvements, and indirect savings from logistics reorganization effects;
- The threshold of time-cost savings at which reorganization would occur;

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<sup>8</sup> "Time cost," as used here, is a composite value reflecting both transit time and reliability. A decrease in transit time is a decrease in time cost. An increase in reliability is also a decrease in time cost.

- The elasticity of logistics costs with respect to time-cost savings (derived from the above two items);
- Current level of firms' demand for freight transportation and elasticity of freight-transportation demand with respect to time-cost savings (also closely related to the first two items);
- Volume of freight traffic and product movement across transportation links by commodity and market; and
- Average travel time and variability following highway improvements, or other policy actions, for various transportation network links and nodes—other policy actions could include such changes as relaxed weight or height restrictions, port clearance characteristics, or the like.

Much of these data would be initially collected at the level of individual firms and then aggregated by type of industry. As noted above, the information would be obtained in detailed interviews with executives of firms that buy freight transportation, executives closely acquainted with logistics operations and strategy and likely investment strategy for achieving increased savings through improved logistics. This line of research would be based on sophisticated interview techniques and employ what are known as stated-preference methods. Stated preference involves designing interviews so as to elicit quantitative information from respondents on choices they would make when confronted with various changes in their business environments.

What we sketch out here is the overall strategy in terms of the kind of information needed and the general approach to obtaining it. Working out the details of the information-gathering process is the next major step for the study team, and it will be a challenging task. It will be necessary to find a substantial number of business executives who are willing to participate in the study and willing to share some detailed information on their firms' business operations.

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## **5. SUMMARY AND NEXT STEPS**

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To recapitulate, the approach to estimating benefits of freight-transportation improvements depends on determining the value of those improvements to the businesses that buy freight-transport services, businesses engaged in the production, distribution, and/or retail sale of physical goods. The earlier work of Herbert Mohring has demonstrated, to the satisfaction of the economics profession, that the full benefit to society from improved freight movement can be estimated on the basis of the reduced costs to these businesses and their responses to those cost reductions. This is because the benefits that businesses get from better freight transportation reflect the benefits to their customers as well as to themselves.

Setting aside the technical jargon of economics, we see that the gains to shippers and their customers are what we need to measure to estimate the benefits from freight improvement. These gains take the form of immediate cost reductions from the freight improvement and subsequent gains from logistics reorganization. Some of the cost reductions achieved in this manner are passed through to the shippers' customers with some resulting increase in output. These are the sources of benefits.

Much of this discussion of our approach to estimating benefits has centered on the economic concept of elasticity. Again, however, we can set economic jargon aside and say that the key to measuring gains from freight improvement is in measuring the degree or the intensity of shippers' responses to freight improvements, particularly their responses to time saving and enhanced reliability. The technical economic arguments make this point with mathematics, but it is intuitively clear—the degree of businesses' response to freight improvements shows how much those improvements mean to shippers and their customers.

What this tells us is that the approach we have developed is both intuitively satisfying and supported by mathematical reasoning. The task now before us is to learn enough about businesses' responses to freight improvements so that we can develop accurate estimates of benefits. This task is challenging but certainly achievable. Two large pieces

of the work will be: (1) establishing the necessary contacts; and (2) designing the interviews and developing the related stated-preference techniques that will elicit the information required for the study.

Establishing the necessary contacts is not just a matter of finding a sufficient number of firms that are willing to participate in the study. It will also be necessary to identify “key informants,” managers and analysts who are closely acquainted with their firms’ logistics operations and strategic thinking about improving logistics.

The required stated-preference tools—interview designs, focus-group structures, and the like—will have to be developed in a way that keeps the whole process focused on the key parameters necessary to estimate benefits in dollar terms.

In carrying out these tasks, we remain mindful that others have conducted investigations in this area, and we will use their work to supplement and support our efforts to the maximum feasible extent. In particular, this means gleaning the literature for quantitative work that is directly relevant to this inquiry and developing, where feasible, numbers that reflect the consensus of previous work. In technical terms, this is called “meta analysis”: a process of surveying individual quantitative studies and combining their independent estimates into a single estimate that is a useful synthesis of the various studies.

By assiduously working along all of these paths, we expect to develop an analytical apparatus that will yield useful, albeit approximate, estimates of the benefits of freight transportation.

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## **APPENDIX A: MORE ON CONSUMERS' SURPLUS**

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In competitive markets, the intersection of the supply and demand curves for some commodity—say gizmos—determines both its market price and the quantity that is transferred from seller to buyer during some time period. A gizmo's price is the additional or marginal cost to some firm in producing what is, in a sense, the last gizmo manufactured today. The price is simultaneously the value its buyer attaches to today's last gizmo. If its price were just a tiny bit higher, this last buyer would not have taken today's last gizmo. Similarly, if its price were just a tiny bit lower, its producer would not have manufactured today's last gizmo. Put differently, the market price of today's last gizmo is the price at which its producer would be indifferent between manufacturing and not manufacturing it and, simultaneously, its buyer would be indifferent between buying and not buying it.

As commonly drawn, supply and demand curves respectively slope upward and downward from left to right. If this characteristic applies in the gizmo market, then, apart from the last gizmo, each of today's gizmos is valued by its buyer at more than its price and costs its seller less than its price. The difference between what a buyer would just be willing to pay for a gizmo and its actual price is commonly termed a "consumers' (or consumers or consumer's) surplus." Similarly, the difference between the market price of a gizmo and its marginal cost to a seller is commonly termed a "producers' (or producer or producer's) surplus." Economists commonly view the sum of the consumer and producer surpluses from, for example, today's gizmo sales as an important measure of the gizmo market's contribution to social welfare.

The vertically shaded area to the left of demand curve D1 in Exhibit 4 is the increase in surplus associated with first-order benefits—the cost reductions to shippers and carriers including those to shippers that result from reduced average travel times and the reduced variability of the difference between actual and average travel times. The horizontally shaded area to the left of demand curve D2 and above the price at which D2 and the new supply curve intersect is consumer-surplus benefits. They are associated with the logistic reorganization that curve D2 summarizes. The part of this area to the left of demand

curve  $D_1$  is benefits associated with the pre-improvement level of transportation services. The triangular area to the left of  $D_1$  is benefits associated with the increased transportation intensity to which the improvement gives rise.

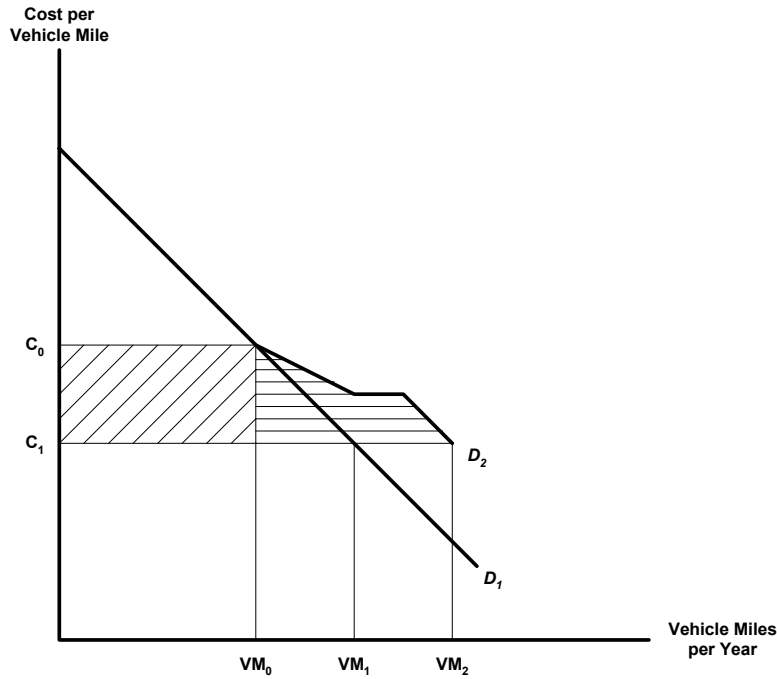


Exhibit 4: Consumer Surplus for Transportation