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PREFACE

Comparatively low-cost freight transportation has been an important element in the growth of the U.S. economy. Goods can be transported between most points in the country quite cheaply and efficiently. To varying degrees, however, the freight transportation services we consume generate costs that are borne by others. Such costs are commonly referred to as external costs.

From a societal perspective, it is desirable for all transportation services to pay their full social (private and external) costs. If the full social cost were reflected in the prices shippers pay, transportation users could choose the amount of each form of service to consume on the basis of the true cost of this service to society. By "internalizing" external costs, policy makers would effectively create a market through which transportation users could weigh the benefits of consuming a particular transportation service against the true costs. The purpose of this monograph is to estimate these true costs for freight truck and rail.

We estimate four general types of external costs for a ton-mile of freight shipped by truck or rail: accidents (fatalities, injuries, and property damage); emissions (air pollution and greenhouse gases); noise; and unrecovered costs associated with the provision, operation, and maintenance of public facilities (primarily roads and bridges). Because the preponderance of freight transportation occurs between cities, we focus on intercity freight flows and ignore the movement of goods within urban areas. Consequently congestion, a primarily urban phenomenon, is not addressed. An intercity focus also simplifies the estimation of air pollution costs. Whereas pollution levels in rural areas are fairly consistent, an additional unit of pollution can bring about costs that vary greatly among metropolitan areas based on existing air quality. Our analysis thereby serves as a benchmark against which more specific external cost estimates can be compared.

The research reported in this monograph was carried out at the University of Iowa Public Policy Center. Funding was provided by the U.S. Department of Transportation, University Transportation Centers Program, with supplemental funding contributed by the Iowa Department of Transportation.

ACKNOWLEDGMENTS

In the preface I mention that this research was funded by the University Transportation Centers Program of the U.S. Department of Transportation and by the Iowa Department of Transportation. Both of these agencies have my gratitude for their support.

Data needs for this project were extensive, and completion of this study would have been much more difficult without the assistance of several people. In particular, Lisa Schweitzer, my colleague at the Public Policy Center, was highly enterprising and thorough in helping me find necessary data. Harry Cohen provided data on air pollution costs in rural counties, and Scott Dennis shared various data from the Association of American Railroads. Alan Krupnick advised me on information sources related to the rates and costs of air pollution.

I acknowledge the important contribution of Gregory Bereskin, who modeled four freight railroad cost scenarios. It was a complex task to estimate the private costs per ton-mile of the four different railroad configurations. His work has enabled me to compare external costs with private costs for representative types of freight rail operations. A draft of this monograph was reviewed by the following people: Gregory Bereskin, Scott Dennis, Sheffer Lang, Sondip Mathur, Robert Pitcher, Thomas Pogue, and Lisa Schweitzer. They provided numerous suggestions that improved the monograph in many ways. Any errors that remain, of course, are my responsibility.

Anita Makuluni, editor at the Public Policy Center, ensured that the text is accessible to a wide audience, while maintaining the monograph's technical accuracy.

With real appreciation I acknowledge the many and diverse contributions of these people.

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CHAPTER 1
INTRODUCTION

Freight transportation is a vital element in the economies of nations, regions, and cities. Low-cost, dependable movement of freight helps a business to be competitive. Location of facilities, choice of shipment size and mode, and competitive bidding are among the ways a business seeks to keep its (private) transportation costs as low as possible. In the same vein, it is good public policy for society to try to minimize its total transportation cost, while ensuring that people and goods are moved effectively. First, however, policy makers must identify the full social costs for different modes of transportation so policies can be adopted that encourage transportation users to consider these costs when making travel or shipping decisions.

Ideally each unit of transportation service used (e.g., a person-trip or a ton-mile of freight) could be assigned a price that would reflect the full incremental cost to society of that unit of consumption. Charging the full incremental or marginal costs of transportation would establish a market in which transportation users could decide whether the benefits to them of consuming a particular unit of transportation would exceed the costs these users face. In economics parlance, such a policy would lead to efficient use of transportation services. It also could lead to equitable pricing of transportation, such that society would not absorb the costs of one mode or type of service to a greater extent than another.

EXTERNAL COSTS AND BENEFITS

External costs (or negative externalities) must be added to private costs to arrive at full social costs. Thus, to achieve full social cost pricing of transportation services, one must first comprehensively and accurately estimate relevant external costs. Varian (1984) defines external costs thus:

> In the basic general equilibrium model economic agents interact only through their effect on prices. When the actions of one agent affect the environment of another agent other than by affecting prices, we say that there is an externality (p. 259).

By this definition, external costs and benefits are outside normal market processes (i.e., are not reflected in prices). Externalities constitute a form of market failure because true costs are not taken into account when production and consumption decisions are made. If external costs are greater than external benefits, not considering externalities may lead to over-consumption of transportation.

Significant external costs arise from transportation, although accurate cost estimates have been difficult to obtain. In this monograph we assemble best available estimates of external costs due to freight truck and rail operations between cities (i.e., in rural areas). To place these costs in a useful context, we compare them with corresponding private costs, which are the market costs directly faced by carriers.

This monograph does not address the issue of external benefits that arise through the transportation of freight. Most transportation economists doubt the existence of significant external benefits from *the provision of transportation services* (e.g., Rothengatter 1994; Verhoef 1994, p. 278). Markets exist for these services, such that cost savings due to economies of scale or density may be retained by carriers, passed on to shippers, or ultimately passed on to final consumers of the shipped goods.

As Greene and Jones (1997, p. 9) observe, some economists believe that external benefits can arise from *improvements to transportation systems* (see, for example, Willeke 1994). An improvement may reduce the costs of firms' operations, thus contributing to increased competitiveness and more output. If scale economies exist, the unit cost of production may drop. Depending on market dynamics, the beneficiaries of this cost reduction may be the producing firm or its customers. In this analysis we focus on transportation services rather than facility investment and therefore do not consider external benefits.

AN INTERCITY FOCUS

Our objective in this monograph is to bring together what is known about the external costs of shipping freight between cities via truck and rail. We focus on intercity freight movements for two primary reasons:

- By far the largest number of vehicle-miles and ton-miles of freight transportation occur between cities, as opposed to within cities.
- External cost levels generally vary much less among rural areas than among cities. For example, ambient air pollution levels may be appreciably higher in one metropolitan area than another. In a city where pollution levels are already relatively high, additional truck- or rail-generated pollution will add greater social costs. Likewise, congestion costs are negligible in rural areas but range from low to quite high in U.S. cities. Applying an aggregate estimate of congestion costs when these costs are so variable would degrade the usefulness of the analysis.

Our general framework is amenable to adjustment for external costs prevailing within a particular metropolitan area or region. Good estimates of specific accident rates, congestion costs, and appropriate cost values for air pollutants would make it possible to estimate social costs for such an area.

MODAL COMPETITION

Under full social cost pricing of freight transportation modes, the true costs to society would be reflected in the prices paid by users, and therefore the modes would be able to compete on an equal basis. How the inclusion of external costs would affect modal competition between rail and trucking would depend on a number of factors, including relative service quality and the extent to which the two modes are able to serve the same markets. In general, rail and trucking compete in markets involving distances that are relatively short for rail yet relatively long for trucking. Most often, the value (dollars per ton) of freight shipped by truck is higher than that shipped by rail. One must recognize that our general unit of analysis, the ton-mile, includes a very wide array of goods.

Figure 1–1 indicates the amount of freight (measured in ton-miles) shipped in the United States by long-haul truck and freight rail in 1994. Of particular interest are the shaded portions of both pie charts: 41 percent of long-haul truck ton-miles are competitive with rail, and 33 percent of rail ton-miles are competitive with truck (Abacus Technology Corp. 1991, Exhibit 5–1). In total, about 768.5 million ton-miles shipped annually are modally competitive.

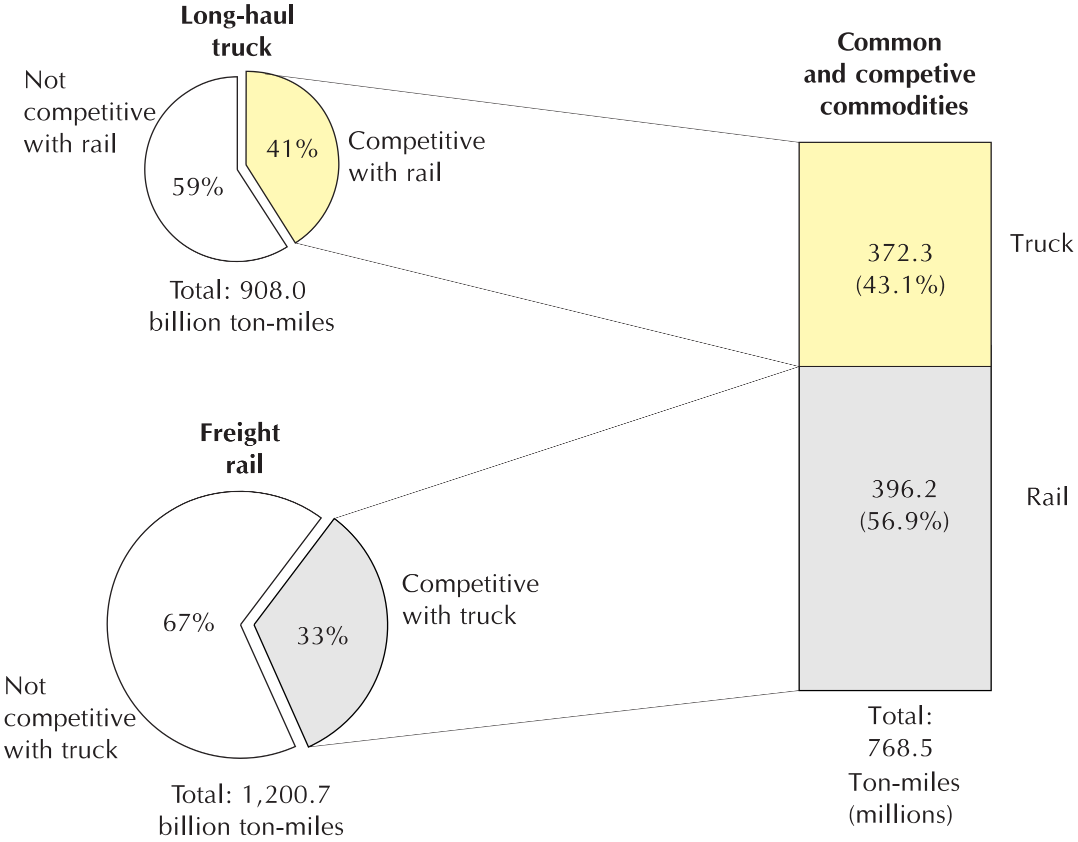

Figure 1–1. Competitive freight service for truck and rail, 1994

SOURCES: Bureau of Transportation Statistics (1996a, pp. 41, 53). Percentage modal competitive estimates are for 1987 from Abacus Technology Corp. (1991, Exhibit 5–1). Freight rail ton-miles are for Class I railroads.

If full social cost pricing were to become policy, the extent of any resulting shift in modally competitive freight in a given market would depend on several factors, including:

- the magnitude of change in relative prices for various types of shippers,
- the difference in quality of service provided by competing modes, and
- specific requirements on the part of shippers.

Aggregate estimates of these factors would be difficult to make. Thus, the change in modal shares if full social cost pricing were in effect can only be speculated on, even if the magnitudes of price changes were known. Our interest in this monograph is to estimate the size of external costs and the extent to which full social cost pricing would exceed current market costs faced by freight rail and trucking carriers. It is not our objective to argue for greater use of one mode or another.

Marginal versus average costs

In estimating social costs, ideally we would examine the marginal cost to society of one more unit of freight transportation service. If a freight carrier pays marginal user charges that equal the marginal social cost of the unit of freight, the provider of transportation service is paying appropriately, from a societal perspective.

As the Transportation Research Board (TRB 1996, p. 2) observes, a marginal cost perspective is quite different from that used in highway (and other) cost allocation studies. Such studies are intended to determine how the costs of providing government facilities and services should be distributed equitably among different vehicle classes. In contrast, a marginal cost perspective is concerned only with whether the costs borne by society are fully assigned to those generating them. Marginal social cost pricing may be equal to, higher than, or less than the budgetary cost of government for providing facilities and services.

As a practical matter, it is difficult to develop accurate estimates of the marginal social costs of freight transportation. For example, good data are available on the number of fatalities and personal injuries associated with 100 million miles of truck operations. Thus, the average accident cost per vehicle-mile can be derived, and using average load factors, average cost per ton-mile can also be calculated. The marginal accident cost of one more truck vehicle-mile or ton-mile is much more difficult to estimate. Trip-specific considerations such as traffic volume on the roadway, design of the roadway itself, weather conditions, and factors peculiar to the truck and driver all enter the picture.

Estimates of marginal social costs are most valid when they pertain to very specific circumstances. In its report on marginal social costs of freight transportation, TRB (1996) used four specific case studies and stressed the limitations of these studies in making general conclusions about marginal social costs. TRB recommended (p. 125) an expanded array of case studies to increase what is known about the social costs of freight transportation.

In this analysis we use average costs largely derived from aggregate data. While our estimates lack the precision of a more specific case study, these estimates provide an overall sense of the magnitude of various types of external costs generated by freight trucks and rail relative to average private costs nationally.

Application of this research

Our objective is to provide an overall assessment of external costs arising from truck and rail freight transportation. If public policies were formulated to internalize these external costs in an aggregate sense, some carriers of either mode would overpay, while others would underpay. The amount of overpayment or underpayment would depend on the difference between average costs in the aggregate and the marginal costs in a particular circumstance.

In short, unless one is able to accurately estimate the marginal social costs of each unit of transportation (e.g., each ton-mile) in widely varying circumstances, two choices are possible. One is to ignore external costs and estimate user charges and taxes solely on the basis of public facility use, and the other is to accept a degree of cross-subsidization within each transportation mode. We tend toward the second option: developing conservative estimates of average social costs in rural areas where the variation in these costs is less likely to be sizable than is the case in metropolitan areas. Our approach thus can serve as a benchmark against which case-specific estimates can be compared.

Overview

To provide a context for our estimates of social costs, in Chapter 2 we develop estimates of the private operating costs faced by freight truck and rail carriers. Although the only important issue from a public policy perspective is the magnitude of external costs (which need to be internalized), private cost estimates enable one to gauge how sizable external costs are *relative* to private costs.

In Chapter 3 we estimate average non-market or external costs for a ton-mile of freight shipped by truck or rail. The three major categories of external costs we include are accidents, emissions (both air pollution and greenhouse gases), and noise impacts.[1] We begin by defining our methodology for estimating accident external costs, which are equal to total costs to society of accidents per unit of service minus any compensation paid by the freight carrier. Then we provide estimates of unit costs of fatal, personal injury, and property-damage-only accidents.

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[1] We use the term "accidents" even though in much of the current safety literature the term "crashes" is more common. On-the-job injuries to employees or pedestrians being struck by a train or truck are better described as accidents than crashes.

Our analysis of air pollution costs is based on a review of previous studies that have assigned dollar values to units of various pollutants. Values we obtained are often quite wide-ranging, reflecting both differences in conditions at the sites being studied and uncertainties regarding the appropriate values to assign. We estimate pollution rates for general freight trucks and the four train scenarios, as well as the resulting costs per ton-mile. A comparable analysis is presented for carbon dioxide (CO_2), the most important greenhouse gas generated by diesel engines.

Finally, in Chapter 3 we explore external costs associated with the noise emitted by trains and trucks operating in rural areas. Following a discussion of noise effects, we review previous studies that assessed the economic costs of noise. Lacking better data on residential densities, a key factor in noise cost estimation, we use a rather low estimate developed in the 1980s. We then apply conservative values of noise costs for trucks and freight rail.

Chapter 4 contains an analysis of the extent to which freight trucks pay the full costs associated with their use of public facilities. Because essentially no freight rail operations use public facilities, the chapter addresses trucking only. Using results of the 1997 Federal Highway Cost Allocation Study (FHWA 1997a), we estimate the difference between user charges paid by heavy trucks and the costs these vehicles occasion. Our estimates include payments and costs for federal, state, and local levels of government.

In Chapter 5, we synthesize the results of the previous chapters and draw implications for trucking and rail.

CHAPTER 2
PRIVATE COSTS

To determine the fractional increase in freight costs that would result if freight trucking and rail were to pay the full costs they occasion, it is necessary to estimate both the private and external costs of the two transportation modes. Private costs are the direct expenses incurred by providers of freight transportation. Such costs consist of operating costs, as well as investments in capital facilities and rolling stock which eventually wear out and must be replaced. Operating costs are those that are closely linked to the amount of service provided: fuel, wages, maintenance, user charges, depreciation, and insurance.

External costs are the result of day-to-day operations, so operating costs are the most appropriate basis for comparisons with external costs. Taken together, private operating costs and external costs can give both shippers and carriers signals regarding the true (full) cost of a unit of service. In turn, the amount of service demanded at this cost will define the appropriate level of capital investment.

Because most data on production costs for freight transportation are averages, these data will differ from the cost at the margin by the magnitude of any remaining long-run economies of scale. In the discussion to follow, we consider the extent to which economies of scale exist in freight trucking and rail. We then estimate average costs per ton-mile for the most common type of intercity trucking operation and for different types of freight train configurations.

MOTOR CARRIER OPERATING COSTS

Types of motor carriers

There are two basic forms of freight truck service operating in the United States: truckload (TL) and less than truckload (LTL). TL services generally transport a shipment of freight from a single shipper to one or more receivers; freight is picked up in a line-haul combination truck at the shipper's dock and transported to the destination in the same vehicle. TL carriers rarely handle freight at their own facilities.

LTL trucking serves many shippers that often send small shipments to be delivered to multiple receivers. To serve numerous shippers, LTL carriers maintain strategically located terminals. Smaller trucks bring freight to the terminals and distribute it from terminals; line-haul combination trucks move the freight between terminals. Because of the large investment in terminal operations, entry into LTL operations is difficult.

As a result, several large companies dominate LTL trucking (e.g., United Parcel Service, Yellow Freight, Roadway Express, and Consolidated Freightways).

The TL market is much easier to enter because all that is needed is a driver, rolling stock, and a freight broker with whom to work. Accordingly, the TL sector is highly fragmented, being composed of many small and medium-sized carriers. Following deregulation of the trucking industry in 1978, the number of TL carriers grew rapidly, up from about 17,000 certified carriers in 1979 to roughly 38,000 in 1987 (TRB 1989, p. 73). During this time the number of Class I carriers (annual revenues of more than $10 million) actually fell, while smaller Class III carriers (annual revenues less than $3 million) more than doubled. According to TRB (1989, pp. 70–71), since deregulation TL carriers have accounted for a steadily increasing portion of the ton-miles of service provided by the trucking sector. By the late 1980s, TL carriers were transporting over 90 percent of the ton-miles shipped by truck. We focus on TL trucking in this analysis.

Private operating costs of TL carriers

TL carriers can be divided into six categories:

- general freight,
- automobile transport,
- refrigerated,
- bulk commodity,
- tank truck, and
- other specialized.

For each of these categories, the American Trucking Associations (ATA) compiles operating and financial data. ATA data include nearly all Class I carriers, some of the Class II carriers, and almost none of the Class III carriers. Available private cost data on TL operations therefore tend to pertain to larger trucking firms. The lack of data on smaller carriers could bias our cost data downward, to the extent that scale economies exist in the trucking industry. Button (1993, pp. 74–75), however, doubts that there are significant increases in returns to scale, citing evidence that large companies compete directly with one- or two-vehicle firms. He further notes that while differential managerial skills may permit some firms to grow larger than others, that does not in itself reflect scale economies of a technical nature.[2] To the extent that there are no sizable scale economies in TL operations, average operating cost data provide a reasonable approximation of the marginal private cost of one more ton-mile of service.

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[2] McMullen and Stanley (1988) conclude that prior to deregulation of the trucking industry in 1980, the industry did have increasing returns to scale; after deregulation the industry has exhibited essentially constant returns to scale.

By far the largest TL category in terms of ton-miles transported is general freight. Because of its dominance and our desire to avoid unnecessary aggregation, we limit our analysis to general freight trucking. ATA breaks down TL general freight trucking by the length of haul carried out by various motor carrier firms. In Table 2–1 we present 13 expense categories and key performance measures for three lengths of haul. Overall, in 1994 TL general freight trucking had a per-mile operating cost of $1.25, a cost per ton-mile of 8.42 cents, and an average load of 14.80 tons.

FREIGHT RAIL OPERATING COSTS

Estimating private costs of freight rail service is inherently more complex than is the case with trucking. Among the complicating factors are joint production among rail companies (e.g., sharing trackage or rolling stock), economies of scale and density, and a lack of data on specific expenditures pertaining to individual freight

Table 2–1. Private operating costs of truckload (TL) general freight trucking, 1994 (thousands of 1994 dollars)

	Length of haul			
Expense category	Under 250 miles	250 to 500 miles	Over 500 miles	All TL general freight carriers
Salaries	46,886	79,729	298,930	425,546
Wages	297,525	358,887	1,939,752	2,596,164
Fringes	94,755	87,227	391,724	573,706
Operating supplies	158,493	275,786	1,284,868	1,719,148
General supplies	39,024	73,156	356,455	468,635
Tax and license	31,238	45,345	329,234	405,827
Insurance	40,743	60,480	316,131	417,354
Utilities	12,525	21,188	100,546	134,259
Depreciation	51,963	80,938	458,853	591,754
Equipment rents	322,098	689,313	2,655,641	3,667,052
Office equipment	5,523	15,472	45,125	66,120
Disposal of assets	(2,516)	(8,905)	(30,218)	(41,639)
Miscellaneous	13,800	27,606	73,231	114,637
Total expenses	1,112,057	1,806,233	8,220,271	11,138,562
Highway miles operated (thousands)	723,052	1,367,380	6,845,397	8,935,829
Ton-miles (thousands)	5,252,908	20,198,788	106,832,649	132,284,345
Cost per mile (dollars)	1.54	1.32	1.20	1.25
Cost per ton-mile (cents)	21.17	8.94	7.69	8.42
Average load (tons)	7.26	14.77	15.61	14.80

SOURCE: ATA (1995, Summary Tables III and V).

movements. To cope with these complexities, a number of researchers have developed econometric cost estimation models.

Previous modeling efforts

Most econometric models are intended to measure changes in rail productivity over time, as well as estimate the effects of mergers. Examples include Caves et al. (1980, 1981a, 1981b, 1981c) and Bereskin (1996). Models that estimate the nature of economies of scale or density have been constructed by Spady (1979), Spady and Friedlaender (1976), Friedlaender and Spady (1980), Bereskin (1983), Barbera et al. (1987), and Lee and Baumel (1987).[3] These authors generally conclude that the rail industry has become more productive over time. Of particular importance to our work, these modeling efforts have shown that rail costs are not linear in nature.

In a review of previous studies, Keaton (1990) reveals significant economies of density in the general or mixed freight rail sector and conjectures that similar economies of density may not exist in the case of unit trains (long trains carrying bulk cargo, such as grain). Keaton further suggests that some economies of density are likely for intermodal trains. Several points are clear: the literature suggests that economies of scale and density exist in freight rail, and these economies probably vary considerably among different types of rail operations.

Four rail scenarios

Because freight rail operations vary widely, a single aggregate value for private cost per ton-mile would hold little meaning. To estimate private rail operating costs for representative operational scenarios, we have developed cost models for four very different types of freight trains.

- **Heavy unit train.** The train has 100 lightweight cars of 26 tons, and each car carries 105 tons of cargo. The trip is 1,000 miles in length, with a 100 percent empty return. Power for the train consists of four 3,000 brake horsepower (BHP) locomotives.
- **Mixed freight train.** Mixed cargo is carried in 90 cars averaging 32 tons. The cargo averages 70 tons per car, and the trip length is 500 miles, with a 45 percent empty return rate. Power for the train is provided by three 3,000 BHP locomotives.
- **Intermodal train.** This train consists of 120 truck trailers riding on 120 articulated spine cars. Trailers average 28 tons, including cargo, and spine cars weigh 14 tons. The trip length is 1,750 miles, and a five percent empty return rate is assumed. Power is supplied by three 3,000 BHP locomotives.

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[3] Economies of scale result if unit costs are lower for larger railroad firms. Grimm and Harris (1983, p. 275) point out that such economies are likely to be associated with the administrative rather than operating functions of the firm. Economies of density result from more frequent service on a given length of route, or from operating longer trains.

- **Double-stack container train.** The train consists of lightweight, five-well platform cars, with an average weight of 16 tons per well (80 tons per car). Each well carries two containers with an average weight of 28 tons, or 56 tons per well. There are 24 cars in the train (120 wells) carrying a total of 240 containers. A ten percent empty return rate occurs. Power consists of four 3,000 BHP locomotives.

The four trains vary substantially in terms of basic configuration, power, trailing tons of cargo, trip length, and empty return rates. While we assume the same accident rates and noise impacts for all trains in Chapter 3, we vary emissions costs per ton-mile. Most important, the private cost per ton-mile varies among the four scenarios. Therefore, realistic and representative private cost estimates for different types of freight trains provide bases for comparing external costs with those experienced by railroad companies.

An analysis of rail operating costs

As part of our research, we modeled operating costs of Class I railroads (those with annual gross operating revenues in excess of $50 million in 1978 dollars).[4] To model these operating costs, we used a translog function (see Bereskin 1998). The function has four input prices: labor, materials and supplies, fuel, and other factors (using the Association of American Railroads index for other expenses). We also incorporate four output measures: gross ton-miles, car-miles, train-miles, and locomotive-horsepower-miles. Data are for a 17-year period, 1978 through 1995. A total of 36 firms are included in the analysis, but through mergers and bankruptcies only 11 firms remained in 1995. Dummy variables are used as proxies for the changing railroad structure due to changes in the number of firms.

Cost estimates are developed for each of the four stereotypical train types listed above. These trains have very different operating parameters; our intent is to estimate the costs of operating hypothetical but realistic train configurations. We have developed two cost estimates for each train scenario, one with the operating parameters averaged and one with the parameters weighted by gross ton-miles of each included railroad firm. Using both definitions enables us to examine costs as total traffic and route density increase with both railroad firm size and volume. We observed sizable economies of size and density.

Our ton-mile operating cost estimates use averaged operating parameters for the four rail scenarios and are presented in Table 2–2. Both the heavy unit train and the mixed freight train scenarios result in ton-mile costs of approximately 1.2 cent. The intermodal train cost per ton-mile is 2.68 cents, and the double-stack train costs 1.06 cent. We compare these estimates with external costs in Chapter 5.

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[4] Class II railroads are those with annual gross operating revenues of between $10 and $50 million in 1978 dollars; Class III railroads have annual gross operating revenues of less than $10 million in 1978 dollars.

Table 2–2. Private operating costs of four railroad freight scenarios, 1994

Railroad scenario	Power	Cargo (tons)	Distance (miles)	Average cost per ton-mile (1994 cents)
Heavy unit train	4 – 3,000 BHP locomotives	10,500	1,000	1.19
Mixed freight train	3 – 3,000 BHP locomotives	6,300	500	1.20
Intermodal train	3 – 3,000 BHP locomotives	3,360	1,750	2.68
Double-stack train	4 – 3,000 BHP locomotives	6,720	1,750	1.06

SOURCE: Research by Bereskin (1998).

SUMMARY

Because TL carriers move over 90 percent of the intercity freight shipped by truck, we focus on this segment of the industry. The preponderant evidence suggests that in an unregulated environment, there are very limited economies of scale in TL trucking, so using average cost data enables us to make reasonable estimates of per-ton-mile costs. Our primary interest is in general freight trucking because it accounts for the vast majority of ton-miles in the TL trucking industry. In 1994, the average cost per ton-mile for TL general freight trucking was 8.42 cents.

Within the rail freight sector there appear to be economies of scale, and costs of different types of service vary substantially. To provide representative estimates of ton-mile costs, we have developed four rail shipment scenarios and estimated costs for each. One of the most valuable outputs of this analysis is an insight into the degree of cost variance by type of train. Our estimates of operating costs range from 1.06 cent per ton-mile for a particular configuration of container train to 2.68 cents for an intermodal train.

In this chapter we estimate private trucking and freight rail ton-mile operating costs incurred by carriers. These estimates constitute the basis for comparisons with external costs developed in the next two chapters.

CHAPTER 3
NON-MARKET COSTS

To charge the full cost of transportation services, it is necessary to estimate the magnitude of social costs as accurately as possible. The difficulty is that few of these social costs can be assigned dollar amounts that will be widely embraced. Also, the effects of different transportation modes on the environment; infrastructure; other travelers; and the health, safety, and welfare of the general population is not fully understood. Keeping these limitations in mind, this chapter categorizes external costs of transportation and provides the best possible estimates of their magnitudes.

External costs can be subdivided into two general classes, those related to impacts on other people who are not fully compensated and those related to unrecovered government expenditures. Subsidies result when a particular type of traveler does not pay the full cost of using public infrastructure.

The most important general categories of external costs arising from freight-carrying transportation modes operating between cities are:

- accidents;
- emissions;
- noise impacts; and
- unrecovered costs associated with the provision, operation, and maintenance of public facilities.

Although congestion is also a significant external cost of highway-based transportation, it is rarely a problem outside metropolitan areas. Given the inter-urban focus of our analysis, we therefore do not include congestion costs. The issue of unrecovered costs associated with public facilities is addressed in Chapter 4. The other three primary categories of external costs germane to inter-urban freight transportation are examined in the following sections.

ACCIDENTS

All transportation modes occasionally are involved in accidents and mishaps of various sorts. When this occurs, people and their property often experience adverse outcomes. The external cost due to accidents of a unit of transportation service (e.g., a vehicle-mile or a trip) includes the uncompensated cost of deaths, injuries, and property damage that occur due to an additional trip by the mode in question.

It is not possible to provide completely accurate estimates of the marginal accident costs of trips by truck or rail. Inaccuracies stem from the effects of various types of traffic on the accident rates of other travelers and non-traveling populations. Accident records can be examined to measure freight truck or train involvement in motor vehicle accidents, but there is no systematic way to determine what role they played in these accidents. If the primary cause of an accident is another vehicle, a pedestrian, or conditions external to vehicles (e.g., severe weather), an involved truck or train may not have precipitated the incident. On the other hand, its presence may have contributed to external costs experienced by other travelers or persons.

It is important to stress that fault is not at issue. Whether a truck or train involved in an accident was completely free of blame or whether it caused the accident is irrelevant to our analysis. Regarding the issue of fault, in a classic work, Vickery (1968) concludes:

> (I)n most of the accidents with which we are concerned there are two or more parties involved, and the damage involved in the accident could have been totally avoided if any party had acted differently, whether by driving less recklessly in the case of the "guilty" party, or by driving more defensively in the case of the "innocent" party, or by accomplishing the purpose in some way not involving the specific activity at all, as by travelling by train rather than automobile, or by living closer to one's place of work, or even giving up the object of the trip entirely… Systems which require payments by the actors only in the case of fault and only to the extent of the compensation received by others (even with the expenses of adjudication and administration added) fail to give an adequate incentive for seeking out alternatives not involving the increased risk of vehicular accident (pp. 466–467).

The real point is that the social cost would not have arisen had the particular transportation service not been provided. Thus, a fatality or injury bears the same societal cost whether the affected person is an employee aboard a train or truck, an occupant of another vehicle, or a pedestrian.

Our approach is to estimate total accident costs to society, per unit of service provided, that result from accidents for each of the two transportation modes being studied. Costs to society consist of fatalities, personal injuries, and property damage. We provide data on the number of incidents and apply cost estimates to arrive at total estimated costs. We then estimate the amount of compensation railroads and motor carriers have provided. Subtracting this compensation from total societal costs due to accidents yields external costs, the uncompensated accident costs that result from motor carrier and railroad operations.

The cost of accidents

It is unpleasant to think of fatalities or personal injuries in monetary terms, but that is what must be done if one is to estimate the cost to society of accidents. Considerable work has been devoted to conceptual issues related to placing a value on saving human lives and preventing personal injuries. Generally, the approach that is becoming dominant is "willingness to pay."[5] According to this concept, the cost of a particular type of accident is the amount people would pay to reduce the risk of it happening.

To estimate willingness to pay for risk reduction, one observes market trade-offs in the amount people pay for risk reduction versus other goods. Because some people would be willing to pay more for a good than the asking price (that is, they enjoy what economists refer to as consumer surplus), the amount that people pay for the good is a lower-limit estimate of the value that they place on it.

For example, suppose we observe that four million people pay $100 each for a safety enhancement on the new cars they buy. Further, suppose the buyers expect this enhancement to reduce their chances of fatal injury by one in 4,000 over the period that they will be using the cars. As a group, the buyers expect their $400 million investment to save 1,000 lives. Collectively, the buyers have demonstrated a willingness to pay $400,000 per life saved.

A report prepared for the Federal Highway Administration by the Urban Institute (Miller et al. 1991) summarized the results of numerous studies of the value of risk reduction. The values suggested by Miller et al. are widely used as estimates of the economic value of reducing the risks of motor vehicle crashes. Miller et al. express their suggested values in 1988 dollars; in Table 3–1 we present their values in 1994 dollars, having applied the Gross Domestic Product (GDP) deflator. These are the values used in our analysis.

Estimated external accident costs per ton-mile for freight trucks and trains follow.

Table 3–1. Cost of accidents (1994 dollars)

Accident type	Per person	Per accident
Fatal	2,903,782	3,304,027
Personal injury	56,255	84,455
Property damage	2,110	5,448

SOURCE: Miller et al. (1991), inflated to 1994 dollars.

Motor carriers

Evidence suggests that motor vehicle accident rates for fatal, personal injury, and property damage accidents increase with traffic volume up to a certain level of traffic, about 7,000 vehicles per lane per day (Hall and Pendleton 1990). Forkenbrock and Foster (1997) have estimated the relationship between average daily traffic (ADT) per lane and accident rates per million vehicle-miles of travel (VMT). Using semi-logarithmic regression and data on 17,767 rural non-interstate highway

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[5] For discussions of the willingness to pay concept of value, see Viscusi (1993), National Safety Council (1993), Jones-Lee (1989), and U.S. Office of Management and Budget (1991).

segments with ADT per lane ranging from 50 to 5,000, they found a significant positive association between traffic volume and accident rate. For example, a highway with 4,000 ADT per lane would have an accident rate 47.4 percent higher than one with ADT per lane of 2,000 (p. 87).[6] This suggests that the marginal accident cost occasioned by one more vehicle operating on most roads and highways will exceed the average of those already on the roadway. Because of data limitations, however, this analysis is based on average accident costs and therefore may have a downward bias in terms of the marginal cost of a vehicle trip.

Accident costs. National accident data indicate that on a per-mile basis, the accident costs of large trucks are significantly less than those of passenger cars.[7] Table 3–2 shows that in 1994 large trucks had a fatal accident rate (per 100 million VMT) nearly one-third greater than passenger cars, though injury and property-damage-only accident rates were considerably less for large trucks. Applying the accident cost values from Table 3–1, we estimate total accident costs for passenger cars and large trucks per 100 million VMT.

In 1994 TL general freight carriers transported an average of 14.80 tons of freight per vehicle-mile (ATA 1995, Summary Table III). Thus, the average cost to society of accidents related to general freight trucking was one cent per ton-mile.

Table 3–2. Accident rates and costs of passenger cars and large trucks, 1994 (per 100 million VMT)

	Rate			
Vehicle type	Fatal	Personal injury	Property damage	Estimated cost (1994 dollars)
Passenger car	2.1	191	351	24,982,000
Large truck	2.7	56	211	14,800,000

SOURCE: Accidents rates from NHTSA (1996, Table 3).

Compensation. To estimate the per-ton-mile external cost of general freight trucking, we determine the amount of compensation paid by affected trucking companies. When this amount is subtracted from the total cost to society, an estimate of the external cost results. Compensation by trucking companies has two principal forms: 1) payment of workers' compensation premiums and 2) payment of personal liability and property damage insurance.

Like most other businesses, trucking companies purchase personal liability and property damage insurance. This insurance provides a means for compensating those

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[6] See also Lundy (1965) and Ceder and Livneh (1982). These authors also found a positive association between traffic volumes and accident rates.

[7] The National Highway Traffic Safety Administration (NHTSA) defines a large truck as having a gross vehicle weight greater than 10,000 pounds. Elsewhere in this report, we use a cut-off of 25,000 pounds.

who are injured, whose family member is killed, or whose property is damaged in accidents involving a motor carrier's vehicles. While almost all types of insurance involve deductible payments by the insured business, these payments tend to be quite small relative to insurance premiums. Generally, corporate balance sheets group premium and deductible loss payments.

As is true of other forms of insurance, personal liability and property damage insurance costs are based on accident experience. This experience applies to the industry of which a business is a part and to the specific experience of the individual business. In 1994, general freight trucking companies paid $417,354,000 in personal liability and property damage insurance (ATA 1995, Summary Table III).

Each of the 50 states has a workers' compensation law. While the laws vary somewhat, they provide for compensation of workers for employment-related injuries and diseases without the need to determine fault. In 1988, 87 percent of all U.S. employees (91.3 million workers) were covered by workers' compensation (U.S. Chamber of Commerce 1991, p. 1). Significantly, workers' compensation acts generally exempt participating employers from damage suits. Premiums paid by employers vary among industries, based on accident experience. In most states, a national organization, the National Council on Compensation Insurance, collects accident data and prepares rates.

Table 3–3 presents our estimate of the compensation paid by motor carriers. The estimate of personal liability and property damage is specific to truckload (TL) general freight carriers. Our estimate of workers' compensation was derived by computing 4.2 percent of total wages and salaries paid to employees of TL general freight trucking companies.[8] According to the ATA (1995, Summary Table III), total wages and salaries paid in 1994 by TL general freight trucking companies amounted to $3,021,710,000. Our estimate of workers' compensation paid is 4.2 percent of this amount, or $126,912,000.

Table 3–3. Compensation for accident costs paid by truckload general freight trucking companies, 1994 (dollars)

Source	Total	Per 100 million VMT
Personal liability and property damage insurance	417,354,000	4,671,000
Workers' compensation payments	126,912,000	1,420,000
Total	544,266,000	6,091,000

SOURCES: ATA (1995, Summary Table III); Bureau of Labor Statistics (1994, Table 4).

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[8] According to the Bureau of Labor Statistics (1994, Table 4), the 4.2 percent figure is the average portion of total employee compensation for blue-collar workers accounted for by workers' compensation.

As Table 3–3 shows, we estimate that TL general freight trucking companies paid $6,091,000 in accident compensation per 100 million VMT. Using the ATA figure of 14.80 tons transported per vehicle-mile, the compensation paid was 0.41 cent per ton-mile.

To summarize, in 1994 TL general freight motor carriers were involved in accidents that cost society $14,800,000 per 100 million VMT. They paid compensation totaling $6,091,000 per 100 million VMT, leaving $8,709,000 in uncompensated accident costs. This accident externality equates to 0.59 cent per ton-mile.

Freight rail

Accident costs. Accidents involving freight trains fall into three primary categories:

- collisions at highway-rail grade crossings,
- persons struck by a train at other locations, and
- accidents involving the train alone.

The most frequent type of fatal accident is collisions at highway-rail grade crossings. Another major cause of fatal accidents is trains striking persons at locations other than grade crossings.[9] No distinction is made here between trespassers and non-trespassers, though it should be noted that for all railroads taken together, trespassers account for the larger share of fatalities (55.9 percent). Most injuries, however, involve railroad employees on duty (81.6 percent) (Federal Railroad Administration 1995, Table 14). In total there were 951 fatalities and 9,669 personal injury casualties in 1994 arising from the operations of Class I freight railroads (Federal Railroad Administration 1995, Tables 38 and 39).[10]

Using the Miller et al. (1991) values expressed in 1994 dollars (see Table 3–1), the costs to society of these fatal and personal injury casualties are $2,761,497,000 and $543,930,000, respectively (see Table 3–4). Property damage resulting from train accidents is difficult to estimate. One estimate of the value of property damage to other vehicles involved in crashes with trains at highway-rail grade crossings is provided by the Bureau of Transportation Statistics (1997, Table 3–2) based on Federal Railroad Administration data. For 1994, the estimate is $18,553,000.[11] We assume that property damage for non-crossing rail accidents, other than that to trains,

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[9] For all freight railroads in 1994, highway-rail grade crossing crashes accounted for 50.4 percent of freight rail-related fatalities and 11.7 percent of the personal injuries. Persons struck by a train at other locations accounted for 42.6 percent of the fatalities and 10.7 percent of the personal injuries. Train accidents, per se, only accounted for 7.0 percent of the fatalities but fully 77.6 percent of the personal injuries (Federal Railroad Administration 1995, Tables 13 and 14).

[10] Both figures exclude Amtrak, a Class I passenger railroad, and other passenger fatalities and injuries.

[11] It is not possible to determine precisely what portion of this amount arose from operations of Class I railroads, but we estimate the portion to be upwards of 90 percent.

Table 3–4. Costs of accidents involving Class I freight rail, 1994

Accident type	Amount (dollars)
Fatal	2,761,497,000
Personal injury	543,930,000
Property damage to other vehicles	18,553,000
Total	3,323,980,000

is comparatively minor and ignore the costs of such damage. The total societal cost of railroad accidents in 1994 dollars was about $3,323,980,000.

Compensation. To estimate compensation made by Class I railroads to victims of accidents involving trains, a different method is required than that used for motor carriers. Railroad employees are compensated for on-the-job injuries through a federally mandated process based on tort claims in lieu of workers' compensation. Also, railroads largely self-insure for personal liability and property damage. Specifically, they purchase insurance with a high deductible amount, $25 million or more. Thus, in cases involving fatalities, injuries to non-employees, and property damage related to rail operations, most payments are made directly by the railroad through claims and suits.

When injured on the job, railroad workers (in contrast to employees of firms that provide transportation services using other modes) seek compensation under the Federal Employers' Liability Act of 1908 (FELA). This act prescribes an approach based on a tort process. To collect, a worker must demonstrate negligence on the part of the employer, and awards are based on the degree of employee negligence.

Especially in recent years, the FELA process has become more similar to the workers' compensation system of most other industries (TRB 1994, p. 3). Whereas FELA was previously a more negligence-based, trial-driven tort system, now the majority of claims are settled without litigation or even legal representation. Conversely, within many other industries, litigation over workers' compensation systems has been increasing, though resolution rarely requires court action.

In general, the FELA process results in more sizable benefits to injured workers than does workers' compensation (TRB 1994, p. 3).[12] The amount injured workers will be compensated remains less certain, however, and legal fees and other transactions costs still constitute a larger portion of FELA settlements than is the case with workers' compensation (TRB 1994, pp. 4–5). According to the Association of American Railroads (nd), legal and administrative costs constitute on average 31

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[12] According to the Transportation Research Board (1994, p. 9), the rail industry would be more competitive with other modes if a system like workers' compensation were adopted, but the effect would probably be modest.

percent of FELA payments. As Table 3–5 shows, FELA compensation to injured railroad workers totaled $1.113 billion in 1994.

For other claims against them, U.S. railroads essentially self-insure. Typically, their personal liability and property damage insurance has extremely high deductible features, often $25 to $100 million per event. Unlike motor carriers, then, railroads generally compensate in the form of paid claims rather than insurance premiums.

Railroads report two general categories of claims: rail crossing accidents and other incidents. In each case, the amount paid may be the result of negotiation or litigation. In 1994, Class I railroads paid $97 million in claims for accidents at rail crossings and another $53 million in other accident claims (see Table 3–5). Adding together rail liability, property damage claims, and FELA judgments, Class I railroads paid a total of $1.263 billion in compensation in 1994 for accidents involving freight trains. Although we are able to include the payout level for property damage as a result of train accidents at rail crossings, there are no similar data on payment levels for other accidents such as train derailments. Still, it is doubtful that the amount paid out for property damage resulting from other accidents is large relative to the total accident compensation paid by Class I railroads (shown in Table 3–5).

Table 3–5. Compensation for accident costs paid by Class I freight railroads, 1994

Source	Amount (dollars)
FELA (railroad employees)	1,113,000,000
Claims for rail crossing accidents	97,000,000
Claims for other accidents	53,000,000
Total	1,263,000,000

SOURCE: Correspondence from the Association of American Railroads Law Department dated March 29, 1996.

In summary, Class I freight railroads were involved in accidents that cost society a total of $3,323,980,000 in 1994, and they paid a total of $1,263,000,000 in various kinds of compensation for accidents. The net uncompensated accident cost of freight rail operations in 1994 was therefore $2,060,980,000. Dividing this figure by the 1,200,701,000,000 Class I rail ton-miles in 1994 (Bureau of Transportation Statistics 1997, Table 1–9) results in an uncompensated cost of 0.17 cent per ton-mile.

EMISSIONS

Vehicle-generated air pollution is an external cost because the transportation users who are producing it are not the only ones who are affected. Two general categories of emissions from internal combustion engines are important to our analysis of external costs: air pollution and greenhouse gases. We begin by estimating the costs of air pollution generated by freight truck and rail, then consider the costs of greenhouse gas emissions.

Nature and magnitude of air pollution

The use of internal combustion engines to transport passengers and freight is a major cause of air pollution. In 1994, highway vehicles accounted for 62.3 percent of all carbon monoxide (CO) emissions and 31.9 percent of all emissions of nitrogen oxides (NO_X) in the United States; for railroads the percentages are 0.2 for CO and 4.0 for NO_X (Bureau of Transportation Statistics 1996b, Tables 7–2 and 7–4). Significant amounts of hydrocarbons (HC) also were generated by the transportation sector.

It is not easy to estimate the external costs of emissions generated by specific types of transportation users, and two basic elements must be understood before full-cost pricing can be implemented. The first element is the amount of air pollution associated with a unit of travel by different types of vehicles operating under different conditions. The second is the dollar value of damage to human health and other things of value—animals, crop yields, buildings and structures, and scenic views. This analysis incorporates the best available estimates of these two elements.

Transportation sources account for about 45 percent of the Environmental Protection Agency's (EPA's) six criteria pollutants (TRB 1995, p. 39), briefly defined in Table 3–6. For diesel engines, the primary emission type is NO_X (nitrogen oxides), followed by CO (carbon monoxide), PM_{10} (particulate matter under ten microns in aerodynamic diameter), SO_2 (sulfur dioxide), and VOC (volatile organic compounds, mainly hydrocarbons) (TRB 1995, p. 45).

Some pollutants are much more localized in nature than others. For example, in rural areas CO emissions are likely to be concentrated along heavily traveled corridors but too dispersed to adversely affect the health or life quality of rural populations (see Forkenbrock and Schweitzer 1997a, Chapter 3). SO_2, on the other hand, leads to the formation of acid rain which can adversely affect vegetation, buildings, and humans over a large area. Similarly, VOC and NO_X react to produce ground-level ozone (O_3), which leads to regional smog production.

Costs of air pollution

Placing dollar values on units of air pollution is at best problematic. For one thing, another unit of pollution bears a higher social cost in a locale where that form of pollution is already relatively high. In places where pollution is high enough to approach maximum allowable levels (beyond which health is threatened), further pollution is especially costly. Because this analysis is concerned with freight movements between U.S. cities, however, the preponderance of truck or rail operations occurs in rural areas where ambient pollution levels are generally low. Especially for more localized pollutants, using high values for the cost of pollution would thus tend to overstate the true costs to society of air pollution stemming from freight movements using either rail or truck.

Table 3–6. Types of air pollution*

Pollution type		Description
Carbon monoxide	CO	Odorless gas formed by incomplete combustion of motor fuels. The higher the fuel-to-air ratio for an engine, the more CO is produced. Fuel-rich operations occur when an engine is cold or is operating under a greater load (steep hills or higher speeds). The current standards are no more than nine parts per million (ppm), not to exceed eight hours per year or 35 ppm for not more than one hour per year. Two-thirds of all CO emissions come from the transportation sector.
Nitrogen oxides	NO_X	These gases, formed by high-temperature chemical processes that occur during the combustion of fuel in an internal-combustion engine, lead to the formation of smog and contribute to the formation of acid rain. The current standard is an annual mean of 0.05 ppm. About 40 percent of all NO_X emissions come from the transportation sector.
Volatile organic compounds	VOC	Chemical compounds that leave the engine through the exhaust system or crankcase and from the fuel system through evaporation. Ground-level ozone (O_3), which leads to smog formation, is produced through a chemical reaction between VOC and NO_X. The transportation sector accounts for about half of all VOC.
Particulate matter	PM_{10}	Inhalable particular matter (less than 10 microns in diameter) emanating from the exhausts of diesel-powered vehicles (a minor source) and road dust, along with more pervasive sources outside the transportation sector. Currently, the standards are no more than 150 micrograms per cubic meter of air for a 24-hour period or 50 micrograms per cubic meter on average for a year. Vehicle emissions per se account for less than one percent of all PM_{10} emissions, but dust raised by vehicle movement (so-called "fugitive dust") is a much more important source.
Sulfur oxides	SO_X	Compounds that lead to the formation of particulate matter and sulfuric acid (leading to acid rain). Of greatest interest here is sulfur dioxide (SO_2). Diesel-powered vehicles emit SO_2 because of the high sulfur content of diesel fuel, but coal-fired electrical utilities are a much greater source of SO_2 emissions. The current standards are no more than 0.14 ppm for a 24-hour period or 0.03 ppm over the course of a year. Approximately one-eighth of all SO_2 emissions are produced by the transportation sector.
Lead	Pb	Transportation sector emissions of this pollutant are insignificant because of the adoption of lead-free motor fuels; lead is therefore not considered in our analysis.

*Fractions of the respective pollutants accounted for by the transportation sector are from U.S. EPA (1994a).

SOURCES: Current pollution standards are from *Code of Federal Regulations* (1995) and U.S. EPA (1997).

Very limited research has been published that assigns actual dollar values to the costs of vehicle-generated air pollution. Small and Kazimi (1995, Table 5) provide estimates of the costs of VOC, NO_X, SO_X, and PM_{10} in the Los Angeles region, a place with comparatively high pollution levels. Haling and Cohen (1995) used results of work by National Economic Research Associates (NERA 1993) to estimate the costs of VOC, NO_X, SO_X, and PM_{10} for 2,233 rural U.S. counties in various states (there are 3,048 rural counties in the United States). Using these estimates, we averaged the costs for the 2,233 rural counties. Table 3–7 shows the results in terms

Table 3–7. Average air pollutant costs for 2,233 rural counties (1994 dollars)

Pollutant	Cost per ton
VOC	385
NO_X	213
SO_X	263
PM_{10}	3,943

SOURCE: Derived from Haling and Cohen (1995).

of dollars per ton of pollution emitted, using a value of $2.9 million per statistical life (see Table 3–1).[13]

NERA bases its emission costs on existing knowledge of adverse effects on health, materials, agriculture, and aesthetic quality brought about by higher ambient concentrations of several air pollutants. Two types of health effects were studied: 1) small changes in the probability of premature death and 2) nonfatal effects ranging from minor irritations to more serious ailments that require medical treatment.

Based on epidemiology literature, NERA concluded that changes in the probability of premature death due to air pollution are primarily related to PM_{10} emissions (see Lippmann and Thurston 1996, Schwartz et al. 1996, and Pope et al. 1995). Nonfatal health effects were estimated using epidemiological and clinical studies of ill effects related to pollutant exposure (see Schwartz and Morris 1995 and Thurston et al. 1994). Damage to materials was valuated using a damage cost function, and agricultural crop damage costs were derived from U.S. EPA-sponsored field tests. The value of aesthetic damage caused by pollution concentrations was estimated using loss of visibility (expressed in visual range miles) as a proxy for overall aesthetic damage; a hedonic price model was applied to infer the deleterious effect of reduced visibility on housing values.

Even though the NERA study is the most salient research effort our review uncovered, NERA's results (upon which we base Tables 3–9, 3–11, and 3–12) cannot be regarded as definitive. While an impressive level of research has been conducted on the health effects and other adverse impacts of air pollution, precise risk factors and the economic value that should be assigned to them are not yet a matter of consensus.

It is important to note that the cost estimates in Table 3–7 are low compared to studies that have focused on urban areas. For example, Wang and Santini (1995, Table 5) use data for 17 metropolitan areas to estimate dollar values per ton of NO_X; at a minimum, their estimates are almost four times larger than those in Table 3–7.

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[13] NERA had used a value of $4.0 million per statistical life.

The SO_X cost estimates in Wang and Santini are over eight times higher, but their PM_{10} cost estimates are a third less than those in our table.

We now apply the resultant pollution costs to freight trucks and rail. Estimates of emission levels for the two transportation modes are presented, and cost estimates per ton-mile are developed.

Motor carriers. Emission factors for various truck configurations are shown in Table 3–8. Of special relevance here are heavy duty diesel trucks, which are used for truckload (TL) general freight transportation between cities. In particular, we are interested in emission factors for such trucks at 55 mph, a common cruising speed.

Table 3–8. Emission rates for selected truck configurations (grams per mile)

Truck type and speed	VOC	NO_X	SO_X	PM_{10}
Light-duty gasoline				
35 mph	2.53	2.31	0.038	0.055
40 mph	2.33	2.35	0.038	0.055
45 mph	2.19	2.39	0.038	0.055
50 mph	2.11	2.61	0.038	0.055
55 mph	2.09	3.12	0.038	0.055
Light-duty diesel				
35 mph	0.71	1.72	0.122	0.380
40 mph	0.64	1.77	0.122	0.380
45 mph	0.59	1.88	0.122	0.380
50 mph	0.55	2.07	0.122	0.380
55 mph	0.52	2.37	0.122	0.380
Heavy-duty diesel				
35 mph	1.74	14.76	0.576	1.527
40 mph	1.56	15.16	0.576	1.527
45 mph	1.43	16.12	0.576	1.527
50 mph	1.34	17.77	0.576	1.527
55 mph	1.28	20.29	0.576	1.527

NOTES:

NO_X and VOC factors are developed from EPA's MOBILE5a model using the following assumptions: operating modes 20.6/27.3/20.6, an ambient temperature of 87.5 with a minimum of 72 and maximum of 92 degrees Fahrenheit, default diesel sale shares, low altitude with no oxygenated fuels, and reformulated gasoline (RFG) included (see U.S. EPA 1994b).

Particulate emission factors are developed from EPA's PART5 model with the following assumptions: low altitude region, no improvement and maintenance program, particle size cutoff of ten microns, and no transient RFG. The particulate emission factors include PM_{10} exhaust, brake, and tire sources (see U.S. EPA 1995).

SOURCE: Cambridge Systematics (1995, Table 4.2).

Multiplying the emission factors from the shaded area in Table 3–8 by the appropriate costs in Table 3–7, we obtain estimates of the costs of air pollution per vehicle-mile. Table 3–9 shows that diesel-powered heavy trucks transporting 14.80 tons on average in rural areas produce air pollution costs of 0.08 cent per ton-mile.

Table 3–9. Emission rates and costs for freight trucks

Emission	Rate (grams per ton-mile)*	Cost per gram (cents)†	Cost per ton-mile (cents)*
VOC	0.086	0.042	0.004
NO_X	1.371	0.023	0.032
SO_X	0.039	0.029	0.001
PM_{10}	0.103	0.435	0.045
Total			0.082

*Based on an average of 14.80 tons in cargo transported per vehicle-mile.

† Derived from Table 3–7.

We should note that our emission rates are somewhat conservative. Harrison et al. (1992, Table 3) citing Weaver (1988) suggest emission rates two to three times greater: VOC, 0.292; NO_X, 2.585; and PM_{10}, 0.359 grams per ton-mile. Emission rates are influenced by assumptions regarding the condition of the trucking fleet, operating circumstances such as topography, and the amount of stop-and-go driving. Our estimated air pollution cost is also somewhat less than that found in or derived from several other studies. Modifying the results of an analysis by Small and Kazimi (1995, Table 8) to estimate 1994 fleet average emission rates and using a value of $2.9 million for a statistical life (see Table 3–1 of this monograph), we obtain a total cost of pollution per vehicle-mile for a heavy-duty diesel truck of $0.287. Dividing this figure by 14.80 tons per vehicle-mile yields a per-ton-mile cost of 1.9 cent. It is important to stress that this estimate is derived from an analysis of the Los Angeles region, which has substantially greater ambient air pollution levels than rural areas.

An even higher estimate of 2.8 cents per ton-mile for air pollution generated by heavy diesel-powered trucks is derived from results published by the European Commission (1996, Annex 10). Because this estimate is based on poorly documented assumptions, direct comparison between it and other estimates is difficult.

Freight rail. In the case of freight rail, we estimate emission rates per ton-mile of cargo for the four general types of freight trains discussed in Chapter 2. With adapted emission rates from Barth and Tadi (1996), Table 3–10 presents VOC, NO_X, and PM_{10} emissions per ton-mile for the four types of trains.[14] As discussed in Chapter 2, the four scenarios vary considerably in terms of locomotive power and trailing tonnage of cargo. Consequently, the emissions rates also vary among the scenarios.

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[14] Barth and Tadi (1996) do not include SO_X. It is an inconsequential pollutant of freight rail.

Table 3–10. Emission rates for four types of freight trains (grams per ton-mile)*

Type of train	VOC	NO_X	PM_{10}
Heavy unit train	0.003	0.257	0.006
Mixed freight train	0.004	0.322	0.008
Intermodal train	0.007	0.603	0.015
Double-stack train	0.005	0.400	0.010

*In each scenario the average train speed is 45 mph, and the throttle setting is notch 8 (full power).

SOURCE: Adapted from Barth and Tadi (1996, Table 1).

In Table 3–11, we apply the estimated emission costs per ton from Table 3–7 to calculate the air pollution cost per ton-mile of the four general types of freight trains. On a ton-mile basis, the total costs of air pollution for any of the general types of freight trains are very small, not more than 0.02 cent.

Table 3–11. Emission costs of four types of freight trains (1994 cents per ton-mile)

Type of train	VOC	NO_X	PM_{10}	Total
Heavy unit train	0.0001	0.006	0.003	0.009
Mixed freight train	0.0002	0.008	0.003	0.011
Intermodal train	0.0003	0.014	0.006	0.020
Double-stack train	0.0002	0.009	0.004	0.013

From this analysis, it is fair to conclude that the external costs of air pollution generated by freight rail operating in rural areas are very small. A higher estimate of these costs is made by the European Commission (1996, Table A.6). The European Commission estimates air pollution costs associated with shipping 1,000 tons one kilometer to be 1.8 European currency units (ECU). Converting this figure to U.S. dollars per ton-mile, an estimate of 0.22 cent emerges. It is unclear what type of freight train, trailing tonnage, or speed were used in the analysis.

Applying emission rates from Blevins and Gibson (1991, Table 7) results in estimates very close to those in Table 3–11. While these authors' rail scenarios differ from ours somewhat, they arrive at similar emission rates for VOC, NO_X and PM_{10}.

Greenhouse gas emissions

While not technically air pollution, greenhouse gas emissions constitute a threat to society by contributing to global climate change. Carbon dioxide (CO_2) is by far the most prominent greenhouse gas released by human activity, accounting for about 85 percent of total emissions weighted by global warming potential (Bureau of Transportation Statistics 1996b, p. 144). Within the United States in 1994, the transportation sector accounted for about 32 percent of all CO_2 emissions (U.S. Department of Energy 1995, Table 5).

Although there is uncertainty as to the likely climatic impacts of the greenhouse effect, the role of the transportation sector in the production of greenhouse gases is clear. CO_2 is a byproduct of any engine that burns carbon-based fossil fuels. The amount of CO_2 released per unit of transportation service (i.e., per ton-mile) is directly related to the energy efficiency of the mode providing that service. One gallon of diesel fuel releases 22.8 pounds of CO_2 (FHWA 1997b, p. I–5).

Researchers have yet to reach anything close to a consensus regarding the cost to society of releasing CO_2 into the atmosphere. Chernick and Caverhill (1991, Table 11–1) document estimates of up to $24.95 but as low as $2.27 (1994 dollars) per ton, while NERA (1993, Table 63) suggests $3.56 (1994 dollars). Perhaps one of the more credible estimates is that of a National Research Council study (NRC 1991) that suggests costs in the range of $10 to $20 per ton of CO_2 emitted. In our analysis, we use the lower figure of $10.

Because the amount of CO_2 emitted is directly proportional to the quantity of diesel fuel burned, one can estimate CO_2 emissions and apply the cost of $10 per ton. For trucking, if we use a fuel efficiency of 5.2 miles per gallon (Bureau of the Census 1995, Table 11; see also FHWA 1993, Table VM–1) and an average payload of 14.80 tons per vehicle-mile, the cost to society of CO_2 emissions per ton-mile shipped by truck is 0.15 cent per ton-mile. CO_2 emissions per ton-mile for three train configurations (mixed freight, intermodal, and double-stack) are estimated by Blevins and Gibson (1991, Table 7). Using their estimated emission rates, the societal cost of CO_2 emissions per ton-mile shipped is 0.02 cent per ton-mile. Table 3–12 presents the rates and costs of CO_2 emissions for both modes.

Table 3–12. Rates and external costs of carbon dioxide emissions, truck and rail, 1994

Freight mode	Emission rate per ton-mile (grams)	Cost per ton-mile (1994 cents)
Heavy truck	134.4	0.15
Mixed freight rail	18.6	0.02
Intermodal rail	17.0	0.02
Double-stack rail	15.4	0.02

SOURCE: Rail emission rates are from Blevins and Gibson (1991, Table 7).

Conclusions

To estimate the social costs of air pollutants and greenhouse gases emitted by freight truck and rail, we have applied the best available data on rates and unit costs. In each case where disparate estimates exist, we used an estimate that is relatively conservative. We must stress, however, that epidemiologists have yet to pinpoint the marginal increases in health problems associated with small increases in pollution levels. We do know that metropolitan areas with higher concentrations of air pollutants are virtually certain to experience greater negative health impacts as a result of an increase in these pollutants than is the case in most rural areas where concentrations are much lower. Because this analysis pertains to intercity freight movements, using relatively low pollutant costs seems prudent. The CO_2 cost estimates, however, would not vary by location of occurrence because greenhouse gas emissions are a global problem.

Although we have disaggregated freight-carrying vehicles as much as possible, there is by necessity considerable averaging in the estimates contained in this analysis. Per ton-mile pollution levels will be higher in hilly terrain or when freight trains or trucks are transporting fewer net tons per mile of travel, for example.

NOISE

Transportation is a major source of noise pollution, which can be defined as unwanted or detrimental sound. While transportation-generated noise affects fewer people in rural areas, noise is a negative externality wherever train or truck traffic occurs.

Measuring noise impacts

The general measure of sound is the decibel (dB). Measuring truck and rail traffic noise involves an adjustment or weighting of high- and low-pitched sounds to approximate human perception of these sounds. Decibels of sound adjusted to approximate human perception are called "A-weighted levels" (dBA). On an A-weighted decibel scale, zero denotes the faintest sound humans can hear. The scale is logarithmic. To most people, for example, noise at 60 dBA (an air conditioning unit) sounds twice as loud as noise at 50 dBA (a clothes dryer) and noise at 70 dBA (a pickup truck) is perceived to be four times as loud as noise at 50 dBA.

Surveys have indicated that people often think of traffic noise as the most disruptive indoor problem caused by nearby highways (Williams and McCrae 1995, p. 80). The amount of disruption caused depends on the volume, speed, and composition of the traffic. Composition is the most important factor: one combination truck produces as much noise at 55 mph as 28 automobiles at the same speed (FHWA 1992, pp. 4–5). A combination truck heard from 50 feet away produces a noise level of 90 dBA.

Noise decreases at more than a linear rate with distance (Ishiyana et al. 1991, pp. 69–70). Traffic noise tends to dwindle away from the road until it reaches background levels at about 1,000 feet from a highway source (Hokanson et al. 1981, p. 7). Table 3–13 shows an example of the relationship between traffic volume, noise, and distance from the road. Conditions other than distance (e.g., topography, trees, and buildings) can influence noise levels, however, so the figures in Table 3–13 should be considered approximations.

Table 3–13. Decibel levels based on traffic volume and distance from the road

	Distance (feet)	
Average daily traffic	55 dBA	65 dBA
Up to 7,999	404	57
8,000–27,999	736	159
28,000–47,999	970	209
Greater than 48,000	1,339	289

SOURCE: Hokanson et al. (1981, p. 17).

Effects of noise

Depending on the individual person, noise can cause sleep disturbance, communication interference, and general annoyance. Communication interference occurs when nearby traffic masks normal conversation, causing people to strain to hear and be heard. "Annoyance" generally describes physical and psychological stress. Table 3–14 summarizes the results of increasing noise levels, including annoyance and communication interference.

Table 3–14. Effects of noise levels

Noise level (dBA)	Effect
55–64	Annoyance
65–69	Communication interference
70–79	Muscles and glands react
Above 80	Changed motor coordination

SOURCE: Bureau of Transportation Statistics (1994, p. 169).

Because people vary greatly in the degree to which they tolerate noise, an absolute change in noise level is not necessarily a predictor of annoyance. In the case of highway noise, for example, researchers have found that individual differences in noise tolerance explain more variance in comfort level than do differences in noise itself. Some individuals show high annoyance at 60 dBA, while others remain unconcerned at 80 dBA (Langdon 1985, pp. 163–167). The intensity, duration, predictability, and controllability of noise are related to the negative impacts of noise on each individual (Llewellyn 1981, pp. 192–196). Even if noise levels are low on average, intermittent noise can be bothersome, especially for people who need to concentrate, rest, or maintain tranquillity. Schools, nursing homes, hospitals, and churches are places where intermittent noise is particularly intrusive.

In addition to (or perhaps because of) the psychological effects of noise, which are very difficult to monetize, noise tends to have an adverse effect on residential property values. Studies of this effect have associated the noise level in decibels above an established noise threshold with average changes in property values. Average property value changes per decibel increase can then be tied to the noise generated by a particular type of vehicle operating at various distances from the property.

Modeling truck-generated noise

The Federal Highway Administration (FHWA) has developed a simple noise emission model pertaining to heavy trucks (FHWA 1979, p. 7; see also Rudder et al. 1979, p. 4). The model takes into account the speed, number of axles, and weight of the truck to predict the peak noise level. Noise dispersion models like the FHWA STAMINA model (FHWA 1982) or derivatives such as the Minnesota Department of Transportation MINNOISE model (Mn/DOT 1991) are applied to estimate noise levels at specified distances from a highway. These models represent a noise gradient that falls at a logarithmic rate (see Hokanson et al. 1981, p. 9).

In conjunction with geographic information systems (GIS), dispersion models can be used to define noise contours, or lines of equal noise levels along transportation corridors. The number of people living within areas where the amount of noise exceeds state or federal standards can then be estimated. To make these estimates, average population per housing unit and average number of housing units per square mile for general categories of land use are taken into account. One such category is "rural character," and it is the most relevant to this analysis of intercity traffic.

Hokanson et al. (1981, p. 10) estimate that near highways (within the distance range where noise levels exceed 55 dBA) sparse rural development has an average of 0.006 housing units per acre, and five housing units on average are found in areas of dense rural development. Using these values, Haling and Cohen (1996, Table 4) estimate that 0.51 housing units are impacted per rural highway system mile (or, presumably, per mile of rail trackage) in areas of dense rural development. Where rural development is sparse, they estimate that essentially no housing units are subjected to traffic noises high enough to lower property values.

In the case of housing units in densely settled rural areas, Haling and Cohen (1996, Table 7) estimate that heavy traffic moving at 55 mph produces a noise cost of about 0.24 cent per VMT. This estimate is derived from the work of Nelson (1978) who concluded that housing unit values fall by 0.4 percent per dBA increase in the constant equivalent noise level. Haling and Cohen (Table 9) estimate a per-vehicle-mile noise cost of 4.7 to 6.9 cents for a combination truck, depending on the truck's operating weight. For housing units in sparsely settled rural areas, they estimate no noise cost from vehicles. Nationally far more miles of rural highway run through sparsely settled areas than those that are densely developed. If we assume that 90 percent of all intercity freight truck VMT occur in *sparsely* settled rural areas and ten percent of the VMT are in *densely* settled rural areas, an approximate noise cost per freight truck mile is 0.58 cent. On an average ton-mile basis (14.80-ton load), the estimate is 0.04 cent.

Rail noise impact

Far less has been written about noise generated by freight rail operating in rural areas than about heavy trucks.[15] Most of the limited literature pertains to high speed passenger rail in Europe, rather than slower moving freight trains. Fath et al. (1974) have measured noise levels at 450 feet from track centerline for trains of varying length and trailing weight. Noise levels ranged from 70 to 90 dBA. Hanson et al. (1991) have estimated the incremental change in freight rail noise with different types and conditions of track and train wheels. Among the limited noise of freight rail estimates available are Planco (1990) who places the cost at 0.22 cent per ton-mile (adjusted to 1994 dollars) and Diekmann (1990) whose figure is 0.20 cent per ton-mile (also in 1994 dollars). Both authors studied Germany where rural development is generally denser than in the U.S., so their estimates are likely to be relatively high compared to ours.[16]

In general, the literature suggests that a given level of noise produced by a freight train is usually perceived as less annoying than noise produced by vehicle traffic on a highway. The so-called "Green Book" of the Commission of the European Communities (OECD 1992) implies that the cost of road traffic noise is over six times greater than noise from freight rail. Similar results are reported by Rothengatter (1989), who found that the ratio of people "annoyed" by road noise compared to rail noise is 3.4 to one; the ratio of people "highly annoyed" is 6.4 to one.

We are unaware of compelling evidence that in rural areas of the United States highway noise is actually more objectionable than freight rail noise. Accordingly, we use the same value of 0.04 cent per ton-mile for both freight modes. In the case of either mode, the social cost of noise per ton-mile of transportation service in rural areas is very small.

CONCLUSIONS

In this chapter we have examined available evidence on the magnitude of accident, emission, and noise external costs generated by freight truck and rail operating between cities. We have not considered certain costs that occur within metropolitan areas, such as traffic congestion. Also, values for air pollution and noise are much lower than would be the case in urban areas.

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[15] A good discussion of the technical aspects of train noise is found in Nelson (1987, Section 1.4.2).

[16] For comparison, the estimates per ton-mile of truck freight are 0.32 cents for Planco and 0.18 for Diekmann. These figures are between four and eight times larger than the value of 0.04 cents for freight trucks we use.

Throughout this monograph we have used ton-miles as the unit of analysis. As we mentioned earlier, it is not particularly meaningful to make direct comparisons between truck and rail because of the generally very different natures of these two modes' operations. The more relevant comparisons are between external costs and private costs for each mode; these comparisons are made in Chapter 5.

In Table 3–15 we summarize the results of the three analyses contained in this chapter. The total external cost for heavy freight trucks operating between cities is 0.86 cent per ton-mile. For freight rail the per-ton-mile external cost totals 0.24 to 0.25 cent.

Table 3–15. Summary of external costs of truck and rail freight (1994 cents per ton-mile)

	Accidents	Air pollution*	Greenhouse gases	Noise	Total
General freight truck	0.59	0.08	0.15	0.04	0.86
Heavy unit train	0.17	0.01	0.02	0.04	0.24
Mixed freight train	0.17	0.01	0.02	0.04	0.24
Intermodal train	0.17	0.02	0.02	0.04	0.25
Double-stack train	0.17	0.01	0.02	0.04	0.24

* Totals from Tables 3–9 and 3–11 rounded to two decimal places.

CHAPTER 4
GOVERNMENT SUBSIDIES

Whenever a transportation user operates a vehicle on a public facility, he or she occasions some level of cost. This cost arises from wear and tear on the roadway over and above what would occur without travel by that user, as well as other publicly borne costs. When the user pays less than the cost occasioned, a de facto subsidy occurs. Depending on how the facility is financed, this subsidy amounts to a transfer from other users of the facility or from society more generally.

In this chapter we review what is known about the costs occasioned and the user charges paid by freight trucks. Because freight rail generally operates on its own facilities, the issue of user subsidies does not emerge in the case of rail service.[17]

COSTS OCCASIONED BY VEHICLES

The costs occasioned on a given trip depend both on the type of vehicle making the trip and on characteristics of the roadway on which the vehicle is operating. In this discussion we focus on infrastructure costs that ultimately result in the need for expenditures by the governmental agency with jurisdictional responsibility.

Highway cost allocation studies

Both the federal government and most states periodically conduct highway cost allocation studies primarily to estimate the responsibility of different vehicle classes for highway costs and the user fees paid by the respective vehicle classes. Comparing the two estimates, one is able to assess which vehicle classes, on balance, overpay and which underpay relative to other classes.

Because other external costs were addressed earlier, this discussion concerns "agency costs" (costs borne by governmental agencies that provide the relevant highway facilities). Federal agency costs largely pertain to the primary cost categories listed in Table 4–1 (pavements, bridges, and other elements of highway infrastructure that wear out and must be refurbished or replaced). When estimating agency costs and how they should be distributed among vehicle classes, cost allocation studies consider the functional classes of the highways on which each vehicle class operates. The per-mile cost occasioned by a heavy vehicle may be quite small on newly reconstructed interstate highways, for example, but very high on lower standard roads.

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[17] According to Chapman and Martland (1997, Exhibit 7), railroads spend slightly more than $8 billion annually on track and right-of-way maintenance.

Table 4–1. Estimated distribution of federal highway obligations in year 2000

Category	Improvement type	Percent of total
New capacity	New construction	10.8
	Reconstruction with added lanes	3.4
	Major widening	6.8
	Subtotal	21.0
System enhancement	Safety/TSM*	9.4
	Environmental	1.9
	Other projects	4.1
	Subtotal	15.4
System preservation	3R preservation†	26.7
	Minor widening	1.8
	Major bridge	1.6
	Bridge replacement	7.8
	Minor bridge	4.4
	Subtotal	42.3
Transit		12.4
Other		8.9
	Total	100.0

*Transportation system management.

†Reconstruction, resurfacing, and rehabilitation.

SOURCE: FHWA (1997a, Table III–7).

Current methods of charging vehicles for their use of the highway system (primarily motor fuel taxes and registration fees) do not enable federal or state user charges to vary according to the particular highway on which the travel occurs. Thus, average cost responsibilities for different vehicle classes must be derived. Such cost responsibilities should be viewed with some caution because they generally will not reflect the actual agency cost occasioned by a given vehicle on a specific trip. In other words, user charges based on average cost responsibilities for a given vehicle class bring about some level of cross-subsidization among vehicles within that class.

The 1997 Federal Highway Cost Allocation Study

In August 1997, the Federal Highway Administration released the 1997 Federal Highway Cost Allocation Study (Federal HCAS), the first such study in 15 years. The primary objective of the study was to evaluate the equity and efficiency of current highway user charges. For purposes of our research, estimates of the magnitude of government subsidies to freight trucks are based on the equity ratios (user charges paid divided by cost responsibilities) produced by the Federal HCAS.

Several points should be kept in mind when applying the Federal HCAS equity ratios. First, HCAS derived two estimates of cost responsibilities for various classes of vehicles. One is based on the traditional cost-occasioned approach which is concerned with the costs created by vehicles of different sizes and weights in terms of the design, construction, rehabilitation, and maintenance of highways. The other estimate approximates the marginal social cost which does not consider agency expenditures, but instead considers the economic cost to society of increments of highway use by each vehicle class.

The economic costs in the second estimate include both infrastructure costs that lead to agency expenditures and some environmental and other social costs. Because we already have developed estimates of environmental and safety costs, it would constitute double counting to include all of the economic costs of the second Federal HCAS estimation method. Additionally, the second approach includes congestion costs which are ignored in this study of freight transportation between urban areas. In this analysis, we apply the traditional cost-occasioned approach.

A second important point in applying the findings of the Federal HCAS is that the study includes estimates that pertain to highway cost allocation for all levels of government, as well as for the federal aid highway system alone. An advantage of considering equity ratios for all levels of government is illustrated by a simple example. The federal user charge for a particular vehicle class may be too low (i.e., the vehicle class is underpaying), but at the state level the same vehicle class may be overpaying. Taken together, the two levels of government may have an equity ratio for the vehicle class that is close to 1.0. Such an equity ratio implies that the vehicle class is paying society fully for the costs the class occasions.

The estimates for all levels of government are by necessity highly aggregated and therefore not indicative of the circumstances in any given state or locality. Nonetheless, these estimates constitute the best picture of the overall government subsidy, if any, received by operators of the respective vehicle classes. A summary of the various cost categories for all levels of government to be allocated to highway users is presented in Table 4–2.

DO FREIGHT TRUCKS UNDERPAY?

Table 4–3 shows a forecast of highway user charge payments at all levels of government in the year 2000.[18] Of the $97.7 billion in total imposts, $27.2 billion (27.8 percent) will be collected via federal user charges, $68.5 billion (70.1 percent)

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[18] The all-levels-of-government analysis in the Federal HCAS is based entirely on forecasts for the year 2000.

Table 4–2. Highway obligations or expenditures for 1994 and year 2000 at all levels of government ($ millions)

Obligation or expenditure	1994 (1994 dollars)	Year 2000 (year 2000 dollars)	Annual growth rate (%)
Federal obligations			
Direct from the Highway Trust Fund (HTF)	1,394	1,819	4.53
Direct from other sources	340	413	3.30
Total direct federal obligations	1,734	2,232	4.29
Transfers to states from HTF	16,916	21,644	4.19
Transfers to states from other funds	569	691	3.30
Transfers to local governments from HTF	259	331	4.19
Transfers to local governments from other funds	440	535	3.30
Mass transit expenditures from HTF	2,304	3,380	6.60
Total federal aid to state and local	20,488	26,581	4.43
Total federal obligations from HTF	20,873	27,174	4.49
Total federal obligations from other funds	1,349	1,639	3.30
Total federal obligations	22,222	28,813	4.42
State expenditures			
Capital outlays	32,059	40,868	4.13
Maintenance	7,152	8,961	3.83
Traffic services	2,984	4,211	5.91
Administration and research	4,847	6,841	5.91
Debt service	4,318	6,094	5.91
Law enforcement and safety	4,209	5,940	5.91
Subtotal	55,569	72,915	4.63
Federal transfers	(17,485)	(22,330)	4.16
Grants-in-aid to local governments	8,838	11,596	4.63
Local government transfers	(1,381)	(1,710)	3.63
Motor vehicle administration	2,667	3,499	4.63
Motor fuel administration	244	320	4.63
Mass transit expenditures	1,796	2,356	4.63
Total state expenditures	50,248	66,641	4.82
Local expenditures			
Capital outlays	9,231	10,630	2.38
Maintenance	11,796	14,085	3.00
Traffic services	1,771	2,115	3.00
Debt service	3,859	5,325	5.51
Administration, law enforcement, and safety	6,133	8,463	5.51
Subtotal	32,790	40,618	3.63
Federal transfers	(699)	(866)	3.64
Grants-in-aid to local governments	(8,838)	(11,594)	4.63
Transfers to states	1,381	1,710	3.63
Total local expenditures	24,634	29,868	3.26
Total obligations and expenditures (all levels)	97,104	125,322	4.34

SOURCE: FHWA (1997a, Table III–8).

Table 4–3. Year 2000 highway user charge payments by vehicle class at all levels of government (year 2000 dollars in millions)

Vehicle class/registered weight	Federal	State	Local	Total
Passenger vehicles				
Autos	11,576	34,520	1,164	47,264
Pickups and vans	5,812	16,260	479	22,554
Buses	20	311	6	337
All passenger vehicles	17,408	51,090	1,649	70,155
Single unit trucks				
≤ 25,000 pounds	1,500	3,831	84	5,415
25,001–50,000 pounds	611	1,802	58	2,471
> 50,001 pounds	487	924	31	1,442
All single unit trucks	2,598	6,558	173	9,329
Combination trucks				
≤ 50,000 pounds	306	560	15	881
50,001–70,000 pounds	504	902	22	1,427
70,001–75,000 pounds	370	548	14	932
75,001–80,000 pounds	5,521	7,651	145	13,317
> 80,000 pounds	468	1,156	12	1,636
All combination trucks	7,169	10,810	208	18,195
All trucks	9,766	17,370	380	27,522
All vehicles	27,174	68,470	2,029	97,677

SOURCE: FHWA (1997a, Table IV–11).

will come from state-level user charges, and $2.0 billion (2.1 percent) will be generated by local user charges. The table shows the amounts forecast to be collected from 11 classes of vehicles, as well as aggregations of these changes.

Table 4–4 displays the cost responsibilities of the same 11 vehicle classes forecast in the year 2000, as estimated in the 1997 Federal HCAS. The total cost responsibility for the year 2000 is $125.3 billion, or about $27.6 billion more than the FHWA forecasts will be collected at all levels of government. This means that as a group, those who use the roads and highways provided by all levels of government will not pay user charges equal to the total costs they occasion.

Among highway users, the 11 classes of vehicles vary considerably in terms of the fraction of their cost responsibilities defrayed by the user charges they pay. Dividing the user charge payments in Table 4–3 by the cost responsibilities in Table 4–4, ratios of payments to cost responsibilities are derived (see Table 4–5).

Table 4–4. Year 2000 federal cost responsibility for all levels of government by vehicle class (year 2000 dollars in millions)

Vehicle class/registered weight	Federal	State	Local	Total
Passenger vehicles				
Autos	12,405	35,988	15,791	64,184
Pickups and vans	4,770	13,678	6,328	24,777
Buses	221	383	268	871
All passenger vehicles	17,396	50,049	22,387	89,832
Single unit trucks				
≤ 25,000 pounds	1,074	1,755	886	3,715
25,001–50,000 pounds	981	1,867	1,349	4,197
> 50,001 pounds	1,098	1,929	1,212	4,239
All single unit trucks	3,153	5,551	3,447	12,151
Combination trucks				
≤ 50,000 pounds	222	325	149	696
50,001–70,000 pounds	528	722	306	1,555
70,001–75,000 pounds	408	517	178	1,103
75,001–80,000 pounds	6,329	8,353	2,950	17,632
> 80,000 pounds	778	1,125	450	2,353
All combination trucks	8,264	11,042	4,032	23,338
All trucks	11,417	16,593	7,479	35,490
All vehicles	28,813	66,642	29,866	125,322

SOURCE: FHWA (1997a, Table V–21).

Several important conclusions can be reached from the figures in Table 4–5. At all levels of government, the aggregate ratios of user charge payments to cost responsibilities for passenger vehicles (0.781), single unit trucks (0.768), and combination trucks (0.780) do not vary much. This suggests that while highway users as a group are only paying about 77.9 percent of the costs they occasion, no major category of vehicles is overpaying or underpaying substantially *relative* to all highway users.

We should stress that the per-mile subsidy varies somewhat among the classes of trucks. As Table 4–6 shows, combination trucks with registered weights of between 70,000 and 80,000 pounds underpay by 4.9 cents per vehicle-mile, while combination trucks registered between 50,000 and 70,000 pounds underpay by only 1.2 cents per vehicle-mile. Overall, combination trucks on average underpay 4.4 cents per vehicle-mile. The figures in Table 4–6 include both LTL and TL trucking and types of service other than general freight. ATA data, however, show that TL

Table 4–5. Ratios of year 2000 user charge payments to allocated costs for all levels of government

Vehicle class/ registered weight	Federal	State	Federal and state	Local	All levels of government
Passenger vehicles					
Autos	0.993	0.959	0.953	0.074	0.736
Pickups and vans	1.218	1.189	1.196	0.076	0.910
Buses	0.109	0.812	0.548	0.022	0.387
All passenger vehicles	1.001	1.021	1.016	0.074	0.781
Single unit trucks					
≤ 25,000 pounds	1.397	2.183	1.884	0.095	1.458
25,001–50,000 pounds	0.623	0.965	0.847	0.043	0.589
> 50,001 pounds	0.444	0.479	0.466	0.026	0.340
All single unit trucks	0.824	1.181	1.052	0.050	0.768
Combination trucks					
≤ 50,000 pounds	1.378	1.723	1.583	0.101	1.266
50,001–70,000 pounds	0.955	1.249	1.125	0.073	0.918
70,001–75,000 pounds	0.907	1.060	0.992	0.079	0.845
75,001–80,000 pounds	0.872	0.916	0.897	0.049	0.755
> 80,000 pounds	0.602	1.028	0.853	0.027	0.695
All combination trucks	0.867	0.979	0.931	0.052	0.780
All trucks	0.855	1.047	0.969	0.051	0.775
All vehicles	0.943	1.027	1.001	0.068	0.779

NOTE: These ratios are based on total revenues and expenditures nationwide and are likely to vary from ratios for individual states and local governments. Federal ratios include obligations not financed by the Highway Trust Fund.

general freight trucking has a higher average payload (and hence weight) than all carriers taken together: 14.80 versus 14.39 tons per vehicle-mile (ATA 1995, Summary Table I). Thus, the overall figure of 4.4 cents may slightly understate the amount by which this type of trucking service underpays.

Using an average of 14.80 tons of freight transported per vehicle-mile, combination trucks will underpay by 0.30 cent per ton-mile in year 2000 dollars. Deflating this figure to 1994 dollars, unrecovered costs associated with the provision, operation, and maintenance of public facilities at all levels of government equal 0.25 cent per ton-mile.

Table 4–6. Underpayment of highway user charges by vehicle class for all levels of government, year 2000 (year 2000 dollars)

Vehicle class	User charge underpayment ($ millions)	Vehicle-miles traveled (millions)	Underpayment (cents per VMT)
Passenger vehicles			
Autos	16,920	1,818,461	0.9
Pickups and vans	2,223	669,198	0.3
Buses	534	7,397	7.2
All passenger vehicles	19,677	2,495,056	0.8
Single unit trucks	2,822	83,100	3.4
Combination trucks			
≤ 50,000 pounds	(185)	6,743	(2.7)
50,001–70,000 pounds	128	10,683	1.2
70,001–80,000 pounds	4,486	92,102	4.9
> 80,000 pounds	717	23,587	3.0
All combination trucks	5,143	115,689	4.4
All trucks	7,968	198,789	4.0
All vehicles	27,645	2,693,845	1.0

SOURCE: Derived from FHWA (1997a, Tables II–10, IV–11, and V–21).

CONCLUSIONS

Applying results of the 1997 Federal Highway Cost Allocation Study, we have compared the cost responsibilities of trucks with different configurations and trucks registered to operate at various weights. Lighter combination trucks, especially those under 50,000 pounds, underpay the least; heavier single-unit trucks underpay the most. The relatively commonplace five-axle combination truck weighing 70,000 to 80,000 pounds underpays almost five cents per vehicle-mile. Overall, combination trucks underpay 4.4 cents per vehicle-mile, or 0.25 cent per ton-mile.

CHAPTER 5
INTERNALIZING EXTERNAL COSTS

In this concluding chapter, we compare the external costs of truck and rail freight transportation operating between U.S. cities with the relevant private costs. We also explore practical methods for internalizing external costs.

PRIVATE AND EXTERNAL COSTS

We have estimated private costs of intercity freight transportation in Chapter 2, external costs in Chapter 3, and de facto subsidies in Chapter 4. Some assumptions are necessary to carry out the analyses underlying these estimates, and our conclusions depend on a careful interpretation of earlier research by others. We first recap the roles of assumptions and antecedent research.

Role of assumptions

Because our analysis focuses on intercity freight movements, we generally ignore such urban impacts as traffic congestion. Although intercity trucks travel from urban factories and warehouses to rural highways, by far the greatest portion of the journey occurs on rural highways where congestion is very rarely a significant problem.

Likewise, we apply comparatively low values for the cost of air pollution with the rationale that urban areas typically experience relatively higher ambient pollution levels than rural areas. The health effects of additional pollutants in already polluted areas are bound to be more severe than in cleaner rural areas (Small and Kazimi 1995, p. 8). Even though we use comparatively low values for air pollution costs because of our rural focus, we cannot be certain that the societal cost is reflected precisely. To date, definitive values of the social cost of various air pollutants have not been published.

The largest externality for both rail and truck transportation is safety-related. Several key assumptions influence our results in the area of safety, including the values assigned to fatal and personal injury accidents. There is only limited consensus on the appropriate values to use for transportation-related mishaps. In a survey of all 50 state departments of transportation conducted in 1993, we found they use an average value of $1.2 million for fatalities and $41,000 for injuries (Forkenbrock et al. 1994, p. 18). FHWA, however, is urging use of the higher values recommended by Miller et al. (1991); these are the values we use in this analysis, inflated to 1994 levels. We should note that studies of the health effects of environmental pollution often use higher values. Hall et al. (1992, p. 815) found that recommended values range from $4.0 million to $9.2 million for the worth to society of saving a statistical life. We have used fairly conservative values for the economic costs of accidents, recognizing that such valuation is by nature normative and imprecise.

Assumptions such as those just reviewed certainly affect our estimates of private and external costs. Because we have opted to use relatively conservative values for key parameters throughout our analysis, the magnitudes of the accident, air pollution, greenhouse gas, and noise externalities generally are comparatively low. Values for public facility costs presented in Chapter 4 are also conservative.

Comparison of private and external costs

Table 5–1 summarizes our best estimates of private costs, external costs, and user charge underpayment for general freight trucking and four freight rail scenarios. For freight trucks, the total external cost and user charge underpayment is 1.11 cent per ton-mile. For freight rail, external costs are substantially smaller: 0.24 to 0.25 cent per ton-mile. Because the average private cost is so much smaller for rail than for trucking, however, external costs for rail often are larger relative to private costs.

Table 5–1. Private and external costs of truck and rail freight (1994 cents per ton-mile)

	Private cost (1)	External cost (2)	User charge underpayment (3)	(2) + (3) as percent of (1)
General freight truck	8.42	0.86	0.25	13.2
Heavy unit train	1.19	0.24		20.2
Mixed freight train	1.20	0.24		20.0
Intermodal train	2.68	0.25		9.3
Double-stack train	1.06	0.24		22.6

Implications for trucking

Table 5–1 indicates that for general freight trucking operations between cities, the per-ton-mile cost would increase by 13.2 percent if all external costs and user subsidies were internalized. User charges would need to be increased about threefold to reflect all external costs and user subsidies in the costs of this mode.

To illustrate the implications of such an increase in user charges for TL general freight carriers, consider a truck that travels 76,700 miles per year (the average derived from ATA 1995, Summary Table III). The approximate private operating cost of the truck is $95,900 per year ($1.25 per vehicle-mile, see Table 2–1), and the operator pays 39.8 cents per gallon in fuel taxes (the 50-state average).[19] To

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[19] The federal diesel fuel tax is 20 cents per gallon (excluding 4.3 cents for deficit reduction). According to the Congressional Budget Office (1998, p. 56), the weighted average state-level diesel fuel tax is 19.8 cents per gallon.

internalize the external cost of $12,660 (13.2 percent of $95,900), the per-gallon tax would need to be increased to $1.26.[20]

The foregoing example is illustrative, not by any means definitive. As Forkenbrock and Schweitzer (1997b) point out, motor fuel taxes are not able to take into account the specific circumstances in which a vehicle is operating. Trucks that operate on low-standard roadways, in metropolitan areas with comparatively high levels of air pollution, or where population densities are higher (so more people are exposed to traffic-related noise) generate greater social costs. These authors suggest using intelligent transportation system (ITS) technology to fine-tune road user charges to particular operating circumstances.

Applying the ITS technology discussed by Forkenbrock and Schweitzer, it would be possible to assess road user charges based on road segments and taking into account vehicle weight and configuration, roadway and bridge design, environmental factors, and state-specific user charge levels. Figure 5–1 depicts the approach schematically. The important point is that freight truck user charges, unlike motor fuel taxes, would be tailored to reflect the costs actually occasioned on a particular trip.[21]

Of relevance to this research, external costs associated with air pollution, noise, and accidents could be factored into road segment classifications. A road segment located in an area with relatively high ambient pollution (e.g., a federal air quality non-attainment area) could have a higher air pollution charge. Similarly, proximity to residences, schools, hospitals, or other activities adversely affected by vehicle noise could be taken into account in the charge for traveling on a road segment. Based on accident data, higher user charges could be levied on road segments where the probability is higher that a truck will be involved in an accident.

Building comprehensive cost factors into road segment classifications would help accomplish three important public policy objectives: to compensate society for the social costs occasioned by a heavy vehicle on a particular trip, eliminate cross-subsidies among heavy vehicles, and encourage vehicle operators to travel on highways where costs would be lower.

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[20] A fuel efficiency of 5.2 miles per gallon is assumed (Bureau of the Census 1995, Table 11; see also FHWA 1993, Table VM–1).

[21] In brief, the approach discussed by Forkenbrock and Schweitzer (1997b) would involve a small computer on board freight trucks. The computer would receive vehicle weight information from an on-board weighing device that would update weight data to the computer when the cargo doors are closed. A global positioning system (GPS) receiver would provide location information, which would be reconciled with stored geographic data that establish the location of road segments. Also coded in the computer would be the vehicle identification and configuration. It would thus be possible to generate an electronic record of road use, taking into account vehicle weight and configuration, road characteristics, and other location-related factors. Research on this concept continues.

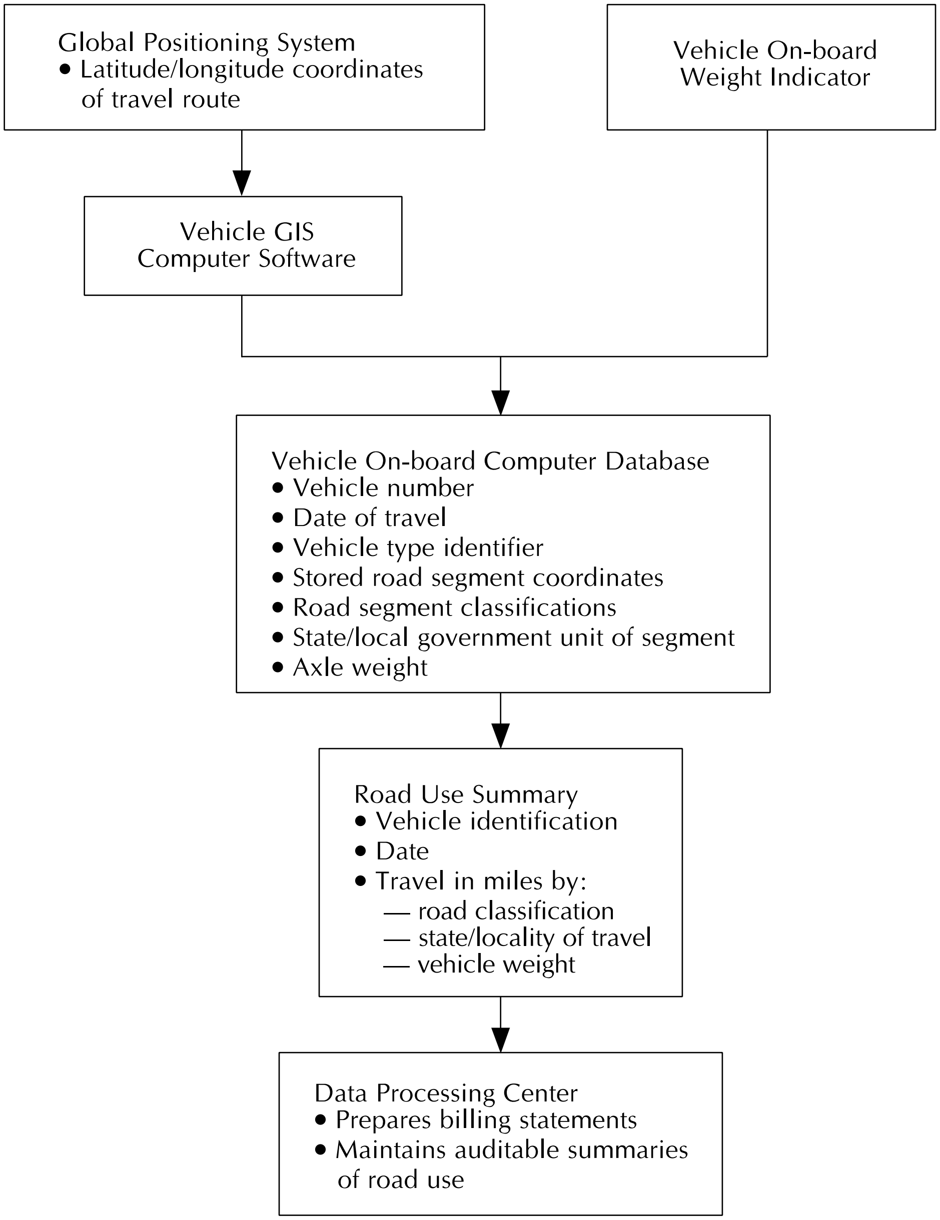

Figure 5–1. ITS approach to charging heavy vehicles for road use

SOURCE: Forkenbrock and Schweitzer (1997b, Figure 2).

Implications for freight rail

Adding external costs to the private costs currently experienced by railroad companies would require a very different approach than for trucking. Because railroads provide their own infrastructure, they do not often pay user charges to governmental agencies for facility use. Fortunately, in Table 3–15 we see that the external costs per ton-mile do not vary appreciably among different train types. Thus, a reasonably simple charge of about one-quarter of a cent per ton-mile could be added to rail shipments.

It is true that the largest type of external costs, accident costs, is not directly related to ton-miles transported. Rather, accident costs are probably more dependent on train-miles operated. The number of miles operated affects accident risk exposure by pedestrians and operators of motor vehicles, with whom trains may conflict.

Specifically, a ton-mile charge based on the external costs of accidents would to a degree discriminate against a railroad company whose trains tend to operate relatively few miles and are short in length but carry very heavy cargo. Conversely, a railroad company operating relatively long, lightweight trains that travel many miles would be favored by a tax on ton-miles.

Quite likely, however, the basic economics of freight transportation make it impractical to operate trains that carry predominately bulky, lightweight cargo. Rail is most competitive in markets where the cargo is relatively heavy and the distances are long. To the extent that the preponderance of rail traffic fits this profile, inequities arising from using ton-miles as a basis for internalizing external costs would not be serious.

CONCLUSIONS

Though important to the U.S. economy, freight trucking and rail create adverse impacts. These impacts are referred to as external costs because they are not borne by those who generate them. Placing an appropriate dollar value on external costs is vital to the process of internalizing them; that is, requiring those who generate these costs to compensate society in an amount equal to the external costs.

Internalizing external costs makes it possible to return to society an amount equal to the costs one imposes; it also gives a clear signal of the actual full cost of an activity, so that consumption decisions can be made on the basis of this cost. In the case of transportation, including external costs generally will lead to some reduction in consumption of transportation services, such as by locating producing facilities closer to markets. Another impact may be greater use of a competing mode that has less total cost, once external costs are included.

Our analysis has focused on freight rail and TL general freight trucking between U.S. cities. This accounts for a very large share of the total ton-miles of transportation, and it enables us to make two important simplifications in the analysis. We are able to ignore congestion costs because very little congestion exists in rural areas. Additionally, we are able to use single values for the costs of various air pollutants. Ambient pollution levels vary among metropolitan areas, so the social costs of further vehicle-generated pollution will differ as well.

Four main types of external costs have been included in our analysis: accidents; emissions; noise; and unrecovered costs associated with the provision, operation, and maintenance of public facilities. In each case we have used conservative values for the various key parameters, so that our estimates of external costs constitute baseline values. Increasing the values assigned to preventing a fatality, reducing traffic noise, or improving air quality will lead to concomitantly higher external cost figures.

Our final estimates of external costs for intercity TL general freight trucking and rail freight transportation imply that these costs are substantial. For general freight truckload trucking, the external cost is 1.11 cent per ton-mile. This figure is equal to 13.2 percent of the private operating cost of that transportation mode. In the case of freight rail, the per-ton-mile external cost is only one-third as large as for trucking. Because the private cost (direct cost to the transportation provider) is much lower for rail (1.06 to 2.68 cents per ton-mile), rail external costs constitute larger amounts relative to private costs. The range of external costs compared to private costs is 9.3 to 22.6 percent.

The conclusion of this research is thus that even when using conservative values for external costs, these costs are sizable enough to warrant concern. External costs affect the well-being of society and should be fully included in the decision-making process of how much service by each transportation mode should be consumed. Our research has sought to provide reasonable estimates of the amounts by which intercity truck and rail transportation costs should be increased to include external costs. We hope that these estimates will help facilitate enlightened public and private sector decision making.

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