PERGAMON

Transportation Research Part A 35 (2001) 321–337

TRANSPORTATION RESEARCH PART A

www.elsevier.com/locate/tra

Comparison of external costs of rail and truck freight transportation

David J. Forkenbrock *

Public Policy Center, The University of Iowa, Iowa City, IA 52242, USA

Received 30 March 1999; received in revised form 1 August 1999; accepted 4 October 1999

Abstract

In this article we estimate external costs for four representative types of freight trains. For each type of freight train, we estimate three general types of external costs and compare them with the private costs experienced by railroad companies. The general types of external costs include: accidents (fatalities, injuries, and property damage); emissions (air pollution and greenhouse gases); and noise. Resulting private and external costs are compared with those of freight trucking, estimated in an earlier article. Rail external costs are 0.24 cent to 0.25 cent (US) per ton-mile, well less than the 1.11 cent for freight trucking, but external costs for rail generally constitute a larger amount relative to private costs, 9.3–22.6%, than is the case for trucking, 13.2%.

Keywords: Pricing; External costs; Railroads; Transportation economics; Transportation finance

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. 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. For total societal cost to be minimized, policy makers must understand the full social costs of different modes of transportation. Policies then 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) would be assigned a price that would reflect the full incremental cost to society of that service.

* Tel.: +1-319-335-6800; fax: +1-319-335-6801.
E-mail address: david-forkenbrock@uiowa.edu (D.J. Forkenbrock).

0965-8564/01/$ - see front matter
PII: S0965-8564(99)00061-0

Charging the full cost of transportation would establish a market in which transportation users could decide whether the benefits to them of consuming a particular unit of transportation service would exceed the costs these users face. Such a pricing approach would mean that society would not absorb the costs of one mode or type of service to a greater extent than another.

In a previous article published in this journal, Forkenbrock (1999) estimates the external costs per ton-mile of freight shipped by truck, including 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 roads and bridges. That analysis focused on intercity movements because social costs are much more consistent in rural areas than in metropolitan areas. The estimates are intended to serve as a lower-bound benchmark against which area-specific cost estimates can be compared.

In this article, we estimate external costs for four representative types of freight trains. The objective is to provide external cost estimates for rail freight transportation between cities, making these estimates as comparable as possible with those for trucks in the previous article. After presenting the several types of external costs for freight rail, we compare them with the external costs arising from transporting freight by truck.

2. Modal competition and social costs

Under full 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 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 were 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 an extremely wide array of goods. For example, according to the 1993 US Commodity Flow Survey, the value of "non-metallic materials" averaged about $11 per ton, and "apparel" averaged $19 249 per ton (Bureau of the Census, 1996, Table 5(a)).

Fig. 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% of long-haul truck ton-miles are competitive with rail, and 33% of rail ton-miles are competitive with truck (Abacus Technology Corp., 1991, Exhibit 5–1). In total, about 768.5 billion ton-miles shipped annually are modally competitive. [1]

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.

[1] Modally-competitive freight shipments are those which fall within the normal distance and service characteristics of both truck and rail.

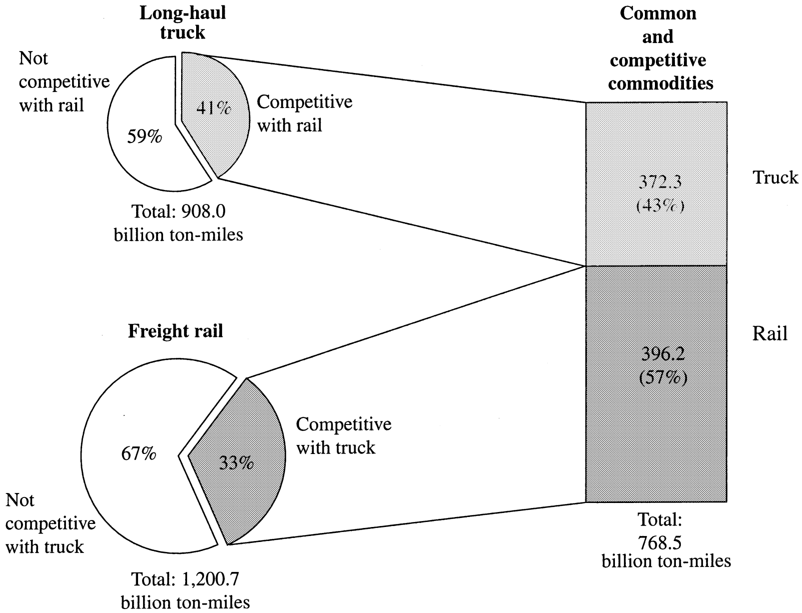

Fig. 1. Competitive freight service for truck and rail, 1994. *Sources*: Bureau of Transportation Statistics (1996a, pp. 41, 53). Percentage modal competitive estimates are for 1987 from Abacus Technology Corporation (1991, Exhibit 5–1). Freight rail ton-miles are for Class I railroads.

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 article is to estimate the size of external costs and the extent to which full social cost pricing would exceed current operating costs faced by freight rail and trucking carriers. It is not our objective to argue for greater use of one mode or another.

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 observes (TRB, 1996, p. 2), 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 social costs of road use 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 freight rail operations nationally, enabling the average accident cost per ton-mile to be derived. The marginal accident cost of one more ton-mile transported by freight rail is much more difficult to estimate. Trip-specific considerations such as topography, condition of the trackage, weather conditions, and factors peculiar to the train and its operator all enter the picture. Thus, 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 rail and trucks relative to average private costs nationally. 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 or other services provided by the public sector; the other is to add some uniform charge to reflect external costs and accept a degree of cross-subsidization within each transportation mode. The analysis in this article tends toward the second option and develops conservative estimates of average costs in rural areas where the variation in such costs is likely to be much less than is the case among different metropolitan areas.

3. Rail and truck operating costs

If external costs were included in the prices paid by users of rail and truck freight service, these prices would increase by some fractional amount. To estimate these fractional price increases, it is necessary to estimate both the private and external costs of the two freight modes. Private costs are the direct expenses incurred by providers of freight transportation; these expenses include operating costs, as well as investments in capital facilities and rolling stock. It is operating costs that are most closely tied to the amount of service provided, including fuel, wages, maintenance, user charges, depreciation, and insurance.

Because external costs also result from routine operations, operating costs are the most appropriate basis for comparisons with external costs. When added together, private operating costs and external costs can give shippers and carriers a clear indication of the true cost of a unit of service. Essentially all data on production costs for rail and truck freight transportation are averages. Average cost data differ from the cost at the margin by the magnitude of any remaining long-term economies of scale. In estimating average costs per ton-mile, we consider the extent to which economies of scale exist in freight trucking and rail.

3.1. Private operating costs of trucking

An analysis of private costs of truckload (TL) trucking firms is presented in Forkenbrock (1999, Table 1). The analysis is limited to TL firms (distinguished from less-than-truckload firms which operate terminals and provide pick up and delivery service) because this category is by far the larger in terms of ton-miles of freight transported, accounting for over 90% (TRB 1989, pp. 70–71). Within the TL category, there are six types of carriers: general freight, automobile transport, refrigerated, bulk commodity, tank truck, and other specialized. General freight carriers account for the sizable majority of TL ton-miles. To avoid unnecessary aggregation, operating expenses for general freight TL carriers were the focus of Forkenbrock's analysis. Overall, in 1994 general freight TL 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.

Regarding economies of scale, Button (1993, pp. 74–75) contends that significant increases in returns to scale do not exist in TL trucking, citing evidence that large TL trucking companies compete with one-or-two-vehicle firms. McMullen and Stanley (1988) likewise doubt that economies of scale have been significant since deregulation of the trucking industry in 1980. Based on these authors' conclusions, average operating cost data probably are a reasonable approximation of the marginal cost of one more ton-mile of service.

3.2. Private operating costs of rail

Estimating private costs of freight rail service is inherently more complex than estimating similar costs for 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 movements. To cope with these complexities, a number of researchers have developed econometric cost estimation models.

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,b,c) 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). [2] 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 he 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 that these economies probably vary considerably among different types of rail operations.

3.3. Four rail scenarios

Because freight rail operations vary widely, a single aggregate value for private cost per ton-mile would have 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.

[2] 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 the operating functions of the firm. Economies of density result from more frequent service on a given length of route or from operating longer trains.

(a) *Heavy unit train*. This train has 100 lightweight cars of 26 tons, and each car carries 105 tons of cargo. The trip is 1000 miles in length, with a 100% empty return. Power for the train consists of four 3000 brake horsepower (BHP) locomotives.

(b) *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% empty return rate. Power for the train is provided by three 3000 BHP locomotives.

(c) *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 1750 miles, and a 5% empty return rate is assumed. Power is supplied by three 3000 BHP locomotives.

(d) *Double-stack container train*. This 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 10% empty return rate occurs. Power consists of four 3000 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 four types of trains, we vary emissions costs per ton-mile. Most important, the private costs per ton-mile vary among the four scenarios. Our objective is to present realistic and representative estimates of the private costs experienced by railroad companies operating different types of freight trains in order to provide bases with which external costs can be compared.

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). [3] 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 incorporated four output measures: gross ton-miles, car-miles, train-miles, and locomotive-horsepower-miles. Data are for a 17-year period, 1978–1995. 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 changes in the number of firms as the railroad industry has restructured.

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 in which the operating parameters are averaged and one in which the parameters are weighted by the gross ton-miles of each included railroad firm. Comparing results of the two approaches enable 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.

It is important to stress that our operating cost estimates pertain to the line-haul portion of rail service. We do not include local freight movements to and from actual traffic generators, nor do we consider drayage in the case of intermodal rail. By focusing on line-haul shipments, we facilitate the most reasonable comparison with TL trucking, which generally operates between

[3] 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 1
Private operating costs of four railroad freight scenarios, 1994[a]

Railroad scenario	Power	Cargo (tons)	Distance (miles)	Average cost per ton-mile (1994 cents)
Heavy unit train	4 – 3000 BHP locomotives	10 500	1000	1.19
Mixed freight train	3 – 3000 BHP locomotives	6300	500	1.20
Intermodal train	3 – 3000 BHP locomotives	3360	1750	2.68
Double-stack train	4 – 3000 BHP locomotives	6720	1750	1.06

[a] *Source*: Research by Bereskin (1998).

single points of origin and destination. As a practical matter, local freight shipments to rail yards vary in many ways, so that including this cost component would be highly problematic. It is likely that by excluding local freight movements, we are slightly underestimating ton-mile rail costs, especially for mixed freight and intermodal trains.

Our ton-mile operating cost estimates use averaged operating parameters for the four rail scenarios and are presented in Table 1. 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.

4. Non-market costs of freight rail

To charge the full cost of transportation services, it is necessary to estimate as accurately as possible the magnitude of external costs. Few of these costs can be assigned dollar amounts that are likely to be widely embraced, largely because there are limits to the extent to which we understand the effects of different transportation modes on the environment, infrastructure, and the health, safety, and welfare of the general population. Given these limitations, we use the categories of external costs in Forkenbrock (1999) and provide the best possible estimates of their magnitudes. Each category is discussed in turn.

4.1. Accidents

Vickery (1968) in a seminal piece concludes that when assigning accident costs to a particular transportation mode, fault is not at issue. He leads one to the conclusion that the social cost brought about by an accident would not have arisen had the particular transportation service not been provided. A fatality or injury to a railroad employee thus imposes the same cost on society as would the misfortune of a person being struck by a train, for example. To generate comparable external cost estimates of accidents involving freight trains or trucks, then, we multiply the numbers of fatal, personal injury, and property damage accidents by the appropriate per-event cost and subtract the amount of compensation paid by the particular mode. Dividing the resulting external cost by the number of ton-miles allows us to estimate the per-ton-mile external cost for each mode.

Table 2
Cost of accidents (1994 dollars)[a]

Accident type	Per person	Per accident
Fatal	2 903 782	3 304 027
Personal injury	56 255	84 455
Property damage	2110	5448

[a] *Source*: Miller et al. (1991), inflated to 1994 dollars.

Table 3
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

The most widely applied estimates of the dollar value to society of reducing fatal, personal injury, and property damage accidents were developed for the Federal Highway Administration by the Urban Institute (Miller et al., 1991). These estimates, updated to 1994 dollars, appear in Table 2. We use these values in our analysis.

Accidents involving freight trains fall into three primary categories: collisions at highway-rail grade crossings, persons struck by a train at other locations, and mishaps involving the train alone. The most frequent type of fatal accident is collisions at highway-rail grade crossings. Trains striking persons at locations other than grade crossings is another major cause of fatal accidents. [4] No distinction is made here between trespassers and non-trespassers, though it should be noted that when all railroads are taken together, trespassers account for the larger share of fatalities (55.9%). Most injuries, however, involve railroad employees on duty (81.6%) (Federal Railroad Administration, 1995, Table 14). In total there were 951 fatalities and 9669 personal injury casualties in 1994 arising from the operations of Class I freight railroads (Federal Railroad Administration, 1995, Tables 38 and 39). [5]

Using the Miller et al. (1991) values expressed in 1994 dollars, the costs to society of these fatal and personal injury casualties are $2 761 497 000 and $543 930 000, respectively (see Table 3). 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

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

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

Table 4
Compensation for accident costs paid by Class I freight railroads, 1994[a]

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

[a] *Source*: Correspondence from the Association of American Railroads Law Department dated March 29, 1996.

Railroad Administration data. For 1994, the estimate is $18 553 000. [6] We assume that property damage for non-crossing rail accidents (other than to trains) 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.

To estimate compensation made by Class I railroads to victims of accidents involving trains, a different method is required than that used in Forkenbrock (1999) 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 mainly 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). To collect, a worker must demonstrate negligence on the part of the employer, and awards are based on the degree of employee negligence. In general, the FELA process results in more sizable benefits to injured workers than does workers' compensation (TRB, 1994, p. 3). [7] 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% of FELA payments. As Table 4 shows, FELA compensation to injured railroad workers totaled $1.113 billion in 1994.

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 4). 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

[6] 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%.

[7] 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.

involving freight trains. [8] 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 accident compensation paid by Class I railroads.

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, Tables 1–9) results in an uncompensated cost of 0.17 cent per ton-mile.

4.2. Emissions

Air pollution generated by freight trains and trucks negatively affects other people than those who produce it, making it an external cost. We estimate the external costs associated with two general categories of emissions: air pollution and greenhouse gases. Assigning dollar values to the emissions generated per ton-mile of freight transportation is inherently difficult. For one thing, the amount of emissions associated with a unit of transportation varies with the specific type of train or truck and the conditions under which it is operating. Additionally, the value of damage to human health and other things of value-animals, crop yields, building and structures, and scenic views-is bound to be subjective.

Most cost estimates of air pollution and greenhouse gases have been made for very specific circumstances, usually a particular city with an air quality problem (see, for example, Small and Kazimi, 1995, who studied Los Angeles). Because this analysis focuses on freight movement between cities, the appropriate unit cost of air pollution should be comparatively low because the ambient pollution levels in rural areas are appreciably lower than those in the urban areas where higher cost estimates have been used. Our cost estimates are based on the work of Haling and Cohen (1995), who use results of work by National Economic Research Associates (NERA, 1993) to assign costs of air pollution in 2233 rural US counties in various states (there are 3048 rural counties in the US). [9] Table 5 shows their estimated costs per ton for four key types of air pollutants: volatile organic compounds (VOC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter under 10 μm in aerodynamic diameter (PM_{10}).

In Table 6 we present estimates of emission rates per ton-mile of cargo for the four general types of freight trains discussed earlier. With emission rates adapted from Barth and Tadi (1996), the table presents VOC, NO_x, and PM_{10} emissions per ton-mile for the four types of trains. [10]

[8] One could argue that not all of the worker injury costs uncompensated by FELA are truly external costs. Labor economics would suggest that if workers are rational, they take the risk of injury into account when deciding whether to accept a job paying a certain wage rate. Competing employers presumably must compensate workers for these risks.

[9] As discussed in Forkenbrock (1999), the NERA study is the most salient estimate of air pollution costs our literature review uncovered.

[10] Barth and Tadi (1996) do not include SO_x. Freight rail is an inconsequential source of this pollutant.

Table 5
Average air pollutant costs for 2233 rural counties (1994 dollars)[a]

Pollutant	Cost per ton
VOC	385
NO_x	213
SO_x	263
PM_{10}	3943

[a] *Source*: Forkenbrock (1999), derived from Haling and Cohen (1995).

Table 6
Emission rates for four types of freight trains (grams per ton-mile)[a]

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

[a] 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).

Table 7
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

Because the four scenarios vary considerably in terms of locomotive power and trailing tonnage of cargo, the emissions rates also vary among the scenarios.

In Table 7, we apply the estimated emission costs per ton from Table 5 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. 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) which estimates air pollution costs associated with shipping 1000 tons one kilometer to be 1.8 European currency units (ECU). Converting this figure to US dollars per ton-mile yields an estimate of 0.22 cent. 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 7. While these authors' rail scenarios differ somewhat from ours, they arrive at similar emission rates for VOC, NO_x, and PM_{10}.

Table 8
Rates and external costs of carbon dioxide emissions, truck and rail, 1994[a]

Freight mode	Emission rate per ton-mile (g)	Cost per ton-mile (1994 cents)
Mixed freight rail	18.6	0.02
Intermodal rail	17.0	0.02
Double-stack rail	15.4	0.02

[a] *Source*: Blevins and Gibson (1991, Table 7).

Turning to greenhouse gases, while they are not technically air pollution, these 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% of total emissions weighted by global warming potential (Bureau of Transportation Statistics, 1996b, p. 144). 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. A National Research Council study (NRC, 1991) 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. [11] 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. 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 for all three train configurations (see Table 8). Because of the consistency of the cost estimates, it seems reasonable to use the same CO_2 cost per ton-mile for our fourth type of train as well.

Although we have disaggregated freight trains 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 are transporting fewer net tons per mile of travel, for example.

4.3. Noise

Even in rural areas where fewer people live and work, noise (defined as unwanted or detrimental sound) is bothersome. Even where noise levels generally are quite low, intermittent noise can adversely affect people, especially when they need to concentrate, rest, or maintain tranquility. While the psychological effects of noise are very difficult to monetize, noise tends to have an adverse impact on residential property values (see Hokanson et al., 1981). It is this impact that has been the basis for dollar costs of truck and rail noise. Because of the generally sparse settlement patterns in rural areas, few housing units are effected by passing trains or highway traffic.

[11] It should be noted that the uncertainties about climate change, and the possible long-term need to reduce carbon emissions substantially, suggest that this cost may rise to a considerably higher level in the future.

Far less has been written about noise generated by freight rail operating in rural areas than about heavy trucks. [12] Most of the limited literature pertains to high-speed passenger rail in Europe, rather than to 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. [13] 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 cost estimates available for freight rail 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 conditions in Germany, where rural development is generally denser than in the US, so their estimates are likely to be relatively high compared to ours.

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 3.4–1; the ratio of people "highly annoyed" is 6.4–1.

One cannot be certain what factors entered into the annoyance ratios estimated by European researchers. Level and mix of highway traffic, distance to highways and railroads, length and frequency of train passages, and numerous other characteristics probably influence these ratios. Lacking definitive research on circumstances and perceptions in the United States, it is imprudent to assign an arbitrary ratio of how objectionable truck noise on highways is relative to freight rail noise. It probably is the case that particularly in sparsely settled rural areas, exposure to rail noise is not very different than to trucks operating on highways (both are very limited). Accordingly, we use the same value for noise impacts of 0.04 cent per ton-mile as applied for trucks in Forkenbrock (1999). In the case of either mode, the social cost of noise per ton-mile of transportation service in rural areas is very small.

5. Comparison of rail and truck external costs

In Table 9 we summarize our estimates of the external costs of three representative types of freight rail operating between urban areas in the United States. We also present the comparable estimates for general freight TL trucks from Forkenbrock (1999). The total external cost for these trucks is 0.86 cent per ton-mile. For freight rail the per-ton-mile external cost totals 0.24–0.25 cent. When comparing these external costs, it is very important to keep in mind the highly different natures of these two modes' operations.

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

[13] Decibles of sound adjusted to approximate human perception are called "A-weighted levels" (dBA). The A-weighted decibel scale is logarithmic. See Forkenbrock (1999).

Table 9
Summary of external costs of truck and rail freight (1994 cents per ton-mile)[a]

	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

[a] *Source*: Truck costs are from Forkenbrock (1999).

Table 10
Private and external costs of truck and rail freight (1994 cents per ton-mile)[a]

	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

[a] *Source*: Truck costs are from Forkenbrock (1999).

The most meaningful comparisons are between the external costs and the private costs of each of the modes. These comparisons are presented in Table 10. [14] One feature of the table should be explained: the user charge underpayment for trucks is based on results of the 1997 Federal Highway Cost Allocation Study (FHWA, 1997a). That study concluded that semi-trailer trucks significantly underpay for their use of public roads. The figure, derived in Forkenbrock (1999), is a weighted average for general freight TL carriers. Because railroad companies operate on their own trackage, no comparable entry is made in Table 10.

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: 0.24–0.25 cent per ton-mile. Because the average private cost is so much less for rail than for trucking, however, external costs for rail generally are larger relative to private costs. In any event, the external costs of intercity freight transportation are considerable, when compared to the private costs that are a basis for current freight rates. Even using the conservative values contained in this analysis, the costs of freight shipments would increase by between 9.3 and 22.6% if all external costs were included in the costs faced by rail and truck freight providers.

6. Conclusions

The purpose of this article is to combine the best available sources of information pertaining to private and external costs that arise from intercity freight railroad operations. We compare the

[14] It also would facilitate comparisons if data were available on the relative number of ton-miles accounted for by each of the four types of trains. Unfortunately, these data are not available.

results of this analysis with those of Forkenbrock (1999), which is a parallel analysis of private and external costs associated with general freight truckload (TL) trucking. On a per-ton-mile basis, trucking generates over three times the external costs of any of the four types of freight trains considered in the analysis.

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

The conclusion of our research is 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 considered when transportation policy is formulated. 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.

Acknowledgements

The author wishes to thank Lisa Schweitzer, who provided research assistance, and two anonymous referees whose suggestions improved the analysis.

References

Abacus Technology Corporation, 1991. Rail versus Truck Fuel Efficiency: The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in a Range of Corridors. US Department of Commerce, National Technical Information Service, Washington, DC.

Association of American Railroads, 1996. Correspondence regarding railroad accident claims. Law Department, Washington, DC (March 29).

Association of American Railroads, Nd. Tort Abuse and the Rail Industry: The Facts About FELA. Washington, DC.

Barbera, A.C., Grimm, M., Phillips, K.A., Selzer, L.J., 1987. Railroad cost structure – revisited. Journal of the Transportation Research Forum 28 (1), 237–244.

Barth, M., Tadi, R., 1996. An emissions comparison between truck and rail: a case study of the California I–40, In: Paper presented at the Transportation Research Board 75th Annual Meeting, Washington, DC.

Bereskin, C.G., 1983. A bi-level model of United States railroad costs. Unpublished dissertation, University of Missouri – Columbia, Columbia, MO.

Bereskin, C.G., 1996. Econometric estimation of post-deregulation railway productivity growth. Transportation Journal 35 (4), 34–43.

Bereskin, C.G., 1998. Economic estimation of costs for specific railroad freight. Unpublished paper, Department of Economics, St. Ambrose College, Davenport, IA.

Blevins, W.G., Gibson, A.W., 1991. Comparison of emissions and energy use for truck and rail. In: Paper presented at the Annual Conference of the Transportation Association of Canada, Winnipeg, CN.

Bureau of the Census, 1996. 1993 Commodity flow survey. Report No. TC92-CF-52, US Department of Commerce, Washington DC.

Bureau of Transportation Statistics, 1996a. National Transportation Statistics 1996. US Government Printing Office, Washington, DC.
Bureau of Transportation Statistics, 1996b. National Transportation Statistics Annual Report 1996: Transportation and the Environment. US Government Printing Office, Washington, DC.
Bureau of Transportation Statistics, 1997. National Transportation Statistics 1997. US Government Printing Office, Washington, DC.
Button, K.J., 1993. Transport Economics second ed. University Press, Cambridge, UK.
Caves, D.W., Christensen, L.R., Swanson, J.A., 1980. Productivity in US railroads, 1951–1974. Bell Journal of Economics 11 (1), 166–181.
Caves, D.W., Christensen, L.R., Swanson, J.A., 1981a. Economic performance in regulated and unregulated environments: a comparison of US and Canadian railroads. Quarterly Journal of Economics 96 (4), 559–581.
Caves, D.W., Christensen, L.R., Swanson, J.A., 1981b. The high cost of regulating US railroads. Regulation 5 (1), 41–46.
Caves, D.W., Christensen, L.R., Swanson, J.A., 1981c. Productivity growth, scale economies and capacity utilization in US railroads, 1955–1974. American Economic Review 71 (5), 994–1002.
Diekmann, A., 1990. Nutzen und Kosten des Automobils. Internationales Verkehrswesen, November–December.
European Commission, 1996. Towards Fair and Efficient Pricing in Transport: Policy Options for Internalizing the External Costs of Transport in the European Union. Office for Official Publications of the European Communities, Luxemborg, Belgium.
Fath, J.M., Bloomquist, D.S., Heinen, J.M., Tarica, M., 1974. Measurements of railroad noise – line operation, yard boundaries, and retarders. Report No. NBSIR 74–488, US Environmental Protection Agency, Office of Noise Abatement and Control, Washington, DC.
Federal Highway Administration (FHWA), 1997a. 1997 Federal Highway Cost Allocation Study. US Government Printing Office, Washington, DC.
Federal Highway Administration (FHWA), 1997b. Federal Highway Cost Allocation Study Draft Report Appendix I. Washington, DC.
Federal Railroad Administration, 1995. Accident/Incident Bulletin No. 163. US Department of Transportation, Washington, DC.
Forkenbrock, D.J., 1999. External costs of intercity truck freight transportation. Transportation Research A 33 (7/8), 505–526.
Friedlaender, A.F., Spady, R.H., 1980. Economic costs and the uniform railroad costing system. In: Paper presented at the Conference on Railroad Costing Procedures, Interstate Commerce Commission, Washington, DC (June).
Grimm, C.M., Harris, R.G, 1983. Structural economies of the rail freight industry: concepts, evidence, and merger policy implications. Transportation Research A 17 (4), 271–281.
Haling, D., Cohen, H., 1995. Air quality cost analysis spreadsheet. Data provided by the authors. Cambridge Systematics, Inc, Washington, DC.
Hanson, C.E., Saurenman, H.J., Towers, D.A., 1991. Rail transportation noise and vibration. In: Harris, C.M. (Ed.), Handbook of Acoustical Measurements and Noise Control. McGraw-Hill, New York, pp. 46.1–46.23.
Hokanson, B., Minkoff, M., Nichols, S., Coward, S., 1981. Measures of noise attributable to motor vehicle travel. University of Iowa Institute of Urban and Regional Research.
Keaton, M.H., 1990. Economies of density and service levels on US railroads: an experimental analysis. The Logistics and Transportation Review 26 (3), 211–227.
Lee, T., Baumel, C.P., 1987. The cost structure of the US railroad industry under deregulation. Journal of the Transportation Research Forum 28 (1), 245–253.
McMullen, B.S., Stanley, L.R., 1988. The impact of deregulation on the production structure of the motor carrier industry. Economic Inquiry 26 (2), 299–317.
Miller, T., Viner, J., Rossman S., Pindus N., Gellert W., Douglass J., Dillingham, A., Blomquist, G., 1991. The cost of highway crashes. Report No. FHWA–RD–91–055, US Department of Transportation, Federal Highway Administration, Washington, DC.
National Economic Research Associates (NERA), 1993. External costs of electric utility resource selection in Nevada. Final report, Prepared for the Nevada Power Company, Cambridge, MA.

National Research Council (NRC), 1991. Rethinking the ozone problem in urban and regional air pollution. Committee on Tropospheric Ozone Formation and Measurement, National Academy Press, Washington, DC.
Nelson, P.M., 1987. Transportation Noise Reference Book. Butterworth, London.
Organisation for Economic Co-operation and Development (OECD), 1992. Environmental Impact Assessment of Roads. Road Transport Research Programme, Paris, FR.
Planco, 1990. Externe Kosten des Verkehrs: Schierre, Strasse, Binnenschiffart. Essen, Germany.
Rothengatter, W., 1989. Aspects Économiques. European Conference of Ministers of Transport Committee of Deputies, Paris, FR.
Small, K.A., Kazimi, C., 1995. On the costs of air pollution from motor vehicles. Journal of Transport Economics and Policy 29 (1), 1–32.
Spady, R.H., 1979. Econometric Estimation of Cost Functions for the Regulated Transportation Industries. Garland, New York.
Spady, R.H., Friedlaender , A.F., 1976. Economic estimation of cost functions in the transportation industries. Report No. 76–13, MIT Center for Transportation Studies, Cambridge, MA.
Transportation Research Board (TRB), 1989. Providing access for large trucks. Special Report 223, National Academy Press, Washington, DC.
Transportation Research Board (TRB), 1994. Compensating Injured Railroad Workers Under the Federal Employers' Liability Act. Special Report 241, National Academy Press, Washington, DC.
Transportation Research Board (TRB), 1996. Paying Our Way: Estimating Marginal Social Costs of Freight Transportation. Special Report 246, National Academy Press Washington, DC.
Vickery, W., 1968. Automobile accidents, tort law, externalities, and insurance: an economist's critique. Law and Contemporary Problems 33 (3), 464–487.

Attachment H
Exhibit 4009-000017-CWF
Columbia Waterfront LLC