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Methods for Analyzing Motor Carrier and Railroad Costs

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INTRODUCTION

In the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Congress declared that it is the policy of the United States "to develop a National Intermodal Transportation System that is economically efficient and environmentally sound [and] provides the foundation for the Nation to compete in a global economy."[1] In furtherance of this policy, Congress required the development of statewide transportation plans that address both freight and passenger issues. Statewide plans must consider "various modes of transport in a manner that will serve all areas of the State efficiently and effectively."[2]

State policies regarding freight transportation efficiency are intended to reflect the economics, competitiveness, and technological advantages of the various modes. However, state policies frequently are based on generalizations regarding the cost structure, technology, and competitiveness of railroad and motor carrier transportation. Few freight analysis tools are in widespread use among state transportation departments today that allow explicit analysis of rail and truck costs for various commodities, distances, and service levels. For many reasons, it is important for state transportation planners to possess the capability to simultaneously analyze railroad and truck shipment costs, and identify trade-offs associated with the use of each mode.[3]

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[1] *Public Law* 102-240, December 18, 1991, Sec. 2.

[2] IBID

[3] This study does not attempt to measure the full social costs of each transport mode. Thus, although they should be considered by state transportation planners, environmental and other external costs are not measured.

Such comparative analyses also are important at the federal level, as the FHWA evaluates issues associated with truck sizes and weights and user fees.

This paper estimates railroad and truck shipment costs for several major commodities and illustrates how public data and analytic tools can be used to analyze multimodal trade-offs and efficiencies. The paper begins with a general description of cost concepts, including definitions of variable and fully allocated costs. A description of motor carrier costs for major truck types, commodities, and operating conditions is presented next. This discussion includes an analysis and illustration of the truck unit costs currently being utilized by the Federal Highway Administration (FHWA) in a comprehensive analysis of truck sizes, weights, and user fees. In part 3, the cost structure of Class I railroad companies is highlighted, including a description and illustration of the Uniform Railroad Costing System (URCS). In part 4, railroad and truck costs are estimated for several major commodities and equi-cost distances are computed—i.e. the distance at which truck and railroad costs are equal. Also in this section, the effects on modal costs of changes in truck backhaul opportunities are simulated. Conclusions also are drawn regarding the cost competitiveness of truck and railroad transportation.

BACKGROUND CONCEPTS

Transportation costs may be classified according to many criteria. Perhaps most important is the time frame for investment decisions and the extent to which costs are traceable to output or traffic.

Over a long-run planning horizon, all costs are variable with output. Roadway, terminals, vehicles, labor and other inputs can be adjusted to optimal levels. However, some costs do not vary with output during shorter planning periods. For railroads — track, yards, and large terminal facilities — have long useful lives that extend beyond a typical planning horizon. Moreover, these assets cannot be adjusted to optimal levels for short run changes in output. Thus, capital investment costs of these assets are fixed in the short run. Once a certain scale of plant or facility is constructed, the resulting opportunity cost, depreciation, and interest are incurred each period regardless of the output level, until the size of the operation can be changed.

In the case of railroads, the Interstate Commerce Commission (ICC) defines an intermediate time period for purposes of cost analysis. Some capital investment costs are fixed for an intermediate planning period. However, some adjustments also are envisioned to the plant or network. The railroad costs discussed later are based on an intermediate time period, during which half of railroad investment in road property is assumed to be fixed and half varies with traffic.

The intermediate run for railroads is usually a long time. Many railroad assets, such as track and structures, are immobile, indivisible and costly to liquidate. Moreover, abandonment of rail lines and railroad restructuring plans are governed by federal regulation. Consequently, adjustments to railroad networks tend to occur in piecemeal fashion over many years. Adjustments tend to occur much faster in the motor carrier industry. Trucks and trailers are mobile assets with high re-use or liquidation values. Therefore, the short run in the motor carrier industry may be much shorter than the short run or intermediate run in the railroad industry. This difference in planning horizons must be considered when comparing railroad and motor carrier costs.

Common and joint costs cannot be traced directly to outputs or activities. Common costs are incurred as the result of several operations or services. Joint costs result from two or more activities that cannot be separated. One event is usually the by-product of another activity. Transportation carriers are multi-product or multi-service companies that frequently experience common and joint costs. For example, railroads may utilize the same track and infrastructure for the provision of both passenger and freight services. In motor carrier operations, the cost of less-than-truckload (LTL) pickup and delivery services typically reflect the collection and distribution of several shipments with the same truck and driver. In both cases, some costs must be allocated to each type of service or commodity. A primary example of joint cost is the empty movement of rail cars or highway trailers necessary to position cars or trailers for new loads.

In the intermediate run, railroads tend to incur large pools of common and fixed costs. Motor carriers also experience some fixed and common costs in the short run. In the long run, all of these costs must be recovered if the railroad or motor carrier is to earn adequate revenues. Fully allocated cost (FAC) is a concept designed to account for fixed system costs for a short or intermediate period. In railroad cost analysis, the ICC allocates fixed and common costs to each shipment using the ratio of total cost (TC) to variable cost (VC) as shown below.

$$FAC = VC * \frac{TC}{VC} \quad (2)$$

Theoretically, if every shipment for a railroad company earned revenues equal to fully allocated cost, then the railroad would be revenue-adequate.

MOTOR CARRIER COST STRUCTURE

Many segments of the motor carrier industry are highly competitive with few capital or regulatory barriers to entry, no exit restrictions, and highly mobile resources. Less-than-truckload (LTL) companies operate fixed terminal facilities where consolidation and distribution of freight occurs. However, the truckload sector of the industry operates few fixed terminals. Thus, most of the costs associated with truckload shipments consist of over-the-road expenses. Moreover, owner-operators (a special class of truckload operators) have limited central office and administrative expenses. Therefore, most of their costs are vehicle- or driver-related.

This section of the paper highlights the operations and cost structure of the motor carrier industry and reviews sources of motor carrier unit costs, including the unit costs developed for FHWA by Jack Faucett Associates and SYDEC [4]. In addition to the FHWA study, refrigerated truck costs published by USDA also are reviewed and used to illustrate truck cost concepts.

Major Cost Factors and Definitions

Truck costs are usually stated in terms of: (1) a cost per loaded or empty mile, (2) a cost per loaded mile, which reflects an assumption regarding the frequency of empty miles prior to and after the loaded trip, and (3) a cost per ton-mile, which consists of the cost per loaded mile divided by the payload tons. All three types of truck unit costs are useful and will be discussed in

[4] Jack Faucett Associates. *Transportation Benefits of the Proposed Wabash Waterway*, prepared for the U.S. Army Corps of Engineers, 1986.

this section. However for purposes of comparing truck and rail costs, the cost per ton-mile is used.

Truck costs per ton-mile are influenced by many physical, operational, and shipment factors. Some cost effects result from the commodities hauled and the markets served and thus are trip-specific. Other cost effects are the result of annual operations, traffic patterns, and utilization rates. In general, the density and loading characteristics of a product affect the maximum practical gross vehicle operating weight and the average payload tons possible for a given type of truck. Commodities are frequently classified as weight-constrained or cube-limited products, depending on whether the maximum vehicle and axle weights are reached before the cubic capacity of the trailers is exhausted. The backhaul opportunities available in specific markets determine the percentage of empty truck miles that must be allocated to a shipment, thus impacting the cost per loaded mile. Within a given market and commodity group, the type vehicle configuration used—e.g. single unit, semi-trailer, double-trailer, or triple-trailer truck—may significantly affect the cost per ton-mile. The number of trailers in the configuration, the cost and useful lives of trailers and tractor, the payload capacity, fuel efficiency ratings, and driver pay and premiums all impact ton-mile costs. Moreover, annual utilization of equipment for a particular type of truck affects the average cost per mile. In general, trucks used in short-haul or local transport spend a greater proportion of time loading, unloading, and standing idle. Thus, these vehicles tend to accumulate fewer miles per year, resulting in poorer utilization of equipment.

Truck Costs for Select Configurations

Table 1 lists a series of truck unit costs and cost factors for select configurations of dry van, hopper, and refrigerated equipment. Grains and related farm products frequently are hauled in hopper trailers with top loading and bottom gravity discharge capabilities. However, hoppers are specialized equipment with limited back-haul opportunities. Therefore, many agricultural commodities also are hauled in dry vans, which allow back hauls from a wider set of commodities. Agricultural and related food products that require refrigeration, such as fresh fruits, vegetables, and meats, are transported in *reefer* vans.

The costs in Table 1 are derived from the Jack Faucett Associates/SYDEC study for the Federal Highway Administration (FHWA).[5] The costs reflect projected 1995 operational and labor conditions, but are stated in 1993 dollars. Costs are shown for conventional semi-trailer and longer-configuration vehicles (LCVs). For each truck type, Table 1 lists the average cost per loaded or empty mile, the percentage empty miles, the cost per loaded mile, the average tare weight, the practical gross weight, net or payload tons, and cost per ton-mile for weight-restricted commodities. For such commodities, the practical gross vehicle weight is constrained by Bridge Formula B, gross vehicle weight limits, and maximum axle weight regulations. The payload tons are the gross weight minus the tare or empty weight of the configuration. The cost per loaded mile is estimated from the cost per loaded or empty mile and the percentage of empty miles using the following equation:

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[5] Jack Faucett Associates. *The Effect of Size and Weight Limits on Truck Costs*, prepared in association with SYDEC, Inc. as part of the *Truck Size and Weight User Fee Policy Analysis Study*, Federal Highway Administration, U.S. Department of Transportation, 1991.

$$\frac{\textit{Cost per Loaded or Empty Mile}}{1 - \textit{Proportion of Miles Loaded}} \tag{3}$$

This equation attributes empty mile costs to the loaded portion of a shipment.

As Table 1 shows, truck configuration and payload have a significant affect on costs per loaded or empty mile and on costs per ton-mile. In general, the loaded or empty cost per mile is lowest for hoppers, followed by dry vans, reefers, and tanks. However, because the ratio of empty-to-total miles typically is greater for hopper trailers, the costs per loaded mile and per ton-mile are much higher for hoppers than for dry vans and reefers. The table also shows that within a particular class of truck (e.g. hoppers) the cost per loaded or empty mile increases with size. However, the average payload also increases with truck size. Therefore, the cost per ton-mile decreases significantly as truck size increases.

Motor Carrier Cost Components

Both railroad and truck variable shipment costs can be separated into terminal and line-haul components. Truck line-haul costs vary directly with shipment distance, while truck terminal costs are a function of the number of shipments only. However, most truck cost studies have not separated line-haul and terminal costs, but instead have provided a single value per mile. Such per-mile unit costs are likely to understate the costs of short-haul movements and overstate the costs of long-haul movements.

A recent study by Jack Faucett Associates (JFA)[6] provides a partial remedy to this problem. Changes in truck costs per mile resulting from changes in shipment distance are re-examined in a later section.

In the long run, all motor carrier costs are variable. However at the beginning of each period, the trucking firm or the owner-operator must decide whether to commence or continue operations for the period, and if so, what the size or scope of operation should be. Once the decision is made to pursue operations at a certain scale for the period, several types of costs are realized regardless of the number of shipments made or the number of miles traveled. These costs include license fees and taxes, insurance, management and overhead costs, and housing and equipment costs, including return on investment. Typically, these costs are placed on a per-mile basis by dividing total annual fixed costs by the average annual miles of travel for a particular truck configuration. To the extent that these costs do not vary with miles of travel, allocations on a per-mile basis are arbitrary.

As discussed previously, costs computed in this manner are frequently referred to as fully allocated or fully distributed costs. Motor carrier pricing strategies may not always reflect fully allocated costs. In actuality, truckers may price some shipments in a manner that will not recover any fixed costs, yet price other shipments so as to recover more than the per-mile fixed cost. The extent of differential pricing among commodities and shipments depends on the level of competition. In essence, management, overhead, fees, and insurance are common costs that are shared by all shipments. However, many of these costs are not completely fixed in the short run.

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[6] Jack Faucett Associates. *Transportation Benefits of the Proposed Wabash Waterway*, prepared for the U.S. Army Corps of Engineer, 1986.

For example, insurance costs increase to some extent with miles of travel; as do vehicle depreciation, overhead and management costs. Thus, even a modest increase in traffic will result in incremental insurance, vehicle, and management costs.

Motor carrier variable costs include vehicle depreciation, repairs, fuel, driver costs — all of which vary with distance and payload. Table 2 shows the portion of total costs attributable to separate cost items for various truck configurations, as estimated from Jack Faucett Associates truck costs.[7] As the table shows, the variable cost components represent roughly 60 percent of the costs of motor carriage while fixed cost components represent the remaining portion. However, to the extent that a portion of the items included in the fixed cost components are truly variable (e.g. portions of insurance, vehicle depreciation, and overhead all vary with traffic), the fixed cost portion is lower. Important variable cost items include driver costs, which comprise roughly half of variable costs, and fuel costs which comprise nearly one-third of variable costs. Vehicle repairs and tires make up the remaining portion of variable costs. Fixed costs are approximately split between vehicle depreciation and return on investment costs, and overhead costs.

The table also shows that the proportions of truck costs attributable to various items vary somewhat by truck configuration. As vehicle size increases, fuel, tires, repairs, and other vehicle costs increase as percentages of total variable cost. On the other hand, driver and overhead costs decline with vehicle size.

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[7] Jack Faucett Associates. *The Effect of Size and Weight on Truck Costs*, prepared in association with SYDEC, Inc. As part of the *Truck Size and Weight User Fee Policy Analysis Study*, Federal Highway Administration, U.S. Department of Transportation, 1991.

Impacts of Backhaul on Motor Carrier Cost

Table 1 showed that the cost per ton-mile can vary considerably due to differences in the truck configuration, the payload, and the ratio of empty-to-total miles. Table 3 shows that for a truck of a given truck configuration the cost per loaded mile and per ton-mile varies considerably with the frequency of back hauls. Specifically, Table 3 shows that the truck cost per ton-mile for a five axle 48 foot dry van increases by 100 percent as the proportion of empty miles increases from 0 percent (100 percent backhaul) to 50 percent (0 percent backhaul).

Impact of Distance on Truck Costs

As stated previously, the use of per-mile unit costs to estimate the costs of truck shipments for various distances is likely to understate costs for very short movements and overstate costs for long distances. Average truck costs per mile are typically computed by dividing annual costs, including fixed costs by the annual miles of travel. Because trucks used in short-haul operations are likely to travel fewer annual miles, the fixed costs per-mile computed from average industry data are likely to understate short-haul carrier costs. The opposite is true of long-haul carriers. Previous studies have provided data that can be used to estimate changes in fixed costs attributable to shipments of varying distances.[8]

Economic engineering studies typically do not include separate terminal and line-haul cost estimates. Because terminal costs do not vary with distance, the terminal cost per mile declines as the length of haul increases. Thus, the importance of terminal costs may be overstated

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[8] Jack Faucett Associates. *Transportation Benefits of the Proposed Wabash Waterway*, prepared for the U.S. Army Corps of Engineers, 1986.

for long-haul shipments and understated for short-haul shipments. Unfortunately, previous studies have not separated costs into terminal and line-haul categories. Thus, changes in truck unit costs resulting from lower terminal costs per mile at longer distances cannot be simulated. However, many truckload operators experience only limited terminal costs particularly in the transportation of bulk commodities hauled in hopper and dry van trailers.

Table 4 shows the change in loaded or empty truck cost per mile for various truck configurations due to differences in annual miles traveled by long-haul and short-haul trucking operations. As the table shows, the loaded or empty truck cost per mile declines at a decreasing rate as the average carrier shipment distance increases. However, the per-mile truck cost savings from distance are still understated because the lessening importance of terminal costs at longer distances is not considered.

Impacts of Pavement Condition on Truck Cost

As the serviceability of a highway declines, fuel consumption, vehicle maintenance costs, and use-related vehicle depreciation costs increase. A Congressional Budget Office study[9] estimated that combination five-axle vehicle operating costs increase by 39 percent per mile of travel when the PSI declines from five to one, assuming a constant operating speed. These cost relationships are applied to the JFA combination five-axle truck costs per mile shown in Table 1 to estimate the change in cost for changes in Pavement Serviceability Index (PSI) or Present Serviceability Rating (PSR). In developing these estimates, it is assumed that the JFA cost

[9] Lewis, D.L. *Public Works Infrastructure: Policy Considerations for the 1980's*. Congressional Budget Office, U.S. Congress, 1983.

estimates are developed at the weighted average PSI for rural and urban interstates in 1991. The results are shown in Table 5.

Moreover, travel speed usually declines with changes in pavement serviceability. The FHWA developed a speed adjustment factor based on PSR for use in the Highway Performance Monitoring System (HPMS). The speed adjustment formula - shown in equation[10] - reflects the overall adjustment to travel flow speeds resulting from changes in PSR.

$$SAF = 0.8613*(PSR)^{0.0928}*(1 + H\,(IRS - 35)) - H\,(IRS - 35) \qquad (4)$$

where: SAF = speed adjustment factor
PSR = present serviceability rating
IRS = initial running speed
H = 0.0130

This equation results in a value of one at a PSR of five, and decreases as PSR decreases. The speed traveled under various pavement conditions is found by multiplying the speed adjustment factor by the initial running speed. To the extent that drivers and equipment are tied up for longer time periods as a result of the reduced operating speed, the costs of truck operation will increase by a greater amount with reductions in pavement serviceability than illustrated in Table 5.

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[10] Jack Faucett Associates. *The Effect of Size and Weight Limits on Truck Costs*, prepared in association with SYDEC, Inc. as part of the *Truck Size and Weight User Fee Policy Analysis Study*, Federal Highway Administration, U.S. Department of Transportation, 1991.

RAILROAD COST STRUCTURE

Railway costing is more complex than truck costing because of the nature of the industry. The railroad industry supplies a wide variety of services, yet utilizes specialized equipment such as covered hopper and tank cars. Therefore, a railroad company typically experiences considerable common and fixed costs. Moreover, railroads have asset bases that are highly indivisible and have long physical lives. Further, these assets are not easily transferred or liquidated. Thus, many costs attributable to railroads are truly sunk costs; i.e. they are not part of the railroad's incremental costs and should not be considered in the railroad's decision of whether or not to make a particular shipment.

The ICC began developing rail costing methods in the 1930s. These efforts culminated in the adoption of the Uniform Railroad Costing System (URCS) as the agency's general purpose costing system in 1989.

The URCS is a process involving three main phases: (1) statistical analysis of railroad cost components, (2) estimation of variable unit costs and a constant cost markup ratio, and (3) application of the variable unit costs and markup ratio to movement attributes (e.g. distance, gross tons, carloads, car miles, etc). In Phase I, clusters of similar railroad expenses, such as running track and maintenance costs regressed on a scale variable (e.g. miles of running track) and an output variable (e.g. gross ton-miles). The regression coefficients are used to estimate the annual percent variable of expense groups, (this is done for 11 major expense groups that correspond to major railroad activities).[11] In Phase 2, the variable portions of these expense clusters are summed on output measures, and variable unit costs are estimated for gross ton-miles, train-miles, locomotive-miles, and other activity measures. In Phase 3, these variable unit costs are multiplied by the shipment service units to estimate variable shipment costs. Fully allocated costs are then estimated by multiplying the estimated shipment variable cost by the constant cost markup ratio.

Interpretation and Limitations of URCS Costs

As noted previously, fully allocated costs include an arbitrary allocation of fixed and common costs to each shipment. If the revenues generated from each shipment cover fully allocated costs on average, then all variable and fixed railroad costs will be recovered. However, railroads do not base individual shipment rates on fully allocated costs. Railroads will attempt to recover more fixed and common costs from commodities and markets with relatively inelastic demands. Thus, rates for these commodities may exceed fully allocated costs by large amounts. Conversely, railroads will charge less than FAC for commodities with relatively elastic demands, where there is likely to be truck, barge, or intermodal competition.

In this paper, URCS costs are not used to estimate or analyze rates, but to compare the costs of railroad and truck shipments for similar commodities and distances. In this regard, URCS variable costs are reasonable proxies for the incremental resource costs consumed in providing shipment services, and FAC represent an arbitrary estimate of full cost recovery.

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[11] Westbrook, M. Daniel. *Research Report on URCS Regression Equations*. prepared for the Interstate Commerce Commission, 1988

Railroad Cost Components

Traditionally, railroad shipment costs have been classified as line-haul or terminal. Although useful, this classification is too aggregate in nature to isolate shipment cost components. Railroad variable costs can be separated into seven major cost categories, including gross ton-mile, locomotive mile, train mile, switch engine, car ownership-running, car ownership-yard, and clerical costs. Gross ton-mile, locomotive-mile, and train-mile costs encompass all direct train operating expenses such as fuel, locomotive ownership, train crew wages, and train supplies. The gross ton-mile category also includes roadway investment and running track maintenance costs. Instead of line-haul versus terminal costs, car ownership expenses are separated into running (road train) and yard costs. Each subgroup includes repairs, depreciation, rentals, leases, return on investment, and shop overhead costs. Switch engine costs reflect both industry and classification yard switching activities, and include locomotive ownership, fuel, crew wages, overhead, switching track maintenance, and switching track investment costs. Clerical costs include waybill processing, billing, and related costs. Other costs, including loss and damage, comprise less than one percent of variable shipment costs.

Table 6 illustrates the portion of total variable shipment costs that each cost component comprises. Utilizing the Burlington Northern's (BN's) 1993 cost structure, the Uniform Rail Costing System (URCS) is used to estimate variable shipment costs and cost components realized for 50 mile, 800 mile, and 2,000 mile shipments of grain loaded at 98 tons per covered hopper car in 25-car blocks.

As the table shows, terminal costs comprise a decreasing portion of variable shipment costs as the shipment distance increases. At 50 miles, clerical, switching, and yard-related car ownership costs comprise 65 percent of variable shipment costs. As the shipment distance increases to 800 miles, these costs comprise only 21 percent of variable shipment costs. At 2,000 miles, these costs comprise 11 percent of variable shipment costs. Over the same distance interval, gross ton-mile and locomotive mile expenses increase from 19 to 54 percent of variable shipment costs. As a consequence of the declining importance of terminal costs with increased distance, variable shipment costs decline from 4.0¢ per ton-mile at 50 miles to 1.2¢ per ton-mile at 2,000 miles.

COMPARISON OF RAIL AND TRUCK COSTS FOR SELECT COMMODITIES

Theoretical rail and truck cost curves frequently are constructed that show motor carrier costs lower than rail costs for short distances and the opposite situation at longer distances. However, the actual equi-cost distance, the distance at which railroad and motor carrier costs are equal, is typically not estimated or shown in graphs. These theoretical relationships are quantified for select commodities in this section of the paper.

The equi-cost distances are estimated as a range of distances where truck fully-allocated costs intersect rail variable and rail fully-allocated costs. As mentioned previously, many rail cost elements are common and sunk in nature. Thus, a rail carrier has a wide range of long-run pricing schemes available to it based on differences in demand conditions. Under the assumption that URCS variable costs are a good proxy for railroad incremental costs, the equi-cost distance could be as short as the distance where truck fully-allocated costs are equal to URCS variable costs, and as great as the distance where truck fully-allocated costs are equal to the costs to the rail carrier of providing the service on a stand-alone basis. In the absence of an estimate of rail stand-alone costs, the rail fully-allocated costs are used to estimate the upper bound of the equi-cost distance. However, the equi-cost distance could be considerably longer than that shown by the intersection of truck and rail fully allocated costs.

Figures 1 and 2 show equi-cost distances for hauling grain in five axle 48 foot dry vans with a 0 percent back haul factor (50 percent of miles empty) and a 100 percent backhaul factor (0 percent of miles empty), respectively. As the figures show, the equi-cost distance falls considerably as the proportion of empty miles increases. With 100 percent of miles loaded, equi-cost distance lies between 164 and 279 miles, while it falls between 64 and 95 miles when only 50 percent of miles are loaded.

Equi-cost distances can be estimated graphically or algebraically. The algebraic solution requires that a regression line be fit to the URCS cost estimates for various distances. The URCS batch procedure can be used to quickly generate a table of variable costs for distance increments (e.g. 100 miles) given a particular service level and commodity. Parameter estimates obtained from a regression of rail costs per ton on an intercept term and distance can be equated with a truck cost per ton-mile in order to obtain equi-cost distances, as the following example for single rail car and truck grain shipment shows:

$$\begin{aligned} &\textit{Rail Cost per Ton} = \textit{Truck Cost per Ton} \\ &4.607 + .0157\, mi = .0515\, mi \\ &mi = 129 \end{aligned} \tag{5}$$

Table 7 provides rail and truck cost per ton equations for grain, chicken, and petroleum products.

CONCLUSIONS

The illustration for grain suggests that the distance at which motor carrier costs are less than or equal to railroad variable costs may be as low as 64 miles without a back haul, or as high as 164 miles with zero empty miles. Even if FAC are used in the comparison, the equi-cost distance only increases to 279 miles with zero empty miles. These values are significantly lower than generalizations that have been used (e.g. 500 miles). These differences underscore the necessity for quantitative analysis of modal costs.

The methods described in this paper can be used for analyses of different commodities by following this general process. First, select the type of highway equipment most frequently used to haul the commodity and adjust the JFA or other unit cost per ton-mile for the back haul frequency and payload. Second, use the URCS batch procedure to estimate variable and fully allocated costs at distance increments (e.g. 50 miles) up to a maximum reasonable distance (e.g. 900 miles). Third, fit a regression line to the URCS data points, equate the resulting parameter estimates with the motor carrier cost per ton-mile, and solve for the resulting intersection point. Alternatively, graphically determine the intersection distance. The area to the left of the intersection point includes distances at which motor carriers have a cost advantage. Conversely, the area to the right of the intersection point represents distances at which railroads have a competitive cost advantage.

REFERENCES

Public Law 102-240, December 18, 1991, Sec. 2.

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Westbrook, M. Daniel. *Research Report on URCS Regression Equations.* prepared for the Interstate Commerce Commission, 1988.

TABLE 1 Cost Estimates For Various Truck Configurations (1993 $)

Configuration	Loaded Weight (lb.)	Tare Weight (lb.)	Payload (lb.)	Cost per Loaded or Empty Mile	Typical Percent Mile Empty	Cost per Loaded Mile	Cost per Ton Mile	Comparison with 5 Axle Semi
5 Axle 48 ft Van	80,000	26,800	53,200	$1.16	15%	$1.37	5.1¢	--------
7 Axle 40 ft & 28 ft RMD Van	105,500	36,300	69,200	$1.32	15%	$1.57	4.5¢	-11.8%
9 Axle Twin 48 ft Van	129,000	46,200	82,800	$1.48	15%	$1.74	4.2¢	-17.7%
5 Axle 42 ft Hopper	80,000	24,600	55,400	$1.12	40%	$1.87	6.7¢	+31.4%
7 Axle 42 ft & 21 ft RMD Hopper	102,000	31,700	70,300	$1.28	40%	$2.13	6.1¢	+19.6%
9 Axle Twin 48 ft Hopper	129,000	40,300	88,700	$1.38	40%	$2.30	5.2¢	+2.0%
5 Axle 42 ft Tank	80,000	24,600	55,400	$1.45	45%	$2.64	9.5¢	+86.3%
5 Axle 48 ft Reefer	80,000	29,900	50,100	$1.26	15%	$1.48	5.9¢	+15.7%

Source: Jack Faucett Associates. *The Effect of Size and Weight Limits on Truck Costs*, prepared in association with SYDEC, Inc. as part of the *Truck Size and Weight User Fee Policy Analysis Study*, Federal Highway Administration, U.S. Department of Transportation, 1991. All costs are updated to 1993 levels by using truck cost indexes provided in the USDA *Fruit and Vegetable Truck Rate and Cost Summary*, 1988-1993.

TABLE 2 Proportion of Motor Carrier Costs Attributable to Individual Cost Elements

	Percent				
	5 Axle 40 ft Van	5 Axle 42 ft Hopper	7 Axle 48 ft & 21 ft RMD	9 Axle Twin 48 ft	Refrigerated Van 5 Axle 40 ft
Variable Costs					
Drivers	28	29	26	24	30
Fuel	20	15	16	16	20
Tires	3	3	4	5	3
Repair	10	11	12	13	9
Total Variable Costs	61	58	58	58	62
Fixed Costs					
Vehicle	19	21	22	24	19
Overhead	20	21	20	18	19
Total Fixed Costs	39	42	42	42	38

TABLE 3 Change in Truck Cost for a 5 Axle 40 Foot Dry Van With Changes in Back haul Opportunities

Percent Miles Loaded	Cost per Loaded Mile	Cost per Ton-Mile
100	$1.16	4.4¢
90	$1.29	4.8¢
80	$1.45	5.4¢
70	$1.66	6.3¢
60	$1.93	7.3¢
50	$2.32	8.8¢

TABLE 4 Changes in Truck Costs Due to Distance As the Result of Increased Annual Miles of Travel

	Cost per Loaded or Empty Mile (1993 $)					
	64 mi	130 mi	195 mi	259 mi	518 mi	1296 mi
5 Axle 48 ft Van	$1.55	$1.38	$1.29	$1.21	$1.19	$1.09
7 Axle 40 ft & 28 ft RMD Van	$1.75	$1.59	$1.47	$1.38	$1.37	$1.29
9 Axle Twin 48 ft Van	$1.96	$1.77	$1.64	$1.55	$1.51	$1.43
5 Axle 42 ft Hopper	$1.51	$1.35	$1.24	$1.16	$1.14	$1.08
7 Axle 42 ft & 21 ft RMD Hopper	$1.74	$1.55	$1.43	$1.34	$1.30	$1.24
9 Axle Twin 48 ft Hopper	$1.88	$1.69	$1.55	$1.45	$1.42	$1.35
5 Axle 42 ft Tank	$1.92	$1.74	$1.61	$1.51	$1.48	$1.42
5 Axle 48 ft Reefer	$1.88	$1.67	$1.55	$1.45	$1.42	$1.34

Cost Estimates are developed from annual distance - average distance relationships shown in Jack Faucett Associates, *Transportation Benefits of the Proposed Wabash Waterway*, prepared for the U.S. Army Corps of Engineers, 1986, and from per mile cost estimates developed in Jack Faucett Associates, *The Effect of Size and Weight Limits on Truck Costs*, prepared in association with SYDEC, Inc. as part of the *Truck Size and Weight User Fee Policy Analysis Study*, Federal Highway Administration, U.S. Department of Transportation, 1991. All costs are updated to 1993 levels by using truck cost indexes provided in the USDA *Fruit and Vegetable Truck Rate and Cost Summary*, 1988-1993.

TABLE 5 Change in Truck Cost for a 5 Axle 48 Foot Dry Van Due to Changes in Pavement Condition

Pavement Serviceability Index	Loaded or Empty Cost per Mile
5 (very good)	$1.09
4	$1.13
3.65 (weighted average PSI for rural and urban interstates, 1991)	$1.16
3	$1.22
2	$1.38
1 (very poor)	$1.53

TABLE 6 Distribution of Railroad Shipment Costs Among Major Cost Categories at Select Distances

	Percent of Variable Cost		
Cost Category	50 miles	800 miles	2000 miles
Gross Ton-Mile	11	33	36
Locomotive Unit Mile	8	17	18
Train Mile	10	18	19
Switch Engine	25	9	7
Car Ownership - Running	3	10	11
Car Ownership - Yard	29	10	8
Clerical	11	2	1

TABLE 7 Railroad and Truck Cost Equations For Select Commodities

	Variable Cost per Ton	Fully Allocated Cost per Ton
Single Car Rail Grain Shipments	4.607 + .0157 mi	6.265 + .0213 mi
26 Car Rail Grain Shipments	1.720 + .0157 mi	2.338 + .0213 mi
52 Car Rail Grain Shipments	1.276 + .0112 mi	1.728 + .0152 mi
Motor Carrier Grain Shipments (5 Axle 48 foot Dry Van - 15 percent of miles empty)	-------------------------[1]	.0515 mi
Single Car Rail Frozen Chicken Shipments	8.556 + .0241 mi	11.593+.0328 mi
26 Car Rail Frozen Chicken Shipments	3.225 + .0241 mi	4.350 +.0328 mi
52 Car Rail Frozen Chicken Shipments	2.467 + .0209 mi	3.320 +.0284 mi
Motor Carrier Frozen Chicken Shipments (5 Axle 48 foot Refrigerated Van - 15 percent of miles empty)	----------------------------	0.0591 mi
Single Car Rail Petroleum Shipments	3.251 + .0271 mi	4.422 + .0364 mi
26 Car Rail Petroleum Shipments	1.245 + .0271 mi	1.693 + .0369 mi
52 Car Rail Petroleum Shipments	0.714 + .0199 mi	0.969 + .0270 mi
Motor Carrier Petroleum Shipments (5 Axle 42 foot Tank - 45 percent of miles empty)	-----------------------------	0.0652 km

Source: Rail cost estimates are from the Uniform Rail Costing System using western region average unit costs, with average load factors per car of 95 tons for grain, 52 tons for frozen chicken, and 81 tons for petroleum. Truck cost estimates are from Jack Faucett Associates, *The Effect of Size and Weight Limits on Truck Costs*, prepared in association with SYDEC, Inc. as part of the *Truck Size and Weight User Fee Policy Analysis Study*, Federal Highway Administration, U.S. Department of Transportation, 1991.

[1] not applicable

FIGURE 1 Equi-Cost Distance Between Single Car Rail Shipment and 5 Axle 48 Foot Dry Van Truck Shipment For Grain (100 percent of miles loaded)

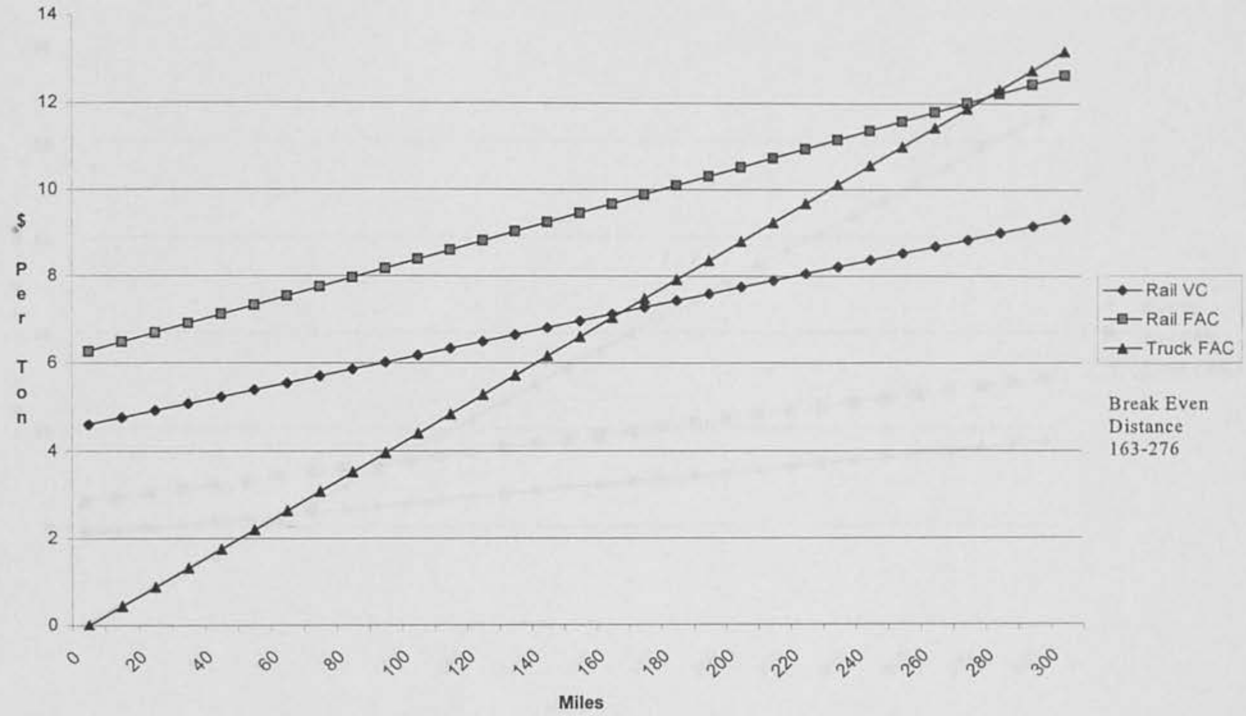

FIGURE 2 Equi-Cost Distance Between Single Car Rail Shipment and 5 Axle 48 Foot Dry Van Truck Shipment For Grain (50 percent of miles loaded)