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Contents

Pricing TOFC Shuttle Trains: An Equilibrium Analysis

Ralph D. Samuelson, Department of Engineering-Economic Systems, Stanford University, Stanford, California
Paul O. Roberts, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge

The determination of the most profitable pricing scheme for a freight transportation service poses difficult analytical problems. Little is generally known about the demand elasticities of a specific transportation market. The problem is especially critical in planning a new service. In this case, there will be no past experience to provide guidance and no present demand to use as a "base case" for sensitivity analysis, yet a mistake in pricing could lead to a costly failure. This paper discusses a pilot pricing study of a high-quality trailer-on-flatcar shuttle train service between three pairs of U.S. cities. The study is an illustration of how demand and cost models may be used in an equilibrium framework to determine optimal price. The demand model simulates the decisions of individual potential users of the service. Thus, it has the potential of providing a much more reliable appraisal of the likely market response to a price-service offering than more conventional methods, including most econometric models. The equilibrium analysis technique illustrated in this report is straightforward and could be profitably applied to many types of carrier marketing planning. Production use of the technique will probably have to await the development of better industry data, production demand models, and techniques for dealing with entire networks.

A trailer-on-flatcar (TOFC) shuttle train service is used in this paper to illustrate a very familiar but difficult problem for freight transportation market planners. The problem is to determine the most profitable pricing scheme for a service. Such pricing questions are always troublesome because there is little information available on demand elasticities. The problem becomes especially difficult when, as in this case, the service is only proposed. The planner thus has little previous experience to fall back on and no present demand to use as a "base case" for some type of sensitivity analysis. Without fairly accurate demand estimates, there can be no reliable revenue or cost estimates and, therefore, no profit forecasts.

This paper will demonstrate the solution of this pricing problem for TOFC shuttle trains using an equilibrium analysis. The approach uses models to estimate the demands and costs for various price alternatives. The profit-maximizing price may then be identified. A unique characteristic of this study is the use of a demand model that simulates the decisions of individual potential users of the service. As such, it has the potential of providing a much more reliable appraisal of the likely market response to a price-service offering than more conventional methods including most econometric models.

Many railroads have started TOFC shuttle train operations of one kind or another in recent years. Under this concept, TOFC operations are consolidated into a few high-volume terminals. Trailers at these terminals are loaded directly onto trains of dedicated equipment. These trains run straight through to destination terminals without further switching. Such trains offer the potential for better service and cost savings through better equipment utilization, lower switching costs, and more economical terminal operations.

The Illinois Central Gulf has been experimenting with a concept similar to the one hypothesized in this paper. The "Slingshot" provides one-day service between Chicago and St. Louis at a Plan 2½ rate of about $125/trailer. This low freight (all kinds) rate has enabled the trains to attract a substantial volume of business. (Plan 2½ is the method whereby the railroad provides the trailer, but the shipper is responsible for pickup and delivery of the shipment at the railroad yard.) Despite the fact that the train operates under a special labor agreement permitting the use of two-worker crews, there are many in the railroad industry who question the profitability of the service.

The equilibrium analysis technique illustrated here is straightforward and could be applied to many types of freight transportation market planning. The TOFC shuttle train pricing problem was selected because it is an especially appropriate illustration of the kind of problem the technique could be used to analyze. The shuttle train concept is being studied widely by both railroads and government for implementation on routes that do not have this service. Although past experience with the concept is still rather limited, a mispriced service can result in a costly failure.

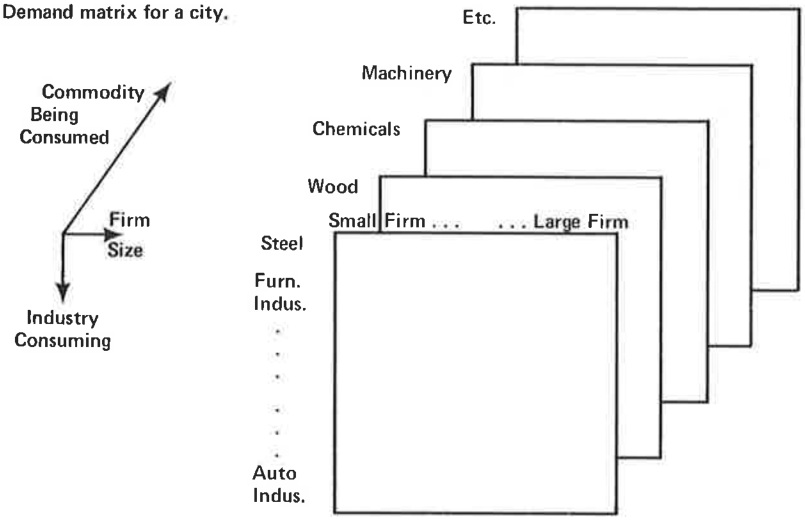
THE DEMAND MODEL

The demand model used in this study was developed at Massachusetts Institute of Technology (MIT) as part of a project to analyze the impact of various government policy options on transportation energy consumption (1). The demand for freight transportation between two cities will be the sum of the demands of many individual firms. The demand model therefore simulates the transportation decisions of a sample of firms, then explodes the sample to obtain an estimate of freight flow by mode.

Given an origin city, a commodity, and a receiving firm, the profit-maximizing transportation decision for the receiving firm may be simulated by a "logistics analyzer." This program searches for the mode and shipment size that minimize the total unit cost to the receiving firm involved in procuring the commodity. This logistics cost includes transportation charges, storage cost, capital carrying cost, spoilage cost, ordering cost, and the expected cost of any stockouts or insufficiently compensated loss and damage expense. Each of these elements of cost may be estimated as a function of the attributes of the commodity (e.g., value, density, shelf life, and storage requirements), the receiving firm (e.g., quantity of commodity used per unit time), and the mode of shipment (e.g., rate, travel time distribution, and expected loss and damage cost). The attributes of the mode are the parameters to be varied when using the model for marketing analysis. Note the assumption of transportation decision making by the receiving firm. Even when the shipping firm actually makes the transportation decision, it acts in the interest of its customer, the receiving firm. Hence, the resulting decision should be the same.

The logistics analyzer may be applied to a representative sample of receiving firms and commodities to obtain mode shares. The probability of sampling a particular firm and commodity should be proportional

Figure 1. Demand matrix for a city.



to the amount of the commodity received by the firm. It was therefore necessary to construct a demand matrix (Figure 1) showing the quantity of each input used by each firm-size class within each industry in the market area. This was accomplished by first estimating the output of each firm-size class within each industry in the market area using industry output data from the Census of Manufacturers and industry employment by firm-size class data from County Business Patterns. These outputs were then multiplied by the technical coefficients for each industry and input commodity combination from a Leontief input/output table to obtain dollar-value commodity inputs by industry and firm-size class. These technical coefficients show the dollar value of each input needed to produce a dollar of industry output. Additionally, estimates of personal consumption expenditures by commodity in the receiving area were developed; these were included in the inputs required by the retail industries. This dollar-value demand matrix was then converted to a tonnage demand matrix using data on commodity value per pound from a commodity attribute file (2).

Cells of this demand matrix are then sampled in proportion to their magnitude. The total weight of each selected commodity required by a firm-size class within an industry is divided by the number of firms in that firm-size class and industry to obtain an expected use rate for one of the firms. This information is then input to the logistics analyzer, which will search for the optimal mode and shipment-size choice. When a sufficient number of cells have been sampled, mode shares by commodity group are calculated. These mode shares are then multiplied by the flow of the commodity group between the origin and destination, as reported in the Census of Transportation Commodity Transportation Survey, to obtain an estimated tonnage by mode. It is important to understand that no modal flow data from the Census of Transportation are used, only total flows by all modes.

It is desirable to use as much commodity detail as possible. The demand matrix and the associated sampling procedure operate at the level of the five-digit Standard Transportation Commodity Code (STCC). The results are aggregated into 17 commodity-group mode shares (generally corresponding to two-digit STCCs), which are then multiplied by the total flows of these commodity groups reported in the Census of Transportation.

The Philadelphia-Cleveland, Chicago-Houston, and San Francisco-Los Angeles pairs analyzed in the MIT energy policy study are used as the setting for this study. An "area," as used here, refers to the Census of Transportation "production area" or "market area," which includes all the Standard Metropolitan Statistical Areas (SMSAs) in the origin or destination metropolis. The rates, travel time distributions, and loss-and-damage estimates of the rail carload, full truckload, less than truckload (LTL), and barge modes are taken directly from the MIT study. These were explored in some detail in that study based on data from waybill samples, contacts with carrier officials, and Interstate Commerce Commission reports.

THE COST MODEL

The TOFC shuttle train service evaluated is envisioned as differing from most conventional TOFC services in that it uses dedicated equipment operating in run-through trains without intermediate loading stops or switching and uses efficient, high-volume trailer loading facilities. The service is assumed to use existing roadbeds maintained well enough to allow for a reliable average origin-to-destination speed of 64 km/h (40 mph). The net result from the viewpoint of consumers should be highly reliable service at timings competitive with those of highway service. In other respects, the service is not drastically different from conventional TOFC service. Use of conventional TOFC equipment is assumed, as well as operation under present work rules, although the alternative of two-person operation will be considered. A flat Plan $2\frac{1}{2}$ rate is assumed, with the rate perceived by the customer including an additional charge for pickup and delivery. The trains would offer overnight service between Philadelphia and Cleveland and between San Francisco and Los Angeles; second-morning delivery would be available between Chicago and Houston.

The cost model used in this study associates unit costs with various elements of TOFC shuttle train operation. For example, a fixed cost of crew wages and benefits per crew day was assumed, as was a fixed locomotive maintenance cost per kilometer, a fixed trailer ownership cost per year, and so on. Fairly accurate estimates of the cost of virtually any type of TOFC shuttle train service could be constructed using these "building blocks". The cost model is basically an adaptation of the cost model presented in a Reebie Associates study (3). Various unit costs and other aspects of the model were adjusted after comparison with one railroad's proprietary data and consultation with several industry experts.

Costing of new railroad services has always been a difficult undertaking due to joint costs and the invariability of many of these joint costs with respect to volume. It may be profitable for a railroad to operate some services that do not cover their "share" of the invariable portion of the joint costs, although all new services should cover any additional costs associated with them. Unfortunately, it is not clear in some areas, such as track maintenance, to what extent costs vary with the traffic handled. Two cost estimates are therefore developed for each service—a "minimum" cost, which includes only costs directly associated with the purchase and operation of the trains and loading facilities, and a "maximum" cost, which includes a share of track maintenance and administrative overhead. This system leaves analysts free to develop their own judgments as to the true cost of the service, although it is undoubtedly closer to the maximum than to the minimum.

A fixed train length is assumed, with the train operating on the average at 60 percent of capacity. This low average ratio of trailers loaded on the train to total places available for trailers was felt to be necessary to ensure service reliability. This low average load factor would ensure that a trailer very seldom would have to be held until the next day because a train was full.

Costs are estimated using both conventional four-person crews and two-person crews such as those used on the "Slingshot." The cost of owning and operating a caboose on each train is included in the four-person crew cost estimates.

Trailers and locomotives are assumed to be purchased under equipment trusts, amortized at 10 percent over 7 years and 12 years, respectively. Trailers are assumed to have a five-day cycle time for the Philadelphia-Cleveland and San Francisco-Los Angeles runs and six days for the Chicago-Houston run. This allows one day for the trip (two days for Chicago-Houston), one day for customer loading, one day for customer unloading, and two days of slack time. This use is considerably better than that achieved by most existing TOFC services; however, it is not as good as that achieved by many truck lines. In order to allow sufficient power to maintain a moderately high average speed, a 1.6-kW/t (2-hp/trailing ton) ratio is assumed in calculating locomotive requirements. Many railroads have a policy of operating more locomotives than actually necessary to pull the train as insurance against frequent breakdowns. As will be shown, the feasibility of a TOFC shuttle train service may hinge on the ability to operate short trains reliably with a single locomotive. Rail cars are assumed to be leased from Trailer Train Corporation at standard rates.

EQUILIBRIUM RESULTS

The basic method used for the equilibrium analysis is fairly straightforward. For each different rate, the tonnage demand for the TOFC shuttle train service in each direction for each city pair is calculated. These tonnage demands are converted to trailer-per-day demands using a 14.5-t/trailer (16-ton/trailer) average payload. Because trailers are assumed to travel both directions by TOFC shuttle train, the maximum demand of the two directions determines the length of the train that must be operated. Given the train configuration, costs can then be calculated for each of the rates. At the same time, revenues for each assumed rate are calculated from the demand estimates. Revenues and costs can then be plotted against rate on the same axis. Profit or loss at each rate level may then be determined by inspection.

It should be noted at the outset that for each of the three city pairs considered, the TOFC shuttle train service is unprofitable on the basis of maximum cost at all rate levels when using a crew of four workers. The short trains used in a TOFC shuttle train service make the crew cost per trailer high. Thus, the difference between a crew of two and a crew of four becomes extremely important. Only the results obtained by using a crew of two will therefore be discussed in the following sections.

Philadelphia-Cleveland City Pair

The service provided by both truck and carload rail modes between Philadelphia and Cleveland is believed to be of only fair quality. Full truckload traffic may be subject to delays waiting for drivers. Rail traffic must be classified at the Pittsburgh yards. A TOFC shuttle train was therefore hypothesized to offer a decided reliability advantage over both truck and rail and a travel time advantage over rail. The lowest rate considered for the TOFC shuttle train is $235/trailer, a rate comparable to present rates on the "Slingshot." This rate undercuts most truckload rates and many carload rail rates.

Figure 2 compares TOFC shuttle train costs and revenues. The solid line indicates total annual revenues at the various rate levels; the upper dotted line represents "maximum" cost of serving this demand, and the lower dotted line represents the "minimum" cost of serving this demand. An interesting feature of this figure is that the revenue line drops slowly, indicating an elasticity of demand slightly less than one. Revenues hold up reasonably well even at high rate levels, due to the willingness of consumers to pay a premium for the higher level of service provided by the TOFC shuttle train.

Although the service appears to do fairly well on a minimum cost basis, the comparison of revenues with maximum costs is not nearly so favorable. The service is profitable only at high rates. A $480/trailer rate would seem to be most appropriate, resulting in a profit of about $260 000/year.

Los Angeles-San Francisco City Pair

Although the rail distance between Los Angeles and San Francisco is roughly the same as between Philadelphia and Cleveland, the nature of the market for transportation between the two areas differs dramatically. The California cities are well served by both truck and rail; both modes offer direct service between the two areas. Truck has an advantage over rail in that the highway route between the two cities is almost 160 km (100 miles) shorter than the rail route. Truck rates also tend to be lower due to the highly competitive, loosely regulated trucking industry serving this intrastate route. Both of these factors tend to make the market for a TOFC shuttle train service less promising than between Philadelphia and Cleveland. On the other hand, the total freight transportation market is much greater between Los Angeles and San Francisco than between Philadelphia and Cleveland—roughly four times greater according to the Census of Transportation.

A comparison of the TOFC shuttle train revenues and costs at various rate levels is presented in Figure 3. The high elasticity of demand with respect to price is reflected in the sharply dropping revenues curve. As with the Philadelphia-Cleveland city pair, the service does reasonably well on a "minimum" cost

Figure 2. Comparison of annual revenues versus costs for a TOFC shuttle train service between Philadelphia and Cleveland.

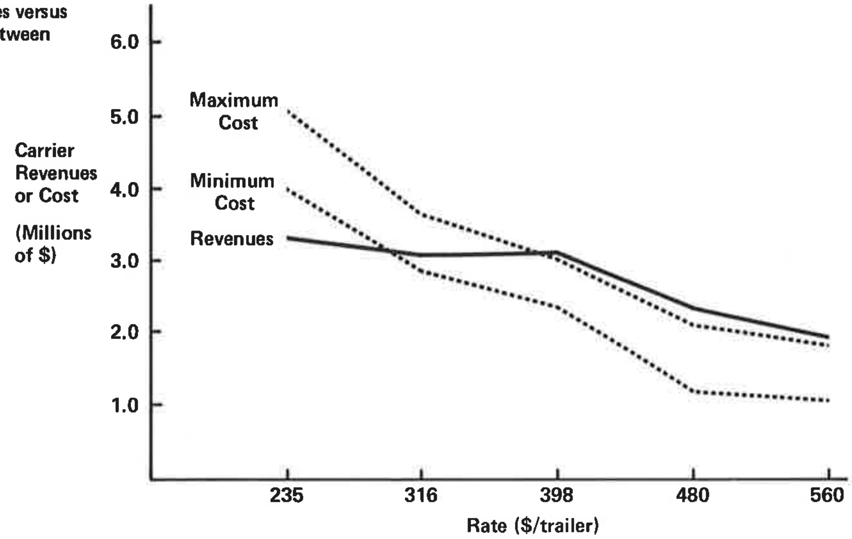


Figure 3. Comparison of annual revenues versus costs for a TOFC shuttle train service between Los Angeles and San Francisco.

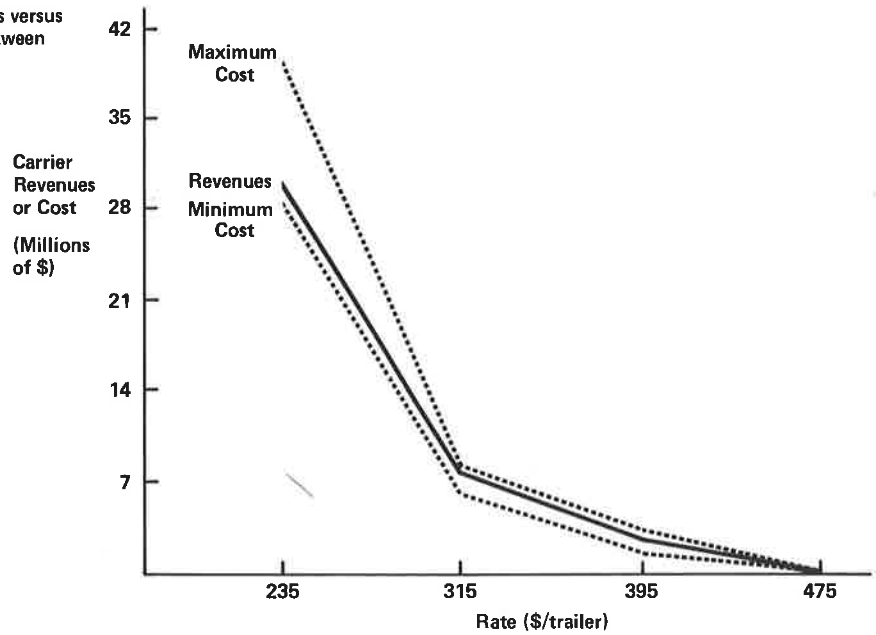
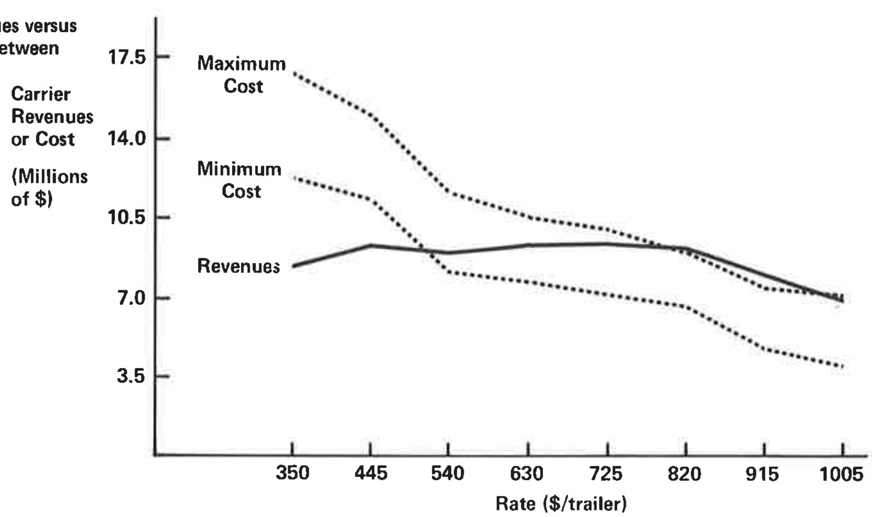


Figure 4. Comparison of annual revenues versus costs for a TOFC shuttle train service between Chicago and Houston.



basis. On a "maximum" cost basis, however, the service is unprofitable at all rate levels.

Chicago-Houston City Pair

The long distance between Chicago and Houston distinguishes this city pair from the other two. Although both rail and truck service tends to be fairly good, a reliable TOFC shuttle train service is believed to offer some improvement in service over both. Despite its long distance, the traffic between this pair of cities is fairly heavy—roughly the same as between Philadelphia and Cleveland. One might speculate that the economies of rail line-haul operation would make a TOFC shuttle train a profitable undertaking between this pair of cities.

Figure 4 presents the comparison of revenues and costs at various rate levels for the Chicago-Houston TOFC shuttle train service. The almost horizontal revenue curve indicates an elasticity of demand near one, although revenues do drop off at higher rates. Like the previous two city pairs, the service does well on a "minimum" cost basis. Profitability is achieved on a "maximum" cost basis only at fairly high rate levels. At a rate of $915/trailer, the service yields a profit of $430 000/year.

Comment

Perhaps the most striking thing about these results is the differences in estimated demands between city pairs and the different responses of these demands to variations in rates. Clearly, the nature of freight transportation markets varies greatly. It is important to have demand forecasting methodologies for production use that take into consideration the characteristics of individual freight transportation markets.

CONCLUSIONS

This study has illustrated the application of equilibrium analysis to a TOFC shuttle train. This same type of analysis could be applied to the pricing of most any freight transportation service, or to other characteristics of the service as well. In fact, the authors have used essentially the same models presented here to compare shuttle trains using several alternative types of container-on-flatcar technology (4).

The results suggested here are somewhat counterintuitive but reasonable considering the service that was assumed. The results suggest that profitability for this TOFC shuttle train will be achieved, if profitability is possible at all, by operating a low-volume, high-rate service. At profitable rates, the Philadelphia-Cleveland and Chicago-Houston services would carry only 13 and 21 trailers a day, respectively. This differs from the more conventional concept of a TOFC shuttle train service, such as the "Slingshot," which emphasizes low rates and high volume. It would be interesting to repeat this analysis assuming a lower cost, but slower, less reliable service. It is possible that such a service might prove more profitable than the premium service hypothesized here.

These models have allowed us to understand the consequences of the multitude of individual firm decisions that will determine the market for a service. As such, they represent a considerable advance over other methods, such as aggregate econometric models, which require gross assumptions about the relationship of transportation demand to the economy of a region. Better industry data, production-type demand models, and the development of techniques to deal with the entire transportation network are imperative before large-scale implementation can begin.

ACKNOWLEDGMENT

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Economics of Improved TOFC/COFC Systems

Robert H. Leilich, Peat, Marwick, Mitchell and Company, Washington, D.C.

The success of future rail intermodal traffic hinges on satisfying demand, meeting new market needs, and realizing railroad profit objectives. To look at these opportunities, the Federal Railroad Administration has sponsored several major ongoing intermodal studies to

evaluate current, proposed, and needed technologies to achieve those ends. This paper summarizes a portion of a preliminary study conducted by Peat, Marwick, Mitchell and Company to examine the economics and markets of current, proposed, and conceptual systems. It analyzes current and proposed systems and how each ranks with respect to one another, common motor carriers, and owner-operators. Study findings are encouraging and suggest opportunities for more cost-effective systems and more market-responsive service capabilities. Contemporary costing procedures plus specially developed life-cycle costing and terminal models were used. Many unit costs were developed on an engineered basis. The Bimodal Roadrailer emerged as a promising new system. The Santa Fe "Ten Pack" and Paton Low-Profile system proved superior as improvements to current trailer-on-flatcar systems. The Southern Pacific Double-Stacked Container Car offers the greatest promise for container-on-flatcar systems.

The growth of trailer-on-flatcar and container-on-flatcar (TOFC/COFC) traffic reflects the ability of railroads to provide highway-competitive service. Next to coal, it is the largest and fastest-growing railroad traffic.

In contrast to coal, most railroads do not regard intermodal traffic as highly profitable. Only western roads, on long hauls of more than 2400-3200 km (1500-2000 miles) claim that intermodal traffic is an important contributor to profits. Although highway competition establishes the upper limit of pricing, it is not always the regulated common carrier that establishes that umbrella.

Under a strongly competitive price umbrella, attributable costs become the principal factor driving profitability. Figure 1 depicts the approximate Rail-Form-A-developed cost structure of TOFC service for each of five major rail cost territories for lengths of haul between 480 and 1600 km (300 and 1000 miles). (Because we will be looking at intermodal alternatives on a comparative basis, Rail Form A is adequate for this purpose even though Rail Form A has some deficiencies.) This exhibit shows the major cost factors, prepared from unit costs developed by the Interstate Commerce Commission. Note, particularly, the major portion of costs that are not distance related.

Costs of rail intermodal service are characterized by high terminal costs—as much as 70 percent of total variable costs at 480 km—and a relatively low-cost unit rate for line haul. The opposite is true for motor carriers. Figure 2 compares rail intermodal costs to the cost structure of common carriers and the owner-operator or private fleet operator. In the latter case, most owner-operators perceive their terminal costs as nearly zero; as a consequence, they tend to price their services accordingly. The wide range of motor carrier costs is influenced by wide variations in labor cost, vehicle use, and operating efficiency. Figure 2 stresses the high crossover point between rail intermodal costs and highway costs. Most alarming is that the efficient owner-operator is competitive with rail intermodal at almost all lengths of haul.

The greatest need in rail intermodal services is to reduce costs, preferably in both terminals and in line haul. Reducing terminal costs reduces the break-even distance compared to highway. Reducing line-haul costs does the same thing but also increases the advantage of railroads with distance. Emphasis on one or the other is influenced by the market in which a carrier competes. Western railroads by virtue of their long line haul should logically concentrate on reducing line-haul costs. Eastern railroads, limited to a shorter-haul market, should investigate better ways to reduce terminal costs. Of course, achieving both is most desirable.

The Federal Railroad Administration (FRA), with the support of the Association of American Railroads and others, has embarked on a series of research efforts to improve the profitability and, hence, marketability of rail intermodal service. One of these research efforts was devoted to examining the economics of current, proposed, and conceptual systems.

The average length of haul for all intermodal traffic in 1976 was estimated at 1798 km/t (1013 miles/ton) from the FRA One Percent Waybill sample. A significant contributor to this high average length of haul is the large volume of traffic moving in the more than 3200-km (2000-mile) block. Excluding the high concentration of intermodal traffic in this category, the average length of haul was 1404 km/t (791 miles/ton).

ECONOMIC ISSUES IN SYSTEMS EVALUATION

The evaluation of alternative systems to reduce intermodal costs should focus on equipment use, equipment value, cost of capital, terminal and origin-destination costs, and line-haul costs.

Equipment Utilization

Freight car trailer/container and other intermodal freight system component use has a major impact on transportation costs in that many of the equipment-related costs are relatively fixed in the short term (though all rolling stock and nonfixed equipment costs are considered to be variable in the long run) and must be distributed over the number of revenue shipments that each equipment component handles. In cost evaluations it is not always appropriate to use historical data in distributing or assigning equipment costs to particular traffic, especially in improved technological, operational, and institutional environments.

Equipment Value

Equipment ownership costs make up a sizable portion of rail transportation costs. Critical to evaluation of intermodal freight systems is the proper recognition of the value (current or replacement) of the equipment being used.

Cost of Capital

Cost of capital is a well-recognized economic cost. In capital-intensive systems with long economic life and slow capital recovery (7 years and more), the cost of capital is a major factor in evaluating system alternatives. This cost should include costs of both debt and equity capital.

Terminal and Origin-Destination Costs

Rail Form A and most other costing methods separately recognize the following: specific major intermodal cost elements origin-destination switching, tie-untie (loading and unloading) costs, pickup and delivery, interchange switching, intermediate switching, station clerical, special services, and highway interchange.

Line-Haul Costs

Similarly, Rail Form A and most other costing methods provide for separate calculation or recognition of these line-haul costs and influencing factors: train tonnage (way and through train), number of locomotive units (way and through train), empty return ratio (flatcars), tare weight (flatcars and trailers), empty trailer dis-

Figure 1. TOFC/COFC variable origin-destination and line-haul expenses for selected territories at January 1978 cost levels (developed from Rail Form A).

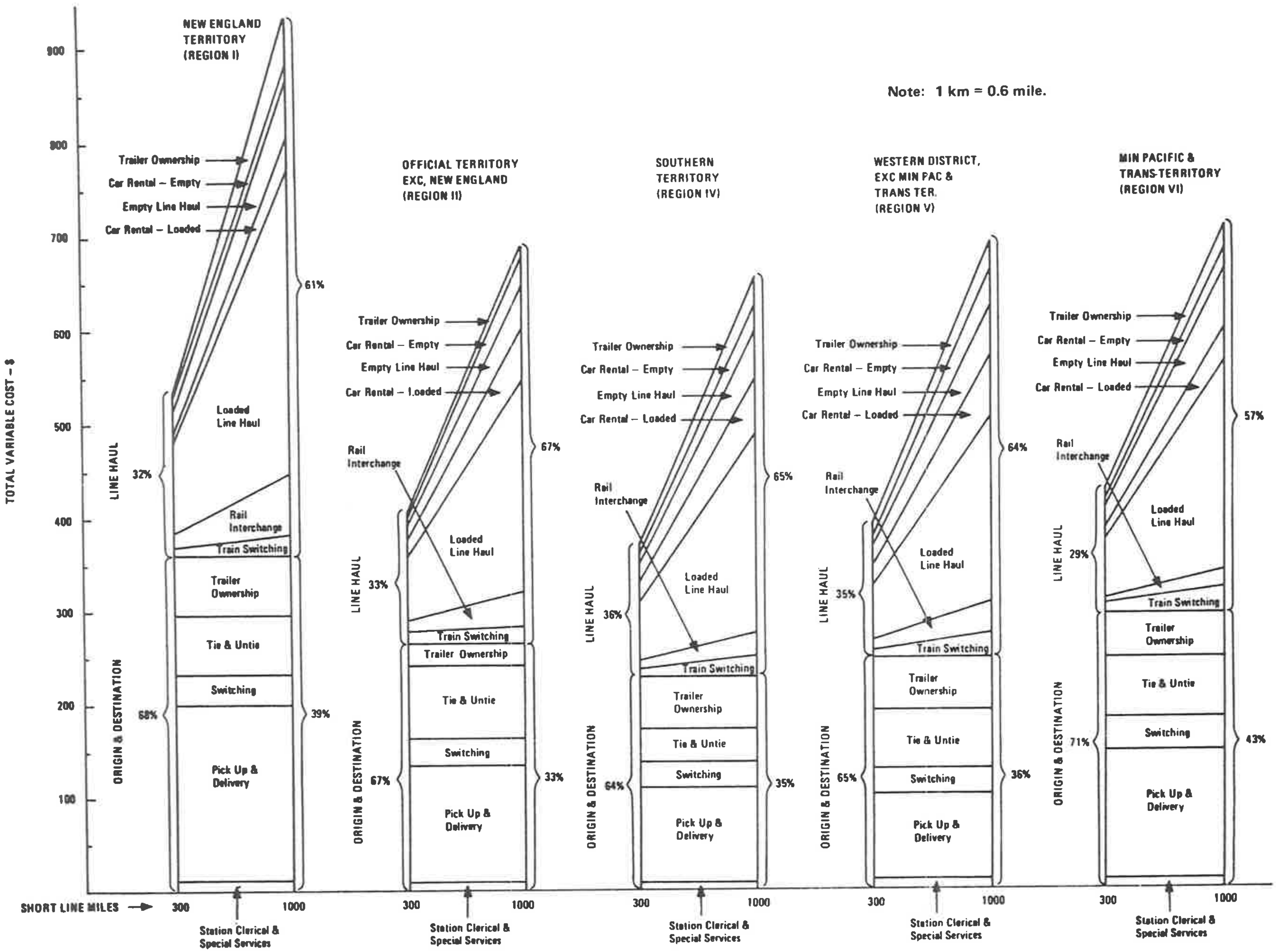
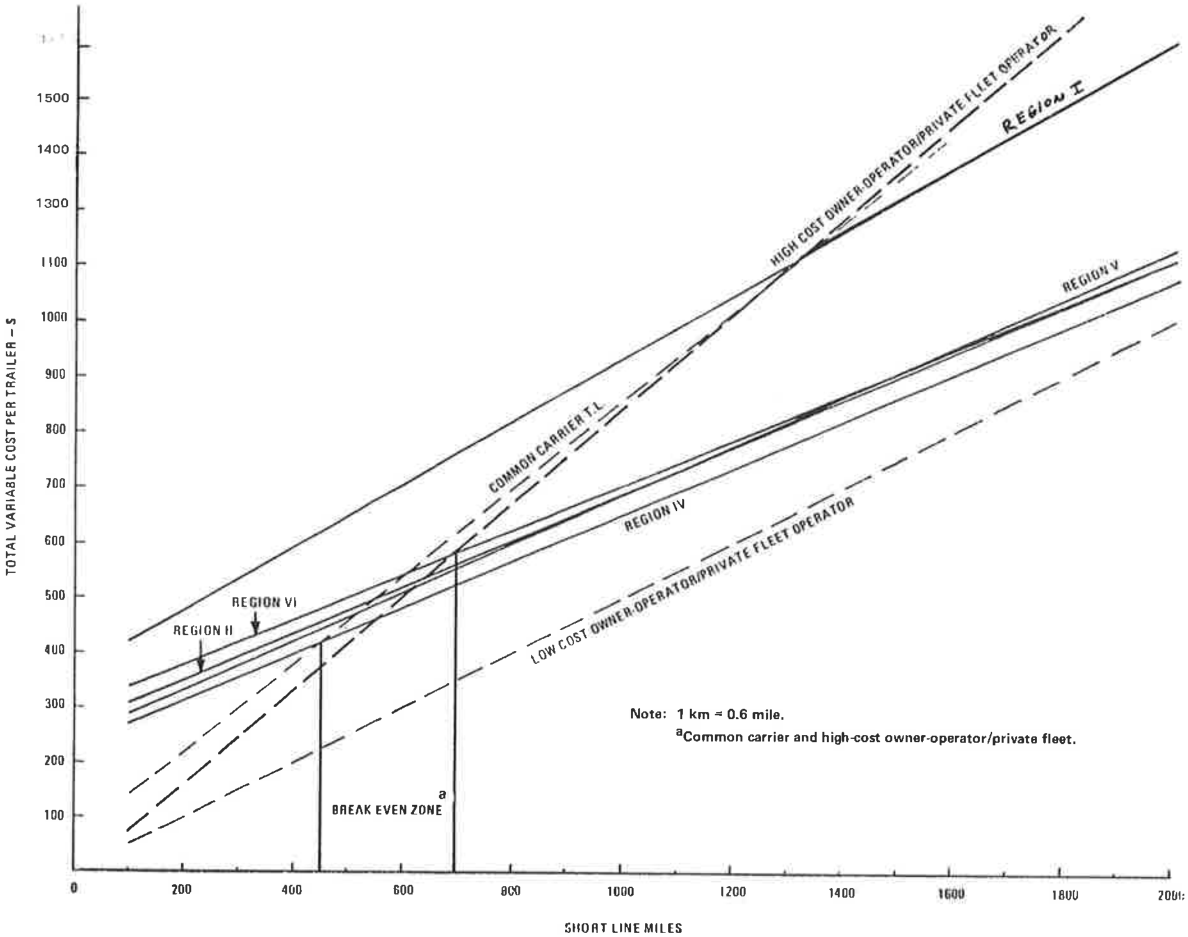


Figure 2. Comparison of rail intermodal costs to the cost structure between common carriers and owner-operators/private fleet operators for a single trailer shipment at January 1978 cost levels.



tance ratio, number of trailers per flatcar, and distance circuity. Each of the costs described here was considered in evaluating improved or potential intermodal systems alternatives.

SELECTED INTERMODAL ALTERNATIVES

Although this study evaluated hundreds of intermodal system concepts and combinations of intermodal system components (such components as lifting cranes, hostlers, and flatcars), the following basic system alternative concepts appeared to be the most promising:

1. Bimodal Corporation Roadrailers—highway trailer equipped with one pair of steel-flanged wheels and couplers for assembly into a "train";
2. Santa Fe "Six Pack"—articulated flatcar that carries one trailer on each articulated section (proposed to be built as a "Ten Pack" when in production);
3. Southern Pacific Lightweight Articulated Equipment—handles containers or trailers [a second concept is an articulated double-stacked container car holding a total of six containers; a third concept is a two-section dual-purpose articulated car that would carry two 12.1- or 13.6-m (40- or 45-ft) trailers or three 12.1-m (40-ft) containers];
4. Trailer Train Prototype TOFC Car—two-unit semipermanently coupled flatcar, four single axles per two-unit car, with each unit holding one trailer up to 13.6 m long;
5. Paton Low-Profile Rail Car—low-profile, lightweight, three-unit articulated rail car to transport conventional trailers and/or containers; and
6. Shannon Side Drive-On—flatcar with swinging "trays" on which to park or remove a trailer.

SYSTEM EVALUATION

Each of the systems was evaluated in 12 basic environments that attempted to characterize short- and long-haul situations under widely different traffic volume levels. The purpose of selecting these environments was to provide a baseline set of conditions against which promising improved and innovative systems would be evaluated.

A life-cycle cost model was constructed to calculate transfer cost (tie/untie) per trailer or container that would result for each combination of environment, terminal concept, and car/trailer/container concept; the rail car "rental" cost per kilometer; and the trailer/container per-diem cost. Calculations are performed on an after-tax basis and account for the following:

1. Cash flows associated with initial capital outlays and the annual servicing of that portion of initial capital outlay financed by borrowing,
2. Investment tax credit,
3. Corporate income tax shield provided by depreci-

ation charges over the accounting life of the investment,

4. Corporate income tax shield provided by interest payments on the portion of the capital investment financed by debt,

5. Cash flow associated with salvage of the capital investment at the end of its economic life, and

6. Operating and maintenance cost per trailer or container (which is added to the equivalent investment cost per trailer or container to determine total transfer cost per trailer or container).

A terminal cost model was constructed that incorporated land, operating, and maintenance costs associated with different systems in each of the proposed environments. Principal categories of TOFC/COFC terminal labor were separately recognized. A separate cost calculator was used to develop line-haul costs.

Noneconomic criteria were included in the systems analysis of each alternative, using a weighting and ranking procedure that converted economic and noneconomic factors into a score. Each factor had a maximum score of 10. Factors were then weighted in proportion to relative importance to each other so that the maximum perfect score was also 10.

EVALUATION RESULTS

Most systems retained their ranking at both long and short hauls with several exceptions.

The Shannon system suffers a line-haul weight and maintenance cost penalty at long distances. The double-stack container car, the best of all container systems studied, gained in economic ranking over longer hauls due chiefly to lower tare ratios and shorter train lengths for a given number of shipments. (This is a distinct plus on high-density lines where train lengths must be limited.)

Surprisingly, trailer systems are generally less costly than container systems. The extra tare and transportation cost of line haul is not enough to offset the generally higher terminal costs (usually double the costs of handling of container car to storage of the chassis and vice versa) and the cost of equipment support needs (chassis).

Five systems that were recommended for further FRA analysis are discussed here.

Bimodal Roadrailer

The Bimodal Roadrailer ranked at or near the top with respect to almost any evaluation criteria except line-capacity considerations. Although potentially the most attractive of all systems analyzed, there is some uncertainty associated with this concept that only can be resolved through field and in-service testing. Field and in-service road tests for this equipment are currently in progess at the U.S. Department of Transportation's Pueblo (Colorado) Test Track. The results of all tests have met or exceeded expectations. The advantages of the Bimodal Roadrailer are as follows:

1. A cost per shipment saving of up to 20 percent compared to conventional TOFC service is possible.
2. The concept required substantially less investment in motive power and no investment in flatcars, at the price of a reportedly nominal increased investment in trailers.
3. The Roadrailer does not require mechanized lifting techniques, ramps, or even special intermodal terminals.
4. Operation with a two-person crew and with no caboose is feasible.
5. The Roadrailer concept has the best clearance characteristic of any concept reviewed.
6. The Bimodal Corporation claims that the lack of operational compatibility is an asset in that running the Roadrailer in designated trains may result in improved service and help control loss and damage due to reduced switching and train handling.

The Roadrailer has the following disadvantages relative to other concepts:

1. Analysis shows that the cost of ownership is still relatively high compared to other system alternatives.
2. The Roadrailer is limited to shorter train lengths, with higher line-haul costs per trailer kilometer offsetting some of the line-haul savings associated with no flatcars and a 50 percent reduction in the number of axles and wheels per trailer.
3. There are potential operating problems by railroads that have severe line-capacity problems.
4. There is some inherent railroad industry resistance to such a major concept change in operations and practices.

There are a number of minor constraints associated with the implementation of the Roadrailer, but none of them appear to be a major inhibiting factor sufficient to preclude the introduction of this service, should its technical feasibility be proven in an actual operating environment.

Santa Fe Ten Pack

Based primarily on characteristics of economically lower cost per shipment compared to other systems (except Roadrailer), the Santa Fe Ten Pack is the most attractive concept for trailer-only traffic in high-traffic-volume corridors. The primary advantages of the Santa Fe Ten Pack are

1. The saving per shipment for the Ten Pack is second only to the Roadrailer, offering potential cost savings of 15 percent over the baseline case at long line-haul distances;
2. The net-to-tare ratio and aerodynamic drag characteristics of the Ten Pack make it an attractive rail vehicle to use in rail line-haul service;
3. Articulation (as claimed by the Santa Fe) offers improvements in reducing loss and damage (due to the use of fewer cars) and in improved truck riding qualities (the Santa Fe reports no truck "hunting"); and
4. In 216 000 km (135 000 miles) of testing (as of January 1978), the Santa Fe reported that no significant structural or operational problems have occurred, thus suggesting the possibility of greater equipment reliability and lower maintenance and operating costs.

Disadvantages include the following:

1. The requirements for loading 10 trailers per car between origin and destination make it unattractive for use in environments where the volume of traffic is relatively small.
2. The Ten Pack requires lift-on/lift-off terminal capabilities.
3. Failure of one component of the car may cause the entire car, with 10 trailers, to be bad-ordered and set out, or require extra time from special facilities to remove or replace the bad-ordered section.
4. The Ten Pack car does not have the capacity to

carry containers except in a container-on-chassis configuration.

The only constraint noted is the logistics needed to support the use of this technology, at least until the use of such equipment is common (although a number of components are standard railroad hardware).

Southern Pacific Double-Stacked Container Car

The Southern Pacific Double-Stacked Container Car was tested for COFC-only traffic. The primary advantages of the double-stacked car are

1. The concept offered the best cost per ton (or shipment) of any container alternative examined;
2. The double-stacked car has the best net-to-tare ratio in line haul of any container concept tested (though the proposed Bimodal concept of container-on-Roadrailer chassis may be superior); and
3. The car has a higher "freight volume capacity rate" (net ton of freight per meter of train length) than any other system, increasing the number of units that can be handled for a given train length (this can greatly increase train capacity where train length is limited by siding length or signal spacing).

The disadvantages of a double-stacked container are

1. Mechanized lift capacity is required at both ends of the movement;
2. Although preliminary testing has proven the concept to be safe, under certain circumstances the car may have a very high center of gravity and reduced safety margins under adverse conditions; and
3. The clearance requirements are a major problem for operation of the double-stacked container in a number of major rail corridors, particularly in the Northeast (up to 9 percent of the track in major intermodal corridors would be unavailable to the double-stacked container concept).

If the ultimate articulated form of the double-stacked container car is built and operated, in addition to the constraints noted here, the car would be limited to relatively high-traffic-volume corridors in order to minimize unused car capacity.

An institutional constraint that may inhibit the use of a double-stacked container car is the persistent imbalance of container traffic in some corridors, which greatly increases the net cost per shipment moved.

Paton Low-Profile Rail Car System

The Paton Low-Profile Rail Car is the most attractive concept evaluated with a capability to carry either trailers or containers (though Bimodal is developing a Roadrailer chassis for containers). The Paton concept has the best clearance characteristic of any TOFC concept tested except Roadrailer, and it has the potential for operating in the Northeast corridor under catenary (though some third-rail clearance problems may exist). A significant technological innovation included in the Paton concept is the car truck that its inventor claims offers significant advantages over contemporary truck systems, including separability. The advantages of the Paton low-profile car include the following:

1. The Paton car has dual (trailer or container) capability.
2. The car is believed to have virtually unrestricted application over the entire railroad network.
3. The Paton truck may offer some improved benefits over conventional trucks, including separability at the articulation points for setouts.

Disadvantages of the Paton car include the following:

1. The concept is not as far advanced as the previous three concepts, and prototype construction and testing are needed.
2. The Paton concept requires mechanized lifts at both ends of the movement and, therefore, does not offer the flexibility to serve shippers at ramp terminals.
3. Insufficient data are available to truly assess the economics, maintainability, and operational performance of the Paton concept.

Other than competition with Trailer Train (see below), there are no other major constraints not applicable to other concepts discussed above that would inhibit the development and use of this concept.

Trailer Train Two-Unit, Prototype TOFC System

The Trailer Train two-unit, semipermanently coupled prototype TOFC car ranks very close to the Paton Low-Profile Car for TOFC service. As with the Paton concept, considerable technological risks exist, particularly those associated with a four-wheel concept.

The advantages of Trailer Train's proposed car are

1. The net-to-tare ratio is significantly improved.
2. The smaller-sized car (less trailers) results in less penalty than other articulated concepts when the equipment is removed from service.

The major disadvantages of the Trailer Train concept include the following:

1. Mechanized lift is required at both origin and destination.
2. The design is too conceptual at this time to adequately assess the economic merits of the system.
3. The potential four-wheel concept with axle centers of 10.9 m (36 ft) or more may create tracking problems on sharp curves (though Trailer Train may be able to solve this problem with an axle steering mechanism).
4. There is significant industry concern relative to the wheel size and track dynamics.
5. The concept offers little in the way of improved aerodynamic streamlining and significant reductions in overhead clearance.

If technically and economically practical, there are no major constraints that would otherwise restrict the use of this concept in specific intermodal system environments.

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Improving Intermodal Service Through Organizational Innovation

Alan J. Stenger, College of Business Administration, Pennsylvania State University, University Park

A great deal of coordination within and between firms is necessary in order to complete a timely intermodal transportation movement. Recent developments in the theory and practice of management offer innovations designed to achieve just such intergroup coordination. This paper describes the type of relationships that exist and are needed in offering intermodal services. Further, the report explores how various managerial initiatives may be applied. Among these are hierarchy (use of common superior), plans and information systems, linking roles, task forces, integrating units, and matrix organizations. This study concludes that top management commitment is imperative, planning is essential, and the other devices facilitate the development of a controlled planning approach.

"The ability to produce a reliable transportation product is now recognized more widely than ever before as a critical element in the service package that must be sold in a competitive environment" (1, p. 1). Although this statement was made with regard to rail transportation, it is equally applicable to intermodal transport. Yet the preponderance of evidence seems to be that very few common carrier transportation firms are able to offer a carefully controlled service package (2). This paper maintains that the reasons for this are managerially oriented, not hardware oriented, and that the managerial problems that arise in intermodal operations are not much different from those found in other sectors of the business world.

The managerial impediments to offering improved service at a reasonable cost generally relate to conflicts in lateral relationships, i.e., conflicts between all the parties involved in an intermodal movement. The conflicts occur at several levels. An intermodal movement generally implies the involvement of two or more firms and two or more modes. Thus, there are interfirm conflicts between modes and, often, conflicts within modes. Within each firm there are often conflicts between marketing and operations. Improvements in service that benefit marketing often raise some operating costs. Finally, within marketing and within operations there may be conflicts. For example, intermodal services may not be the carrier's main business. Thus, there are disagreements as to what priority intermodal marketing efforts and intermodal operations should receive.

Lateral conflicts such as these are not new to managers of business firms in general nor to managers of carriers in particular. They are, perhaps, more difficult to resolve in intermodal circumstances because of the involvement of different firms and different modes. However, the many techniques developed by management theorists for resolving and mitigating lateral conflicts are applicable to intermodal operations as well as other types of business. This paper explores these techniques and their applicability to the improvement of intermodal freight service performance. However, only those intermodal movements that involve a highway movement at beginning or end will be considered.

NATURE OF INTERMODAL OPERATIONS

Factors Affecting Lateral Relations in Intermodal Operations

Management theorists indicate that there are three major determining factors that "are likely to influence the extensiveness and sophistication of formal mechanisms or devices in managing intergroup relations" (3, p. 219). These are the degree of differentiation between the groups, the degree to which the groups must be integrated to achieve the desired overall goals, and the level of uncertainty facing the groups in their interactions. The choice of the mechanisms to use in a given situation will depend on the levels of these factors. These mechanisms are discussed in the next section of this paper. The following briefly reviews the factors and then examines the intergroup relationships found in intermodal operations.

Intergroup differentiation refers to differences between organizational units with regard to management level (top management, middle management, and so on), orientation to time (short run versus long run), orientation toward other members in the group (permissive versus authoritarian), and orientation toward the environment (how the groups view outside factors and influences) (4).

Integration refers to the degree to which the different groups are required to coordinate their efforts in order to achieve the overall goals. The successful completion of a long-distance transportation movement obviously requires a good deal of coordination between groups within a firm and often between firms. However, it is possible to over-coordinate the effort to the point where the costs of integration go far beyond any possible benefits.

The uncertainty factor refers to the groups' perceptions of their external environments (3, pp. 62-66). Groups will differ as to the number of factors they must consider in making a decision (the complexity of the environment). Groups will also differ in terms of the speed with which individual factor values are changing and the frequency with which new and different factors become important.

Relations Between Intermodal Operating Groups

Any transportation movement usually goes through a series of terminal-line-haul operations. The terminal operations are often controlled independently; the connecting link—the line haul—may be controlled by the initiating (or dispatch) terminal or by a centralized dispatch operation.

There is not too much differentiation between terminals within a given mode. They are all generally on the same management level, although smaller terminals are sometimes considered to be satellites of the larger ones. Terminal operations are usually short term in orientation, for the big problem is how to get today's operations completed today. Terminal managers often opt for the authoritarian approach to management because of the constant pressure.

There can be important differences between modes in the way terminal managers view their environment and in the way they manage their operations. In this report the important differences will relate to the orientations of the respective mode's terminal managers toward intermodal service versus other orientations, such as the minimum cost operation of the terminal or the maximization of service for unimodal traffic.

Integration between terminals and between terminals and line-haul operations is important. Each terminal affects adjoining terminals through the initiation of line-haul operations destined for those terminals. Line-haul operations begun for the benefit of the originating terminals can severely overload receiving terminals for short periods of time. Therefore, some planning of line-haul operations is necessary to smooth the work load at the terminals.

The major uncertainty facing terminal and line-haul operations is the question of what traffic will actually materialize from day to day. Traffic flows can vary substantially from day to day and week to week. If too few crews are available, traffic is delayed. If too many are available, labor costs can easily become excessive. The other complicating factor is that the complexity of terminal operations seems to increase exponentially as the number of transactions (operations) processed by the terminal increases (5, p. 27).

Relations Between Marketing Groups

The rail mode may be the only mode that has important differences between marketing groups. Highway carriers probably do little marketing of intermodal services, and the air and containership operators depend almost totally on intermodal traffic. The railroads face the problem that their customers may use both intermodal and carload services, yet the two types of service often compete with each other. (There is some justification for having two separate sales forces to maximize the penetration of both types of service because they are different. However, there is also reason to combine the two in order to minimize sales personnel and spare the customer multiple sales calls.) For the railroads, then, there is a need to integrate market planning for both carload and intermodal services because they serve many of the same customers and use many of the same terminal and line-haul facilities.

Between modes, the mode with the major portion of the haul usually performs the marketing and sales functions. Their concerns about integration and differentiation, although extremely important in operations, are not nearly as important in marketing.

The most important uncertainty facing marketing is the question of what will be the future demand for the various types of services that might be offered. This uncertainty is faced by marketing and business people in all fields, but because transportation demand is a derived demand and there are only a limited number of possible services and competitors, transportation faces no unique challenges here.

Relations Between Marketing and Operating Groups

The differences between marketing and operations are substantial, both within the given modes and between them. An article in the Harvard Business Review (6) explores the differences between marketing and operations in manufacturing firms, asking the question, "Can marketing and manufacturing coexist?" Changing "manufacturing" to "operations" makes this question equally relevant for carriers. For the purposes of this paper, it is sufficient to say that the differences range from cultural to technical and that the two groups generally have completely different outlooks.

Nonetheless, marketing and operations must achieve an important degree of integration if intermodal operations are to be successful. Ideally, marketing should identify the needs of potential customers and then work with operations to design a price and service package that will profitably meet these needs. Among carriers, however, it is often the reverse: Operations determines what services will be offered and marketing is charged with finding customers to utilize those services (5, pp. 46-48).

The uncertainties facing marketing and operations exacerbate their differences. Too often, marketing forecasts of traffic are not accurate; this makes operations planning difficult. Lacking good forecasts, operations resorts to its own new schedules and equipment plans that may or may not meet the needs of the marketplace. Marketing, uncertain about what types of service will be offered in terms of on-time delivery and speed of delivery, promises more than can be delivered or fails to sell what could be very good performance.

Conclusions

Of all the lateral relations described here, marketing and operational relations are probably the most difficult to resolve within the individual firm; they are also most important to resolve in order to maximize the health of the business. Between firms in intermodal operations the need is to bring together operating groups to ensure that the services sold are actually delivered.

MECHANISMS FOR MANAGING LATERAL RELATIONS

There are a variety of formal mechanisms that might be utilized by carriers to improve the management of lateral relations. These include hierarchy (use of common superior), plans and information systems, linking roles, task forces, integrating units, and the matrix organization (3, pp. 221-231). Generally these mechanisms can be viewed as existing on a continuum in the order given above with hierarchy at the low end and the matrix organization at the high end. As the degrees of uncertainty, differentiation, and desired integration increase, more of the mechanisms on the spectrum will be used in concert. This section of the paper will discuss the mechanisms and their applicability to the management of intermodal freight services.

Hierarchy

The hierarchical organization is the most common method of integrating groups. The groups to be coordinated are placed under a common superior who will sense and resolve differences between the various units. The different modes vary in their use of this mechanism for coordinating marketing and operations. For example, most railroads have only the president as the common superior for marketing and operations. At the other extreme, many large less-than-truckload motor carriers place the terminal manager in charge of both functions. Air and water carriers vary between these extremes with air closer to the trucking approach and water closer to the railroad approach.

The problem with forcing the hierarchy down to lower levels is that a substantial degree of suboptimization may occur in operating the transportation system. On the other hand, integration only at a high level removes the incentive for lower-level coordination and often creates a very rule-oriented bureaucracy.

Between firms, hierarchy takes the form of horizontal integration; i.e., naturally following the hierarchical approach, common ownership of the modes of transportation would be the result. Because this approach is severely circumscribed in this country, it will not be considered here. It should be noted, however, that firms such as Canadian Pacific and some U.S. railroads that own other modes essentially operate the modes separately.

Hierarchy, then, is probably not sufficient to achieve the needed level of integration in intermodal operations.

Plans and Information Systems

Plans and information systems have a great deal of potential for integrating and coordinating intermodal operations. Carriers traditionally have been strong in information systems but less effective in planning. Both marketing and operations need to improve their planning and the integration of those plans. One approach to operations planning is described here.

In the long run, of course, the company must decide what kind of services it will offer. Presuming that intermodal transportation is a desirable business, then both marketing and operations must make their intermediate range plans (six months to two years). In the case of marketing, this involves identifying what types of traffic are most amenable to the ranges of service and price the firm can offer and the origins and destinations of such traffic. When there are natural traffic imbalances, pricing differentials may be necessary to minimize empty movements of equipment.

The mid-term plans of operations relate to achieving the most effective use of available fixed facilities. This requires routing decisions (through what terminals should a shipment from A to B pass) and capacity decisions (how intensively should the various facilities be operated) and inventory policy decisions (when and where should excess capacity exist). Capacity decisions determine how many line-haul operations to run and when to run them, as well as how many terminal crews to operate at various times. Inventory decisions refer primarily to planning numbers and the locations of empty vehicles to be held awaiting anticipated orders. Routing, capacity, and inventory decisions are all interrelated and depend on the forecasted traffic levels determined by marketing.

In the shorter run (up to six months) marketing needs to take two very important steps. The first is to identify potential short-term traffic imbalances and allocate field selling efforts to ensure that balanced operations are achieved. The second step is to assign priorities to traffic that is moving in order to help operations manage inevitable bottlenecks without damaging important commercial relations.

Over this same planning horizon, operations must make short-term capacity, routing, and inventory policy adjustments to most effectively handle the traffic that is materializing. The various modes have differing degrees of flexibility here, particularly with regard to line-haul operations, but crews and equipment can often be added or subtracted in the short run.

The execution of the plan requires all the day-to-day adjustments necessary to handle traffic actually tendered. As traffic is received, the movement plans between the particular origin and destinations are consulted. Based on the route, the schedule of operations along that route (set in the planning process), and the availability of uncommitted capacity in those operations, it should be possible to lay out a detailed schedule of any movement as soon as it is received for handling. If there are conflicts between the scheduled arrival time at the destination and the customer's desired arrival time, these may be resolved in several ways. It may be possible to add crews or equipment at certain points where a bottleneck exists. Another alternative is to delay some lower-priority traffic (as determined by marketing) in order to make capacity available to handle the shipment in question. Or marketing may have to face the problem and indicate to the customer that the late schedule is the best that can be provided under the circumstances.

Clearly there will be times when actual capacity differs from that planned because of breakdowns or other reasons. In those cases, the affected shipments will have to be rescheduled and all those involved, including the customer, will need to be informed.

The final aspect of managing the network concerns comparing the conformity of actual performance with the plan. Often this aspect is not emphasized due to the pressures of day-to-day business or the lack of a realistic plan to begin with. But it is extremely necessary and important. Performance involves both costs and service. The plan has for the most part dictated what the costs should be because it has established resources (schedules and capacities) for each operation. Given this, the more important question becomes, "Was the scheduled work assigned to each operation performed on time within the resource constraints?" If not, management must identify why and seek to remedy the situation. The question of on-time performance of individual operations, of course, is the major determinant of the service level offered.

The planning approach described herein is not beyond the realm of possibility for intermodal transportation. Such a system is currently being developed by the Missouri Pacific Railroad for use in managing its system (7). By implication, such an approach is also used by some large motor carriers (8). This basic approach is also used to manage large-scale manufacturing job shops that are conceptually similar to the production of transportation services (9).

This type of planning goes a long way toward reducing the uncertainty faced by the various operating groups and integrating their tasks. For example, once a shipment is received and scheduled, then all downstream operations can count on its arrival if operations adheres to that schedule.

Developing the plans probably cannot be achieved without the use of some of the integrating devices higher on the spectrum, however.

Linking Roles

In view of the need for close cooperation between marketing and operations in implementing the planning approach described in this paper, it may be necessary to establish several "linking roles." This is "a specialized position in which the individual attempts to facilitate communications and problem-solving between two or more interdependent units" (3, p. 225). Such a role is described in greater detail in Lawrence and Lorsch (10).

The linking role might be very useful in fostering interfirm communication and coordination. One individual from the firm with the major portion of the haul might be placed in offices of each of the connecting carriers in order to raise the consciousness of the connector with regard to service objectives and future plans. In addition, this representative would monitor service performance by that carrier. The connecting carrier might also place its representative in the offices of the line-haul firm to facilitate communication.

Another use for the linking role might be within the individual firm. For example, it might be useful for marketing to be represented at major terminals by individual integrators. Similarly, operations may find it advantageous to have a representative in each of the major sales offices in order to inform the sales personnel of current operating conditions and service levels.

The linking role is useful. However, it will probably not bring about sufficient integration on its own to ensure that the overall planning approach described here is implemented.

Task Forces

Task forces are generally temporary in nature. Consisting of one or more representatives from each of the affected firms and departments, they usually serve until the problem in question is solved. Because planning procedures are ongoing, task forces will not be too useful. However, there are at least two occasions where they facilitate matters.

An interfirm task force might be formed to draw everyone into the initial planning attempt. This would encourage all partners in the service to participate in the process. Later, the formal planning could be done primarily by the major carrier.

Another possible use for a task force might be when a particularly difficult operations or marketing problem arises. For example, a major change in operating procedures might require the reconvening of the original task force. A problem with service to a major customer might also call for the task force approach. Generally, however, something more permanent than a task force will be required to maintain coordination.

Integrating Units

If the members of a task force are formally and permanently assigned to the task of facilitating integration between two or more firms or departments, the task force becomes an "integrating unit." Generally this group will have its own manager.

Integrating units are not new to rail transportation. Several rail firms have intermodal departments. Usually part of the marketing department, these groups have responsibility for planning and selling intermodal services. Although they work closely with operations, few of these groups have operations personnel assigned as formal members. The Consolidated Rail Corporation recently has gone a step further by assigning such groups for other equipment types as well as intermodal equipment. A different approach has been to assign the groups on the basis of commodities rather than equipment and service. Thus, several rail firms and some trucking firms have "market managers."

Integrating units can also exist between firms. For example, in the 1890s, such organizations as Trade Dispatch and Merchants Dispatch Transportation Company were formed to ensure that high-priority freight was moved expeditiously (11, pp. 287-288). Each had a general manager with marketing agents to get business and employees judiciously located to watch movement. The general manager "keeps a close record of his business, and reports promptly to the transportation office of any road on his line any neglect or delinquency he may discover" (11, p. 288).

The problem with integrating units is that they have no real power except the power of their expertise. If the involved units recognize their need for the integrating units, the power of expertise can be considerable. The problem with many of the rail efforts described herein is that they were accepted by marketing but much less frequently by operations. Further, as Wyckoff points out, top management has often been lukewarm toward such efforts (5, p. 16). Such units probably should be independent of both marketing and operations (though with representatives from each); these units can prepare the plans and then use the services of each to implement them.

Matrix Organizations

The matrix organization takes the integrating unit approach to its logical conclusion by establishing true "dual authority, information, and reporting relationships and systems" (3, p. 299). The intermodal organization on a railroad would become separate from operations and marketing but would be made up of operating and marketing personnel who would formally report to both their respective functional departments and to the intermodal organization. The leader of the intermodal department would be equal in stature, if not in pay, to the operations and marketing vice presidents. This concept could also be used between firms, with the intermodal organization becoming a jointly owned subsidiary of the involved firms.

Naturally there are many problems to be overcome in moving to a matrix organization, not the least of which is the availability of the proper type of personnel to make it work. These problems and their possible solutions are discussed thoroughly in Davis and Lawrence (12).

CONCLUSION

There are clearly a variety of managerial mechanisms available to help improve the quality of intermodal transportation services. Whichever mechanisms are chosen will depend on the nature of the problem, the sophistication of the firms involved and their current organizations and personnel, the complexity and uncertainty existing in the external environment, and so forth. It is clear that at least three basic conditions must be met if intermodal services are to flourish:

1. Top management must be committed to achieving the required degree of integration both between the firms and within the firms.
2. A comprehensive, operational planning system such as that described in this paper must be established.
3. A performance-monitoring system must exist to ensure that service objectives, not just cost objectives, are met.

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Regulation of Discrimination in Railway Freight Transport

John C. Spychalski, College of Business Administration, Pennsylvania State University, University Park

Controls over discrimination in railway rates and services are scrutinized in terms of (a) problems stemming from their existing application and (b) their relationships with recent proposals to change economic regulation and carriers' practices in the pricing and contract carriage areas. Although originally identified with the achievement of equity and economic efficiency, such controls now appear to contravene those objectives in situations involving competition between railways and unregulated water and motor carriers. Legislative and administrative efforts to reduce rate regulation and carrier antitrust immunity and place greater reliance on market forces must not be undertaken without giving adequate attention to interrelationships between such changes and provisions for the regulation of discrimination. Proposals to transfer control over transport discrimination to the jurisdiction of other price discrimination laws and other agencies (e.g., the Federal Trade Commission) could produce problems no less onerous than those ascribed to existing statutory and institutional arrangements. This paper examines the basic meaning of discrimination and the reasons for its control.

The control of discrimination in rates and service has long been a key element in the economic regulation of railways at both the state and federal levels. Indeed, public resentment against rail carriers' discrimination among individual shippers, geographic locations, and types of commodities was a leading cause of the enactment of commission-administered railway regulatory statutes during the last quarter of the nineteenth century. Provisions proscribing the practice of certain types or degrees of discrimination were accorded prominent positions in such statutes. Similar, although not identical, statutory language was included in subsequent twentieth-century extensions of economic regulation to motor, water, and air freight carriage (1, 2). A summary of existing federal legislative provisions pertaining to rail freight transport discrimination is presented in Table 1.

Enforcement of these provisions is one of the basic purposes of freight rate regulation. Hence, their need, content, and application are inextricably bound up with the intense debate and pressure for change currently weighing against both rate control and other leading elements of the economic regulation of transport. Yet, despite this relationship, commentators on all sides of the contemporary controversy over regulation have given little attention to either (a) problems stemming from the present structure and administration of statutory controls over transport discrimination per se or (b) alternative courses of action (and implications thereof) that might be taken toward the future form and role, if any, of such controls. This paper scrutinizes conditions and questions concerning these two focal points.

NATURE OF DISCRIMINATION

Ambiguity and total unfamiliarity with the basic meaning and causes of discrimination and the reasons for its control by government are widespread, even among individuals directly concerned with transport. Price or rate discrimination, as viewed in an economic sense, occurs when a carrier charges different rates for the movement of different categories of traffic in instances where the differences in rates are not proportional to the differences in costs, if any, of accommodating each category of traffic. Discrimination in an economic sense also occurs when identical rates are charged for the movement of different categories of traffic in instances where the costs of accommodating each category differ. Categories of traffic can be distinguished from one another on the basis of (a) type of commodity carried; (b) time at which service is performed; (c) spatial differences, i.e., the particular origin and destination points between which specific consignments are moved; (d) direction of movement over the same route; and (e) particular consignor or consignee served. (The latter is known as personal discrimination and involves the charging of different rates to different shippers for the movement of identical or substantially identical shipments over the same route in the same manner between the same origin and destination points.)

Some additional attention to terminology is necessary at this point. One should be aware that the words "preference" and "prejudice" appear in the Interstate Commerce Act of 1887 in reference to the results of rate differentials that may, but need not necessarily always, represent instances of discrimination in the economic sense described here. Preference and prejudice are deemed unlawful under the terms of the Act only when determined to be "undue" or "unreasonable." Also, judicial, regulatory, and political representations of discrimination sometimes differ from its meaning in an economic sense. For example, differences in rates based largely or wholly upon differences in a carrier's costs have sometimes been looked upon as unjustly discriminatory or unduly prejudicial by those who purchase the carrier's service under higher-cost conditions—for example, certain ocean ports disadvantaged by greater distances from inland traffic origination centers vis-à-vis other competing ports (3)—a view that is understandable on emotional and self-interest grounds but indefensible when judged by economic criteria.

Causes of Rate Discrimination

The incentive to engage in discriminatory pricing stems from (a) the existence of some degree of excess capacity in a carrier's plant and equipment, (b) fixed costs, and (c) indivisible costs—i.e., cost elements that cannot be traced or assigned on a causal basis to individual sales units of a carrier's services. Inability to trace all of a carrier's costs to individual freight traffic sales units will compel the firm to attempt to earn enough to cover its aggregate traceable or divisible costs and untraceable or indivisible overhead costs by extracting as much revenue as it can from each of its individual categories of traffic. Rates charged in each category (or market) thus will vary with differences between shippers' or shipper groups' ability and willingness to pay for the carrier's service. The presence of fixed costs and excess capacity lead a carrier to seek increases in traffic volume and revenue by reducing rates in markets where additional traffic can be obtained only at charges below those already in effect for traffic already being handled, but not below traceable costs, assuming rational economic behavior by the carrier. The attraction of traffic by differentiating rates in this

Table 1. Principal federal provisions for control of discrimination in railway rates and services.

Legislation	Purpose
Interstate Commerce Act, Part I, Section 2	Holds personal discrimination in any form to be illegal per se
Interstate Commerce Act, Part I, Section 3	Prohibits all forms of undue preference or advantage and undue prejudice or disadvantage
Interstate Commerce Act, Part I, Section 4	Prohibits long- and short-haul rate discrimination except in instances where specific relief therefrom is obtained from the Interstate Commerce Commission; contains the so-called Aggregate-of-Intermediates Rule, which prohibits through rates from exceeding summations of rates between intermediate points on the same route
Interstate Commerce Act, Part I, Section 6	Requires that all rates and fares be filed with the Interstate Commerce Commission and that tariffs showing rates and fares be kept open to public inspection; requires full adherence to published rates and fares
Interstate Commerce Act, Section 10	Prohibits solicitation of rebates and concessions by shippers or the offering of rebates and concessions by a railway
Elkins Act (supplementary to Interstate Commerce Act)	Prohibits the solicitation, offering, receipt, and/or payment of rebates or any other form of concession that constitutes a departure from published and filed tariffs

manner will increase use of the carrier's plant; improve coverage of the carrier's indivisible overhead costs, thus spreading the burden of overhead cost coverage over a greater number of units of traffic; and make freight service and its benefits available to additional shippers able and willing to purchase it only at lower rates.

Prerequisites for Successful Rate Discrimination

The ability to achieve revenue gains through rate discrimination is based on three conditions. First, the discriminating firm must possess some degree of discretion over establishment of the level of its selling price. It must command some degree of monopoly power, or a range within which it can set a price without causing shippers to either divert traffic to a competing carrier or cease movement of the traffic. Second, the discriminating firm must be capable of isolating its markets from one another to prevent customers purchasing at lower prices from trading with those subjected to higher prices. Such market segmentation is facilitated in transport by various forms of discrimination—e.g., types of commodities shipped, geographic location, and direction of movement. Third, differences in price elasticity must exist between the various markets served by the carrier. If such differences did not exist, the incentive to discriminate would be absent because revenue would be maximized by charging identical rates in each of the carrier's markets.

RATIONALE FOR SOCIAL CONTROL OF DISCRIMINATION

The immediate goal or purpose of the social control of discrimination can be construed as the prevention, mitigation, or elimination of economic injury stemming from the exercise of monopoly or monopsony power, or the failure of competitive forces to produce appropriate price-cost relationships in the sale of transport services, either at all or within an acceptable period of time. Beyond this immediate goal or purpose are two fundamental objectives, equity and economic efficiency. Equity can be characterized as the maintenance or achievement of fairness or justice in economic relationships between (a) carriers and individual shippers; (b) one shipper or shipper group vis-à-vis another, as affected by their comparative transport service purchasing conditions (i.e., bargaining powers); and (c) particular regions or communities and the carrier serving them. Economic efficiency emerges as the second basic objective to the extent that regulation of discrimination minimizes or prevents misallocative consequences of the nonoptimal price-cost relationships that can ensue from various types of discrimination.

CURRENT PROBLEMS

Incongruity

There is reason to question whether the just-mentioned objectives of equity and economic efficiency are being served or subverted by the existing framework of control over discrimination.

Under the statutory provisions depicted in Table 1, regulated rail common carriers presently face constraints against rate and service discrimination that do not apply to either interstate for-hire truck movements of agricultural products or for-hire domestic waterway movements of liquid and dry bulk commodities, which are exempted from all economic regulation by provisions contained in the Interstate Commerce Act. Motor and water carriers doing business under the terms of the exemptions thus are immune from those regulatory provisions that are indispensable for preventing or minimizing the practice of personal discrimination by regulated carriers—i.e., the requirements that (a) rates be published, (b) charges for transport services be billed and paid in conformance with terms published in applicable tariffs, and (c) rates be initiated or adjusted only in conformance with advance notice and tariff publication requirements. In addition, exempt carriers have no legal obligation to provide service of any type.

Exempt water and motor carriers, therefore, can freely accept or reject traffic whenever, wherever, and with whomever they please, and they may price their services on whatever terms they find it possible to command in negotiations with their customers. The handicap that this set of circumstances imposes upon regulated carriers competing with exempt carriers for the movement of rate-sensitive commodities is obvious. Exempt carriers, or brokers of the services, can use published regulated rates as pricing benchmarks or targets against which to "sharpshoot"—i.e., as points of departure from which to quote whatever prices they deem acceptable for capturing particular movements from regulated carriers. The latter firms cannot readily respond with rate changes of their own because both rate publication requirements and other regulatory controls prevent instantaneous or timely reactions.

The pricing flexibility enjoyed by exempt carriers vis-à-vis regulated carriers enables the former to achieve a higher degree of efficiency in equipment use in freight markets where traffic fluctuates widely and rapidly. For example, exempt barge rates on grain fluctuate freely in response to changes in the demand for, and supply of, barge lines' grain-carrying capacity. During peak periods, they sometimes exceed regulated rail rates by more than 200 percent. At other times, they decline to levels well below the lowest published rail grain charges (4).

This pricing discretion, together with the absence of any legal obligation to provide service per se, gives exempt carriers full ability to maintain their capacity at investment levels that do not greatly exceed the aggregate value placed on exempt transport service by shippers during peak and off-peak periods taken together. Such carriers need not either (a) limit rates in "strong" markets to levels construed as "reasonable" via governmental regulatory criteria or (b) meet requests for service in instances where costs exceed revenues. Yet, the pricing and service patterns of exempt carriers have never drawn perceptible negative reaction from either shippers or the commercial representatives of communities served by such carriers.

It can be argued that the chronic problem of severe seasonal shortages in grain-carrying railway rolling stock would not exist if comparable rate-making flexibility were possessed by rail firms. The price system would function to ration the supply of rail equipment in the same manner that it presently allocates resources committed to exempt barge and truck grain-hauling capacity. Moreover, grain shippers might well be drawn away from the frequent practice of fulfilling their basic movement requirements with exempt water and motor carriage, as well as using rail transport only when exempt truck and barge rates exceed rail rates, or when exempt motor and water carrier services are interrupted, or both. Such a shift would serve the cause of equity as well as economic efficiency, for it is ludicrous to contend that any measure of fairness prevails when a carrier or mode of carriage cast in a secondary or supplemental role and encumbered with both constraint on discrimination and other regulatory obligations and limitations must compete against carriers with no such restraints on their market behavior.

The anomaly posed by inequality in the imposition of regulatory control over discrimination in freight transport is amplified by the fact that exempt water and motor carriers face no statutory antidiscriminatory controls whatsoever because the proscriptions against price discrimination contained in Section 2 of the Clayton Act and Sections 2 and 3 of the Robinson-Patman Act apply only to the sale of commodities; coverage of services is omitted from their purview.

Questions of Obsolescence Versus Relevance, Infeasibility Versus Attainability

The following alternatives are among those that conceivably could be considered for dealing with the situation sketched above:

1. Extend the agricultural and bulk exemptions to railways on either a selective or an across-the-board basis.
2. Extend the exemptions to rail transport as in the previous option, but subject both rail carriers and the currently exempt sectors of motor and water transport to either (a) price discrimination provisions of the Robinson-Patman and/or Clayton Acts, as administered by the Federal Trade Commission, or (b) controls over discrimination specifically attuned to transport, perhaps transferred with modification from provisions contained in the Interstate Commerce Act, and administered by an agency solely concerned with transport, e.g., the Interstate Commerce Commission, with requisite reforms, or a new successor agency to the Commission.
3. Repeal the agricultural and bulk exemptions and subject the exempt water and motor transport sectors to all rate and service controls borne by nonexempt water and motor carriers. It should, however, be acknowledged immediately that the political feasibility and economic merit of this alternative are dubious at best (5).

ELIMINATION OF CONTROL OVER DISCRIMINATION: POSSIBLE CONSEQUENCES

Basic to the making of a rational choice among these alternatives (from the vantage point of economic desirability rather than political feasibility) is a determination of the degree to which regulated carriers can, if freed from regulatory constraints, exert economic injury by imposing rates, or service characteristics, or both, that depart from the norms of workable, if not a purer form of, competition.

Predatory Discrimination

Desirable consequences of rate discrimination—i.e., the extension of service to transport markets or shipper groups capable only of paying lower rates than hitherto charged, greater utilization of capacity, and a wider basis for spreading the burden of overhead or indirect costs—were presented in the introductory section of this paper. However, it is also possible for a carrier possessing relatively high degrees of monopoly power in some markets, and facing discernible competition in others, to engage in predatory discrimination by selling its services in the latter markets at rates below the direct or traceable costs of serving them. Such behavior is predicated on the expectation that the discriminating firm's competitors will be destroyed, whereupon rates in the affected markets can be raised to levels sufficiently above costs to (a) recoup the losses incurred during the period of predation and (b) provide returns in excess of those that could have been earned in the continued presence of competitors.

Instances of such pricing behavior have been cited at various points in transport history, both on an intramodal basis within rail transport and in rivalries between railways and other modes, particularly water carriage. Indeed, barge-line representatives continually raise the spectre of its recurrence as part of their arguments in opposition to proposals that would reduce or end railway regulation on commodity movements highly susceptible to water carriage (6).

The validity of the water carriers' case against railway deregulation rests on (a) the traditional conceptual rendition of the "typical" rail firm's cost structure—i.e., a relatively high proportion of indivisible costs vis-à-vis traceable costs—coupled with the ability to serve a wider range of transport markets as identified or delineated in terms of both geographic coverage and types of commodities, thus providing rail managers with a wide range of discretion in the establishment of rates on individual movements; (b) sufficient liquidity for financing bouts of predatory pricing; and (c) little or no threat or possibility of reemergence of nonrail competitors following the rail firm's winning of an initial round of predatory pricing combat.

Arguments Supportive of Abolition

Proponents of railway deregulation through either extension of the agricultural and bulk exemptions or even broader forms of decontrol contend that the relatively low costs of initiating both for-hire and private motor carrier operations on freely accessible publicly provided way facilities will preclude rail firms from garnering monopoly-level earnings (in either individual freight markets or on an aggregate basis) via predatory pricing, and that this is fully perceived by contemporary railway managers. Other points frequently cited in support of the view that substantial or total railway deregulation will not open the door to either predatory discrimination or the simpler case of exploitation of shippers in existing captive markets are as follows:

1. The decline and even virtual disappearance of rail market share in the movement of numerous commodities and the availability of evidence that rail carriage no longer commands significant cost advantages (excluding social costs)—even at levels approximating traceable or marginal costs—over motor carriage in the long-distance movement of either most types of manufactured goods or agricultural commodities (7);
2. Restraint of rail-pricing discretion by competition between alternative types of materials and alternative production locations for specific commodities, respectively;
3. Critical and seemingly intractable qualitative defects that afflict many rail services and make it difficult to either recapture traffic lost to other modes or win new traffic (7, 8);
4. The financial malnutrition that besets much of the railway industry, both in the absolute sense of bankrupt companies and in the relative sense of carriers earning inadequate rates of return (8); and
5. The rise of executives cognizant of the role that properly developed cost information should play in rate making, thus obviating the possibility that minimum rate regulation might have to be invoked to prevent carriers from self-impairing their ability to serve the shipping public through pricing errors stemming from ignorance of costs.

Arguments Against Total Abolition

Other students of transport accord varying degrees of acceptance to these phenomena, but they contend that the distribution of bargaining power on both the buyers' and sellers' sides of at least some transport markets remains uneven enough to warrant the retention of some measure of social control over both carriers' pricing and service behavior and the influence of shippers on these factors (6, 9-11). This view is based on the following arguments:

1. Rail service continues to be the only means for moving some socially significant types of commodities (e.g., utility steam coal and grain) in great quantities between certain pairs of points.
2. Some situations still exist in which rail use cannot be circumvented by lower-cost alternatives without the endurance of lengthy lead times involving either the creation of a completely new transport alternative such as a slurry pipeline or the discovery of a substitute commodity or new supply source bearing more favorable terms of transport.
3. The concept of threat of entry by a competitor at a somewhat distant point in time cannot be relied on to influence a market-dominant firm's price and service policies within the near future for reasons such as (a) incumbent managers and/or directors who desire to maximize profits within the limits of their terms of office and who leave the problem of coping with future competition to their successors, and (b) managerial ignorance or insensitivity toward potential future forms of competition that, even if perceived, might be viewed as having relatively low probabilities of emergence.
4. The reinforcement of tendencies toward inertia and indifference in pricing and service that can stem from exclusive access to particular segments of right-of-way by individual rail carriers.
5. The presence in some freight transport markets of monopsony or oligopsony—i.e., imbalances in bargaining power favoring certain shippers vis-à-vis carriers and other shippers.

Further discussion concerning the relative workability (or imperfection) of competition between rail firms and carriers in other modes and its implications for the overall spectrum of economic regulation exceeds the scope of this paper. However, if continuance of some degree of public control over discrimination and related aspects of the pricing and supply of freight services is judged to be desirable in principle, then judgments must also be made about the administrative feasibility and prospective results of alternative means for achieving it. Conversely, moves toward substantial reductions in both rate regulation and the antitrust immunities heretofore accorded rail pricing activities conducted under the aegis of rate bureaus (as noted in the Interstate Commerce Act and Public Law 94-210) should be accompanied by appropriate action concerning some little-recognized but crucial relationships between such proposed changes and existing controls over rate discrimination.

Standards for Judging Discrimination: Problems

The history of efforts to control both railway price and service discrimination and the reasonableness of rates per se has been clouded by varying degrees of ambiguity over criteria for drawing distinctions between just and unjust discrimination, due and undue preference and prejudice, and reasonable and unreasonable levels of charges and service (1, 12). It has been noted that

> The decisions made by the ICC and reviewed by the courts...determine when discrimination will be permitted and when it will not. But the line thus drawn between legality and illegality is not always clear. The limits of discrimination, at any time, will depend upon the composition and the judgment of the Commission and the courts (13).

At the heart of this ambiguity are debate and uncertainty over (a) the roles that cost evidence and comparisons between different rates and movements, respectively, should play in determining the appropriateness of rate differentials; (b) the particular cost concepts to be employed (e.g., marginal versus average and variable versus fully allocated); (c) methods or formulas most appropriate for computing cost evidence admissible in a commission or court proceeding; and (d) the selection and application of criteria for judging the justness or reasonableness of contribution margins (or elements of rates and revenues in excess of traceable costs related thereto) and the aggregate level of one particular rate or group of rates vis-à-vis another (1, 3, 9, 12).

Cost: Dominant Criterion

The greatest potential for improvement of the process and results of discrimination control might well be realized by (a) the pursuit of opportunities for achieving a greater measure of definitiveness in the construction of cost evidence and the specification and application of cost standards numerated by such evidence and (b) placement of sole or dominant reliance upon cost evidence in determining a particular rate's reasonableness per se and whether a particular rate is excessively low in comparison with another in cases involving allegations of undue preference and prejudice. For example, the concepts of "variable cost" and "contribution to going concern value" specified in the Railroad Revitalization and Regulatory Reform Act of 1976 (also known as the 4-R Act) could be given a stronger, more dominant joint role in determination of the lawfulness of particular rates. This or a similar course of action, if properly implemented, could (a) prevent or diminish the delay or rejection of proposed new freight services and rates (on the grounds that they might, or do, respectively, violate one or more discrimination control provisions of the current Interstate Commerce Act) in instances where such rates are cost justified, and/or (b) give railways the ability to adjust rates and service characteristics on unremunerative movements without being greatly delayed or barred from doing so by the invocation of discrimination control provisions.

Intractable Problems Involving Rate Maximums

The task of judging whether a particular rate's aggregate level—or its level in excess of the traceable cost element within it—is just and reasonable, either in and of itself or in comparison with another rate, is inherently subjective for reasons that have been amply discussed in the literature of rate regulation (1).

Subjective judgment—and the provocation of widely differing reactions, ranging from exuberant approbation to vitriolic condemnation—also obtains in cases involving choices between reliance on efficiency-oriented cost criteria and those types of equity criteria that may be in conflict with efficiency. A prime example can be found in the Interstate Commerce Commission's attempt to make at least some rail service available to all grain shippers during the 1978 car shortage by ordering the reassignment of covered hopper cars from lower-cost unit train movements (limited to shippers large enough to utilize the higher individual load minimums of such operations) to higher-cost, less-efficient single-carload service (14).

OTHER PRICE DISCRIMINATION LAWS OF QUESTIONABLE MERIT

Substitution of the price discrimination control provisions of the Robinson-Patman and Clayton Acts, or adaptations thereof, for existing discrimination control provisions in the Interstate Commerce Act was mentioned earlier in this paper as a conceivable alternative (and Robinson-Patman Act language was incorporated in the proposed but never-enacted Transportation Act of 1974, which was directed toward relaxation of rate regulation). However, such a change does not hold promise for improvement because the administration and impact on competition of the Robinson-Patman and Clayton Act provisions have posed difficulties no less onerous than those that have beset known experience with Interstate Commerce Act provisions (13). There is also reason to question whether the inevitable difficulties of continued control over transport discrimination, even in modified form, could be dealt with more effectively by the Federal Trade Commission rather than by another agency with greater expertise in the vagaries of transport markets.

In summary, the process of controlling transport discrimination, particularly in cases focusing primarily on rate maximums, is inherently subjective and imprecise. Decisions about whether the costs of its imperfections will outweigh whatever social benefits it might confer are subject to sociopolitical value judgment.

ANTITRUST IMMUNITY AND EXISTING CONTROLS OVER DISCRIMINATION

The 4-R Act repealed antitrust immunity for the collective pricing of single-line rail freight movements, but continued language permitting rate-bureau-administered pricing of interline movements by carriers participating in such movements. However, in a recent ruling concerning rate bureau procedures for interline rate matters, the Interstate Commerce Commission appears to have effectively blocked rail-pricing executives from collectively establishing rates on interline traffic in which they participate.

If the Commission's ultimate disposition of this case remains substantially the same, it would appear that railways could and would revert to individual negotiations with one another for the construction and publication of joint through rates. However, such an approach would increase the possibility of potential violations of Sections 2, 3, and 4 of Part I of the Interstate Commerce Act. For example, a rail carrier connecting end-on with two or more other railways extending to a common metropolitan area destination would have to carefully monitor the relationships between the levels of each of the through rates that it might negotiate with each of the connecting carriers. If one rate happened to differ from another (all other things being equal), the initial carrier could conceivably be confronted with a charge of violation of Section 2 (personal discrimination) and/or Section 3 (undue prejudice of a particular point or location) by a shipper or consignee confronted by the higher rate and limited to one-carrier private siding access within the metropolitan area. This example, although oversimplified, should stimulate recognition of the possibilities for inadvertent violations when consideration is also given to the vast number of changes and combinations of origin and destination points and types of commodities that characterize rail movements.

The Commission's action could terminate the pricing and marketing of interline rail freight services by individual carriers. Shippers requiring interline rail service would be forced to negotiate separately with each carrier participating in operation of the service. Or, alternatively, a new industry consisting of carload (and multiples thereof) freight service brokers (as distinguished from freight forwarders) might appear. It would serve as an intermediary between rail carriers and shippers for the development, pricing, and marketing of single- and multiple-carload interline services.

The discontinuities and consequent costs of this possible outcome (e.g., traffic losses to other modes of transport at the same time that the railway industry's financial performance and condition are already at lows not matched since the 1930s, and the forcing of marked adjustments in shippers' logistics systems and traffic management functions) strongly suggest that any and all types of effort directed toward deregulation of railway rate making and increased play in the interaction of rail freight market forces must be accompanied by significant reductions in the scope and stringency of existing controls over discrimination.

Another illustration of the need for coordinating reductions in a particular aspect of regulation with controls over discrimination can be found in current moves to reduce long-standing restrictions on the offering of common and contract carriage by the same firm (15, 16). These moves are at the core of statutory proscriptions against personal discrimination and bring into question both the relevance or necessity of such proscriptions and the feasibility of their continued application in a consistent manner.

CONCLUSIONS

Existing controls over railway rate and service discrimination, in common with other aspects of economic regulation, have reached a critical point in their history. Although originally identifiable with equity and economic efficiency objectives, they (together with other facets of economic regulation) now appear to contravene the achievement of those objectives in instances where railways face competition from unregulated water and motor transport. The decline and even disappearance of rail transport's economic advantages vis-à-vis other regulated and unregulated carriers for the movement of many commodities and significant lengths of haul cast doubt on the continued need for control of discrimination in affected transport markets.

The administration and effects of discrimination control in areas where it might still be needed could be improved in some ways by placing greater reliance on cost information and criteria. However, the judgment of cases involving the reasonableness of profit or contribution margins and rate maximums is inherently subjective and subject to ambiguity and conflicting value judgments.

Efforts to reduce or eliminate regulatory barriers that limit or prevent the offering of both contract and common carrier services by the same transport firm pose questions about the future role of proscriptions against personal discrimination.

Finally, recent legislative and administrative moves toward reductions in rate regulation and greater reliance on competitive market forces have apparently been taken without adequate consideration of their interrelationships with controls over discrimination (17). Larger measures of immediate attention to these circumstances by transport researchers and policymakers are necessary.

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Analysis of Implicit Trade-Off Between Costs and Benefits of Rate Bureaus

Garland Chow, College of Business and Management, University of Maryland, College Park

Responses to questionnaires were analyzed to determine the implicit trade-off made by shippers between the costs and benefits of rate bureaus. The responses indicate that shippers perceive rate bureaus as beneficial and necessary to prevent rate discrimination, to maintain rate stability, and to facilitate joint rates and services. The responses also indicate that these benefits are not obtained at the expense of having too little rate or service competition. Small shippers perceive the benefits more strongly than large shippers. However, neither the freedom of independent rate making nor the flexibility of rate and service were viewed as adequate. These results suggest that some changes may be necessary in rate bureau organization, but these changes do not include the repeal of current antitrust exemptions.

Many motor carrier rates are set collectively in the regulated trucking industry. This is accomplished through the regional rate bureau, an intramodal organization of carriers established to consider jointly rates, classifications, divisions, and other pricing matters in a given region. Under ordinary circumstances such collective action would be a violation of federal antitrust laws. However, the U.S. Congress exempted rate bureaus from federal antitrust laws by passing the Carriers' Rate Bureau Act of 1942 (also referred to as the Reed-Bullwinkle Act).

The antitrust exemption for rate bureaus has been a source of controversy from its inception. Recent activity includes the U.S. Department of Transportation's call for reducing the role of the rate bureau in its legislative program for regulatory reform (1). In June 1975, the Interstate Commerce Commission (ICC) concluded its own rate organization changes (2). The U.S. Senate Subcommittee on Antitrust and Monopoly, Senate Judiciary Committee, recently completed its own hearings on freight rate competition in the motor carrier industry. Also, in January 1976, the ICC initiated two ongoing proceedings to (a) reconsider existing Section-5a exemptions and (b) determine if terms and conditions on railroad rate bureaus established by the Railroad Revitalization and Regulatory Reform Act, enacted later in 1976, should be applied to other modes (3, 4).

This paper examines some of the issues raised in connection with the recent concern over the antitrust exemption for motor carrier rate bureaus. Particular emphasis is placed on the questions raised in Ex Parte 297 (Sub No. 4). A questionnaire was used to pool expert opinion on pertinent issues.

COLLECTIVE RATE-MAKING ISSUES

In Ex Parte No. 297 (Sub No. 4) the ICC ordered each motor carrier rate bureau to submit evidence to determine if their collective rate-making agreement still qualifies for ICC approval.

The evidence submitted must be relevant to one of the following issues and related questions (4):

1. Does the agreement enhance one or more national transportation policy goals (benefits)?
2. Will the agreement harm interests intended to be protected by antitrust laws (costs)?
3. Do the benefits exceed the costs?
4. Can any of the goals that justify the collective rate-making agreement under consideration be accomplished by some method other than collective action?
5. Can any of the goals that justify membership in the agreement by any specific parties be accomplished without belonging to the agreement?
6. What regulates the number of carriers with operating authority from the ICC that qualify for membership in the agreement but are not parties to the agreement?

The questions and issues posed by the ICC are based on the premise that the ICC will continue its regulation of entry and rates. The same premises do not exist in all arguments against the existence of rate bureaus. Many arguments that support the abolition of rate bureaus are based on the assumption that the motor freight industry is workably competitive. The underlying premise is that there should neither be rate bureau exemptions nor economic regulation of rates or entry.

Two observations are relevant. First, it is not evident to every academician, transportation policy analyst, and other interested parties that the motor freight industry is workably competitive (5). Current knowledge of the structure, conduct, and performance of unregulated or regulated trucking is woefully incomplete, and it is slowly being recognized that the trucking industry may be better viewed as several industries (6). Basic questions, such as whether economies of scale exist in trucking, remain controversial despite the plethora of recent empirical evidence (7). Thus the validity of the expected performance of various deregulation measures is only as good as the underlying assumptions about market structure, and these assumptions are not as certain as they frequently are perceived.

Second, in analyzing prospective policy changes, what is being changed must be separated from what is not being changed. Thus, for the purposes of the current ICC investigations, it is important to identify consequences resulting from changes in regulation of rate bureaus alone and not changes in overall rate or entry regulation as well. Indeed, the effect of the latter changes appears to be the central issue in the Senate's freight rate competition hearings.

The Senate hearings, however, did raise several questions about rate bureau costs and benefits that deserve further attention. One issue is that of differential benefits to small shippers versus large shippers. It was observed that

> Certain shippers command substantial and sometimes overwhelmingly superior bargaining power stemming from a number of factors. These include financial strength, amounts of freight service purchased, varied mixes of "controlled traffic," creative and aggressive management of logistics and traffic functions, geographically diverse alternative locations for the procurement of raw materials and production for sale of outputs, and participation in intercorporate collective efforts involving certain aspects of shippers' relationships with carriers. The existence of this power could mean that in a free market situation, shippers dominating transport markets could force the level of rates down to where a shortfall could exist between carriers' total revenues and total costs. Carriers, in turn, would attempt to increase rates on traffic of other shippers. Small shippers would no doubt bear the brunt of these increases (8).

Inasmuch as it is also desirable to encourage small enterprise, it would be important to distinguish the differential consequences of the rate bureau process on large and small shippers.

METHODOLOGY AND OBJECTIVES

A mail questionnaire was used to collect data from shippers affected by the actions of a major rate bureau. The questionnaire was designed to solicit responses on three of the issues or questions posed by the ICC order in Ex Parte 297 (Sub 4). Shipper respondents were asked

1. To agree or disagree with statements asserting that the rate bureau and collective rate making enhances specific goals [There are numerous goals identified or implicit in the statement of national transportation policy and other parts of the Interstate Commerce Act. With regard to the general issue of collective rate making, three goals are especially relevant. It is frequently asserted that the collective rate-making process (a) protects the shipping public from unjust, unreasonable, and discriminatory rates; (b) ensures the shipping public a high degree of rate stability and certainty; and (c) facilitates the making of joint rates essential to the availability of joint services];
2. To agree or disagree with statements asserting that specific goals would not be achieved without the existence of rate bureaus and collective rate making; and
3. To agree or disagree with statements regarding the significance and nature of competition in trucking.

In addition, carriers were asked questions designed to indicate whether bureaus are discouraging rate competition.

Shipper respondents were those on the Middle Atlantic Conference (MAC) tariff mailing list. Firms on this list are interested in the issues central to the current ICC investigation. However, the possibility exists that shippers (doing business in the geographic areas served by MAC carriers) who do not subscribe to the tariff publications have attitudes different from the subscribing shippers. Until a profile of such shippers can be developed, the extent of any bias is uncertain. The 2313 shippers on the MAC tariff list were sent questionnaires. Multiple listings and unmailable addresses reduced this figure to 1761. Usable returns numbering 412 resulted in a response rate of 23.4 percent.

The shippers were asked to indicate the number of dollars spent annually on transportation. The distribution of those responding is summarized in the following table:

Annual Freight Bill ($)	Number of Shippers	Percentage of All Shippers
Under 100 000	18	4.4
100 000-1 000 000	85	20.6
1 000 000-10 000 000	168	40.8
More than 10 000 000	126	30.6
Not indicated	15	3.6
Total	412	100.0

In analyzing specific responses, shippers with freight bills below $1 million annually were classified as small shippers.

ROLE OF RATE BUREAUS IN PRESERVING RATE STABILITY

Shippers were asked questions relating to the effectiveness of rate bureaus in their role of maintaining rate stability. Tables 1 and 2 indicate that shippers generally perceive the rate bureaus as a necessary instrument assisting in the maintenance of rate stability. The small shippers agree more strongly than the large shippers. In Table 1, for example, 89.1 percent of the small shippers agreed or strongly agreed that rate stability is maintained by the bureau process; only 78.6 percent of the large shippers made similar responses. In addition, the small shippers had proportionately more "strongly agree" responses.

The shippers were also asked if they would be able to guarantee for themselves the present level of rate stability. As shown in the following table, the majority of the shippers answered this question in the negative:

Group	Yes	No	Miscoded	Total Cases
All shippers	109	285	2	396
Small shippers	17	83	–	100
Large shippers	89	191	2	282

The χ^2 statistic (i.e., the variation between shipper size and response) of 8.75 at the 0.0328 level also indicates that small shippers feel they have significantly less ability to do so.

ROLE OF RATE BUREAUS IN MAINTAINING JOINT LINE RATES AND SERVICE

Shippers were asked to respond to statements about the need for collective rate making to maintain joint line rates. The responses shown in Tables 3 and 4 indicate that the majority of the shippers perceive collective rate making as essential to the availability of joint line rates and service. For example, in Table 4, 71.1 percent of the shippers agreed or strongly agreed. Table 4 also indicates that the small-shipper group agrees more (79.4 percent) than the large-shipper (68.0 percent) group. Again, the small shippers had relatively more "strongly agree" responses.

ROLE OF RATE BUREAUS IN PREVENTING RATE DISCRIMINATION

Shippers were asked questions relating to the effectiveness of rate bureaus in the role of assisting in the prevention of rate discrimination. Tables 5 and 6 indicate that the bulk of the shippers perceive the rate bureaus as an effective instrument for maintaining nondiscriminatory rates.

The small shippers again agree more strongly and frequently than do the large shippers on these questions. This is evident in Table 6 where 84.3 percent of the small shippers agreed or strongly agreed, while 74.5 percent of the large shippers agreed or strongly agreed.

Each respondent also indicated whether it could ensure that its firm is receiving nondiscriminatory rates in the absence of rate bureaus. As shown in the following table, the majority responded to this question in the negative:

Group	Yes	No	Total Cases
All shippers	106	293	399
Small shippers	15	88	103
Large shippers	87	194	281

As with assuring themselves with rate stability, the large shippers appear to be able to assure themselves of nondiscriminatory rates more often than the small shippers. Again a statistically significant χ^2 (9.56 at the 0.0020 level) supports this observation.

Table 1. Responses to "Rate instability and uncertainty would occur without rate bureaus".

Group	Strongly Agree No.	Strongly Agree %	Agree No.	Agree %	Neutral No.	Neutral %	Disagree No.	Disagree %	Strongly Disagree No.	Strongly Disagree %	Total Cases
All shippers	129	31.7	199	49.1	15	3.2	43	10.6	19	4.7	405
Small shippers	43	42.6	47	46.5	2	2.0	7	6.9	2	2.0	101
Large shippers	82	28.2	145	50.1	12	4.2	34	11.8	16	5.5	289

Table 2. Responses to "The rate bureau process results in rate stability".

Group	Strongly Agree No.	Strongly Agree %	Agree No.	Agree %	Neutral No.	Neutral %	Disagree No.	Disagree %	Strongly Disagree No.	Strongly Disagree %	Total Cases
All shippers	91	22.4	243	59.9	30	7.4	32	7.9	10	2.5	406
Small shippers	29	28.4	60	58.8	6	5.9	6	5.9	1	1.0	102
Large shippers	58	20.1	175	60.6	24	8.3	23	8.0	9	3.1	289

Table 3. Responses to "Joint line agreements would be cancelled and the benefits of joint line service lost without rate bureaus".

Group	Strongly Agree No.	Strongly Agree %	Agree No.	Agree %	Neutral No.	Neutral %	Disagree No.	Disagree %	Strongly Disagree No.	Strongly Disagree %	Total Cases
All shippers	99	24.7	187	46.7	43	10.7	56	14.0	15	3.7	400
Small shippers	34	34.6	45	45.5	10	10.1	10	10.1	0	0.0	99
Large shippers	61	21.3	137	47.7	31	10.8	44	15.3	14	4.9	287

Table 4. Responses to "Collective rate making is essential to the availability of joint line rates and services".

Group	Strongly Agree No.	Strongly Agree %	Agree No.	Agree %	Neutral No.	Neutral %	Disagree No.	Disagree %	Strongly Disagree No.	Strongly Disagree %	Total Cases
All shippers	93	23.5	188	47.6	46	11.6	59	14.9	9	2.3	395
Small shippers	31	32.0	46	47.4	12	12.4	8	8.2	0	0.0	97
Large shippers	58	20.4	138	48.6	32	11.3	47	16.5	9	3.2	284

Table 5. Responses to "Rate discrimination would occur without rate bureaus".

Group	Strongly Agree No.	Strongly Agree %	Agree No.	Agree %	Neutral No.	Neutral %	Disagree No.	Disagree %	Strongly Disagree No.	Strongly Disagree %	Total Cases
All shippers	117	28.9	175	43.2	21	5.2	72	17.8	20	4.9	405
Small shippers	38	37.3	40	39.2	8	7.8	13	12.7	3	2.9	102
Large shippers	73	25.3	132	45.8	11	3.8	56	19.4	16	5.6	288

Table 6. Responses to "The rate bureau's activities assist in the prevention of rate discrimination".

Group	Strongly Agree No.	Strongly Agree %	Agree No.	Agree %	Neutral No.	Neutral %	Disagree No.	Disagree %	Strongly Disagree No.	Strongly Disagree %	Total Cases
All shippers	88	21.8	222	55.0	25	6.2	52	12.9	17	4.2	404
Small shippers	29	28.4	57	55.9	5	4.9	8	7.8	3	2.9	102
Large shippers	54	18.8	157	54.7	19	6.6	43	15.0	14	4.9	287

NATURE AND EXTENT OF COMPETITION IN THE TRUCKING INDUSTRIES

Shippers were asked to indicate their levels of agreement with statements about competition and rate making. Tables 7 through 14 summarize these responses. Separate responses for each statement were requested for less-than-truckload (LTL) and truckload (TL) traffic.

Most shippers agree that significant rate and service competition exists for both LTL and TL freight as indicated in Tables 7 through 10. In nearly every case, small shippers agreed on this question more strongly than large shippers.

A great many shippers do not perceive the existence of rate differentials for differences in service. Thus, only 34.9 percent of the shippers agree that there are varying levels of LTL rates reflecting varying levels of LTL service. Only 46.4 percent of the shippers agreed with respect to TL rates and service and this indicates that variations in levels of service occur more frequently with TL rates than with LTL rates. The responses varied significantly between large and small shippers for LTL traffic but not for TL traffic.

Shippers also feel there is difficulty in getting independent rates. As shown in Tables 13 and 14, the majority of all shipper respondents agreed that independent rates are difficult to obtain—47.2 percent strongly agreed or agreed that independent TL rates were difficult to obtain, and 64.2 percent strongly agreed or agreed that it was difficult to obtain independent LTL rates.

SUMMARY

There is significant controversy as to whether motor carrier rate bureaus should retain their antitrust immunity. Whether the activities performed by rate bureaus benefit the shipping public depends on whether such activities enhance the achievement of national transportation policy goals and to what degree this is offset by reduced competition. This paper analyzed survey responses that suggest the implicit trade-off between the costs and the benefits made by shippers. The

Table 7. Responses to "There is significant rate competition for less-than-truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	63	16.1	186	47.4	28	7.1	92	23.5	23	5.9	392
Small shippers	24	24.7	43	44.3	7	7.2	22	22.7	1	1.0	97
Large shippers	38	13.6	135	48.2	19	6.8	67	23.9	21	7.5	280

Table 8. Responses to "There is significant rate competition for truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	62	17.7	192	54.7	14	4.0	70	19.9	13	3.7	351
Small shippers	15	20.0	38	50.7	6	8.0	14	18.7	2	2.7	75
Large shippers	44	16.8	145	55.3	8	3.1	55	21.0	10	3.8	262

Table 9. Responses to "There is significant service competition for less-than-truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	95	24.4	226	57.9	20	5.1	43	11.0	6	1.5	390
Small shippers	37	38.1	48	49.5	5	5.2	6	6.2	1	1.0	97
Large shippers	54	19.4	168	60.4	14	5.0	37	13.3	5	1.8	278

Table 10. Responses to "There is significant service competition for truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	83	23.5	202	57.2	12	3.4	44	12.5	12	3.4	353
Small shippers	22	28.9	42	55.3	6	7.9	5	6.6	1	1.3	76
Large shippers	57	21.7	153	58.2	6	2.3	38	14.4	9	3.4	263

Table 11. Responses to "Different rates reflecting different levels of service exist for less-than-truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	14	3.8	116	31.1	65	17.4	149	39.9	29	7.8	373
Small shippers	3	3.3	30	33.0	19	20.9	34	37.4	5	5.5	91
Large shippers	9	3.3	85	31.6	39	14.5	113	42.0	28	8.6	269

Table 12. Responses to "Different rates reflecting different levels of service exist for truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	27	7.9	132	38.5	45	13.1	112	32.7	27	7.9	343
Small shippers	3	4.3	22	31.9	13	18.8	26	37.7	5	7.2	69
Large shippers	21	8.0	106	40.6	27	10.3	86	33.0	21	8.0	261

Table 13. Responses to "Independent rates are difficult to get for less-than-truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	77	20.4	166	44.0	43	11.4	73	19.4	18	4.8	377
Small shippers	19	20.7	40	43.5	15	16.3	15	16.3	3	3.3	92
Large shippers	59	21.0	118	43.4	28	10.3	55	20.2	14	5.1	272

Table 14. Responses to "Independent rates are difficult to get for truckload traffic".

Group	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total Cases
	No.	%	No.	%	No.	%	No.	%	No.	%	
All shippers	37	10.8	125	36.4	38	11.1	117	34.1	26	7.6	343
Small shippers	14	19.4	27	37.5	13	18.1	15	20.8	3	4.2	72
Large shippers	22	8.5	93	35.9	25	9.7	97	37.5	22	8.5	259

survey was made in the context of the continuation of present ICC regulation of rates and entry.

The responses indicate that the majority of the shippers perceive the rate bureau as critical to preserving rate stability, maintaining joint line rates and services, and preventing rate discrimination. These are all widely recognized goals of national transportation policy. Theoretically, any collusive structure, i.e., the rate bureau cartel, will lead to noncompetitive performance and conduct in the form of decreased rate or service competition or both. However, a majority of the shippers agree that significant rate and service competition exists in both the LTL and TL freight markets. Based on these responses, the majority of the responding shippers feel that rate bureaus do provide essential benefits without seriously reducing competition.

The responses do not suggest that the procedures and organization of the rate bureaus are perfect. The shipper responses indicate that more rate innovation and easier independent rate making is desirable, but it appears that most shippers would prefer these changes under the present framework of rate regulation. It should be noted that commensurate changes in the ICC's procedures are necessary too. In the case of more rate and service options, the ICC will have to modify its rigid costing procedures to reflect costs of different services and service levels in order for carriers and the rate bureaus to legally respond.

The frequency and degree of independent action and bureau protests have been documented elsewhere, and the impact on competition is subject to considerable debate (9). It is notable that the majority of shipper respondents agree that significant rate competition exists and, at the same time, agree that independent rates are difficult to obtain.

It is frequently asserted that rate bureau protest of independently filed rates effectively limits rate competition. A plausible explanation for this inconsistency is that independent action is only one form of rate competition. Rate actions made through rate bureau procedures are a form of rate competition among bureau carriers as well as between bureau and nonbureau carriers. Shippers may be satisfied with overall rate competition resulting from both independent and nonindependently filed rates.

The responses verify the notion that the intensity of competition differs between the LTL and TL markets. The respondents indicate that there is less rate competition, fewer rate and service combinations, and greater difficulty in getting independently filed rates for LTL traffic than for TL traffic. However, it is not clear that the existence of rate bureaus is the cause of this difference. It is well recognized that tendencies toward industry concentration are more evident in the LTL segment than in the TL segment of trucking (10).

Finally, the responses suggest that small shippers have different attitudes and perceptions than large shippers though these differences are a matter of degree rather than of conflict. The majority of both the small and large shippers agrees that rate bureaus perform necessary functions, but generally a larger percentage of small shippers agree and they agree more strongly. Responses indicate that relatively fewer small shippers feel that they can assure themselves of the present level of rate stability and nondiscriminatory rates when compared to large shippers. In light of the ICC's concern for the protection of small shippers, serious consideration and investigation of the role of the rate bureau in this process are warranted.

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Design Considerations for Experiments in Major Regulatory Change

Rolf R. Schmitt, National Transportation Policy Study Commission, Washington, D.C.

Major changes in the regulation of transportation have been frequently proposed and occasionally tried on a nationwide scale. Beyond theoretical and poorly substantiated evidence, the effects of proposed and trial changes are generally unknown or inadequately understood. This paper argues that field experiments provide the most sound basis for evaluating major regulatory changes. It also examines the conditions that must be met for experimentation to be effective. After briefly surveying the variety of experimental designs used in nontransportation research, criteria are developed for selecting designs to evaluate regulatory changes. The paper concludes with a recommended evaluation strategy and some caveats.

Major changes in the regulation of transportation are being proposed with increasing frequency. These changes range from modifications to the criteria for setting rates to total deregulation. Several changes have been implemented on a trial or permanent basis, yet surprisingly little validated information on the impacts of these changes exists to guide future regulatory policy.

Existing information on major regulatory change comes from two sources: (a) systemwide changes in federal policy toward specific modes and (b) comparisons between differing federal and state regulatory environments. Information on systemwide policy changes is easily distorted by many concurrent events and extraneous factors that affect measured outcomes but are not germane to the policy being evaluated. Information is also distorted by unanticipated or indirect impacts of the policy that are not measured. These problems are exacerbated by national data-collection efforts, which currently tend to be myopic, disjointed, or inaccessible (1). Knowledge gained from comparative studies of federal and state regulatory policies is similarly degraded by infrequently considered variations in local conditions that affect the performance and impacts of transportation. The policymaker is thus left with theoretical speculation and poorly substantiated empirical evidence to evaluate proposed regulatory changes.

When faced with the possibility of adverse consequences, a frequently advocated solution to inadequate information is to experiment. Although field experiments have been used to evaluate proposed housing, income maintenance, and other social programs, this method has not been applied to transportation subjects other than structural engineering, vehicle safety, and small-scale traffic control. Carefully controlled field experiments in major regulatory change are virtually nonexistent.

The utility and design of field experiments for evaluating major regulatory change in transportation are explored in this paper. The reasons for experimentation and the conditions that must be met for field experiments to be useful are examined first. The wide range of experimental designs developed in other fields and applicable to transportation are surveyed. Criteria are developed for selecting appropriate designs. The paper concludes with a recommended evaluation strategy and some caveats.

FIELD EXPERIMENTS AS AN EVALUATION TOOL

Evaluations of transportation policy are largely molded by their sources of information, which include predictive models, case studies, and field experiments. A currently popular source of information is the predictive model, which includes the simulation experiment (2). Predictive models are useful for evaluating proposed actions with potentially traumatic and irrevocable consequences, and simulation experiments can indicate the sensitivity of the model's estimates to its assumptions and to stochastic events; however, this approach ultimately requires faith in the model's theoretical underpinnings and in the temporal and geographic stability of its parameters. Case studies are the second and most common source of information on the effects of regulatory change. They include narrative histories, dockets filed with regulatory commissions, and demonstration projects. Although based on observations of actual (rather than predicted or simulated) events, case studies do not comprehensively analyze the concurrent events and extraneous factors that can distort empirical observations. This is not true of field experiments, which are the third and least used source of information on the effects of regulatory change. In evaluation research, field experiments are the measurement of the effects of a policy or program implemented in a physically or analytically controlled environment. Unlike case studies (particularly demonstration projects), field experiments are designed explicitly to cancel out or reveal extraneous factors so that the measured effects can be attributed with confidence to the policy or program being evaluated.

Predictive models and case studies have been considered to be acceptable sources of information on regulatory change largely because many transportation analysts are content with reliable measurements. This contentment is myopic because reliability is a necessary but not sufficient condition to establish validity. Reliable measures address unknown and nebulous phenomena in a reasonable and uniform manner; however, the results may misrepresent actual outcomes either by incorrectly labeling actual elements of change or by being sensitive to extraneous factors. To assure valid results, information must be collected and analyzed in a way that certifies proper labeling of measures and that reveals or controls for extraneous factors. Field experiments are explicitly designed to do this and thus provide superior evidence that a policy does or does not work and indicate how the policy might work better.

Like any evaluation technique, field experiments are not always appropriate and occasionally may be misused. Even the term is often used incorrectly as a label for demonstration projects that are at best primitive forms of experimentation and lack adequate controls for extraneous influences. More importantly, actual field experiments can be used to postpone major reforms, to avoid responsibility, to create public relations cannon fodder, to divert attention from serious issues, or merely to fulfill requirements (3). Even if the policymaker desires a careful evaluation of a regulatory change, field experiments require adequate time, financial resources, and professional talent to yield useful findings.

Beyond requisite time and financial support, the feasibility and appropriateness of field experiments depend on the following considerations (4):

1. Political considerations: Has the policy been irrevocably committed? Has adequate flexibility for post-evaluation alterations of the policy been allowed? Is the cost of delaying full-scale implementation less than the cost of a full-scale faux pas?

2. Ethical considerations: Are potentially adverse effects of the experiment harmful to individuals? Is experimentation just an excuse for delaying action or for distributing actions unevenly?

3. Technical considerations: Can substantive questions asked in the experiment be answered without resorting solely to "black box" explanations?

4. Administrative-managerial considerations: Can a working, knowledgeable team be gathered or trained to execute the study? Can they develop credibility with their clients (the policymakers)?

If any questions are answered "yes" in the first two considerations and "no" in the remainder, then experimentation will most likely be a fruitless or counterproductive exercise that should probably not be attempted.

Although political and related conditions vary among types and timing of proposals for regulatory change, there is nothing intrinsic to transportation that precludes the use of field experiments to evaluate major regulatory policies. The difficult task is to design the field experiment in a way that creates both timely and generalizable results. Fortunately, the transportation analyst can draw on past experience with the design of field experiments for social psychology, agriculture, and other areas. To properly utilize this experience, however, the analyst must master at least some of the terminology of these fields and understand the differences between evaluation and transportation. In particular, the spatial characteristics of transportation can affect the selection of experimental designs used previously in social policy research.

EXPERIMENTAL DESIGNS USED IN PAST EVALUATIONS

Most of the experimental designs that have been developed to evaluate social policies and programs can be applied to the evaluation of major regulatory changes in transportation. These designs have been inventoried in detail and classified by Campbell and his associates (5-7), whose works were placed in the transportation context by Charles River Associates (8) and Schmitt (9). The 28 experimental designs are grouped as follows:

1. True experimental designs: pretest-posttest control group design, posttest-only control group design, Solomon four-group design;

2. Quasi-experimental designs: (a) classic one-treatment before-and-after designs—nonequivalent control group design, nonequivalent dependent variable design; (b) separate-sample one-treatment before-and-after designs: separate-sample pretest-posttest design, multiple separate-sample pretest-posttest design, separate-sample two-pretest-one posttest design, separate-sample pretest-inclusive-posttest design, separate-sample pretest-posttest control group design, expanded separate-sample pretest-posttest control group design; (c) basic time-series designs: interrupted time-series design, interrupted time-series design with nonequivalent dependent variables, interrupted time-series design with nonequivalent control group, interrupted time-series design with switching replications; (d) one-group multiple-treatment designs: repeated treatment design, removed-treatments pretest-posttest design, equivalent time samples design, equivalent materials sample design; (e) multiple-group multiple-treatment designs: recursive separate-sample pretest-posttest design, reverse-treatment nonequivalent control group design, counterbalanced design, institutional cycle design; and (f) regression-correlation designs: regression discontinuity analysis design, quantified multiple control group posttest-only design, posttest-only design with predicted higher-order interactions, path analysis correlation design, cross-lagged panel correlation design.

Each of the experimental designs is a specific plan that includes procedures for (a) selecting the group to be exposed to the policy change (the "treatment group") and, for most designs, selecting a "control group" that is not exposed to the change for subsequent comparisons; (b) implementing the policy change (the "treatment"); and (c) making observations (called "pretests" when made before implementation of the change and "posttests" when made afterwards).

Campbell (10) has shown that an experiment can be designed after the change is implemented, provided that relevant conditions were adequately monitored and that the policy implementation was distinct (to act as a treatment). Whether devised before or after the regulatory policy is changed, the experimental design is a process of monitoring and analysis, carefully tailored around the implemented policy to counter problems of research validity.

The 28 designs are classed as true or quasi experiments. True experimental designs are generally the more powerful and desirable because the random assignment of individuals, organizations, or areal units to treatment and control groups assures that differences between the groups, which are not relevant to the policy change, can be statistically removed. Measured changes are then attributable solely to the policy being evaluated. Unfortunately, the ability to randomly select individuals or other units for exposure to a new policy is limited in transportation research. The random exclusion of individuals or other units from the affected transportation service is generally less practical for political, ethical, and geographic reasons (9). (How can potential patrons along a bus line be randomly allowed to use or not use the service?) Equivalence between treatment and control groups must therefore be assured by other means. These varied means that do not use random assignment techniques are quasi-experimental designs. (These designs may use randomization techniques for drawing sample observations from—but not for assigning membership to—treatment and control groups.) Both true and quasi-experimental designs are explained and their strengths and weaknesses documented in several inventories (5-9).

CRITERIA FOR SELECTING AN EXPERIMENTAL DESIGN

No one experimental design is a panacea for the problems of evaluation research, nor are all designs appropriate for the evaluation of a particular regulatory change. Because many variations of and additions to the list of designs given here are possible, design specifications for evaluating a particular regulatory change can and should be tailor-made to deal with the most important problems at hand. This flexibility in coping with diverse situations makes evaluation "cookbooks" impractical or inappropriate (11), so the transportation analyst must rely on experience, the previously cited inventories, and four basic criteria to select or modify an experimental design.

Criteria for the selection or modification of an experimental design to evaluate a regulatory change include the control of validity threats, timeliness, analytical complexity, availability of data-collection instruments, and applicability to recursive innovation development. These interacting criteria simultaneously establish the costs and constraints under which the evaluator selects an experimental design to provide the most credible findings possible.

Control of Validity Threats

The central purpose of an experimental design (and the most complex criterion for its selection) is to expose or eliminate validity threats so that the measured outcomes of a regulatory change can be attributed with confidence solely to the policy being evaluated. Validity threats are the generic labels for the concurrent events and extraneous factors to which the evaluation measures and their interpretation may be sensitive. These threats have been classified by four conditions for validating measured outcomes of an experimental policy and the relevance of those measurements to other situations (6).

One condition is that the action taken and the condition to be ameliorated actually covary. Covariance is not always obvious when sampling is involved. "Statistics are used for testing whether there is covariation... (and) function as gatekeepers. Unfortunately, there are fallible gatekeepers even when they are properly used, and they fail to detect both true and false patterns of covariation" (6). Problems associated with correctly determining covariation are called threats to statistical validity.

Another condition is that the field experiment itself is not a source of bias. Did the observed groups react unnaturally because they knew that they were part of an experiment? Did changes in the data-collection procedure—rather than changes in the condition being monitored—create measured differences? As proposed in the last century (12), questions such as these are answered by considering rival hypotheses to establish internal validity.

In social settings, change is rarely measurable directly. The data must be interpreted, generally with the aid of a theoretical construct or explanatory model. Problems of interpretation are called threats to construct validity, and these should be understood as threats to correct labeling of the cause and effect operations in abstract terms that come from linguistic usage or formal theory. Actually, the problem of construct validity is broader than this and obviously applies to attempts to label any aspect of an experiment including the nature of the setting, the nature of persons participating, and so forth (6).

For purposes of evaluating regulatory change and other transportation policies, a field experiment has little value if the results cannot be generalized beyond the specific time and place of the policy change. The conditions for generalizability are addressed as threats to external validity.

Listed below are 34 validity threats that have been identified from experience in evaluating experimental programs in education, criminal justice, and industrial management (6):

1. Threats to statistical validity: statistical power, fishing and error rate problem, reliability of measures, reliability of treatment implementation, random irrelevancies in the experimental setting, random heterogeneity of respondents;
2. Threats to internal validity: history, local history, maturation, testing, instrumentation, statistical regression, selection, mortality, interaction with selection, ambiguity about the direction of causality, diffusion or imitation of treatment, compensatory equalization of treatment, compensatory rivalry, resentful demoralization of respondents receiving less desirable treatment;
3. Threats to construct validity: inadequate preoperational explication of constructs, mono-operation bias, mono-method bias, hypothesis-guessing within experimental conditions, evaluation apprehension, experimenter expectancies, confounding levels of constructs and constructs, generalizing across time; and
4. Threats to external validity: interaction of the treatment and treatments, interaction of the treatment and testing, interaction of the treatment and selection, interaction of the treatment and setting, interaction of the treatment and history, and generalizing across effect constructs.

Very little of this experience includes research in which geographic space plays a significant role. Geographic space creates an additional set of validity threats, such as those listed below, particularly when observations are made on areal units (e.g., counties) rather than individuals or organizations:

1. Boundary distortions—overextension, truncation;
2. Partition distortions—spurious location and diffusion, spatial autocorrelation, excessive heterogeneity within zones, density bias;
3. Scale distortions;
4. Interaction of scale and constructs;
5. Interaction of scale and statistical validity;
6. Generalizability across scales;
7. Interaction of space and time; and
8. Confusion of spatial and aspatial issues.

As defined and explained elsewhere (13), these threats are commonly relevant to transportation research.

The types of validity threats and the degree of their control vary among experimental designs. Selection is largely a problem of matching a design's strengths and weaknesses with the threats that are most important to the policy or program being evaluated. For example, time-series designs are very useful for evaluating policy changes with slowly consummated effects because these designs control the internal validity threat of history rather well. The threat of history is a label for the likelihood that an event occurred in between measurements that affected the conditions being monitored but had nothing to do with the implemented policy. The potential for this threat obviously increases with greater lengths of time between observations. To evaluate major policy changes such as the removal of railroad exit restrictions, substantial lengths of time are necessary for monitoring to precede anticipatory reactions and to capture long-term adjustments; therefore, time series are most appropriate. Policy changes entailing shorter-term adjustments, such as the increased enforcement of safety regulations affecting intercity truck drivers, can be evaluated with more timely and less complicated before-and-after designs. These designs do not control for the validity threat of history as well as do time-series designs, but this threat is far less important because the periods between observations can be short.

Beyond the nature of the policy and its effects, the importance of a design's inherent strengths and weaknesses is largely determined by the evaluation's purpose. Designs that emphasize control of threats to external validity, for example, are very desirable for field experiments in federal regulations attempting to provide generalized information for a nationwide spectrum of affected parties and environments. This emphasis is far less important for a locally sponsored effort to solve a local problem. The former could include a regional experiment in changing federal entry restrictions on common carrier trucking; the latter could include a municipal government's experimental change in awarding taxicab medallions.

Although the relationships among experimental designs and most validity threats are well documented, the control of threats inherent to geographic space are little studied and potentially the most difficult to control. These threats are particularly important in the present context because experiments in regulatory change range in scale from local jurisdictions to the entire globe.

One effect of geographic space on the selection of experimental designs has already been cited: geographic proximity generally precludes the use of true experimental designs to evaluate network-based or areawide transportation services. It is rarely possible to allow randomly selected individuals or organizations to use a transportation service while excluding others.

Of the quasi-experimental designs, those that use either separate treatment and control groups or use multiple treatments with separate groups are particularly susceptible to validity threats related to geographic space. If groups are defined by areal units, these designs require the units to be far enough apart to eliminate social or economic contact; otherwise, the policy change or knowledge of its existence may diffuse to the control group, which would no longer provide a valid base-line comparison. On the other hand, greater spatial separation increases the possibility that local differences along social, economic, and political dimensions may distort the comparisons. For example, deregulation of a particular commodity by the federal government could be evaluated by implementing the policy change only within one region and comparing any subsequent differences in ton-kilometers between counties in the treatment (deregulated) region and the control (unaffected) region. Because the treatment and control counties would probably be in different states, comparisons would be distorted by different state regulations (e.g., truck size and weight restrictions) and by other factors that are extraneous to the removal of the rate restriction. Either the effects of these factors must be removed analytically, or the policymaker should be thoroughly warned of their potential existence.

The designs that suffer least from threats related to geographic space are those that allow all groups to be exposed to the policy change. In these designs, diffusion of the treatment (the policy change and its effects) to a control group is irrelevant. The difficulties in finding separated but similar locales is thus eliminated. For these reasons, the nonequivalent dependent variable design; most of the separate-sample, one-treatment, before-and-after designs; the one-group, interrupted time-series designs; and the one-group, multiple treatment designs are particularly useful for transportation research.

Timeliness

Although basic research can be afforded the luxury of long-term data collection and analysis, the evaluation of transportation services that are already on the street requires more immediate results. This criterion may preclude time-series and cross-lagged panel designs for short-term evaluations of just-implemented policies. Any of the designs that use more than one preimplementation measurement, such as the separate-sample, pretest-posttest design with two before measures, may also be precluded if the regulatory change is implemented before the pretests can be made.

Analytical Complexity

The criterion of analytical complexity is primarily an issue of interpretability by policymakers who are not technically disposed. As in the case of large-scale predictive models critiqued by Lee (14), Carver (15) notes that the credibility of an evaluation is diminished if its measures or design cannot be explained in lay terms. Regression-correlation designs are particularly difficult to portray simply, other than as a black box, and will probably be viewed with more suspicion than a simpler design.

Complexity is also a problem for the analyst if large quantities of data must be processed without computer assistance. Both the probability of error and the requisite staff hours are increased by increasingly complicated designs.

Although complexity is an important criterion, it is the least critical. If the other criteria are reasonably met, the selection of a design can finally be resolved by Occam's razor: the least complicated, viable design to implement and explain is the best.

Data-Collection Instruments

In contrast to the criterion of analytical complexity, the availability of data-collection instruments is crucial to the range of experimental designs that can be used to evaluate a particular regulatory change. These instruments, such as personal interviews, mailback questionnaires, tabulations of waybill entries, and mechanically recorded field observations, involve varying degrees of accuracy, respondent reactivity (i.e., falsifying reports), requisite personnel time and expertise, set-up time, processing capability, and monetary expense. Each attribute is magnified by the sampling rate (16), and the instrument's use may be constrained by public reactions to invasion of privacy, reporting burdens, and similar real or perceived issues that should be addressed by a comprehensive federal information policy. In general, the evaluator should select the most cost-effective sampling rate and the most accurate available data-collection instrument that is affordable, and then select a design from among those that the resulting data base will support.

Applicability to Recursive Innovation Development

Because policymakers are rarely omniscient when devising innovative policies, it is generally desirable to apply experimental designs in a recursive process of policy implementation, evaluation, policy refinement, reevaluation, and so on (9). The multiple-treatment designs are particularly well suited for this approach, although reusing one-treatment designs is also possible. If space and population size permit, the application of one-treatment designs in different locales for each policy adaptation is desirable. This alternative lessens the threats of patron reactivity and testing-induced change that are inherent to the multiple-treatment designs.

RECOMMENDED EVALUATION STRATEGY AND SOME CAVEATS

Given the speculative nature of much evidence on the effects of major regulatory change, it is important to learn as much as possible from any policy action, be it a small-scale experiment or a systemwide trial. When the effects are potentially adverse and widespread, the small-scale field experiment is preferable because it allows maximum control of validity threats and minimizes the consequences of inappropriate policy changes; however, major regulatory changes are occurring and the knowledge that could be gained should not be lost or subverted. In order to consistently improve the information base for future regulatory policymaking, the following evaluation strategy is proposed.

Whenever the political, ethical, technical, and administrative-managerial considerations indicate that experimentation is viable, proposed regulatory changes should be evaluated and refined through a four-step process:

1. Objectives of the policy change (treatment) are defined as measurable conditions.
2. The policy change is implemented under a carefully designed monitoring procedure that may or may not be initiated prior to the treatment, depending on the specific experimental design used. (Implementation may be in limited areas or nationwide, which will affect the design's selection.)
3. Controls on and results of the monitoring procedure are analyzed to determine whether the measured impacts are attributable solely to the policy change.
4. If the measured impacts are considered desirable, modifications of the new policy are implemented with concurrent experimentation until the objectives are maximized within the constraints of available resources. If the measured impacts are considered to be undesirable, policy objectives are reviewed to determine whether they were properly defined. New or modified objectives, policies, or both, are developed, and the process restarts at Step 2.

This process should be reiterated until doubts about the policy's outcomes are removed and the policy has itself evolved with the experience to provide the most desirable transportation service.

When political or other factors require immediate systemwide regulatory change, field experiments need not be abandoned as a source of validated information. If steps are taken to collect adequate data beforehand, then an experiment can be designed after the new policy is implemented. Although the results of a post-hoc experiment will probably be less robust than their premeditated counterparts, such results are better than the speculative hypothesizing and poorly validated evidence that are now commonplace.

Current arguments concerning the effects of transatlantic air travel are a case in point. Simple before-and-after comparisons of ridership levels neither confidently explain changes in these levels nor suggest directions for further regulatory change. An interrupted time-series design with nonequivalent dependent variables could control for the concurrent effects of changing seat capacity, leisure time, levels of disposable income, and similar factors that are not components of the new policy. It may turn out, for example, that diversions from other carriers and skyjacking frequency explain many changes in ridership. If such a finding were reasonably validated, then a pricing policy might be supplanted by a policy of intensified countermeasures against skyjacking to effect desired ridership changes.

Since regulatory changes are often imminent or already in effect by the time their evaluations have been mandated and financed, the maintenance of a comprehensive, ongoing transportation data base is critical. Without adequate data on transportation demand, stocks and flows, performance, and impacts, neither public nor private evaluators will be able to learn fully from the regulatory changes that are occurring now. If this experience is not to be lost, the federal regulatory and other transportation agencies must become comprehensive and anticipatory, rather than remain myopic and reactive, in designing their reporting requirements, periodic censuses and surveys, and information storage-and-retrieval systems.

Even when robust field experiments can be implemented in a timely and adequate fashion, whether before or after the regulatory change, they cannot be used without cognizance of some significant caveats. Already mentioned are the abusive purposes to be avoided and the preconditions to be met for experimentation to be worthwhile. More importantly, experimentation should not be seen as a guarantee of totally unbiased objective results. Even if an objective reality exists from all perspectives, the process of designing and interpreting an experiment, especially one outside of the laboratory, requires much professional judgment to deal with the rampant uncertainties of evaluation research. In dealing with subjectivity, experimentation differs from other approaches in its requirement that the evaluator be highly self-critical and seek all alternative explanations for any research finding. It is not enough to predict the present with historical data or to demonstrate a measurement's goodness-of-fit with someone's pet theory. All validity threats must be explained or otherwise be published as explicit grains of salt for the policymaker's consideration.

Perhaps the greatest difficulty with experimentation is the need to specify objectives and impact measures. Although attention to construct validity may reduce some of the problems in specifying measures, it is very difficult to determine appropriate goals in the byzantine world of transportation policymaking. For example, was Amtrak created to provide an economically efficient rail passenger service, to serve other societal ends, to provide a hidden subsidy to freight railroads, or to provide a politically expedient method of abolishing passenger service from the rails? Each purpose embodies a very different set of appropriate measures and their valuation may be in conflict.

A final caveat is the need for a change in the attitudes and strategies among policymakers and their analysts. When public officials advocate a policy change as a solution rather than as an attempt to solve a major problem, then a careful evaluation exposes them to failure. Campbell (17) suggests an alternative strategy: Emphasize that the status quo is untenable and so important that several tentative solutions should be tried. A specific disappointment can thus be rationalized as only one in an ongoing series of efforts to deal with a difficult and multifaceted condition. The analyst's attitudes must also change. Although experimentation uses many commonplace techniques, these techniques must be used in a highly self-critical fashion rather than to prove a point or go on a statistical fishing expedition. One must always ask: Does the policy work, why, and how might it work better?

Careful experimentation is not a panacea for resolving the problems of regulated transportation; however, it does provide sensitive tools and a powerful discipline for developing policy. Experimentation can help better define the questions surrounding regulatory change, but even a successful experimental program does not eliminate our radical ignorance of the future. It may, however, increase the general confidence that what is true and workable today will persist into tomorrow (18).

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Evaluation of Trucking Entry Control: The Exempt Backhaul Case

Merrill J. Roberts, University of Maryland, College Park

This paper traces the potential effects of limiting trucking regulation by permitting independent operators to carry nonexempt general commodities on backhauls following the transportation of exempt agricultural products. These effects are determined by vehicle flows that establish the physical opportunity for traffic switches among regulated carriers and independent operators promoting efficiency, economically feasible modifications in traffic patterns, and the behavioral patterns of the regulated carriers, independent operators, and shippers. The logistical data are drawn from an Interstate Commerce Commission survey of more than 13 000 truck trips in 1975 that defines the competitive relations among the industry segments. These data indicate little prospect for productivity improvements due to saving empty trips; however, cost savings by independent operators are possible. They would gain in lease-bargaining strength, but orderly price competition between them and the regulated carriers would be quite limited except for Florida where it might be extreme. Service improvements are not indicated, but some deterioration may be hypothesized for Florida's outbound general commodities. The proposed regulatory change offers disadvantages with minimal gains. Adverse effects arise from the continuing regulation of outbound general commodities that can destabilize the Florida trucking market; the eligibility rule for inbound general commodities, which both limits competition and prevents intermarket capacity mobility; and the danger of disorderly market behavior. Even though regulation may be wasteful according to the dictates of the competitive model, partial deregulation may be counterproductive unless it is carefully designed so that the residual element of freedom and control mesh and do not clash as in this case.

Much of the economic support for partial or complete decontrol of the trucking industry is based on the classic competitive model. Manifesting the model's stipulated economic attributes, trucking should produce more efficient pricing and output results with less or no regulation. This model was designed, however, for commodity production in a "state of nature" and not for transport service production by an industry that has been strictly regulated for more than 40 years. The model's ability to predict the benign consequence of withdrawing that complete control from this complex and fragmented industry, with its institutional encrustation and behavioral idiosyncracies, warrants examination (1).

The analytical starting point is present conditions and not a competitive norm. Empirical analysis, largely lacking to date, is required to grasp the institutional and behavioral realities that will shape the market dynamics and associated results of a regulatory change (2). Accordingly, this paper assesses the potential market results and associated impacts on affected interests of a specific step in trucking deregulation. It is designed both to explore key elements of the evaluation process as it is applied to an incremental change in regulation and to develop insights and conclusions about its effects.

The paper focuses on issues raised by the role of an industry segment composed of independent truckers categorized as owner-operators. More specifically, it deals with a subgroup specializing in hauling exempt agricultural products but that is excluded from carrying other (general) commodities except as lessors for the regulated carriers.

The restrictions on the market participation of these operators are said to hamper trucking productivity, impair trucking services to agricultural product shippers, and constrict artificially the economic viability of an important segment of the transport system and a socially significant set of small businesses. Entering the general commodity transport markets only as agents of the carriers (through vehicle and driver leases), they are without real bargaining power under prevailing oligopsony and, accordingly, are inadequately compensated.

The postulated change would permit these owner-operators to carry nonexempt general commodities on backhauls following the transportation of exempt agricultural products. The permitted backhaul movement must return to or near the front-haul origin or to intermediate points on reasonably direct routes. For the most interesting case, competitive pricing freedom is also stipulated for the eligible hauls and no restrictions are placed on the amount of capacity the independent operators are allowed to introduce into these markets. A more restrictive but less interesting case would require observance of published tariff rates and impose a "grandfather" requirement.

It is argued that this proposal would introduce a new competitive element into general commodity trucking with favorable implications for productivity. Efficiency gains would result from the elimination of duplicated vehicle travel, from squeezing down high markup rates, and from the dynamic pressure of competition itself. Desirable income distribution effects would also be realized from traffic attraction to the independent operators and from their strengthened position in lease negotiations, along with shipper-carrier redistributions from rate reductions.

Translating changed regulation into market effects involves a long and complex process; predicting the results of a regulatory proposal entails an equally intricate analysis. The broad leap from a posited change in regulation to its indicated impacts on affected interests requires numerous analytical steps to match the induced market dynamics. The empirical results of a regulatory change are sensitive to subtle market relationships; by the same token, the analytical results are sensitive to the associated measurements.

This paper concentrates on three sets of key relationships that significantly affect the potential results of implementing the postulated regulatory change:

1. Traffic and vehicle flows determine the physical opportunity for efficiency-promoting traffic switches between the common carrier and independent operator segments.
2. Intersegment competitive relations regarding vehicle-kilometer costs and reverse-direction revenues determine whether the options available to both segments are economically feasible for achieving modifications in operating and traffic patterns that promote efficiency.
3. The decision criteria and behavioral patterns of the regulated carrier and independent operator participants and of the shippers determine the extent to which managerial implementation of the efficiency potential will be pursued. These responses are conditioned by economic criteria, institutional constraints, and behavioral (subjective) propensities. The realized responses will be transmitted to the markets through output and price effects involving intersegment and intermarket resource shifts in both primary (invaded) and secondary markets, depending on demand and supply elasticities.

LOGISTICAL PROFILE

The dynamics that would be triggered by the proposed regulatory policy change, and hence its ultimate impact, depend initially and primarily on the logistics profile. This profile delineates the flows of commodities and vehicles associated with transportation service to the relevant markets and thus establishes the physical base for potential market dynamics.

The relevant industry segments embrace the regulated carriers and independent operators. The former class basically covers irregular-route common carriers certified by the Interstate Commerce Commission (ICC) and authorized to carry general commodities between the agricultural production origins and their markets. The commodity categories are agricultural products exempt from regulation and general commodities requiring ICC authorization for their transportation. The primary hauls involve the transportation of exempt commodities from the important agricultural produce areas to major consuming areas in the Northeast and of general commodities into the agricultural regions. Relevant movements are those for which the two industry segments are acceptable substitutes, as determined primarily by vehicle compatibility, regulatory restrictions, and timing.

A primary logistical consideration is the directional balances of the loaded vehicle movements. In general terms, the hauls of interest involve a preponderant flow of manufactured commodities from the Northeast and a much smaller reverse movement. Agricultural commodities move in large volumes into the Northeast. The vehicle flows thus entail a larger capacity requirement from the Northeast than in the return direction for the regulated carriers. The main haul of the exempt operators is accordingly in the opposite direction into the Northeast. The indicated balances are mitigated, however, by the hauls of general commodities from the Northeast by the independent operators through leases to the regulated carriers and of exempt products by the regulated carriers.

The lack of empirical data has seriously hampered research in truck transportation markets. Although the problem persists, some significant progress is being made. The logistics data for this paper were drawn from the tapes of the ICC survey reported in Empty/Loaded Truck Miles on Interstate Highways During 1976 (3). This survey covered more than 13 000 vehicle trips in that year, providing details of vehicle type, carrier category, origin and destination, commodity carried, and whether the vehicle was under lease. The data extracted cover loaded and empty vehicle trips in vans (including refrigerated vans) by owner operators and irregular-route common carriers between specified agricultural production areas and the Northeast. The producing regions are Florida, Texas, and the West (California, Arizona, and Washington). Loads are segregated between exempt agricultural products and general commodities.

These logistical data establish the physical feasibility of effecting efficiency-producing changes in vehicle use. Further, they define and measure the competitive relationships between the industry segments that could result from the regulatory proposal. Favorable efficiency effects can stem from two bases. The logistical pattern may feature reverse-direction empty backhauls that could be eliminated by the proposed institutional change; this action would make the independent operators an acceptable substitute for the regulated carriers. The new arrangement may also permit the use of a more efficient substitute.

Observations about the comparative efficiency of the two industry segments are discussed next when addressing the economic feasibility of market developments from the regulatory proposal. But assumptions or hypotheses about comparative economic advantage are required to warrant the first step of determining physical feasibility. If the economic conditions underlying substitution are lacking, the physical arrangement of vehicle flows is of little consequence and significant intersegment competition is unlikely. This discussion thus postulates an economic basis for the independent operators to compete effectively for the traffic of the regulated carriers as a result of the regulatory proposal. The alternative assumption is sterile because it implies that the independent operators are powerless to respond to the physical opportunities that may be available in the face of the regulatory change.

Although some attributes of the vehicle flows are rather general, the most interesting aspect is strong regional differentiation. The diversities involve such variables as proportions of exempt traffic, traffic balance ratios for commodity categories and industry segments, vehicle employment, and vehicle leasing. The variations consistently combine to produce highly differentiated logistical patterns for the several regions that strongly condition the potential response to the regulatory change.

One critical regional difference is in traffic balances. The predominant West displays the most unbalanced traffic flows for each commodity category but a fortuitous combination that produces a highly balanced composite pattern. The associated industry segment imbalances are significantly in opposite directions but are relatively modest. This feature permits only minor productivity gains from the elimination of redundant vehicle kilometers. Traffic flows are characterized by a very high degree of regulated carrier participation in exempt product hauls.

Texas, the least important quantitatively, is characterized by a critical reversal. Unlike the West, where the predominant flows are inbound for the regulated carriers and outbound for the independent operators, inbound traffic is heavier for both groups in Texas. This anomaly arises because of the relatively small share of exempt products in the traffic mix. The independent operators are thus used relatively more for hauling outbound general commodities under lease and accordingly assume the haul pattern of the regulated carriers. This pattern offers no opportunity to reduce redundant vehicle kilometers.

In contrast to the West, Florida is characterized by an unusually high proportion of regulated commodities in its outbound mix, partly reflecting frozen foods shipments. As a result, the regulated carriers demonstrate a very close traffic balance and an orderly in-and-out flow of vehicles. The independent operators provide a sharp contrast, experiencing by far the most unbalanced traffic of any category with poor inbound vehicle utilization. As in Texas, the prospects are dim for improved vehicle utilization. The logistics do permit, however, a straight substitution of independent operator vehicles for those of regulated carriers for inbound general commodity loads.

Another significant attribute of the logistical pattern is the sharp regional difference in the critical determinants of potential competition. The following table summarizes some key relationships for the three regions (the first line indicates the relative weights of the separate markets; the other lines relate the indicated variables to the inbound general commodity loads in index form for comparative purposes):

Load Category	West	Florida	Texas
Weight (inbound general commodity loads) (1)	0.58	0.25	0.17
Inbound general commodity loads (2)	100	100	100
Independent operator eligible loads (3)	67	78	31
Reserved loads, regulated carriers (4) (2 minus 3)	33	22	69
Vehicle supply, regulated carriers (5)	35	49	47
Vehicle supply, independent carriers (6)	68	109	62
Guaranteed loads, regulated carriers (7) (smaller of 4 or 5)	33	22	47
Price competition loads (8) (5 minus 4)	2	27	0
Direct carriage option loads (9) (3 minus 8)	65	51	31
Ratio, available vehicles to eligible loads (10)	1.2	1.7	1.1

The general commodity loads for which the independent operators are eligible are determined under the regulatory proposal by the number of outbound loads of exempt agricultural products they carry, with the balance "reserved" for the regulated carriers. The Texas ratios are the most favorable for the regulated carriers, and the Florida ratios are the least favorable. The ratio of available carrier-owned vehicles is low in the West; independent-operator vehicles are relatively numerous in Florida. The number of loads guaranteed for the regulated carriers (the reserved loads covered by owned vehicles) is relatively low in Texas and high in the West. A significant indicator of market penetration is the direct-carriage-option-lease category, which denotes the number of loads that the independent operators are eligible to carry directly without competition from available carrier vehicles. This option is relatively low for Texas but high for the West because of the low ratio of carrier-owned vehicles. Another important indicator is the direct price competition between the regulated carrier and the independent operator segments; this denotes a confrontation between eligible independent operator vehicles and carrier vehicles that exceed the number of reserved loads. Florida is highest in this respect and Texas is lowest. The final vehicle ratio is a more inclusive indicator of competitiveness, introducing the ineligible independent operator vehicles. They can participate through straight leasing without the direct-carriage option, correspondingly can reduce the availability of that leasing option to eligible carriers, and can force the equivalent number of operators into price competition if they are to participate in the traffic. Florida is by far the highest for this significant indicator, with nearly two vehicles available for every load for which the independent operators are eligible; this indicates severe competition in contrast to Texas and the West. If this competition is sufficiently severe to jeopardize inbound regulated-carrier capacity, outbound general commodity service is thereby threatened.

The competitive patterns revealed in the vehicle logistics and thus the possible effects of the regulatory proposal are quite different for the several regions. In summary, the West offers little possibility of price competition but a great opportunity for the independent operators to engage in direct solicitation as an alternative to leasing. The Florida case also provides substantial opportunity for direct solicitation as a negotiating base for leasing, but in addition features a high degree of potential price competition both between the regulated and independent segments and among the independents. The Texas pattern emphasizes the status quo because the independent operators are ineligible to carry directly a sizable share of the trips, which precludes price competition and limits their bargaining power in leasing.

Although these logistical arrangements independently do not determine the competitive impacts that might be expected from relaxing regulation of independent operator backhauls, they set the stage and define limits. They are critical for determining the options available to the industry segments under changed regulatory rules.

COMPARATIVE ECONOMIC ADVANTAGE

The vehicle trips depicted represent a case of joint supply with multiple products resulting from provision of bi-directional transportation capacity. The round trip is the unit of output and cost because it is impossible to meaningfully segregate directionally the joint vehicle operating costs. Of course, they may be supplemented by the special costs peculiarly associated with the actual movement of traffic (beyond the provision of capacity) in each direction. These special costs would include extra fuel, loading and unloading, use-related depreciation or repair, billing, and solicitation. Although the round-trip sequence is not strictly realized in all cases because of some overlapping regional flows and triangular trips, that pattern is generally characteristic.

Cost is a patently significant element in determining the comparative economic advantage of the two industry segments, including those for providing round trips between the Northeast and the agricultural areas and those incurred specially from hauling loads in each direction. The other significant element in this joint product case is the comparative revenues received from the outbound general commodities and exempt agricultural products. Thus, the amount each industry segment must get for hauls from the Northeast to participate in the market depends both on their round trip and special costs and on their opposite direction revenues.

Costs

The relationship between the generalized costs of the regulated carriers and independent operators has not been established definitively. The uncertainty of this relationship is reflected in the ICC's long and largely unsuccessful struggle to deal with it in industry rate cases where leased transportation is significantly involved. Despite the problems, recent research appears to be fruitful and indicates a slight cost advantage for exempt owner-operators over irregular route common carriers employing company drivers and operating similar equipment (4). This cost advantage (approximately 5 percent) is not overwhelming but would permit a meaningful degree of competition.

Of potentially greater significance than the vehicle operating costs, however, are those for the marketing and other ancillary services rendered by the carriers for themselves and their lessors and by brokers for the exempt operators. The commission charged by the brokers is around 8-10 percent of the trip revenues; carriers typically keep 25 percent (5). Direct comparison is difficult because the services performed are not identical. The hypothesis that the carrier commission contain a rental for the use of a relatively scarce operating certificate is not verified by any significant correlation between the extent of vehicle leasing and favorable operating ratios. One attempt at unraveling these comparative costs suggests an advantage for the brokers (6).

More significant than present arrangements, however, are the cost and effectiveness of the market mechanism that might emerge with the competitive freedom involved in the regulatory proposal. An integrated marketing system may be contemplated that capitalizes on available information technology to provide more cost-effective services than are feasible for individual carriers under the present system. These speculations, combined with the vehicle operating cost indications, make it reasonable to posit some cost advantage for the independent operators.

Revenues

The revenue side of the comparative economics coin is even more speculative. The regulated general commodity rates are not uniform by commodities and the exempt agricultural product rates are subject to sharp seasonal swings. Furthermore, neither set of rates is immutable. An expansion of the role of brokers in organizing exempt truck transportation could firm up the agricultural commodity rates. By the same token, if demand elasticity permits, any competitive assault on the general commodity rates from the Northeast might warrant an authorized increase in the reverse-direction rates.

Some insights are available, however. The significant participation of the regulated carriers in exempt hauling, particularly from the West, warrants the hypothesis that the earnings from the exempt and general commodity traffic categories would balance out over the year of seasonal swings in the agricultural produce rates. This hypothesis is supported by limited inquiry in the industry. It is at least doubtful that any one-way revenue considerations would overbalance the cost advantage posited for the independent operators.

Available empirical evidence appears to support hypotheses pointing to a modest competitive advantage for the independent operators. Such an advantage is far from overwhelming in general and would be most uneven in its application, depending on specific commodities carried by particular regulated carriers and by individual operating efficiency. The advantage appears to be great enough, however, to permit an entry by the independent operators into the general commodity markets and to suggest that the regulatory proposal would not be trivial because of a lack of economic opportunity for these operators.

DECISION PATHS

Decision options responsive to the logistical and economic feasibility of competitive interaction are distinguished by reference to four traffic categories characterizing the inbound general commodity movements that represent the field for the potential new competition:

1. The guaranteed loads for the common carriers are both reserved by limited independent operator competitive eligibility and covered by owned vehicles.
2. Direct-carriage-option-lease loads are open to the independent operators by virtue of their eligibility for hauling general commodities but are not confronted by regulated carrier vehicle capacity able to compete for the traffic.
3. Straight-lease loads are the reserved loads neither covered by owned vehicles nor subject to the direct-carriage-leasing option because of limited independent operator eligibility.
4. Price competition loads fall within the limits of independent operator eligibility but are confronted with competition from regulated-carrier vehicles in excess of the number required for reserved loads.

These categories represent only proportions of the inbound general commodity loads because the traffic is not earmarked. The options are exercised and the decisions made by individual carriers and operators and not by composite industry segments. Orderly markets require employment of the independent operator vehicles; this action is consistent with the overall regional allocations. Independent operators can cover the entire market, but the regulated carriers are limited by their operating authority. If, for example, independents should offer shippers reduced rates in direct solicitation when favorable leasing arrangements are available, owned vehicles prohibited from turning to other commodities or hauls are displaced. The indicated result of this excessive price competition is capacity disruption and service deterioration. Orderly market results may be elusive where alternative business arrangements are required and only some of the capacity is freely allocated among submarkets.

Despite the complications, these categories establish the types of decisions and the options open to members of the two industry segments. The guaranteed and straight-lease loads create no additional options and require no new choices by either type. The direct-carriage-option-lease loads give the independent operators the choice of leasing or carrying the traffic on their own account; the carriers' choice is to meet the lease conditions or relinquish the traffic. The price-competition loads give both parties little choice in the usual sense of whether to institute active competition with a price reduction to increase market share. Rather, in the "one-on-one" relationship that would prevail in these markets, independent operators in specific situations must quote less than the initial price in order to attract the business requiring a regulated carrier response. There is a link between the direct-carriage and price-competition loads arising from the determination of the traffic to be accorded each type of treatment. The carriers can open with lease concessions in one category in an effort to protect it or another from price competition. Similarly, the independent operators can choose where they will direct their competitive attention.

The decision path will embrace both outright competition from some independent operator vehicles and the threat of such competition from others, with concomitant effects on lease terms and on the negotiating position of the trucking parties. Some independent operators stand to gain either by entering direct carriage or from more favorable leases. On the other hand, those under lease may lose out to other independents in the new competition. Competition among the independent operators could drive rates down to a level yielding less revenue than that provided by the leases.

Leasing

In one independent operator choice, leasing proceeds must be compared to the profit potential from direct carriage. For the carriers, the minimum acceptable share of revenues is established by their costs of providing marketing and ancillary services. For the independent operators, the maximum allowance is set by the cost of obtaining these services elsewhere, ostensibly from brokers. Preliminary measurements are established by the 25 percent share usually retained by the carriers and the 8-10 percent commission paid the exempt brokers as adjusted for service differences.

The objective, however, is not the percentage of revenue but the actual dollar yield, requiring further consideration of the respective base revenues. The 25 percent retained by the carriers applies to the trip yield derived from current rates. The 10 percent commission taken by the brokers, on the other hand, may apply to rates forced down by price competition. To illustrate, with rates of $1.00 and $0.80, the 25 percent would give the independent operator a net of $0.75 compared to $0.72 that results from a more favorable share of the lower rate. The anticipated yield from direct market participation is clearly an imponderable where price competition is involved, particularly when compounded by the joint cost influence.

The independent operators would probably favor leasing even where direct carriage is an option because rate concessions would probably be required. The regulated carriers would also lose from price competition and would accept it only as the last resort. Having no alternative in the short run, leasing carriers (lessees) have every incentive to maintain this relationship on the most profitable basis possible. Those with both owned and leased capacity, the most common configuration, would presumably make leasing adjustments to forestall price competition.

Price Competition

In assessing potential market reactions to the proposed regulatory change, a fundamental question is the extent of the price cuts that might be expected under competition. In the absence of regulatory or other institutional restraint, the competitive solution is dictated by the joint product-joint cost character of these markets. The cuts would depend on the relative elasticities of demand in the primary market and in the reverse direction. In purely competitive terms, equilibrium would be reached when the prices on general commodities moving from the Northeast provided the required marginal capacity with revenue sufficient to cover fully round-trip and special directional costs. However, competitive reductions would be restrained by leasing, with the available lease revenues setting the lower rate limits. Because the independent operators would have no incentive to press rates below this level, this limit also hinges on the real gap between the commissions of the carriers and the brokers.

Shipper Decisions

Given the required logistical and economic relationships, shippers are the ultimate arbiters of the primary market effects of the regulatory proposal. Their attitudes and decisions will significantly determine the results of carrier-operator choices between leasing and direct carriage and, where it arises, the outcome of price competition. The critical question is the acceptability of independent owner-operators as direct substitutes for the regulated carriers for transporting nonexempt general commodities.

Shippers may be hesitant to deal directly with independent operators because of feelings of abstract loyalty to common carriers and because of concerns for service and financial responsibility. On the positive side, there is evidence that the performance of independent operators may be superior to that of hired drivers (7). Such attributes should carry over to direct carriage to confirm that their solicitations would not be rejected by shippers on grounds of inferior or undependable service.

In addition to these inferences, manifestations of shipper behavior are instructive. Using agricultural cooperative vehicles on backhauls provides some direct evidence. Recent ICC hearings involving this traffic elicited testimony from important shippers, such as General Mills, Eli Lilly, and PPG Industries, of the attractiveness of the service and the rates offered by operators bypassing the organized common carrier segment (8).

Although the shipping community's probable general acceptance of independent operators as direct carriers is indicated, an effective market mechanism would be required as a substitute for the functions performed by the regulated carriers under the lease arrangements. In addition to brokerage and related activities, some assumption of responsibility for service and financial reliability would probably be required.

Indicated Results

The leasing preference indicates a decision option hierarchy for both the independent operators and the regulated carriers. The independent operators, under the impetus of the regulatory proposal, are the active force in accommodation and the regulated carriers are the responders. Self-interest criteria indicate that independent operators with the direct-carriage option will want to match up with a regulated carrier that requires a lessee. This may be done as well under direct carriage only if rate reductions are not required to obtain the haul. Direct price-competition confrontations with regulated carriers would be reserved for the minimum number of loads requiring it in terms of regional logistics. Carriers, on the other hand, would in the abstract prefer straight leasing with ineligible independent operators or carriage in owned vehicles free of price competition, depending on vehicle ownership posture. Leasing adjustments under the pressure of the direct-carriage option and price competition are the regulated carriers' last resorts.

The regional (macro) markets have a place for each of these categories. Slotting the independent operator capacity is confounded, however, by the absence of earmarked traffic and atomized and relatively uninformed decision making. This potential market imperfection suggests and reinforces the need for the advanced mechanism previously indicated.

Perfect slotting would not be achieved in any case. In practice, the independent operators would distribute their capacity among the carrier-defined submarkets according to economic opportunity reflecting both traffic availability in geographical terms and profit potential, engaging in price competition or filling a vehicle void as circumstances dictate. But the essential interchangeability of the independent operators in combination with their dominant market weight should dictate an outcome in which the marginal rewards of price competition and leasing are fairly equalized.

This hypothesis is strengthened by the common denominator variable that measures the limits of both competitive price cuts and the lease-bargaining advantage from the direct-carriage alternative. The critical variable of cost and service is associated with the commissions of the brokers and lessee carriers that determine the cost advantage that the broker-independent operator combination would have in price competition. The result of the regulatory change thus depends even more on the market mechanism that would be created to serve the direct-carriage option of the independent operators and its efficiency in performing the required services.

MARKET RESULTS

Having traced through the aspects of the evaluation process dealing with the logistical attributes, economic capabilities, and behavioral patterns, the interesting question centers on the ultimate implications of the associated factors that have been established, hypothesized, or postulated. The results are not only cloudy but highly sensitive to relatively few key variables. These include the directional balances of the two traffic categories and industry segments, economic capabilities as measured in cost and revenue relationships, vehicle ownership patterns of the carriers, and the market mechanism that emerges. Alternative readings of or experiences with these variables can produce analytical or real market results that range from trivial to fundamental.

Despite this sensitivity, the observations and plausible hypotheses advanced thus far warrant further hypotheses with respect to potential market effects of the regulatory proposal. Because of the highly differentiated logistical bases in the several regions, it is necessary to deal with these markets separately and, at the same time, to recognize their respective weightings in assessing overall results. The hypotheses advanced here deal with efficiency effects, rate reductions, segment impacts, and service effects.

Efficiency Effects

Potential efficiency sources are the elimination or reduction of unutilized vehicle kilometers or capacity substitution. The logistical evidence indicates that the prospects for improving vehicle utilization are dim for the West and nil for Florida and Texas. Some modest savings in vehicle operating costs might arise from the substitution of independent operator for regulated carrier capacity. More impressive opportunities appear to arise from the performance of marketing and ancillary services by a new market mechanism more effective than the existing carrier arrangement. Real resource savings may not be impressive, however, if the regulated carriers necessarily maintain these functions for other unaffected services. Cast in terms of the carriers' incremental costs, there may be no significant savings.

Rate Reductions

Potential rate reductions are a function of cost savings and competitive pressures. Assuming cost savings (consistent with the preceding efficiency discussion), the rate effects will depend on and be limited by validation of these underlying hypotheses: (a) Current competitive pressures associated with the ICC's liberal policy in granting irregular-route truckload certificates have minimized the significance of high markup rates; (b) the independent operators and regulated carriers have a mutual interest in avoiding direct price competition and associated rate reductions; and (c) market logistics in the several regions indicate that, with orderly market behavior, competitive pressures between regulated carriers and independent operators and among independent operators for the general commodity loads will be minimal. Florida is a probable exception, but the preponderant weight of the West and Texas spells minor results overall.

There is empirical support for the first hypothesis and the other two are highly plausible given the indicated logistics patterns. The major hypothesis of minimal rate reductions resulting from the regulatory proposal is accordingly attractive.

Industry Segment Impacts

The regulated carriers face reduced lease revenues in all regions; also, Florida faces probable competitive pricing and vehicle utilization losses. Because of the market differentiation, impacts on regulated carriers depend on the distribution of their business between these three markets collectively and other unaffected markets and among these three regions. Owning carriers in the western and Texas markets should suffer minimal effects.

The independent operators would gain in the West and Texas from improved lease revenues or from alternative direct carriage. The Florida implications are less clear because of conflicting indications from improved vehicle utilization and rate reduction losses, but with a probable net gain. In addition, some excess profits may be foreseen in the West and Texas.

Service

There are no indications that warrant a hypothesis for service improvement from carrier substitution. However, the advanced market mechanism envisioned could offer improvements, particularly in terms of vehicle availability as a result of broader integration of shipper needs and vehicle supply. Any improvement could be offset by the deterioration of service for Florida's outbound general commodities as a result of the destabilization of the inbound flow of carrier capacity. Disorderly market behavior also poses a threat of service deterioration.

CONCLUSIONS

If the hypothesized market effects are realized, the regulatory proposal would offer limited benefits while posing the threat of unfavorable impacts. Although some efficiency improvement is possible, an income transfer from the regulated carriers to the independent operators is more certain. However beneficial this might be to the financially depressed independents, it is tainted by the possibility of adverse corollary conditions. This income transfer is the indicated result of market aberrations that limit competition and would thus tend to deny shippers the benefit of any reduced costs. Although price reductions appear likely in the Florida market, this advantage might well be realized at the cost of destabilizing the regulated carrier segment, essential in the northbound movement of general commodities. Prospects for the independents in Florida, on the other hand, are not significantly enhanced despite the prospective deterioration in the condition of the regulated carriers. In effect, the income transfer would largely be from regulated carriers in Florida to independent operators in Texas and the West.

The adverse indications stem from institutional factors inherent in the proposal. Opening up the general commodity transportation market in just one direction creates harmful aberrations. In the case of joint output with the vehicle round trip as the production unit, directional differences in demand but not in market participation imposed by regulation are an integral part of the case. Also disruptive is the regulatory restraint created by the eligibility rule that ties the independents' participation in the general commodity markets to specific exempt hauls. The resulting market conditions could permit excess profits for independent operators in the western and Texas markets concomitant with a vehicle surplus in Florida. Another market aberration arises from the freedom of the independent operators to cover the entire inbound general commodity market while the regulated carriers are confined to their certificated services. This restriction opens the possibility for disorderly market behavior and unwarranted price reductions that impair service.

These considerations suggest several plausible propositions involving the applicability of the competitive model. Even though regulation may be wasteful according to model dictates, partial deregulation can be counterproductive unless carefully designed so that the residual elements of freedom and control mesh and do not clash as in this case. The competitive model does not reliably predict results when disruptive market constraints are maintained. Reliability requires that its highly restrictive postulates and conditions be met. It does not follow from the model's logic that a step toward deregulation is superior to the status quo. These propositions do not imply, however, limitations on the competitive model's predictive capabilities with respect to an unregulated trucking industry. The objectionable features of the proposal examined arise precisely because of continued restrictions on the transportation of outbound general commodities, of the regional inflexibility of independent operator vehicle employment, and of the close confinement of one set of suppliers in combination with the more universal freedom of the other.

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Motor Carrier Freight Classification and Costs of Providing Transportation Services

Allan D. Schuster, Graduate School of Business, University of Texas at Austin

The Interstate Commerce Commission is currently conducting an investigation of the motor carrier classification system. One aspect of this investigation centers on whether the factors used to categorize shipments by different rate classifications significantly impact the costs incurred by motor carriers in providing transportation services. This paper presents the results of several multiple-regression analyses on data collected by the Interstate Commerce Commission for use in motor carrier cost studies. The regression analyses provide an indication of the factors that cause differences in motor carrier costs. Conclusions are drawn about these factors and their effects on the costs incurred by motor carriers in providing transportation services.

The Interstate Commerce Commission (ICC) recently completed an investigation into the possible restructuring of motor carrier less-than-truckload (LTL) shipment rates (1). One finding of this investigation was that a number of parties to the rule-making proceeding criticized the current motor carrier classification system. Criticisms levied against the classification system included excessive complexity and the use of factors to classify shipments that have minor impact on transportation cost.

It is well known that the National Motor Freight Classification (NMFC), which is used by all general commodity motor carrier rate bureaus except those providing primary service in New England, is essentially a copy of the railroad's Uniform Freight Classification. The shipment characteristics used by the NMFC to determine the class ratings for individual commodities are shipment density, liability to damage, liability to damage other commodities with which it is transported, perishability, liability to spontaneous combustion or explosion, susceptibility to theft, value per kilogram compared to other articles, ease or difficulty in loading or unloading, stowability, excessive weight, excessive length, care or attention necessary in loading and transporting, trade conditions, value of service, and competition with other commodities transported. In contrast to these characteristics the Coordinated Classification used by New England-area motor carriers uses only the characteristics of shipment weight and density to determine a shipment's class rating. Schuster (2) and Winship (3) have also shown that the NMFC permits extensive internal cross-subsidies to occur between shipments of different weights, class ratings, and those that are moved in different traffic lanes.

The purpose of this paper is to determine whether the factors used to place shipments in different rate classifications are related to the costs incurred by the general freight motor carrier in providing transportation services. First, an overview of the ICC's motor carrier cost model is presented. Second, research findings that indicate factors causing differences in motor carrier costs are presented. Finally, conclusions are drawn as to whether factors used in the classification process affect the costs incurred by motor carriers in providing transportation services.

ICC MOTOR CARRIER COST MODEL

The ICC model of the general freight motor carrier firm (4) postulates four major sets of activities required to accomplish intercity freight movements: (a) line haul (intercity movement), (b) pickup and delivery, (c) terminal platform handling, and (d) billing and collection. The activities—with the exception of billing and collection—undertaken by motor carriers to effect commodity movements include loading on truck at shipper's dock, unloading at terminal to cart, loading highway trailer from cart, unloading highway trailer at destination terminal, loading city delivery truck, unloading delivery truck at consignee's dock, unloading at break bulk terminal, and loading on another trailer for destination terminal. Break bulk terminal adds two more stage handlings, and interlining adds at least four more handlings.

The ICC cost methodology uses two formulas, Highway Forms A (5) and B (6), to estimate the costs of motor carrier freight movements. The formulas postulate that motor carrier costs are primarily a function of shipment weight and density. In other words, the ICC motor carrier cost formulas assume that, for shipments of equal weight, shipment density is a major determinant of the differences of the variable costs experienced in handling individual shipments. Thus, of the 15 factors used in the rate classification process, the ICC motor carrier cost formulas use only one factor—shipment density—as a major explanatory variable of differences in motor carrier variable costs.

FACTORS IN MOTOR CARRIER COSTS

Alternative Cost Methodology

An alternative methodology, which is described in greater detail elsewhere (7,8), can be used to cost motor carrier transportation services. This methodology is similar to the ICC's cost methodology in two major aspects: (a) its use of the line-haul, pickup and delivery, terminal platform handling, and billing and collection activities as major cost centers of the motor carrier firm and (b) its use of demand and operational data gathered from motor carrier firms to parameterize the motor-carrier-firm cost model.

The methodology differs, however, from the ICC's motor carrier cost methodology in three key areas:

1. The methodology focuses on determining the variable costs attributable to specific shipments to a greater extent than the ICC's cost methodology, which focuses to a higher degree on determining systemwide average costs.
2. The cost methodology uses many factors, including the number of pieces comprising a shipment and urban congestion, to explain motor carrier costs in addition to shipment weight and density, which are included in the ICC motor carrier cost formulas.
3. Sophisticated computer-based statistical techniques, primarily multiple-regression analysis, are used throughout the cost methodology; however, the ICC motor carrier cost methodology is, except for the sampling of carrier demand and operational data, essentially a manual procedure.

Data Base

The data base used to analyze motor carrier costs consisted of (a) demand and operational data obtained by the ICC for use in its 1971 territorial motor carrier cost studies (9-12) and (b) the shipment platform handling data obtained by the ICC in its recent platform study (13). The cost study data provided information on the weight, traffic type, and number of shipments in 13 weight brackets; the operational characteristics of pickup and delivery trips and data on the shipments handled on each trip; the operational characteristics of line-haul trips and the weight of the shipments handled on each trip; and the frequency with which shipments that are members of various weight brackets and traffic types are handled over the terminal platform.

The shipment platform handling data contained information on individual shipment characteristics, the time required to handle shipments over the platform, and the means used to handle individual shipments over the terminal platform. The following sections discuss the factors that affect motor carrier costs in the platform handling, pickup and delivery, and line-haul cost centers.

Factors Affecting Platform Handling Costs

Multiple regression analysis was used to analyze the platform handling data collected in the ICC's 1969-1970 platform study. The methodology used to conduct the analysis and the results of the analysis are reported more completely in studies by Schuster and others (7, 14).

Table 1 shows the variables that the multiple regression analyses indicated affected platform handling time for shipments handled over the platform manually and by dragline and also by forklift. The multiple-regression analyses permit the following conclusions to be drawn relative to the factors that significantly impact shipment platform handling time and, therefore, shipment platform handling costs:

1. The factors that affect shipment platform handling time differ depending on whether the shipment is handled manually or by forklift. Thus, the handling time function for unitized (containerized or palletized) shipments is different from the platform handling time function for nonunitized shipments.
2. For shipments handled manually, the major determinants of shipment platform handling time are the number of pieces comprising the shipment and the distance the materials handling equipment moved the shipment across the terminal platform.
3. For shipments handled by forklift, the number of trips made by forklift across the platform and the total distance the forklift moved are the major determinants of shipment platform handling time.
4. The factors of shipment weight and density, which are used in the ICC motor carrier cost formulas to determine platform handling costs, have relatively little impact on shipment platform handling time. Shipment density becomes important only when it exceeds 480 kg/m^3 (30 lb/ft^3). The ICC platform study contains the most recent data in the public domain on shipment density. Table 2 contains the proportions of shipments in various shipment density classifications. Table 2 indicates that the platform handling times of less than one-third of all shipments are affected by shipment density.
5. The size of the terminal dock will also affect shipment platform handling time.
6. Shipment platform handling strategies (defined in terms of materials handling equipment used, cross-docking, and so forth) used for shipments in different weight brackets have a significant impact on the time required to handle shipments over the terminal platform.
7. The data support the conclusion that the time required to handle shipments, on a per unit of weight basis, differs for shipments in different weight brackets. There are significant economies of scale realized in handling shipments in the heavier weight brackets, particularly if the shipment is unitized.

Factors Affecting Pickup and Delivery Costs

A pickup and delivery trip can be disaggregated into the time spent at each stop (stop time) and the time and distance spent traveling to and from the terminal and between each stop (running time and distance traveled). Consequently, pickup and delivery trips can be measured in terms of the time and distance required to complete each trip.

It is helpful to understand the ICC's pickup and delivery cost model in order to contrast it with the re-

Table 1. Variables that impact shipment platform handling time.

Variable	Shipment Handling Method	
	Forklift	Manual
Number of pieces in the shipment		X
Shipment weight		X
Shipment volume		X
Shipment density		X
Distance moved over platform	X	X
Number of trips across platform	X	
Truck-to-truck movement[a]	X	X
Platform-to-truck movement[a]		X
Four-wheel hand truck used to move shipment[a]		X
Interchange receiving shipment[a]	X	

[a]A qualitative, or dummy, variable.

Table 2. Percentage distribution of shipments in various shipment density classifications.

Shipment Density Classification (kg/0.3 m^3)	Shipments Handled by Forklift (%)	Shipments Handled by Means Other than Forklift (%)	All Shipments (%)
0-2.24	3.27	10.44	9.58
2.25-4.49	13.45	18.99	18.33
4.50-6.74	11.64	14.84	14.45
6.75-8.99	7.27	10.34	9.97
9.00-13.49	15.64	14.39	14.54
13.50-17.99	14.91	10.48	11.01
18.00-26.99	14.18	11.37	11.71
27.00 and over	19.64	9.15	10.40

sults of the cost analysis reported in this paper. The ICC model assumes that pickup and delivery trip stop time is a linear function of the number and weight of the shipments handled at each stop. This relation is applied to the total stop time for the shipments belonging to each of 13 shipment weight brackets to obtain an average stop time per 45 kg (100 lb) for each weight bracket. Any variation of actual stop time from average stop time is assumed to be a function of shipment density. A set of density adjustment ratios is determined that allocate stop time variations to shipments in various density classes.

Pickup and delivery trip running time and distance traveled are assumed to be a function of the number of stops made in each pickup and delivery trip. Variations in the number of stops made in a pickup and delivery are assumed to be partially explained by shipment density. Average pickup and delivery distance traveled per trip is divided by average pickup and delivery trip running time to obtain an average vehicle speed that can be used to estimate the running time and distance for trips with specified number of stops.

The ICC model assumes pickup and delivery trip stem running time and distance traveled, i.e., the time (distance traveled) from the terminal to the first stop and from the last stop to the terminal to be a constant, regardless of the characteristics of the locality in which the trip was made. Consequently, the model computes the average stem running time and distance traveled and allocates it to shipments in each weight bracket on the basis of the ratio of the total weight of the shipments in each weight bracket to the total weight of the shipments in all weight brackets.

The ICC's cost methodology contends that shipment density is a major factor in the determination of pickup and delivery costs. In order for shipment density to be a major factor affecting pickup and delivery trip distance traveled and running time, pickup and delivery vehicles would have to be filled to their cubic capacity prior to reaching their maximum weight limitation a substantial portion of the time. However, McDermott's study of urban pickup and delivery operations (15) indicates that the typical vehicle engaged in pickup and delivery operations uses a low percentage of its available cubic capacity.

Further evidence on the degree of vehicle capacity use can be found in ICC documents. Carriers participating in ICC territorial cost studies submit a Field Report of Highway Form A, which contains information on the rated load capacity and cubic capacity of their line-haul, peddle-trip, and pickup and delivery vehicles. A vehicle's rated load capacity is the weight of a typical mix of shipments that will fill a vehicle's available cubic capacity. Thus, the rated load capacity considers shipment density because the carrier must consider the density of a typical shipment in making such a determination. It was believed that the rated load capacity of pickup and delivery vehicles would be a conservative measure of the weight that could be carried in the typical pickup and delivery vehicle.

The ratio of the mean total weight of the shipments delivered to the mean rated load capacity measures the utilization of the vehicle's available capacity when the vehicle departs the terminal. The ratio of the mean total weight of the shipments picked up to the mean rated load capacity measures the vehicle's capacity utilization on the vehicle's return to the terminal. Because motor carriers generally make deliveries prior to pickups, the degree of capacity utilization during a pickup and delivery trip will decline as deliveries are made and increase as pickups are made. Thus, the greater of the pickup or delivery mean capacity utilization statistics can be viewed as the maximum mean capacity utilization of the vehicle during the entire pickup and delivery run. The data shown in Table 3 were developed using this logic. The data in Table 3 indicate that the highest mean capacity utilization is 53.05 percent in the New England II cost territory. The data also indicate that, if pickups were made prior to deliveries, the mean capacity utilization of pickup and delivery vehicles would not on the average be exceeded.

If shipment density does affect pickup and delivery running time and distance traveled, the cubic capacity of pickup and delivery vehicles would have to be filled before all of the stops that could be made on the trip could be accomplished. Unfortunately, data are unavailable on the variance of rated load capacity. An approximation of the probability of filling the pickup and delivery vehicle, prior to making all of the stops that could have been made on the trip, can be computed assuming that the mean rated load capacity is fixed and computing the probability, on the average, of exceeding the mean rated load capacity. This was accomplished by using a one-tailed test (the right tail of the distribution curve) and assuming that the distributions of shipment weights picked up, delivered, and total shipments handled on the trip were normally distributed. These probabilities are shown in Table 3. Using the maximum probability for either shipments picked up and delivered (from Table 3), it appears that shipment density will impact pickup and delivery running time and distance traveled costs in only 21.51 percent of the pickup and delivery trips.

Does shipment density affect pickup and delivery stop time? An answer to this question can be obtained by viewing the results of the A. T. Kearney study (16). It shows that the motions required to load and unload shipments at the stop are similar to the motions required to handle freight on the terminal platform. Consequently, the results of the analysis of shipment platform handling time are applicable to pickup and delivery stop time.

Table 3. Use of pickup and delivery vehicle capacity in nontrailer drop runs.

	Related Load Capacity Use					
	Pickups		Deliveries		Total Shipments Handled in Run	
Cost Territory	Average Use (%)	Probability Vehicle Filled	Average Use (%)	Probability Vehicle Filled	Average Use (%)	Probability Vehicle Filled
New England I	33.86	0.1151	46.53	0.1727	79.67	0.4254
New England II	43.76	0.1641	53.05	0.2151	96.81	0.4836
Central	36.01	0.1050	52.76	0.2000	88.16	0.4354
Eastern-Central	28.40	0.0337	38.35	0.0589	66.58	0.2640

Table 4. Variables that impact pickup and delivery trip time and distance traveled.

	Pickup and Delivery Trip Component		
Variable	Distance Traveled	Running Time	Stop Time
Number of stops	X	X	
Participant in New England II region cost study[a]	X	X	X
Distance traveled during trip		X	
Urban area population[a]	X	X	X
Whether trip involved a trailer drop[a]			
Time of day when trip was made[a]		X	X
Shipment weight			X
Number of shipments			X
Stop made at carrier's terminal[a]			X
Stop made at freight forwarder[a]			X
No shipment or pallet pickup[a]			X
Stop is a delivery[a]			X
Participant in Eastern-Central territory cost study[a]	X	X	X

[a]A qualitative, or dummy, variable.

Shipment density primarily impacts shipments that are (a) handled manually at the stop and (b) whose density is 480 kg/m³ (30 lb/ft³) or more. The majority of these shipments are in the upper less-than-truckload (LTL) and truck-load (TL) weight brackets.

In summary, shipment density appears to have little effect on pickup and delivery costs. If shipment density has little effect, what factors impact pickup and delivery costs? This question was answered by analyzing the pickup and delivery trip data collected by the ICC for its 1971 territorial cost studies. Three multiple regression analyses were performed using the pickup and delivery trip data. The methodology used to conduct the analyses and the results of the analyses are reported by Schuster and others (7, 17). Table 4 shows the variables that the multiple regression analyses indicated affected pickup and delivery trip distance traveled, running time, and stop time.

The regression analysis of pickup and delivery trip distance traveled indicated that (a) the number of stops made on the trip, (b) the population of the urban area in which the trip was made (a proxy for urban area size and congestion), and (c) whether the carrier is a long-haul (Eastern-Central cost study carriers) or short-haul carrier (other 1971 cost study carriers) were major factors impacting trip distance traveled. The regression analysis also showed that there were discontinuities and changes in the slope of the variable "number of stops."

The multiple regression analysis of pickup and delivery trip stop time indicated the following as affecting pickup and delivery stop time:

1. The factor that the regression analysis showed had the greatest impact on pickup and delivery stop time was shipment weight. The regression analysis showed that shipment weight provided an explanation of more than 50 percent of the variation in pickup and delivery stop time. Because shipment handling time at each stop is the major determinant of pickup and delivery stop time, it was believed that shipment weight in this model acted as a proxy variable for a host of other shipment factors considered the real determinants of pickup and delivery stop time. These factors have been presented in the discussion of shipment platform handling time and include the number of pieces comprising the shipment, shipment density, the distance the shipment was moved on the consignee's-consignor's dock, whether the shipment was palletized or containerized, the type of materials handling equipment used at the stop, and so forth. Consequently, it appears that data should be recorded and analyzed on these factors and shipment weight in order to better explain the determinants of pickup and delivery stop time.

2. The number of shipments handled at each stop significantly affected pickup and delivery stop time. Because this variable represented freight bill processing time, significant economies in stop time can be achieved by consolidating several smaller shipments into a single large shipment.

3. The population of the urban area in which the stop was made had a significant impact on pickup and delivery stop time. Because the equation's intercept term can be interpreted as the mean waiting time for the vehicle to receive a space at the dock where the stop was made, the value of the intercept is a measure of the typical vehicular congestion at shipping and receiving docks in urban areas of different populations. In general, it can be concluded that pickup and delivery stop times are longer in urban areas that have populations greater than 500 000.

4. The regression analysis of pickup and delivery stop times showed that pickup and delivery stop time per unit of weight declined as shipment weight increased. Thus, significant economies can be realized by carriers if shippers adopted transportation service strategies that increased average shipment weight (e.g., shipment consolidation and multiple shipment tender). In addition, it showed that pickup and delivery stop times vary by the population of the urban area in which the stop is made, the time of the day at which the stop was made, whether the shipper is a carrier or a freight forwarder, whether the stop involves pickups or deliveries, and whether the carrier was a long- or short-haul carrier.

The regression analysis of pickup and delivery trip sample data has several implications for rate making. First, many of the current factors used in the rate classification process have little, if any, impact on pickup and delivery costs. In particular, shipment density appears to have much less impact on pickup and delivery costs than is assumed by both the classification process and the ICC motor carrier cost formulas.

Table 5. Pickup and delivery performance factors and costs, Eastern-Central Territory, by urban area population category, 1978.

Performance Factors/Costs	Urban Area Population 100 000-249 999	250 000-499 999	1 000 000-2 499 999	2 500 000-4 999 999	5 000 000 and over
Stem distance traveled (km)	25.245	30.721	39.247	43.010	49.202
Distance traveled between stops (km)	26.108	32.686	40.490	44.462	46.378
Total distance traveled (km)	51.353	63.407	79.737	87.472	95.580
Stem running time (min)	65.800	70.245	100.243	109.391	124.534
Running time between stops (min)	68.050	75.975	103.417	112.849	117.386
Stop time (min)	210.789	220.441	241.635	262.689	273.754
Total time (min)	344.639	366.661	445.295	484.929	515.674
Variable distance costs ($)	9.783	11.984	15.191	16.681	18.209
Variable time costs ($)	47.738	50.789	61.681	67.171	71.429
Total variable costs ($)	57.521	62.773	76.872	83.852	89.638
Cost/45 kg ($)	0.297	0.324	0.397	0.433	0.463
Minimum variable costs (%)	100.00	109.13	133.64	145.78	155.84

Note: 1 km = 0.6 mile, 1 kg = 2.2 lb.

Table 6. Percentage of single-line LTL shipment costs by cost center, 1971.

Shipment Weight (kg)	Cost Study Territory: Central Region — Platform Handling	Pickup and Delivery	Line Haul	Billing and Collection	Total*	Eastern-Central Territory — Platform Handling	Pickup and Delivery	Line Haul	Billing and Collection	Total*
0-66	16.18	64.17	6.19	13.46	100	25.05	56.32	8.91	9.72	100
67-134	19.67	57.47	12.09	10.76	100	29.19	47.17	16.34	7.30	100
135-224	21.90	51.35	17.82	8.93	100	31.05	40.10	22.98	5.87	100
225-449	21.18	47.21	24.49	7.12	100	36.92	31.82	27.24	4.02	100
450-899	20.13	40.92	33.94	4.99	100	31.64	26.25	39.22	2.88	100
900-2249	17.62	32.82	46.41	3.15	100	28.44	19.32	50.51	1.73	100
2250-2699	8.99	27.59	61.29	2.23	100	15.87	16.94	65.99	1.20	100
2700-4499	9.40	24.16	64.82	1.62	100	16.50	14.56	68.07	0.87	100

Note: 1 kg = 2.2 lb.
*Totals may not add to 100 percent due to rounding errors.

Second, urban congestion has a major impact on pickup and delivery trip costs. Table 5 contains some selected operational and cost data for a 10-stop pickup and delivery trip by an Eastern-Central territory carrier involving 14 LTL shipments in five selected urban area population categories. The data show that pickup and delivery costs in urban areas with more than 5 million population are more than 50 percent higher than pickup and delivery costs in urban areas in the 100 000-249 999 population category. The data also show that the mean pickup and delivery trip takes more than eight hours to complete in the most heavily populated urban areas, even though the pickup and delivery vehicle experiences a load factor of less than 50 percent utilization of rated weight capacity.

Third, the multiple regression analysis of pickup and delivery data clearly supports the use of multiple tender rates as a means of reducing pickup and delivery costs. Finally, the data support the possibility of carriers offering lower rates if pickups and deliveries are made during hours other than the normal working day.

Factors Affecting Line-Haul Costs

Two major factors affect line-haul costs: shipment density and line-haul load factor. Because freight rates are quoted on the basis of shipment weight, shipment density is a major factor in determining the proportion of line-haul costs that should be allocated to individual shipments. Shipment density affects line-haul costs because the density of the commodity determines the total weight of the commodity that can be loaded on a line-haul vehicle. As long as the commodity's density is sufficiently high so that the vehicle's maximum weight limitation can be equalled or exceeded by a vehicle load of a commodity, shipment density is a neutral factor and the ratio of shipment weight to traffic-lane load factor or maximum weight limitation can be used in allocating line-haul costs to individual shipments. If the commodity's density is such that a vehicle load of the commodity will not exceed the vehicle's maximum weight limitation, the ratio of the space occupied by the commodity to the total space available, or the space occupied by shipments of neutral density at traffic-lane load factor, can be used in allocating line-haul costs to individual shipments.

Line-haul load factor affects line-haul costs. In general, the higher the line-haul load factor, the lower the costs of moving a shipment of constant weight. The major problem with the ICC's line-haul cost methodology is that it assumes line-haul load factors are constant in all traffic lanes. Knowledgeable observers of the motor carrier industry know that this assumption is false because there are significant variations in load factor between traffic lanes. Thus, if a carrier routes traffic through his network of routes so as to achieve relatively high load factors in all traffic lanes, the carrier's costs will be significantly lower than a carrier that has significant variations in load factors between traffic lanes.

Variable Costs by Shipment Weight

The preceding sections of this paper have discussed the factors that affect motor carrier costs in three of the four motor carrier cost centers. Costs in the fourth cost center, billing and collection, were not discussed, as they are generally assumed to be constant for shipments of a given traffic type. This section discusses how the proportion of total variable costs that can be attributed to each cost center vary by shipment weight.

Table 6 shows the proportion of single-line LTL shipment variable costs by cost center for eight LTL shipment weight brackets. Three major conclusions can be drawn from the data displayed in Table 6. First, shipment density has relatively little effect on the costs associated with smaller LTL shipments. As the analysis of the individual cost centers indicated, shipment density primarily affects line-haul costs. Line-haul costs become relatively important only when shipment weight exceeds 900 kg (2000 lb).

Second, shipment density has a relatively large impact on the costs associated with shipments weighing in excess of 900 kg. In fact, in the case of TL shipments that require no platform handling services, shipment density and load factor are the major factors affecting shipment variable costs. Finally, factors that affect terminal costs, e.g., number of pieces, unitization, and urban congestion, are the major factors impacting the costs of LTL shipments weighing less than 900 kg.

CONCLUSIONS

Four major conclusions can be drawn from the preceding analysis of motor carrier costs. First, different factors affect transportation costs for shipments of different weights. For shipments weighing more than 900 kg, shipment density is the major factor affecting motor carrier costs. In fact, as shipment weight increases, shipment density becomes increasingly more important.

Other factors used in the current classification process that affect motor carrier costs are stowability and the ease or difficulty in loading and unloading shipments. These classification factors were implicitly considered in the cost analysis as the shipment's degree of unitization and the number of pieces comprising the shipment. These factors particularly affect the costs of shipments weighing less than 900 kg. It also should be noted that, because these factors are not explicitly considered in the ICC's motor carrier cost formulas, it is difficult for the current classification system to accurately reflect the costs incurred by motor carriers in providing transportation services to the smaller LTL shipments.

Second, the cost analysis has shown that other factors not included in the present set of classification factors are important in determining motor carrier costs. Three of these factors are (a) traffic-lane load factor, (b) urban congestion, and (c) the strategy the carrier uses to provide pickup and delivery and platform handling services. Traffic-lane load factor is extremely important for the costs charged to the heavier LTL and all TL shipments, two factors that are extremely important for LTL shipments weighing less than 1.1 t (2000 lb).

A third conclusion is that the current classification system requires modification in order to represent the factors that significantly affect the costs incurred by motor carriers in providing transportation services. Only three of the current 15 NMFC classification factors can be considered cost causative. Two of these three factors can only be implicitly considered in any motor carrier cost formula. The third factor—shipment density—pertains to less than one-third of all shipments, although it is explicitly considered in both the current ICC motor carrier cost formulas and the NMFC as a major determinant of motor carrier costs.

Finally, the New England Coordinated Classification does not reflect the costs incurred by motor carriers in providing transportation services to shipments that require large amounts of terminal services (LTL shipments). The Coordinated Classification can reflect the costs incurred in moving TL shipments if the individual rate basis reflects traffic-lane load factors.

In summary, if a current objective of national transportation policy is to make motor carrier freight rates more cost related, the current classification systems—both the NMFC and the New England Coordinated Classification—must be revised to explicitly include shipment characteristics that have a significant impact on motor carrier costs. Revising the classification system in this manner can also encourage the development of innovative practices in the pricing of motor carrier transportation services.

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Observations of Unregulated Transport Service in Honduras

Jeffrey S. Gutman, Tippetts-Abbett-McCarthy-Stratton, Washington, D.C.
Ralph E. Rechel, Rechel and Revis, Washington, D.C.

This paper presents statistical and substantive observations of the growth of freight service in a developing country that has no significant government regulation. These observations are then used to make some comparisons with U.S. regulatory policy. From November 1975 to May 1978, the authors served as advisers to the Director General of Transport of the government of Honduras. The data and observations used in the paper are derived from various surveys covering a broad spectrum of transport operators throughout Honduras. Where statistics are unavailable, the discussion is based on the authors' personal observations. In Honduras, a highway-oriented economy, transport services are developing through the initiatives of a large number of individual owner-operators, loosely organized cooperatives, and a small number of multivehicle companies. As the paved highway network is being completed, transport service is growing and the level of service is improving with little, if any, government involvement. Market-determined freight rates generally reflect the costs of providing the service and vary reasonably with highway conditions and fluctuating seasonal demands. The unregulated trucking industry has successfully met the rapidly changing needs of the Honduran economy. Although the government maintains broad regulatory powers in reserve, in practice it has minimized political intervention in the economic marketplace. The Hondurans have rejected many U.S.-style regulatory objectives and have instituted nonregulatory measures to meet valid objectives.

Although primarily concerned with the evolution from nonregulation to some regulation in a small country, this paper also comments on how these findings relate to the debate over transport deregulation in the United States. As a backdrop for this discussion, it is useful to summarize regulatory objectives as they have evolved in North America and northern Europe.

The principal regulatory objectives that have evolved in the United States, based primarily on Anglo-Saxon legal concepts, include the following:

1. Equity in the treatment of the public, i.e., the same rates for apparently similar services, and uniform rules (in published tariffs) for carrier-shipper relationships;
2. Maintenance of an "orderly market" in order to avoid the excesses of competition—benefiting the public with stability and quality (or at least uniformity) of services while assuring "honest, efficient and well-managed carriers" a reasonable return on investment and relief from "cutthroat" competition.
3. Providing assured service at fixed rates for all members of the shipping and traveling public, no matter where they are located or how infrequently they use the service, through development of a doctrine of common carrier responsibility defined and enforced by the government; and
4. Closely related to the equity issue, the protection of users (the public) from paying excessive profits to monopolists or semimonopolists.

Other countries outside the North American and northern European areas have developed indigenous (as differentiated from imported) regulations with three objectives:

1. Obtain greater stability in provision and pricing of services (no apparent cases outside Europe and ex-British colonies);
2. Protect state railways from highway competition (also an objective in the United Kingdom at one period and still so in former dependencies); and
3. Allocate entrepreneurial highway transport operations to selected classes or ethnic groups (ethnic Malays in Malaysia, army officers in Spain).

A key difference in most of these other countries, even those giving great weight to stability in pricing and providing services, has been the little emphasis placed on regulation attempting to specify precise rates, routes, and commodities.

During the debate over the pros and cons of deregulating the truck and railroad industries in the United States, one of the major drawbacks has been the lack of data and real-world examples that might lend credence to the theoretical projections of what would occur under different deregulatory schemes. Indeed, it is difficult to find a country that has not practiced some form of government intervention in the economics of the transport service sector, thus making international comparisons subject to a long list of limitations and caveats.

The following case study, an observation of unregulated transport in Honduras, is not devoid of such caveats. The geographic, economic, and cultural differences and the lack of intermodal competition limit the degree to which direct comparisons with the United States can be made. What is unique about the Honduran experience and pertinent to the discussion of freight regulation, however, is that it is a truly unregulated system. It provides an opportunity to strip away the multiple layers of regulatory policy and to observe the open exchange of transport supply and demand as described in microeconomic theory. The case study provides an example of a nation that rejected the validity of many of the objectives of regulatory policy adopted by the United States and, in many instances, chose different means other than transport regulation to meet what they considered to be valid objectives.

This paper describes the development of the Honduran trucking industry in each of the major commodity sectors. The government's response to actual or supposed problems is presented and the most significant lessons for the United States are discussed.

OVERVIEW OF HONDURAN ECONOMY AND TRANSPORT DEVELOPMENT

Honduras, with a population of less than 3 million and an area of more than 112 000 km^2 (43 000 miles^2) is one of the lesser developed countries of Central America. Since the early 1900s, the Honduran economy has centered on the development of the Atlantic Coast, where North American banana companies were cultivating and exporting bananas and other types of tropical fruits. Over the last 15 years, however, the country has expanded its range of exports and currently is experiencing unprecedented economic growth.

As the transport network expanded and other productive regions of Honduras gained access to international markets, the export of lumber, coffee, tobacco, meat, and sugar increased. This broadening of export commodities was a crucial factor in the economic recovery of the country after the north coast was devastated by Hurricane Fifi in 1974. With fertile valleys that have yet to reach their productive capacity and relative political stability, Honduras has been successfully attracting large amounts of investment capital from international lending agencies and from other nations.

The characteristics of Honduran production and the country's topography have contributed to the importance of highways and the trucking industry in the domestic movement of the nation's goods. Honduras, the most mountainous country of Central America, is noted for its rugged terrain; it has had to overcome many challenges in the development of its transportation infrastructure. With its production centers well dispersed in numerous valleys throughout the country and with strong seasonal fluctuations in production, Honduras needed a transport mode that was efficient in handling small loads of low-value commodities, a mode that could easily be transferred among geographic regions to offset seasonal highs and lows and that could handle the rough terrain. Therefore, the government concentrated on developing a road network that was followed by the growth of the trucking industry. Only along the north coast, where large-scale banana plantations and level terrain made it feasible, were rail lines constructed for internal transport.

The primary transport network in Honduras is a recent development. The banana companies introduced the first road-building equipment, which was used to construct feeder roads from the banana plantations to the ports of Honduras. The first paved road was the Pan American Highway, built across the southern portion of Honduras after World War II; it has little effect on internal Honduran transport. It was not until 1958 that the government began a comprehensive program to construct modern highways. This program has resulted in the present primary system scheduled to be completed within the next few years.

The road network connects the production centers of the country with the main urban centers—Tegucigalpa (population, 300 000) and San Pedro Sula (population, 150 000)—and with the centers for international trade, including the ports (especially Puerto Cortes on the Atlantic coast) and the Central American Highway network. As the primary system nears completion, the emphasis is expected to shift toward building and improving penetration and feeder roads from the farming areas to regional market centers.

The development of transport service in Honduras, both passenger and freight service, has been largely due to the efforts of individual owner-drivers, many of whom were farmers from outlying rural areas. Due to an unusually good harvest during a year of high market prices (such as coffee in 1976), many of these farmers managed to obtain a loan for a bus or a small truck and began serving their immediate neighbors to and from the regional market centers. With the extension of the road network and the concomitant economic growth, more Hondurans were financially able to enter this industry and the number of independent operators proliferated. Large-scale freight transport service did develop around the specialized needs of specific sectors within the economy such as mining, cement, and petroleum; but most of the nation's freight is still handled by small operators with less than three vehicles per firm.

As a result of this individualistic type of development, the country's transport sector consists of a multitude of diverse types of transport organizations, which operate a wide range of vehicles imported from all parts of the world with varying capacities and ages. In spite of this seemingly anarchic situation, the development of transport service has followed a logical pattern, based on the principles of open competition without government economic regulation. It has resulted in a relatively high level of service throughout the country for both passengers and freight at apparently low fares and rates even by developing-country standards.

Most of the Honduran truck fleet of about 13 000 vehicles is comprised of two-axle, six-wheel, single-unit trucks (C-2) with a tare weight of 5200 kg (11 465 lb) and a gross permitted weight of 12 000 kg (26 455 lb). Their popularity is due principally to their relatively low price ($15 000 excluding interest in 1977), which, when coupled with interest rates of around 15 percent, represents the maximum amount affordable by typical owner-drivers. The other popular truck type is a three-axle, 10-wheel, single-unit truck (C-3) with a tare weight of 7800 kg (17 195 lb) and a gross permitted weight of 18 500 kg (39 685 lb). Together, single-unit vehicles comprise about 94 percent of all trucks.

The age distribution of the fleet, based on a review of registered trucks in 1974, shows that most trucks are less than 10 years old, with a large proportion of vehicles manufactured in 1970 and 1973. More recent surveys (1977-1978) revealed that the single-unit, two-axle trucks tended to be imported new from Japan, with an apparent wave of imports in 1974 and 1975. Most vehicles are underutilized, accumulating only 50-55 000 km (30-33 600 miles) annually, which indicates that there is an excess of capacity during certain seasons of the year, especially in the agricultural production centers where such vehicles are dominant.

Tractor-trailer combinations, mainly three-axle tractors pulling two-axle trailers (T3-S2), represent the remaining 6 percent of truck types purchased. These vehicles are imported used from the United States and were manufactured in 1967-1969. Because they are primarily operated by larger transport cooperatives and companies, their utilization is much higher, averaging around 80 000 km (49 700 miles) annually.

Another aspect of Honduran truck service that is important in comparing the U.S. situation is that most operations are full truckload (TL) service. The low income per capita and the geographic concentration of the consumption centers limit the need for less-than-truckload (LTL) services.

TRANSPORT SERVICE BY MAJOR COMMODITY GROUP

The organization of Honduran trucking and the effects of regulation are best observed through a discussion of transport service for various commodities.

Agricultural Products

The transport of agricultural products represented the beginning for most transport operators. Often the operation began with one person in a village who owned a pickup truck and agreed to carry his neighbors' produce to market. Today, this type of service is still provided, but the prevalent operation is one in which a "transportista", or transport agent, located in the local market center, has two or three vehicles to bring in produce from the tributary farms. The transportista usually buys the produce at the farmgate, transports it to the local or regional market, and then sells it. The farmers refer to this agent as an "intermediario", or intermediary, and the difference between the market price and the farmgate price is the fee charged for transportation and marketing.

Although there is very little information on the operations of the intermediarios, field interviews with farmers and transport operators suggest that the fluctuation of farmgate prices, and thus transport rates, is related to the accessibility of the farm. Where farms are isolated, there is little or no competition and the farmer must sell his produce at depressed prices to the first truck that arrives. In areas where access is easier, the competition between intermediarios drives up farmgate prices. The intermediario, meanwhile, receives a differential for serving higher-cost inaccessible areas. Some argue that the differential is exorbitant.

More industrialized agriculture such as tobacco and cotton is served by transportistas who are paid only for carrying the cargo. Again, the service is dominated by owner-driver operations with the exception of sugar, which is handled by a cooperative.

In general, the truckers refer to the transporting of agricultural goods as their most lucrative service. The agricultural demand for transportation usually peaks during a few specific months of the year. For example, in Danli, the harvesting of rice, coffee, tobacco, and cotton will all occur at about the same time. Thus, there is a temporary shortage of truck capacity from January to March. Tariffs rise and the farmers, unable to store their produce, pay premium prices. In the other months, however, there is an actual excess of trucking capacity and tariffs fall, often to the level of out-of-pocket costs. The unregulated free market system provides adequate truck capacity, even for the peaks, at rates that are roughly equivalent to the amount of stress a shipper places on the system; thus, peak-period users pay the costs of unused capacity during the off season.

Thus, an extensive flexible for-hire truck service has been stimulated by the agricultural development of the country. The problems, some actual and others supposed, that have arisen and have generated a demand for regulation in that sector are that

1. The ease of entry and the seemingly lucrative rates in the peak season have attracted too many inexperienced operators who misjudge the complex seasonal fluctuations and who fail after one or two years (no statistics are available yet on business failures in trucking, and there has been no apparent effect on service from such instability), and
2. Farmers in outlying areas receive depressed prices from intermediarios that, in turn, restrict production.

Lumber

There are more than 110 sawmills located throughout Honduras. Some are located near the urban centers and others are located nearer to the logging areas. The government is directly involved in the lumber industry. As the owner of the nation's forest reserves, the government agency—la Corporacion Hondurena Para El Desarrollo Forestal (COHDEFOR)—issues permits to mill owners to buy and cut the trees in specific areas. After processing the lumber, the mill owners either sell to domestic consumers or to the government marketing agency (also COHDEFOR) for export. By setting the port price for lumber that it buys for export, the government has, in effect, set the price of transport to the port that is implicitly included.

Transport operations in the lumber industry are dominated by independent owner-operators in for-hire service, often the same ones who are serving nearby agricultural production centers. The carrying of logs from the forests to the mills is handled by various owner-drivers who use older two- and three-axle trucks to maneuver through the rugged terrain to and from the forests.

From the mill to the market centers, whether the ports or main cities, the route is a mixture of earth, gravel, and paved highways. Approximately 56 percent of the trucks handling this traffic are two-axle and 20 percent are three-axle vehicles; the rest are tractor-trailer combinations.

Unlike the farmers, the mill owners can schedule their shipments around the peak agricultural season so that they hire truck operators when there is an excess of carrying capacity. As a result, the tariffs are very low and the trucker, in order to cover out-of-pocket costs, has had to critically overload the vehicle. These low tariffs have also stifled the use of private transport by mill operators; under different tariff situations this would be a logical transport alternative.

Besides the self-serving complaint by sawmill operators that they cannot find sufficient transport capacity at their regular rates during the agricultural peak season, several serious problems have arisen requiring governmental attention:

1. Low tariffs have resulted in severe overloading of single-unit trucks; 40 percent of all trucks on the

road were (prior to 1977) more than 15 percent overloaded with a high proportion of lumber truckers carrying 30-40 percent more than their vehicles' design loads.

2. Overloaded trucks were destroying newly paved highways and were a safety hazard.

Petroleum and Cement Products

Petroleum and cement products are grouped together in this discussion because they exhibit similar transport characteristics in Honduras. Both commodities are produced at a single facility that makes them easy political targets for organized truckers; both require specialized larger-capacity vehicles rather than the 7-t capacity truck in for-hire service. Also, both commodities are crucial in the day-to-day functioning of the economy. Obviously, without petroleum all commerce is affected. Less obvious is the fact that without cement all major development projects experience costly delays. Another similarity between cement and petroleum is that the government, through the Ministry of the Economy, fixes the price of both commodities. This action implies the fixing of transport tariffs as well.

In the case of petroleum, there are four distributors and one refinery. The refinery is foreign owned and only one of the distributors is locally owned with its own brand name. Traditionally the distributors depended on private haulage using their own vehicles for most operations and contract operators for routes where demand was low, irregular, or where road conditions were poor. As the roadway network was improved, the distributors attempted to extend the use of their own vehicles rather than contract carriers.

As for the cement plant, transport is handled on a contract basis with one cooperative, many of whose vehicles are financed through the locally owned cement company. This cooperative has been able to easily restrict the entry of other operators, mainly due to the facts that no one else could offer adequate vehicles, and an unwritten code exists between transportistas to limit competition, at least in this sector.

The problems that have arisen from this situation pose a significant challenge to the government in its attempt to minimize political intervention in transport operations. Local truckers are seeking limitations, if not total outlawing, of private carriage, especially in the case of foreign-owned companies. As an interim measure, they are also seeking a minimum amount of reserved petroleum movements for local truckers. Anticompetitive actions by strong trucking cooperatives threaten the normal and efficient flow of nationally critical commodities.

International Cargo Movements

International cargo is handled by a wide variety of truck operators. The dominant type of organization is the cooperative. In Honduras a transport cooperative is a loose federation of individuals, each of whom owns at least one truck. Usually each member maintains his own vehicle and manages his own income. The cooperative serves as a means of obtaining cargo, like a clearinghouse, and facilitates purchasing spare parts in bulk and setting up vehicle financing. Also, it handles the operators' administrative paperwork. Rates, however, are not necessarily fixed by the cooperative. In international operations there are as many as 35 members in one organization.

Prior to 1977, there was very little information collected on Honduran international truckers, and the reported problems described here were typically based on the opinions of various interested parties and on limited surveys. Progressive government and quasi-government agencies feared that local operators would not be able to meet the rapidly changing needs of the economy as development advanced. The Empresa Nacional Portuaria, the Honduran port authority, was installing a container crane at Puerto Cortes and feared that foreign truckers would reap the benefits of overland transport that would be generated by increased roll on-roll off (RO-RO) and container movements. The World Bank was similarly fearful and was investigating mixed governmental and private investment schemes. Local truckers complained that restrictions imposed by neighboring countries on Honduran operators without retaliatory restrictions by Honduras were promoting foreign trucking and that local truckers were not capturing their fair share of the traffic.

HONDURAN GOVERNMENT RESPONSE

The government's response to each of the above problems was a controlled incremental approach to economic regulation. In February 1976, the omnibus Ground Transport Law was signed. It gave the Direccion General de Transporte (DGT) broad regulatory powers over all passenger and freight transport on the nation's urban and intercity roads. The reasoning behind the government's decision can only be hypothesized because of the large number of participants and motives involved. A basic psychological motive behind the legislation appears to have been the fact that economic transport regulation is associated with highly developed economies, a sign of progress because all developed countries were thought to have intricate regulatory policies.

There were, of course, more practical motives by each of the participants in the drafting of the legislation. Both bus and truck operators were seeking to limit competition through entry and capacity restrictions. Transport users and government officials, however, wanted to stabilize the sector and guarantee the availability of sufficient and adequate service to meet the country's development needs.

Although on paper the DGT's authority is sweeping, in actual practice the effective implementation of the Ground Transport Law is restricted by limited personnel and funding available to the agency. With these limitations the Director General of Transport set out to verify and resolve the transport problems in each of the commodity sectors.

The basic restriction imposed by the government is that all public transport service be provided by Honduran firms in which Hondurans have the controlling share of the capital. Furthermore, the law requires that all public, for-hire, and contract operators register with the DGT and request a "Permiso de Explotacion"; this gives them the right to operate a trucking firm anywhere in the country, involving any type of commodity over any route for whatever price is negotiated between parties. This permit is good for five years and costs the operator one percent of the value of his vehicle (original purchase price) to a limit of $1250.

In addition, the operator must request a "Permiso de Operacion", which allows hime to use a specific vehicle for his operation. Each vehicle needs a separate permit, valid for one year and renewable on the satisfactory inspection of the vehicle.

Thus, through these two permits, the DGT has the power to limit both entry and capacity in trucking. The initial approach, however, in addition to the standard "grandfather" clause, has been to allow any Honduran operator to enter with whatever size vehicle as long as the registration fee is paid, the operator has no record of seriously abusing transport regulations, and the vehicle is in satisfactory condition.

In agricultural transport the government rejected the use of restrictive entry regulations to maintain an orderly market and minimize business failures. No major instability had been observed and the long-run adjustment of the marketplace was considered a more appropriate solution.

Field interviews showed that operators' gross income frequently just covers the operation of the vehicle, interest, and amortization with some amount for driving time. The owner-driver often receives no return on his investment and, moreover, does not receive compensation for time spent maintaining the vehicle. Recent tariff changes, however, show that the growing sophistication of the operators should slowly resolve this situation. The aggressive competition, which logically characterized the initial period after the improvement of the road network, should subside as more realistic estimates are made of the financial returns in trucking.

As for subsidizing service to outlying areas through rate fixing and cross-subsidization, a typical objective of western regulation, the initial decision has been to leave rate negotiation open. Fixing rates would be nearly impossible to implement and enforce and could distort development by fostering increased production in areas where production would be less efficient. Instead, selected farm-to-market feeder road projects based on a national development plan should be implemented that will stimulate more transport service and competition, resulting in better farmgate prices and more production where it is desirable.

The problems arising from lumber required more immediate direct action, and the government responded by imposing weight limits on paved highways and installing 13 weighing stations for enforcement. Lumber truckers responded with a two-week national strike demanding that the government forestry agency raise lumber prices at the export yards; this increase would be passed along to the truckers via the sawmill operators to compensate for the loss of 30-40 percent of revenues per truckload.

The DGT entered the dispute as a mediator between the government forestry agency, the truckers, and the mill owners. An increase in the price of lumber was negotiated without specifically fixing truck tariffs. Although the truckers' original demands were exorbitant, more than recouping projected losses, sawmill operators countered by importing tractor-trailers for private carriage. As a result the truckers tempered their demands to more competitive levels.

Furthermore, weight limits reduced the proportion of trucks that were 15 percent or more overloaded from 40 to 3 percent and fostered a change in the makeup of the fleet so that the importation of two-axle, single-unit trucks came to a standstill. Instead, operators purchased more efficient tractor-trailers, pooling their resources in newly formed cooperatives of former independent owner-operators.

In the case of petroleum and cement transport, the DGT again acted as a mediator without itself fixing tariffs or for-hire quotas. The government, faced with poor antitrust laws and the political difficulty of allowing private transport by foreign-controlled companies, has not resolved the potential crisis of anticompetitive actions in this sector. Private transport may be the only means of countering monopolist rates and maintaining efficient service without direct government intervention. The refinery has attempted to form a subsidiary Honduran transport firm as a contract carrier. The future direction of the government is still uncertain.

The last sector that the DGT analyzed for possible regulatory intervention was international trucking. It is natural for a country to want to protect and encourage its own operators, especially if it believes that other countries' restrictions are putting them at a disadvantage. Fortunately, prior to imposing retaliatory restrictions in response to reported, but never verified, restrictions by neighboring nations, the DGT conducted surveys to determine if Honduran truckers were not carrying their share of the traffic between Honduras and the other countries.

Statistics that were compiled at two different periods of the year at weighing stations near the borders showed clearly that the Hondurans had captured a considerable share of international traffic. A review of license plates in one month revealed that there were 460 Honduran-loaded trucks moving between Honduras and Nicaragua compared to 200 Nicaraguan-loaded vehicles. Between Guatemala and Honduras there were 300 Honduran-loaded trucks compared to 330 Guatemalan vehicles. Weight figures showed similar results. On the basis of this evidence the Director General refused to impose new limitations that could inevitably hurt the seemingly strong competitive position of Honduran operators if other countries take retaliatory measures.

In addition, the data illustrated the fact that there was a greater use of larger capacity vehicles by Hondurans in international movements. More than 50 percent of the Honduran trucks were tractor-trailer combinations. The resilience of the trucking sector and its ability to respond to new demands was confirmed when the national port authority installed a container crane at Puerto Cortes. Contrary to the initial fears that there would be insufficient capacity to handle containers and RO-RO trailers, agents at the port were surprised to find a ready supply of adequate vehicles to meet the heavy increase in demand.

COMMENTS AND COMPARISONS

The first steps to regulate intercity trucking in Honduras are being taken at a relatively strong period in the evolution of the economy. As important users of the newly created, all-weather highway network, the truck owners have made an important contribution to the recent and soundly based expansion of the economy. The problem is that "business has been too good." Everybody wants in and a surplus of two-axle trucks has resulted.

When national regulation was adopted in the United States, trucking was in a relatively earlier stage of development than at the present time in Honduras, although in the eastern part of the country highways were more extensively developed than they were in Honduras in 1975-1976. The owner-driver pattern was quite strong due to the depression-era search for work.

The expansion of interstate commerce regulation in 1935 occurred at a time of severe economic depression, deflation, and declining productivity—the reverse of the Honduran case. In the United States, trucking (spasmodically regulated by the states) was passing through a period of operator instability, poor maintenance, overloading, and harsh price competition. It is clear in hindsight that this pattern of events led to the excessive protective and detailed regulation in the United States, i.e., accepting temporary conditions as the norm. This political action is only now being subject to question and significant revisions.

There are some important differences between the United States and Honduran settings under which regulation has been instituted. In Honduras, truck-rail competition has never been a problem except for the short stretch between San Pedro Sula and Puerto Cortes. Truck rates have at all times been set from some notion of cost rather than value of service or rates of another mode, a healthier base from which to build regulatory policy.

Furthermore, LTL service is of much less concern in Honduras as opposed to the United States, where LTL movements are a significant portion of all truck movements. This has led to the U.S. emphasis, perhaps exaggerated from the perspective of the European experience, on the tight regulation of common carrier rights and responsibilities.

The pertinent comparisons that follow revolve around four of the typical objectives of U.S. regulatory policy in transport described earlier. In each case the Hondurans either rejected the validity of the objective or selected other means for satisfying the objectives, resulting in a much more limited regulatory structure as compared with the U.S. complex apparatus.

The Hondurans have rejected the need to fix rates, routes, and commodities to preserve equity in carrier-shipper relationships. The resultant fluctuation in seasonal tariffs that could be considered discriminatory by U.S. standards has encouraged the efficient distribution and level of truck capacity with shippers paying rates more closely related to the costs they impose on the system. In addition, shippers are given an incentive to schedule their movements around the peaks that reduce distortion in defining capacity requirements. With few, if any, economies of scale in this mostly TL service, healthy competition between a large number of operators has been generally maintained.

The need to maintain an orderly market in trucking and avoid the excesses of competition has also been rejected by the Honduran government. The high turnover of operators in Honduras is due more to the lack of basic education and business experience rather than the rigors of open competition and should be reduced as the educational standards and business experience of the country are improved. In fact, trucking in such a country plays a major role in entrepreneurial education.

Similarly, the Hondurans rejected the tight regulation of common carrier responsibilities and cross-subsidization as a means of assuring service to outlying areas. Setting rates below costs for such service could have distorted the economic development pattern of the country. By allowing rates to be flexible, service did reach these areas as long as the shippers were willing to pay full costs. Rate reductions and improved service were achieved through indirect means by improving the feeder roads and directing agricultural development funding to selected areas.

U.S. legal, not economic, doctrines have, in effect, produced a de facto policy of providing a basic service at a uniform price to anyone living and producing anywhere. This results in subsidizing those in high-cost locations to reach the markets through the excessive freight rates paid by those with low costs for reaching the same markets. This violates market economic precepts and shows that the notion of regulation substituting for marketplace is quickly corrupted in practice. The spread of private and exempt transportation in the United States, which tends to be much more closely related to the vehicular costs of providing the service, is gradually undermining the regulator's capability to maintain historiopolitically based regional relationships that have no real economic foundation.

Protection against monopolist pricing, however, was considered a valid objective that required regulatory policy. Instead of fixing rates across the board, the government will allow private trucking to increase, where politically feasible. Where private trucking is not feasible, the government has acted as a mediator. In the future this may lead to rate setting but only in selected situations. This type of regulation "by exception" is an interesting concept that is receiving more attention in the U.S. deregulation debate. Administration proposals for handling railroad rates in monopolist cases under deregulation is one example of regulation by exception. The test in the future will be whether a policy with such discretionary flexibility can be maintained without being corrupted and diverted from its original intent.

One regulatory objective that is important in developing countries such as Honduras but unnecessary in the United States is the control of capacity. Excess capacity in countries that must import vehicles and parts can cause a significant drain on foreign exchange reserves. In Honduras the truck sector does not exhibit a need for such regulation at the moment. Intercity bus operations, however, have resulted in extreme overcapacity and underutilization of imported vehicles and is now subject to close regulatory scrutiny.

CONCLUSION

As has been shown in this paper, the development of Honduran trucking has historically been left to the stimuli of largely open competition. This competition has resulted in a large number of operators who are steadily improving the quality of service to meet the growing needs of a rapidly changing economy. Under pressure from various interest groups, the government passed a Ground Transport Law with broad regulatory powers. In implementing the law and studying the transport service sector more closely, however, the government decided to either reject typical U.S. objectives of regulatory policy or to find alternative means of reaching those objectives without distorting the competitive transport market.

Although the context of many of the reported observations seems very remote from U.S. experience, international boundaries do not repeal the laws of economics. Our context is so complex and so "covered", due to massive gray-area services and trip-leasing operations by authorized common carriers, it is very difficult to be certain how the system really works or to identify the action of the market on prices and services. This is why it is beneficial to analysts and practitioners to observe conditions in simpler, uncontrolled economies.

Perhaps the most distinct difference in the United States and Honduran perspectives is that, from the U.S. point of view, Honduran freight rates may accord with the economics of trucking but not with equity, a political concept. It certainly seems ironic that what is referred to in the United States as economic regulation is not economic in any true sense; it is legal and political. The lack in foreign countries of this equitable nondiscriminatory pricing, for many years a cause of concern in the United States, presents the authors of this paper with no problems as economists. In the course of working in 28 other countries, almost all with less motor carrier regulation than the United States, we do not see end results from discriminatory pricing that are economically unacceptable. The purpose of market-set prices is, in fact, to discriminate between the various producer-plus-transport cost levels to be found among suppliers to any large market.

In one way, however, the two countries appear to be headed in the same direction. Honduras has embraced the policy of regulation by exception, entering the market only in specific cases where distortions have occurred. The administration's latest deregulatory schemes in the United States have suggested a similar approach.

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Elementary Theory of Traffic Diversions: A Tool for Analysis of Restructured Railroad Networks

Alain L. Kornhauser, Princeton University, Princeton, New Jersey

This paper outlines a computer-based methodology that may be used to estimate traffic diversions resulting from limited restructurings of the U.S. railroad system. A basis for the methodology is presented. Coefficients of diversion for various combinations of carriers and routings are suggested on the basis of experience and historical data. The availability of the 1 percent National Carload Waybill Sample data and of the Princeton version of the Federal Railroad Administration Network Model now makes it possible to carry out before-and-after diversion analyses rapidly by means of a computer algorithm. A preliminary application of these techniques to the restructuring proposal between the Illinois Central Gulf and the Southern Railway Company arising from recent legislation is described. The potential use of the results of the methodology as a basis for the planning of capital expenditures is discussed.

Throughout the long history of railroad activity in the United States, companies have continually rearranged the corporate structure of the railroad system—a process referred to as the geopolitics of railroad restructuring. Recently, interest in system restructuring has increased. The bankruptcy of the Penn Central system prompted legislation to simplify the regulatory procedure for the evaluation and approval of restructuring proposals. These laws, the Regional Rail Reorganization Act of 1973 and the Railroad Revitalization and Regulatory Reform Act of 1976, have led to numerous proposals for mergers, acquisitions, restructurings, and abandonments. Given the recent financial reports by Consolidated Rail Corporation (Conrail), terms such as rail use, mergers, acquisition, and perhaps even controlled transfer and controlled liquidation may be appropriate labels for railroad system restructuring exercises. Each of these approaches involves goals and objectives that encompass the many dimensions of structure and industry viability.

One major aspect of railroad restructuring is traffic diversion, that is, traffic gained or lost by the restructured system. Traffic diversion analyses have probably been a part of every merger proposal, but past analyses have been long and tedious manual exercises carried out by teams of traffic clerks. With the availability of comprehensive machine-readable traffic data bases, e.g., Carload Waybill Statistics, and a machine-readable network description of the U.S. railroad system as contained in the Princeton version of the Federal Railroad Administration (FRA) Network Model, background data are available that may allow the calculation of traffic diversions by computer. This paper takes the tried-and-true rules of thumb of the traffic clerk and converts them into a computer-based methodology capable of estimating traffic diversions resulting from limited restructuring of the U.S. railroad system.

Two theories of railroad traffic diversion may be postulated: an elementary theory—the subject of this paper—and an advanced theory. The elementary theory is based on historical traffic flows and market shares among existing routes and considers only incremental changes in those market shares resulting from mergers, acquisitions, or dismemberments. The advanced theory does not rely on historical routings. Instead, it calculates the best route for each competitor and assigns market shares on the basis of substitute measures of the level of service. The best route may be defined in terms of level-of-service measures such as distance, track conditions, and number of gateways encountered by each route. The advanced theory is required whenever there are significant changes in ownership patterns, e.g., many mergers, because shippers are more likely to completely reorient their logistic patterns rather than to make incremental adjustments. Because it is a behavioral model of shippers' route selection processes, the advanced theory defines the unrestrained potential of the restructured railroad system. On the other hand, the elementary theory is constrained to redistribute traffic over routes used prior to restructuring. The elementary theory is well suited to analyzing the impact of relatively small changes in network structure, such as the proposed Illinois Central Gulf (ICG)-Southern Railway (SOU) merger, the BN-Frisco merger, Family Lines-Chessie merger, or the acquisition of a portion of the Milwaukee by the Union Pacific.

DEFINITIONS

The following definitions are presented here as aids to understanding the discussion of railroad restructuring efforts:

1. Market refers to an origin-destination pair where the origin and destination each encompass a finite area in which shippers, receivers, or both are located. If an area is served by more than one railroad, then it is implicitly assumed that each railroad had access to each of the shippers and receivers in that area. Access can be either through direct siding, terminal railroad, or reciprocal switching agreement. This implicit assumption tends to limit the size of these areas so that artificial competition is not introduced. Analytically, such locations are designated by FRA Network node numbers of the Association of American Railroads' Standard Point Location Codes (SPLCs). The size of this area can be selected by the analyst but it should usually be smaller than the size of a county.
2. Route is a sequence of railroads and interline junctions that connect an origin and destination. Only those routes actually appearing in the historical waybill data are considered in the analysis, even though other routes may appear in published tariffs. (In special markets, it is possible to consider a small number of new routes by introducing dummy data into the waybill file. However, the amount of manual input required makes this impractical to be anywhere near exhaustive.)
3. Merger is the functional union of two or more railroad operating networks, irrespective of the financial or organizational arrangements under which they are brought together; thus, the term is used very loosely in this paper.
4. Best route, from the perspective of the shipper, is considered to be a function of level of service, defined quantitatively in terms of readily available route

and network characteristics. These include number of railroads required to construct the route, the route distance, the track quality (measured by its mainline-branchline designation), and the length of haul of the originating railroad. These characteristics can be compiled from the enhanced FRA Network Model and the Carload Waybill Statistics.

Other characteristics such as car availability (although this is considered implicitly in the allocation of traffic to the route that maximizes the length of haul by the originating railroad, subject to total route-distance circuity constraints), travel time (considered implicitly in the track-quality measure), and travel time reliability are not explicitly considered because of the lack of available quantitative data on them.

APPLYING ELEMENTARY THEORY

It is obvious that the elementary theory will be relevant and meaningful only in markets served before the system restructuring by one or more routes, at least one of which involves a carrier or carriers to be restructured. The elementary theory postulates that the restructuring will merely redistribute the existing traffic among the routes already observed; that is, the restructured railroad has no opportunity to enter new markets. This is one limitation of the elementary theory not applicable to the advanced theory. This limitation, however, also means that the number of markets and feasible routes to be analyzed is greatly reduced. Thus only readily available historical traffic data (such as the Carload Waybill Statistics) are needed to define the set of affected markets, and the differential (before and after) impact on carload routings of the restructuring may be readily computed.

PROCESS

The elementary theory of traffic diversion proceeds as follows:

1. Several years of waybill statistics are used to define the before market shares of all routes in each market, i.e., the percentage of the carload using each route between the same origin and destination.
2. The extent of probable traffic diversion in each market is estimated on the basis of the hierarchy of markets outlined in the next section of this paper.
3. After market shares are allocated to each modified route in each market. This traffic is assigned to the new railroad network configuration and yields traffic flow on each link of the railroad network as well as distances that allow for the computation of new divisions and costs.
4. Comparison of all before and after values of total, as well as link-by-link, transportation activity indicates the differential impact on each carrier involved, i.e., both the merged railroads and their neighboring unrestructured railroads.

HIERARCHY OF MARKETS

Each market is defined as an origin-destination pair, each of which is served by at least one independent railroad and for which railroad traffic has been observed. In general, there are an infinite number of ways to route traffic in each market, but, for example, routing traffic between Chicago and Detroit through Jacksonville, Florida, is illogical. A small number of these routes are feasible routes from a shipper's viewpoint because they are published in tariff books. Martland (1) has indicated that over 200 unique routes are published between Chicago and Boston. Unfortunately, these routes are not machine readable and are therefore unsuitable for use in computer analysis. In any event, only a few of these routes are actually used by shippers. A machine-readable history of a sample of the routes actually used by shippers is available in the form of the Carload Waybill Samples. These data are available for 1973 through 1977 and contain the railroad-junction sequences for each of the approximately 1 percent of the railroad carload traffic during each year. By reorganizing these data for one or several of these years, one gets a good picture of which routes are used and to what extent. Also, one obtains a quantitative picture of which railroads actually serve which geographical areas (origins and destinations). By first defining the size of the area encompassed by a general market endpoint, these data show the absolute and relative activity in carloads originated and/or terminated in each geographical area. (Various definitions can be used for the area. The most convenient are either various levels of specificity of the 6-digit SPLC or, what seems to be most appropriate, the FRA Net-3 nodes, which tend to encompass areas served in common by several railroads if competition exists in the area. Railroad freight station accounting codes are not appropriate because they are unique to each railroad.) For example, the following table lists the gross and share of the traffic originated or terminated in Toledo, Ohio, by competing railroads for 1974:

Railroad	Carloads Generated	Percentage of Carloads Generated
Ann Arbor	28	2
Chessie System	1503	51
Detroit and Toledo Shore Line	15	1
Detroit, Toledo and Ironton	84	5
Penn Central	811	28
Norfolk and Western	501	17

The Carload Waybill Sample data can define all of the railroads that actually generate (originate or terminate) traffic at either end of each market and can identify the number and relative strength of routes used in any market.

For a traffic diversion analysis these markets can be classified in such a way that all markets may be analyzed in an orderly sequential manner. These markets may be classified according to the following hierarchy:

1. No traffic diversion—markets that are unaffected by the network restructuring;
2. Single-carrier potential—markets that exhibit potential single-carrier service by restructured parts of the railroad network;
3. Long-haul potential—markets in which the restructured parts of the railroad network have the potential of increasing the length of their originating haul;
4. Retaliation—markets in which the restructured parts of the railroad network can be adversely affected by retaliation by the unrestructured railroads; and
5. Overhead—markets in which the restructured railroad participates only as an overhead carrier.

Each of the classes of markets, when considered as a hierarchy, covers all markets without double counting. Each market can be identified and analyzed in turn. The process is sequential and thus potentially efficient, certainly more efficient than an iterative process.

All markets can be considered; however, a large number of markets have very little traffic and thus few observations exist about the Carload Waybill Samples. At some point, because of the lack of observations, there is an insufficient basis for defining feasible routes. On the other hand, because of the small amount of traffic at stake in these markets, errors will have only minor impact. Thus, they simply can be dropped from the analysis. It is suggested that markets with fewer than five observed carloads of traffic be placed in the category of traffic in which there is no traffic diversion, i.e., category 1. Thus, they are contained in both the before and after summaries but are assumed to remain unchanged. Depending on the size of the carload data base, this may amount to as little as 10 percent or less of a railroad's traffic.

Each of the five classifications of markets has several level-of-service characteristics that would be affected by a restructuring of the U.S. railroad system. The level-of-service characteristics most affected include the following:

1. The number of railroads that cooperate to form a single route is important. A merger of two railroads will enable some markets to be served by a single railroad company. Other markets will have the number of railroads required to cooperate reduced by one. Historical traffic data indicate that shippers overwhelmingly route their carloads over routes requiring the fewest number of cooperating railroads. For 1974, 97 percent of the traffic in markets served by single-carrier service was captured by those single-carrier routes (2). Additional data can also be found in Strong (3).

2. Most traffic tends to travel over routes whose distance does not vary widely from the shortest of the observed route in each market. Rarely does any route that is more than 25 percent longer than the shortest observed route capture any of a market's traffic. This circuity constraint provides a convenient way to limit the search for alternate feasible junctions between railroads on routes that require cooperation among the restructured railroads and other independent railroads (4).

3. The track-quality measure of mainline-branchline provides a means by which the best route within any independent railroad network can be computed, using a minimum pathfinding algorithm. Used at Princeton is an impedance measure that simply multiplies link distance by FRA's "503" mainline-branchline code. A factor of one is applied to A mainlines, two to B mainlines, three to A branchlines, and four to B branchlines.

TRAFFIC DIVERSION IN EACH CLASS OF MARKETS

The following suggested diversion values can only be substantiated qualitatively, although Kornhauser (5) and Strong (3) do provide some quantitative support. Readers are encouraged to criticize the suggested values. (The analysis is structured so that the user can specify the amount of traffic to be diverted in any class of market. Thus, one can do systematic parametric analyses based on various assumed values of diversion.) All examples assume a merger between RR_1 and RR_2. Railroads $RR_3, \ldots, RR_n$ are other railroads whose network remains unchanged but compete in various markets with RR_1 and RR_2.

Unaffected Markets

These markets can be identified by the fact that neither RR_1 nor RR_2 appear in any observed route of these markets nor do either generate any traffic at the origin or destination of the market. These markets can be readily identified algorithmically. Markets that have very little traffic—for example, less than five observed carloads—may also be included and are also readily identified algorithmically. These markets are segregated and their after-merger routes and market shares are assumed identical to their before-merger values.

Potential Single-Carrier Service

A merger may result in new single-carrier service only if one of the merging railroads serves the originating station and the other serves the destination. The following subclasses cover all possibilities:

1. RR_1 and/or RR_2 only serve the route's origin and RR_2 and/or RR_1 serve the destination. No other competing routes are observed. Resolve: All traffic is diverted to the RR_1-RR_2 route having the minimum impedance as defined here.

2. This subclass is the same as the first, except other competing routes are observed that have RR_3 as the originating railroad:

(a) The competing originator's route is a multiple-carrier route. Resolve: If the competing route involves two carriers, X (X may be 75 percent) of the competitor's traffic, is diverted to the new single-carrier route; if the competing route involves three or more carriers, Y (Y may be 100 percent) of the traffic, goes by the new single-carrier route.

(b) One of the competing originator's routes is a single-carrier route. Resolve: In this case, it can be expected that the existing multiple-carrier routes retain their market shares; the existing single-carrier route and the newly established single-carrier route share equally in the remainder.

Potential Long-Haul Service

For shipments originating on RR_1 and destined beyond RR_2, the combined railroads have an opportunity to increase their length of haul and thus gain better revenue divisions. Resolve: All traffic originated on RR_1 is diverted to the most renumerative RR_1-RR_2-other railroad(s) route that appeared in the historical sample.

If the origin is competitive, the market shares of routes involving the same numbers of railroads can be expected to be equalized; if the new route has one less railroad than the best existing route, the new route can expect to capture about 85 percent of the market and, if it has two less railroads, it may capture 100 percent. If the new route involves more carriers than the best competitive route, its market share remains unchanged.

Retaliation: Merged Railroads Serve Only Destination

If the merged railroads serve only the destination in a given market, they are susceptible to retaliatory diversion by connecting railroads from which a significant amount of originated traffic has been diverted. Connecting carriers may be unfriendly (those who have been hurt by the merger) or friendly (those who have not been hurt).

1. The destination is captive to RR_1 and/or RR_2, and there is no change in the number of railroads in any route. Resolve: no change in market shares.

2. The destination is captive to RR_1 and/or RR_2, the merger has reduced the number of carriers in one or more routes, and the originating carrier is friendly. If the new route's number of railroads equals the best competitive route's railroad, each route with that number of railroads receives an equal share; if the new route has one less carrier, it may capture 85 percent of the

Figure 1. After-merger flows on the ICG-SOU.

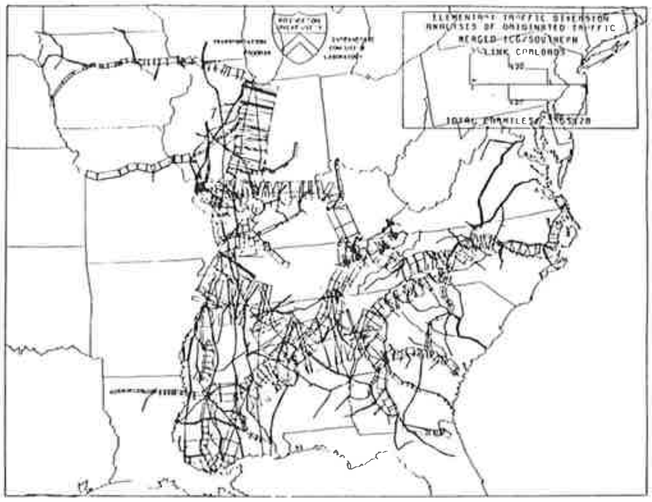


Figure 2. Traffic volume increases on the Memphis cutoff.

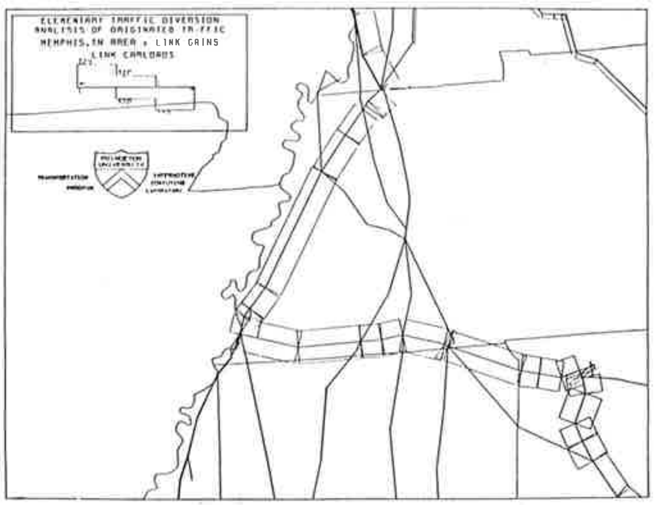
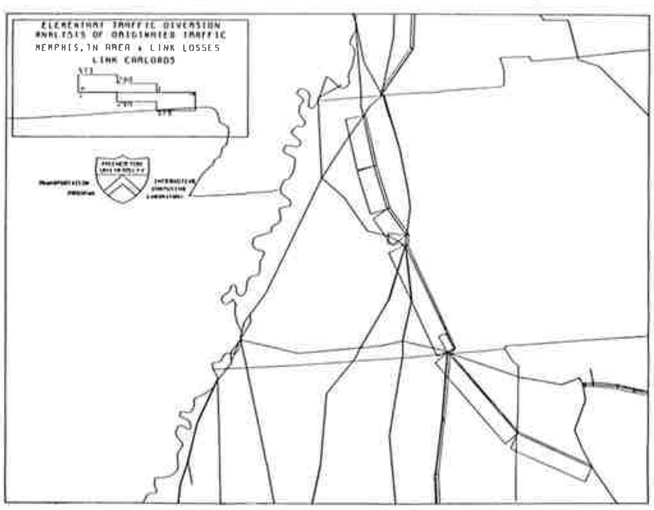


Figure 3. Traffic volume decreases on the Memphis cutoff.



traffic; and if it has two less carriers, it may capture 100 percent of the market.

3. The destination is competitive and the number of railroads in the past-merger route stays the same. If the originating railroad is friendly, there is no change in market shares; if it is unfriendly, the merged railroad terminates about 25 percent of its before traffic.

4. The destination is competitive, the number of railroads in the merged route is one less than before, and the connection is friendly. The new route receives 85 percent of the market if the number of carriers on the merged route is one less than on competing routes and 50 percent if the number of carriers is the same. If the new route still has more carriers than the competition, its market share remains unchanged. If the connection is unfriendly, the market share remains the same if the new route is one railroad shorter than the competition, retains 25 percent of its before traffic if the numbers of railroads are the same, and goes to zero if the number of railroads is one greater than on the competing route.

Overhead Traffic

If RR_1 and/or RR_2 serve a given market only as overhead carriers and the originating carrier is friendly, the market share can be expected to remain the same. If the originator is unfriendly and an alternate overhead route exists, the market share of the merged route probably goes to zero if the merged route involves more railroads than the competing route. If the number of railroads is the same, the merged route retains about 25 percent of its before traffic. If the number of railroads is one greater than the competing route, then the market share goes to zero.

RESULTS OF ANALYSES

The elementary theory of traffic diversions has been applied to one test case—the merger of the Illinois Central Gulf and the Southern Railway System. The test was carried out only through the potential single-carrier service step of the methodology. The data used in the example were the combined sample Carload Waybill Statistics for 1973, 1974, and 1975. Before traffic was assigned to the ICG, SOU, and neighboring railroads. Traffic volumes were accumulated by direction on each link of each railroad. Traffic that had historically originated on the SOU or ICG and that could be terminated by the ICG or SOU was diverted to a single-carrier SOU-ICG route. A new traffic assignment was made on the merged SOU-ICG system. This produced the after-link volumes displayed in Figure 1. By taking the difference between the before- and after-link volumes, one obtains the impact by direction on each link of the merged railroads.

Some interesting redistribution of traffic flows appeared on the merged system. Figure 2 shows traffic increases on a portion of the system in the neighborhood of Memphis, Tennessee. Figure 3 shows traffic decreases on other links of the merged system in the same neighborhood. The traffic decrease on the southbound leg of the cutoff is due to a reassignment of that traffic to a route combining the ICG mainline into Memphis and the SOU's mainline beyond. In the past, this southbound traffic had been longhauled by ICG. In the restructured system, the railroad might well take advantage of better track conditions on the ICG and SOU mainlines and opt for the more circuitous routing through Memphis. This one small result of the traffic diversion analysis has important implications for capital planning on the restructured system. Options that are suggested include (a) increasing the yard capacity at Memphis, Tennessee, and (b) improving the track on the Memphis cutoff to take advantage of the more direct route.

Other impacts of the merger on traffic volumes were made readily apparent by interactive graphic displays of the before and after traffic volumes. Such methods are extremely important in the ongoing strategic planning activities of railroads, particularly in contingency planning. Actual results for the ICG-SOU merger are not given here, principally because they are preliminary results intended only for planning and contingency analysis.

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Transportation Manpower Adjustments to Technological Change Through Collective Bargaining: The Crew-Size Dispute in the Railroad Industry

Douglas M. McCabe, Georgetown University, Washington, D.C.

Most industries adjust work-force size to technological and economic changes, but the number of brakemen on railroad crews is inflexibly fixed by labor agreements. This paper traces the controversial and still unresolved crew-size dispute from its origins in 1959 through 1978. The dispute was heated between 1959 and 1970 and was punctuated by strikes. The government intervened with a Presidential Railroad Commission, the National Mediation Board, Arbitration Board 282, and Emergency Boards 154 and 172. The federal courts were also involved. The brakemen succeeded in upholding their position and in securing a general rule of two brakemen per crew over management protests that technological changes had made one brakeman sufficient. The research involved in this study was divided into library research and field research. The former consisted of a comprehensive examination of the available literature. The latter consisted of (a) an examination of relevant documentation, including correspondence, and other primary sources of written information in the files of pertinent railroads and their General Committees of Adjustment and (b) interviews with railroad and union officials and with operating and nonoperating employees, as well as informed neutral parties (e.g., mediators and arbitrators). Policy recommendations for labor, management, and the government are also made.

The most protracted labor dispute in the railroad industry over the past 20 years concerns the size of road and yard crews. This still unresolved dispute stems from the 1959 demand by railroad management for the prerogative to specify the number of brakemen on train and yard crews, upsetting the position held by the railroad operating unions that crew size should be subject to the collective bargaining process. This issue highlights not only the labor relations problems endemic to the railroad industry, but also characterizes the larger quandary facing all the other transportation sectors (trucking, airlines, and longshoring)—the need for rationalization of employee job security with the exigencies of technological progress, which, in turn, is energized by competitive pressures.

The crew-size dispute was heated between 1959 and 1970 and was punctuated by strikes. The government intervened with a Presidential Railroad Commission, the National Mediation Board, Arbitration Board 282, and Emergency Boards 154 and 172. The federal courts were also involved. On June 13, 1977, the industry broke the uneasy truce that had been in effect since 1970 as a reaction to a union wage-increase demand by serving notice of its intention to gain the right to determine crew size. This analysis, therefore, seeks to contribute to an understanding of the critical issues that labor, management, and the government will have to consider in the near future.

Most existing crew sizes include a conductor (engine foreman on a yard crew) and two brakemen (called helpers on yard crews). Management has believed that the second brakeman or helper is unnecessary, whereas the United Transportation Union has asserted that at least two are needed. The dispute thus has a single clear-cut issue: Do some (management claims many) crews have an excessive number of brakemen? The ramifications of this basic issue are extremely complex.

It has been traditional for the number of brakemen and helpers on railroad train and yard crews to be determined by quid pro quo bartering at the collective bargaining table. That is in contrast with the practice in most industries of management's having the authority (frequently described as "management prerogative" or "management right") to determine unilaterally the size of a work force. It is common in such cases for employees to be protected against a possible abuse by management of its authority, particularly in the two key matters of safety and work burden, by a grievance procedure, coupled with provision for grievance arbitration.

In 1959, pursuant to the procedures of the Railway Labor Act, the railroad industry announced its intention to regain the management authority over crew sizes that had gradually been bartered away over many decades in exchange for union concessions deemed desirable by the industry at the time. Negotiations on the announced intention, which were required by the Railway Labor Act, were fruitless and, because of the tension between the industry and the brakemen's union, the Brotherhood of Railroad Trainmen (BRT), which is now part of the United Transportation Union, the government intervened in 1962 with a Presidential Railroad Commission that proposed additional negotiations. In 1963 Emergency Board 154 made a similar recommendation. The Commission and Board 154 did not cool the dispute. In 1963, Arbitration Board 282 recommended a continuance of negotiations and imposed certain provisions that had the force of law. For two years, effective January 24, 1964, all crew members then employed would be "protected" in their jobs against layoff and discharge and a breakdown in negotiations on an individual railroad was to be followed, at the request of either management or the union, by compulsory arbitration—the first peacetime compulsory arbitration in this country.

The BRT feared such arbitration, although many railroads looked forward to it with high hopes and invoked it. Numerous one-brakeman (helper) crews were authorized by arbitrators during 1964 and 1965. In the arbitration cases the railroads had asked that 5571 jobs be eliminated and were granted a reduction of 4855; the highest figure, which applied to the Illinois Central Railroad, was 98.3 percent.

Of all the nation's railroads, the Illinois Central had been the most adamant in insisting on management's right to determine the size of crews and the most innovative in pursuing that objective. During 1964-1965, with arbitrators authorizing crews to be reduced but with Board 282 "protecting" the affected employees against layoff or discharge, the Illinois Central had eliminated numerous surplus employees by offering them voluntary severance pay scaled to age and earnings.

The crew-size dispute is far from settled. A truce since 1970 was broken on June 13, 1977, by industry management in formal action, pursuant to Section 6 of the Railway Labor Act, which reinstated its 1959 claim that crew size is properly a matter of management's authority. The future of the dispute is difficult to predict.

What has been the position of the two parties regarding the major areas of disagreement in this dispute over the past 20 years? Union and management have agreed that there have been significant technological changes in railroad operations; they have differed, however, as to the extent to which the introduction of technological changes has affected employees' duties, responsibilities, and workloads.

The railroads have said that technological changes have increased safety but have diminished the job content of crews, their work requirements, and the major responsibilities of individual crew members. They have pointed to such technological improvements as centralized traffic control, automatic block signal systems, communication equipment, and the improved quality of rolling stock, all of which enable work to be done properly with fewer employees. Furthermore, they have complained that existing crew-size rules, agreements, and practices prevent them from realizing potential productivity gains from such technological progress.

The union has argued that most employees' duties have not been lightened but have been increased. Furthermore, technology has intensified the burden of responsibility carried by crews because of increased speeds, increased train lengths, and increased car weights, all of which have increased employees' need for alertness against equipment failures and accidents. Thus, the union has insisted that management's desire to reduce crews would increase employees' work burden and the dangers inherent in railroad operations.

The railroad industry today is substantially in the same position it was in at the beginning of the crew-size dispute in 1959, with the exception of the Milwaukee Road. On April 1, 1978, the United Transportation Union and the Milwaukee Road reached agreement on train crew reduction. The terms of the agreement provide for reducing present three-member road and yard ground crews to two members based on straight and pure attrition. No employees will be laid off or transferred, but reductions in crew size will occur as present employees retire, resign, are promoted, or leave the service for other valid reasons. The carrier and the union estimate the current attrition rate at 5-8 percent annually.

When crews in yard and road service are operated in the "reduced" status (road trains subject to train length limitations), each crew member will receive a special allowance of $4 as compensation for the additional service and responsibilities consistent with the operation of a reduced crew. This $4 allowance is subject to applicable cost-of-living and basic wage increases. In addition, each time a reduced crew is used, the company will deposit $48.25 into the employees' productivity fund. At the end of each year, this fund will be divided by the employees eligible to participate, according to the number of tours of duty they have worked in road freight or yard service that calendar year. Interest earnings of the fund will be added to the carrier deposits for the sole benefit of the participating employees.

The year-end division will increase each year until the maximum of one-third total compensation for that calendar year is reached for each protected employee. The employees may leave their individual bonus or shares in the fund for future interest growth as a savings fund or a supplemental pension or may elect to withdraw it at the time of the annual division.

The new agreement also allows operation of non-revenue trains, such as work trains and snowplows, and the operation of new business trains, handling only business not previously handled by this line, with reduced crews.

The Milwaukee agreement, which could spread to other lines, reportedly caused shock waves among negotiators for the nation's railroads currently bargaining with the unions over proposals for new labor agreements. Some spokesmen for the carriers complained that the productivity bonus was too generous and that the clause limiting the agreement to 70 cars or less was too restrictive.

The crew-size issue has thus been the cause of 20 years of intermittent impasses, strikes, and intervention by government boards. Although a few railroads have dealt effectively with the crew-size problem, most railroads still have not eliminated numerous trainmen whom they consider unnecessary with respect to the safe and efficient operation of train and yard activities.

LESSONS TO BE LEARNED

Some of the lessons to be learned from the crew-size dispute are of interest primarily to the railroad industry, but, on a broader basis, much is applicable to labor-management relations in the other transportation sectors.

Relative Economic Power

At the collective bargaining table, the relative economic power between a union or a group of unions and a railroad or a group of railroads tends to be felt in terms of the degree of concern generated by a strike threat. That is, both union and management weigh their individual capacity to endure a dispute and the probable endurance of the other party. In order to adjust the scales, groups of unions or groups of employers may band together. In the crew-size dispute, the union's strike tactic was the use of the selective strike in which one railroad at a time is struck. When a selective strike is properly planned and executed, the relative economic power, given the conditions in the railroad industry, is definitely on the side of the union.

One reason for relative economic power tending to be in favor of the unions is that the railroads are "time sensitive," i.e., they quickly lose their customers to competing modes of transportation during a strike, and in some instances the loss is permanent; unlike a manufacturer, they cannot stockpile inventories in anticipation of a strike, and opportunities to recover losses after a settlement are limited. Thus the capacity of a railroad to resist, which is not too substantial, may not be as great as total union strength, and the unions may force uneconomic settlements on the railroads. In disputes, then, which involve an individual railroad, a major union may be deemed on balance to have somewhat greater economic power than an individual railroad.

In the railroad industry the strength of a union in a strike so outweighs the ability of an individual employer to endure a strike that collective bargaining can become a mockery. Although agreements are reached, they may not necessarily be equitable. The economic plight of the railroad industry creates a serious imbalance of power between labor and management. The limited finances of most railroads and the relative ease with which other railroads and particularly the truckers can take business away from a struck railroad make railroads susceptible to strikes, and labor takes advantage of this situation at the same time that they may be maneuvering to avoid triggering emergencies that would result in government intervention unfavorable to a union.

Economic Environment

In the economic environment of the railroad industry, both labor and management feel the severity of competitive pressures, which necessitate improved service, increased efficiency, and the reduction of costs. Where such pressures are strong, management can be expected to pressure unions to accept newer techniques or to modify restrictive practices. Conversely, where market pressures are relatively weak, management is less inclined to risk confrontations with unions by pressing for change.

Although the unions feel the severity of competitive pressures, it is essential to note that they do so only indirectly, namely, as a result of management action at the collective bargaining table, of reduced calls for new employees, and of employee layoffs. Consequently, it is likely that the unions do not sufficiently appreciate the pressure that competition and other economic factors put on management, particularly inasmuch as the unions do not have a direct interest in the interpretation of comparative financial statements. At the union level that interpretation is a tenuous one that, at best, usually requires some time for its severity to be recognized. Thus, the unions tend to blame management for its insistence on technological change rather than to concede that management is merely reacting to intermodal competitive pressures in the transportation industry.

Lack of Creative Thinking in Board Decisions

The only contribution of intervening government agencies was to postpone a final settlement of the crew-size dispute. There was no originality of any significance in the proposals of the Presidential Railroad Commission and the Emergency Boards, at least as far as the pursuit of a final settlement was concerned. Those intervening agencies appeared to have but two objectives in view: to avoid strikes and to maintain the status quo ante. They all told the parties to go home and bargain some more.

Management Authority

The great issue in the 20-year-old crew-size dispute is whether crew size should be subject to management authority or to collective bargaining. A railroad crew is merely one kind of work force, and the broader issue is whether the size of work forces is properly subject to management authority or to the barter of the collective bargaining table. I take the former view, and I see a line in labor-management relations: On one side of that line there are subjects that belong in the area of management decision making, and on the other side there are subjects that belong in the area of collective bargaining, that is, subjects to be settled by a process of barter, of an exchange of concessions, of a giving of quid pro quo, and, in extreme situations, of the parties' recourse to their economic strength—labor's strike and management's lockout.

Basically, it is my view that the size of a railroad crew or any other work force is a matter for determination in an industrial engineering analysis, with the industrial engineer paying attention to considerations of safety and the work burden. Such an analysis is on management's side of the line and any resulting grievances are on labor's side of the line.

Collective Bargaining Structure

Where several unions negotiate for closely related employee groups, it is often more difficult for one union to adopt a more receptive attitude toward change than the others. Conversely, if bargaining is carried out only by one union, or with a high degree of coordination among several, the possibility of accommodation to change will be greater. There are two reasons for this; one is economic and the other political. From an economic point of view, the presence of several unions bargaining separately make it very difficult for any one of them to consider the possible favorable impact of its own policies on the demand for its own members' services. If the policies of the unions were coordinated, however, or if only one union represented all or a very large proportion of the work force, it would be able to give more serious weight to the possible favorable effect on employment of a more willing acceptance of technological change. From a political point of view, the presence of several unions in an industry presents the danger that any one union that adopts a more receptive attitude than the others will open itself to charges of failing to protect the interests of its members. Again, where only one union is involved or where all the unions are adopting a similar approach, this danger is reduced.

The craft unionism of the railroad industry, as differentiated from the industrial unionism of the manufacturing industry, is one of the most important variables in the railroad industry's collective bargaining structure; a craft union is characterized by the possession of cherished traditions in the way things are done, a circumstance that is not conducive to flexibility in the acceptance of innovations. To some extent, however, in the instance where there is multicraft bargaining on an issue, such bargaining provides a kind of half-way house between craft and industrial unionism.

One additional implication of the union bargaining structure deserves emphasis. It has been noted above that there is a high degree of substitutability between railroad and trucking service; this suggests that the introduction of greater efficiency, particularly in the form of faster and more dependable railroad service, could considerably improve the volume of freight handled by rail and hence improve the employment situation for railroad labor. Because of the large number of individual unions involved in negotiations, however, it is very difficult for any one of them to have a significant impact on overall operations to take this relationship into account. Were only a few unions involved, or greater coordination achieved among them, the relationship between their policies and employment might be considered more directly.

The craft unions in the railroad industry are thus like a jigsaw puzzle. Their number and their competitive interests have contributed to labor unrest and strikes, and they create rigid work-rule restrictions blocking responsiveness to the need for technological change. The multiplicity of unions and their frequent jurisdictional rivalries have hurt the railroad industry particularly in its efforts to compete with other modes of transportation. Further, the fractionalized union structure contributes to fractionalized response on the part of railroads, singly or in groups.

Craft loyalty is intensified whenever a craft is threatened by the contraction of employment opportunities in the declining industry, particularly in the case of abrupt technological changes. Not only do the railroad unions adhere tenaciously to their traditional jurisdictional claims to jobs on a craft basis, even where technological or other changes have blurred lines of demarcation between the original crafts, but, furthermore, the principle of seniority creates problems when employment is reduced; job security becomes a highly sensitive issue, with union emphasis on traditional work rules impeding management efforts to effect changes in those rules necessitated, in management's view, by changed conditions. A prime example of this situation is the crew-size dispute. In addition, as the average age of those retained in employment rises, job security issues become more serious in each craft's negotiations.

Employer Attitudes and Policies

In the crew-size dispute the principal feature of management's attitudes and policies has been the lack of uniformity in the industry. Some railroads were not particularly interested in reducing crews, others merely followed the lead of a few influential railroads in signing agreements regarding crew size during the dispute, and only a handful fought aggressively for management's 1959 claim that crew size is a matter of management authority and not subject to determination by negotiation. It can be expected that the union will continue to take advantage of the general lack of energy and cohesion in the industry in later phases of the dispute.

Facts Regarding Safety and Work Burden

In reviewing the 20-year history of the crew-size dispute, one of my principal criticisms is that, during all that time, with the exception to some extent of the arbitrators during the Arbitration Board 282 period and the Presidential Railroad Commission, neither the parties nor government boards walked out onto the tracks to assess two key factors—safety and work burden.

The industry's position was that it could not afford the expense of what it deemed to be unneeded brakemen; the union's position was that they were needed because of considerations of safety and work burden. Such claims cannot be settled in conversations across a labor-management conference table. The facts can be determined only by going out onto the tracks and into the yards and observing crews at work and analyzing that work in accordance with the principles of an industrial engineering study.

Government Regulation

Railroads have not had the freedom to respond to many competitive challenges because government regulation restricts the industry as a quasi-public utility, although the essential feature of a true utility—namely, its monopolistic character—is not present in the railroad industry.

Regulation circumscribes the freedom of management to adapt operations to evolving markets. For example, it seriously encumbers rate making, a vital competitive marketing tool vis-à-vis crew size. Regulatory procedures and decisions have delayed the abandonment of services that no longer attract patronage sufficient to defray their costs, such as light-density branch lines. Mergers, provisions for ancillary trucking or barge lines, and other basic responsibilities that are normal prerogatives of management in other industries have been subject to detailed regulatory scrutiny and prohibitions. Furthermore, government approval of some changes often entails years of delay and costly legal procedures at both the state and federal levels.

The long-term effect of such intensive regulatory control has been to discourage innovative progress and to blunt management incentives and initiative. Government regulation has produced a sense of helplessness and despair on the part of railroad management regarding its ability to control and improve the destiny of the industry and even to save the industry without turning it over to the taxpayers under nationalization.

Perfunctory Negotiations

Many observers subscribe to the thesis that the Railway Labor Act by its very nature was certain to preclude settlement of the crew-size dispute through collective bargaining. This was so because federal assistance, including mediation by the National Mediation Board and factfinding by emergency boards, cannot practically do more than merely delay the parties' final step in collective bargaining, namely, "self-help" such as a strike or a threat of a strike, which is acknowledged as an intrinsic and legitimate extension of the collective bargaining process. Furthermore, the writing of the status quo ante into law (all the way until 30 days subsequent to the report of emergency board if one is convened) shows an obvious bias in favor of the status quo ante that reinforces the ever-present influences opposed to change in the industry's collective bargaining system. Finally, it is asserted that collective bargaining cannot function as it should with statutory and extrastatutory government intervention on the horizon; why bargain away something that, hopefully, government intervention of one sort or another might later grant?

The public interest emphasis on the maintenance of labor peace in the railroad industry limits the parties' freedom to engage in self-help. Strikes are discouraged as are changes made by management that would precipitate strikes. Because the government will not accept a major railroad strike as an acceptable extension of the collective bargaining process, disputes have tended to shift to the political arena, imposing an untested set of criteria on the settlement process. Equity has become dependent on the political process; some settlements have been achieved only after political pressure has been brought to bear on the parties. There is little question that substantial progress toward labor relations peace cannot be assured by requiring employers and employees to behave toward each other in a manner mandated by the government. Such measures can postpone but not necessarily prevent crises; for example, settlement of the 20-year-old crew-size dispute has been delayed, if anything, by various government interventions.

Critics note that, if the result of an impasse in collective bargaining is to be the appointment of an emergency board or the imposition of some other form of government required status quo rather than an immediate work stoppage, the consequences of nonagreement are materially changed. A work stoppage, or a threat of one, is generally acknowledged as an integral part of the collective bargaining process, as is a lockout by management. Thus, a basic assumption underlying the bargaining process is that a built-in automatic stimulus for settlement exists that will become operative when the costs of nonsettlement become too great for one party. Although this is an ultimate recourse—not to reason but to force in the collective bargaining process—it is a legitimate recourse in the free enterprise system. If such costs are absent, there is no inducement for either of the parties to change its position. Congress stands ready to eliminate the costs of nonsettlement by special legislation whenever major interruption of railroad service threatens the economy; pending such an eventuality, the parties tend to jockey at the collective bargaining table toward placing themselves in strong positions that can be argued before an emergency board.

Consequently, the RLA procedures and their concomitant political environment have eroded the collective bargaining process in the railroad industry because the parties are deprived of incentive to reach agreement prior to the exhaustion of RLA procedures and the report of an emergency board. Even then, good-faith bargaining is unattainable if only one party welcomes congressional intervention.

Union Leadership

In the context of the crew-size dispute, the primary characteristic of the union's leadership has been its indifference to the financial plight of most of the railroads. The record indicates that fear rather than hope has dominated the union position. This fear has been manifested in adherence to old traditions: large-sized crews, crew changes at closely spaced seniority district boundaries, transfer of trains from road to yard crews on entering a yard (known as the road-yard distinction), the prohibition against interdivisional runs of trains, and retention over the years of pay practices developed to suit a set of circumstances that no longer apply.

This contrasts with the attitude held by other union leaders, such as some West Coast longshoremen, who felt it to be in the best long-run interest of their unions to work cooperatively with management in improving business conditions. The West Coast longshoremen's 1960 Mechanization and Modernization Agreement grew out of their realization that the best interests of their union lay in cooperating with management in assuring the health of their industry by means of technological change and relaxation of restrictive work rules.

RECOMMENDATIONS

The following actions are suggested where appropriate by either labor, management, or the government, or in combination as required, in order to promote a healthy and viable railroad industry capable of paying good wages and providing maximum job security.

First, it is important to note that, in contrast with most other industries, government policy covering the railroad industry regulates many aspects of the underlying economic environment, including the rates to be charged for freight service, the ease or difficulty of merger attempts, and the extent and nature of intermodal transportation competition and cooperation. Such types of regulatory control have made intermodal competition an important factor contributing to the pressures on management to improve efficiency, and these pressures have in turn caused management to adopt aggressive policies in collective bargaining directed at inducing the unions to accept changes. This suggests, therefore, that an important aspect of public policy should be the adoption of a regulatory policy that will maintain a relatively high degree of price and service competition among the railroads, truckers, barge lines, and airlines.

Second, more experimentation is required in the use of short trains because of the promise that they hold of eliminating the disadvantages of long trains. In the manufacturing industries, minimum inventories are essential in order to conserve working capital, and such inventories require fast and frequent transportation service. The trucking industry stepped into this gap and provided such service, but at a higher price that was preferable to enlarged inventories. It is obvious that the longer the train, the greater the delays in terminals. It is at this stage that the railroads have been losing the traffic battle to truckers. On the other hand, it is not possible to operate a short train with standard crews, including the yard crews handling it, and to cover its expenses out of income. Yet the short train has a high potential for meeting truck competition if the United Transportation Union will waive present agreements covering crew size, remembering particularly that the short train's purpose is not to replace existing crews but to give new crews employment by securing new business. The future of inexpensive high-priority freight movement for many commodities could belong not to the truckers but to the short train.

One advantage of a contemplated change from long trains to short trains for selected shippers is that the change need not be a radical move; initially, it can be made on a purely experimental basis so that both the railroad and the union can be fully satisfied as to the impact of the change on them before any full-scale operations are initiated. Its objectives are clear: a more marketable transportation service, an improved share of the transportation market, and enhanced job security in a healthier industry. Complete implementation of the short-train concept will require, in addition to identification of current barriers to railroad efficiency and service reliability, commensurate modification in management and union policies and practices, and preliminary experimentation with government cooperation, particularly in granting the railroads flexibility to design competitive freight rates relative to the truckers' rates.

Finally, every effort should be made by responsible union leadership to broaden the base of collective bargaining in the railroad industry. At present a railroad may deal with as many as 20 unions, which are splintered by craft distinctions. The continuing existence of the Brotherhood of Locomotive Engineers outside of the four operating brotherhoods that merged into the United Transportation Union has complicated negotiations materially and made the adoption of progressive policies toward technological change more difficult. The strongest type of union for weathering the storm of technological and economic changes would be a multicraft or semi-industrial union; with such a structure each craft would have a greater chance to forestall total displacement in changing times. Thus, I urge more union mergers within both the operating and nonoperating crafts.

CONCLUSION

The size of a work force is properly a function of management and employees can adequately be protected against management's possible abuse of its authority by a grievance procedure, culminated if necessary by grievance arbitration. This is the general rule and practice in the economy, which has proven to be an effective and enforceable safeguard against unsafe working conditions.

ACKNOWLEDGMENT

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Parametric Study of Track Response

James C. Kennedy, Jr., and Robert H. Prause, Applied Dynamics and Acoustics Section, Battelle Columbus Laboratories, Columbus, Ohio

This paper presents the results of a parametric study of track response using a comprehensive track analysis model. Track response parameters include rail and tie bending moments, rail displacement, tie rail-seat load, and the distribution of stresses in the ballast and subgrade. The effects of variations in tie size, tie spacing, ballast depth, and rail fastener stiffness are presented in graphs suitable for track design trade-off studies. Alternative wood and concrete tie track configurations are evaluated using equivalent maintenance criteria.

Experience from several foreign countries indicating advantages of longer tie life and reduced track maintenance for concrete versus wood ties has aroused considerable interest in developing concrete ties for main-line use in North America. However, few quantitative data are available for comparing wood and concrete tie loads and roadbed stresses, or long-term performance, as a basis for evaluating the technical and economic feasibility of alternative track and tie designs.

Current and past research has shown that the evaluation of track performance and design for vertical loads requires a capability for predicting realistic pressure distributions at the tie and ballast interface and at the ballast and subgrade interface. This requires a track analysis model that includes the effects of many track parameters.

The main purpose of the work presented herein is to use a MUlti-Layered Track Analysis (MULTA) model for vertical loads to develop track design guidelines that include the effects of various tie and fastener characteristics, tie spacing, and ballast depth on track response. Alternative wood and concrete tie track configurations based on equivalent maintenance criteria are evaluated for use in future life-cycle cost analyses.

DESCRIPTION OF TRACK ANALYSIS MODEL

The analysis model selected for this program is a combination of an available multilayer model for the ballast and subgrade and a finite element model to combine the loads for individual ties and rails (load combination program). The load combination program was developed by the Association of American Railroads (AAR). It was modified by Battelle's Columbus Laboratories to incorporate influence coefficients from the multilayer roadbed model to provide a complete track model.

Figure 1 shows a schematic of this combination model known as MULTA. This provides a linear track analysis that includes single or multiple wheel loads on two rails supported by ties of variable size and spacing and a finite bending rigidity. The tie-bearing area is divided into segments of approximately square dimensions, and these are used to generate influence coefficients for pressures and displacements from the multilayer roadbed model. This system of equations is solved using matrix analysis techniques to calculate ballast and subgrade stresses and rail and tie displacements.

REFERENCE TRACK PARAMETERS

A MULTA model of a track section having 11 ties and separate layers for the ballast and subgrade was used for this parameter study. The track was loaded vertically at the center tie of 1.07 MN (240 000 lbf) using the load for a single axle of a freight car and a wheel load of 133 kN (30 000 lbf). This is a linear analysis program, so results for heavier or lighter wheel loads can be obtained by direct scaling. Because MULTA presently handles a single vertical load per rail for each computer run, adjacent axle loads were not simulated. However, adjacent axle loads could be included by superposition. This effect is discussed later in the paper. The parameters of particular interest for this study were rail and tie displacement, vertical rail-seat load, tie bending moments at the center and rail-seat regions, maximum rail bending moment, displacement (strain) throughout the foundation, bulk stress at selected points in the foundation, vertical and deviatoric stress at selected points throughout the foundation, and tie-ballast interface pressures.

Table 1 lists the track parameters included in this study. Variations in tie size, stiffness, and spacing and ballast depth were selected as the key parameters. The effect of varying rail size can be evaluated adequately using conventional track design procedures based on beam-on-elastic-foundation (BOEF) equations when the track modulus has been established. Work by Tayabji and Thompson (1) shows that variations in ballast and subgrade modulus over a typical range for field conditions do not cause large changes in predicted stresses. Track degradation under repeated load would vary considerably, however, for different materials. The roadbed material properties used for this study are based on average values reported in Tayabji and Thompson (1). For purposes of the parameter study, a reference track designated by the underlined parameters in Table 1 was used for baseline comparisons. (Measurement units reported in this paper are those used in the study; in most instances, SI units are reported without their customary equivalents. Further, because some studies are reported in customary units, no SI equivalents are given.)

TRACK MODEL EVALUATION

The MULTA model was evaluated previously by Prause, Harrison, Kennedy, and Arnlund (2) by comparing predicted and measured data for the distribution of tie and ballast pressures along the tie length and by comparing measured and predicted tie bending moments. When the input data are selected properly, predicted and measured results were in agreement except for ties that have a severe center-binding condition. This nonuniform support condition cannot be simulated with MULTA because a uniform elastic support model is used for the roadbed. MULTA has also been evaluated by comparing results from other track analysis models. This comparison is shown in Prause and Kennedy (3).

TRACK FOUNDATION STRESSES

Vertical pressure distributions at the tie and ballast interface and on the subgrade at the ballast and subgrade interface were calculated for the ballast depths listed in Table 1. Deviatoric (σ_D) and bulk (θ) stress distributions along the tie were also calculated at selected depths through the foundation. Knutson and Thompson (4) have shown the dependence of resilient modulus (E_R) on these quantities. For ballast material, the resilient modulus is a function of θ; for typical subgrade materials the resilient modulus is a function of σ_D. The deviatoric stress is calculated midway through the ballast depth and at the ballast subgrade interface. Deviatoric stress is monitored at these two locations because the work of Raymond, Lake, and Boon (5) shows that foundation material is a function of deviatoric stress for both ballast and subgrade materials. Therefore, θ, and especially σ_D, are used to evaluate degradation in the ballast and subgrade. The reduction of

Figure 1. Schematic for track model.

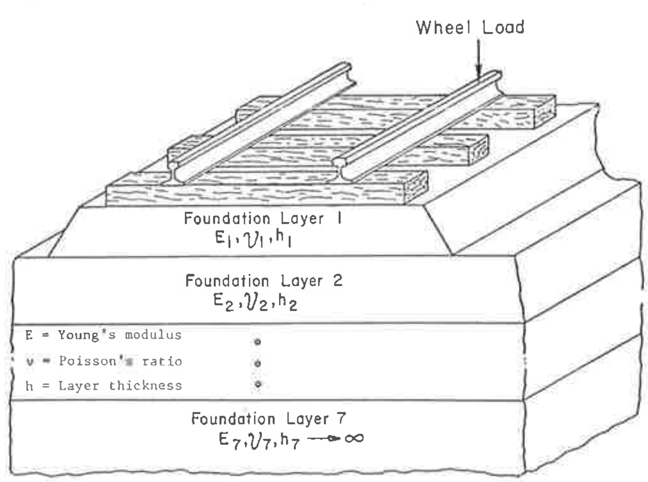


Table 1. Track model parameters.

Item	Parameters[a]
Rail	67.5 kg/m, I = 3950 cm^4, E = 232.3 × 10^6 kPa, A = 86.13 cm^2
Wood tie	17.8 cm thick, 22.9 cm wide, 259.1 cm long, EI = 1349 × 10^7 N·cm^2, spacing = 0.50 m
Concrete tie	259.1 cm long, spacing = 0.51, 0.61, 0.76 m
Small	25.4 cm wide, EI = 2192 × 10^7 N·cm^2 A = 387 cm^2
Medium	26.7 cm wide, EI = 2902 × 10^7 N·cm^2, A = 413 cm^2
Large	26.7 cm wide, EI = 6719 × 10^7 N·cm^2, A = 529 cm^2
Ballast/subballast	E_1 = 241 000 kPa, ν_1 = 0.4, depth = 30.5, 61, 91.4 cm
Subgrade	E_2 = 80 400 kPa, ν_2 = 0.4, depth = infinite
Rail fastener stiffness	1.8, 3.5, 7, 17.5, 70 × 10^4 kN/m
Wheel load	133 kN

Note: 1 kg/m = 2 lb/yd, 1 cm = 0.4 in, 1 kPa = 0.15 lbf/in^2, 1 N·cm^2 = 0.035 lbf·in^2, 1 m = 0.3 ft, 1 kN = 225 lbf.
[a] Reference track parameters are underlined.

Figure 2. Effect of ballast, tie size, and tie spacing on track modulus.

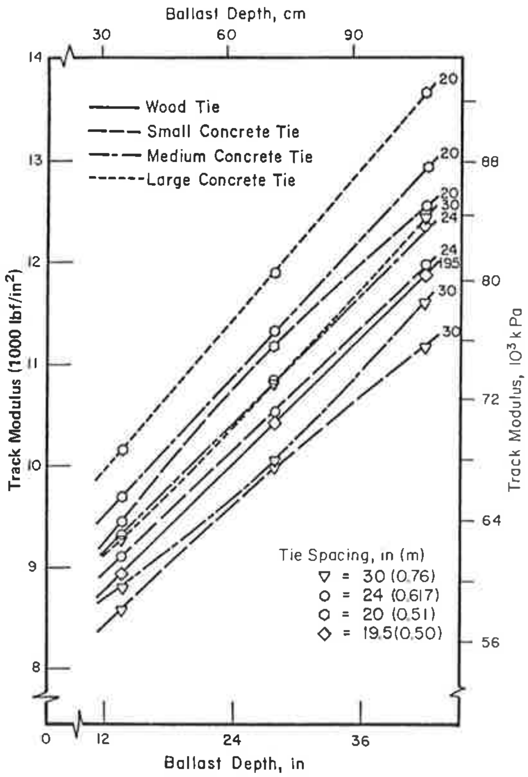
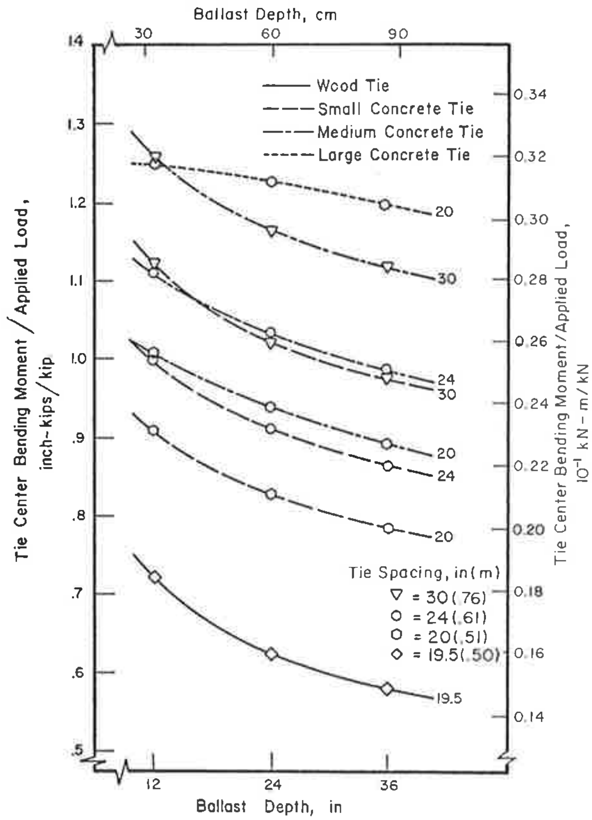


Figure 3. Maximum tie center bending moments.



deviatoric stress by judicious selection of track design parameters is one of the main interests of this parametric study.

TRACK MODULUS

The track modulus (U) is defined as the force per inch of rail required to depress the track roadbed 1 in. This parameter has been used historically to quantify the effective stiffness or resilience of a track structure, and it is a key parameter in the BOEF analysis procedure used for conventional track design. Thus, the MULTA results have been used to calculate an effective track modulus in order to give a recognizable measure of the roadbed stiffness.

Figure 2 shows the range of track modulus data included in the parametric study of tie spacing, ballast depth, and tie size. Track modulus increases with increasing values of tie size and ballast depth and decreases with an increase in tie spacing. This effect of tie spacing is consistent with conventional track design procedures. However, the effect of ballast depth on track modulus is not usually considered, and it is obviously very significant.

The calculations of track modulus shown in Figure 2 are based on the BOEF equations for vertical rail displacement in the form

$$U = [(P/Y_o)^4/64\ EI]^{1/3} \quad (1)$$

where

Y_o = maximum rail displacement predicted by MULTA,
P = wheel load, and
EI = rail bending stiffness.

SUMMARY OF TRACK RESPONSE

The following sections summarize the results from the parametric study of tie size, tie spacing, and ballast depth in graphs suitable for track design and performance trade-off studies.

Tie Bending Moments

Maximum tie center bending moments normalized to the wheel load are shown in Figure 3. The center bending moment increases as tie spacing and tie size increase, but increasing the ballast depth reduces the bending moment. Tie center moments increase approximately 40 percent in going from the small concrete tie to the large concrete tie and approximately 75 percent when going from the wood tie to the large concrete tie. The tie center moments decrease about 16 percent when going from a 30-cm (12-in) ballast depth to a 90-cm (36-in) ballast depth.

Figure 4 shows that tie rail-seat bending moment increases with tie size, tie spacing, and ballast depth. Both tie center and rail-seat moments increase significantly with tie size and tie spacing. Rail-seat bending moments increase about 10 percent when using the large concrete ties instead of the small concrete ties, and about 23 percent when using the large concrete ties compared to the wood ties. Rail-seat moment increases less than 3 percent when going from a 30-cm ballast depth to a 90-cm ballast depth, and ballast depths greater than 90 cm have a negligible effect.

These predicted tie bending moments do not include the effects of nonuniform support conditions found in typical track. Tie center bending moments in particular can be much higher with center-bound ties and can change with end-bound ties.

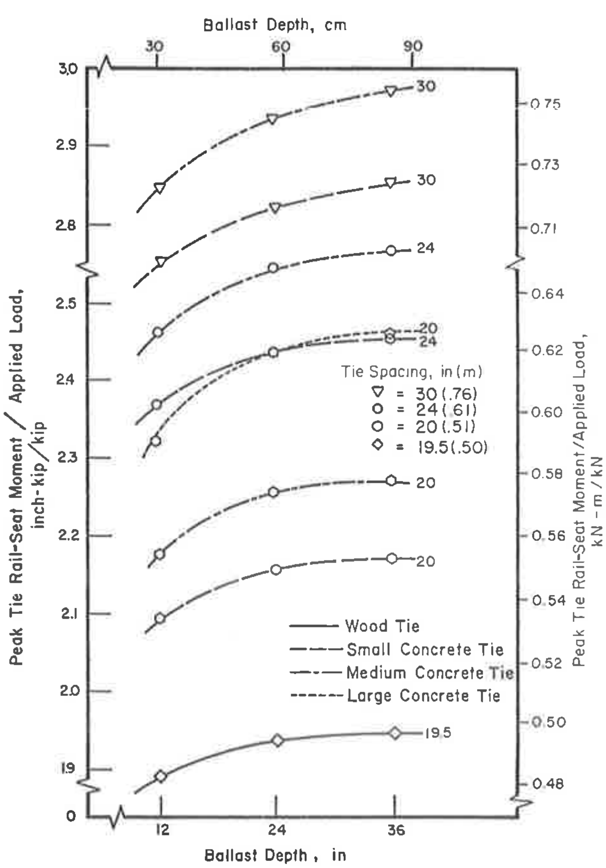
Rail Displacement

Figure 5 shows rail displacement normalized by the applied wheel load as a function of ballast depth, tie size, and tie spacing. This comparison shows a slight increase in displacement with tie spacing—about a 10 percent increase when tie spacing changes from 50 cm (20 in) to 75 cm (30 in). This is a much smaller change than would be predicted by conventional track design procedures. Rail displacement decreases slightly (about 7 percent) when the tie size is changed from the small to the large concrete tie. Rail displacement also decreases with an increase in track stiffness, i. e., a deeper ballast. When the ballast depth is increased from 30 cm to 90 cm, the displacement is reduced by about 20 percent. Figure 5 shows that synthetic ties of different size, spacing, and ballast depth can reduce track displacements from that of the wood tie track structure. This result has been confirmed in practice.

Rail-Seat Load

Figure 6 shows the variation in tie vertical rail-seat load (q_o). The rail-seat load increases with a corresponding increase in each of the varied parameters, as expected. When the small synthetic tie configuration was changed to the large tie configuration, q_o increased about 6 percent, but changing ballast depth from 30 cm to 90 cm increased q_o by about 13 percent. An increase in synthetic tie spacing from 50 cm to 75 cm amounted to about a 33 percent increase in q_o. It is apparent from Figure 6 that the rail-seat loads will be consistently higher with synthetic ties used in place of wood ties because of the increased tie spacing and higher track stiffness from the wider ties.

Figure 4. Maximum tie rail-seat bending moment.



Ballast Stresses

The deviatoric and bulk stresses have been selected as important quantities to monitor because these stresses influence track degradation rate. Figures 7 and 8 show the stress levels in the ballast for different tie sizes, tie spacing, and ballast depth. Figure 7 shows that comparable levels of peak deviator stress midway through the ballast depth can be obtained for several combinations of tie spacing and ballast depth. Using a 30-cm ballast depth for reference, an increase in ballast depth of 3.8-7.6 cm (1½-3 in) is about equivalent to a 2.54-cm (1-in) reduction in tie spacing with regard to its effect on reducing ballast pressure. Maximum deviator stress decreases rapidly as ballast depth increases—decreasing about 44 percent as ballast depth is increased from 30 cm to 90 cm for the 75-cm tie spacing, about 36 percent for the 49-cm (19½-in) spaced wood ties, and about 30 percent for the 50-cm spaced concrete ties. As ballast depth increases, the level of deviator stress converges to within 20.67 kPa (2.5 lbf/in^2) of a common value for all ties and tie spacing.

Figure 7 also shows that increasing the tie size for a given tie spacing reduces the level of deviator stress in general, but the range of tie width evaluated in this study was limited. However, an anomaly exists with 50-cm tie spacing because the larger tie actually increases ballast stress compared to a smaller tie for thin layers of ballast. The large concrete tie generates higher deviatoric stress midway through the ballast layer than the medium synthetic tie. This is due to the high stress at the tie end that is generated when the tie stiffness is quite high relative to the roadbed stiffness. In this study, the large concrete tie was three times stiffer than the small concrete tie and five times stiffer than the wood tie. When the tie is quite stiff relative to the roadbed, the pressure distribution under the tie would

Figure 5. Maximum rail displacement.

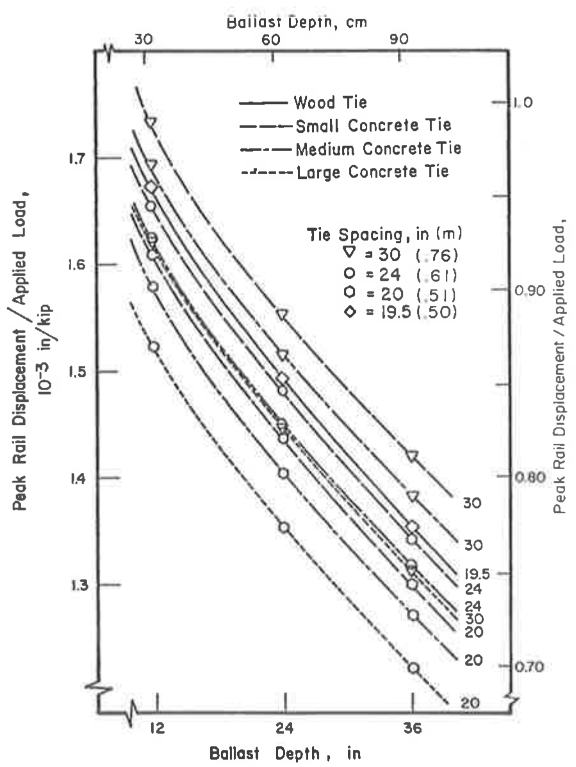


Figure 6. Rail-seat load.

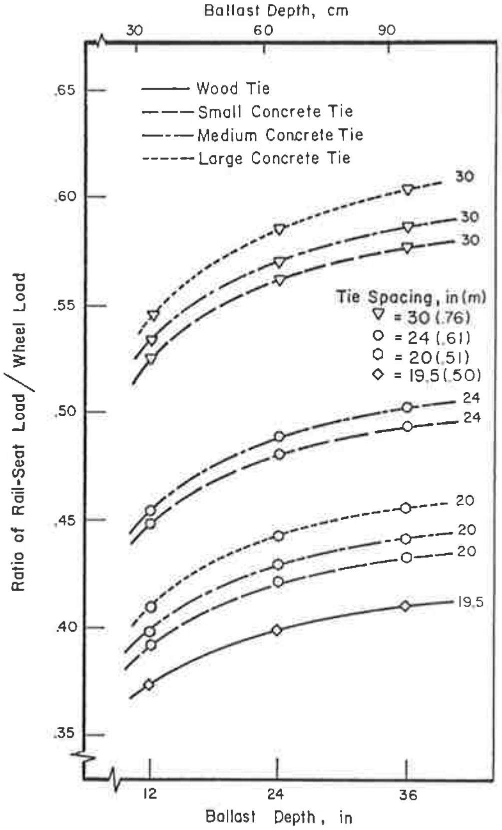


Figure 7. Maximum deviatoric stress midway through ballast.

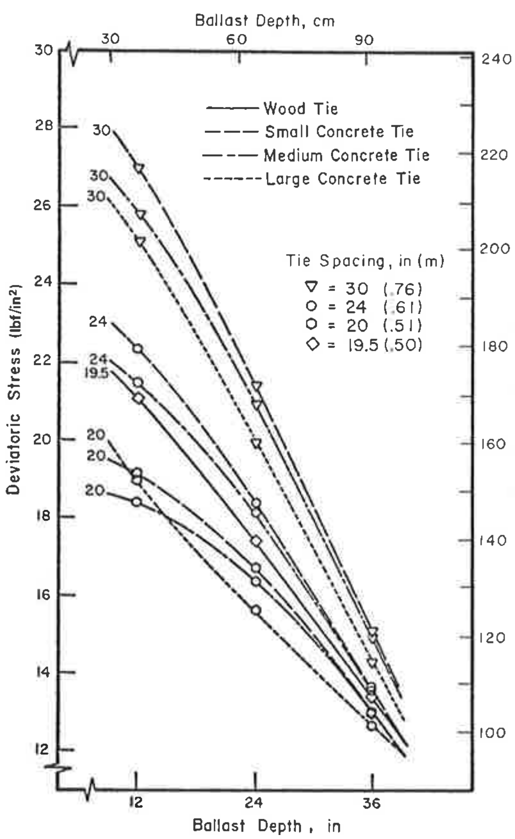
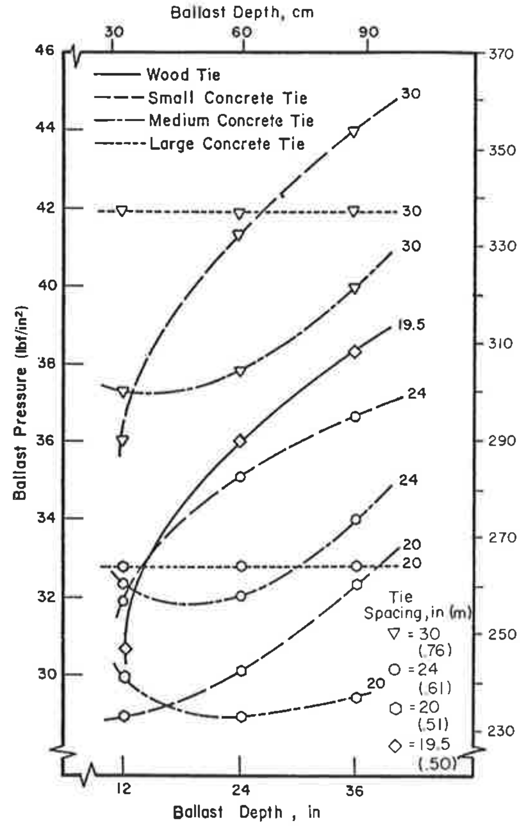


Figure 8. Maximum vertical ballast pressure at tie ballast interface.



resemble that of a rigid punch on an elastic medium. The vertical pressure at the ends of the tie would be very high (theoretically infinite) and reduce to some minimum value at the tie center. The punch effect of the stiff, large tie causes high stresses at the end of the tie on the relatively flexible roadbed with only 30 cm of ballast. Thus, crushing and flow of the ballast at the ends of the tie may be a problem. This loss of ballast support at the tie ends has been observed recently at the Facility for Accelerated Service Testing track in Pueblo, Colorado. Loss of ballast at the tie ends may also be increased by vibration aggravated by tie center-binding and rail corrugation.

The effect of too thin a ballast layer for a stiff tie should not be ignored. As the ballast depth is increased, ballast stiffness and, thus, roadbed stiffness increase. Therefore, the ratio between tie and roadbed stiffness decreases and the punch effect is reduced.

Maximum bulk stress at a location midway through the ballast for the same parameter variations behaved in much the same manner as the deviatoric stress. The stress level reduced rapidly and converged to within 13.78 kPa (2 lbf/in^2) of a common value as ballast depth increased from 30 cm to 90 cm. The punch effect of using a large concrete tie with a thin ballast layer was evident. Increasing the size without properly increasing ballast depth could minimize the advantages of a larger tie.

The maximum pressure on the ballast surface under ties is one of the criteria used in conventional track design procedures. A maximum allowable pressure at 448 kPa (65 lbf/in^2) is typical. Figure 8 shows the maximum vertical ballast pressure predicted by MULTA. Increasing tie spacing increases the ballast pressure in all cases, as expected. Increasing track

Figure 9. Maximum subgrade deviatoric stress.

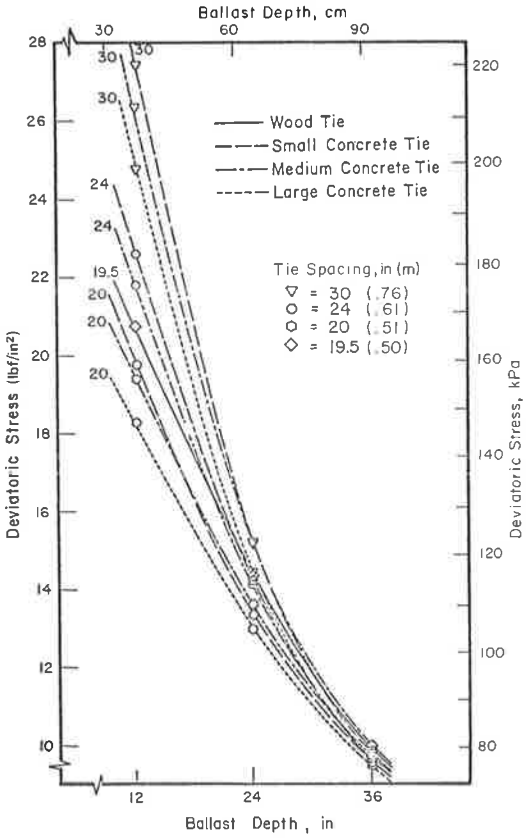
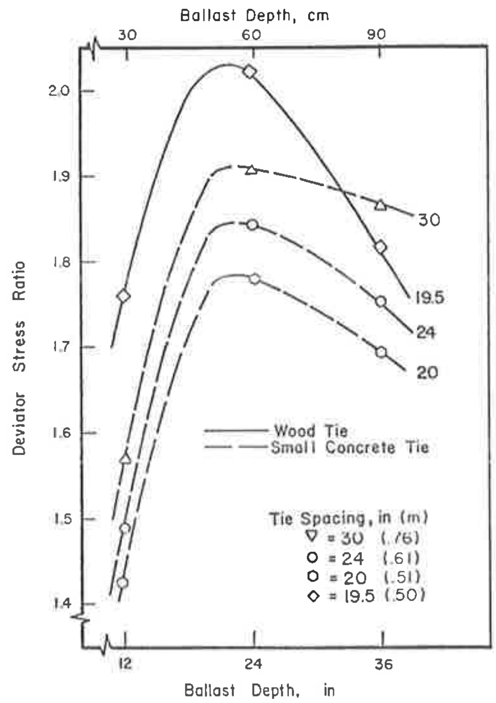


Figure 10. Maximum-minimum deviatoric stress ratio across tie midway through ballast.



stiffness by increasing ballast depth also causes some increase in ballast pressure due to the increase in rail-seat load. However, the interaction between tie and roadbed stiffness is also evident, thus obscuring any clear trends. Increasing the roadbed stiffness with a relatively flexible tie such as wood or the small and medium-sized concrete ties does increase the maximum ballast pressure. However, the ballast pressures from the stiff large tie are independent of ballast depth and can provide some advantage over the smaller ties at the same spacing on deep ballast due to the more uniform pressure distribution along the tie length.

Subgrade Stresses

Figure 9 shows the maximum subgrade deviator stress that occurs at the ballast and subgrade interface. The maximum deviator stress is very sensitive to increases in ballast depth and tie spacing. For ballast depths of about 30 cm, stress increases from increasing tie spacing can be offset by equal changes in ballast depth. For ballast depths greater than about 75 cm, the effects of tie size and spacing become negligible.

The maximum vertical subgrade stress at the ballast and subgrade interface behaved in the same manner as the subgrade deviatoric stress. The maximum values of subgrade stress decreased rapidly with increased ballast depth. Vertical stress on the subgrade increased with a corresponding increase in tie spacing, but this effect can be offset by a small increase in ballast depth. The vertical stress converged to a common value for all tie sizes and spacings for ballast depths greater than about 61 cm (24 in).

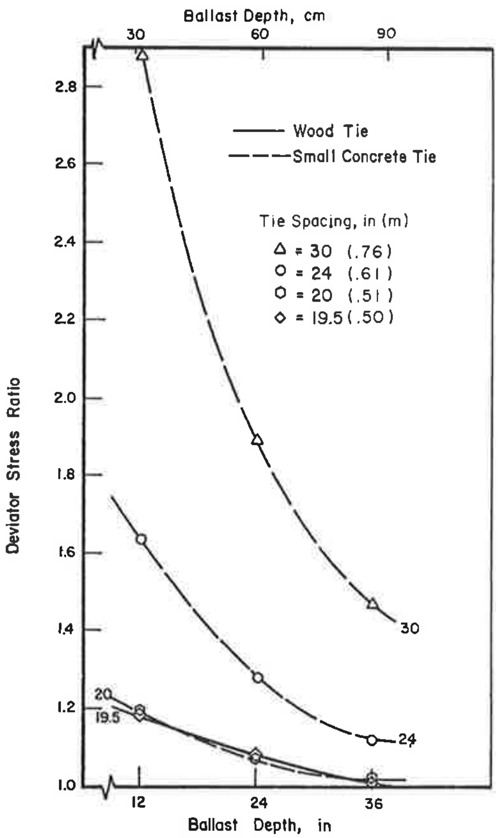
Ballast and Subgrade Stress Distribution

The previous data showed maximum stresses that occur at some point under a tie. Although the maximum stress is certainly a major factor in track performance, the variations in stress under a tie and along the track length also contribute to degradation. Nonuniform ballast stresses cause differential compaction and flow under the ties leading to an end-bound or center-bound support condition. Uniform ballast stresses would hopefully cause uniform settlement. This would minimize the effects of nonuniform support condition and reduce the peak pressures to the average pressure, thereby effectively utilizing the entire bearing area of the tie.

Nonuniform stresses on the subgrade cause depressions or rutting. These depressions will collect and retain moisture in climates with significant rainfall, and the resulting local reduction in subgrade strength will cause a rapid increase in the rate of settlement and pumping. This possibility was recognized by Salem and Hay (6), and they recommended a ballast depth of about 46 cm (18 in) to minimize subgrade pressure variations along the track with wood ties spaced at 53 cm (21 in). However, significant subgrade pressure variations remain under the tie even with ballast depths of 46 cm. This indicates that even greater ballast depths may be required to achieve a uniform pressure distribution and eliminate subgrade rutting under the rails. This observation has previously been ignored in track design.

Several pressure ratios have been calculated as a quantitative measure of the uniformity of roadbed pressure distributions. A pressure ratio for the maximum to minimum pressure variation under a tie and for the maximum to minimum pressure variation from under the tie to midway between ties at the rail-seat region gives an indication of the tie and track pressure variations. A pressure ratio close to 1.0 represents the ideal pressure distributions to minimize differential ballast degradation and rutting in the subgrade. Figures 10 and 11 show these two pressure ratios in the ballast for the small concrete tie compared to the referenced wood tie track. The stiffer concrete tie produces a more uniform pressure distribution under the tie (Figure 10) for practically all tie spacing and ballast depth combinations, but the wood tie track shows more uniform pressures along the track (Figure 11). Increasing tie spacing causes a relatively large increase in pressure ratio along the track compared to under the tie, but the pressure variations under the tie are higher and are, therefore, the more critical design problem.

Figure 11. Maximum-minimum deviatoric stress ratio along track midway through ballast.



The same pressure ratios were calculated at the subgrade as a measure of potential rutting. Increasing ballast depth effectively attenuates subgrade pressure variations both under the tie and along the track. The effects of increasing the tie spacing are relatively minor for ballast depths greater than about 61 cm. The subgrade pressure variations under the tie are more important than those along the track for ballast depths greater than about 30 cm.

Effect of Rail Fastener Stiffness

The results presented in the previous paragraphs were based on a rail fastener having a nominal vertical stiffness (spring rate) of 40 × 10^5 lb/in, typical of many fasteners currently being used with concrete ties in the United States. This stiffness represents the total load-deflection characteristics for a rail fastener assembly consisting of rail restraining devices and a tie pad. Rail fasteners are simulated in the MULTA program by linear vertical springs between the rail base and each tie.

Figure 12 shows that reducing the rail fastener stiffness increases rail displacements significantly when the fastener stiffness is less than about 500 000 lb/in. This reduction in stiffness also distributes the wheel load over more ties so that the maximum rail-seat loads and, therefore, tie deflections are reduced. The effect of varying the rail fastener stiffness depends on the stiffness of the fastener relative to the effective roadbed stiffness at each tie. When the fastener is rigid relative to the roadbed, the track response is governed by the roadbed stiffness and the deflection of the rail fastener is very small, as the right side of Figure 12 indicates. When the fastener is very flexible relative to the roadbed, the track response is governed by the fastener stiffness as indicated on the left side of Figure 12.

Figure 13 shows that a flexible rail fastener does reduce the maximum rail-seat load and the tie and ballast pressure. The maximum tie bending moments

Figure 12. Effect of rail fastener stiffness on maximum rail and tie deflections.

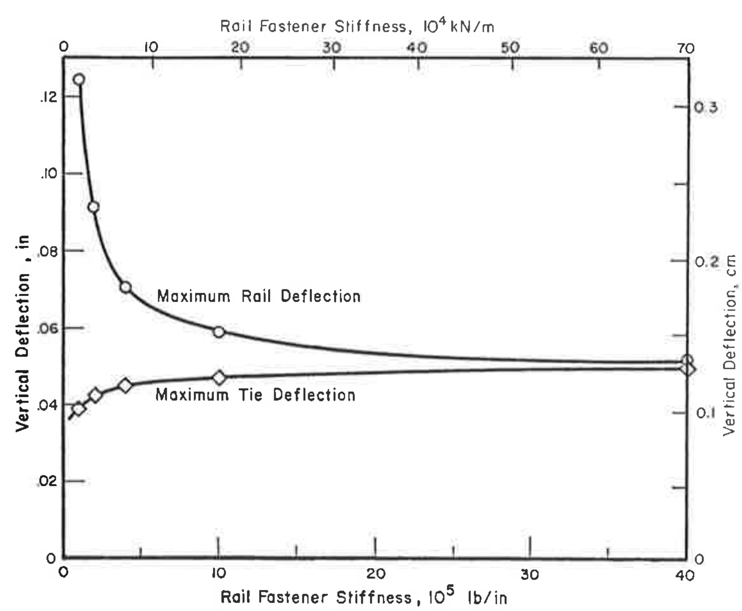


Figure 13. Effect of rail fastener stiffness on maximum vertical rail-seat load and ballast pressure.

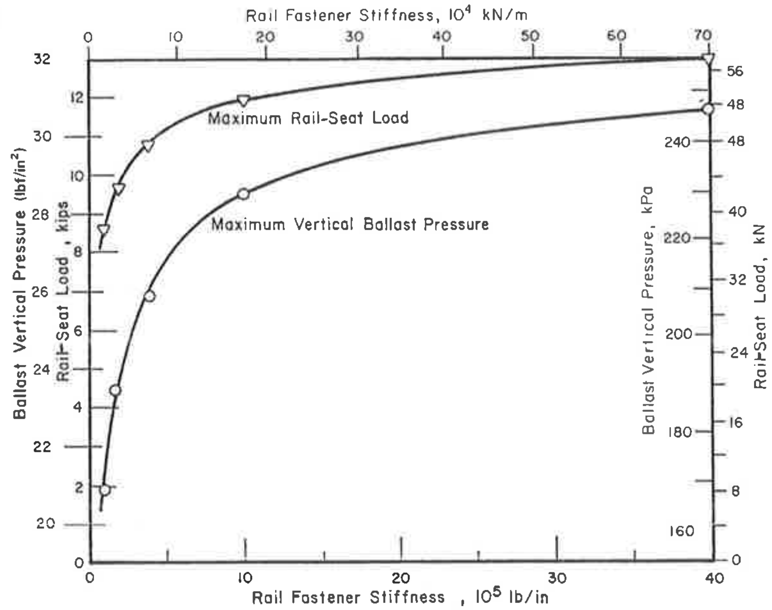
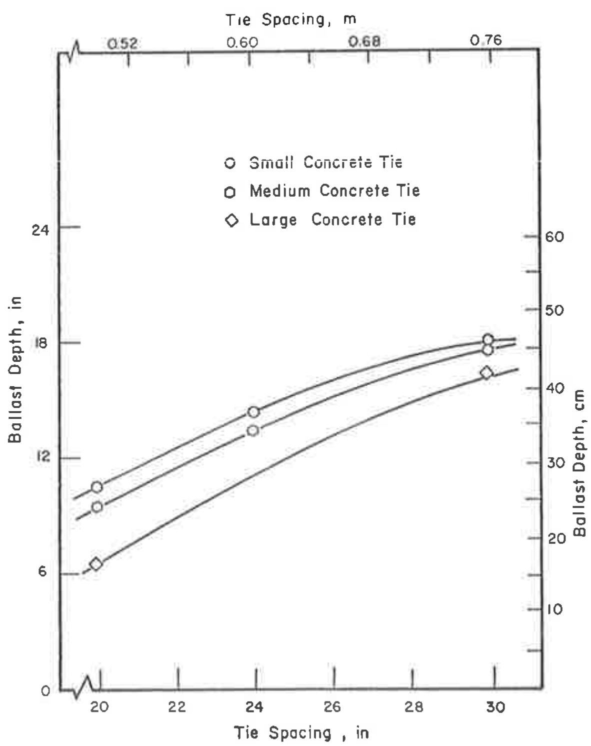


Table 2. Typical rail fastener vertical stiffness data.

Fastener Type	Toe Load (kN per clip)	Clip Stiffness (10^4 kN/m per clip)	Total Fastener Stiffness (10^4 kN/m)
Very flexible	-	-	1.75-3.50
Flexible	7.1-12.0	0.035-0.123	8.75-28.0
Rigid	-	0.35-8.76	35.0-123

Note: 1 kN = 225 lbf, 1 kN/m = 68 lbf/ft.

Figure 14. Tie spacing and ballast depth requirements to give same maximum subgrade deviatoric stress as wood tie track.



and subgrade pressures would be reduced accordingly. Rail bending moments are increased somewhat, but this is not usually critical unless a relatively small rail is used.

It is important to realize that practically all of the rail fasteners currently being used for concrete ties in the United States are relatively rigid compared to the roadbed. Table 2 shows some typical stiffnesses for three general classes of fastener. Very flexible fasteners are used for direct fixation transit track, such as in Toronto, where it is important to attenuate ground vibrations in subways. These fasteners restrain the rail by thick pads of rubber and are sufficiently flexible to reduce tie loads. However, they are not designed for the higher axle loads of U. S. railroads.

The flexible fastener category includes several different configurations with metal retaining clips having considerable flexibility. However, these are generally installed in the United States with a relatively thin (⅛-³⁄₁₆ in) rubber or plastic rail pad that is very stiff relative to the clip. This produces a fastener with a vertical stiffness of 5 to 16 × 10^5 lb/in, which provides very little reduction of track loads. The stiffness of the rail pad determines the total stiffness of the fastener assembly for these designs.

Rigid fasteners include several configurations of stiff metal clips with thin rail pads of very hard material. The rail pad must be quite stiff to avoid fatigue failures of the rigid clip and attachment hardware. The stiffness of these fasteners is typically in the 20 to 70 × 10^5 lb/in range, and this cannot be expected to produce any substantial reduction of static or dynamic rail loads.

These results show that rail fasteners must have a vertical stiffness less than about 500 000 lb/in in order to provide any significant benefit by distributing wheel loads over more ties. These conclusions are based on a static analysis where the load is assumed to be constant. A second potential benefit of a flexible fastener is in reducing dynamic loads resulting from track irregularities, such as joints or rail welds and wheel flats. The increased stiffness of concrete tie track is undesirable from the standpoint of producing higher dynamic forces that adversely affect mainte-

Table 3. Comparison of concrete tie track designs expected to perform in the same manner as standard wood tie track.

Concrete Tie Type	Tie Spacing (m)	Ballast Depth (cm) Equal Subgrade Vertical Stress[a]	Equal Subgrade Deviator Stress[b]	Equal Ballast Surface Vertical Stress[c]	Equal Ballast Deviator Stress[d]
Small	0.55	27.9	30.5	43.2	26.7
	0.61	30.5	36.8	26.7	40.6
	0.69	33.0	41.9	22.9	53.3
	0.76	35.6	45.7	22.9	62.2
Medium	0.55	24.1	27.9	-	17.8
	0.61	26.7	34.3	-	34.3
	0.69	29.2	40.6	-	48.3
	0.76	31.8	44.5	-	59.7
Large	0.55	19.1	21.6	-	21.6
	0.61	22.9	27.9	-	30.5
	0.69	26.7	35.6	-	43.2
	0.76	31.8	40.6	-	55.9

Notes: 1 m = 3.3 ft, 1 cm = 0.4 in.
Wood tie reference track is 17.8-cm x 22.9-cm x 259-cm wood ties at 0.50-m spacing.
[a] Maximum subgrade vertical stress = 93.3 kPa.
[b] Maximum subgrade deviator stress = 166.4 kPa.
[c] Maximum ballast vertical stress = 246.8 kPa.
[d] Maximum ballast deviator stress midway in ballast layer = 169.6 kPa.

nance of both track and vehicles. Previous studies by Battelle Laboratories (7, 8) and others have shown that it is desirable to introduce resilience into the rail fastener to compensate for this increased stiffness. Development efforts in Europe and the USSR of fasteners having multiple thick elastomeric pads indicates that increased flexibility is a major design objective. This trend appears to have been ignored in the United States where recent fastener modifications have included reducing the thickness and increasing the durometer of pads to improve fatigue life of the rail clips—all steps that increase fastener stiffness.

It is recognized that, once fastener resilience is given a high design priority, achieving a successful design is no small challenge. Maintaining adequate lateral restraint against gauge spread and rail rollover while reducing the vertical stiffness is the major problem. Another problem is that stiffness characteristics of most elastomers vary considerably with temperature, making it difficult to maintain uniform performance throughout the year. However, the reduction of impact loads and the improvement in load distribution that can be obtained with more flexible fasteners should be adequate to encourage additional development efforts by industry.

DESIGN FOR EQUIVALENT TRACK PERFORMANCE

The lack of criteria to relate track response parameters in the form of ballast and subgrade stresses to quantitative predictions of track degradation rate make it difficult to compare different track structure designs in a meaningful way. However, it is possible to select track structures expected to give equal performance with regard to surface maintenance by comparing selected track response parameters from the parametric study.

For example, Figure 14 shows those concrete tie track designs that have the same maximum subgrade deviatoric stress as a wood tie track with 49.5-cm (19.5-in) tie spacing and 30 cm (12 in) of ballast. All calculations are based on 136 lb/yd rail and the same subgrade and material properties used for the parametric study. These results show that relatively small increases in ballast depth will compensate for substantial increases in tie spacing.

Table 3 summarizes the equivalent track design parameters for several tie spacings based on equal subgrade and ballast stresses. Equivalent designs are shown based on maximum vertical stresses as used in conventional design procedures and maximum deviator stress, which is recommended as a more suitable indication of long-term performance.

This comparison shows that the greatest ballast depths for a selected tie spacing will be required to equalize the ballast deviator stress. Both ballast and subgrade deviator stress criteria require greater ballast depths and, therefore, a more conservative design than the vertical stress criteria used for conventional track design. These summary data also show that the larger concrete tie has the advantage of requiring less ballast depth or wider spacing for comparable performance. This results primarily from the increase in bending stiffness because the tie width is almost the same for the small, medium, and large concrete ties. A substantial increase in width would give an added performance advantage to the large tie.

Increasing ballast depth also reduces the subgrade pressure variations as measured by the pressure ratios under the tie and along the track. An exercise similar to that shown in Table 3 could be done using equal pressure ratios as the criteria. The difficulty is that an overall performance index that combines these different parameters with appropriate weighting factors for track degradation is needed to further quantify track design.

SUMMARY

MULTA, a track analysis model, was developed in order to predict realistic stress distributions in the ballast and subgrade. This model also includes the effect of tie bending and changes in ballast depth, ballast and subgrade material properties, tie size, and tie spacing. This is a significant improvement over conventional track design practice.

Results from the MULTA model with vertical loading show the influence of tie bending stiffness on the variations in tie-ballast pressure along the tie length. Wood ties and small concrete ties that are flexible relative to the roadbed cause maximum pressures under the rail-seat region. Large concrete ties with a high bending stiffness relative to the roadbed stiffness can cause maximum pressure close to the tie ends. The maximum stress levels in the ballast and subgrade are major factors in track settlement, but nonuniform stress distribution on the subgrade under the tie and along the track can cause local depressions or rutting. These depressions will collect water resulting in possible slow drainage. The local reduction in subgrade strength from excess moisture will cause a rapid increase in settlement and pumping. For this reason,

both the maximum ballast and subgrade stresses and a ratio of maximum to minimum stress as a measure of stress variation are recommended as critical factors for track design. Increasing tie spacing causes a relatively large increase in pressure ratio along the track, but the pressure variations under ties are higher and are therefore the more critical design problem. Track design data generated with the MULTA program can be used to evaluate the effects of changing ballast depth, tie size, and tie spacing on roadbed stresses. The parametric study showed that a track system with various combinations of synthetic tie size, tie spacing, and ballast depth gave equal or superior roadbed stress conditions when compared to a track structure with wood ties.

Results from the parametric evaluation of vertical rail fastener stiffness showed that the distribution of track loads can be improved by using a flexible fastener with a vertical stiffness less than about 500 000 lb/in. Other studies show that a flexible fastener can also reduce impact loads from wheel flats and rail joints and thereby can compensate for the normal increased stiffness of concrete over wood tie track. European and Russian fastener development efforts have been concentrated on designing more flexible rail fasteners. This trend has been largely ignored in the United States, where all fasteners currently used with concrete ties are rigid relative to the track. Maintaining adequate lateral restraint against gauge spread and rail rollover is the major design problem in developing a fastener with a lower vertical stiffness. However, the reduction in impact loads and the improved load distribution that can be obtained with more flexible fasteners should be adequate to encourage additional development efforts by the industry.

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Effects of Ride Environment on Intercity Train Passenger Activities

Anna M. Wichansky*, Transportation Systems Center, U.S. Department of Transportation, Cambridge, Massachusetts

The ability to read, write, talk, and sleep on a transit vehicle has been cited frequently in the ride quality literature as an important factor in passengers' comfort and satisfaction with transportation systems. A field study of passenger activities on intercity trains was conducted to quantify and describe the relation between the relative frequencies of various passenger behaviors and the physical parameters of ride quality. Vibration in six degrees of freedom, acoustic noise, temperature, relative humidity, and illumination were measured at the same time as observations of passenger activity were made aboard 77 Amtrak vehicles on 14 trains between Newark, New Jersey, and Washington, D.C. Rotational vibration rates (1-20 Hz) were found to be negatively correlated with the observed performance of social and motor activities and positively correlated with resting behaviors. Linear vibrations did not significantly affect observed activity frequencies. Noise levels resulting primarily from passengers' conversations were negatively correlated with frequencies of sleeping. Activity levels also varied with vehicle type and time of day. Multiple regression techniques were used to develop linear equations of physical ride quality and trip variables that predict approximately 20 percent of the variance in activity levels. Individual differences are postulated to explain the remaining activity variance. The activity equations could be used to specify acceptable levels of ride quality factors for passenger activity performance in the design of advanced transportation systems.

The ability to read, write, talk, and sleep on a transit vehicle has been cited frequently in the ride quality literature as an important factor in passengers' comfort and satisfaction with various transportation systems. It has been suggested by Stone (1) that activity factors are among the most probable human factors elements associated with ride quality and, hence, with comfort. Allen (2) indicates that the most common type of discomfort experienced by passengers is probably caused by interference with activity. The only internationally recognized guidelines for evaluation of human response to whole-body vibration, International Organization for Standardization (ISO) Document 2631 (3), also implicates activity interference as a source of discomfort in its description of the reduced comfort boundary, which is related to difficulties in carrying out such operations as eating, reading, and writing.

Although passenger activities have received some recognition as human response patterns that might depend on ride quality and vary in some way with subjective assessments of comfort and willingness to use a transportation system on a regular basis, no systematic study of these relations is currently available. If comfort does depend on the ability to perform activities, then quantifying the relations between the physical ride environment and levels of activity could provide a tool that would enhance passenger satisfaction.

The majority of studies in the ride quality and vibration research literature are concerned with either (a) the subjective effects of vibration on human sensation, as measured by using psychophysical methods or rating scales in laboratory experiments or through controlled field studies of passenger comfort (4-7), or (b) the objective effects of vibration on human performance, as measured by using task-specific dependent variables in highly controlled laboratory experiments (8-10). The question remains, however, as to the effect of vibration and other environmental variables on passenger performance of activities such as reading, writing, and sleeping in various transportation environments.

Some information regarding the subjective importance and difficulty of performing various passenger activities is available from studies of passengers on short takeoff and landing (STOL) airplanes (11-14). The results of these surveys generally indicate that passengers' perceived ability to perform activities is significantly related to subjective assessments of comfort and satisfaction and to objective measures of the ride environment. The passenger activity data from these surveys, however, consist solely of passengers' subjective reports of their own behavior. Because actual behavior does not always correspond to self-reports of that behavior, it is usually preferable to obtain objective data whenever possible from observations, experimental performance measures, or other direct methods of behavioral assessment.

If activities could be established as an objective behavioral correlative of the physical ride environment and if the relations between levels of activity and the environment could be described in a quantitative form, then this quantitative description might be used as a tool to further specify ride environment variables at levels acceptable for the performance of passenger activities. Design of such an environment might in turn enhance passenger satisfaction. In the following field study, measurements of the ride environment and observations of passenger activities were made simultaneously aboard Amtrak intercity trains in order to determine the nature and strength of activity and ride quality relations and to describe them in a quantitative form that might be used as a design and evaluation tool.

METHOD

Subjects

The subject sample consisted of 2829 revenue passengers observed on 14 Amtrak rides in the Northeast Corridor.

Apparatus

Linear ride vibrations in three degrees of freedom (X=longitudinal, Y=lateral, and Z=vertical) were measured using the battery-operated portable accelerometer set developed by the National Aeronautics and Space Administration's (NASA) Langley Research Center (15). This unit consisted of three independently calibrated, seismic mass piezo-resistive accelerometers (0-100 Hz bandwidth) that were mounted in three mutually perpendicular directions. Rotational motions were measured by attaching three independently calibrated Unholtz-Dickie PA-1000 accelerometers to the outer casing of the NASA accelerometer package. The sensitivity of the PA-1000 accelerometers was set at 3.33 V/g, and their maximum response range was 0.1 to 2000 Hz. The six independent motion signals (three linear, three rotational) were recorded on a Lockheed eight-channel FM tape recorder (Model No. 4170).

Instrumentation used to measure nonmotion environmental variables included a General Radio USA sound-level meter (Model No. 1565-B), an Abbeon certified hygrometer and temperature indicator (Model No. HTAB 169B), and a Gossen Luna-Pro light meter.

Procedure

Prior to the actual data-collection efforts on the trains, track charts of the Washington-Newark section of the Northeast Corridor were analyzed to select a number of internally homogeneous segments that might be sampled during the tests. To represent straight and curved track over uphill, downhill, and undulating terrain, 32 nonoverlapping segments were chosen.

Measurements and observations were recorded over a total of 81 test segments on 42 different vehicles of 14 trains during seven weekdays of testing between December 5 and 13, 1977. Data were collected on two trains each day: the Patriot (no. 172) from Washington to Newark (9:00 a.m.-12:41 p.m.) and the Colonial (no. 169) from Newark to Washington (1:15 p.m.-5:00 p.m.). Each train had approximately six Amfleet vehicles, including several Amcoach cars and at least one Amcafe snackbar car.

The experimental procedure involved the simultaneous observation of passenger activities by the observer and measurement and recording of ride environment variables by two test assistants. The test team boarded each train through the rear vehicle. The equipment for measuring the environmental variables was set up at a reserved pair of center seats and the accelerometer package was placed on the floor underneath. This test location was chosen because it was close to the pitch and roll center of the vehicle. Once the train was in motion, the test assistants determined the milepost location by contacting a technician riding in the locomotive at the head end via walkie-talkie. As the train approached a predetermined test track segment, the observer proceeded to the rear of the vehicle. When a hand signal was given by the assistant to indicate the beginning of a recording period, the observer walked through the vehicle, unobtrusively observing and recording the activity of each passenger on a preprinted coding sheet. At the center of the vehicle, the observer also made an ambient light measurement in the center aisle. At the same time, measurement and recording of the ride motion variables were made by one test assistant, while the other monitored and recorded the ranges of noise, temperature, and humidity on the smaller instruments and kept track of the mileposts via walkie-talkie during the 100-s test interval. At the end of each test, the equipment was moved to the next car forward and the test procedure was repeated.

Observational Technique

The observational methodology was developed in the course of an earlier pilot study involving observations of the activities of 850 Northeast region Amtrak passengers (16). Because almost all seats on the trains faced forward (in the direction of motion), it was convenient to progress from the rear of the train toward the head end in performing the test. In this way, the observer could approach the passengers from behind, determine their activity, and record it, usually without attracting the passengers' attention. Also, the equipment could be transported between vehicles without confronting passengers face-to-face, thus preventing undesirable disruption of passenger behavior.

The results of the pilot study showed that activities could generally be coded into these 12 operationally defined categories: high effort—writing, reading, drinking, eating; medium effort—handcrafts, games, talking-listening; low effort—viewing, smoking, sleeping, doing nothing; and other unranked activity. Behavior was coded according to the activity the passenger performed at the exact time of observation. Thus, a passenger with a book open but who was looking out the window at the time of observation was coded in the viewing rather than reading activity category.

Multiple activities were coded into the category of the more effortful behavior component, according to the ranking of activity difficulty noted above. The activities were ranked according to the sum of their scores on six behavioral criteria suggested in the ride quality and vibration research literature as important in performing activities on moving vehicles. These included balance, eye focus, sustained visual attention, eye-hand coordination, hand-mouth coordination, and extraordinary compensation for vibration and noise.

DATA REDUCTION

For each test segment, the analogue data measured by each accelerometer were digitally sampled, and a set of data sequences for rotational acceleration in each axis was computed by subtractive methods (16). A discrete Fourier transform process was applied to the data points in each axis to calculate the frequency content of all test records. The three linear accelerations were then frequency-weighted according to the ISO guideline document for human response to whole-body vibration (3). One-third octave band root mean squares (RMS) were computed for the rotational data sequences, the original unweighted linear accelerations, and the ISO-weighted linear accelerations. The rotational acceleration data sequences were integrated to produce rotational rates, from which RMS values were then generated.

For each test segment, ISO-weighted linear acceleration indexes were computed by using the formula:

$$\text{linear acceleration} = \sqrt{(1.4a_x)2 + (1.4a_y)^2 + (a_z)^2} \quad (1)$$

where

a_x = longitudinal acceleration,
a_y = lateral acceleration, and
a_z = vertical acceleration.

Rotational acceleration indexes were computed by using the formula:

$$\text{rotational acceleration} = \sqrt{\alpha_x^2 + \alpha_y^2 + \alpha_z^2} \quad (2)$$

where

α_x = roll acceleration,
α_y = pitch acceleration, and
α_z = yaw acceleration.

Rotational rate indexes were computed by using the formula:

$$\text{rotational rate} = \sqrt{\omega_x^2 + \omega_y^2 + \omega_z^2} \quad (3)$$

where

ω_x = roll rate,
ω_y = pitch rate, and
ω_z = yaw rate.

Temperature and humidity data for each test segment were converted to effective temperature indexes by using the revised American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) comfort chart (17). These effective temperatures, average noise levels in dB(A), average speed levels in miles per hour, and light levels in foot-candles (fc), in addition to the motion variables, were used as predictor variables in subsequent multiple regression analyses. (The study was conducted using customary measurements; thus, SI equivalents are not given.)

Because the actual vehicles varied in absolute seating capacity and also had different levels of occupancy when observations and measurements were made, the activity data for each test segment were converted from absolute frequencies to percentages (relative frequencies). Handcrafts and games were combined into a single category because the relative frequency of each individual activity was so small and these behaviors were similar in purpose and effort.

RESULTS

Activity Distributions

The frequency distribution of the 11 activities is shown in Table 1. In general, the most frequently observed activities were reading, sleeping, and viewing; handcrafts-games, eating, and drinking occurred least often. The low percentage of passengers smoking is deceptively small because smoking often occurred simultaneously with other more effortful behaviors. These data are very similar to the activity distributions of 3300 passengers observed in previous efforts on Northeast Corridor trains (16).

The distribution statistics for the 11 activities were calculated based on the percentage values of each activity observed over all 81 test segments. The wide relative frequency range of most of the activities between test segments reflects not only the actual differences between activity distributions of different vehicles, but also the effects of converting the absolute

Table 1. Distribution statistics for activity percentages.

Activity	Total	Percentage of Total	Mean	SD	Range
Doing nothing	128	4.5	4.5	4.7	0-22.2
Sleeping	565	20.0	20.0	10.7	0-48.3
Smoking	19	0.7	0.7	1.9	0-9.4
Viewing	575	20.3	20.3	10.0	0-64.3
Talking-listening	368	13.0	13.0	9.3	0-40.7
Handcrafts-games	42	1.5	1.5	2.7	0-15.0
Eating	83	2.9	2.9	3.9	0-23.1
Drinking	75	2.7	2.7	3.9	0-16.7
Reading	719	25.4	25.4	9.2	7.1-50.0
Writing	121	4.3	4.3	4.3	0-23.5
Other	134	4.7	4.7	4.8	0-21.2
Total	2829	100.0			

Table 2. Statistical summary of ride motion data.

Ride Variable	Mean	SD	Range
Longitudinal (X) acceleration (RMS g)	0.007	0.002	0.005-0.014
Lateral (Y) acceleration (RMS g)	0.015	0.003	0.007-0.023
Vertical (Z) acceleration (RMS g)	0.021	0.004	0.013-0.036
ISO-weighted X-acceleration (RMS g)	0.003	0.001	0.001-0.007
ISO-weighted Y-acceleration (RMS g)	0.010	0.003	0.002-0.019
ISO-weighted Z-acceleration (RMS g)	0.009	0.002	0.005-0.015
Weighted ISO index	0.015	0.004	0.009-0.025
Roll (X) acceleration ($^\circ/s^2$)	74.94	29.14	20.57-150.49
Pitch (Y) acceleration ($^\circ/s^2$)	56.51	31.41	18.74-158.92
Yaw (Z) acceleration ($^\circ/s^2$)	51.43	20.14	10.56-105.59
Rotational acceleration index	110.39	38.74	42.43-226.40
Roll (X) rate ($^\circ$/s)	2.56	2.04	0.08-10.57
Pitch (Y) rate ($^\circ$/s)	1.69	1.93	0.02-10.67
Yaw (Z) rate ($^\circ$/s)	1.66	1.15	0.05-5.39
Rotational rate index	3.79	2.65	0.10-12.22
Acoustic noise, dB(A)	67.7	3.5	60.0-80.0
Effective temperature ($^\circ$F)	68.1	1.06	65.9-72.8
Light (fc)	6	5	1-32

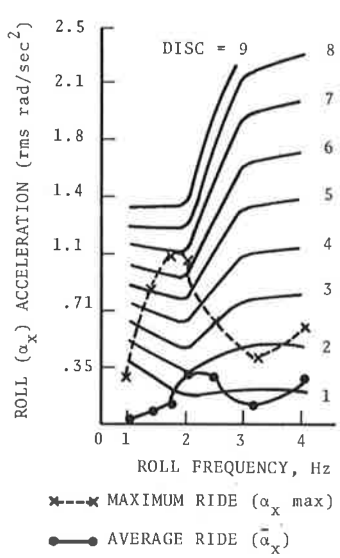

Figure 1. Comparison of roll accelerations measured on Amtrak trains (December 1977) with discomfort curves for roll vibration.

frequency data to percentages. The zero-value lower limits of some of the activity distributions result from the fact that these behaviors were not observed at all in some test segments.

Distributions of the Measured Environmental Variables

The distributions of the major motion and nonmotion variables recorded in this field study are described in Table 2. The statistics for motion variables were computed based on the data collected in 77 test segments for the frequency range of 1-20 Hz.

The linear motions experienced by passengers on these trains were quite small and in compliance with standards for reduced comfort boundaries (3) for daily 2.5-h exposures for lateral (Y-axis) vibration, and 8- and 16-h exposures, respectively, for Z- and X-axis vibrations. Rotational accelerations, however, were generally of much greater intensities. In Figure 1, the roll acceleration amplitudes from test segments in this study are broken down into one-third octave band frequency components and plotted against discomfort curves for roll acceleration. It is clear that the levels of motion recorded on the trains exceed the comfort threshold (DISC = 1) by a factor of almost 2 for a typical ride segment representing the mean RMS roll level of the 77 test segments and by a factor of 2 to 6 for the ride segment recorded with the maximum level of RMS roll acceleration.

Further evidence of the perceived severity of the rotational motions for passenger transportation may be derived by applying the intercity train comfort equation of Pepler and others (7) to existing data:

$$C = 0.73 + (N - 60) + 0.96\ \omega_x \qquad (4)$$

This empirically derived model may be used as a means of predicting passengers' comfort responses (C) on a scale of 1 to 7, given roll rate (ω_x) and noise (N) levels. Calculation of the mean predicted comfort rating from the roll rates recorded in this study yields a neutral comfort value of C = 4, representing an approximate 80 percent level of passenger satisfaction. Using this criterion, 72.7 percent of the ride segments measured in this study fall in the comfortable range ($C < 4$) and 27.3 percent in the uncomfortable ($C > 4$) range.

In terms of nonmotion environmental variables, the acoustic noise levels measured in this study are comparable to or lower than those measured in previous studies of intercity train environments (7) and are generally below the maximum recommended by the U.S. Environmental Protection Agency (18) for a 2-h daily exposure on this type of conveyance. However, compared with the speech interference level (SIL) curves (19), the mean noise level of 68 dB(A) is high enough to require very loud speech for communication between speakers separated by 0.6 to 1.2 m (2 to 4 ft), the approximate distance between passengers seated together on the trains. Comparison of the effective temperature levels recorded in this study with the ASHRAE (17) equal-comfort curves indicates that the mean effective temperature would be considered comfortable by approximately 80 percent of the population. Although the light levels measured in the vehicle aisles were low compared with those recommended by the Illuminating Engineering Society (20), illumination measured with the reading lights on at the seats attained levels of up to 130 fc, which is perfectly adequate for the performance of passenger activities.

Effects of Environmental Variables on Activity Levels

Simple correlations were computed between the measured levels of the motion variables and the relative frequencies of the individual activities over all test segments. In general, there were no significant correlations between the activities and the linear accelerations. There were, however, a number of small but significant correlations between the activities and the rotational motions. In particular, many of the rotational motions were positively correlated with frequencies of sleeping ($r = 0.28$ with yaw, $p < 0.01$), smoking ($r = 0.25$ with pitch, $p < 0.01$), and doing nothing ($r = 0.17$ with roll, $p < 0.10$) and negatively correlated with frequencies of talking-listening ($r = -0.26$ with roll, $p < 0.01$), handcrafts-games ($r = -0.16$ with pitch, $p < 0.10$), eating ($r = -0.21$ with roll, $p < 0.05$), and writing ($r = -0.20$ with the rotational rate index, $p < 0.05$). Frequencies of viewing and reading, the two most popular activities, and drinking were not significantly influenced by changes in rotational motion levels.

In general, there were few significant correlations between the activity levels and the nonmotion environmental variables. Noise was significantly correlated only with the relative frequency of talking-listening ($r = 0.27$, $p < 0.05$). As effective temperature increased, levels of doing nothing increased ($r = 0.20$, $p < 0.05$), and the relative frequencies of smoking and viewing decreased ($r = -0.20$, -0.18, respectively; $p < 0.05$). As the level of illumination increased, doing nothing and handcrafts-games were observed less frequently ($r = -0.21$, -0.18, respectively; $p < 0.05$) compared with other activities; talking-listening was observed more frequently ($r = 0.20$, $p < 0.05$).

Correlations were also computed to determine any systematic relation between the relative frequencies of individual activities and trip variables such as time of day, vehicle type, and vehicle occupancy. Viewing increased from morning to afternoon ($r = 0.18$, $p < 0.05$). Handcrafts-games and writing decreased with time into the day ($r = -0.23$, -0.19, respectively; $p < 0.05$). More smoking ($r = 0.25$, $p < 0.01$), talking-listening ($r = 0.25$, $p < 0.01$), and drinking ($r = 0.18$, $p < 0.05$) occurred in Amcafe cars than in Amcoaches, and less sleeping ($r = -0.16$, $p < 0.10$) and viewing ($r = -0.17$, $p < 0.10$). Sleeping increased ($r = 0.33$, $p < 0.01$) and eating and reading decreased ($r = -0.15$, -0.16, respectively; $p < 0.10$) as the level of vehicle occupancy (crowding) increased.

Because the correlations between individual activities and the environmental variables were generally small but significant, it was decided to combine the activities into three groups based on the previously defined effort categories in order to see how well these activity indexes might be correlated with the environmental and trip variables. Regrouping the activities in this way resulted in an increase in the size of the correlation coefficients for many of the same relations found previously; many frequencies of zero that entered into the correlations for individual activities were eliminated. The frequency of high-effort activities decreased as a function of roll-rate magnitude ($r = -0.22$, $p < 0.05$) and was marginally related in the same negative way to the X-linear and angular accelerations, time of day, and vehicle occupancy. Medium-effort activities were negatively correlated with the magnitudes of the angular rates of motion in all three degrees of freedom ($r = -0.19$, -0.21, and -0.27 for roll; pitch, $p < 0.05$; and yaw, $p < 0.01$), while low-effort behaviors increased in frequency with increases in the rates of rotational motion (e.g., $r = 0.26$ with roll, $p < 0.01$). However, low-effort activities decreased marginally in frequency as a function of noise and were observed more often in Amcoach vehicles ($r = -0.23$, $p < 0.05$). Medium-effort activities were positively correlated with noise ($r = 0.26$, $p < 0.01$) and occurred more often in Amcafe snackbars ($r = 0.23$, $p < 0.05$).

Based on similarities in physical action components and common correlations with environmental and trip variables, the activities were regrouped into a second set of indexes. Rest activities, in which no physical exertion could be observed, included doing nothing and sleeping. Social-oral activities, involving hand-mouth coordination or interpersonal communication, included eating, drinking, smoking, and talking-listening. Motor activities, which require hand-eye coordination and hand movements, included handcrafts-games and writing. Reading and viewing, which were not well correlated with any major environmental variables, were omitted from this second set of activity indexes.

Rest behaviors were found to be positively correlated with roll ($r = 0.27$, $p < 0.05$) and yaw ($r = 0.23$, $p < 0.05$) rates. Motor activities decreased significantly in frequency with increases in roll and pitch rates ($r = -0.19$, -0.22, respectively; $p < 0.05$). Social-oral activities decreased marginally as roll and yaw rates increased and were positively correlated with noise ($r = 0.21$, $p < 0.05$), light ($r = 0.20$, $p < 0.05$), and vehicle type (i.e., Amcafe vehicles: $r = 0.32$, $p < 0.01$). Motor behaviors occurred more frequently in the morning than in the afternoon ($r = -0.26$, $p < 0.05$).

Multiple regression techniques were used to develop linear models to predict the levels of activity based on the environmental and trip variables measured and recorded in this study. Environmental and trip variables that were significantly correlated with activity levels but relatively uncorrelated with other predictor variables were selected for inclusion in the stepwise regression process. The linear equations shown in Table 3 represent the best fit of the physical and trip variable data to the observed levels of activity.

It may be seen that levels of all types of activity except high-effort behaviors may be predicted to some appreciable level of significance by the environmental and trip variables recorded in this study. Except for the high-effort behaviors, linear combinations of five or fewer predictor variables may be used to account for approximately 20 percent of the variance in the various activity categories. The sign preceding the coefficient of each predictor variable in each equation reflects the direction of the correlation between the activity and the predictor variable. Thus, a negative sign before a particular factor indicates that the presence of that

Table 3. Linear multiple regression models for activity indexes (motion variables in 1-20 Hz range).

Activity Index (A)	Activity Model	F (df)	Multiple R	R^2	Significance
Low effort	$\%A = 1.04\omega_{XYZ} - 0.59N + 1971.43a_{XISO} - 6.61(V) + 3.69(T) + 78.62$ $(\sigma) = (0.56)\ (0.42)\ (1387.26)\ (4.10)\ (2.96)$	3.05 (5, 71)	0.42	0.18	$p < 0.05$
Medium effort	$\%A = -1.09\omega_{XYZ} + 0.55N + 5.28(V) - 25.00$ $(\sigma) = (0.39)\ (0.30)\ (2.93)$	5.52 (3, 73)	0.43	0.18	$p < 0.01$
High effort	$\%A = 1.03\omega_x + 1.42ET - 568.55a_x - 0.10(VO) - 2.18(T) - 46.70$ $(\sigma) = (0.65)\ (1.25)\ (788.66)\ (0.08)\ (2.67)$	1.83 (5, 71)	0.34	0.11	NS
Rest	$\%A = 1.14\omega_x + 1.67\omega_z - 5.44(V) + 24.99$ $(\sigma) = (0.60)\ (1.08)\ (3.28)$	3.55 (3, 69)	0.37	0.13	$p < 0.05$
Social-oral	$\%A = 0.50N + 0.40I - 0.79\omega_{XYZ} + 9.64(V) - 25.40$ $(\sigma) = (0.37)\ (0.22)\ (0.48)\ (3.61)$	4.33 (4, 71)	0.44	0.20	$p < 0.01$
Motor	$\%A = 0.50\omega_{XYZ} - 0.20I - 0.17N - 2.21(T) + 0.11(SP) + 15.02$ $(\sigma) = (0.23)\ (0.11)\ (0.17)\ (1.28)\ (0.09)$	2.78 (5, 67)	0.41	0.17	$p < 0.05$

Notes: a_* = linear acceleration (* axis); a_{*ISO} = ISO-weighted linear acceleration (* axis); ET = effective temperature (°F); I = illumination (fc); N = noise, dB(A); σ = standard error of coefficient; SP = speed (mph); T = time (1 = a.m., 2 = p.m.); V = vehicle type (1 = Amcoach, 2 = Amcafe); VO = vehicle occupancy (%); ω_* = rotational rate (* axis); and ω_{XYZ} = rotational rate index.

variable in the ride environment contributes to the inhibition or decrease in the activity level (% A) on the opposite side of the equation. A positive sign indicates that the presence of a given variable is associated with a relative facilitation or increase in the relative frequency of activity. The variables in the equations are generally those with the highest simple correlations with the individual activities that make up the activity indexes. In some cases, a given variable may serve to facilitate one type of activity and inhibit another type (e.g., noise for social-oral versus motor activities).

SUMMARY

The results of this field study indicate that a small but significant proportion of the variance of passenger activity could be explained by combinations of physical ride quality and trip or situational factors. The variables that had the greatest effect on observed levels of activities were the rates of rotational motions, noise, vehicle type, and time of day. The variable that influenced passenger activity levels the least was linear vibration.

The fact that rotational motions were found to play a more significant role than linear vibration in affecting the frequencies of passenger activity supports a growing body of evidence about the importance of rotational motions for passenger comfort (7, 22). The above threshold discomfort levels of the roll accelerations measured in this study (Figure 1) and the neutral comfort index corresponding to only 80 percent passenger satisfaction as computed with the roll-base comfort equation of Pepler and others (7) contrast with the high level of acceptability of the linear vibrations as judged by using the ISO 2631 (3) reduced comfort boundaries. It is clear that both subjective estimates of passenger comfort and the ability to do activities involving anything more than a low level of effort (as evidenced through changes in the activities' relative frequencies) significantly depend on angular motions, which are not addressed in the existing ISO guideline.

Some comment is necessary to explain the findings that measured noise levels were positively correlated with medium-effort social-oral activities and that the noise variable figured prominently in the linear equations generated to predict these behaviors. In general, it was expected that environmental noise coming from the train would be negatively correlated with the frequencies of most activities due to its disruptive and interferential effects. The facts that noise was generally uncorrelated with dominant vehicle motion levels and that both noise and vehicle type were significantly correlated with talking-listening led to the hypothesis that the passengers were the chief source of noise in this study rather than the train itself. This hypothesis was supported by the finding that noise levels in Amcoach cars were lower than those in Amcafe snackbars, where more talking-listening was observed (one-tailed $t = 1.89$, $df = 79$, $p < 0.05$). Thus, in this case, the environment was influenced more by the passengers' activity than the activity was influenced by the environment. Regardless of the causative direction of this relation, noise remained the best environmental correlative of several types of activity and was therefore retained as a predictor variable when the linear equations of activity were generated.

A major goal of this study was to provide a useful tool for designers and evaluators of transportation systems who wish to accommodate a certain level of passenger activity in order to increase passenger satisfaction. The activity equations in Table 3 could be used by a design engineer to specify the minimal levels of environmental variables that are required to allow a certain relative frequency level of performance for a particular type of activity. This could be done by plugging in the relative frequency value of activity that the designer wishes to accommodate and then trading off or adjusting the values of the ride environment factors until both sides of the equation are equal. Information regarding a desirable level of activities for maximum passenger satisfaction might be obtained from passenger opinion surveys, for example, Amtrak's passenger-activity and ride-quality survey described in Wichansky (16) or in other data sources. Conversely, a systems evaluator might wish to determine what level of passenger activity the existing ride quality and trip conditions on any given system might allow. This could be computed by plugging in the predetermined values of the ride environment and trip factors and solving for the percentage activity (% A) value.

It is recommended, however, that the activity equations developed here be applied with caution. First, these models need to be validated on an independent sample of Amtrak system users to confirm the existence and accuracy of the activity-ride quality relations that they describe. Second, only about 20 percent of the variance in activity may be accounted for by using the ride quality and trip variables recorded in this study. This 20 percent of the variance in activity is considered to be that proportion attributable to the interference or (relative) facilitation effects of vibration, noise, and other aspects of the ride environment, which are the factors at least theoretically under the control of the design engineer. The fact that physical ride quality and trip variables could influence even this much of the variation in activities is considerable in light of the dominant role played by individual differences in the majority of ride-quality-related research efforts (21, 23, 24). Also, the emergence of statistically significant relations in a field study of this type indicates at the very least that a great amount of effort is being expended on the passengers' part to perform the more complicated activities, probably resulting in increased levels of fatigue and passenger discomfort.

This study clearly indicates the importance of ride quality and situational variables in determining relative frequencies of passenger activities. Further research is necessary to determine how well passengers are able to perform activities in transportation environments and how motivational factors influence the frequency and quality of activity performance. Use of the relative frequencies of behavior as dependent variables can only give a rough indication of passengers' difficulties in doing various activities in transit. The assumption that people will do what is the easiest for them to do (6) may be confounded by their varying motivations to perform different activities and the resulting level of effort they are willing to expend. These issues require experimental study in a controlled research environment, where individual differences between subjects may be more easily controlled.

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**A.M. Wichansky is currently with Bell Laboratories, Whippany, New Jersey.*