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Price and Subsidy in Intercity Transportation and Issues of Benefits and Costs

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page 65, Equation A-1
Change $(+ \sin\phi)$ to $(1 + \sin\phi)$
page 67, footnote to table
Change $\underline{N}_\sigma$* to $\underline{N}_c$* and $\underline{N}_c$ to $\underline{N}_\sigma$

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Figure shown as B-3 is B-4; figure shown as B-4 is B-3.

Effects on Motor-Carrier Operations of ICC Regulation of Operating Authority

William B. Tye and Joseph G. Altonji, Charles River Associates, Cambridge, Massachusetts
Paul O. Roberts and James T. Kneafsey, Cambridge Systematics, Inc., Cambridge, Massachusetts

Interviews with motor carriers and other data sources were used to assess the direct impact of federal regulation of motor-carrier operating authority on energy consumption and economic efficiency. The major conclusions of the study are that gateways are the principal restriction affecting regular-route carriers but that these carriers are the least restricted of the carrier classes with regard to operations within the areas they are authorized to serve. The operating authority of irregular-route specific-commodity carriers is substantially more restricted, but these carriers make more use of their options to avoid impacts on efficiency. Nevertheless, in some cases these options do not entirely offset the consequences of inadequate operating authority. Owner-operators make effective use of trip leasing to certificated carriers or haul exempt commodities to remain competitive despite their lack of operating authority. Restrictions on operating authority are partly responsible for the low load factors of private motor carriers, but private carriers still compete because of service and rate motivations.

Critics have long argued that federal regulatory restrictions on motor-carrier operating authority have reduced load factors and increased circuity (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11). Energy consumption and economic efficiency in truck transportation are sensitive to load factor and circuity of truck movements. Trucks frequently move empty, with less than full loads (12), and by circuitous routes. Regulation of motor-carrier operating authority imposes detailed operating restrictions on routes, cargo, equipment, points served, type of shippers, solicitation of backhaul cargo, leasing of equipment, and mixing of exempt, common, contract, and private carriage. If detailed regulation of operating authority accounts for the difference between the existing load factor and the circuity of the industry and greater utilization of truck capacity, a significant energy and efficiency savings might be realized through modification of regulatory policies.

A review of the literature and the operating authorities of a sample of individual firms indicates that restrictions on operating authority are pervasive in the trucking industry (13). However, conclusions cannot be based on the mere existence of operating authority restrictions. The degree to which such restrictions affect efficiency depends on the economics of trucking, the objectives of the firm, and the carrier's ability to avoid the restrictions.

Because carriers who have certificates of public convenience and necessity have a common-carrier obligation to serve any shipper who requests service within their authority, carriers have an incentive to ask for no more authority than they intend to use (or sell). If service cannot be provided profitably, the carrier is motivated to apply for authority that excludes unprofitable service.

If the Interstate Commerce Commission (ICC) routinely approved every request for operating authority, it would be seen that many restrictions on the operating authority of carriers are restrictions on the common-carrier obligation and not necessarily on the efficient provision of service. Given that the award of authority imposes a legal obligation to serve, unrestricted operating authority is an unworkable concept. The real issues in a regulated industry with a common-carrier obligation are the criteria used in restricting certificates and the impacts of the restrictions on economic efficiency and energy consumption.

This paper is based on excerpts from a recent study of the energy impact of federal regulation of motor-carrier operating authorities (13), and readers are referred to that study for supporting data. The direct impacts on general economic efficiency of restrictions on operating authority are ordinarily related to those on energy efficiency. This paper reports only a qualitative assessment of the energy impacts, based primarily on a series of in-depth interviews with different categories of motor carriers.

The question involved is, To what extent is the present efficiency of truck transportation the result of ICC regulatory policies and to what extent is it a reflection of the fundamental economics of truck transportation? The standards against which the performance of the trucking industry should be measured are load factors and levels of circuity that are economical in terms of energy constraints and service requirements.

RECENT CHANGES IN TRUCKING INDUSTRY STRUCTURE

A popular view of the U.S. domestic trucking industry has been that it is made up of two large sectors: ICC-regulated common carriers and fleets of private trucks. These sectors were complemented by intrastate carriage and local and farm trucking. The oil shortage of 1973 changed this view dramatically. For the first time, owner-operators were recognized as a growing and significant segment of the industry. Owner-operators became prominent during the national trucking strike, which was organized and carried out to dramatize the importance of "fuel price increase flow-through" clauses in the contracts under which these independent truckers operate.

Many of the independents drive their own trucks over 161 290 km/year (100 000 miles/year) and some achieve equipment utilizations of as much as 322 580 km/year (200 000 miles/year) by hauling agricultural exempt commodities or working on lease arrangements with ICC-authorized carriers (14). When lease arrangements are involved, it is common for the independent owner-operator to receive approximately 75 percent of the revenue and the carrier who holds the operating authority to receive the balance. The effective wage rates for lease arrangements of this type are lower than standard teamster union wages. As a result, independent and union operations are not ordinarily mixed. Use of owner-operators for less than truckload operations is difficult because dock workers in the terminals are typically organized and insist that teamster drivers operate under the labor agreements in force between the carrier and the local union chapter. The owner-operator thus usually hauls full truckloads for a contract trucker or an irregular-route common carrier or hauls agricultural exempt commodities for which terminal operations are unnecessary.

Low wage rates, high equipment utilization, and the avoidance of terminal handling costs by the owner-operator combine to produce a comparatively low-cost form of trucking. Wyckoff and Maister (14) estimate that the costs of owner-operator trucking are close to railroad tariff rates. Obviously, the costs vary across commodities and, for high-volume, low-value goods, rail rates are considerably lower. Nevertheless, owner-operators have begun to compete successfully for traditional rail traffic and to pose a competitive threat to unionized regular-route carriers.

Specialized Carriers

Specific-commodity carriers, or irregular-route specific-commodity (IRSC) carriers, have operating authorities that are well suited to the use of leased drivers operating their own equipment. (Specific is used here rather than special because IRSC carriers often handle large amounts of general freight as well as commodities requiring specialized equipment, such as automobiles, bulk liquids, and machinery.) IRSC carriers ordinarily deal in truckload quantities for which terminal operations are unnecessary.

Regular-route authority, by contrast, is granted to scheduled common carriers of general freight who receive a large share of their revenue from less-than-truckload traffic. Regular-route common carriers of general freight typically do not employ owner-operators on a widespread basis. Private carriers are prohibited from leasing drivers who operate their own equipment. Of course, the agricultural exempt shippers also have direct access to the owner-operator.

As a result of these operating restrictions and institutional constraints, IRSC carriers have been in a position to exploit the economic advantages of the owner-operator. To circumvent problems posed by unionization, some regular-route carriers have formed special commodities divisions, which are segregated from the company's normal regular-route, less-than-truckload operations and tend to use the services of owner-operators almost exclusively.

Impact of Owner-Operators

The regular-route segment of the industry is losing market share (13, 15, 16, 17, 18), and the share of irregular-route carriers using nonspecialized equipment is growing at an annual rate of slightly less than 2 percent. Of course, regular-route carriers are experiencing absolute growth in traffic. However, total megagram-kilometers for specific commodity carriers now exceed amounts for regular-route carriers (this figure compares only the larger class 1 and 2 carriers and does not include the 12 000 or so smaller class 3 carriers).

Grant of Route Authority as a Mechanism of Change

ICC awards of operating authority have been favorable to the growth of the irregular-route carrier. The hearings require that an applicant prove public convenience and necessity before new authority is granted; substantial weight is given to the rights of existing carriers to the traffic that would be served by the new applicant. Carriers already serving the market strongly oppose the granting of new regular-route authority. The expedient way to acquire authority that would substantially extend the carrier's market area is to buy it from, or merge with, someone who already holds the authority. Awards of operating authority to regular-route carriers therefore tend to effect minor changes that do not materially affect competition. Irregular-route authority is easier to get precisely because it is so restricted. The wording of grants of irregular-route authority often specifies service from a single point (a city, a county, or in some cases a single plant) to points in a limited region (a state or a group of states) for a narrow range of commodities (the outputs or inputs of a single firm or industry). The service provided is for a single shipper or at most a narrow group of industries and gives the shipper low truckload rates for very specialized transportation services. Competing carriers have been less successful in blocking these types of applications (13).

Although ICC certification policies have facilitated the growth of IRSC carriers, ICC is not solely responsible for this growth. IRSC carriers have also benefited from the increased competitive position of truckload transportation because of increases in the productivity of line-haul trucking, the decline of the railroads, the increased demand for service quality in intercity transportation, and IRSC access to owner-operator service. Nevertheless, an important policy issue is whether ICC, through its liberal policy toward awards of narrowly defined IRSC authority and its restrictive policy toward grants of broad authority, should continue to encourage recent trends in the trucking industry that enhance the role of the owner-operator and the irregular-route common and contract carrier. Part of this important issue is the potential for inefficiency caused by increased reliance on firms having highly circumscribed operating authority.

ANALYSIS OF THE EFFECTS OF FEDERAL REGULATORY POLICY

To assess the need for changes in regulatory policy, in-depth interviews were conducted with a sample of carriers. These data are synthesized with other data sources on the industry. The general approach of the analysis is to identify means by which carriers can avoid the inefficiencies caused by regulatory restrictions on operating authority and other related effects of regulation.

Detailed results of the interviews may be found elsewhere (13, Appendix D). In this paper, detailed case studies illustrating the conclusions are not presented. An attempt is made to assess operating authority restrictions qualitatively based on the interview data and other sources of information on the industry (15, 16, 17, 18, 19, 20, 21, 22).

An important issue in assessing the impact of regulation on energy consumption is the degree to which the inherent demand characteristics of trucking, rather than regulation, impose empty, circuitous truck movements. Data from reports by Bisselle (1) and Charles River Associates and Cambridge Systematics (13, Appendix A) and a 1972 continuous traffic survey by Central States Motor Freight Bureau and others suggest that both long-run (or net) imbalances and short-run, day-to-day (or stochastic) imbalances are important causes of empty truck movements and reduced load sizes.

The operating authority of each of the sampled carriers was studied in detail, and the resulting evidence (13, Appendix D) confirms the long-standing contention that there are restrictions in the operating authorities of motor carriers and that the type and frequency of the restrictions differ with the type of firm involved. These restrictions, in addition to the previously mentioned natural demand forces in the industry, are a potential cause of empty truck movements and circuity. However, the degree to which these restrictions actually cause inefficiency in the industry depends on the options available to a carrier for easing the effect of the restrictions. A carrier can

1. Apply for new authority, merge, or purchase authority from other carriers,
2. Use a complementary provision in another operating authority already held by the firm,
3. Carry exempt commodities,
4. Trip lease equipment to a carrier who has the authority,
5. Interline shipments,
6. Engage in illegal operations, or
7. Engage in selective marketing.

The impact of restrictions on operating authority therefore depends on the extent to which the carrier is motivated to avoid the restrictions. Clearly, the more onerous a restriction is, the more highly motivated the carrier is to avoid it. The conclusion of the research is that each of the above options lessens inefficiencies but that a measurable level of restriction persists. The most significant restrictions, such as those affecting private carriage, cannot usually be avoided by these devices.

Applications for New Authority, Merger, or Purchase of Operating Authority

ICC policy has differed significantly in evaluating applications for regular-route general commodity (RRGC) authority and IRSC authority. IRSC authority has been awarded much more freely. Private carriers cannot secure authority to correct the inefficiencies imposed by regulatory restrictions unless they convert to regulated carriage or show that existing common carriers will not be injured.

Grants of RRGC Authority

The study interviews support the conclusion that ICC has been reluctant to grant regular-route general-commodity authority (23). With one exception, the firms interviewed acquired all major portions of their authority through "grandfather rights," purchases, or mergers. It is difficult for carriers to obtain large additions to their authority through application to the ICC because present regulations require them to prove that existing service is inadequate. An early ICC decision stated:

> Existing motor carriers should normally be accorded the right to transport all traffic which they can handle adequately, efficiently, and economically in the territories served by them, as against any person now seeking to enter the field of motor carrier transportation in circumstances such as are here disclosed.

It is difficult to prove inadequate service over wide areas in which a number of competing firms have authority. The protests of other carriers are reflected in restrictions on commodities, intermediate points, off-route points, and plant sites. All the carriers interviewed indicated that they routinely protest applications affecting their market areas.

The direct impact of the restrictive policy on energy consumption hinges on whether regulatory policy has the primary effect of imposing inefficiencies on trucking firms in serving existing traffic or whether the restrictions limit the size of the market that may be served by a carrier. Effects of the first type have a measurable direct impact on energy efficiency.

The motivations of carriers in purchasing or merging to obtain additional authority were questioned in the interviews. The firms were asked whether they had expanded to increase the market area or to improve operating efficiency. The replies indicated that most of the purchases were made to expand the market area but that some purchases had made possible a significant improvement in efficiency. ICC does not generally approve mergers that will result in increased efficiency if the merger results in a new service and the existing service was adequate, e.g., if there is no evidence of significant interlining before the merger. Mergers may not be used to "tack" authorities to create a new service. If a new service is created it must pass basically the same test as an application for new authority. Thus, an efficiency test on existing traffic must be passed before the market share can be expanded (13).

Most of the interview evidence suggests that the restrictiveness of ICC policy on major grants of general-commodity authorities primarily affects the size of the area that can be served directly by individual truck firms rather than operating efficiency within the areas they serve. Although limits on the number of new authorities raise the value of old certificates and raise the cost to carriers of acquisitions, some firms are able to purchase authority or merge with others if additional authority will permit economies.

Applications to improve a limited portion of a firm's authority (e.g., eliminate a gateway through an application for an alternate route for operating convenience only) are more successful than applications to improve a firm's overall operating efficiency through a large-scale expansion in the geographical or commodity scope of the firm's authority. Applications for additional authority and small additions through purchases appear to be important ways by which RRGC carriers can eliminate restrictions affecting portions of their authority.

To eliminate gateways (circuitous truck routes imposed by ICC regulation and resulting from the combination of two separate awards of operating authority), ICC has frequently granted authorities for alternate routes for operating convenience only. Most of the general-commodity carriers in the sample have obtained a number of these authorities. These firms were often able to eliminate gateways affecting traffic lanes in which they have significant market shares and traffic volume by applying for new authority. Some carriers, however, who served substantial traffic volumes through gateways experienced difficulties in getting authority. It is impractical to apply for additional routes for operating convenience only to cover the optimal routes between the points permitted in the firm's authority where truckload shipments occasionally arise and it is not necessary to go through a terminal point. The ICC superhighway deviation rules have improved the situation, but their impact is obviously limited by the highway network. Some unnecessary circuity exists in RRGC operations, but it is difficult to determine how much.

Grants of IRSC Common-Carrier and Contract-Carrier Authority

The extent to which carriers are able to get IRSC common-carrier authority for points already served by other IRSC and RRGC carriers is not clear. Despite conflicting evidence from the interviews in this study, it is clear that irregular-route specific-commodity firms have been successful in expanding their authorities during the last 10 to 15 years (15, 16, 17, 18). This type of authority is much easier to obtain than regular-route authority, especially for points not served by other IRSC carriers. The interviews produced evidence that purchases and mergers are not as important for IRSC carriers as they are for RRGC carriers.

Because IRSC authority is very narrow in commodity coverage, is often limited to plant sites, and is frequently for one direction only, IRSC firms must possess combinations of these authorities if they are to achieve balanced traffic flows and minimize empty truck movements. Carriers may gradually increase their energy efficiency through a series of applications (the motivations of IRSC carrier applications appear to be both to improve traffic balance and to increase market size). At any point in time, however, there is significant variation in the scope of the authorities of individual firms in this sector of the trucking industry. Having to demonstrate a need for service to get new authority can therefore hinder IRSC carriers from achieving efficient traffic flows. However, the ICC gateway elimination ruling (25) has enabled irregular-route carriers to eliminate gateways resulting from the tacking of authority.

The carriers who are most disadvantaged by inadequate operating authority are those for whom a major restructuring of operations is necessary but impossible to achieve because the change in operating authority cannot be accomplished through application for minor changes. As a result, one firm in the sample continues to provide services that are not suited to the markets it serves.

Complementary Authority

This study produced considerable evidence that the various complementary authorities in a firm's overall certificate are important in achieving operating efficiency. Often an apparent restriction is not binding because of complementary authority elsewhere in the firm's operating authority. Carriers provided many examples of moving trucks laterally from a destination point under one authority to a nearby origin point under another authority. Complementary authority is probably more important for IRSC than for RRGC carriers; RRGC authority is typically bidirectional, covering all shipments that do not require special equipment. The narrow definition of individual grants of IRSC authority and the fact that such authorities are often for one direction only make it necessary to combine them with other authorities to achieve efficiency. The ability of IRSC common and contract carriers to combine separate authorities is important in reducing empty truck movements. Many of these firms could, however, benefit from broader grants of authority.

One large IRSC firm noted that its probability of obtaining a backhaul is proportional to restrictions on its authority in an area. Several firms interviewed noted that they experience empty truck movements in moving laterally from a destination point to the nearest authorized origin point rather than in returning from destination to origin.

Exempt Commodities

Many of the IRSC carriers interviewed cited hauling of exempt commodities as a means of reducing empty truck movements. The total amount of megagram-kilometers of exempt commodities accounted for by regulated truck firms is not clear, but apparently it is a relatively small percentage of the total. In 1969, farm, food, and similar products accounted for only 9.9 percent of the truckloads of class 1 carriers (24). Agricultural cooperatives, whose main business is exempt commodities, are permitted to ease their problems with empty truck movements by hauling some regulated commodities under certain conditions.

The ability of private carriers shipping primarily regulated commodities to compete for exempt commodities is not sufficient to enable those firms to balance movements. Many firms do not exercise this right in any case because movements of agricultural commodities tend to be seasonal and confined to specific geographical areas and thus their availability is limited.

Leasing

Leasing of drivers and equipment is potentially an important means of avoiding operating authority restrictions. Leasing is a way for regulated carriers without authority for a loaded movement in one direction to obtain traffic under another carrier's authority. More important, it is also a way in which regulated carriers can lease equipment one way from an owner-operator when a backhaul would be hard to fill. Interviews with RRGC and IRSC carriers indicate that the ability to use independent drivers on a short-term lease is important in avoiding empty truck movements and in serving traffic that the firm cannot balance by a return haul under its own authority (13). The independent drivers then seek exempt traffic or arrange to sublease to another regulated carrier on return haul. One class 1 contract carrier stated that, because its existing authority is not broad enough to balance traffic between most points, it would have serious problems with empty truck movements if it were not permitted to trip lease to other carriers and to lease owner-operators. However, trip leasing between class 1 and class 2 IRSC common and contract carriers does not appear to be very common, partly because of institutional barriers and because of costs of arranging the agreements.

For independent drivers, who cannot haul regulated commodities except under lease to a regulated carrier, leasing is particularly important. The ability of uncertificated carriers to trip lease to regulated carriers and the authority of regulated firms to sublease owner-operators and permit them to haul exempt commodities give the independent driver considerable flexibility in obtaining regulated traffic.

The importance of trip leasing for general-commodity carriers is limited. The interviews found examples of general-commodity firms trip leasing vehicles and drivers to or from other firms. However, union rules against using independent drivers and a desire to maintain control over equipment limit the use of trip leasing by these firms.

Interlining

Interlining is sometimes used by regulated carriers (primarily RRGC carriers) to avoid circuity in the firm's authority between points it is authorized to serve. It is also used to obtain access to markets for which the firm does not have authority and to enable the firm to improve its balance of traffic by avoiding traffic for which its direct authority is insufficient to maintain balance. Interlining, however, was not found to be a significant means of reducing imbalances and circuity.

Illegal Operations

The larger number of firms in the industry and the decentralization of its activities have created enforcement problems for the regulatory agencies. The Bureau of Operations of the Interstate Commerce Commission is responsible for the enforcement of regulatory measures and auditing operations for over 15 000 regulated motor carriers. In addition, there are large numbers of private carriers and approximately 100 000 highly mobile owner-operators. Illegal operations are rarely detected, and the penalties for violation are not serious (14).

The interviewed firms were asked how frequently they detected illegal operations by their competitors. The replies suggest that illegal operations are relatively uncommon among general-commodity carriers, somewhat more common among IRSC carriers, and most common among private carriers and uncertificated for-hire carriers.

Marketing and Competition

The volume of traffic obtained by a given carrier over a portion of its authority is in part a function of marketing. Several RRGC firms noted that they engaged in selective marketing to balance traffic flows. Marketing is used to counter both long-run net imbalances and short-run stochastic imbalances in operations. In the first case, a firm's traffic may be imbalanced because the extent of the firm's authority in one area is greater than in another area and because the overall traffic between the specific points of authority is imbalanced. When the overall flow of traffic is imbalanced, marketing simply shifts empty backhaul between firms. When the imbalance experienced by one carrier is attributable to its operating authority, however, marketing may reduce net imbalances experienced by the firm without shifting empty truck movements to other firms.

Competitive factors also tend to lessen the impact of operating authority restrictions. The energy efficiency of individual truck firms in handling traffic between certain points depends in part on their operating authorities. For example, as a result of regulation, one firm may have a circuitous route between two points while another firm has a direct route. The restriction in the authority of the first firm will affect energy use only if the firm successfully competes for traffic between the two points. Operating authority restrictions, by increasing circuity and reducing load factors, also tend to raise line-haul costs. Thus, the market share of carriers having inefficient operating authorities will tend to be smaller than those having the most efficient authorities, if it is assumed that other factors determining costs are not systematically lower for the firms having inefficient authority.

The responses of firms in this study suggest that firms with serious gateway problems that have not been eliminated by certificates for operating convenience only or by other means carry a relatively small share of traffic in the affected markets. The allocation of traffic between firms thus reduces the impact of circuitous gateways on the authority of individual firms. However, most of the firms do serve some traffic between the points selected for analysis in the interviews, and it is obvious that gateways do have a detrimental impact on energy consumption.

REVIEW OF CURRENT REGULATORY DILEMMAS

Because operating authority restrictions impose some operating inefficiencies, the issue is how to take economic and energy efficiency into account in the process of awarding operating authority. Unfortunately it is exceedingly difficult, short of deregulation, to introduce efficiency as a consideration. Operating authority restrictions are "fingers in the dike" of the regulatory system. They have been designed to effect a structure of the industry, and the existing standard of public convenience and necessity is often difficult to compromise with efficiency considerations.

One expedient way of reducing the inefficiency imposed by operating authority restrictions would be for ICC to issue a ruling that reduces the restrictions inherent in existing authority. The ICC gateway elimination ruling (25) for irregular-route carriers is an example of such a modification. Improving the efficiency of the trucking industry by such means is attractive because it does not require carrier initiative in applying for authority. However, general rules easing restrictions in existing authorities will vastly increase the difficulty of securing new authorities under the existing ground rules. For example, a general ruling that eliminates commodity restrictions will make it impossible for carriers to use such restrictions as a means of reducing opposition to applications. Because of the emphasis placed by ICC on adverse impacts on existing carriers, such a ruling may in effect bring new authority awards to a standstill. Any change in the interpretation of existing authorities may require substantial procedural changes in the awarding of new authorities, which would create considerable opposition.

Restrictions on routes, gateways, and intermediate points serve a similar function. Why, it may be asked, would not everyone be better off if carriers were relieved of these restrictions? However, if these restrictions on regular-route carriers were eliminated, carriers could use a very simple initial network of authority (e.g., New York, Chicago, Los Angeles, Miami) to serve the entire country. Given the "slippery slope" inherent in choosing any particular percentage limit for partially eliminating gateways, the potential for complete deregulation of RRGC carriers through gateway elimination is obvious. Such detailed restrictions on existing carriers perform a role in limiting entry that is no different from prohibition on entry by entirely new firms.

The basic problem is finding a middle-ground criterion for awarding operating authorities that balances the traditional ICC criteria and efficiency. Almost by definition, movements away from the criterion of the adequacy of existing service to a criterion of greater efficiency imply greater reliance on competitive forces, and grants of authority that improve the efficiency of one class of carriers will almost invariably have adverse impacts on other carriers. The choice, therefore, is to specify the circumstances when existing criteria should be rejected in favor of efficiency criteria. This may impose heavy litigation costs if the standard adopted is not so extensively applied that restrictions on entry become meaningless.

CONCLUSIONS

ICC regulations concerning motor-carrier operating authority specify detailed restrictions on routes, cargo, equipment, points served, type of shipper, solicitation of backhaul cargo, equipment leasing, and mixing of different types of operations for interstate motor carriers. Data collected in this study indicate that two segments of the industry whose operating authority is highly circumscribed—owner-operator carriers and irregular-route specific-commodity carriers (who frequently employ owner-operators)—are growing rapidly in comparison with other segments of the industry, especially regular-route common carriers. Because of this rapid growth, there is a danger that operating authority restrictions could become increasingly burdensome to the industry.

The degree to which restrictions affect efficiency depends on the economics of trucking, the objectives of the carriers, and the opportunities available to avoid the restrictions. Apparent restrictions in a firm's operating authority may not actually be constraining and may even be desired by the carrier. The interviews identified a substantial number of specific operating restrictions in the authorities of the sampled carriers and studied the effects of the restrictions on the carriers' operations. Options available to the carriers to avoid restrictions, such as applying for or purchasing new authority, using a complementary authority, hauling exempt commodities, and trip leasing, were examined in detail.

The principal operating authority restrictions affecting regular-route carriers are gateways, but these carriers are the least restricted of the carrier classes in the areas they are authorized to serve. Irregular-route specific-commodity carriers have substantially more restricted operating authority but make much more use of their options to avoid the impacts on efficiency of inadequate operating authority, especially options such as complementary operating authority, leasing of independent drivers, and hauling of exempt commodities. Despite the resourcefulness of the carriers, these options do not always offset the effects of inadequate operating authority. Owner-operators are highly effective in using trip leasing to certificated carriers or hauling exempt commodities to remain competitive, despite their lack of operating authority. Restrictions on operating authority are partly responsible for the low load factors of private motor carriers, but such carriers still compete because of service and rate motivations. Private motor carriers are disadvantaged the most by operating authority restrictions because they ordinarily enjoy few of the options available to the other carriers to ease the effects of the restrictions.

This paper considers only the direct effects of operating authority restrictions on operating efficiency; it does not consider the indirect effects on the structure of the industry or on rate and service competition resulting from the entry constraints imposed by restrictions on operating authority.

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The views and conclusions stated here are ours and should not be interpreted as representing the official policies of the Federal Energy Administration.

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Analysis of Rail-Water Price Competition

Edward B. Hymson, U.S. Department of Transportation

The pricing debate between the water carriers and the railroads is examined. Water carriers assert that railroads discriminate against them in pricing, and railroads assert that they price in a manner that will permit them to hold on to traffic that would otherwise be lost to their unregulated competitors. Both assert that their pricing practices benefit society. Competitive rail pricing practices and their effects on water carriers, shippers, railroads, and the general public are discussed.

Representatives of the water-carrier industry have argued that railroads discriminate against them in pricing practices, to the detriment not only of water carriers but of the general public as well (1). They assert that railroads practice what is known as "sharpshooting"—charging a lower rate for a freight movement in a market that faces water competition than for a similar movement in a market that does not face such competition. Railroads, the water carriers say, also practice price squeezing—charging higher rates for the rail portion of a rail-water freight movement than for a competing all-rail route. The railroads respond that, in the first case, they are only lowering rates to hold on to traffic and meet competition. In the second case, they are attempting to prevent loss of traffic to water carriers who can attract the traffic primarily because of their subsidized status. This paper examines who is benefited and who is hurt by such railroad pricing practices.

The parties affected by restriction or encouragement of these practices are (a) shippers who have access to a water route as an alternative to a rail route, (b) shippers who have no water alternative, (c) investors in railroads, (d) investors in water carriers, and (e) the general public. The analysis given in this paper indicates that sharpshooting results in lower transportation cost to shippers and to the general public and leaves only water carriers worse off. Determining the effects of price squeezing is more difficult. If waterway subsidies are taken as given (with the economic inefficiency that implies), an optimal system of price squeezing can result in a net reduction to society of transportation costs. If railroads lower rates to shippers who have access to a water alternative and raise rates on traffic not subject to diversion until the resulting rate structure produces a competitive rate of return, price squeezing simply results in a transfer payment from shippers of water-competitive traffic to shippers of non-water-competitive traffic.

A railroad's ability to respond to water competition is constrained by those sections of the Interstate Commerce Act prohibiting undue discrimination or preference. The constraints these sections impose on rail pricing adjustments can result in railroads losing traffic to water carriers when the water-carrier rate is above the rail variable cost of providing the service. In such a situation the total transportation cost to society rises by an amount equal to the difference between rail variable cost and the water-carrier rate.

If water competition results in a reduction in earnings for the railroads below competitive levels, there is a transfer of revenue from railroad investors to shippers. If it results in a government subsidy to railroads, there is a transfer of revenue from society to rail shippers equal to the reduction in shipping rates, plus a loss equal to the administrative costs of providing the subsidy.

Recent experience in the Northeast suggests that railroad main lines will generally continue to operate whether they are financed privately or by subsidy. Under such conditions, transportation costs to society could be minimized by imposing user charges on water carriers equal to the costs of maintaining the waterways. Such a program would minimize the total public cost of transportation and would shift the costs of waterway maintenance from taxpayers to those who benefit directly from waterway movements.

PRICING OUTPUT OF A REGULATED FIRM

The simplest firm to regulate is one that produces a single output product by using inputs that can be acquired discretely with changes in output. When such complete divisibility of inputs exists, all costs of production are said to be variable with output (2) and the price that results in most efficient output levels is the price that covers all costs of production. If inputs can be purchased in quantities that vary with output, output can be produced at a constant cost per unit. The regulator should normally require a single price for all buyers; that price should be set at a level that will ensure a competitive rate of return to the regulated firm.

The only reason to charge different prices to different classes of customers would be to cross subsidize among groups of buyers. Some regulatory bodies believe that their mandate includes a requirement to cross subsidize to achieve social objectives (3). Under such conditions, one class of buyers would pay more than the cost of the output, another class less. Whether this results in a greater or smaller output depends on the elasticity of demand in each market. The cost of production per unit is the same for each unit produced. The effect on those paying the higher rate is the same as if an excise tax were imposed, and the result on those paying the lower price is the same as if a subsidy were provided. The resulting redistribution is a result of conscious social planning and is as efficient or as inefficient as any other reallocation of resources that uses an excise tax and subsidy approach. It normally results, however, in a non-pareto-optimal distribution of resources (by which is meant a distribution that is economically inefficient).

The problem becomes more complex when a single, indivisible investment is required to produce a variable number of units of output. Railroad investment in track and roadbed is such an investment. The investment cost does not vary proportionately with the number of cars moving over the track. In this instance, it cannot be said that a single price for all users will generally result in the most efficient utilization of the investment. In fact, a single price to all users will result in the most efficient use of the resource only in the limiting case in which the facility is fully utilized at that price (4, 5). The argument that subsidy is preferable to pricing at other than prices that reflect the marginal cost of each individual output has been refuted by Baumol and Bradford (6, p. 265). When the production process is complicated by requirements for indivisible, long-lived capital, imposing different prices on different classes of users leaves society better off than does imposing a single price because, as output increases, fixed inputs become more fully utilized and cost per unit of output falls.

For example, a firm must buy a machine that can produce 10 to 100 output units/week and wears out in 52 weeks regardless of the number of units produced. The machine costs \$5200. (For simplicity, capital costs are included in the cost of the machine.) Other raw materials and labor can be precisely tailored to the weekly output; they cost \$1/unit produced. To cover all costs, the firm must recover its \$5200 investment plus \$1/unit to cover raw material and labor costs. The capital investment is, for any intermediate period, a fixed cost, and the raw material and labor cost is a variable cost. If 100 units/week are sold at \$2/unit, total cost per unit will be minimized and the firm will earn a fair return.

Suppose, however, that 50 customers would be willing to pay \$3 or \$4 rather than do without the firm's output and that others have access to substitute products and would forego purchasing the output if the price rose above \$1.50/unit. Should the regulator permit different classes of customers to be charged different rates? The answer is yes because all parties are better off if the monopolist can sell the product at different rates. If only 50 units/week are sold, the cost of production is \$3/unit. If an additional 50 buyers can be found who will buy the output at $1.50, then the first 50 buyers need only pay $2.50/unit. In the absence of regulation, if the producer were a true monopoly he or she could charge the lower price to those who would only pay the lower price and the $3 or higher price to those would be willing to pay $3 or more. The efficient regulator would permit only sufficient discrimination to minimize costs to each class of buyers consistent with a competitive rate of return for the firm. The regulator should prevent discrimination that would result only in an overall monopoly rate of return. The precise amount of permissible price discrimination is a function of the capacity of the physical plant and of differing elasticities of demand of different groups of potential purchasers.

When a railroad provides some services that are substitutes for water-carrier services and some that are not, a multipart pricing structure can be used to attain the permitted rate of return. The reasoning is similar to that employed by Williamson (4) and Stigler (7) in which, for a given scale of plant, a single price would not cover the costs of providing service. As long as a reasonable rate of return is not exceeded, those with access to alternative transportation service should be charged a rate equal to or greater than the short-run marginal cost of providing service that maximizes the contribution to fixed cost. Those without alternatives, for whom the demand for service is presumably more inelastic, should be charged whatever rate (presumably above the average total cost) maximizes the total contribution to fixed cost. More precisely, the rates should be set equal to the reciprocal of the respective price elasticities of demand of each class of customers. Such a pricing structure could conceivably yield returns above those permitted by the regulator. In such a case, the two rates would somehow have to be reduced to yield no more than the permitted return. The downward adjustment that would minimize total societal transportation cost depends on the elasticity of demand for rail service of each class of customers and on any equity factors the regulator takes into consideration.

SHARPSHOOTING

Railroads operate trains that move only when there is traffic but pay property tax, capital costs, and maintenance on right-of-way regardless of whether or not the trains move. Part of the cost of maintaining the right-of-way is related to use, but a large part of the costs continue as a function of time, independent of use. Thus, the more traffic moves over the railroad at a rate above variable costs, the lower the average level of rates must be to cover fixed costs and provide for a given rate of return.

Variable costs are defined here as those costs that vary directly with traffic, including the capital and depreciation cost of equipment. The Interstate Commerce Commission (ICC) uses the term full cost to include variable cost plus a pro rata allocation of the fixed costs of operating a railroad. [ICC is currently under mandate from Congress to define variable costs (Pub. L. 94-210, The Railroad Revitalization and Regulatory Reform Act of 1976).] The allocation of fixed costs is done to examine changes in the amount remaining to be paid by different classes of shippers given a change in the amount paid by one class of shippers. In practice, there is no nonarbitrary way to make the allocation. Average full cost is thus defined by convention, and it does not reflect the costs uniquely or unalterably associated with producing a unit of output.

In those markets in which railroads are faced with water competition, shippers who can choose to ship by either water or rail will not normally be willing to pay as high a rate as shippers who do not have access to waterways (all other things being equal). Shippers with access to water competition are analogous to those buyers in the previous example who are only willing to pay $1.50 for the product. They are not willing to pay more because the availability of a substitute product (water transport) removes the incentive for them to pay rates higher than water-carrier rates to secure rail services, except to the extent that service differences warrant a premium. Other shippers, either because their products cannot move by water or because they do not have access to a waterway, are willing to pay a higher price for rail service.

Assume, for example, that two commodities—coal and wood doors—are moving over a rail line that faces water competition. The number of megagrams of each commodity moving between the two points is the same and each has the same handling costs. If each commodity is charged the same rate per 45 kg (hundredweight), each commodity will contribute one-half of the fixed costs. Assume, however, that doors, unlike coal, cannot move by water. If the railroad tries to charge a rate on coal higher than the water rate, the coal traffic will move by water rather than by rail. Even if the coal shipper is charged a rate that is equal to only a small part of the fixed costs, the door shipper is better off if the coal moves by rail. Otherwise, the rates charged the door shipper would have to be high enough to cover all the fixed costs of operating the line. Alternatively, the shortfall could be made up by subsidy by railroad investors or by the government. In either case, average rate plus subsidy will result in a higher public cost of transportation than would result if sharpshooting were permitted.

The coal shipper is better off because, as a result of competition, he or she gets a rate by rail that is as low as or lower than rates available by water. Water carriers have no fixed costs of right-of-way because waterways are provided free by nature or by the government. If they lose traffic they do not have to keep up a right-of-way but can quickly disinvest or seek other traffic in that or any other market. If they cannot meet the rail rate, they simply lose that business and the profits they would have earned had they carried it. The policy yielding the lowest societal transportation cost is to allow a railroad to compete directly with the water carriers. Sharpshooting by a regulated railroad is nothing more than trying to cover the costs of the indivisible investment to generate the lowest possible average level of rates consistent with the competition the railroad faces. (Since fixed costs are also largely common costs, there is no way to argue how they should be covered. The only measure of adequacy of rates is whether total return covers the costs of production.)

ICC regulation of railroad rates of return was presumably established to assure that practices such as sharpshooting result in a minimum level of rates to all customers consistent with no more than a fair rate of return. Part 1, Section 4 of the Interstate Commerce Act authorizes railroads to reduce rates to meet competition but prohibits railroads who once lowered rates to meet water competition from raising them on grounds that such competition no longer exists. The Railroad Revitalization and Regulatory Reform Act of 1976 further encourages rail pricing flexibility.

To the extent that waterway improvements are subsidized as an increasing function of use, the government subsidy for waterways declines with the decline in waterway use brought about by sharpshooting. This reduction in subsidy is in addition to the reduction in the aggregate freight bill and is an added benefit to the public.

PRICE SQUEEZING

Analysis of railroad price squeezing is more complex than analysis of sharpshooting. Changes in the currently imposed set of subsidy and tax programs affecting the two modes can cause changes in the societal costs and benefits associated with any particular railroad pricing policy. Water carriers now benefit from free use of the water right-of-way. Railroads must finance their right-of-way themselves. One can reasonably assume that (a) railroads will continue to operate, by government subsidy if necessary; (b) railroad companies will earn their market cost of capital in the long run or impose a loss on either their investors or the government equal to the difference between the market cost of capital and what they actually earn; and (c) because of the administrative costs of collecting taxes, budgeting, and making subsidy expenditures, a dollar of subsidy costs the public considerably more than a dollar increase in cartage charges. It is not clear whether waterway charges will be imposed in the future or what form they will take. In this analysis the first assumption will be that waterways continue to be subsidized. Then the effect of imposing waterway user charges will be examined.

If railroads were earning returns above their opportunity cost of capital, a marginal diversion of traffic from railroads to waterways would not increase the total subsidy. Instead it would lower transportation costs to society by the amount of the reduction in the total freight bill. As a practical matter, few railroads are earning rates of return equal to the market cost of capital (8). A digression on the long-term implications of less than market rates of return will serve to clarify the subsequent discussion.

Railroad assests are long-lived and of little value in any other business activity. Railroads thus continue to operate for decades without earning a market rate of return on their investment, simply to recoup some of the money already invested in the existing physical stock of railroad capital. At some point, however, usually as the physical plant falls apart, it becomes clear that investors will not invest funds in new railroad capital because the expected return on investment is inadequate. The long gestation period provides no basis for assuming that railroads require a lower return on equity than do other firms.

Historically, it was possible for a railroad to go through bankruptcy and wipe out part of its debt. The railroad would then issue new debt to a new set of optimistic investors in order to secure funds to reinvest in the firm. In spite of past revenue problems and probable future problems, investors bought new securities. The Chicago, Milwaukee, St. Paul and Pacific Railroad Company, for example, was formed as a successor to the bankrupt Chicago, Milwaukee and St. Paul Railroad in January 1928. After going bankrupt again, the company was reorganized in 1945. New capital was raised after both bankruptcies. The Erie Lackawanna has a similar history; it was reorganized in 1895 and again in 1941 and raised new capital after both bankruptcies (9).

Information currently available has adversely affected investor expectations. The bankrupt roads of the Northeast are in such bad condition that they could not cover even their operating expenses, much less service any portion of their debt. The precedent of government subsidy established in the Northeast is likely to replace Section 77 of the Bankruptcy Act as the device used to keep the weaker U.S. railroads operating. The depressingly long lists of widows, orphans, insurance companies, and pension funds holding stock in the bankrupt roads of the Northeast is a reminder that even traditional bankruptcy refinancing has shifted the cost of rail transport from the shippers to that large portion of the general public who are disenfranchised by the bankruptcy. In the future, one can speculate that, following bankruptcy, shippers or the general public, rather than a new set of optimistic investors, will pay the share of costs of operating and rebuilding the railroads that is not covered by operations. Recent experience indicates that the vast majority of railroad main lines, including most lines where significant water competition exists, will as a matter of national policy be forced to remain in service. If a railroad is earning less than a competitive rate of return, price squeezing can reduce the amount of subsidy the government or investors will be called on to provide and reduce the total societal cost of transportation.

Let us examine who pays what when a railroad earning a competitive rate of return is forced to lower rates in response to water competition. In equilibrium, a railroad earns a competitive rate of return (K). The traffic that can be hauled over a part of a route only by rail is T_r and over the rest of a route by either rail or water is T_w. The traffic moves at rail rates (R_{rr}) and (R_{rw}) respectively. Other non-water-competitive traffic (T_o) moves at rates (R_o). R_{rr} covers variable costs (VC_{rr}) and makes a contribution to general costs (GC_{rr}) (general costs, which here refer to costs that do not vary directly with the specific output and will continue to exist independent of the particular output, in the long run must be covered to attract investment funds needed to rebuild the facility); R_{rw} covers variable costs (VC_{rw}) and makes a contribution to general costs (GC_{rw}); R_o covers variable costs (VC_o) and makes a contribution to general costs (GC_o). Taxes are represented by AC. In long-run equilibrium, the regulator permits rates such that

$$K = VC_{rr} + VC_0 + GC_{rr} + GC_{rw} + GC_0 - AC \quad (1)$$

As long as some combination of rates results in maintenance of the required K, the mix of rates can be determined by whatever policy the regulator chooses to impose. Any shortfall in contribution to K in one transport market is made up either by other shippers in other markets through rates that contribute more to GC_o or GC_{rr}, through losses incurred by investors, or through subsidy paid by government.

Assume that a water carrier institutes service on the water portion of a rail-water freight movement at a rate (R_w) below R_{rw} but above VC_{rw}. If the water rate is below rail variable cost, then moving the commodity by water will be less costly to society than allowing the railroad to price squeeze because the reduction in rates paid by the shipper who benefits from the lower rates is greater than the loss in contribution to GC from this source incurred by the railroad. The result is that other rates go up by less than the savings to those shippers who shift to water. Unless the railroad is permitted to price squeeze, it cannot simply lower R_{rw} to R_w but must also make a proportional adjustment in R_{rr}. As a result, to compete by reducing rates the railroad must reduce contribution to GC_{rr} by an amount proportional to the reduction in contribution to GC_{rw}. The railroad will meet the water rate only if the volume of traffic moving over route (T_r) relative to the volume moving over route (T_w) results in a higher contribution to GC_{rw} after water competition is met than if the railroad does not lower rates. If the railroad does not make the adjustment, then the cost to the public of not permitting price squeezing is equal to R_w minus VC_{rw} times the volume of freight involved. If the carrier does make the adjustment, then there is a transfer as higher rates to other shippers make up the revenue shortfall equal to R_{rw} - R_w. If the carrier is permitted to price squeeze by lowering rates on the competitive portion of the route to meet competition and leaving rates on other portions of the route unchanged, transportation cost to the public will not increase. There will be a transfer from one group of shippers to another smaller than would have resulted had price squeezing been prohibited.

In the absence of legal constraints, it would be possible for the railroad to (a) lower the rate on the water-competitive portion of the movement from R_{rw} to R_w but leave other rates unchanged (mild price squeezing), (b) lower R_{rw} to R_w but increase the rate on the noncompetitive portion of the movement (R_{rr}) to make up the difference (extreme price squeezing), or (c) lower R_{rw} and lower R_{rr} proportionally (no price squeezing). The first alternative can lead to charges of discrimination or of undue preference and prejudice. Although, under current regulation constraints, meeting competition may be an effective defense against mild price squeezing, it is not a defense against extreme price squeezing. As shown above, the effect of implementing the third alternative is to reduce not only contribution to GC_{rw} but also contribution to GC_{rr}. This leads to a loss in contribution to K greater than the reduction in transportation charges to shippers shifting to water transport and thus to an increase in the total societal cost of transportation.

If mild price squeezing is allowed, the problem does not arise. The only loss in revenue that occurs is the loss resulting from lowering R_{rw} to R_w on the water-competitive portion of the movement to meet the rates of the water carrier. The mild form of price squeezing that results from not reducing rates on the noncompetitive portion of the movement minimizes the total transportation cost to the public. Extreme price squeezing cannot further reduce transportation cost except indirectly by minimizing the probability that a rail subsidy will be needed and thus minimizing the costs to society of administering a subsidy.

The greater the amount of rate adjustment that is required to maintain traditional rate relationships, the greater are the related rates that must be reduced when the R_{rw} rate is lowered. As the quantity of rates to be reduced rises, the possibility that the railroad will give up water-competitive traffic rather than make the rate adjustments necessary to retain it also rises. The larger the required rate adjustment is, the more likely it is that the cost of transportation to society will rise.

WATERWAY SUBSIDIES

Even in the long run, the common cost problem makes it impossible to specify who should pay what share of rail fixed costs. There is no way to determine the effect of shifting the proportion of fixed costs covered by different classes of traffic to efficiency of resource allocation. To the extent that waterways are subsidized as a function of use, the subsidy will rise as traffic is diverted from railroads. If the water subsidy increases, society is worse off because the total cost of transportation is increased. The cost of waterway maintenance is held down to the extent that price squeezing retards the increase in barge traffic. Shippers having access to the water alternative pay a higher rate; other shippers are spared a rate increase. Subsidizers are better off because subsidies to both water and rail are limited.

In some markets, waterways are natural and do not involve significant government investment. In many markets, however, the reason that water carriers can offer lower rates than railroads is that they receive a subsidy in the form of free waterway maintenance and free use of lock facilities. The preceding analysis was predicated on the assumption that either the waterway was natural or the subsidy to the waterway would continue regardless of the level of use and without imposition of user charges on the water carriers. If there were a user charge imposed on water carriers that covered the costs of maintaining and rebuilding each waterway segment, the rates water carriers would have to charge would increase in many markets. Given a 1974 Corps of Engineers annual operation and maintenance figure for shallow-draft waterways of $155 811 000/year, the necessary increase in water rates would reduce incentive to transship to barges on all but natural waterways. Increased revenue to the railroads would be likely to improve their financial position and reduce both losses to railroad investors and the government subsidy required to maintain the roads. Freight rates would rise on water-competitive traffic. The contribution required from other shippers, however, would decrease. Because the government would probably continue to build and maintain the waterways, there would probably be little or no reduction in the costs of administering waterway subsidies. The cost of collecting user charges, which could be insignificant or considerable depending on the type of charge and method of collection, would represent an increase in transportation cost. Railroad shortfalls made up by government subsidy would fall, reducing costs by the decline in subsidy and the decline in the cost of administering the subsidy. Government expenditures would fall, and the burden of paying for transportation facilities would be shifted onto those who benefit directly from the facilities.

Alternative toll proposals would result in different types of rate adjustments. The general fuel or freight tax will raise operating costs on all waterways by a relatively uniform percentage (although a fuel tax imposes a de facto higher tax on upriver movements because of the increased fuel consumption required in moving against the current). A section toll would increase costs on sections of the waterway system in proportion to the costs of improvements and maintenance on that section. In general, the effect of a section tax on rates for traffic moving longer distances is not likely to differ greatly from the effect of a fuel tax because tolls for high-maintenance areas and those for natural portions of the waterway system will tend to average out. Thus, although some cross subsidy is created by the imposition of a fuel tax on users who only use the natural portions of the waterway system, such inequities may well create fewer allocation problems than might be expected.

The effect of any toll on rates is a function of the profit level of the water carriers and of the elasticity of demand for water-carrier service. Pressure from railroad rates would result in some tolls being absorbed by water carriers. The substantial variation in barge rates over the year, however, makes it very difficult to measure the amount of toll absorption. To the extent that water carriers absorb any part of the user charge, the net federal subsidy to water carriers is reduced and the total cost of transportation to society is reduced by the amount absorbed. If water-carrier rates rise as a result of user charges, less traffic will be diverted from railroads. Given the continued maintenance of both rail and water service, there will be some optimal user charge on waterways that minimizes the total government subsidy to both modes and minimizes the total cost of transportation to the general public.

From the viewpoint of economic efficiency, imposing user charges results in allocation efficiencies as well as minimized government expenditure. Such a pricing mechanism also shifts the cost of the service to those who benefit from it—shippers and the buyers of products shipped—which economists generally consider preferable to the government paying part of the cost of the service offered (6). It is inconsistent, inequitable, and, as shown above, inefficient to finance waterways by government grant and at the same time require private investors to finance railroad right-of-way until bankruptcy prevents further operations.

CONCLUSIONS

Railroads are frequently prevented from raising rates on "captive" traffic to a point where they can earn a reasonable return on total investment on the grounds that such rates would be unreasonably high and therefore unlawful. At the same time, water carriers argue that, whenever a joint water-rail rate would result in a lower rate to the shipper than an all-rail rate, railroads should be compelled to interchange with water carriers on a nondiscriminatory basis. Water carriers raise or lower rates in response to market conditions; railroads are compelled by law to provide service only at published prices. This amounts to forcing a railroad to give traffic to its competitor, who responds to market conditions in a way rail carriers cannot respond and receives subsidies rail carriers do not receive. Permitting railroad sharpshooting and mild price squeezing helps to redress the competitive imbalance between the modes. Imposing user charges further reduces the financial imbalance. User charges and increased rail pricing freedom would lower transportation costs to society and encourage a more equitable distribution of resources within the transportation system.

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Economic Cross Subsidization in Domestic Air Transportation

Douglas V. Leister, University of Nevada—Reno
Bruce N. Stram, Office of the Secretary, U.S. Department of Transportation

This paper presents an analysis of the economic incentives for a particular air carrier to provide air service to a particular point. Economic cross subsidization is discussed as it exists in many industries other than domestic air service. A suggested definition of economic cross subsidization is presented as well as an argument for recognizing this economic concept as primarily one of allocation of revenues rather than as primarily an allocation of accounting costs, which has been the traditional approach. Issues of product definition are also discussed.

There are a variety of proposed legislative measures currently before the Congress designed to reform economic regulation of the domestic airline industry. During the debate over regulatory reform, a central argument offered by the industry in defense of the 1958 Federal Aviation Act and against regulatory reform has been that there is extensive interdependence among air travel markets in the domestic airline industry and that, because of important economic cross subsidization of air routes, many air travel markets cannot stand on their own but must be supported by other markets (1, 2, 3, 4). Deregulation, the argument continues, would result in "cream-skimming," the collapse of the cross-subsidy system, and wholesale abandonment of service. From the point of view of this paper, the primary significance of this argument is in its assertion that, if existing cross subsidization among the routes of a particular carrier were removed by some external force, that removal would result in wide-scale abandonment by the carrier of points currently served. If such abandonment by carriers is not the result of an external removal of supposed interdependence among markets, then the argument loses its significance and need not be considered an important issue in regulatory reform.

Opponents of regulatory reform have argued that extensive cross subsidization currently exists between and among markets (or points served by particular carriers) and that the removal of cross subsidization would mean an end to profits that are necessary to support marginal service to marginal points served and would thus destroy a national, integrated system of air service. Inherent in this argument is the belief that (a) many of the markets served are not independent markets that can stand on their own two feet but rather interdependent markets; (b) service to one market is dependent on service to other markets; and (c) reduced profits for a more profitable market mean reduced service to less profitable markets. Opponents have also argued that larger markets are the most profitable and that smaller markets are either less profitable or lose money. It has been argued in both instances that, because of the inherent economics of the interrelated markets, profit reductions or increased competitiveness in the larger markets would preclude service to the smaller markets (5). The argument would be true from an economic standpoint if (a) extensive cross subsidization does exist and if profits, particularly excess profits, from larger markets are being consciously used to provide service—whether as a result of public interest objectives of private carrier managements or by regulatory fiat—to unprofitable smaller markets whose services are unrelated to the profits in the larger markets; and (b) larger markets are more profitable, by their nature or rate structure, than smaller markets.

During the lengthy Civil Aeronautics Board (CAB) investigation of domestic passenger fares, a deliberate attempt was made to remove any existing cross subsidization inherent in the regulated rates of the domestic 48-state passenger fare structure. Since the CAB decision, air passenger fares have been adjusted to remove cross subsidization. Shorter haul fares have been increased more rapidly than have longer haul passenger fares in an attempt by CAB to remove what was regarded as historic, inherent cross subsidization.

It is the position of this paper that economic interdependence among markets may or may not qualify as economic cross subsidization under the traditional definition. Market conditions are examined in which interdependence among markets may exist as a result of the natural conditions of the marketplace or markets may be linked by law or by regulatory fiat. (For example, many certificates of public convenience and necessity in the domestic airline industry require that market A be served only if market B is served.) The main purposes of this study are to explore the natural interrelationships among various markets for air service and, specifically, to question whether regulated circumstances or unregulated competitive circumstances are likely to lead to greater incentives for airlines to serve medium-sized and smaller air travel markets.

ECONOMIC THEORY OF CROSS SUBSIDIZATION

In its most general sense, economic cross subsidization exists when there is interdependence of markets, i.e., when individual markets are not independent. The traditional economic concept of cross subsidization is based on the idea that profits from services rendered in larger markets are used by the supplier to directly subsidize services in smaller markets that are less profitable or unprofitable and that the services performed in the smaller markets have no direct economic relation to the services performed in the larger, profitable markets.

Accountants and economists do not agree about when and where the traditional concept of cross subsidization occurs in a particular market. Two important economic thresholds at which cross-subsidization begins are those points at which (a) the immediate service in a market fails to cover the fully allocated economic costs of providing the service, including a return on the required capital investment; and (b) the variable costs of providing a service are not being covered by the revenues from the service in that market. The important accounting definition involved in each of these economic thresholds is of course variable costs. Variable costs are defined here as including only those costs that vary immediately and directly with the particular service being provided in the particular market. In other words, the second threshold begins when out-of-pocket costs of providing the market service are not being exceeded by market revenues from that service in that market.

In the development of airline management strategies, there are several reasons why management would voluntarily provide service in a market even though service revenues are not covering fully allocated economic costs: (a) The future looks better than the present; (b) revenues in one market are related to revenues in another market; (c) a competitor is close to suspending service and the market would be economically attractive if that occurred; and (d) externalities such as aircraft positioning needs and maintenance needs, or employee benefit requirements, such as free, first-class travel for airline employees on various types of passes, may be achieved through the service.

Cross subsidization is not unique to air passenger transportation. The concept of the interdependence of markets is widely recognized in many regulated and unregulated industries. For example, as demand in higher education shifts toward more occupationally related courses, an assistant professor teaching an accounting course to 200 students may often cross subsidize an assistant professor of languages tutoring individual students. Although the accounting professor may receive $4000/year more than the language professor, this does not cover the differential contribution that the two make to the operation of the university.

For example, some private universities are currently charging tuition at the universal rate of $100/credit hour, and all undergraduate courses are usually priced similarly for the same number of course hours per week. Thus the accounting course generates $80 000 in revenue (200 × 4 credit hours × $100) against the language course at $400. Even considering the cost of the larger room needed for the accounting course, if there exists the universal pricing scheme common in higher education coupled with a nearly universal salary scheme and everything else is held constant, cross subsidization exists between the two courses and the university's revenue-cost situation. This is a simple example in that the direct costs of providing the language course are not being covered by the $400 in revenue that the course earns.

A more complex situation develops if there are 10 students in the language course and the resulting $4000 in revenues covers all direct or variable costs of offering the course. If the accepted definition is that no cross subsidy exists if revenues in a particular market cover the direct costs of providing the service, then in this instance no cross subsidy exists. Merely covering all direct costs of offering the course, however, does not help to replace the room the course is taught in, operate the library where language students study and listen to tapes, maintain the cafeteria, or support the football team that attracted the students to the university in the first place. In simple accounting terms, there is no contribution to overhead.

Natural market relations that result in cross subsidization evolve from conditions of complementarity and relatively high cross elasticity of demand. Two goods are said to be complementary if the purchase of one is directly related to the purchase of the other, e.g., cameras and film and razors and blades. In the case of cameras, the market structure is such that one dominant firm is able to earn the majority of profits from either instant or regular film. The demand for film and film developing is directly related to the number of cameras in circulation and in use and the time of year. Whether or not film-related profits are covering or cross subsidizing camera marketing costs need not be determined if what is known in marketing as product-line pricing is considered. In this case, one item is viewed as a necessary accessory or condition of sale of another item in the same product line and no arbitrary allocation of further economic costs is made. In the context of oligopolistic marketing strategies, this cross subsidization is a rational procedure under certain conditions. In particular, the economic losses associated with the cross-subsidized product (razors or cameras) could be more than recovered by the excess or economic profits earned on additional sales of the subsidizing product (razor blades or film).

When this rationale for cross subsidization is translated into the terms of the air service market, cross subsidization might be said to exist under the following conditions. If excess profits are earned in dense and medium or long-haul markets, it is rational for carriers to provide net loss service for smaller points connecting into the major markets to obtain a competitive advantage in selling longer haul seats to passengers originating at the smaller points. Presumably the loss incurred in serving the smaller points is more than offset by excess profits earned on the sale of tickets to small-point traffic traveling beyond in the longer hauls. By using the razor-razor blade analogy, one can go on to suggest the possibility of abandonment of smaller points in a price-competitive air service market. Clearly, if the market for razor blades were such that a manufacturer was unable to obtain a price for the basic product greater than that required to offset economic cost, the economic incentive to cross subsidize the complementary product, razors or cameras, would evaporate and the price of razors or cameras would increase. In air service markets, it might be suggested that straightforward, discretionary fare flexibility with relatively free entry into markets would cause long-haul excess profits to be bid away in a competitive process. It might also be argued that, as a result, the economic incentive to cross subsidize small points would evaporate and fares at small points would increase. Add to this the fact that the fare increase would be so great as to reduce demand below minimum service levels at many small points, and the result is clearly abandonment (that is, abandonment of air services as they are presently provided by certificated carriers, which, of course, does not preclude the existence of such alternative services as commuter airlines).

A typical industry expression of this line of reasoning might be stated as follows: The X-to-Y long haul is where our system earns its profits and, if all the profits are bid away by new entrants lowering prices, we will have to stop serving small points and concentrate on the long haul. This analysis by analogy leads to a false conclusion. Intermarket relations observed in air transportation are largely distinct and unique (with the possible exception of telecommunications) and are not primarily related to the existence of excess profits in any market. The cross-subsidization analysis, at least as outlined above, does not hold in domestic air transportation. The analysis centers on the proper allocation of costs and revenues among markets and points served and partially on the definition of the product. Cost allocation is fairly straightforward and is primarily dependent on the time horizon of the analysis. Appropriate revenue allocation is the basic source of confusion.

In the short run, it is conceivable that a carrier will provide service in a market or to a point whose marginal contribution to system revenue just offsets the additional short-run costs associated with providing that service. In other words, short-run services might be provided even if those services do not make an appropriate contribution to the cost of the capital used to provide the service. This may happen if the carrier simply has no better use for the capital equipment and is not able to sell it in the marketplace at a price that reflects his or her perception of the long-run value of that capital in the system. Because the focus of this analysis is the conditions for abandonment of service to a point or a market, such a short-run view of costs is not entirely appropriate.

If a carrier is not able in the long run to recover the costs of all capital equipment, his or her stock of equipment will decline through simple attrition unless the carrier is willing to continue to obtain capital at a net loss. Therefore, a point or a market that does not cover the marginal costs of capital associated with providing service may receive service for a period of time but in the long run will be abandoned. Thus, for purposes of this analysis, it is assumed that points and markets whose marginal contribution to system revenues does not cover or exceed the marginal contribution to system costs, including capital, will eventually be subject to abandonment.

REVENUE ALLOCATION BY MARKET AND POINT

Market interrelationships are highly complex with regard to revenue. The following example will serve to establish the principle of intermarket relations and its significance for market-by-market and point-by-point allocation of revenues.

During 1976, Eastern Airlines provided three daily flights from Macon, Georgia, to Atlanta (6). One flight continued on from Atlanta to Baltimore and then to Hartford, Connecticut. Suppose Eastern typically carries 50 passengers from Macon to Atlanta and that 21 of those fly on to Baltimore or Hartford. Clearly, Eastern has a substantial competitive advantage in selling Atlanta to Baltimore or Hartford tickets to those 21 passengers flying on from Macon.

For simplicity, it will be assumed here that all passengers choose to continue on Eastern. From the evidence, it would seem extremely unlikely that a passenger would get off one plane and on to another even if he or she were able to reduce connecting time as a result. It would also seem likely that the through and beyond flight would minimize connecting times. Carriers contend that they are able to control a substantial portion, if not all, of connecting traffic to points they serve. Whether or not single-plane service is offered from a smaller point to a major hub and beyond to a final destination, the carrier providing the feeder service has a greater advantage over competitors in carrying a connecting passenger to a beyond area point. With the development of satellite terminals segregated by carrier rather than destinations or lengths of haul, the inherent advantages to a carrier of providing feeder service to on-line connecting passengers have increased. Further advantages have been gained by use of the "sterile concourse" concept of airport security, to the extent that it is a major project for a passenger on an incoming carrier to change carriers at a major air hub.

Eastern, in 1974, provided about $^3/_7$ of the available seats and flights from Atlanta to Baltimore. If Eastern did not fly to Macon, one would roughly expect that, at best, only 9 ($^3/_7 \times 21$) of the 21 passengers would fly Eastern to Baltimore. If the 21 passengers had flown to Atlanta by another carrier providing connecting or through service to Baltimore, much fewer than 9 would be expected to continue on Eastern. Clearly, the ticket revenues from these additional 12 to 21 passengers would not be earned by Eastern unless the Macon service was provided. To properly evaluate the marginal system contribution of the Macon-Atlanta flight, these ticket revenues must be added to the revenues directly earned from Macon-Atlanta service.

The apparent Atlanta-Baltimore revenue, which properly should be allocated to Macon-Atlanta service, must also be offset by the local Atlanta-Baltimore passengers displaced. It cannot be assumed that, because an average 40 to 45 percent of the Atlanta-Baltimore seats are empty (i.e., a 55 to 60 percent load factor), the n through passengers will fill seats that would otherwise be empty. There is a probability distribution about the mean load factor and mean number of through passengers so that at specific points in time the through passenger may displace a local Atlanta-Baltimore passenger or, alternatively, the through or connecting passenger might not be able to obtain a seat on the appropriate Eastern flight.

Therefore, the a priori expected intermarket revenue (IR) that should accrue to the Macon-Atlanta service for a given through or connecting passenger may be expressed as

$$IR = \delta \times F[1 - p(LF)] \tag{1}$$

where

δ = probability that the through or connecting flight provided by the same carrier will be the preferred flight for the through or connecting passenger (assuming $\delta = 1$),
F = long-haul fare, and
$p(LF)$ = probability that the marginal through or connecting passenger will not displace a long-haul origin-and-destination passenger [this frequency function is taken to vary with load factor (LF)].

It should be noted that the number of passengers on a flight is LF × capacity.

The total expected revenue from those passengers continuing to Baltimore that should be allocated against the Macon-Atlanta flight may be expressed as

$$IR = F \int_{N}^{N+n} p(x)dx \tag{2}$$

where N = expected or mean number of long-haul origin-and-destination passengers and n = expected number of through or connecting passengers available from the incoming short-haul flights over and above the carrier's expected share, i.e., those passengers that would be distributed among other competing carriers providing service on the long haul if short-haul service were not provided. [The frequency function has simply been transformed to be an equivalent function of number of passengers (LF = x/capacity); capacity of the aircraft is here considered a constant.]

$\int_N^{N+n} p(x)dx$ is the expected net gain in the number of passengers flying from Atlanta to Baltimore, related to the Macon service. On a marginal basis, these passengers and the associated ticket revenues accrue to the airline because and only because the Macon-Atlanta service is provided. If that service were stopped, this intermarket revenue and the revenue from the direct Macon-Atlanta ticket would be lost to the carrier. Except for minor costs associated with in-flight services provided to Macon-Atlanta-Baltimore passengers on the Atlanta-Baltimore haul (such costs are not dealt with here), there are no additional costs associated with the intermarket revenues.

Clearly, service to Macon may be profitable for the system even though direct revenues do not offset the fully allocated costs of that service. Further, an unsophisticated observer could contend that the profits derived from service between major centers are supporting the whole system. Analyzed on a simple market-by-market or segment-by-segment basis, that would appear to be the case. Eastern's Atlanta-Baltimore segment runs a load factor of $[\int_N^{N+n} p(x)dx]$/capacity, whereas hypothetical competitors not providing Macon service would run a load factor of N/capacity, assuming this N/capacity is the break-even level established by either a regulated or unregulated market dynamic (i.e., flight frequency competition versus flight frequency and price competition).

Because the Atlanta-Baltimore market for Eastern achieves a higher than break-even load factor, partially because of feeder traffic from Macon, an unsophisticated observer might argue that the lucrative hub-to-hub market supports the whole system and is the source of the profits that support the rest of the carrier's system. Yet, as the above analysis demonstrates, if the feeder markets are dropped as unprofitable (if direct ticket revenues do not cover fully allocated costs), the apparent excess profits in the hub-to-hub market will evaporate.

The design of major air hubs such as Atlanta, where both Delta and Eastern "marry" large numbers of passengers from various origins seeking service to a common destination, is such that changing planes on line (i.e., changing from one plane to another plane of the same airline) is made simple. The respective carriers make a great effort to control on-line connecting traffic by carefully timing connecting flights, using adjacent terminal gates for related flights, and in some cases holding longer haul connecting flights for feeder flights that arrive late. All major domestic airlines have major connecting hubs where they vigorously solicit the business of on-line and interline connecting passengers.

COMPETITION VERSUS REGULATION

The simple market structure developed in the previous section can be used as a tool to examine potential reduction of service at small or feeder points as a consequence of deregulation. For these purposes, deregulation is defined as a condition characterized by complete carrier discretion with regard to fares, flight frequency, and entry and exit.

Carriers and others contend that allowing free entry into lucrative long-haul markets will destroy an integrated (interrelated) air service network. In the example of market interrelation given above, however, no such outcome can be observed.

Entry into the long-haul market of itself can potentially affect the long-haul market share (represented by N in Equation 2). If, irrespective of profit potential, additional capacity (additional flights and additional available seat miles) were allocated to the market by new entry, the expected number of long-haul origin-and-destination passengers carried on a typical flight would fall. All other things being equal, this would increase the likelihood that Macon-Atlanta beyond passengers would fill otherwise empty seats; i.e., $\int_N^{N+n} p(x)dx$ increases if N decreases and n remains the same. The amount of revenue that should be allocated to the feeder route would thereby increase. The portion of Macon originating passengers that Eastern would be expected to carry without providing Macon-Atlanta service would also fall. Under the initial entry-protected regulated conditions, it was assumed that, if no Macon-Atlanta service was provided, passengers originating at Macon would travel to Atlanta by other transport modes and be distributed to air carriers by the percentage of flights or available seat miles in the long-haul market. Thus, without providing the Macon-Atlanta service (assuming it to be monopoly service), Eastern would normally be expected, if no one else serves Macon, to carry

$$(EFL/TFL)MACBAL \tag{3}$$

where

EFL = number of Eastern flights from Atlanta to Baltimore,
TFL = total number of flights in the market, and
MACBAL = Macon-Baltimore passengers.

The additional number of passengers gained by providing the service is

$$n = MACBAL - (EFL/TFL)MACBAL \tag{4}$$

If Eastern's proportion of long-haul flights or available seats declines, the number of additional Macon-Baltimore passengers obtained by Eastern because Macon-Atlanta service exists increases. Under these conditions (denoted by the superscript), revenue allocated to Macon-Atlanta service, expressed as

$$IR^1 = F\int_{N^1}^{N^1+n^1} p(x)dx \tag{5}$$

clearly increases, and the Macon-Atlanta service is more profitable from the carrier's point of view.

Of course, if the original equilibrium capacity provided in the market achieved break-even load factors for the typical equipment, it is also clear that average load factors for the long-haul origins and destinations, or for carriers only serving the long-haul market, will have fallen below the break-even point on a fully allocated basis (given the fare level). Logically, from a long-run point of view, one might ask why such entry would occur. Such entry is postulated here to establish the point that it does not reduce but rather increases the advantages offered a carrier that provides feeder services. Given that such feeder service, with properly allocated revenues, at least covered fully allocated costs in an entry-protected environment, its allocated revenues would increase under the entry conditions considered above. The feeder service in this context is in danger only to the extent that long-haul service is in danger. Given that long-haul service continued to exist, the incentives related to short-haul service would continue as long as the short haul continued to feed the long haul.

Although this scenario represents the viewpoint of many carriers it seems highly likely that air fares will decline in high-density, long-haul markets if a deregulated regime is introduced. Clearly, if fares fall, expected intermarket revenues allocated to feeder routes could conceivably fall as follows:

$$IR = F\int_{N+n}^{n} p(x)dx \tag{6}$$

This circumstance is examined more specifically below.

The final point that should be made here is that intermarket support is not financed by excess profits in long-haul markets but could tend to increase when long-haul markets become less profitable. The more competitive the high-density, long-haul routes become as a result of open entry, the greater will be the market advantage to carriers who control feeder passenger traffic from smaller hubs. In addition, whether or not intermarket allocated revenues decline or increase is not directly related to whether or not more capacity is provided in an unregulated environment as opposed to a regulated environment but rather to whether or not fares decline or increase. Under current conditions of intensive economic regulation and strongly restricted competition, the value of attracting both on-line and interline connecting traffic to a particular carrier at a major traffic hub is apparent.

Because, under the current regulatory scheme, prices as well as market entry and exit are tightly controlled, airlines today are limited in attracting and attempting to control connecting passengers. The carriers have, however, been able to offer both common fares and joint fares, which in effect offer price discounts designed to do two things in the marketplace: (a) attract connecting-passenger revenue (fares) for travel to beyond-area points and (b) prevent freeloading by carefully enforced provisos that preclude stopovers at intermediate points between longer haul origins and destinations.

For example, Macon and Atlanta could have a common fare as an origin for a passenger en route to Boston. The practical implication of this pricing scheme is that the Macon passenger is carried from Macon to Atlanta for free on the enforced conditions that he or she (a) continues on to Boston and further and (b) does not stop over in Atlanta on the way to Boston, except as required by the airlines to marry traffic (separate the origins and destinations) and to switch to the optimal flight equipment for the longer haul, higher density portion of the total trip.

A joint fare is an airline fare offered in air travel markets that involve an intermediate stop between a passenger's origin and final destination. A joint fare usually involves an interline connection or a change in airlines, although not necessarily a change in aircraft, and a reduction in price from the sum of the local or flight-segment fares. The typical purposes of joint fares are to (a) stimulate passenger traffic between the origin and destination by offering a lower fare between the two points than would otherwise be offered and (b) attempt to control the connecting-passenger revenue earned on the longer haul from hub to hub. In effect, a joint fare is a price discount that is given to a connecting passenger on the leg of a longer journey but is not given to a passenger having a local origin and destination, e.g., a Macon-Atlanta passenger.

The longer haul passenger is given a joint fare on the condition that additional revenues are to be paid by that passenger during the particular single-ticket trip in question. In the case of a common fare between Macon and Atlanta to Boston, the Macon-Boston passenger would be "given" the flight to Atlanta and the flight from Atlanta to Macon on the return trip on the condition that the longer haul revenue is captured by the carrier providing the Atlanta-Macon service. Both common-point fares and joint fares have provisos, or artificial barriers, that preclude freeloading. A freeloader in this case would be a passenger taking advantage of the discounted, or free, Macon-Atlanta air service without paying the airline additional revenue for a longer haul flight segment that is part of the Macon-Atlanta trip.

PRICE-COMPETITIVE OLIGOPOLY

An extremely static analysis applied to the example market structure would suggest that intermarket allocated revenue would fall under competitive conditions of price and entry that result in fare reductions. Obviously IR in Equation 2 declines in proportion to any decline in the fare level (F). However, a lower fare also implies a higher break-even load factor (N/C); more precisely, the number of passengers per flight required to break even increases. If planes generally fly with fewer empty seats, this would mean that the likelihood that through passengers will fill empty seats declines {the definite integral $[\int_N^{N+n} p(x)dx]$ declines}. Thus, the intermarket allocated revenue declines both because the fare revenue received from passengers flying to a beyond area declines and because through and beyond passengers more frequently displace local, long-haul origin-and-destination passengers.

If, however, one assumes that fares are reduced, it is unreasonable to suppose that passenger traffic, specifically Macon-Baltimore traffic, is totally inelastic with respect to fare levels. Further, given a price-service competitive market (deregulated) as opposed to a service competitive market (regulated), it is not clear that equipment configuration will continue to resemble today's service-oriented mode. Aircraft may be reconfigured to make more seats available and dispense with service facilities that take up valuable space, such as kitchen facilities on flights providing meals. This has been the experience with the service provided by intrastate carriers (i.e., low fares and high load factors). This means that, in an environment competitive with respect to price, even if lower fares cause the break-even passenger load to increase, the average number of empty seats available for connecting traffic may not decrease.

In determining the elasticity condition that results in zero change or an increase in intermarket revenues, the revenues associated with marginal feeder or short-haul service may be expressed as

$$R = F_{ab}\int_N^{N+P_{mb}} p(x)dx + F_{ma}P_{ma} + F_{ma}\int_N^{N+P_{mb}} p(x)dx \qquad (7)$$

where

F_{ab} = long-haul fare (Atlanta to Baltimore);
N = expected or break-even level of long-haul passengers;
$p(x)$ = density function indicating the probability that a flight with an average of x passengers will have at least one empty seat;
F_{ma} = short-haul fare (Macon to Atlanta, assumed constant);
P_{ma} = local short-haul passengers (Macon to Atlanta); and
P_{ab} = passengers traveling over both the long and short haul (Macon to Baltimore).

The question is how the revenue allocated to the short-haul, or feed, segment is affected by a reduction in the long-haul fare:

$$dR/dF_{ab} = \int_N^{N+P_{mb}} p(x)dx + F_{ab}\, p(N + P_{mb})(dP_{mb}/dF_{ab}) + F_{ma}\, p(N + P_{mb})(dP_{mb}/dF_{ab}) \qquad (8)$$

The conditions under which such revenues do not decrease as a result of a fare decrease may be obtained by setting

$$dR/dF_{ab} \leq 0 \qquad (9)$$

or

$$+F_{ab}\, p(N + P_{mb})(dP_{mb}/dF_{ab}) + F_{ma}\, p(N + P_{mb})(dP_{mb}/dF_{ab}) + \int_N^{N+P_{mb}} p(x)dx \leq 0 \qquad (10)$$

$$F_{ab}\, p(N + P_{mb})(dP_{mb}/dF_{ab}) + F_{ma}\, p(N + P_{mb})(dP_{mb}/dF_{ab}) \leq -\int_N^{N+P_{mb}} p(x)dx \leq 0 \qquad (11)$$

$$dP_{mb}/dF_{ab} \leq -\int_N^{N+P_{mb}} p(x)dx \Big/ [F_{ab}\, p(N + P_{mb}) + F_{ma}\, p(N + P_{mb})] \qquad (12)$$

$$dP_{mb}F_{ab}/dF_{ab}P_{mb} \leq (-F_{ab}/F_{ab} + F_{ma}) \times \left[\int_N^{N+P_{mb}} p(x)dx \Big/ P_{mb}\, p(N + P_{mb})\right] \qquad (13)$$

$$E \leq -F_{ab}/(F_{ab} + F_{ma})\left[\int_N^{N+P_{mb}} p(x)dx \Big/ P_{mb}\, p(N + P_{mb})\right] \qquad (14)$$

This expression is similar to that derived previously except for the term in brackets on the right, which the simplifying assumptions used earlier defined as equal to unity. This term is the ratio of the average probability that the short-haul connecting passenger will not displace a local long-haul passenger to that probability for the last short-haul connecting passenger. Given that the probability that a flight with an average of x passengers will have at least one empty seat [p(x)] declines as x increases, the term in parentheses should be greater than one, which would imply that market elasticities must be somewhat higher than previously suggested, all other things being equal, to compensate for long-haul fare reductions.

The simplified condition of elasticity is

$$E \leq -F_1/(F_2 + F_{ma}) \qquad (15)$$

where

E = Macon-Baltimore price elasticity,
F_1 = initial fare, and
F_2 = deregulated fare.

By setting $F_1 = F_2$ one can determine the point elasticity required for revenues allocated to the short haul to increase or remain the same. For example, if the short-haul fare is 25 percent of the long-haul fare,

$$E \leq -F/(F + 0.25F) \qquad (16)$$

or $E \leq -0.8$. Any market that has an elasticity of -0.8 or less will observe an increase in revenue allocated to the short haul for a unit reduction in the long-haul fare. Conversely, for any market having elasticity greater than 0.8, revenues allocated to short-haul service will decline. Alternatively, if the elasticity is -1, allocated revenues will increase regardless of how small the short-haul fare is relative to the long haul:

$$-1 \leq -F/(F + F_{ma}) \qquad (17)$$

$$-F - F_{ma} \leq -F \qquad (18)$$

$$F_{ma} \geq 0 \qquad (19)$$

Any assumption that such allocated revenues will decline in the price and entry competition could only be justified in relation to specific empirical or a priori hypotheses concerning specific market conditions. In particular, to suggest a reduction in revenues allocated to short levels, one must specifically assume a decline in long-haul fare levels plus low price elasticity of demand. In intrastate markets, low fares have coincided with high price elasticity.

SUMMARY AND CONCLUSIONS

This analysis has considered smaller air service points whose profitability to a carrier might be marginal or nearly marginal even with allocated intermarket revenues. It has been implicitly assumed that such markets would support only one carrier. (Macon is in fact served by two federally certificated carriers, Delta and Eastern, which between them fly several daily flights.) For larger points—small or medium hubs—the principle of intermarket relations remains the same but the profits accruing from traffic to beyond areas lead carriers to compete for these revenues. It is thus conceivable that a medium hub providing a great deal of feed traffic might receive extensive service even though many of the segments served from that hub do not directly generate enough revenue to cover fully allocated accounting costs.

The clear result of current pricing strategy in the competition for feeder traffic is the existence of joint fares and common-point fares. The reason for these pricing practices is, of course, to encourage feeder traffic from short-haul markets to long-haul markets.

As a result of the analysis we have concluded that

1. Determining whether or not economic cross subsidization exists between or among one or a group of markets and one or another group of markets is more an issue of revenue allocation between and among the respective markets than it is an issue of allocation costs;
2. The economic threshold where cross subsidization begins in a particular market is as much related to the definition of the product as it is to the definition or allocation of accounting costs;
3. The domestic airline business is somewhat unique in that profits from hub-to-hub service in large-volume markets are partly a function of service from the origins and destinations to smaller hubs in beyond areas (the telecommunications industry is conceptually similar);
4. Current joint fares and common fares, both of which reduce the costs of on-line connecting and interline connecting passengers traveling from smaller points over large hub-to-hub service, provide ample evidence of the value in larger markets of the passenger revenue that is a function of service to smaller points; and
5. On-line and interline connecting passengers clearly are highly valued under the current conditions of limited competition and intensive regulation; the value of these passengers will undoubtdely increase conditions of greater competition and less economic regulation (as a result, because an even more intensive effort will be made to control the flow of connecting passengers at major hubs, extensive abandonment of smaller hubs will not occur).

ACKNOWLEDGMENT

The views expressed in this paper are ours and do not necessarily represent the official views of the U.S. Department of Transportation.

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Allocating Highway Program Costs to Washington State Highway Users

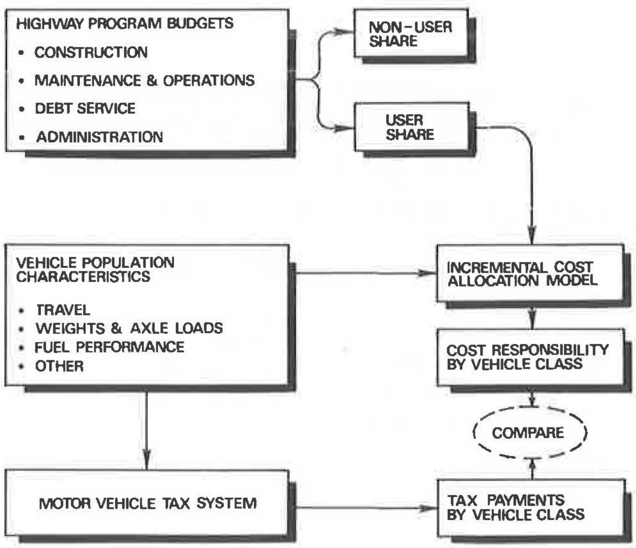
Dennis Neuzil, Transportation Development Associates, Inc., Seattle

This paper analyzes a Washington State highway cost-allocation study that determined road-user cost responsibilities for support of the state-aided highway program at both the state and local levels. The study used an incremental cost-allocation model for over 350 individual highway user subclasses correlated with vehicle type, use class, power type, and registered gross vehicle weight. Cost responsibilities for alternative funding programs were compared with user tax payments to assess equity performance. There is considerable variance among vehicle classes in the degree to which tax payments meet cost responsibility. The automobile consistently fails to meet its cost responsibility, trucks generally attain measures of equity comparable to that of the automobile, and intercity buses generate the lowest level of tax payment relative to cost responsibility. Equity performance among trucks varies with engine power type and use class; commercial-class and gasoline-powered trucks generally attain the highest equity levels. Cost responsibility for heavier vehicle subclasses varies significantly with changes in budget composition. The proportion of the budget devoted to construction—and in particular to pavement—is a prime factor. The sensitivity of the results to allocation model variations and input data is also addressed.

In the state of Washington, as throughout the nation, mounting highway construction and maintenance costs, heavier trucks, and the impact on revenue flow stemming from energy shortages and rising fuel costs have generated numerous proposals for raising existing highway user taxes and instituting new taxation devices. Equity for the various classes of highway users is one of the first considerations in assessing proposed tax changes, and appraising the equity of the existing user tax structure is a logical first step in this process. The most technically challenging task is determining, for each class of road user, its fair share of the cost of the highway program in comparison with its user tax payment.

Among the charges to the transportation tax study undertaken in Washington State was the execution of a highway cost-allocation study. The share of the state's highway development program attributable to each highway user type (or class of vehicle) was to be compared to its user tax contribution. Such a study had been conducted in Washington in the mid-1960s (1), but, in view of significant changes since that time in vehicle user characteristics and in the composition and funding process of the highway program, an update study was considered essential (2, 3, 4). Figure 1 shows the essential steps of the highway cost-allocation study.

Figure 1. Study process.



HIGHWAY PROGRAM EXPENDITURES

Allocable Costs

Highway program costs assigned to the state's highway users include only those expenditures supported by the state motor-vehicle fund. Expenditures by the state motor-vehicle fund for county and city road programs were included, but federal-aid and non-user-funded road and street support were excluded. Conversely, only state highway user taxes were included in the analysis of tax payment equity.

In Washington the user-nonuser proportions of total highway expenditures have remained relatively constant in recent years. The state-administered highway program is wholly funded by user tax funds. In contrast, only one-third of the city and county program derives overall from user taxes. The balance of the local program is funded from traditional local revenue sources; property tax revenue is the principal source.

Arguments have been made for apportioning part of the cost of the highway program to nonusers—the general public—because of the indirect public benefits of an adequate street and highway system. Various methods have been advanced for determining the user-nonuser split, but considerable disagreement exists as to their validity and relative merits. The approach described here is considered a reasonable and conservative approach to the problem.

Expenditure Elements

In Table 1, allocable expenditures for the "desirable" 4-year program budget on which the cost-responsibility re-

Table 1. 1978 to 1981 desirable program budget for highway user funds.

	Expenditure by Governmental Level ($000s)			
Agency Type and Activity	State	County and City	Total	Percentage of Total
Highway				
Construction				
Pavement and shoulders	146 530	258 070	404 600	30.8
Bridges	58 980	20 090	79 070	6.0
Grading and drainage	75 600	31 960	107 560	8.2
Other	94 730	69 050	163 780	12.5
Subtotal	375 840	379 170	755 010	57.5
Maintenance				
Pavement and shoulders	13 430	–	13 430	1.0
Other	205 900	–	205 900	15.7
Subtotal	219 330	–	219 330	16.7
Administration	90 770	–	90 770	6.9
Total	685 940	379 170	1 065 110	81.1
Nonhighway				
Puget Sound ferry system	57 450	–	57 450	4.4
State patrol				
Weigh-station operations	10 150	–	10 150	0.8
Other	129 850	–	129 850	9.9
Subtotal	140 000	–	140 000	10.7
Department of Motor Vehicles	40 000	–	40 000	3.0
Other state agencies	10 000	–	10 000	0.8
Total	247 450		247 450	18.9
Total expenditures	933 390	379 170	1 312 560	100
Annual average	233 347	94 793	328 140	

sults in this paper are based are broken down by agency, activity, and governmental level. Note that construction represents only 58 percent of the total $328 million average annual expenditure. Construction and maintenance expenditures were allocated to road users according to their use of the five functional classes of state highways and county and city arterials.

Program Budget Levels

Since mid-1974 the Washington cost-allocation study has treated eight program budgets, or funding levels, ranging from $260 million to $560 million on an annual basis. The budgets varied from the lower dollar levels of sharply scaled-back programs associated with revenue projections made soon after the energy crisis, through precrisis program levels, to the maximum level associated with the traditional needs program. Budget composition also varied in relation to distribution among highway functional classes and construction-nonconstruction sectors, as well as in assumptions concerning inflation. The budgets analyzed were 2, 4, and 6-year budgets covering the 1976 to 1981 fiscal period.

TAX PAYMENTS

Projected tax payments were produced by the computerized vehicle revenue model of the Washington State Department of Highways. A single forecast of motor-vehicle-fund tax payments, based on the energy crisis revenue forecast, was used for comparison with cost responsibilities for the treated program budgets. Of the $230 million aggregate revenue, 71 percent derives from taxes on motor fuel and the balance from motor-vehicle fees and miscellaneous revenues. Fuel tax accounts for 81 percent of the total annual user tax payment for automobiles; for trucks, fuel tax typically accounts for only about 60 percent of the total payment and most of the balance is generated by fees on gross vehicle weight. Motor-vehicle fees for trucks vary according to use class—commercial, farm, log, and miscellaneous—and power type—gasoline, diesel, and propane.

CHARACTERISTICS OF THE VEHICLE POPULATION

Comprehensive data on characteristics of the vehicle population are a basic input to the cost-allocation process. For purposes of cost allocation (and analysis of tax payments), the vehicle population consists of over 350 individual subclasses based on vehicle type (visual class), registered gross vehicle weight (GVW), use class, and engine power type. Table 2 gives a profile of the projected 1978 vehicle population by 15 basic vehicle types. A relatively small number of tax-exempt (public) vehicles are omitted from the basic cost allocation. Out-of-state trucks and buses licensed to travel in the state of Washington are converted to equivalent in-state vehicles based on the amount of their annual travel on Washington highways.

The percentage distribution of the 15 basic vehicle types and their share of total travel in the state is noteworthy, particularly for later comparisons of aggregate cost responsibility and tax payment by vehicle type. The dominance in numbers and in total travel of light vehicles—automobiles, motorcycles, and two-axle, four-tire, single-unit trucks (pickup and light panel)—is evident: Collectively they account for 96 percent of the vehicle population and 91 percent of total travel.

Trucks are licensed and taxed according to use class and power type. Ninety-two percent of the truck population falls in the commercial class, 6 percent are farm class, and the log and miscellaneous classes each compose less than 1 percent of the total truck population. Log trucks, however, make up one-third of the state's most populous heavy truck class: the five-axle tractor-semitrailer. Ninety-seven percent of the truck population is gasoline-powered but 84 percent of truck-trailers (the last three vehicle types in Table 2) are diesel-powered.

Data on vehicle operating weight and axle load are important determinants of cost responsibility. Truckload data were obtained from the 1974 and 1975 annual highway load surveys, each of which surveyed nearly 2700 trucks. The observed frequency distributions of axle loads and operating weights were input directly to the cost-allocation model; empty, part-load, and fully loaded vehicle operations were thus accounted for. Individual load profiles were used for each vehicle type classified by GVW. Because of survey limitations, truck use class was not differentiated except in the case of the heavy, log-hauling, semitrailer truck. While 32 660 kg (72 000 lb) is the regular maximum GVW, some heavy three-axle trucks and many large five-axle combination trucks are licensed to operate routinely at heavier weights under overweight permits.

METHODOLOGY

Concept of Incremental Cost

The incremental cost method used in this study is today generally considered to be the most conceptually valid method for highway cost allocation. It requires, however, an extensive data base and a rigorous analytical framework, which combine to create a somewhat formidable and time-consuming exercise.

The central thesis of this method of highway cost allocation is that each vehicle type or class of highway user shall bear the cost it occasions in the construction, maintenance, and operation of the highway system. The cost of the structural and geometric highway elements necessary to bear the load of a given vehicle and to accommodate it in the traffic stream is properly assignable to that vehicle and all other vehicles having the same requirements and is assigned on the basis of relative use.

Consider a simplified example for pavement construction requirements and associated construction cost in which uniform vehicle populations consisting of light, medium, and heavy vehicles are assumed. A minimal pavement thickness, the first increment of pavement thickness, would be adequate to carry the light loads imposed by the light vehicle class. The cost responsibility of light vehicles should therefore be restricted to a share of the cost of this first increment of thickness. Because medium and heavy vehicles also require this first thickness increment, they must also bear a share of its cost. The cost of the first increment is distributed to each of the three vehicle classes based on their proportion of total axle kilometers of travel by all vehicles. A second increment of pavement thickness is required to accommodate vehicles of medium weight; the cost of this increment is shared with the heavy vehicle class, which also requires a pavement increment thicker than the first increment required by light vehicles. The heaviest vehicle class bears the entire cost of the third or final increment of thickness, a cost that would not occur if this vehicle class were not present in the traffic stream. Total pavement cost responsibility for the heavy vehicle class is determined by adding its use-proportioned share of the first two increments to the third increment for which it is solely responsible. The incremental cost system is thus the result of a repeated redesign process that accommodates successively heavier classes of vehicles up to the vehicle class of maximum weight (axle load).

Some nonconstruction highway program costs also have an incremental nature. For example, the cost of truck weigh-station operation is properly assignable to those truck classes (essentially all dual-tired trucks) that are monitored by this operation.

Procedure

The incremental cost procedure requires examination of all major program costs to determine the portion of those cost elements, such as pavement and bridge construction, that are dictated by specific motor-vehicle characteristics such as axle load, gross operating weight, axle pattern, and vehicle geometry. Parameters must be determined for distributing these cost increments among the responsible vehicles. Axle kilometers and vehicle kilometers of travel and vehicle type and vehicle registrations, which are the typical cost-allocation parameters, were used in this study. Program costs that are basically nonincremental in nature, e.g., traffic signing, roadside maintenance, motor vehicle administration, and highway policing, are allocated equally to all vehicle classes per kilometer of travel or per registered vehicle, as appropriate.

Each vehicle type is assigned a share of the costs of individual highway systems based on its travel on those systems and its operating weight and axle-load profile, which are taken from the highway load survey. Non-system-specific costs (e.g., the vehicle licensing program) are assigned by travel rate or on a flat per-vehicle basis by cost item. Determinants of cost-allocation increments for various program costs are given in Table 3.

The incremental cost model used in this study is a synthesis of the methodology developed by the Washington State Highway Commission for the 1967 cost-allocation study (1) and methods of the U.S. Bureau of Public Roads and the Federal Highway Administration (5,6) that were developed in the early 1960s and reflect the results of the comprehensive AASHO Road Test of highway pavements and bridges. Several modifications and refinements developed by the study consultants were incorporated, and pavement cost increments were updated by the Washington State Department of Highways for use in the most recent budget runs.

The first cost increment for each program cost, which is shared equally (e.g., per kilometer or per axle kilometer of travel) by all vehicles regardless of vehicle size or weight, can be referred to as the nonweight increment or nonweight cost. Weight cost refers to all succeeding increments because these are shared only by vehicles heavier than the lightest vehicle classes (automobiles, motorcycles, and pickups). When these weight and nonweight proportions were applied to the program cost elements, it was found that, depending on program budget, nonweight costs make up 80 to 85 percent of total program costs. Heavy vehicles alone were thus assigned the 15 to 20 percent weight portion of total program cost, as well as a share of the nonweight portion. However, the relatively small number of such vehicles, combined with their typical high travel rates, results in very high cost responsibilities for heavier vehicles as compared to most light vehicles.

RESULTS

Table 4 gives the average annual cost responsibility and tax payment per vehicle for each of the 15 basic vehicle types for the program budget given in Table 1. These are average values that afford a good overview of comparative cost responsibility and equity performance. However, detailed results for each vehicle type subclassified by GVW, power type, and use class reveal a

Table 2. Selected characteristics of 1978 vehicle population.

Vehicle Type	Vehicles		Annual Travel in State	
	Number	Percent	Percentage of Total	Kilometers per Vehicle
Automobile	2 072 548	70.88	76.63	15 800
Taxi	1 244	0.04	0.47	160 500
Public bus (intercity type)				
2-axle	734	0.03	0.19	113 900
3-axle	50	—	0.02	134 100
Private bus	4 501	0.15	0.13	12 500
Motorcycle	152 592	5.22	2.47	6 900
Single-unit truck				
2-axle, 4-tire	578 107	19.77	11.72	8 700
2-axle, 6-tire	87 274	2.98	3.84	18 800
3-axle	7 590	0.26	1.07	60 200
Tractor-semitrailer				
3-axle	2 564	0.09	0.24	39 600
4-axle	2 338	0.08	0.21	39 300
5-axle	10 499	0.36	2.04	82 900
Truck-trailer				
4-axle	144	0.01	0.04	111 700
5-axle	1 951	0.07	0.53	115 600
Tractor train	1 722	0.06	0.40	99 100
Total	2 923 858	100	100	

Note: 1 km = 0.62 mile.

Table 3. Incremental cost allocation for various program costs.

Expenditure	Increment Determinant	Number of Increments	Cost in First Increment (%)	Allocation Parameter
Construction				
Pavement and shoulders	Observed axle load	9 to 11[a]	32 to 52[a]	Axle kilometers
Bridges	Observed gross operating weight	17	86	Vehicle kilometers
Grading and drainage	Observed gross operating weight	2	91	Vehicle kilometers
Other	Nonincremental	1	100	Vehicle kilometers
Maintenance				
Pavement and shoulders	Observed axle load	9 to 11[a]	32 to 52[a]	Axle kilometers
Other	Nonincremental	1	100	Vehicle kilometers
Department of Highways, other	Nonincremental	1	100	Vehicle kilometers
Debt service	Incremental[b]			
State ferry system	Vehicle type	2	95	Vehicle registrations
State patrol				
Weigh-station operations	Trucks with dual tires	1	100	Vehicle kilometers
Other	Nonincremental	1	100	Vehicle kilometers
Department of Motor Vehicles				
Fuel tax administration	Power type	—	—	Vehicle kilometers
Other	Nonincremental	1	100	Vehicle registrations
Other state agencies	Nonincremental	1	100	Vehicle kilometers

[a] Varies with highway class. [b] The majority of debt service is for highway construction and is allocated accordingly.

fairly wide range of values about the averages presented here; those results are discussed later in this paper.

Light vehicles are seen to have annual cost responsibilities ranging from $31 for motorcycles to $94 for automobiles. An exception is the taxi: Its high cost responsibility stems from a high annual travel rate, nearly 10 times that of the private automobile. Medium-weight trucks show cost responsibilities of $400 to $1200, and cost responsibilities for heavy five-axle trucks range from $2800 to $4500, or 30 to 50 times that of the automobile. Public buses of the intercity type, with their relatively high average axle loads and high annual travel rates, have cost responsibilities comparable to the heaviest trucks; the annual cost responsibility of the large three-axle public bus is $4800, more than that of any other vehicle type. These annual cost responsibilities translate to unit travel cost responsibilities ranging from about 0.6 cents/km (1 cent/mile) for light vehicles, 1.2 to 2.5 cents/km (2 to 4 cents/mile) for medium-weight vehicles, and 2.5 to 3.7 cents/km (4 to 6 cents/mile) for the heaviest vehicles.

Table 4 also shows annual user tax payments for the basic vehicle types. Ratios of heavy-vehicle tax payments to automobile tax payments are somewhat less than cost-responsibility ratios; tax-payment ratios for the heaviest vehicles range from 20 to 30 times those of the automobile.

Table 4. Annual per-vehicle cost responsibility and tax payment by vehicle type.

Vehicle Type	Annual Cost Responsibility per Vehicle ($)	Annual Tax Payment per Vehicle ($)	Cost Less Tax ($)	Tax/Cost Ratio ($)
Automobile	94	64	30	0.68
Taxi	531	909	378	1.71
Public bus (intercity type)				
2-axle	2200	706	1494	0.32
3-axle	4798	1283	3515	0.27
Private bus	85	81	4	0.95
Motorcycle	31	18	13	0.58
Single-unit truck				
2-axle, 4-tire	69	63	6	0.91
2-axle, 6-tire	344	212	132	0.62
3-axle	901	846	55	0.94
Tractor-semitrailer				
3-axle	1172	695	478	0.59
4-axle	1095	875	221	0.80
5-axle	2805	1862	943	0.66
Truck-trailer				
4-axle	3016	1725	1291	0.57
5-axle	4467	2083	2381	0.47
Tractor train	2927	1898	1029	0.65

Cost Responsibilities Versus Tax Payments

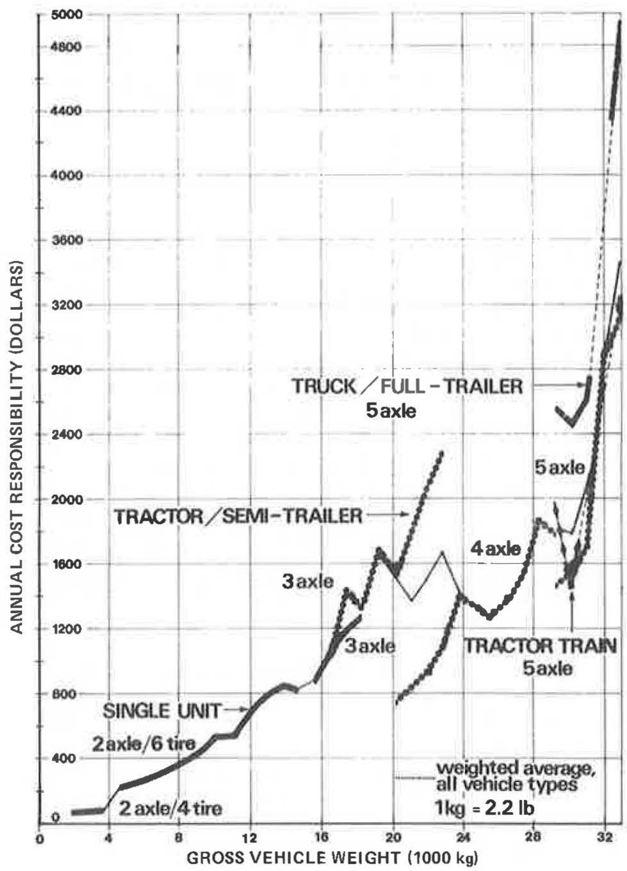
Evaluating the equity of the tax structure for motor-vehicle users requires a comparison of user tax payments to cost responsibilities. The difference between tax payment and cost responsibility, and particularly the ratio of tax payment to cost responsibility, are of concern here. The tax/cost ratio provides the single best measure for equity comparisons among various users. The dollar difference scales the potential financial impact on the individual user if the tax system were to be altered to eliminate or reduce inequities (Table 4). The $64 annual automobile tax payment falls $30 short of its annual cost responsibility, which is $94. Medium truck classes have tax-payment shortfalls of $100 to $500, and tax payments for heavy trucks fall $1000 to $2400 short of their assigned costs. Heavy intercity buses fail to meet cost responsibilities by as much as $3500/year. Only the taxi shows a tax overpayment—nearly $400 in excess of its annual cost responsibility. The prevalence of tax-payment shortfalls partly results from the fact that the subject program budget ($328 million) exceeds total revenue ($230 million) by $98 million/year. Tax/cost ratios given in Table 4 show that the automobile tax payment covers only 68 percent of the automobile cost responsibility for this program budget but tax payments for trucks range from 50 percent to over 90 percent of their cost responsibilities.

In Table 5, cost responsibilities and tax payments are aggregated by vehicle class and the difference between them is given. The percentage distributions of cost and tax payment relative to total program cost and total tax revenue respectively are also given. Thus, Table 4 gives a tax payment per automobile that is $30 less than cost responsibility, and Table 5 translates this to a $61 million shortfall by vehicle class (roughly 2 million automobiles times a shortfall of $30/vehicle). Per-vehicle tax shortfalls for heavy truck classes amount to an aggre-

Table 5. Aggregate annual cost responsibility and tax payment by vehicle class.

Vehicle Class	Annual Cost Responsibility		Annual Tax Payment		Cost Less Tax ($000s)
	Amount ($000s)	Percentage of Total Program Cost	Amount ($000s)	Percentage of Total Tax Payment	
Automobile	193 828	59.07	132 643	57.68	61 185
Taxi	661	0.20	1 131	0.49	470
Public bus (intercity type)					
2-axle	964	0.29	309	0.13	655
3-axle	1 655	0.50	443	0.19	1 212
Private bus	383	0.11	365	0.16	18
Motorcycle	4 784	1.46	2 747	1.19	2 037
Single-unit truck					
2-axle, 4-tire	39 787	12.12	36 430	15.84	3 357
2-axle, 6-tire	30 029	9.15	18 503	8.05	11 526
3-axle	6 837	2.08	6 418	2.79	419
Tractor-semitrailer					
3-axle	3 006	0.92	1 782	0.77	1 224
4-axle	2 560	0.78	2 046	0.89	514
5-axle	29 459	8.98	19 554	8.50	9 905
Truck-trailer					
4-axle	434	0.13	248	0.11	186
5-axle	8 715	2.65	4 064	1.77	4 651
Tractor train	5 040	1.54	3 269	1.42	1 771
Total	328 142	100	229 952	100	98 190

Figure 2. Annual cost responsibility versus registered gross vehicle weight for commercial diesel-powered trucks.



gate shortfall of $2 million to $10 million, depending on class, in spite of the small population of these trucks.

Table 5 underscores the fact that even fairly substantial tax-payment increases among selected vehicle types will not bring tax revenues into balance with the projected program budget unless the more populous vehicle classes are involved. Four of the 15 basic vehicle types—the automobile; the two-axle, four-tire truck; the two-axle, six-tire truck; and the five-axle tractor-semitrailer—in the aggregate account for 90 percent of both program cost responsibility and revenue and 94 percent of the vehicle population (Table 2).

The findings in Table 5 and the vehicle population characteristics given in Table 2 provide insight into relationships among vehicle population and use, cost responsibility, and tax revenue. Although the automobile represents over 71 percent of the total vehicle population and 71 percent of total statewide travel, it is assigned only 59 percent of total program cost and generates only 58 percent of total user tax revenue. In contrast, the popular five-axle tractor-semitrailer collectively accounts for only 0.4 percent of the vehicle population and 2 percent of systemwide travel but 9 percent of program cost and 8.5 percent of total user tax revenue.

Effects of Vehicle Subclass Characteristics

The analysis of 15 vehicle classes presented above provides an overall assessment; the following analysis reviews the results for a number of common vehicle subclasses, alternatively holding constant variables such as use class and power type to reveal the effect of these factors on cost responsibility and equity.

Table 6. Annual cost responsibility and tax payment for three truck classes and combinations of vehicle type, power type, and gross vehicle weight.

Truck Class and Type	GVW (kg)	Engine Power Type	Annual Cost Responsibility ($)	Annual Tax Payment ($)	Cost Less Tax ($)	Tax/Cost Ratio (¢)
Commercial						
Single-unit						
2-axle, 6-tire	12 700	Gasoline	660	390	270	0.59
		Diesel	790	410	380	0.52
3-axle	18 145	Gasoline	1050	1070	20	1.02
		Diesel	1250	1030	220	0.82
Combination						
5-axle tractor-semitrailer	32 660	Gasoline	2270	2480	210	1.09
		Diesel	3120	2130	290	0.68
5-axle truck-full trailer	32 660	Gasoline	3630	2570	1060	0.71
		Diesel	4950	2200	2750	0.44
Farm						
Single-unit						
2-axle, 6-tire	12 700	Gasoline	440	240	200	0.55
		Diesel	610	280	300	0.46
3-axle	18 145	Gasoline	630	540	90	0.86
		Diesel	1030	640	390	0.62
Combination						
5-axle tractor-semitrailer	32 660	Gasoline	1070	1140	70	1.07
		Diesel	2190	1250	940	0.57
5-axle truck-full trailer	32 660	Gasoline	—	—		
		Diesel	3480	1310	2170	0.38
Log						
Single-unit						
2-axle, 6-tire	12 700	Gasoline	500	330	170	0.66
		Diesel	570	340	230	0.60
3-axle	18 145	Gasoline	700	710	10	1.01
		Diesel	910	730	180	0.80
Combination						
5-axle tractor-semitrailer	32 660[a]	Gasoline	625	1230	605	1.97
		Diesel	2640	1500	1140	0.57
5-axle truck-full trailer	32 660	Gasoline	—	—	—	
		Diesel	—	—	—	

Note: 1 kg = 2.2 lb.

[a]Nominal GVW for a log vehicle is 30 845 kg, but allowable operating weight with overload tolerance is 33 930 kg.

Table 7. Annual cost responsibility of selected vehicle types for various program costs.

Cost	Automobile		Single-Unit, 2-Axle, 12 700-kg Truck		Tractor-Semitrailer Truck: 3-Axle, 20 865-kg		Tractor-Semitrailer Truck: 5-Axle, 32 660-kg	
	Amount ($)	Percentage of Total	Amount ($)	Percentage of Total	Amount ($)	Percentage of Total	Amount ($)	Percentage of Total
Construction								
Pavement	15.43	16.6	478.52	75.2	1 007.03	75.3	1 806.25	60.1
Grading and drainage	8.98	9.6	29.10	4.6	53.22	4.0	152.44	5.1
Bridges	6.08	6.5	18.75	2.9	43.05	3.2	244.69	8.1
Other	15.03	16.0	24.97	3.9	40.47	3.0	103.12	3.4
Subtotal	45.52	48.7	551.34	86.6	1 143.77	85.5	2 306.50	76.7
Maintenance								
Pavement and shoulders	0.52	0.5	7.63	1.2	20.81	1.5	93.19	3.1
Other	18.69	20.0	24.38	3.8	54.25	4.1	201.88	6.7
Subtotal	19.21	20.5	32.01	5.0	75.06	5.6	295.07	9.8
Total	64.73	69.3	583.36	91.7	1 218.84	91.2	2 601.58	86.6
State ferry system	4.93	5.3	11.18	1.7	11.18	0.8	11.18	0.4
Highway administraion plus state patrol	20.81	22.3	26.71	4.2	71.59	5.4	267.12	8.9
Weigh-station operations	0	0	12.17	1.9	32.61	2.4	121.78	4.0
Department of Motor Vehicles[a]	2.94	3.1	2.94	0.5	2.95	0.2	2.94	0.1
Total costs	93.41	100.0	636.36	100.0	1 337.18	100.0	3 004.60	100.0

Notes: 1 kg = 2.2 lb.
Weighted average values for all power types and use classes.
[a]Excludes cost of fuel tax collection (typically 1 to 4 percent of total cost responsibility).

Vehicle Type and Gross Vehicle Weight

Figure 2 shows the relation for trucks among annual cost responsibility, registered gross vehicle weight, and vehicle type as demonstrated by the commercial-class, diesel-powered truck. For most individual truck types, annual cost responsibilities are seen to approximately double between low and high points of the GVW range. Note that, in instances where several truck types fall within the same GVW interval, sizeable errors would occur if cost allocations were made solely on the basis of GVW without consideration of vehicle type (this is true of the current Washington State GVW fee schedule). Weighted average cost responsibility based solely on GVW is shown in Figure 2 as a light dashed curve. Cost responsibilities vary, in some instances, from $200 to $600 or more above or below the average and reach a peak in the case of the 32 660-kg (72 000-lb), five-axle truck-full trailer, which has a $5000 cost responsibility in contrast to the $3400 weighted average value for all vehicles of 32 660-kg GVW.

Use Class

Variations in cost responsibility and tax payment among truck use classes are given in Table 6 for some of the most common combinations of vehicle type, power type, and GVW. A detailed examination of the results for all truck subclasses indicates that commercial-class trucks generally have the highest cost responsibilities and tax payments, owing to high travel rates, and typically most closely approach equity in terms of the ratio of tax payment to cost responsibility.

Power Type

The general effect of power type on cost responsibility and tax payment can be seen in Table 6. Cost responsibilities for commercial diesel-powered trucks are typically about 20 percent greater than those for gasoline-powered trucks, except in the case of trucks of 32 660-kg (72 000-lb) GVW. At that weight annual diesel travel rates rise more steeply than gasoline travel rates and diesel cost responsibilities are typically 40 percent greater than gasoline cost responsibilities. Cost responsibilities and tax payments for propane-powered trucks, which are not included in the table, are generally comparable to those for gasoline-powered trucks.

Annual tax payments for most commercial gasoline-powered trucks are seen to be about 5 to 15 percent greater than those for the same type and class of diesel-powered truck; the higher percentage for the heaviest trucks represents a difference of over $300. Although the diesel truck typically travels more kilometers per year, it often achieves 50 percent more kilometers per liter than the counterpart gasoline vehicle, which results in a lower annual tax payment. In the categories of cost less tax and tax/cost ratio, gasoline-powered vehicles overall generally come closer to ideal equity than do diesel-powered trucks.

Cost Responsibility for Selected Vehicle Types

To gain a better understanding of the effect on cost responsibility of the composition of the highway program and the incremental cost system, an analysis was made of the contribution of individual program costs such as pavement construction, grading and drainage, and state patrol to the overall cost responsibility for selected vehicles representative of some of the most important vehicle classes. This analysis indicates that overall cost responsibility for heavier vehicles is highly sensitive to the cost composition of the program, particularly in terms of the emphasis on pavement construction and reconstruction.

In Table 7 construction cost accounts for a much higher share of the total cost responsibility for trucks (75 to 85 percent) than for automobiles (49 percent). The relative importance of pavement construction is evident. Although pavement construction constitutes 31 percent of total program cost (Table 1), it accounts for 60 to 75 percent of the total cost responsibility for trucks but only 17 percent for the automobile. Thus, modifying incremental cost factors for pavement construction could substantially affect cost responsibility for heavier vehicles.

Sensitivity Aspects

Sensitivity analyses indicated that variations in treatment of incremental cost factors and errors or biased sampling in vehicle population characteristics (such as travel rates, the relative amount of travel on the various highway classes, and load characteristics) as well as changes in program budget composition can significantly alter the results of cost allocation. Many of these variations, particularly those dealing with cost increments, have as their principal effect a redistribution of cost responsibility among medium and heavy trucks and buses rather than between trucks and light vehicles.

In one test the percentage of cost for the first increment (that shared by all vehicles) of all construction elements was arbitrarily reduced 50 percent and reassigned to the remaining higher weight increments—those supported solely by trucks and buses. This reduced the annual cost responsibilities for automobiles and pickups by only about $10. In contrast, heavy-truck cost responsibilities were increased by $500 to $1000 depending on truck type.

An examination was made of the sensitivity of cost responsibility to rather small changes in program budget composition. In this analysis budget dollar level was held constant. Construction expenditures for the desirable budget were reduced 2.5 percent for pavement, 1.1 percent for structures, and 0.1 percent for all other construction elements, for a total change of 3.7 percent. Cost responsibilities for light vehicles remained virtually the same. Cost responsibilities for heavy trucks and buses declined by 5 to 15 percent (by $200 to $500/vehicle depending on vehicle type).

Increment Cost Factors for Pavement Construction

Although current truck axle-load data have been used in the allocation of pavement costs in the Washington State study, the initial study phases used increment cost factors for pavement construction (expressed as percent of total pavement cost) developed in the mid-1960s. In the most recent study phase these increment factors were updated to account for shifts in truck population, axle loads, and travel rates.

Two alternative updates for pavement increment factors were developed by the Washington State Department of Highways. The alternative cases differ only in the way in which higher axle loads are suppressed in determining the percentage cost savings (increment factors) that would occur as progressively lower axle loads are eliminated from the pavement design. In case 1 the suppressed axle-load repetitions were proportionally assigned to all lower load (increment) levels. In case 2 the suppressed axle-load repetitions were entirely assigned to the next lower load level. The latter method is referred to as the federal procedure (3) and was used in developing the pavement increment factors for the 1967 study. Both update cases also used a finer gradation of load intervals—910 kg (2000 lb) for single-axle increments rather than 1360 to 2270 kg (3000 to 5000 lb) as in the 1967 study. This yielded 9 to 11 pavement increments, depending on highway class, compared to 6 increments in the 1967 study.

Three cost-allocation model runs for total cost responsibility were performed: the two update cases as well as the 1967 case. In all three runs the same current axle-load profiles and projected travel rates were used in the cost-allocation model. In general, case 2 (the federal method) produced cost responsibilities comparable to those obtained with the 1967 increment factors; case 1 yielded cost responsibilities $200 to $500 more for the heaviest vehicles, although these dollar differences generally represent differences of 10 percent or less in total annual cost responsibility. Automobile cost responsibility was almost identical in all three model runs. The differences among the three cases were even further reduced when they were translated into measures of equity performance by use of the tax/cost ratio. The alternative sets of pavement increment factors did not appear to significantly alter comparative equity among the various vehicle types for the particular factors of program budget and vehicle population that characterize the Washington State situation.

CONCLUSIONS

The findings of the Washington State cost-allocation study are obviously conditioned by the particular characteristics of Washington's vehicle population, the composition and dollar level of the budgets analyzed, the state's user tax structure, and the particular features of the incremental cost treatments of the cost-allocation model. Differences in highway user equity among vehicle types were observed among the alternative budgets analyzed. In general, however, the following results tended to hold true throughout all phases of the study.

1. Non-weight-related expenditures dominate total program cost.
2. The automobile fails to meet its cost responsibility.
3. Most truck classes attain equity levels comparable to those of the automobile.
4. Intercity buses grossly fail to meet cost responsibilities, and taxis heavily overpay user taxes.
5. In addition to registered gross vehicle weight, truck type is a significant variable.
6. Trucks of the commercial use class and gasoline- and propane-powered trucks have the highest overall equity performance.
7. Cost responsibility for heavy vehicles is extremely sensitive to program budget composition, particularly to the percent of the budget earmarked for pavement construction and reconstruction.
8. Alternative updates of pavement increment cost factors had only a minor impact on cost responsibility and equity performance.

It should be emphasized again that these findings are based only on expenditures by the state motor-vehicle fund and on tax payments. Federal and local funding and taxes are not included.

ACKNOWLEDGMENTS

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Improving Ferry Service Across Long Island Sound

Michael R. Cohen, * Sikorsky Aircraft, Stratford, Connecticut

A study of vehicle-carrying ferry service across Long Island Sound is described. The purposes of the study were (a) to consider a wide range of possible services; (b) to explore and evaluate the economic performance, environmental impacts, and economic development impacts of these services; and (c) to combine the various measures of performance into an overall measure of feasibility that could be used as a basis for making recommendations. Five types of vessels were earmarked for study, from small, conventional-displacement vessels to high-speed hovercraft. A range of volumes and several possible crossing sites were chosen. A relatively simple economic model was constructed that used as input cost and performance data for ferry vessels, crossing distances and limitations on harbor speed, site-specific terminal cost estimates, and projections of fare versus the volume of vehicles carried at each site. A computer program written for this model was run for a wide range of vehicle volumes, crossings, and vessel types. Detailed studies were made of environmental impacts and the feasibility of terminal locations for services that performed well economically. The study concludes that high-technology vessels are not economically viable for vehicle-carrying service across the Sound and recommends near-term improvements to existing services that would lead to greatly expanded services over the long term.

Travel between Long Island and New England must currently take either a long, circular route passing over congested highways and bridges in New York City or one of two relatively high-cost ferry routes, one of which operates in the summer only. A bridge study conducted in 1971 (1) was part of an early attempt to improve travel between Long Island and the mainland. The study evaluated several potential bridges at various sites on the Sound. A bridge between Rye and Oyster Bay was proposed but met with strong public opposition and was subsequently abandoned. The proposed bridges east of the Rye-Oyster Bay Bridge were ruled out from the start because their tolls would not be able to cover their costs. The New York and Connecticut Departments of Transportation then decided to consider ways of improving ferry routes and services.

This paper describes the methodology and results of a study of ferry service across Long Island Sound performed by the Tri-State Regional Planning Commission for the New York and Connecticut Departments of Transportation (2). The purpose of the study was to examine a variety of potential ferry routes and determine the costs and benefits of each route. This involved a careful analysis of ferry vessels, terminals, sites, and a range of volumes of vehicles and passengers as well as an evaluation of the impact that such a ferry service would have on the environment and on local development. The results were then combined to formulate a set of recommendations.

SERVICE CHOICES AND IMPACTS

The basic choices that must be made in setting up a ferry service and the major impacts of these choices are summarized in the following table.

Choices	Impacts
Vessels	Economic
Speed	Capital cost
Vehicle capacity	Operating cost
Turnaround time	Fare revenues
Length	Deficits
Draft	Developmental
Operating cost	Employment
Terminal sites	Population
Crossing distance	Environmental
Harbor cruise	Ferry traffic on local roads
Water depths	Terminal construction and operation
Site location	Vehicle emissions
Size of service	Energy use
Annual volume	
Peak-day volume	
Load factor	
Crossing time	
Vessels required	
Vessel hours	
Vessel berths	
Headway	

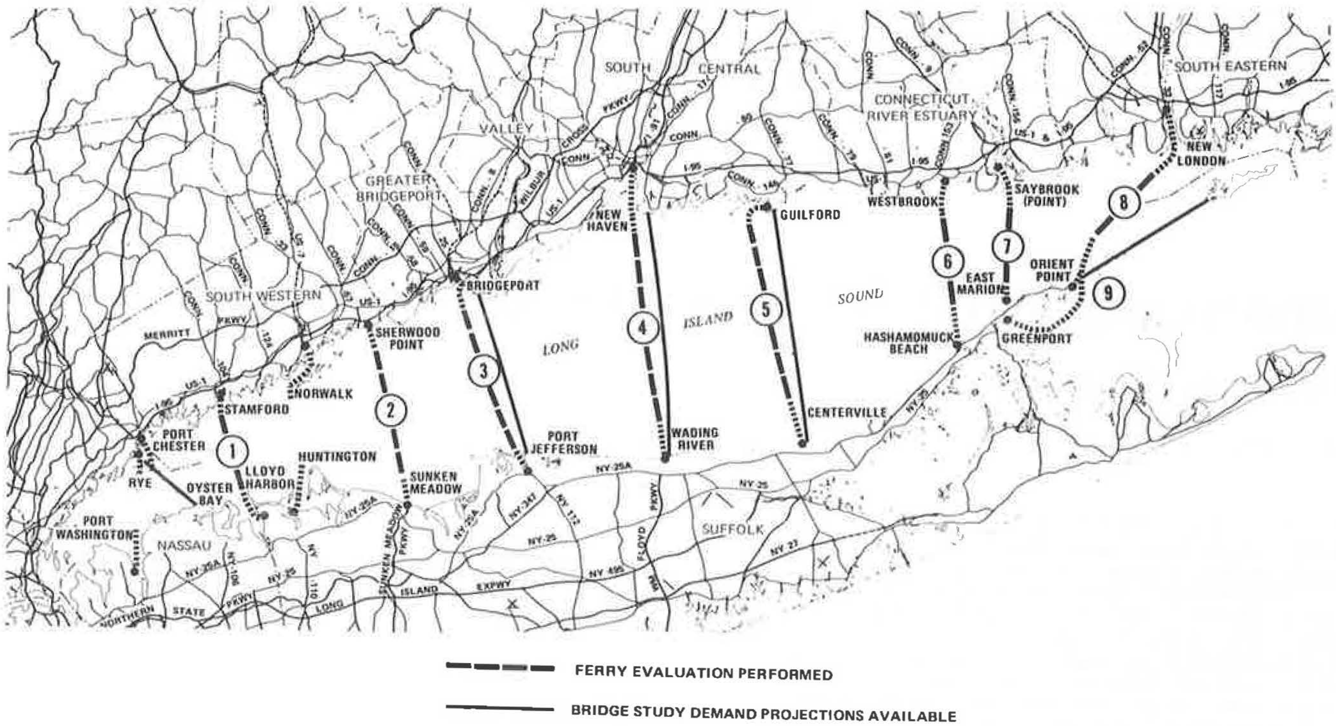
Each of the basic choices (vessels, terminal sites, and size of service) is critical in determining the economic and environmental consequences of a ferry service.

Vessels

The types of vessels studied were

1. The conventional displacement vessel, which has low capital and operating costs as well as relatively low speeds and high capacities. Four vessel types were studied, including 200-vehicle, 100-vehicle, 100-vehicle used (converted from steam to diesel power), and 50-vehicle "T-boat" (designed to operate with a smaller crew).
2. The amphibious hovercraft, which floats on a cushion of air. This feature gives the vessel high speed and allows it to land directly on shore. Capital and operating costs (especially for fuel) are high as are noise-emission levels.
3. The rigid-sidewall surface effect ship, which floats on a bubble of air trapped between rigid sidewalls that pierce the water. Its costs and speed are less than those of hovercraft but more than those of a conventional-

Figure 1. Ferry crossing sites.



displacement vessel. Noise emissions are low. Surface effect ships that carry vehicles have not yet been produced.

Terminal Sites

Nine crossing sites were considered, from Stamford-Lloyd Harbor in the east to Greenport-New London at the western end of the Sound (Figure 1).

Size of Service

The study considered four annual service volumes (vehicles carried): 200 000, 500 000, 1 000 000, and 2 000 000 vehicles/year. If government support is involved, the ultimate decision on which type of ferry service to establish, if any, will most likely be based on (a) ferry economics (capital investment, operating costs, fare revenues and subsidies); (b) economic development impacts; (c) environmental impacts (local traffic and terminal construction and operation); (d) political and policy considerations; and (e) available funds and competing uses for these funds. This report examines only the first three of these decision criteria.

STUDY APPROACH

A relatively simple model was developed to determine the economic consequences of each ferry service as a function of vessel performance and cost, estimated capital cost of terminals and access roads, and revenue projections made at each site. The study approach consists of the following procedures.

1. Define service by vessel type, crossing site, and annual volume.
2. Determine service characteristics as a function of the related factors listed below (asuming a minimum service level of 13 h/d, 2-h headways, and a 14-h average service day):

Characteristic	Related Factors
Crossing time	Vessel speed, crossing distance, in-harbor cruise time
Peak-day volume	Annual volume
Vessels required	Peak-day volume, crossing time, turnaround time
Average annual load factor	Annual volume, minimum trips per day, vessel size
Vessel trips	Average annual load factor, annual volume
Vessel hours	Vessel trips, crossing time, turnaround time
Vessel berths	Peak-day trip frequency, turnaround time
Average headway	Annual volume, vessel size, average length of service day

3. Determine economic impacts as a function of the related factors listed below (assuming that ferry crossing time and wait time reduce revenue per vehicle by $2 to $3/h and $3/h respectively and that annual amortization rate is 8 percent):

Impact	Related Factors
Capital costs	
Vessels	Vessels required, cost per vessel
Terminals	Water depths at site, berths required
Operating costs	
Vessels	Vessel annual costs, hourly costs, hours
Terminals	Annual volume served
Revenues and subsidies	
Fare revenue	Ferry crossing time and wait time, location of crossing site, vehicles served per year
Operating subsidy	Revenue and operating cost
Annual capital cost	Total capital cost, amortization rate

4. Evaluate other impacts by considering their related factors, as follows:

Impact	Related Factors
Developmental	Ferry volume, automobile and truck savings, desirability of growth in area of crossing site

Impact	Related Factors
Environmental	
Ferry traffic	Ferry volumes, current local conditions
Terminal construction and operation	Local site conditions, pleasure boat traffic
Energy use and pollution reduction	Ferry fuel use and emissions, fuel savings and reduced emissions for automobiles and trucks
Aesthetic and other	Local conditions, ferry facilities required

5. Summarize and compare the costs and impacts of alternate services and assess their feasibility.
6. Make recommendations.

A computer program was written for this model and run for many combinations of crossing site, vessel type, and service size. Detailed studies were then made for the most attractive services.

FINDINGS

Revenue Projections

The factors considered in predicting fares were current zone-to-zone travel (on existing bridges), time and distance saved on each ferry route, ferry fares, and existing ferry patronage. The volume of business at each ferry site is increased by reducing fares, increasing ferry speeds, or providing more frequent service. As might be expected, projected demand for ferry service at crossings farther east of the competing bridges was less elastic. The eastern crossings could charge the highest fares at low volumes, but to increase business they would have to make greater cuts in their fares than ferry services farther west.

Peaking of ferry demand also has far-reaching consequences on the economics of ferry service. The peak-day demand determines the size of the fleet required, and the greatly reduced demand at other times means that vessels lie idle or operate at far below their full capacity. It is expected that, as the size of a ferry service increases, demand will shift away from highly peaked summer vacation travel to more business and commercial travel and the peaking problem will become less severe.

Costs

The basic costs of providing ferry service are those for vessel operation—including crew, fuel, and maintenance—and terminal operation and maintenance. Vessel operating and capital costs were determined for each site and volume of service based on the cost and performance data given in Table 1. Terminal operating and maintenance costs were estimated based on recent experience on the Cape May-Lewes Ferry Service. A consultant was employed to determine the feasibility of terminals at certain locations, to develop a design concept, and to make preliminary estimates of terminal costs and environmental impacts.

An analysis of the costs of a typical service (New London-Orient Point) is shown in Figure 2. Costs and benefits for this service are itemized in the following table (assuming service volume of 200 000 vehicles/year, T-boat vessels of 50-vehicle capacity, and an annual amortization rate of 10 percent).

Item	Amount
Vessels required	5
Capital costs ($000 000s)	
Vessels	6.9
Terminals	0
Total	6.9
Annual costs ($000s)	
Amortization	688
Operating costs	1643
Total	2331
Annual benefits ($000s)	
Fare revenue	2706
Consumer surplus	474
Total	3180
Projected annual profit ($000s)	375

The benefit/cost ratio for the New London-Orient Point service (total annual benefits divided by total annual costs) is 1.36. Funds for terminals for this service are already committed by the operator and New York State. Consumer surplus, which represents the value to ferry users of their time and travel savings in addition to the fares paid, is discussed in more detail later in this paper. The total cost is about half amortization and half operating. Crossing distance is critical in determining the cost of providing service because both vessel operating costs and the number of vessels required on a given service will vary directly with the time it takes to make a round trip.

Impacts

Development

Any new transportation facility will have an impact on the area it serves. The degree of the impact increases with the number of people served by the facility and the amount of time, kilometers, and money saved by using the new facility. Businesses may expand and hire new workers because of the reduced time and cost of shipping and receiving goods. Individuals may move in to fill new jobs or may relocate because the area is now more accessible to jobs elsewhere. Development can also occur in the form of restaurants, shops, and hotels to serve travelers who use the facility.

Compared to a bridge, a ferry is a low-capital, high-operating-cost facility economically suited to carrying small volumes at relatively high tolls. Beyond a certain volume ferry fares must be lowered to a point where they do not cover the operating costs of additional service. Thus a ferry service will probably be a comparatively low-volume, high-fare facility, which will limit its impact on development.

One way to estimate the size of ferry-service impacts on development is to evaluate the consumer surplus. In economic terms, consumer surplus is the total amount of additional revenue that could be generated by charging the maximum fare that each patron would be willing to pay to use the service and is a measure of the benefits received by users of the service beyond what they pay in fares. Consumer surplus is shown in Figure 3 as the shaded area above the demand curves. Although both facilities can charge the same fare at volume V, facility B has a larger consumer surplus and its users would derive more benefits.

Environment

The aspects of ferry service that would affect the environment are terminal construction, vessel operation, and ferry traffic on local and regional roads.

Terminal Construction

The environmental impact of the construction of a ferry terminal depends on the site, the terminal design, and the construction methods used. Breakwaters and dredging, especially in an area such as the North Shore of Long Island, could block the flow of sediments, change the currents along the shore, and lead to shoaling and erosion of beaches. It was determined, however, that protective breakwaters would not be required; an open-pile pier leading out to deep water would virtually eliminate beach erosion.

Ferry Vessel Operations

The operation of ferry vessels could interfere with local pleasure boating. If ferry docking facilities were located in an estuary or near wetlands, the propeller wash could cause the accumulation of sediment, which would be harmful to shellfish and other forms of marine life.

Table 1. Cost and performance of ferry vessels.

Type of Vessel	Capacity (automobiles)	Length (m)	Draft (m)	Cruising Speed (km/h)	Capital Cost ($000s)	Annual Cost ($000s)	Cost per Hour Under Way[a] ($)	Cost per Operating Hour[a] ($)	Turnaround Time (min)
100-vehicle displacement	100	97.2	3.0	31.5	7 480	160	80	120	25
200-vehicle displacement (double ended)	200	134.1	5.5	37.1	15 200	308	213	185	20
Surface effect ship	40	67.1	1.5	74.1	10 700	316	540	135	20
Hovercraft (SRN4)	30	39.6	0	111.2	15 400	434	530	170	20
Used steam (diesel conversion)	100	111.9	3.2	25.9	1 500	160	80	120	30
50-vehicle T-boat	50	66.1	2.4	27.8	1 375	38	31	64	20

Note: 1 m = 3.3 ft; 1 km = 0.6 mile.

[a]Annual operating cost = annual cost x number of vessels + cost per hour under way x hours under way + cost per operating hour x operating hours.

Figure 2. Cost analysis for New London-Orient Point service.

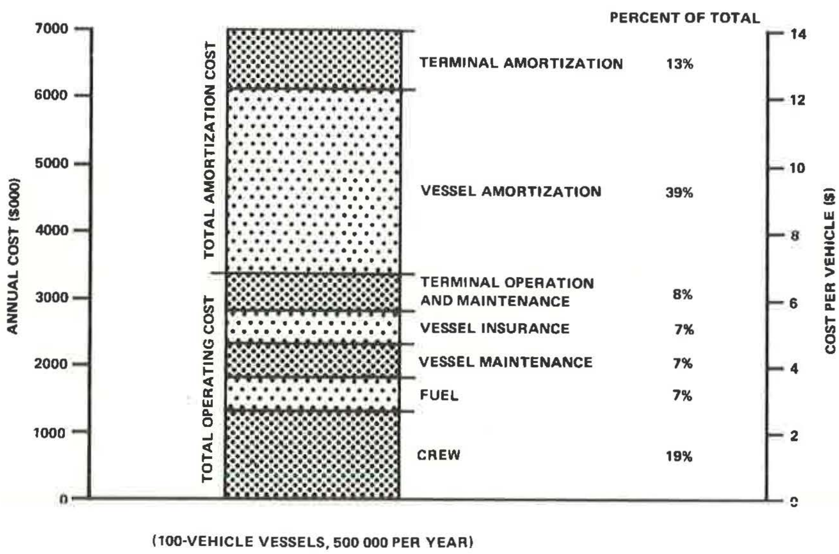
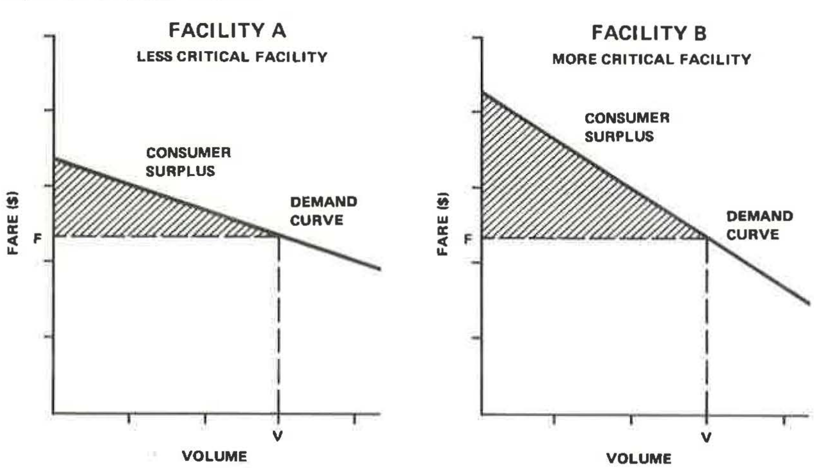


Figure 3. Consumer surplus.



This could be a factor at the Bridgeport-Fayerweather Island site and in East Marion. The other sites are not expected to be affected by propeller wash.

Ferry Traffic

The most noticeable and probably the most significant environmental impact of a ferry operation is the effect the ferry traffic has on the immediate terminal area. The traffic expected on a ferry facility is small compared to the capacity of a two-lane rural highway. Figure 4, which uses as an example traffic on open areas of NY-25 for which 1973 one-way, peak-hour volume was 365 vehicles, shows that at an annual volume of 500 000 vehicles/year the peak-day, peak-hour ferry traffic is less than half the capacity of a single lane of traffic under conditions of stable flow. The impact of the ferry traffic depends on the spare capacity available on existing roads. In this case the ferry would cause only a slight reduction in travel on the Throgs Neck and Whitestone Bridges. Even a ferry serving 2 000 000 vehicles/year would reduce the total traffic on these

Figure 4. Impact of ferry traffic on a two-lane road.

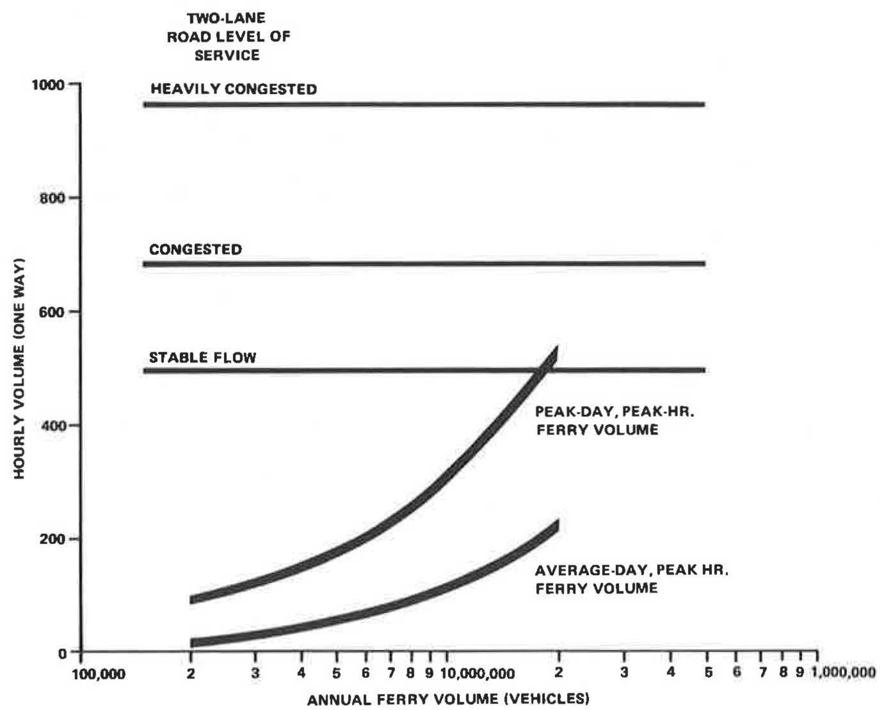
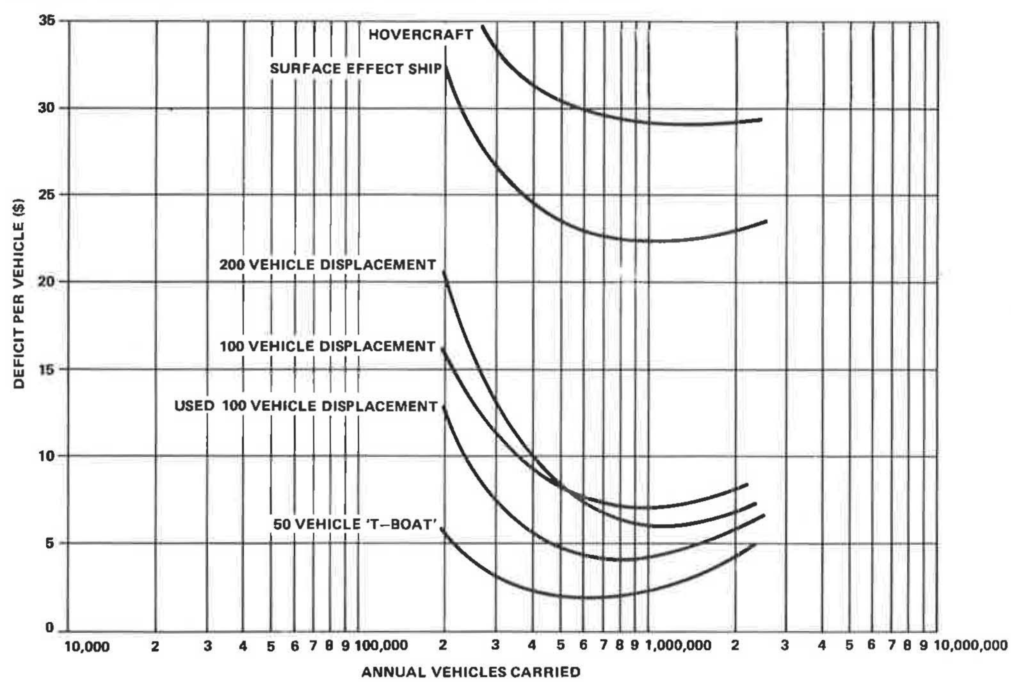


Figure 5. Deficit by type of vessel for New Haven-Wading River service.



bridges by less than 2 percent.

Air Pollution and Fuel Use

By eliminating the land trip around the Sound, a ferry service would reduce fuel use and air-pollution emissions, but the effect would be relatively small and the bulk of the reductions would occur outside the areas of highest congestion and pollution concentrations.

The high-speed surface effect ship and the hovercraft would add to fuel use and emissions because they would burn considerably more fuel per vehicle than it takes to go around the Sound.

Summary of Costs and Benefits

The subsidies required for a typical crossing are shown in Figure 5 for each of the vessel types studied. The costs and deficits for high-technology vessels—the surface effect ship and hovercraft—are much greater at all volumes than those for the conventional-displacement vessels studied. The high speeds, high fares, and high load factors projected for these more sophisticated craft are not expected to outweigh their high capital and operating costs in vehicle-carrying ferry service.

Costs and benefits of ferry services at each site are summarized in Table 2 for services using vessels of 100-vehicle capacity. By using 100-vehicle vessels, all of the ferry services are expected to cover their operating costs through fare revenues. Only one site, Westbrook-Hashamomuck, is expected to cover the amortization cost of vessels and terminals. Because of the inclusion of consumer surplus in the calculation of benefits, ferry services at Westbrook-Hashamomuck and East Marion-Saybrook Point show benefits that are greater than their total cost. Unfortunately, the most attractive sites from an economic point of view have severe problems with land access and environmental impact.

Evaluation of Findings

A decision on implementing ferry service must take into account

1. Costs versus revenues;
2. Impact of ferry traffic on local roads and feasibility of making needed improvements;
3. Access from local roads to shorelines; and
4. Impact and feasibility of terminal location and construction.

High-speed ferry vessels were ruled out because of their poor economic performance. The conventional ferry services still being considered were compared by rating each on a scale ranging from very poor to very good. The ratings, which are based on other studies and are described briefly elsewhere (1), were then combined into an overall measure of feasibility (Table 3). This method proved to be the most practical way of combining and presenting various measures of ferry-service performance.

CONCLUSIONS AND RECOMMENDATIONS

The study reached the following major conclusions.

1. High-technology craft are extremely expensive to purchase and operate in vehicle-carrying service and

Table 2. Costs and benefits of ferry services.

Ferry	Capital Costs ($000s) Vessel	Capital Costs ($000s) Terminal	Capital Costs ($000s) Total	Cost per Vehicle ($) Operating	Cost per Vehicle ($) Total	Benefits per Vehicle ($) Fare Revenue	Benefits per Vehicle ($) Consumer Surplus	Benefits per Vehicle ($) Total	Annual Profits ($000s) Operating	Annual Profits ($000s) Total	Benefit/Cost Ratio
Stamford-Lloyd Point	28 838	11 370	40 208	5.78	12.21	6.57	2.03	8.60	398	-2818	0.70
Sunken Meadow-Sherwood Point	25 457	16 276	41 733	5.17	11.85	7.40	2.15	9.55	1116	-2223	0.81
Bridgeport-Port Jefferson (current)	32 353	9 199	41 552	6.40	13.05	7.03	2.30	9.33	312	-3012	0.71
Port Jefferson-Bridgeport (Fayerweather Island)	31 617	10 376	41 993	6.27	12.99	7.10	2.30	9.40	414	-2945	0.72
New Haven-Wading River	38 906	14 962	53 868	7.57	16.19	8.38	2.50	10.88	406	-3903	0.67
East Haven-Wading River	32 457	14 962	47 419	6.42	14.01	9.02	2.50	11.52	1298	-2495	0.82
Guilford-Centerville	31 859	14 970	46 829	6.31	13.81	10.08	2.69	12.77	1881	-1866	0.92
Westbrook Harbor-Hashamomuck	21 834	13 538	35 372	4.53	10.19	10.76	3.44	14.20	3117	287	1.39
New London-Greenport	48 053	8 400	56 453	9.20	18.24	9.44	3.44	12.88	116	-4400	0.71
East Marion-Saybrook Point	24 626	14 943	39 569	5.02	11.36	10.49	3.44	13.93	2731	-435	1.23
New London-Orient Point	34 279	10 878	45 157	6.75	13.97	9.54	3.44	12.98	1396	-2217	0.93

Note: Service volume of 500 000 vehicles/year; vessel of 100-vehicle displacement.

Table 3. Evaluation of impact and feasibility of ferry services.

Ferry	Economic Performance	Highway Access	Site Access	Terminal Location	Overall Feasibility
Stamford-Lloyd Point	Poor	Poor	Fair	Very poor	Poor
Sunken Meadow-Sherwood Point	Fair	Good	Very poor	Very poor	Very poor
Bridgeport-Port Jefferson (current)	Poor	Fair	Good	Good	Fair
Port Jefferson-Bridgeport (Fayerweather Island)	Poor	Fair	Fair	Poor	Poor
New Haven-Wading River	Poor	Very good	Fair	Fair	Poor
East Haven-Wading River	Fair	Good	Fair	Fair	Fair
Guilford-Centerville	Fair	Poor	Good	Fair	Fair
Westbrook Harbor-Hashamomuck	Good	Fair	Very poor	Very poor	Poor
New London-Greenport	Poor	Poor	Good	Good	Poor
East Marion-Saybrook Point	Good	Good	Very poor	Very poor	Poor
New London-Orient Point	Fair	Good	Good	Good	Good

Note: Service volume of 500 000 vehicles/year; vessel of 100-vehicle displacement.

would require very high subsidies in spite of their high speed, higher load factors, and higher fares as compared to displacement vessels. A fleet of 200-vehicle vessels would be more expensive to operate than smaller 100-vehicle vessels for volumes up to 1 000 000 vehicles/year. Even at the highest volumes the savings are modest.

2. At some point fares will fall below the cost of providing service and the deficits per vehicle will increase. In economic theory, ferry volume should be set at a point where the fares plus the marginal dollar value of external benefits (such as pollution and road use saved by the ferry) are equal to the marginal cost of providing ferry service. Both the fares and the marginal cost of providing service, however, are best determined in practice.

3. The relative development impacts of a ferry are projected to be small. Passengers commuting to work are not likely to use ferry service in large numbers because of the costs and time involved.

4. At most ferry sites the most significant environmental impact results from the traffic that is generated on local access roads. Peak-day, peak-hour traffic is expected to make up as much as 40 percent of the capacity of a single lane of traffic on a rural highway under relatively uncongested conditions. In some areas, however, there is not enough spare capacity on existing roads and extensive improvements are necessary. Only slight savings in fuel and emissions result from ferry use.

This study was not able to find any clearly desirable sites for large-scale ferry service. Those sites that are most desirable economically have severe problems with land access and terminal construction. The current prospects for improvements to ferry service in the private sector are excellent. The current operator of the New London-Orient Point Ferry, Cross Sound Ferry Services, has received Coast Guard approval on the design for, and has begun construction of, a 50-vehicle vessel called a T-boat, which could significantly lower the costs of providing ferry service.

Near-Term Improvements

It is recommended that the states closely monitor and provide assistance to the development of ferry service in the private sector. A relatively modest investment by the states could serve the following short-range goals:

1. Ensure reliable service,
2. Reduce fares by introducing more efficient vessels, and
3. Maintain the incentive in the private sector to hold down the cost of providing service.

New London-Orient Point

On the New London-Orient Point route, if the operating and capital costs of the T-boat vessel are as low as projected, substantial improvements in ferry service could be instituted without the need for continuing subsidies. The potential here is for a ferry service serving 200 000 vehicles/year (at higher volumes substantial improvements to land access would have to be made). Such a service is projected to be self-supporting.

Bridgeport-Port Jefferson

The current Bridgeport-Port Jefferson service operates only 4 months out of the year. This service, which operates a single, side-loading, 35-vehicle vessel, provides a round trip every 4 h but carries no trucks. A through-loading displacement vessel and improved terminals could substantially reduce the operating costs of the service as well as reduce round-trip vessel time from 4 to 3 h.

The potential here is for a two-vessel operation carrying 50 000 vehicles/year. Congestion on local streets in Port Jefferson may prevent the service from carrying trucks. Improvements would be needed to relieve this congestion if volumes greater than 50 000 vehicles/year were to be carried. The costs of such improvements are as follows:

Item	Cost ($000 000s)
Vessels (2 at $1.375 million each)	2.8
Terminal improvements	0.5
Total	3.3
Annual amortization (at 10 percent)	0.33

A large portion of these costs could be financed through reductions in the operating cost of the service and through increased revenues in response to improved service.

In addition to substantially improving current service, the following measures would also aid the states in establishing a much larger service at a later date.

1. Test the T-boat design in service to determine its near-term improvement costs and performance.
2. Test the market for improved ferry services to establish more points on the demand curve for ferry service.
3. Develop the market for improved ferry service.

Long-Term Improvements

Major services appear to be feasible at four sites: Bridgeport-Port Jefferson, East Haven-Wading River, Centerville-Guilford, and New London-Orient Point. Of the four, the Bridgeport-Port Jefferson and New London-Orient Point sites are the most attractive. The costs and benefits of services at the four sites are comparable. However, services at Bridgeport and New London could be developed in stages, whereas service at either of the other sites would require the commitment of $15 million in terminal facilities, including long piers out into the Sound, before the market for ferry service could be tested. If more than one major service were set up they would undoubtedly compete with each other. The actual volumes are best determined in practice. Based on our analysis the following combinations appear to be desirable and feasible.

Site	Annual Volume (000s)
Bridgeport-Port Jefferson	500
New London-Orient Point	200
New Haven-Wading River (or East Haven-Wading River	500
New London-Orient Point	200
Guilford-Centerville	>500
New London-Orient Point	500

The decision on whether to invest in ferry service depends on the availability of funds and the competing uses for these funds. An investment in a viable, large-scale ferry service is one whose value will grow through time. If the service covers its operating costs, the burden of fixed debt service payments should gradually diminish as revenues and other costs rise through inflation. In the meantime, the near-term recommendations made here can provide substantial improvements to current service at a relatively modest cost and also help to test and develop the market for a greatly expanded ferry service.

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**Mr. Cohen was with the Tri-State Regional Planning Commission, New York, when this research was performed.*

Significance of Benefit/Cost and Cost/Effectiveness Ratios in Analyses of Traffic Safety Programs and Projects

G. A. Fleischer, Traffic Safety Center, University of Southern California, Los Angeles

This paper is a critique of NCHRP Report 162, Methods for Evaluating Highway Safety Improvements. Several important conceptual errors in that publication concerning the use of benefit/cost and cost/effectiveness ratios in evaluating traffic safety programs and projects are identified and discussed. Qualitative and quantitative arguments, as well as supporting numerical examples, are provided.

In the fall of 1971 the National Cooperative Highway Research Program (NCHRP) of the Transportation Research Board initiated a major research effort primarily funded by the American Association of State Highway Officials (AASHO). The principal objective of the study was to develop a set of guidelines detailing the methodology and techniques for evaluating the effectiveness of highway safety improvements in terms of reduced accidents. It was also expected that a methodology would be incorporated for evaluating these safety improvements by cost-benefit analysis.

The final report, NCHRP Report 162, is for the most part a well-written, useful document. But, in my view, its usefulness is markedly diminished by several serious conceptual errors concerning the proper application of benefit/cost and cost/effectiveness ratios.

FISCAL OBJECTIVES

The authors of NCHRP Report 162 point out that "the method of analysis chosen to select from among mutually exclusive improvements at a location depends upon the fiscal objective of the agency making the selection" (1, p. 8). They further assert that there are two fiscal objectives:

1. Optimum improvement, in which the goal is to obtain the most net benefit from each investment opportunity; and
2. Benefit maximization, in which the goal is to obtain the most net benefit from the funds budgeted.

After reference to an example listing of candidate projects (which will be discussed later in this paper), the authors conclude: "The theoretically correct fiscal objective is the optimum improvement objective" (1, p. 9). This statement is not only puzzling; it is misleading. A false distinction is created that has no meaningful operational significance. For a given budget constraint, the agency's proper fiscal objective should be the maximization of net benefits from all investment opportunities. The optimum budget is that combination of investments—among sites, roadway designs, equipment, and so on—that maximizes net benefits. All subproblems at the design level can be accommodated under this rule.

BENEFIT/COST RATIOS

The NCHRP report discusses three methods for evaluating independent alternatives: (a) benefit/cost (B/C) ratio, (b) rate of return, and (c) payback period. Here, alternatives are independent if the selection of one alternative does not preclude the selection of any of the others.

The B/C ratio for a given project is defined in the usual way, as equal to either (a) the ratio of equivalent uniform annual benefits (EUAB) to equivalent uniform annual costs (EUAC), or (b) the ratio of the equivalent present worth of benefits (PWOB) to equivalent present worth of costs (PWOC). That is,

$$B/C = EUAB/EUAC = PWOB/PWOC \quad (1)$$

The authors then assert that the B/C ratios should be used to rank independent alternatives: "Order the improvements by magnitude of the B/C Ratios, largest to smallest" (1, p. 42). An example of the basic data for this procedure, as well as calculations of the B/C ratios, is given in Table 1.

The authors conclude that "the order by magnitude for these independent alternatives is B, D, A, C" (1, p. 42). That conclusion is strictly correct, but the inference is unjustified. It is true that

$$B/C(B) > B/C(D) > B/C(A) > B/C(C) \quad (2)$$

But it is not true that the economic preferences for these

Table 1. Economic data for four independent alternatives.

Improvement	Cost ($) Initial	Cost ($) Annual	Terminal Value ($)	Service Life (years)	Annual Benefits (constant)	EUAC at 10% ($)	EUAB at 10% ($)	B/C Ratio
A	200 000	4000	20 000	20	80 000	27 143	80 000	2.95
B	100 000	2000	10 000	15	55 000	14 833	55 000	3.71
C	50 000	1000	0	10	25 000	9 137	25 000	2.74
D	75 000	0	0	10	40 000	12 206	40 000	3.28

Table 2. Capital budgeting problem.

Location	Alter-native	Initial Cost ($)	EUAC ($)	EUAB ($)	Net Annual Benefits ($)	B/C Ratio
A	1	1000	228	800	572	3.51
A	2	2000	456	700	244	1.54
A	3	2500	570	1170	600	2.05
B	1	2000	456	750	294	1.64
B	2	4000	912	1750	838	1.92
C	1	1000	228	700	472	3.07
C	2	2000	456	900	444	1.97
C	3	3000	684	1000	316	1.46
D	1	1000	228	800	572	3.51
D	2	5000	1040	2000	960	1.54
E	1	500	114	500	386	4.39
E	2	4000	912	1600	688	1.75
F	1	1500	342	1200	858	3.51
F	2	3000	682	1100	418	1.61

alternatives are necessarily reflected by this ordering.

It should be observed at this point that ranking the four improvement projects is unnecessary if they are truly independent. The only relevant test is whether the resulting B/C ratios exceed unity. In this case they do. Each of the projects is therefore preferred to the do-nothing alternative. All of these independent projects should be accepted.

Suppose that, contrary to the original assumption of independence, ranking the four projects is desirable because (a) funds are not available for all improvements or (b) the projects are, technologically or physically, mutually exclusive. Then the correct ranking can be inferred by examining the net equivalent uniform annual benefits (or, alternatively, the net present worths):

1. Net EUAB (A) = $80 000 - $27 143 = $52 857;
2. Net EUAB (B) = $55 000 - $14 833 = $40 167;
3. Net EUAB (C) = $25 000 - $9137 = $15 863; and
4. Net EUAB (D) = $40 000 - $12 206 = $27 794.

It is also true that the incremental analysis of B/C ratio, properly computed, leads to this same conclusion. Let IB/IC represent the incremental B/C ratio between a pair of alternatives. Then IB/IC (C) = 2.95 and thus C > do-nothing alternative; IB/IC (D versus C) = ($40 000 - $25 000)/($12 206 - $9137) = 4.89 and thus D > C; IB/IC (B versus D) = ($55 000 - $40 000)/($14 833 - $12 206) = 5.71 and thus B > D; and IB/IC (A versus B) = ($80 000 - $55 000)/($27 143 - $14 833) = 2.03 and thus A > B.

Using both the net equivalent uniform annual cost method and the incremental B/C ratio method, we conclude that

$$A > B > D > C \quad (3)$$

This is not the ranking that results from merely ordering on the basis of project B/C ratios.

In Appendix K of NCHRP Report 162, Alternative Methods of Evaluating Completed Highway Safety Programs, three phases of a program are identified: lighting, signing, and deslicking. Initial construction costs, operating costs, and benefits are given, and the PWOB, PWOC, and resulting B/C ratios are then computed. The results (1, pp. 59-60) are as follows:

Phase	PWOB ($)	PWOC ($)	B/C Ratio
Lighting	66 200	56 550	1.17
Signing	19 650	8 200	2.40
Deslicking	147 900	133 100	1.11

The analysis is correct as far as it goes. However, the authors then state, "Thus, the signing phase of the 1970 program is producing more benefits per dollar spent than the lighting and de-slicking phases. The comparison of these ratios gives top management an indication of the relative merits of each phase of the program" (1, p. 60). This statement is, at best, misleading.

If management's problem is to choose between three alternatives, then closer examination of the data indicates that the deslicking phase is in fact preferable. That is, net PW (lighting) = $66 200 - $56 550 = $9650; net PW (signing) = $19 650 - $8200 = $11 450; and net PW (deslicking) = $147 900 - $133 100 = $14 800.

But perhaps of greater interest in this example is the use of the phrase "more benefits per dollar spent." Does the benefit/cost ratio actually give a measure of economic efficiency in the sense of output (benefits) per unit of input (costs)? The answer is no, and for reasons that may not be sufficiently apparent, particularly because the magnitude of the benefit/cost ratio can be manipulated by judicious planning of certain economic consequences in the numerator or denominator of the ratio. Consider, for example, the following consequences of a proposed investment: PW of construction costs = $100 000, PW of maintenance costs = $50 000, and PW of user benefits = $200 000. There are two possible B/C ratios for this project, both of which are meaningful: (a) B/C = ($200 000 - $50 000)/$100 000 = 1.50 and (b) B/C = $200 000/($100 000 + $50 000) = 1.33. The same project is being dealt with in both cases. The benefit/cost ratio can be either 1.33 or 1.50. In each instance the ratio exceeds unity and the project is thus preferred to the do-nothing alternative.

If the above example represents one phase of a certain program and there is a second phase yielding a B/C ratio, say, of 1.40, does it follow that phase 1 yields "more benefits per dollar spent" than phase 2—or less? The answer, of course, is that the B/C ratio is not a measure of economic efficiency and should not be used to rank alternatives. The significance of an alternative's B/C ratio lies in its relation to unity; i.e., the ratio indicates whether the additional benefits (compared to the alternative) are in excess of the additional costs (compared to the alternative).

It should be noted at this point that, although the magnitude of the ratio can be altered by placing a factor either in the numerator or denominator, it is not possible to change a ratio from less than unity to more than unity. This conclusion—that the position of an economic consequence in either numerator or denominator is irrelevant—has been discussed in detail elsewhere (2).

Table 2 (slightly modified from the table in NCHRP Report 162) was designed to illustrate the objectives of benefit maximization and optimum improvement. It reflects the problem of selecting from among a number of mutually exclusive design alternatives at six problem locations with a budget limitation of $5000. Although only one design may be chosen for any given location, several locations (independent alternatives) may be selected within the overall budget constraint.

NCHRP Report 162 notes: "Under the optimum improvements objective, the candidate projects with the highest net benefit for each location are F-1, C-1, A-3, E-2, and D-2" (1, p. 8). There are six alternatives, including the do-nothing case. With the budget limitation of $5000, improvements A3, C1, and F1 provide the most net benefits as shown below.

Alternative	Initial Cost ($)	EUAC ($)	EUAB ($)	Net Benefits ($)
A3	2500	570	1170	600
C1	1000	228	700	472
F1	1500	342	1200	858
Total	5000	1140	3070	1930

The report also notes that, under the benefit maximization objective, the candidates from each location selected on the basis of highest B/C ratio are E1, A1, D1, F1, C1, and B2 and that improvements E1, A1, D1, F1, and C1 will use up the $5000 budget (1, p. 9).

Alternative	Initial Cost ($)	EUAC ($)	EUAB ($)	Net Benefits ($)	B/C Ratio
E1	500	114	500	386	4.39
A1	1000	228	800	572	3.51
D1	1000	228	800	572	3.51
F1	1500	342	1200	858	3.51
C1	1000	228	700	472	3.07
Total	5000	1140	4000	2860	

It is clear in this example that (a) preliminary ranking of mutually exclusive projects by net annual benefit (or net present worth) can lead to suboptimal global solutions when projects are combined and a capital budget limitation is imposed and (b) preliminary ranking on the basis of B/C ratios will lead to the optimal combination of projects.

One should not conclude, however, that ranking by benefit/cost is appropriate in all cases. There are two important reasons for this. First, the EUAC in this example consists solely of the initial cost, annualized by multiplying by the appropriate capital recovery factor. That is,

$$\text{EUAC} = (\text{initial cost}) \left\{ i(1+i)^n / [(1+i)^n - 1] \right\} \quad (4)$$

where i = interest rate used for compounding and N = project life. The denominators in all of the B/C ratios, therefore, are directly related to the input, i.e., the budget. Because the B/C ratios in this case are measures of economic efficiency and do reflect output (benefits) per unit of input (costs), the substitution of a higher efficiency alternative for a lower efficiency alternative will have the effect of increasing the efficiency of the overall budget. In other words, given the need for a $5000 budget package, it is desirable that the components maximize benefits per unit of cost.

In this case, because the denominators are "pure" in the sense that they account only for initial investment, the numerator-denominator issue may not appear relevant. But in real-world applications the denominator is likely to include economic consequences in addition to those dollars that are prospectively part of the agency's capital budget, e.g., annual costs of maintenance or operations or both, terminal salvage values, and construction costs incurred in time periods other than that for which the current budget has been established.

This point is illustrated in the following simplified example.

Alternative Location	Design	Benefits ($)	Maintenance Costs ($)	Initial Costs ($)
X	1	200	50	100
	2	140	0	100
Y	1	145	0	100

If B = benefits, K = maintenance costs, and C = initial costs, then

(B - K)/C	B/(C + K)	B - K - C ($)
1.50	1.33	50
1.40	1.40	40
1.45	1.45	45

There are two mutually exclusive design alternatives in location X; there is only one design alternative in location Y. The projects at locations X and Y are independent but, since only $100 has been budgeted, only one of the two can be selected.

The B/C ratios for these alternatives can be computed by including the maintenance costs (K) in either the numerators or denominators. If the maintenance costs are considered to be negative benefits, then the objective of benefit maximization would lead to the selection of X1. If the maintenance costs are included in the denominator as a cost, this objective leads to the selection of Y1. There should be no ambiguity in this example, however: X1 is preferred to Y1, and Y1 is preferred to X2. This may be seen by examining the net present worths of the three alternatives.

The second reason for using caution in ranking projects by B/C ratios is that such ranking can lead to operational difficulties. In the example given in Table 3, there are two locations, A and B, and two mutually exclusive design options at each location. There are eight possible combinations or budget alternatives (2^3). The maximization objective would lead to the selection of projects A1 and B1 at a total cost of $200. But if $300 were available, then A2 and B1 would be the proper combination. How would the correct solution be identified if the analyst was instructed to select, in each case, the alternative having the highest B/C ratio?

This example is an illustration of the preselection problem (3). One cannot determine the global optimum simply by combining locally optimal solutions. That is, the net benefits of an entire investment program cannot be maximized, with budget constraints, merely by aggregating design alternatives that appear optimal with respect to their mutually exclusive alternatives. All combinations of programs, or budget packages, must be identified and the optimal program selected from this set. There can be a large number of such alternative programs. Fortunately, however, some efficient algorithms have been developed through dynamic and linear programming.

SIGNIFICANCE OF COST/EFFECTIVENESS RATIOS

It is not always possible to evaluate all of the consequences of a proposed investment in economic terms. Evaluations that treat both economic and noneconomic values are referred to as cost-effectiveness analyses; in these evaluations the monetary consequences are costs and the nonmonetary consequences are effectiveness.

NCHRP Report 162 defines cost-effectiveness as "a comparison of cost to achievement of a given unit of effect. Cost/effectiveness is similar to benefit/cost ratio. It is the average cost per unit of benefit" (2, p. 43). A procedure is prescribed in which the analyst is instructed to calculate cost-effectiveness "by dividing the equivalent uniform annual cost by the estimated annual reductions in the unit of effectiveness selected." The next step is to array "the improvements by cost/effectiveness ratio, lowest to highest" (2, p. 44). This view of cost-effectiveness analyses is incorrect. Except in relatively rare situations, the magnitude of the cost/effectiveness ratio has no relevance to rational decision making.

The example used here to demonstrate this point is drawn from NCHRP Report 162 (1). Four mutually exclusive alternative improvements and their cost, effectiveness, and cost-effectiveness per accident reduced are considered, as follows:

Improvement	Cost (EUAC) ($)	Effectiveness (accidents reduced per year)	Cost-Effectiveness (per accident reduced) ($)
A	27 150	32	848
B	14 850	22	675
C	9 150	10	915
D	12 200	16	762

According to the report (1), the order of preference for these alternatives is B > D > A > C.

The problem is shown in Figure 1. Note that the C/E ratio is the reciprocal of the effectiveness/cost (E/C) ratio, and that minimum C/E is equivalent to maximum E/C. Also note that the slopes of the lines drawn from the origin to each of the four points (A, B, C, and D) are the E/C ratios for the four alternatives. Again, the report asserts that improvement A is preferred to improvement C because the C/E ratio for the former is less than that for the latter; i.e., A > C because C/E (A) < C/E (C). If the principle is accepted that only differences between alternatives are relevant, these differences should be examined more closely, as follows:

Alternative	Cost (EUAC) ($)	Effectiveness (accidents reduced per year)
A	27 150	32
C	9 150	10
Difference	18 000	22

The choice between A and C depends entirely on the relation between the additional $18 000 expenditure and the additional 22 accidents/year reduced. Specifically, if the utility of an additional 22 accidents reduced is in excess of the utility of saving $18 000, then the more expensive alternative (A) is preferred. Otherwise, the less

Table 3. Economic analysis of independent and mutually exclusive alternatives.

Alternative	Location	Design	Initial Cost ($)	PWOB ($)	Net Benefits ($)	B/C Ratio
1	A	1	100	150	50	1.50
2	A	2	200	280	80	1.40
3	B	1	100	160	60	1.60
4	B	2	200	240	40	1.20
5	A1 + B1		200	310	110	1.05
6	A1 + B2		300	390	30	1.30
7	A2 + B1		300	440	140	1.47
8	A2 + B2		400	520	120	1.30

Figure 1. Effectiveness versus cost for sample problem.

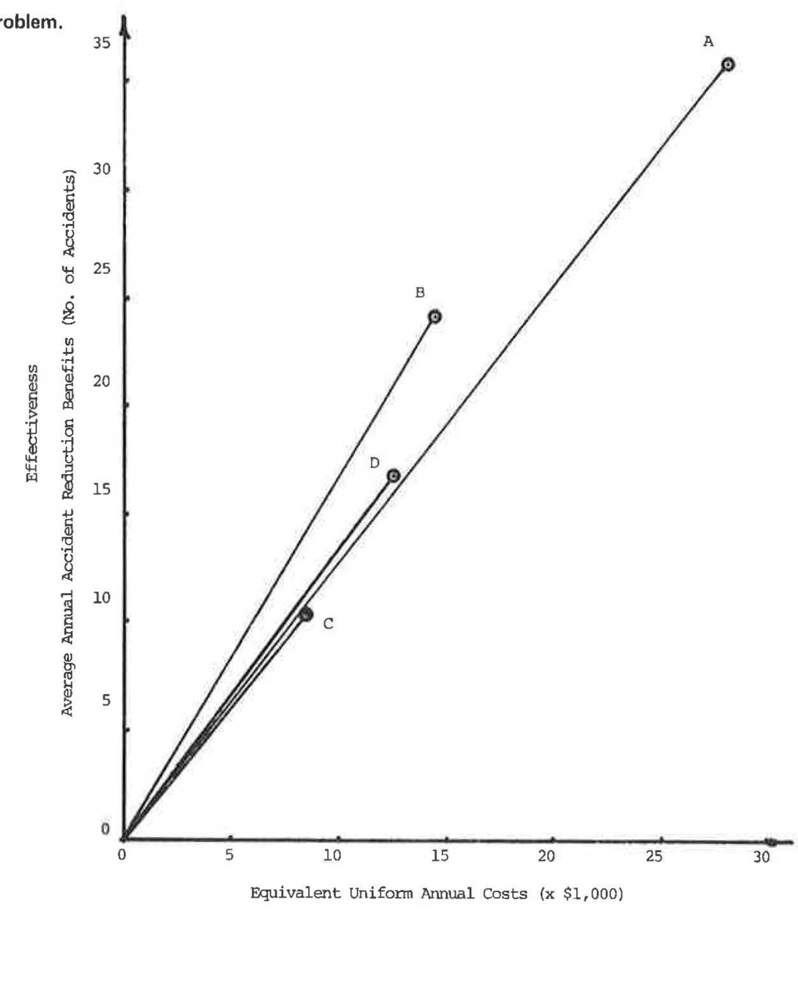
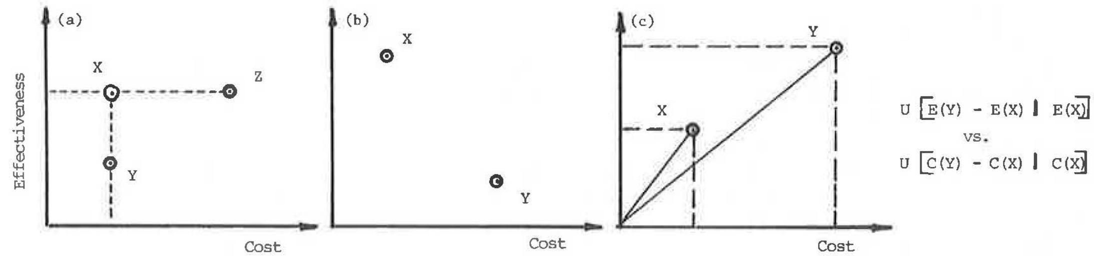


Figure 2. Differences in cost-effectiveness between a pair of alternatives: (a) equal effectiveness (X and Z) and equal cost (X and Y), (b) dominance (X > Y), and (c) no dominance.



expensive alternative (C) should be preferred. In the absence of the relevant utility function, i.e., without knowing anything about the trade-off between costs and accidents reduced, the alternatives cannot be ordered and no preferences can be determined.

The above argument relates to only one comparison (A versus C) in the example given in NCHRP Report 162 (1). The same argument can be applied to any of the six comparisons (A versus B, A versus C, A versus D, B versus C, B versus D, or C versus D) given in that example.

Conditions are detailed below and shown in Figure 2 in which alternatives cannot be rank ordered on the basis of their C/E ratios alone because effectiveness and cost are unequal between alternatives (x) and (y) or no dominance exists:

$$I(x) = E(x)/C(x) \quad (5)$$

$$I(y) = E(y)/C(y) \quad (6)$$

where I = index of cost-effectiveness. The following decisions can be made by using C/E ratios [I(x)] and [I(y)]:

1. Given E(x) = E(y) or C(x) = C(y), if I(x) > I(y), then x > y.
2. Given E(x) ≥ E(y) and C(x) ≤ C(y), there is dominance and x > y.
3. Given E(x) ≥ E(y) and C(x) ≤ C(y), or E(x) ≤ E(y) and C(x) ≤ C(y), if I(x) and I(y) may be computed but have no decision-making significance, then no conclusions may be inferred.

There are only three conditions under which ranking by C/E or E/C ratios is appropriate.

1. Effectiveness for all alternatives is equal. Then ranking by ratios is equivalent to ranking on the basis of decreasing costs.
2. Costs for all alternatives are equal. Then ranking by ratios is equivalent to ranking on the basis of increasing effectiveness.
3. Dominance obtains. Consider any pair of alternatives, x and y. If E(x) ≥ E(y) and C(x) ≤ C(y), then alternative x is said to dominate alternative y. Under these conditions, of course, E/C (x) ≥ E/C (y) and likewise C/E (x) ≤ C/E (y).

Unfortunately, in the real world these conditions rarely occur. The usual case is one in which an increase in effectiveness is brought about by an increase in project or program costs. When this occurs, it is not possible to establish a unique, unambiguous ordering of alternatives without knowledge of the utility function relating cost and effectiveness.

SUMMARY AND CONCLUSIONS

NCHRP Report 162 is intended to affect significantly the methods and procedures used by public agencies to evaluate improvements in highway safety. Unfortunately, several key concepts presented in the report are critically defective and adherence to these concepts could lead to misallocation of resources. The serious problems in NCHRP Report 162 appear to result from failure to consider properly the following principles.

1. B/C ratios cannot, in general, be used to rank order a set of competing investment alternatives. Only incremental B/C ratios are significant; that is, given two alternatives, x and y, the appropriate statistic is IBC = [B (y) - B (x)]/[C (y) - C (x)].
2. The magnitude of the ratio is relevant only in regard to whether or not it exceeds unity. That is, y is preferred to x if and only if (a) IBC > 1.0, if C (y) - C (x) > 0; or (b) IBC < 1.0, if C (y) - C (x) > 0. Otherwise, y is not preferred to x.
3. The magnitude of the ratio can be modified by moving consequences from numerator to denominator. However, the result of the relevance test above cannot be changed by this modification.
4. When effectiveness and costs are unequal between alternatives, and where no dominance exists, alternatives cannot be rank ordered on the basis of their respective C/E ratios alone.

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Misunderstandings of Cost-Benefit Analysis as Applied to Highway Transportation Investments

Robley Winfrey, Consulting Civil Engineer, Arlington, Virginia

Misunderstandings about the concepts, principles, procedures, and applications of cost-benefit analysis seem to be increasing. The role and pricing of traffic accidents in such analyses are often inconsistently and illogically handled. At the same time cost-benefit analysis is being increasingly applied and is attracting newcomers from several disciplines. Suggestions are made for overcoming the current deficiencies of cost-benefit analyses for highway investments, including additional research into the cost pricing of traffic accidents, especially of fatal accidents, and additional education and training in the whole subject of cost-benefit analysis and its application.

One purpose of this paper is to draw attention to some current misunderstandings about cost-benefit analysis. Readings and conversations on the subject of cost-benefit analysis for highway transportation investment proposals lead the author to conclude that there is an ever-increasing confusion about principles, concepts, procedures, and applications of results in this area. More writers are coming into print but, instead of clarifying the misunderstandings, they tend to perpetuate them. A new writer depends on what he or she has read and been taught. If the reading and the teaching were wrong, then the writer too is wrong—and so on through additional readers and writers.

Perhaps we are losing ground rather than gaining ground in improving our understanding of cost-benefit analysis because laymen and laywomen are now included in the group concerned—lay in the sense that they have no real professional experience in cost-benefit analysis and have not read the works of authoritative writers on this subject. Although they may be competent in the fields of social and business economics, technical engineering, sociology, business, planning, and government, they have read, practiced, and studied but little in cost-benefit analysis of proposed investments in highway transportation facilities.

At the same time it is encouraging that the application of cost-benefit analysis to all modes of transportation is becoming more widespread. Now an improved understanding of the concepts, theories, principles, and objectives of cost-benefit analysis is needed.

The fundamental question in an economic analysis of proposed transportation investments is simply, Will the investment pay off in the sense of realized cost reductions over a chosen future time period? With proper regard to the time cost of money, investments, and annual operations, if the cost reductions are greater than the expenditures necessary to produce the cost reductions, then the proposed investment is economically feasible. In this discussion, future cost reduction may be taken as a measure of the conservation of resources. That is what cost-benefit analysis is all about when it is used as a management tool in allocating monetary budgets and in efforts to get the maximum return on resources committed to investment projects and programs.

The purpose of cost-benefit analysis is to determine whether a proposed investment is economically justified in light of the total economic consequences generated. The objective is not to justify the proposed improvement but to determine whether it is justifiable. In their reports on their analyses, some analysts give the impression that they seek the wrong objective—justification. Such a position is probably more often found in traffic-accident analyses than in other proposals. In these analyses there seems to be an effort to include a large range of cost factors at high dollar amounts each and to play down those consequences resulting from traffic accidents, particularly from fatal accidents, that produce economic gains.

LEAST UNDERSTOOD PRINCIPLES

The principles of cost-benefit analysis that are least understood include the following.

1. It is the difference between a pair of alternatives that is significant.
2. The analysis should include all consequences, to whomever they may accrue (this is equivalent to making a total system analysis).
3. The basic concept is "with and without" or "to do or not to do."
4. The analysis should be based on net costs and net consequences.
5. A cost-benefit analysis is not the decision on what to do but a tool for the decision-maker to use in arriving at a decision.
6. There is a difference in meaning among the terms price, cost, and value.
7. The objective of cost-benefit analysis is to weigh the differences in the conservation of resources between different proposals, or alternatives, for accomplishing an objective to improve highway transportation.
8. In all methods of analysis, but particularly in analyses using benefit/cost (B/C) ratio and net present value, the answer is not a rigidly calculated figure that is precise and unchangeable, a figure that all analysts would arrive at, as is believed by many readers and analysts.
9. The statement of many writers that the net present value method of analysis is the only method that will give the correct result is untrue. All methods will give the identical selection of the alternative of greatest economy when the procedures of analysis are correctly chosen and properly used.

Some analysts interpret their cost-benefit results as being of a high degree of precision because the B/C ratio and percentage rate of return are calculated to three and four decimals. Further, they try to establish dollar measures for factors that can be neither quantified nor market priced. They seem to have a goal of including in their factors a dollar term for every variable so that they can calculate one overall result—B/C ratio or rate of return—that includes everything (e.g., such factors as comfort, convenience, air pollution, aesthetics, scenery, relocation of persons and businesses, human pain and suffering, and so on). Is not the preferred procedure the one that puts into the calculated numerical B/C ratio or the rate of return only those inputs that can be quantified and market priced and leaves all other factors in a descriptive form that the decision maker may weigh and consider for each specific proposal and alternative?

In this age of computers there is a tendency to put the whole procedure into the computer. Such a practice has merit, of course, when the computer is a calculating machine. But many people seem to believe that any product of the computer is superior to what could be done by hand, is beyond error, and must be universally accepted.

Many analysts desire a specific, step-by-step procedure that is applicable to all possible situations and that requires simply plugging in the required input data. They appear not to wish to exercise the judgment required to produce the correct and properly selected input data nor a knowledge of the theory, concepts, and principles of analysis but to be willing to accept any published dollar measure of travel time, traffic accidents, fatalities, and discount rates. This trend toward following a strict step-by-step procedure determined by someone else is reminiscent of a statement in the preface of a book by Henck (1):

> It may be remarked that it was not part of the author's design to furnish a collection of mere "rules," professing to require only an ability to read for their successful application. Rules can seldom be safely applied without a thorough understanding of the principles on which they rest. . . .

In cost-benefit analysis, it is necessary to know not only the rules and principles on which the analysis is founded but also the specific factors used as input data. In the presentation of the results of a cost-benefit analysis for investments in highway transportation, it is essential that the decision-maker (or other reader of the results) have a complete statement of the input factors and assumptions. For instance, unless the discount rate used in calculating a B/C ratio or net present value is known, the final answer is meaningless. Analysis period, traffic growth rate, and annual cash flows are also important.

Discussions in the literature often relate to differences in analyses when applied to (a) single projects having mutually exclusive alternatives, (b) multi-independent projects (priority ranking), and (c) programs composed of a series of several projects covering a span of years. To begin with, of course, the base alternative is to do nothing as compared to doing something. But once a decision to do something is made, any number of mutually exclusive alternatives may be analyzed. If it has been determined that doing something will provide more transportation economy than continuing the existing situation, each independent project in the group of multi-independent projects must be compared with each other independent project by the principle of differences. This procedure is a form of reiterative analysis and can become complex, especially if each independent project has more than one proposed design alternative.

The analysis of a program of investments over a period of years, such as a bridge improvement or replacement program or a program to reduce traffic accidents, may use the same procedures and concepts that are applied to mutually exclusive alternatives and selections of multi-independent priority. All that needs to be done is to make certain that the principles of analysis are followed, especially the principle of analyzing the differences in each pair of alternatives and including all consequences that accrue from each alternative. In addition, all cash flows must be properly discounted to a common date.

Some of the confusion in writing and discussing cost-benefit analysis comes from the popular use of the word benefit. The confusion can be somewhat relieved by thinking in terms of cost reduction between a pair of alternatives. The calculations of an analysis deal with cash flows in dollars—highway construction and maintenance cost in dollars, motor vehicle running cost in dollars, and travel time in dollars. In each of these factors, if cost is emphasized and is represented by cash-flow expenditures somewhere along the time scale, the analysis will always remain on solid ground. It is when benefits and values are introduced that difficulties arise.

It should be emphasized that what is being dealt with is cash-flow expenditures for two alternatives (a pair); any lesser discounted differences in the cash flow of the proposed new investment and its operation of the facility, as compared to the base alternative, would represent a cost reduction—a conservation of resources.

METHODS OF ANALYSIS

There is still controversy in the literature concerning the choice of methods of analysis for analyzing the economy of proposed highway investments. The procedures commonly cited are known as (a) equivalent uniform annual cost (EUAC), (b) present worth of costs (PWOC), (c) rate of return, (d) benefit/cost ratio, and (e) net present value (NPV). When calculations are made properly, based on the principles of analysis, these five procedures will all identify the same alternative as the one having the greatest transportation economy, whether the analysis is applied to mutually exclusive projects, a collection of independent projects, or to an improvement program.

The mistake most often encountered in analysis is the failure to compare all alternatives or projects in pairs by differences, so that each alternative is in effect compared directly with each other alternative. A common procedure, though an incorrect one, is to compare each do-something alternative with the base do-nothing alternative and then to choose the alternative that has the highest B/C ratio or the highest rate of return. In the EUAC, PWOC, and NPV procedures the comparison is still by differences: The calculated results are compared visually in order of magnitude. If, in each of the five procedures, the identical input cash flows are used in combination with discount rates, it is only reasonable to expect agreement in results.

Some PhD graduates in economics strongly insist that the rate-of-return procedure could give the wrong answer. It is true that the rate-of-return procedure will give two or more answers in a data set that has a reversal of sign in the accumulation of the minus and plus cash flows. The common method of proving this is to start out with a large plus (income) cash flow and then to follow it with a large negative (construction cost) cash flow. What most writers overlook is the fact that two answers can also be gotten from the NPV procedure simply by using two different discount rates: a rate less than the rate that gives a zero NPV and a rate above the rate producing the zero NPV. This possibility of two or more specific numerical answers is not known without a test of the calculations. However, the situation can easily be recognized by examining the cash-flow series for the reversal of sign.

One objection to the rate-of-return method is that it assumes that the returns (positive inflows) are reinvested at the rate of discount that comes from the solution. If such an assumption is actually the case, whether recognized or not, it is also a correct assumption for the NPV method and B/C ratio. All methods discount the identical cash flows over the time chosen for analysis. If, in the NPV method, a discount rate of 9 percent is used and an NPV of $45 000 is determined, then the total operation of cash flow must have earned, in some fashion, a return of more than 9 percent. If the same basic information and the rate-of-return method are used, the solution gives a rate of return of 15 percent. Is it not logical then to conclude that the cash flows being analyzed produced a compound earning rate of 15 percent and that any reinvestment factor assumed must also be assumed in the NPV method? If the NPV is calculated at 15 percent, the answer is zero dollars of NPV. This is the same 15 percent that was calculated as the rate of return for the combination of plus and negative cash flows. What is true in one method must also be true in the other.

COST VERSUS VALUE

Management must be presented with an economic analysis made on the basis of costs (expenditures) for each pair of alternatives considered. These costs must be in terms of market prices—dollars currently paid by the public. These prices, in terms of the total cost required to gain the objectives, are not equivalent to values or the willingness to pay dollars; they are dollars actually paid or forecast to be paid. The decision-maker wants to know the extent to which a new investment will consume resources in the future as compared to the extent to which resources will be consumed if the investment is not made or, between two competing new proposals, which one will consume the least future resources.

The concepts of willingness to pay and value to persons have been injected into cost-benefit analysis of highway transportation investments basically in two areas: travel time and traffic fatalities. Neither willingness to pay nor value is an appropriate measurement to use in cost-benefit analysis for either travel time or fatality, and neither should be used as a surrogate for economic cost.

Willingness to pay a certain price or to suffer a certain cost in no way represents a conservation of resources. Willingness to pay an amount for a reduction in travel time or for the probable prevention of a fatal accident is, in a sense, a measurement of a value. Value, however, is normally in excess of cost, or the willingness-to-pay sum, because people expect and receive greater value from the gain or satisfaction in a transaction than they expend or are willing to expend to receive that gain or satisfaction. If the value were not greater than the cost, people would not pay the cost. Value may be defined or explained in the sense of worth, merit, usefulness, or importance of an object, favor, satisfaction, or experience. Value is what people would be willing to sacrifice to gain possession or ownership of or to experience something. In this sense, value is closely related to what people are willing to pay or to sacrifice to make a gain, to achieve a satisfaction, or to avoid an event or experience.

Value should not be used in cost-benefit analysis in the place of market cost. Value is more than cost would be if cost were obtainable and therefore, in a dollar sense, value is in excess of cost. In the broad sense, the economic structure of the nation would be severely disrupted if new highway facilities were constructed on the basis of what the general public considered the value of the improvements to be. To finance these investments in new facilities it would be necessary for the public to shift their expenditures from other satisfactions in life to highways because the values they place on highways would not increase their incomes and would not reduce their transportation costs by the difference between true cost reductions and the higher value placed on the highway improvement. The theory is that, if cost reductions are used as the basis of selecting new highway projects for investment, people will not suffer economically because their cost reductions will more than pay for the cost of the construction and operation of the new facility as compared to costs for existing operations.

An example of this concept is the recent increase in the price of gasoline from about \$1.32 to \$2.46/liter (35 cents to 65 cents/gal). Without considering any inflation in the value of the dollar, this increase in gasoline price has been absorbed by the motoring public with little or no reduction in vehicle use, which proves that the 1975 value of automotive fuel was considerably greater than the market price. If, in a cost-benefit analysis for highways, the concept of value (or willingness to pay) is used for travel time or fatalities, then why not use the value concept for fuel, tires, vehicle maintenance, and all other factors in the calculations? Why not be consistent in selecting the factor to put into the analysis?

Another popular economic concept that merits discussion is that of perceived cost. In many transactions, decisions, and agreements, people do develop—consciously or unconsciously—some impression of the cost they are committed to. Their perceptions are generally inaccurate, hazy, and poorly developed. In motor-vehicle trip making, route selection, speed selection, and driving action, any perception of cost used in technical papers can be nothing better than a vague conception of the true cost. Even if a vehicle driver makes such a perception, his or her numerical answer is worthless in cost-benefit analysis. Persons who have a solid concept of what it costs to operate a motor vehicle under any specific condition are very rare. It is actual economic cost that must be used in cost-benefit analysis, not perceived cost or value dollars. Perceived costs may be appropriately used in traffic diversion studies when there is proof that the driver bases his or her route decision on such factors.

TRAFFIC FATALITIES

The current emphasis in reducing the annual number of traffic fatalities is on safety programs and spot improvements. This emphasis includes cost-benefit and cost-effectiveness measurements. The result is a renewed search for a dollar cost for traffic fatalities suitable for use in cost-benefit analyses. At this point researchers, analysts, and writers fail to realize that those factors that cannot be market priced are to be taken into consideration by the decision-maker as separate factors. There is no necessity to cost price these factors for inclusion in the calculation of B/C ratio or the rate-of-return solution.

How to handle traffic fatalities in cost-benefit analyses is a subject of great controversy and uncertainty. Much has recently been written on the subject and studies are still under way. However, analysts in this area have so far taken the wrong track, examining all the devices and procedures for placing a value on human life. The following discussion of the factors involved in fatal accidents is based on the assumption that the economic consequences would be market priced and the human and social factors would be identified and described for use as desired by the decision maker.

The analysis of a traffic fatality, like the analysis of direct economic cost factors that are priceable, is no different from the basic analysis concept: The objective is always a comparison of with and without—do-something or do-nothing—alternatives. When a fatality is involved, the measure sought is the economic change in society over the expected time of survival of the fatality. This change is found by comparing the economic costs incurred over that period with the economic cost to society after the death for the same time period. A comparison should be drawn between the economic impact of a living person on society over the period of normal life expectancy with the economic impact after he or she became a traffic fatality.

The development of a dollar amount for a traffic accident fatality to be used in cost-benefit analysis for proposed highway transportation investments, regardless of their character, should begin by answering the following questions:

1. How should the dollar amount be used?
2. Why is it necessary to use a dollar amount in the calculations?
3. What is the basic objective of the cost-benefit analysis?
4. What are the characteristics of a fatality that could possibly affect such a measurement (age, sex, economic status, employment status, trade, or profession)?
5. What information is available and of possible use?
6. Should the dollar amount be determined for separate geographical locations and different time periods—say, yearly?
7. What are the possible measures for consideration without attention to their suitability or possibility of quantifying and pricing?
8. What is the basic comparison that is to be made on a with and without basis?
9. What are the differences between the with and without situations?

In such an analysis, the concept of value of life is irrelevant, as are also the social and emotional aspects of human life and death. Income, in the sense of support for a surviving family or other dependents, is also irrelevant except as it affects economic factors. What is needed is a dollar amount for a fatality that is consistent with the dollars of cash flow that represent highway construction and maintenance costs and the cost of running motor vehicles on the highway. The same is true of the other factors of traffic accidents that represent physical goods consumed and labor or professional services involved in treating injured persons and in repairing vehicles and roadside and highway structures.

There is unquestionably a need to put a price on fatalities in economic dollars and not social dollars and to include these dollars in the analysis along with highway and motor-vehicle dollars. The principle of including all consequences that may accrue (a form of system analysis) requires that the dollar amount for a fatality must be the net of all costs to the economic system based on the comparison between the economic costs had the person lived and the costs following the death. This means that the costs of food, housing, clothing, education, health, and other similar costs of maintaining a person in society until death should be included in the calculations on a time-discounted basis. Another factor requiring consistency in the total procedure is the handling of temporary disability and permanent disability with reference to a fatality.

A procedure or concept should be developed that will make the dollar for vehicle fuel equivalent to the dollar applied to a fatality; this means an economic base related to consumption of resources.

There have been few attempts to study the gains accruing to society from a traffic fatality. When a death occurs in a traffic stream, the main consideration is the timing of that death with respect to when that death might reasonably have occurred otherwise, i.e., normal life expectancy based on the causes and conditions of all deaths with respect to age and occupation or daily activity. The only economic difference between a temporary disability caused by bodily injury and a fatality is one of time duration. In both cases a logical procedure and one following the principles of analysis is to compute the time discounts of all cash flows over the time periods applicable and then calculate the net present worth of these discounts plus and minus cash flows. An illustration is the case in which the death of a worker in a traffic accident requires the training of a replacement employee. That training expense would be required eventually without the traffic accident. The employed victim could resign, get sick and die, or be promoted to another position. So the net cost in economic analysis is the discounted cost of training between the date of the fatality and the expected future date when training would be necessary. The same logic applies to funeral cost and other items.

If the future earnings of a fatality are to be expressed as a cost to society, why then should not the future earnings accruing to the fatality's replacement be considered a gain to society? Does not the principle of considering all consequences apply to such actions or events? If an accidental death comes at a younger age for the deceased than it would have come had the accident not taken place, then the analysis of fatalities should be directed to what the economic system gains and loses by the earlier death as compared to gains and losses resulting from a later death.

What worthwhile economic contribution is now made to society that will not continue to be made after the death of the principal contributor? This is the critical question. If the contribution is not continued and is important to society, then there is an economic loss; if some other person continues the contribution, then there is no loss—no change in the economic balance. The loss of the services of a citizen who devoted his or her energies to civic activities without direct pay is expressed as a loss to society. But this ignores the fact that, if society wants to continue the dead person's activity, some living person takes it over. In addition, if older persons did not die, younger persons coming up would find no employment and no role in community functions.

Certain writers have objected to the use of probable future income of the fatality as a measure of his or her economic worth to society on the ground that a high-salaried executive is given a much higher value than a day laborer. But in this type of economic analysis the objective is not to determine a dollar sum for a specific individual. What is wrong about using different dollar sums for the fatality according to age, sex, economic status, and education? What is sought is the total economic impact, calculated by including any subdivisions that will be helpful in arriving at the grand total. No attempt should be made to apply the results to an individual as a social entity.

Suppose that a man is killed in a traffic accident and within a few days his job vacancy is filled by a replacement. The replacement comes in the form of an employee promoted or transferred from within the organization, transferred from another organization, or hired from the old or young on the unemployed rolls. In a few days it is business as usual as far as the economic consequences of the accident are concerned. Suppose that a motor vehicle is wrecked in a traffic accident. Within a few days the owner has procured another vehicle: a used automobile purchased from a dealer, a friend, or a stranger, or a new automobile. In a few days, the owner has returned to his or her normal motor-vehicle use. These two types of events are similar, even though one refers to a human fatality and the other to a machine fatality. For cost-benefit analysis based on the economic factors related to conservation of resources, the procedure should be the same in both cases. Basically, the procedure is to decide what the economic consequences of the accident are and their timing. It must be remembered that in our economic system what is a loss to one person may be a gain to another. The total system (all consequences) must be considered and the economic changes (gains or losses to society) and their relative time periods determined.

When a human fatality is to be input to a cost-benefit analysis, calculations must be restricted to solidly based, market-determined costs. The nonquantifiable, nonpriceable social and emotional aspects of human life must be left as abstract elements to be given such weight as the decision-maker believes is proper. If efforts can be directed toward the economic goal and away from the social goal, a workable solution can be found that should be comparatively easy to apply and one that will keep all the dollar inputs in cost-benefit analyses on the same basis instead of mixing cost dollars with value dollars.

As mentioned above, we need to hunt more diligently for a true cost basis of measuring the economic effects of death on the highway. Attempts to place a value on human life have been unsatisfactory. One concept that could be explored is that of considering the human being in the various early stages of life—infancy, childhood, youth—as a net economic burden to society in the sense that, in these stages, maintenance cost (i.e., food, shelter, clothing, health, education) is greater than contribution to economic production. Up to the time of gainful employment or gainful activity, a person's cash flow is outgoing (negative sign). When productivity starts, approximately between the ages of 14 and 22, he or she begins to produce cash flow (positive sign) as opposed to economic consumption. It would be reasonable to compound the negative sums up to the age of economic productivity and then write them off over the future period of productivity, based on life-expectancy tables. This concept is similar to that applied to depreciable plant. The investment cost when a facility is installed and ready for use is written off as depreciation expense over the years of usefulness. In cost-benefit analyses, a fatality could be handled in a similar manner.

This may be perceived as treating man as a machine. That is exactly the concept that should be used. Placing a value on man as a human being in society makes no sense when such value is to become dollars in an economic analysis along with the dollars for highways and for motor vehicles. We must use the same kind of dollars for all factors.

Another concept that should be considered in the search for new concepts and bases for getting highway traffic fatalities into cost-benefit calculations on an economic basis is longevity. Schwing (2) in his paper presents rough figures on the number of years of increase in human life expectancy that would result from 100 percent achievement of fatality reduction from certain causes of death. He considers diseases and classes of accidents, including highway traffic accidents segregated by method of accident reduction. His increased longevity varies from 0 to about 10 years. No mention is made, however, of how to convert increase in longevity to dollars. Schwing mentions that the concept of longevity is more appropriate than the concept of mortality, and this author agrees with his conclusion.

Another possible consideration is one related to time. The main economic difference between a temporary, disabling injury and a fatality is one of time duration. Placing a dollar amount per hour on a vehicle or its occupants as the cost of travel time is generally accepted practice; the same concept and the same unit dollar cost could be applied to a fatality. All that this application would require is calculating the present worth of the expected hours of work over the life expectancy of the fatality and then applying the same price per hour as that applied to travel time. This concept needs to be applied under the principle of total consequences and, from the computed dollar amount, the present worth of the cost of sustaining the fatality over the normal life expectancy should be deducted from the dollar cost of time calculation.

CONCLUSIONS

The available literature on itemized costs associated with traffic fatalities consists of compilations made by individual investigators, who were in turn guided by what they found in the literature. In attempting to put a dollar amount on a fatal traffic accident, not one of these investigators starts with an analysis of the real objective of the effort, the basic logic to be followed, or the concepts and the basic criteria commonly associated with cost-benefit analysis. They also omit a discussion of the internal factors of the total system to be investigated.

The whole approach to pricing fatal accidents should be reexamined by doing the following in the order listed.

1. Set forth the concepts, principles, and theories involved both in the gathering of information and in the use of this information in calculating the cost-benefit answer.
2. Determine the total system to be analyzed and, within this system, identify and isolate each factor of input and consequence.
3. Thoroughly study the factors of input and consequence to determine their role, if any, in the analysis.
4. Determine the basis of quantifying and pricing each factor.
5. Set forth the procedures to be followed in the pricing of each factor.
6. Complete the actual quantification and pricing of the factors in the form and concept to be used in the final calculations and tabulations.

The main item in this procedure that has been followed in past efforts is the pricing of the factors—the last step. Many past studies began and ended with this step, having paid little or no attention to the first five steps. New research on the pricing of traffic fatalities must begin at the beginning, with step 1.

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