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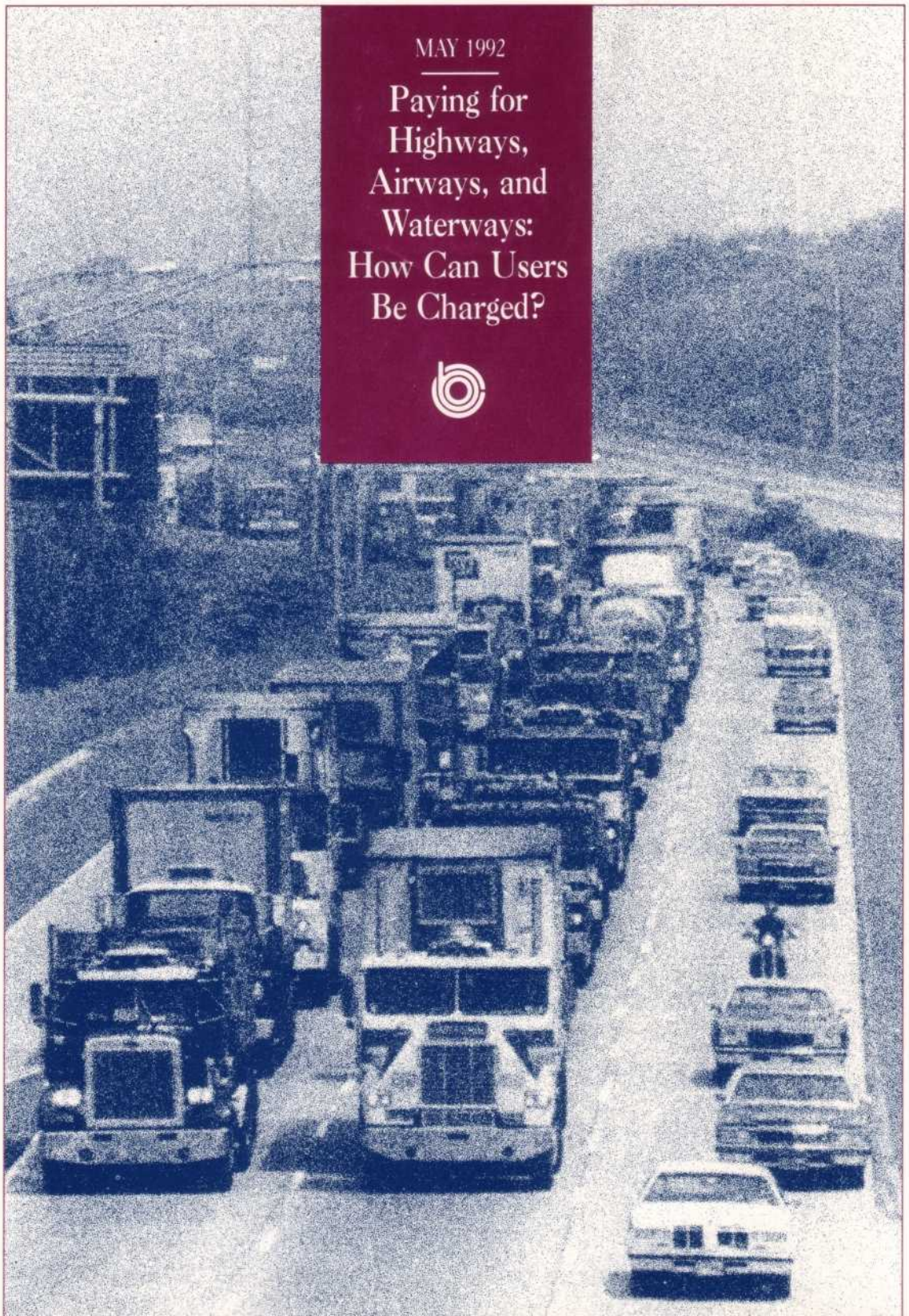
Paying for Highways, Airways, and Waterways: How Can Users Be Charged?



PAYING FOR HIGHWAYS, AIRWAYS, AND WATERWAYS: HOW CAN USERS BE CHARGED?

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NOTES

Unless otherwise indicated, all years referred to in this study are fiscal years.

Numbers in the text and tables of this study may not add to totals because of rounding.

Cover photo: A convoy of 18-wheel tractor-trailers on Interstate 91 in Connecticut in 1979. (UPI/BETTMANN)

Preface

The combination of budgetary pressures at all levels of government and increasing demands on transportation facilities has generated increased interest in directly charging users of highways, airways, and waterways. In response to a request from the Senate Committee on the Budget, this study examines the advantages and disadvantages of alternative user fee structures, including existing taxes. In keeping with the Congressional Budget Office's (CBO's) mandate to provide nonpartisan analysis, no recommendations are made.

Elizabeth Pinkston and Rajagopalan Kannan of CBO's Natural Resources and Commerce Division wrote the study under the supervision of Jan Paul Acton and Elliot Schwartz. Robert Arnold, Maureen Griffin, Theresa Gullo, Marjorie Miller, Linda Radey, Pearl Richardson, and Mitchell Rosenfeld of CBO offered insightful comments and criticism. The authors wish to thank George Antle, Dan Badger, John Fischer, Richard Golaszewski, Stefan Hoffer, Thomas Hopkins, Jeff Hornbeck, Jack Lane, Douglass Lee, James March, Daniel Taylor, William Vickrey, Jack Wells, and Clifford Winston for their helpful comments.

Sherwood D. Kohn edited the manuscript. Chris Spoor provided editorial assistance. Gwen Coleman produced numerous drafts of the study. Kathryn Quattrone prepared the report for publication.

Robert D. Reischauer
Director

May 1992

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Summary

The methods of financing highways, airways, and waterways influence both the amount of revenue that can be raised and the efficient allocation of resources. The concept of revenue adequacy--whether revenues cover costs--is important to the cash-strapped federal government, but it also has implications for efficient allocation of resources in the long run. If the costs of an investment project cannot be recovered from those who use it, the project's feasibility comes into question. But an investment that benefits society is worth making, even though it may not be possible to charge users for it. This often characterizes goods and services provided by the federal government, and it underlies the rationale for government rather than private activity in certain sectors. Revenue adequacy can provide information about the demand by users for public investments, but it alone cannot be the criterion upon which investment decisions are made.

Economic efficiency is the second criterion by which financing mechanisms are evaluated. The standard definition of allocative efficiency is used here: does the price--the value consumers place on the product or service at the margin--equal the marginal cost--that is, the value of resources used in producing the last unit? If the price is less than the marginal cost, consumers tend to overuse the resource; if the price exceeds the marginal cost, they use it too little.

The objectives of revenue adequacy and economic efficiency sometimes conflict. Economic theory offers some ways of minimizing the trade-offs, and these are included in the discussions of alternative pricing mechanisms.

This study concludes that existing federal taxes produce enough revenue to cover current spending on the nation's system of highways. But the present highway tax structure is not as efficient as it could be. Some users--such as 13-ton single-unit trucks with three axles--pay taxes that exceed their marginal cost, while others--such as 40-ton tractor semitrailers with five axles--pay less than their marginal cost. An alternative approach that would include charging users according to the pavement damage and congestion they cause could cover costs and lead to greater economic efficiency.

Existing federal taxes do not meet the criterion of revenue adequacy for airways--the air traffic control system. As prescribed by law, aviation tax revenues cover all investment spending by the Federal Aviation Administration (FAA), but only part of the operating costs. Taxes paid by commercial air carriers appear to cover their costs, while those of general aviation fall short. Aviation taxes are not particularly efficient either, since they do not closely correlate with the costs of services provided by the FAA. Marginal-cost pricing of air traffic control services

probably could not raise enough revenues to cover costs. When combined with congestion charges, however, it might meet the criterion of revenue adequacy. This study examines ways of mitigating the trade-off between cost recovery and efficiency.

Existing fuel taxes raise less than 10 percent of spending by the Army Corps of Engineers for navigation purposes on inland waterways. On a systemwide basis, fuel taxes appear roughly equal to marginal costs, although a lack of data hinders a detailed analysis of costs. If the federal government could determine marginal costs with confidence and charge users accordingly, revenues would probably be about the same as now, falling far short of covering all costs. In relation to the amount of traffic they bear, some segments of the waterway system cost much more to operate than others. This finding suggests that users of low-cost waterways subsidize those of high-cost waterways. Many tow operators use both low-cost and high-cost waterways, however, thus complicating assessment of the amount of cross-subsidy.

Chapter One

Introduction

In recent years, the combination of budgetary pressures at all levels of government and increasing demands on transportation facilities has generated increased interest in directly charging users of public infrastructure. As a result, alternative ways of setting prices for the use of highways, airways, and waterways, and the advantages and disadvantages of different approaches, are of vital concern.

One key characteristic of the transportation infrastructure is that investments are costly, but once made can accommodate individual users at relatively low marginal costs (up to the point where congestion becomes important, after which the marginal cost rises steeply). Once a highway has been built or a waterway dredged, the cost of accommodating an additional automobile or barge tow is usually quite small. Thus, if users were charged a price equal to the marginal cost--the rule prescribed by economic theory to achieve efficiency in allocating resources--there would not be enough revenue to cover the total cost of the investment.

The dilemma is how to balance objectives of efficiency and revenue when they seem to conflict. Economic theory suggests pricing structures that allow revenues to be raised while preserving most of the economic efficiency derived from marginal-cost pricing. This chapter provides an introduction to the economic principles underlying these schemes.

Federal Financing of the Transportation Infrastructure

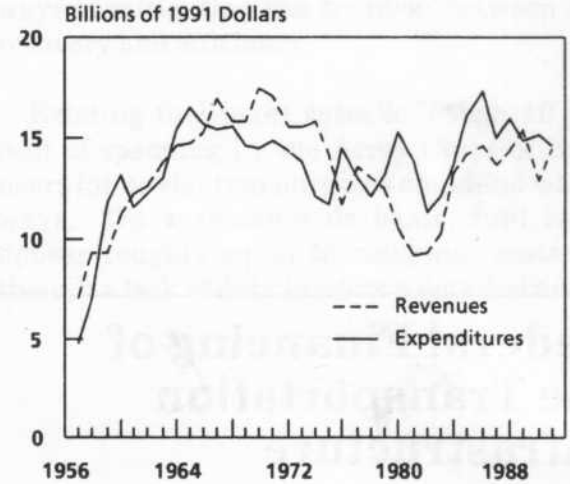
The federal government finances the construction and maintenance of highways, airways, and waterways through a mixture of general revenue funds and excise taxes levied on users. Over the past five years, federal outlays, in 1991 dollars, on these parts of the transportation infrastructure totaled $108 billion.[1] Revenues from excise taxes amounted to $91 billion. General revenues financed the balance of $17 billion. These total figures, however, do not show how much of the costs are recovered in each mode.

Figures 1, 2, and 3 show how trust fund revenues have correlated with expenditures since the formation of the highway, aviation, and inland waterway trust funds.[2] The high-

1. Outlays in a given year also include construction contracts signed in previous years for which money is now being spent. Thus, revenues collected in a year need not correspond exactly with the amount spent on users in that year. Over five years, however, the difference is likely to be smaller than in a given year.

2. As discussed in Chapters 2, 3, and 4, the laws governing the trust funds specify the kinds of spending that are authorized from them. For aviation and waterways, some kinds of spending are authorized from the general fund, not from the trust funds. The figures presented here simply compare spending with revenues from taxes related to use.

Figure 1.
Federal Highway Expenditures and Trust Fund Revenues, 1957-1991



SOURCES: Congressional Budget Office and "Historical Tables" of the *Budget of the United States Government: Fiscal Year 1992*. GNP deflator from the *Economic Report of the President, February 1991*.

NOTE: Figure 1 shows only revenues that go to the highway account of the Highway Trust Fund.

way trust fund began earmarking taxes for spending on roads in 1957, the aviation trust fund started in 1971, and the inland waterways trust fund began in 1980.

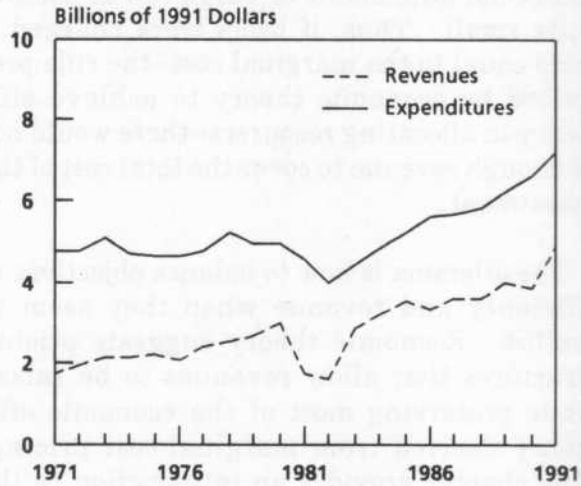
Highway tax revenues have been dependent on the state of the economy--falling, for example, during the recession of the early 1980s (see Figure 1). Spending on highways has fluctuated over the years because of a combination of economic conditions, changes in the scope of the highway program, and changes in the limits on obligations that could be incurred.

Aviation excise tax revenues, of which passenger ticket tax revenues formed the major part, dipped during 1981 and 1982 (see Figure 2). The reasons were a change in the ticket tax rate from 8 percent to 5 percent and the 1981-1982 recession.[3] Aviation expenditures remained at roughly the same level until 1986 (with a small drop in 1981 and 1982 because of the air traffic controllers' strike and its aftermath). Since then, spending has risen steadily, driven by the costs of developing and installing new technologies in air traffic control.

Tax revenues from traffic on inland waterways, shown in Figure 3, have remained about the same, in real terms, since the founding of the Inland Waterway Trust Fund. Spending on inland waterways declined in the early 1980s because of a hiatus for several years in the authorization of new construction projects. Spending rose after new authorization in 1986.

When expenditures are compared with trust fund revenues, federal spending on highways approximately balances federal revenues. Aviation revenues are consistently below expenditures. On a percentage basis, the inland waterway system is the most heavily subsidized of the three modes of transportation, although aviation is more heavily subsidized in absolute terms.

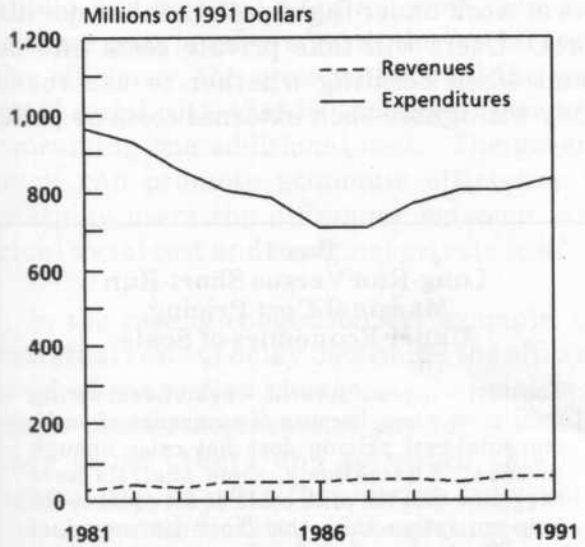
Figure 2.
Federal Aviation Expenditures and Trust Fund Revenues, 1971-1991



SOURCES: Congressional Budget Office and "Historical Tables" of the *Budget of the United States Government: Fiscal Year 1992*. GNP deflator from the *Economic Report of the President, February 1991*.

3. The dip in revenues during 1981 and 1982 was also caused by the expiration or decline of all other aviation excise taxes besides the passenger ticket tax between October 1980 and September 1982.

Figure 3.
Federal Inland Waterway Expenditures and Trust Fund Revenues, 1981-1991



SOURCES: Congressional Budget Office; Army Corps of Engineers, *1990 Inland Waterway Review* (draft); and "Historical Tables" of the *Budget of the United States Government, Fiscal Year 1991*. GNP deflator from the *Economic Report of the President, February 1991*.

Economic Efficiency and Other Goals

Economic efficiency is defined as the allocation of resources that produces the greatest satisfaction of wants within the constraints of scarce resources and technological limits. Resource allocation is considered efficient when no one can be made better off without making someone else worse off.

Cost recovery is also significant in deciding how to allocate resources, and it is especially important to deficit-ridden governments as they attempt to meet growing demands. The need to finance investment in the transportation infrastructure has led officials to seek ways of recovering a larger share of costs from users of the systems. Many previous studies have focused on cost recovery (or subsidy reduction) as the primary purpose of user fees. This study emphasizes economic efficiency and the trade-offs between efficiency and cost recovery.

Fairness is another issue. While efficiency is concerned with increasing the size of the resource pie, equity is concerned with its distribution. Changes in user taxes or user fees are likely to have different impacts on different users. It is important that the results be considered fair.

Finally, in government programs, administrative feasibility is a concern. A fee or tax system designed to increase economic efficiency may be so complex that the costs of collection and enforcement outweigh the benefits. Economic efficiency and administrative feasibility must be balanced.

The Role of Prices in Fostering Economic Efficiency

In a market economy, prices serve three key functions: they provide incentives for efficient allocation of resources, serve as a mechanism to recover the cost of production, and signal whether additional capacity is needed. If the price of a good or service is equal to the value of the resources used in producing it, resources are allocated to their most efficient use. If a good or service is provided free of charge or heavily subsidized, people tend to demand more of it and to use it more wastefully than they would if they had to pay a price that reflects its costs. The federal government can promote efficient and productive use of the goods and services it provides and controls by charging prices that reflect the cost of resources.

Designing user charges would be easier if a single fee structure could satisfy all of the objectives--namely, cost recovery, equity, and efficiency. Unfortunately, a fee structure that satisfies one or two of these objectives often violates the third. But the problem is not

surprising. It is often an important reason for government to provide the good or service. If the private sector cannot recover costs by charging users, it usually will not provide the good or service. If society judges that the benefits from the good or service are great enough to justify the expenditure, it is left to the government to provide it.

The Prescription for Efficiency: Set Price Equal to Marginal Cost

To achieve efficiency, the price of a service should equal its marginal cost--or, to be more precise, its marginal social cost in the short run. (See Box 1 for a discussion of long-run and short-run marginal costs.) The marginal cost is the value of the resources used in producing one more unit of service.

On the demand side, users compare the price of a good or service with the expected benefit of buying an additional unit. If the price is greater than the marginal benefit, users will not buy it; if the price is less than the marginal benefit, they will. When the marginal benefit equals the price and the price equals the marginal cost, resources are allocated efficiently and consumer welfare is increased to the maximum. On the one hand, if users are charged less than the marginal cost, they may be encouraged to overuse the service. On the other hand, if users are charged more than the marginal cost, they will be discouraged from using the service, even though they are willing to pay the cost of the marginal unit. Either way, resources will be used inefficiently.

Externalities and Social Costs

Some of the costs of using infrastructure are not incurred directly by the user or producer but by other members of society. These are called "external costs" or "externalities." For example, an additional automobile on a crowded highway imposes costs of delay on other motorists. Motor vehicles emit pollutants that make the air less healthy for motorists and nonmotorists alike. Aircraft noise detracts from the quality of life of people who live or work under flight paths near major airports. Users will take private costs into account when deciding whether to use roads. They will ignore such external costs as pollu-

Box 1.
Long-Run Versus Short-Run Marginal-Cost Pricing Under Economies of Scale

The text suggests several ways of recovering total costs when, because of economies of scale, marginal-cost pricing does not raise enough revenue. Alternatively, some analysts have suggested that the price could be set equal to the long-run rather than the short-run marginal cost. The long run is defined as a period in which all inputs can vary--that is, a period during which capital investments can be adjusted to an optimal level. For instance, in the long run, a highway can be built to the capacity needed to satisfy demand. Since investment can be adjusted in the long run to achieve optimal size, it follows that long-run costs can be viewed as the lowest costs that might occur in the short run for a given capacity. But capacity is not always optimal in the short run. If a shortage of capacity leads to congestion, for instance, the short-run marginal cost will exceed the long-run marginal cost. The efficient price would equal the short-run marginal cost; if the price were set equal to the long-run marginal cost, the result would be even more congestion.

Advocates of charging prices equal to long-run marginal costs imply that this approach will cover investment costs, since the cost of investment is an increment of costs. But this incremental cost applies only to the first use of the new facility. For each successive use--for example, the second and subsequent automobiles on a highway after it has opened--the marginal cost continues to be low in relation to the cost of the investment. Charging the first user of the new highway the entire cost of building it clearly is not feasible.

To get around this problem, some analysts suggest assigning increments of new investment to groups of users and charging a kind of average incremental cost divided by the number of users. But this does not yield the efficiency associated with marginal-cost pricing. The source of the problem remains the increasing returns to scale. Once the fixed capital is in place, the marginal cost of one additional user is often very small.

tion and noise, however, and thus will use more than the efficient amount.

An efficient price must reflect the private, public, and external marginal costs. The sum of these costs is referred to as the "social cost." For efficiency, the price must equal the marginal social cost--that is, the cost to society of consuming one additional unit. The government can promote economic efficiency by charging users the difference between marginal social cost and marginal private cost.

In the case of congestion, for example, the marginal costs of delay determine the efficient level of congestion charges. The goal is to make users recognize and pay for the delay they cause others and to weigh this cost against the benefits they derive from using the congested facility. If congestion charges are set too high, the additional benefits will be outweighed by the price (to the user) and usage will fall below the amount that the facility could sustain. If the charge is too little, the system will be overloaded.

Joint Costs

Although some costs are clearly associated with certain services, many costs of transportation infrastructure are joint costs. Joint costs are those incurred in simultaneously producing more than one service. For instance, a dam may aid navigation and control flooding. After subtracting any costs that are clearly attributable to navigation and those that are clearly attributable to flood control, assigning the remainder of the cost to either purpose is essentially arbitrary.

How, then, could the government charge users for joint costs? If efficiency is the goal, there should be no charge, since the marginal cost is zero. If cost recovery is the goal, the government must devise a way of allocating costs. One widely advocated approach is to allocate costs according to the benefits received by each user or class of users. The Federal Highway Administration, the Federal Aviation Administration, and the Army Corps of Engineers have developed procedures for allocating joint costs among users of highways, airways, and waterways.

Taxes, User Fees, and Marginal Costs

Users of transportation infrastructure are taxed to help finance the facilities. These levies include taxes on gasoline, diesel, and other motor fuel; trucks and equipment; airline passengers and freight; fuel used by general aviation, and fuel used by tow operators on specified inland waterways. If these taxes closely reflected the marginal costs of infrastructure use, they would serve as good proxies for prices and would encourage efficient use. But existing taxes do not generally reflect the marginal costs. They raise revenues, but they do not necessarily provide the proper signals for efficient use. This does not mean that taxes are always less efficient than user fees. Taxes can be designed to be efficient, and user fees can be inefficient in design.

Although taxes imposed on users are sometimes called user fees, a distinction should be made between taxes and user fees. Taxes may or may not be closely related to the cost of using a facility; their primary purpose is to raise revenues. User fees, however, are more closely related to the cost of using a facility. For example, tolls are generally considered user fees, while excise taxes on fuels are considered just taxes.

Cost Recovery Under Economies of Scale

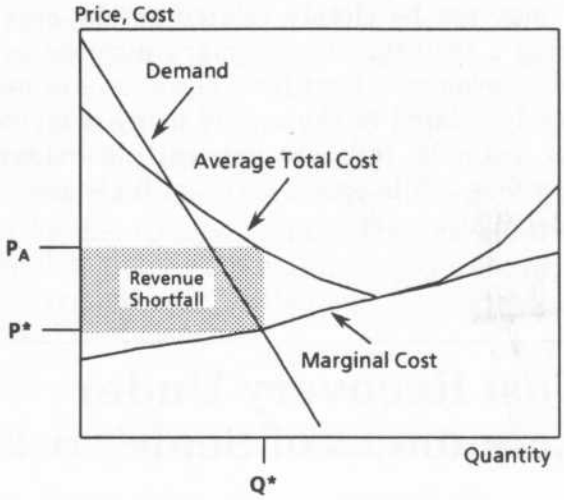
Transportation infrastructure is often characterized by economies of scale (see Box 2). Fixed costs tend to be large compared with marginal costs. The marginal cost of one additional automobile on an uncongested highway is quite small when compared with the cost of

Box 2.
Costs, Revenues, and Economies of Scale

"Economies of scale" means that the cost per unit falls as greater numbers are produced. One implication is that the marginal cost is less than the average total cost. Setting the price to be equal to marginal cost fails to cover the average total cost.

The cost structure of a firm characterized by economies of scale is illustrated in the figure below. The demand curve--which shows the quantity demanded at each price--intersects the marginal cost curve where the average total cost is greater than the marginal cost. The efficient quantity of output is shown as Q*, the quantity at which the demand (price) equals the marginal cost. But, as the figure shows, at this price and quantity, total costs (equal to quantity Q* times the average total cost of producing that quantity, shown as P_A) exceed total revenues (quantity Q* times price P*). The revenue shortfall is shown as a rectangle. The objective is to find a way of producing an efficient quantity while also covering total costs.

The Cost Structure of a Firm Characterized by Economies of Scale



SOURCE: Paul A. Samuelson and William D. Nordhaus, *Economics*, 12th ed. (New York: McGraw Hill Book Co., 1985), p. 525.

NOTE: The marginal cost curve intersects the average total cost curve at the latter's minimum point.

building and maintaining the highway. Once a waterway is dredged, the cost of one additional tow or ton-mile (the movement of one ton the distance of one mile) is small. One additional airplane in uncongested airspace imposes little cost on the air traffic control system. Because marginal costs are relatively low, charging a price equal to the marginal cost usually will not raise enough revenue to cover the total cost.

Deciding on a trade-off between efficiency and cost recovery when there are economies of scale is essentially a political choice. But there are ways of decreasing the inefficiencies of diverging from marginal-cost pricing while raising additional revenue.

General Subsidy

One way to recover costs is to charge users the marginal cost and make up any shortfall in revenues with subsidies from general government funds. This approach employs a simple pricing structure to encourage efficient use. One disadvantage is that the taxes used to raise general fund revenues may themselves distort incentives for efficiency. For example, individual income taxes--the source of 45 percent of federal receipts in 1991--may affect people's decisions about investing or dividing their time between work and leisure in ways that reduce productivity in the economy. Another disadvantage of using general revenues is that people who pay for something they do not use may perceive that financial policy as unfair.

Price Discrimination

Another approach to cost recovery is to divide users into different classes and charge them different prices. Airlines, railroads, telephone companies, electric and gas utilities, and other industries with large fixed costs practice price discrimination extensively. The idea is to charge a higher price to--and recover a greater share of costs from--users whose demand is

relatively inelastic, while charging a lower price to attract marginal customers.

Ramsey Pricing

Ramsey pricing, which calls for charging users according to their elasticities of demand (the percentage change in the quantity demanded in response to a percentage change in price) is a technique that uses price discrimination.[4] It is a "second best" pricing rule in the sense that it departs minimally from the "first best" rule of price being exactly equal to marginal cost. Ramsey pricing increases economic welfare while meeting a revenue constraint (typically that the organization break even or earn a target rate of return). It is an efficient pricing mechanism because each use is charged a price that is as close as possible to the marginal cost of supply. Users who value a commodity most (as reflected by inelastic demand) receive larger adjustments to price in order to equate needed total revenue with total cost. Ramsey pricing transfers some of the consumers' surplus to the producer--in the case of highways, airways, and waterways, the federal government. It allows total costs to be covered while meeting the efficiency criterion of setting the price equal to the cost of the marginal unit.

Ramsey pricing has some disadvantages. One is the information requirement. Estimating different users' elasticity of demand is often difficult, as is administering a system that employs different prices for different users. Another disadvantage of Ramsey pricing is that it often cannot be sustained over the long run because users who are charged higher prices seek alternatives. When railroad rates were strictly regulated, for example, the relatively high rates charged for transporting manufactured goods induced many shippers to switch to trucks.

Users with inelastic demands might complain about the inequity of paying more for a service because they have the fewest alternatives. But as long as the price paid for each unit of output exceeds the marginal cost, all users benefit; the excess of price over marginal cost contributes to overhead costs and makes it possible to continue providing the service.

Two-Part Tariffs

A two-part pricing mechanism is still another way to handle the problem of high fixed and low marginal costs.[5] Users could be charged a flat rate--a kind of admission fee allowing them access to infrastructure--to cover the fixed costs and a per-use price to reflect the marginal cost. Barge companies, for example, could be charged a fixed fee for a license entitling them to operate on the inland waterway system (or part of the system) plus a fee per use reflecting the marginal cost.

This approach preserves the incentives for efficiency of marginal-cost pricing while raising revenue to cover fixed costs. One disadvantage might be a perception of inequity arising from the fact that all users would face the same fixed fee, regardless of whether they used the service regularly or only occasionally. Another disadvantage is that some users who might be willing to pay the per-use price might not be willing or able to pay the fixed fee. A two-part tariff loses efficiency if users who are willing and able to pay the marginal cost are denied service. These disadvantages could be tempered by allowing users

4. Frank Ramsey, "A Contribution to the Theory of Taxation," *Economic Journal*, vol. 37 (March 1927), pp. 47-61. See also William J. Baumol and David F. Bradford, "Optimal Departures from Marginal Cost Pricing," *American Economic Review*, vol. 60 (June 1970), pp. 265-283; Elizabeth E. Bailey and Lawrence J. White, "Reversals in Peak and Offpeak Prices," *Bell Journal of Economics and Management Science*, vol. 5, no. 1 (Spring 1974), pp. 75-92; and Stephen Brown and David Sibley, *The Theory of Public Utility Pricing* (New York: Cambridge University Press, 1986), p. 50. The last offers a numerical example as well as a complete exposition of Ramsey pricing.

5. For an early discussion of two-part pricing, see Walter Y. Oi, "A Disneyland Dilemma: Two-Part Tariffs for a Mickey Mouse Monopoly," *Quarterly Journal of Economics*, vol. 85, no. 1 (February 1971), pp. 77-90. See also Brown and Sibley, *The Theory of Public Utility Pricing*.

If existing infrastructure services are priced, the reaction of users can provide information about their demand for new services.

to choose between paying a large entry fee and low unit price, or no entry fee but a relatively high price per use.

Average-Cost Pricing

An alternative to marginal-cost pricing as a way of raising enough revenue to cover costs is to charge users the average cost of the services.[6] By definition, this approach ensures that total costs will be covered by revenues. But some efficiency is lost, since the average-cost price exceeds the marginal cost. Users who value an additional unit of service at more than the marginal cost but less than the average cost will not be willing to pay a price as high as the average cost. Thus, they will not buy more of the service, even though they place a higher value on it than it costs to produce. The resulting output will be less than the efficient amount.

The main advantage of average-cost pricing is that it raises enough revenue to cover total costs. It also may be perceived as equitable, since all users pay the same price for a service.

6. Where there are joint products, however, average costs cannot be precisely defined.

Equity Considerations

Adopting a more efficient system of user fees would probably have distributional consequences. Some users would wind up paying more, and some less, than they do now.

Economists use several concepts of equity in assessing taxes or user fees. One is that similarly situated individuals should be treated similarly. Another is that individuals who have more money should pay higher taxes than those who have less. A third concept of equity is that people who derive benefits from a service should pay for it.

Administrative Feasibility

One of the disadvantages of alternative pricing schemes is that they are difficult to administer. There are well-developed systems for collecting and enforcing taxes on users of transportation infrastructure. New administrative mechanisms would be needed if user fees reflected marginal costs.

As discussed in the following chapters, marginal costs associated with use of infrastructure have been estimated, but additional refinements would be desirable if the estimates were to be the basis for user fees. If the Congress expressed interest in pursuing cost-based user fees, however, researchers would probably step up their efforts to determine the efficient level of fees and to develop collection and enforcement mechanisms. Increased interest by policymakers in toll roads, for instance, has stimulated development of electronic toll collection, and the concern of the states about truck weights has prompted development of mechanisms to weigh trucks while they are moving at highway speeds. Efforts of states to comply with the Clean Air Act have generated research on the costs of vehicle emissions.

At the federal level, improved cost accounting is needed to generate the data that would make efficient charging possible. The Chief Financial Officers Act of 1990 calls for improved accounting systems and procedures. Although the focus is on financial management, the law also provides for developing and reporting cost information.

Finally, more information about the demand for transportation infrastructure would illuminate the expected responses to alternative pricing arrangements. This outcome would be especially helpful for designing efficient schemes of pricing and estimating the revenue impacts. Efficient prices also would help predict how users might change their patterns of use--including possible shifts between rail and barge or trucks and rail.

Efficiency in Investment

This study focuses on using prices to create incentives for efficient use of the existing infrastructure in the short run. But prices can also play a role in making efficient investments in new infrastructure.

Benefit-Cost Analysis

Investment decisions typically are guided by benefit-cost analysis, which estimates expected benefits and costs over the life of an investment. Estimating the benefits of a public investment project can be difficult, however, especially if indicators of demand--how much users are willing and able to pay--are not available. If existing infrastructure services are priced, the reaction of users can provide information about their demand for new services. The amount users are willing to pay to alleviate congestion delays, for instance, can suggest how expanding capacity would be beneficial.

In some cases, there may be an economic rationale for not charging users the full cost of the system. If an investment provides benefits to nonusers, such as economic development or national defense capabilities, the beneficiaries of these external benefits could be charged or taxed accordingly.

Charging for Prospective Investments Versus Past Investments

In considering efficient pricing mechanisms, a distinction should be made between existing capital and future investments. Past investments can be regarded as sunk; that is, whatever resources have gone into them have already been spent. What is relevant for economic efficiency is that prospective resource allocation be cost beneficial. If the marginal cost of using a past investment is zero, economic efficiency would require that users not be charged because even a small fee might cause use to decrease when the resource cost of doing so is less than the value. That would diminish efficiency.

This leaves open the question of whether the prospect of having to pay fees for using a new investment can help shape the demand for that investment. If users expect to pay fees for an investment, they may press more vigorously for an efficient investment than if it were paid for out of general tax revenues.

The Transition from Taxes and Subsidies to Prices

Any change in user fees could impose significant costs on whole industries or individual classes of users of transportation infrastruc-

ture. The questions then arise: how great would the difficulties of transition be, and what steps could be taken to ameliorate them?

The Costs of Transition

Many of the user fees considered in this study would not greatly increase the total economic burden on users. Since highway expenditures are already in balance with highway excise taxes, user fees would only redistribute the burden of its cost among the classes of users. Similarly in aviation, the revenues from passenger ticket taxes appear to cover the costs that commercial airlines impose on the aviation system.

For some groups, however, the burden of user fees would increase substantially. If asked to cover their costs, barge operators would face much larger fees than they now pay in fuel taxes. General aviation users would also face a steep increase in their operating costs if fees were set to recover the costs they impose on the aviation system.

In addition, many private-sector investment decisions are based on the existence of public subsidies, and imposing user fees to reduce these past subsidies could create difficulties. Barge operators on the inland waterway system have come to expect the subsidies they receive. Large increases in user fees could jeopardize some of their operations and the businesses of their suppliers and customers. Similarly, trucking companies have made decisions about investments in trucks and trailers in part on the basis of the current tax structure, as well as on federal and state policies regarding truck size and weight. If fees based on axle weight and distance traveled were imposed, trucking companies would incur the costs of altering their fleets to reduce costs.

Easing Transition Problems

Gradually imposing user fees could help such users to adjust to new cost conditions. Fees phased in over a period of years could allow users to absorb new operating costs. But phasing in user fees would delay the benefits of recovering federal costs and realizing gains in economic efficiency. Such delays, however, might be worthwhile if they would ease the transition to a system that would yield the net long-term gain to the economy that user fees on transportation infrastructure would deliver.

Conclusion

The economic principles set forth in this chapter provide a framework for assessing the current set of taxes imposed on users of transportation infrastructure. As discussed in the following chapters, the existing taxes fall short on the efficiency criterion. Alternative financing mechanisms that more closely resemble marginal-cost pricing could promote greater efficiency in infrastructure use.

Chapter Two

Highways

Deteriorating roads and increasing traffic congestion are often cited as being detrimental to our nation's quality of life and impediments to its productivity. The Federal Highway Administration (FHWA) reports that

> Highways in poor condition cost users as much as 25 to 30 percent more per mile than highways in good condition. Highly congested peak-period travel . . . can add as much as 35 percent to the unit operating and time costs of a commercial vehicle. Every 1 percent increase in highway user costs adds about $15 billion to the Nation's total highway bill . . . .[1]

How can these problems be alleviated in an environment of tight budgets at all levels of government? What can be done at the federal level? For one thing, user charges could provide incentives for more efficient use of the nation's highways. More efficient use of roadways can enhance their productivity and prolong their life, thereby reducing the need for additional investments.

Highways are financed primarily through taxes on fuels, vehicles, and equipment used by motorists. Although this arrangement adheres to the principle that users of roads should pay for them, current taxes provide little or no incentive for efficient use of highways. The taxes paid by different kinds of highway users--automobiles and trucks, in urban and rural areas--correlate only roughly to the costs imposed by different groups. For example, an automobile driven at rush hour in a major city incurs the same federal fuel tax as one driven on an uncongested rural highway (assuming they use the same amount of fuel per mile). But the automobile driven in heavy traffic imposes congestion costs on other motorists and may--depending on the ambient air quality--add significantly to environmental pollution.

The fact that existing taxes do not correlate well with costs has led planners to seek taxes or charges that do. Researchers have made progress recently in finding practical alternative mechanisms for pricing. One proposal that has received considerable attention is a fee based on distance driven and weight supported by each axle of a vehicle. This approach would better represent the cost of pavement damage and encourage operators of heavy trucks--which do a disproportionate amount of damage to pavement--to spread the weight over more axles and thus reduce road damage. A fee or toll reflecting the costs of delay of an additional vehicle on a congested highway could help alleviate congestion by inducing some motorists to shift to less congested times or places, or to another mode of transport. A fee that also reflected pollution costs would provide incentives to reduce vehicle emissions.

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1. *The Status of the Nation's Highways and Bridges: Conditions and Performance*, Report of the Secretary of Transportation to the United States Congress pursuant to Sections 307(e) and 144(i) of Title 23, U.S. Code (September 1991), pp. 4-5.

The principle of designing efficient charges for congestion, weight, distance, and pollution is well developed: set the price equal to marginal social cost. Analysts have made rough estimates of the marginal social costs of these factors, although additional research to update and refine the estimates--especially of emissions costs--would be desirable. Efficient pricing could raise enough revenue to reduce or eliminate existing taxes.

Background

The federal government collects and distributes funds for highways. In 1990, it disbursed about $15 billion in grants to states from federal taxes levied on highway users. State and local governments raised and spent another $60 billion on roads, for a total of about $75 billion.[2]

Although the federal government's share of highway finance is just one-fifth of the total, it plays an important role in highway policy, for several reasons. First, the absolute amount of money spent on highways is quite large. Second, the federal government attaches conditions to its financial aid. It allocates money to projects and requires the states to contribute matching funds. It also sets standards and rules governing the construction and operation of highways built with federal aid. Policies affecting highways built with federal aid often affect local streets and roads as well. Finally, the federal government provides technical assistance, research and development, and leadership in trying new solutions to the many problems confronting state and local highway officials.

In the debate over the 1991 reauthorization of the federal-aid highway program, the principal concerns were how to allocate federal aid among the states and how to design the program--the types of highways to receive federal aid, how the federal government and the states would share the costs, and the conditions that the federal government attached to aid to the states. Less attention was paid to pricing. But the Congress recognized that the scarce resources available for highways must be used ever more productively. The result was provisions for toll roads, experimentation with congestion pricing, and increased funding for research. Technological advances from research on intelligent vehicle/highway systems (IVHS) are expected to provide opportunities for new pricing mechanisms that promote more efficient use of the highway system, alleviate congestion, and indicate where additions to capacity are needed most.

The federal government can affect incentives for efficiency through its choice of financing mechanisms, such as taxes on motor fuels and heavy trucks and equipment, fees based on vehicle weight and distance driven, and fees reflecting costs of congestion and pollution, and through the regulations it imposes on states as a condition of federal aid. Restrictions on the ability of the states to impose tolls, for instance, can dramatically affect efficiency as well as financing ability.

Since state and local governments finance and control policies over most of the nation's roadways, the federal government influences highway efficiency indirectly. Even when the federal government pays most of the cost of a road, it turns ownership and management over to the state and local governments. But the federal government can assist the states in several ways. It can encourage efficiency, especially where it provides money with strings attached; coordinate policies and resolve conflicts among states; provide leadership in developing and putting into effect new ways to improve efficiency; and refrain from inhibiting state and local efforts to promote efficiency, especially when the effects are felt primarily at the state or local level.

2. Department of Transportation, Federal Highway Administration, *Highway Statistics 1990*, Table HF-10, p. 42. The last year for which final state data and estimates of local data are available is 1990.

Federal Spending on Highways

In 1991, the federal government obligated $16.3 billion for highway programs. Most of the money was for grants to states. States match these funds to build new highways and bridges and make major improvements to existing ones. The federal government pays from 75 percent to 90 percent of the cost and the state pays from 10 percent to 25 percent for projects that comply with federal requirements.[3] The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) provides a federal share for most projects of up to 80 percent. For Interstate Highway construction, the federal share is 90 percent, and for construction or expansion of facilities primarily for single-occupant vehicles, the maximum federal share is 75 percent. Before the 1991 act was passed, the federal government's share was generally as follows: Interstate Highway System and safety construction projects, 90 percent; bridge projects, 80 percent; most other projects, 75 percent. States with large tracts of federal land may receive a larger proportion of federal aid.

The federal government distributes highway funds to the states on the basis of formulas prescribed by law. The formulas are based on such factors as miles of highway, area, rural and urban population, and vehicle-miles traveled.[4] Each state is guaranteed a minimum share of funding based on its estimated contributions to the Highway Trust Fund.

The federal government attaches conditions to its aid to force states to comply with national policies. For instance, the federal government withholds funds from states that allow trucks heavier than those permitted under federal law. States must spend at least 10 percent of the amount authorized for highways on purchases from small businesses owned and controlled by socially and economically disadvantaged individuals. States also must comply with "Buy America" provisions.

In the past, the federal government generally prohibited states from charging tolls on roads built with federal aid. The rationale for this prohibition, which dates back to the original Federal Aid Act of 1916, was that free and open highways stimulate economic growth and development. But as early as 1927, the Congress allowed exceptions to this policy, recognizing that toll financing would enable additions to highway capacity sooner than would otherwise be possible. Section 1012 of the Intermodal Surface Transportation Efficiency Act of 1991 allows the federal government to pay up to 50 percent of the cost of toll highways, bridges, and tunnels. It also permits a federal share of up to 80 percent of the cost of rehabilitating existing toll facilities or converting existing free facilities to toll facilities. Section 1008 of ISTEA establishes a program to ease congestion and improve air quality. Together these policies could help improve traffic management, alleviate congestion and pollution, and encourage more productive use of the existing highway system.

Current Financing Policy

Federal highway spending is financed by taxes paid by highway users. Excise taxes on gasoline, diesel fuel, and other fuels are the largest source of revenue; in 1991, they brought in about $15.5 billion, or 89 percent of revenues from taxes on highway users. Excise taxes on heavy trucks and trailers generated $1.0 billion, or 6 percent of revenues, in 1991.

3. For a thorough explanation of how the federal aid program works, see Department of Transportation, Federal Highway Administration (Legislation and Strategic Planning Division), *Financing Federal-Aid Highways*. This volume was last published in November 1987 but is being revised to reflect the ISTEA of 1991.

4. For apportionment formulas, minimum allocations, and their underlying statutory authority, see Department of Transportation, *Financing Federal-Aid Highways*, Appendix C-1, pp. 54-56.

Taxes on tires and heavy vehicles accounted for the remaining 5 percent.

Revenues increased by about $3.5 billion in 1991 as a result of increases of 5 cents a gallon in tax rates on most motor fuels provided under the Omnibus Budget Reconciliation Act of 1990 (OBRA). The tax rates on motor fuels before and after the passage of OBRA are shown in Table 1. Most of the revenues from these taxes are deposited in the Highway Trust Fund, from which grants to states are made.[5]

Table 1.
Federal Tax Rates on Motor Fuels Before and After the Omnibus Budget Reconciliation Act of 1990 (OBRA) (In cents per gallon)

	Pre-OBRA[a]	Post-OBRA
Gasoline	9.0	14.0
Diesel Fuel	15.0	20.0
Special Fuels	9.0	14.0
Gasohol[b]	3.0	8.6
Diesohol[c]	9.0	14.6
Ethanol[d]	3.0	8.6
Methanol[e]	3.0	8.6
Fuels from Natural Gas	4.5	7.0

SOURCE: Internal Revenue Code, 26 USC 4081.

NOTE: An additional 0.1 cent a gallon tax is collected and deposited in the Leaking Underground Storage Tank Trust Fund.

a. Tax rates from 1985 through November 30, 1990.

b. Mixture of at least 10 percent ethanol or methanol made from biomass, and 90 percent gasoline.

c. Mixture of diesel and 10 percent alcohol made from biomass.

d. Ethanol containing at least 85 percent alcohol and not derived from petroleum or natural gas.

e. Methanol containing at least 85 percent alcohol and not derived from petroleum or natural gas.

Gasoline and Other Fuel Taxes

The federal gasoline tax is 14 cents a gallon, and the diesel fuel tax is 20 cents a gallon.[6] OBRA raised these taxes by 5 cents a gallon. In addition, OBRA eliminated or reduced favored treatment of other motor fuels, such as gasohol and diesohol. Until 1984, tax rates on gasoline and diesel fuel were the same. The so-called "diesel differential" was enacted into law as part of a compromise that reduced the direct tax on heavy vehicles; it is intended to reflect the fact that trucks do more damage to roads than automobiles.

Proponents of fuel taxes cite several advantages of using them as a source of highway financing:

- They are a lucrative source of revenue at both federal and state levels. Because the demand for fuel is relatively insensitive to small changes in the price, an increase in fuel taxes can be counted on as a revenue-raiser; a penny a gallon generates about $1 billion a year at the federal level.

- The general public seems to accept fuel taxes as a legitimate--and even desirable--way to raise funds for highways.

- Earmarking taxes for the benefit of users generally appeals to the public. Proponents of raising fuel tax rates note that people did not complain much about the 1990 tax increases, even though some of the revenues were to go to the general fund of the U.S. Treasury,

5. Until OBRA was passed, all revenues from fuel taxes were deposited in the Highway Trust Fund with the exception of 0.1 cent a gallon designated for cleanup of leaking underground storage tanks. One cent a gallon went into the transit account of the Highway Trust Fund, which was earmarked for mass transit projects. A provision that 2.5 cents a gallon is to be deposited in the general fund of the U.S. Treasury came with the fuel tax increases of OBRA. The amount designated for the transit account was increased to 1.5 cents a gallon.

6. An additional 0.1 cent a gallon is levied under Title 26, U.S. Code, Section 4091 to pay for cleanup of leaking underground storage tanks.

rather than the Highway Trust Fund, for the first time since the trust fund was established. These tax increases, however, came at a time when fuel price fluctuations resulting from the Persian Gulf turmoil may have been large enough to mask the tax increases at the pump.

- Finally, the mechanisms for collecting the fuel taxes are in place, and increases in tax rates add little to collection and enforcement costs.

As concerns about pollution and energy independence have mounted in recent years, fuel taxes have been proposed as incentives for reducing pollution and conserving energy. If the costs of pollution and energy waste could be determined, imposing fuel taxes reflecting these costs would lead to more economically efficient patterns of use. But a single policy tool, such as fuel taxes, cannot be counted on to achieve multiple policy goals, such as clean air, energy conservation, and highway financing. Therefore, if fuel taxes come to be viewed as a way of discouraging highway use--to promote environmental protection or energy security--the present policy of directing most of the revenues to the highway trust fund should be reexamined.

On the minus side, although fuel taxes are good revenue generators, they do not provide strong incentives for the efficient use of highways. The reason is that they do not correlate closely with actual costs imposed by specific users. Automobiles that get 35 miles to a gallon of gasoline impose about the same pavement and congestion costs as automobiles that get just 20 miles a gallon, assuming similar driving patterns. But the fuel-efficient cars pay far less in gasoline taxes than their gas-guzzling counterparts.

Even more important, fuel taxes do not adequately reflect different pavement damage caused by automobiles and trucks. Pavement damage rises rapidly as the weight borne by each axle increases. Although heavier trucks consume more fuel and therefore incur more fuel tax, pavement costs rise more rapidly with weight than do fuel tax revenues. For example, according to the American Association of State Highway and Transportation Officials (AASHTO), an 80,000-pound truck typically does twice as much damage per mile as a 50,000-pound truck, but uses only 14 percent more fuel.[7] The diesel differential of 6 cents a gallon does not pay for the damage done by trucks with heavy axle weights, but it overcharges light trucks and trucks that distribute their weight over more axles.

Vehicles incur approximately the same fuel taxes per mile regardless of whether they are driven on empty or congested roads. Although stop-and-go driving on congested roads diminishes fuel economy, it does not result in enough of an increase in fuel taxes to reflect the social costs of congestion, discourage use during peak hours, or signal the need for future investment.

Some states have developed tax structures based on vehicle weight and distance traveled.

Excise Tax on Trucks and Trailers

With certain exceptions, there is a 12 percent excise tax on the retail price of trucks and trailers. This tax raises relatively little revenue compared with fuel taxes: slightly more than $1 billion in 1991, or 6 percent of revenues from taxes on highway users. It bears

7. "Oregon Develops New System of Road User Taxation," *AASHTO Quarterly* (January 1991), p. 3.

little relationship to the costs the vehicle may impose on highways, since the price of a vehicle depends more on its special features or outfitting than on its weight. And, of course, the excise tax bears no relationship to mileage. This is critical for piggyback trailers, which travel long distances by rail and relatively short distances on local highways. Since the excise tax is tied to sales price, revenues rise with inflation. Although this characteristic neither adds to nor detracts from the efficiency of the tax, it provides an interesting contrast to fuel taxes, which are based on the physical unit of gallons and are not tied to inflation.

Heavy Vehicle Use Tax

The heavy vehicle use tax (HVUT) is an annual tax on heavy motor vehicles. For vehicles with gross weights of 55,000 to 75,000 pounds, the tax is $100 plus $22 per 1,000 pounds over 55,000 pounds; for vehicles with gross weights over 75,000 pounds, the tax is $550.[8] This tax generated $575 million, or 3 percent of highway tax revenues, in 1991.

The HVUT is intended as a method of charging heavy motor vehicles for the pavement damage they cause. But it is levied on an annual basis, without regard to how many miles the truck is driven or how much weight it carries. Since the tax is based on registered gross vehicle weight, it roughly reflects how heavy a truck's loads are likely to be--and therefore how much damage the vehicle would cause to pavement--but does not make allowance for the fact that some vehicles run more miles than others in empty backhauls. Although the HVUT generally varies in the same direction as highway damage, it does not increase with weight as rapidly as highway damage does. Nor does it account for differences in vehicle configuration, although spreading the same weight over more axles reduces pavement damage.

Excise Tax on Tires

New tires are taxed at 15 cents for each pound between 40 and 70, and $4.50 plus 30 cents for each pound between 70 and 90. Tires heavier than 90 pounds are taxed at $10.50 plus 50 cents for each pound over 90 pounds. Retread tires are not subject to this tax. The tax on tires generated about $357 million, or about 2 percent of revenues from highway sources, in 1991.

Since tires wear out with use, the tire tax varies with mileage and, to a lesser extent, with weight of load, and thus correlates with pavement wear. But the tax works perversely, since using additional tires to spread a truck's load over additional axles reduces the damage it does to the pavement. The exemption of retread tires also diminishes the ability of this tax to reflect costs.

Taxes at State and Local Levels

Although the federal government relies on taxes on motor fuels, vehicles, and equipment to finance highways, state and local governments draw upon a wider variety of revenue sources. In 1989 (the most recent year for which local data are available), 18 percent of highway spending financed by state sources came from receipts not related to highways, as did 93.9 percent of local highway spending financed by local sources (see Table 2).

Many of the user-related taxes imposed at the state level parallel those imposed at the federal level. Motor fuel taxes are the largest single highway-related revenue source at both federal and state levels. The structure of state fuel taxes generally follows that of the federal--expressed in cents per gallon--but some states also include an excise tax component that is a percentage of the sales price. If the revenues go to a general fund, the tax should

8. Lower rates apply for certain logging and farm trucks and others that drive relatively few miles on public highways.

not be considered a user tax. Registration fees for trucks are similar at the state and federal levels, as are registration fees for automobiles. Both are levied annually and often based on vehicle weight.

Table 2.
Funding from Own Sources for State and Local Highways, 1989

	Receipts (Thousands of dollars)	Percent
State Receipts from State Sources		
Highway Users		
Motor fuel taxes	11,641,684	45.3
Motor vehicle and carrier taxes	6,959,812	27.1
Tolls	2,500,162	9.7
Subtotal	21,101,658	82.0
General Sources		
General funds	1,455,562	5.7
Other state imposts	1,131,191	4.4
Miscellaneous state receipts	2,035,817	7.9
Subtotal	4,622,570	18.0
Total	25,724,228	100.0
Local Government Receipts from Local Sources		
Highway Users		
Local highway user revenue	837,057	4.3
Tolls	355,666	1.8
Subtotal	1,192,723	6.1
General Sources		
Property tax	4,302,805	22.1
General fund[a]	8,502,843	43.6
Miscellaneous	3,418,295	17.5
Bond proceeds	2,093,014	10.7
Subtotal	18,316,957	93.9
Total	19,509,680	100.0

SOURCES: Department of Transportation, Federal Highway Administration, *Highway Statistics 1989*, Table SF-3, p. 73, and *Highway Statistics 1990*, Table LGF-21, p. 106.

a. May include receipts from property taxes when they are commingled with general fund appropriations.

Tolls raised about $2.5 billion at the state level and about $355 million at the local level in 1989. They undoubtedly could have contributed still more to revenues if it had not been for restrictions imposed by the federal government. Tolls are often based on the number of axles for ease of enforcement. This basis provides an incentive to use fewer axles, a perverse incentive, since wear and tear on pavements increases at a disproportionate rate as more weight is loaded on an axle.

Some states have developed tax structures based on vehicle weight and distance traveled. Such taxes can promote efficient use of highways by making users recognize the pavement damage caused by heavy vehicles and creating disincentives to overload trucks.

Costs and Efficient Charges

The foregoing discussion suggests that federal taxes imposed on highway users do not correlate very well with the costs these users impose on highways. Designing efficient charges requires a good understanding of costs, especially marginal costs. Pavement and congestion constitute the two principal types of costs. Environmental costs make up a third category, about which less research has been done.

Pavement Costs

There are two basic approaches to the study of pavement costs. One is a "top-down" cost allocation study, which starts with total federal spending on highways and attempts to allocate it among different classes of users, such as heavy trucks, light trucks, and automobiles. The costs attributable to each class of users are then compared with the revenues generated by the taxes imposed on it. The other approach proceeds from the bottom up; it attempts to estimate the cost associated with each additional unit of use--the marginal cost.

It then compares the marginal cost with the marginal revenue from the taxes paid by users. This study focuses on the latter approach, since the primary concern is marginal-cost pricing. For comparative purposes, two top-down cost-allocation studies are discussed in the Appendix.

Factors Affecting Pavement Costs. What causes pavement to crack and crumble? Vehicles--especially heavy trucks--passing over pavement contribute to its damage and destruction, along with other factors such as weathering. Studies of pavement damage have attempted to sort out these factors and to calculate how much pavement cost to attribute to automobiles and trucks of different weights and configurations.

Cost studies generally find that pavement damage is a function of the weight carried on each axle of a vehicle, although there is some disagreement about the exact relationship between axle weight and damage. Pavement deterioration is also accelerated by adverse weather conditions, such as freezing and thawing. The precise relationship between weather and axle weight is not clear. There may be an interactive relationship in which additional use of vulnerable pavement is especially damaging; alternatively, weather may act independently of use.

Automobiles do very little damage to standard highway pavements. The size of a truck-trailer combination is less important than how much it carries and how the weight is distributed. Carrying a load of 26,000 pounds on two axles instead of three, for example, increases the marginal cost of pavement by a factor of four (see Table 3).

Two studies that have examined marginal costs are Appendix E of the Federal Highway Administration's *Highway Cost Allocation Study (HCAS)*, and *Road Work* by Kenneth A. Small, Clifford Winston, and Carol A. Evans.[9] (See Table 3 for selected common truck types and configurations, estimates of current taxes, and marginal costs of pavement maintenance.) Some configurations, such as three-axle single units with gross weights of 26,000 pounds, and five-axle tractor-semitrailers with gross weights of 33,000 pounds operating in urban areas, pay more in taxes than their marginal costs. Many other kinds of vehicles pay less than their marginal costs.

The authors of both *Road Work* and *HCAS* Appendix E started with the proposition that pavement damage is a function of the weight supported by each axle. Because vehicles come in many shapes and sizes, researchers must choose a standard unit by which they can measure and compare the loads that different vehicles impose on roads. The unit commonly used for this purpose is the amount equivalent to a single 18,000-pound axle load, called an equivalent standard axle load, or ESAL. (For estimates of pavement repair costs per ESAL-mile for different types of roads, see Table 4). The differences between the estimates of *HCAS* Appendix E and *Road Work* are caused by the fact that they use different functional relationships between axle weight and damage.[10] The jury is still out on the correct relationship, and new testing would be desirable if weight per axle were to become the basis for user charges.

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9. Department of Transportation, Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study*, Report of the Secretary of Transportation to the United States Congress Pursuant to Public Law 95-599, Surface Transportation Assistance Act of 1978 (May 1982). The main part of the *HCAS* is described in the Appendix. Because Appendix E of the *HCAS* took a different approach from that of the main volume, it is appropriate to distinguish between the two. Kenneth A. Small, Clifford Winston, and Carol A. Evans, *Road Work* (Washington, D.C.: Brookings Institution, 1989).

10. The source of both estimates is an experiment sponsored in the late 1950s by the American Association of State Highway Officials (AASHO), known as the AASHO Road Test. (AASHO has since become AASHTO, the American Association of State Highway and Transportation Officials.) Small and others explain their estimation procedure in the Appendix to Chapter 2 of *Road Work*. *HCAS* used the AASHO road test results, but the authors of *Road Work* took the data from the AASHO road test and reestimated the relationship using different econometric techniques. A critique of the analysis is contained in Michael T. McNerney and W. Ronald Hudson, "An Engineering Analysis of the Economics of Predicted Pavement Life" (paper presented at the 71st Annual Meeting of the Transportation Research Board, Washington, D.C., January 1992).

Pricing to Reflect the Marginal Costs of Pavement Damage. Drawing on their research linking vehicle weight and pavement damage, the authors of the studies discussed above have proposed prices that would reflect marginal costs and thereby promote efficient pavement use. Efficient charges are based on the weight loaded on each axle and on the distance traveled by the vehicle.

In the proposals developed by the authors of *HCAS* Appendix E (see Table 5), there are no charges for pavement damage done by automobiles, since the injury they do to roads is negligible. Efficient charges for pavement damage by trucks range from 5 cents a mile for a nine-axle tractor-semitrailer-trailer with a gross weight of 105,000 pounds on a heavy-duty road such as a highway on the Federal

Table 3.
Comparison of Marginal Cost Responsibility and User Taxes Paid, for Selected Truck Types, 1982
(In 1982 cents per vehicle-mile)

Vehicle Type, Gross Weight	Current Taxes	Marginal Cost[a]	Ratio of Taxes to Marginal Cost[b]
	Urban Travel		
Single Unit			
2-axle 26,000 pounds	2.52	9.16	0.28
3-axle 26,000 pounds	3.88	2.07	1.87
5-Axle Tractor-Semitrailer			
33,000 pounds	4.07	1.20	3.39
55,000 pounds	5.34	9.22	0.58
80,000 pounds	7.19	41.26	0.17
105,000 pounds	8.28	122.44	0.07
5-Axle Tractor-Semitrailer-Trailer			
55,000 pounds	6.01	10.04	0.60
80,000 pounds	7.85	44.92	0.17
	Intercity Travel		
Single Unit			
2-axle 26,000 pounds	1.95	3.21	0.61
3-axle 26,000 pounds	3.25	0.73	4.45
5-Axle Tractor-Semitrailer			
33,000 pounds	3.16	0.42	7.52
55,000 pounds	3.86	3.23	1.20
80,000 pounds	4.96	14.46	0.34
105,000 pounds	5.56	42.91	0.13
5-Axle Tractor-Semitrailer-Trailer			
55,000 pounds	4.44	3.52	1.26
80,000 pounds	5.54	15.74	0.35

SOURCE: Kenneth A. Small, Clifford Winston, and Carol A. Evans, *Road Work* (Washington, D.C.: Brookings Institution, 1989), Tables 3-4 and 3-5, pp. 45-46.

NOTE: The estimates shown here are based on current highway investment. Small, Winston, and Evans also provide estimates of marginal costs if investment levels were optimal.

a. Estimated marginal pavement cost under current investment.

b. A ratio of less than 1.0 indicates underpayment.

Table 4.
Estimates of Marginal Costs of Pavement (In 1982 cents per equivalent standard axle load mile)

Road Class	Marginal Costs: Brookings Institution	Marginal Costs: Federal Highway Administration
Rural Travel		
Principal Arterial		
Interstate	1.48	9
Other	4.38	21
Minor Arterial	10.02	a
Major Collector	16.49	28
Minor Collector	31.18	a
Local	101.3	50
Urban Travel		
Principal Arterial		
Interstate	2.38	25
Other freeways	4.32	66
Other	10.92	a
Minor Arterial	33.92	a
Collector	125.45	64
Local	40.92	80

SOURCES: Kenneth A. Small, Clifford Winston, and Carol A. Evans, *Road Work*, (Washington, D.C.: Brookings Institution, 1989), Table 3-3, p. 42; and Department of Transportation, Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study* (May 1982), Appendix E, Table 3, p. E-25.

a. Numbers for arterials and collectors are not split into major and minor.

Interstate System, to $4.08 a mile for a four-axle truck with gross weight of 100,000 pounds on a road built for light traffic. The cost estimates of the *HCAS* are out of date now, but they illustrate well the principles involved in setting prices that reflect marginal costs. Of special interest is the fact that the weight supported by each axle is much more important than the total weight. That is, if truckers spread their loads over more axles, their vehicles would cause far less damage to pavements.[11] Charging according to axle weight is a way of providing an incentive to do this.

The authors of *Road Work* developed a similar pricing structure, shown in Table 6. The numbers differ somewhat from those of the *HCAS*, reflecting *Road Work's* conclusion that the relationship between axle weight and pavement damage is less acute than that used in the *HCAS*. The *Road Work* estimates show (reading across the rows of the table) how quickly the efficient level of charges increases as gross vehicle weight increases, for any given vehicle. They also show that spreading the weight over more axles (reading down the columns) reduces efficient charges for any given weight.

Revenues from Marginal Cost Pricing of Pavement. If marginal cost pricing could raise enough revenue to pay for pavement, it could serve as an efficient substitute for federal fuel and other taxes. Unfortunately, estimating revenues is difficult because the required information is scarce. Data are lacking on distances traveled by various vehicles on various kinds of highways. Technological advances that enable officials to weigh vehicles while they are moving and to identify them automatically will facilitate collection of this information.

Revenues also depend on how truckers would respond to being charged by axle weight. If many respond quickly by shifting to equipment with more axles, revenues would be lower than under the present configurations.[12] Traffic might increase as loads are spread over more vehicles and more axles. More loads might be carried by rail instead of by truck, especially where piggyback trucking is feasible.

The authors of *Road Work* conclude that "... efficient pricing of heavy vehicles would fail to recover the entire public cost even of the pavement, much less of the entire highway."[13]

11. Adding axles does not necessarily entail making the vehicle combination longer. Vehicle combinations are subject to restrictions on length. The question of the maximum safe length is beyond the scope of this study.

12. In this case, of course, costs would also be lower.

13. Small and others, *Road Work*, p. 93.

Table 5.
Efficient User Charges for Selected Vehicles and Operating Conditions
(In 1982 cents per vehicle-mile traveled)

Vehicle Type and Gross Weight	Location	Traffic Volume	Pavement Repair	Excess Delay	Air Pollution	Noise	Total[a]
Automobiles (3,000 pounds)	Rural	Light	b	0.3	b	b	0.6
Automobiles (3,000 pounds)	Urban	Heavy	b	11.2	1.5	0.1	13.5
3-Axle Single Unit Truck (60,000 pounds)	Urban collector or local	Moderate	180.0	3.1	4.0	8.0	259.6
4-Axle Truck-Trailer (100,000 pounds)	Rural arterial	Light	408.0	0.3	b	0.2	504.0
5-Axle Tractor-Semitrailer (72,000 pounds)	Rural interstate	Light	8.0	0.4	b	b	14.6
5-Axle Tractor-Semitrailer (72,000 pounds)	Urban interstate	Moderate	24.0	1.4	3.0	4.0	49.0
9-Axle Tractor-Semitrailer-Trailer (105,000 pounds)	Rural interstate	Light	5.0	1.2	b	0.1	10.3

SOURCE: Department of Transportation, Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study* (May 1982), Appendix E, Table 12, pp. E-53 - E54.

a. Total includes administration costs and excess costs to road users associated with poor pavement quality.

b. Not estimated by Federal Highway Administration.

This is due to economies of scale in pavement construction and repair. But according to *Road Work*, combining congestion prices (which rise sharply as the number of vehicles increases) with marginal-cost pricing of pavement would generate more revenues than are currently raised by taxes on road users.

The *HCAS* Appendix E is more optimistic about the revenue-raising potential of efficient pavement charges. It estimates that revenues from efficient pavement damage charges would total $25 billion in 1981 dollars (and reflecting 1981 costs and conditions).[14] This is considerably more than the $6.5 billion that the federal government raised in taxes on highway users in 1981, although it falls short of the $40 billion spent on highways by all levels of government that year. When revenues from congestion pricing--estimated at nearly $54 billion--are added, however, revenues far outweigh spending.[15]

Feasibility of a Charge Based on Axle Weight and Mileage. The Federal Highway Administration has explored the feasibility of several ways of charging vehicles by weight and distance traveled.[16] In its study *The Feasibility of a National Weight-Distance Tax*, the FHWA concluded that a weight-distance tax "should be considered as a feasible alter-

14. Department of Transportation, *HCAS* Appendix E, Table 13, p. E-58.

15. Department of Transportation, *HCAS* Appendix E, Table 14, page E-59.

16. Department of Transportation, Federal Highway Administration (Highway Revenue Analysis Branch), *The Feasibility of a National Weight-Distance Tax*, Report of the Secretary of Transportation to the U.S. Congress Pursuant to Section 933 of the Deficit Reduction Act of 1984 (December 1988).

Table 6.
Marginal Costs of Pavement Maintenance for Current Traffic and Levels of Investment (In 1982 cents per vehicle-mile)

Vehicle Type	Gross Vehicle Weight (Thousands of pounds) 26	33	55	80	105
Urban Travel					
Single Unit					
2-axle	9.16	23.77	183.38	a	a
3-axle	2.07	5.37	41.43	125.43	a
Truck-Trailer					
4-axle	a	a	23.67	105.94	314.39
5-axle	a	a	9.18	41.07	121.87
Tractor-Semitrailer					
3-axle	2.30	6.16	47.54	212.78	631.43
4-axle	a	2.93	22.61	101.19	300.30
5-axle	a	1.20	9.22	41.26	122.44
6-axle	a	0.71	5.45	24.42	72.45
Tractor-Semitrailer-Trailer					
5-axle	a	1.30	10.04	44.92	133.31
6-axle	a	0.81	6.22	27.83	82.58
Intercity Travel					
Single Unit					
2-axle	3.21	8.33	64.26	a	a
3-axle	0.73	1.88	14.52	64.98	a
Truck-Trailer					
4-axle	a	a	8.29	37.13	110.18
5-axle	a	a	3.22	14.39	42.71
Tractor-Semitrailer					
3-axle	0.81	2.16	16.66	74.57	221.28
4-axle	a	1.03	7.92	35.46	105.24
5-axle	a	0.42	3.23	14.46	42.91
6-axle	a	0.25	1.91	8.56	25.39
Tractor-Semitrailer-Trailer					
5-axle	a	0.46	3.52	15.74	46.72
6-axle	a	0.28	2.18	9.75	28.94

SOURCE: Kenneth A. Small, Clifford Winston, and Carol A. Evans, *Road Work* (Washington, D.C.: Brookings Institution, 1989), Tables 3-4 and 3-5, pp. 45-46.

a. Not estimated.

native to existing nonfuel taxes."[17] The study found that administrative and compliance costs would depend on several factors. Taxing all vehicles weighing more than 26,000 pounds would be much more costly to administer than setting the threshold at 55,000 pounds. Basing the tax on registered axle weight instead of a vehicle's registered gross weight would impose greater costs for compliance on trucking companies. Evading a weight-distance tax would not be much (if any) easier than evading the present heavy vehicle use tax, since the distance traveled

17. Department of Transportation, *The Feasibility of a National Weight-Distance Tax*, p. xi.

could be cross-checked with current records of odometer readings and fuel use. The feasibility study reported that evasion of weight-distance taxes currently imposed by several states is apparently no more prevalent than evasion of the fuel tax.

The state of Oregon has used a weight-distance tax for nearly 45 years. The tax is based on registered gross vehicle weight and the number of miles traveled in Oregon. Vehicles weighing between 26,001 pounds and 80,000 pounds are classified in 2,000-pound increments, with higher tax rates for each increment. For example, a 28,000-pound truck would owe 4.45 cents per mile, while an 80,000-pound truck would owe 14.55 cents per mile. Vehicles heavier than 80,000 pounds are classified by number of axles as well as gross weight. For any given weight, the more axles, the lower the tax rate. As much as possible, this structure reflects the costs associated with vehicles of different weights. Oregon's weight-mile tax is its second largest source of highway revenues after fuel taxes. It brought in about $142 million in gross receipts in 1990, about 28 percent of the state's highway tax receipts.[18] The state estimates that truckers evade at most 5 percent of the weight-mile tax, a number that compares favorably with fuel tax compliance.

The Oregon experience suggests that weight-distance charges are feasible. Advances in technology, moreover, offer the promise of improving collection and enforcement. For instance, weigh-in-motion (WIM) technologies, which enable trucks to be weighed while moving at highway speeds, are becoming increasingly accurate. Several states now use WIM to monitor compliance with weight restrictions. Combining WIM and automatic vehicle identification would help officials collect weight-distance charges.

Distributional Considerations of Weight-Distance Charges. Charging on the basis of axle weight and distance would affect distribution. Heavily loaded trucks would pay more, and lightly loaded trucks or trucks spreading heavier weights over more axles would pay less. Over the long run, adjustments would be likely. As trucking companies replaced old equipment with new, they would be encouraged to increase the number of axles on their vehicles. Some heavy loads might be diverted from truck to rail.

The 1991 legislation expanded the ability of states to establish tolls on federally aided roads.

Congestion Costs

Congestion is another principal cause of the costs for using highways. As traffic increases, it reaches a point at which travel times tend to increase. When an additional vehicle enters a busy roadway it causes some motorists to slow down and adjust their spacing so that they are separated at a safe distance from the cars ahead. The more congested the road, the slower the traffic, until at some point it all grinds to a halt. The costs of delay rise steeply as congestion increases.

Factors Affecting Costs. Because congestion varies greatly over time and place, it is difficult to estimate the costs of congestion. Such an assessment requires making a number of assumptions about such key elements as average and marginal travel times, elasticity of demand, and value of time. For example, the *HCAS* Appendix E calculates the costs of delay, and the tolls that would be required to reduce traffic to the efficient amount (the

18. Department of Transportation, FHWA, *Highway Statistics 1990*, Tables MF-1, p. 74, and MV-2, p. 78.

amount at which the marginal social cost equals the marginal benefit), for urban highways not on the Interstate System. In very light traffic, time delays are relatively small, but they rise rapidly as the road gets more crowded. *HCAS's* 1982 estimates of charges to reflect time delays ranged from 0.23 cents per vehicle-mile for passenger cars to 16 cents as the volume of traffic neared the road's capacity.[19]

The costs of congestion could be better understood if more data were available about the number of miles traveled by different types of vehicles at different times of day. This information would help pinpoint who is contributing to congestion, with its attendant costs of delay and demands to build additional lanes or new roads. The effectiveness of a policy measure designed to alleviate congestion depends on the nature of demand for road use at peak times. If drivers could travel at other times, charging a peak-hour price might cause some to change the time they use the road, but if the demand for travel at a given time is inelastic, then other measures--such as lanes reserved for vehicles with more than one occupant--might be more effective. Their effectiveness, however, would involve a loss of economic efficiency.

Pricing to Reflect the Marginal Costs of Congestion. Congestion is an external cost. Each additional vehicle is not only delayed--its marginal private cost of congestion--but also delays other vehicles on the road. Because the marginal social cost is greater than the marginal private cost, drivers tend to use congested highways more than is efficient, since they choose the quantity at which demand equals marginal private cost; they would choose less if they had to bear the higher marginal social cost.

For many years, economists have advocated charging users of roadways at peak periods as a way of reducing congestion.[20] Although telephone companies have long used peak-load pricing for long-distance calls and electric utilities have more recently instituted the practice, it has been slower to catch on in transportation. Some transit systems, such as the Washington (D.C.) Metropolitan Area Transit Authority, charge higher fares at peak hours. But highway authorities have generally dealt with congestion through other means than pricing, such as restricting use of certain roadways or lanes to vehicles carrying more than one person. Section 1012(b) of the Intermodal Surface Transportation Efficiency Act of 1991 provides a stimulus for pricing based on congestion by establishing a program for pilot projects.

The *HCAS* Appendix E estimates the excess costs of delay for different types of vehicles operating in different kinds of locations on different types of roads (see Table 5). As one might expect, the costs of delay and their resulting efficient prices vary primarily according to whether the vehicle is operated in urban or rural areas; they are many times higher for urban than for rural travel. The differences between vehicle types in efficient charges based on congestion are relatively small, in contrast with efficient pavement charges.

After reviewing a number of studies of pricing for congestion in specific localities, Small, Winston, and Evans conclude that

> "... studies to date suggest that tolls on the order of $1.00 to $2.00 per round trip for typical congested commutes might reduce round-trip travel time by ten to fifteen minutes per commuter, raise revenues of tens of billions of dollars annually, and pro-

19. Department of Transportation, FHWA, *HCAS* Appendix E, Table 5, p. E-33.

20. For examples of early works on road pricing, see Herbert Mohring and Mitchell Harwitz, *Highway Benefits: An Analytical Framework* (Evanston, Ill.: Northwestern University Press, 1962); William Vickrey, "Pricing as a Tool in Coordination of Local Transportation," in *Transportation Economics* (New York: National Bureau of Economic Research, 1965), pp. 275-291; and A. A. Walters, "The Theory and Measurement of Private and Social Cost of Highway Congestion," *Econometrica*, vol. 29 (1961), pp. 676-699 (reprinted in *Transport*, Baltimore: Penguin Books, 1968).

vide some $5 billion in net benefits a year to society."[21]

Feasibility of Pricing Based on Congestion. Although congestion pricing has much in its favor as a theoretical principle, it presents practical problems: notably, setting the right price and collecting the charges.

Because efficient charges for congestion are related directly to location and time, determining the right price for all roads at all times becomes a mammoth undertaking. Selecting the roads on which to impose charges based on congestion and setting the schedule of fees by time of day may be a problem best left to state and local officials, who have more immediate and direct knowledge of specific local conditions than the federal government. But the federal government can suggest the conditions under which congestion charges might be most effective and can facilitate the flow of information about the experiences with alternative types of charges for congestion.

Any mention of tolls conjures up visions of interminable delays as long lines of vehicles queue up at toll booths. A solution to this problem is electronic sensing that identifies and charges vehicles automatically when they pass the toll-collection location.[22]

Electronic toll collection (ETC) is already in use on several highways. The Dallas North Tollway has used ETC for several years, and the Oklahoma Turnpike adopted it in 1991. Vehicles that regularly use the toll roads are equipped with transponders, small boxes about the size of credit cards, that are usually placed on the windshield. Users establish accounts and deposit toll prepayments in them. As the vehicles go through a toll booth, the toll is deducted automatically. The ETC systems use read-only technology. The monitor at the toll booth can read users' cards and deduct tolls. It works only at barrier tolls; it cannot keep track of where (or when) a vehicle enters and where it leaves a limited access highway.[23]

The Intermodal Surface Transportation Efficiency Act of 1991 authorizes a program for research in intelligent vehicle/highway systems which promises to provide better information about traffic flows on busy roads, identify vehicles using roads at congested times, and facilitate collection of tolls. Advances in IVHS would make it feasible to charge road users according to the time and location of use, and to do so without toll barriers or other impediments to the free flow of traffic.

The Federal Role in Congestion Pricing and Tolls. Until passage of the ISTEA, the federal government restricted states from imposing tolls on roads built with federal aid, with certain exceptions. In general, tolls were allowed only on highways that were toll roads before becoming part of the Interstate Highway System and on highways for which the states had repaid all federal aid.[24] When the Congress reauthorized the federal highway program in 1987, it established a pilot program allowing seven toll roads to be built or reconstructed with federal aid of up to 35 percent of the cost. The 1991 legislation expanded the ability of states to establish tolls on federally aided roads and raised the federal government's share to 50 percent. This development reflects a growing awareness of the useful purpose that tolls can serve in alleviating congestion and helping to finance additional road work.

Opponents of tolls often express concern that some states might establish toll policies designed to obtain most of their highway revenues from out-of-state vehicles passing through their jurisdiction. The federal gov-

21. Small and others, *Road Work*, p. 98.

22. Electronic toll collection can advance environmental objectives as well. It can reduce pollution at toll booths by maintaining traffic flow and thus avoiding the extra pollution emissions associated with stop-and-go traffic in queues.

23. More advanced read-write systems, which could keep track of entry and exit, are under development.

24. The exceptions are incorporated in Title 23, U.S. Code, Section 129.

ernment could help ensure that tolls were not discriminatory and did not impose undue burdens on interstate commerce.

Distributional Considerations. To be most effective, charges would be highest at the most congested times of day--the morning and evening commuting periods. They would affect all--rich and poor alike--commuting by automobile during those hours. If charges based on congestion were imposed, the working poor--or, more specifically, those working poor who drive to work at peak hours in downtown or other congested areas--would be hit with a rise in commuting costs. The size of congestion charges depends on how high they must be raised to induce some travelers to use mass transit, shift the time of their trips away from peak hours, change routes, carpool, or reduce the number of trips they take; whether mass transit is available; and whether employers offer subsidies (as many do) for parking.[25]

Defenders of congestion pricing point out that charging higher prices for peak-hour use than for off-peak use is common in the telephone and electric utility industries. In some cases, special provisions, such as rates for lifeline service, are made on behalf of poor consumers.[26] Any assessment of the burden of pricing based on congestion should take account of what is done with the revenues derived from it. If, for instance, revenues are used to improve mass transit, poor--and other--transit users will benefit. Proceeds from congestion charges could be used to reduce or eliminate other taxes or fees imposed on highway users, such as vehicle registration fees, which tend to be regressive.[27] If fuel taxes were reduced, rural drivers would benefit, as would operators of vehicles that get relatively few miles per gallon.

25. For an analysis of the effect of congestion pricing on the poor, see Kenneth A. Small, "The Incidence of Congestion Tolls on Urban Highways," *Journal of Urban Economics*, vol. 13 (January 1983), pp. 90-111.

26. A more general way of helping the poor--and one with fewer distortions--is to allow them refundable personal income tax credits.

27. Small and others, *Road Work*, p. 97.

Other External Costs Associated with Highway Use

For the sake of completeness, numerous other costs should be included in marginal social costs. Appendix E of *HCAS* contains discussions of these, including accident costs, air and water pollution, and noise, as well as estimates of their values. The marginal costs of these factors are small in relation to the costs of pavement damage and congestion.

The effects of traffic on noise and air pollution and their resulting costs are not as well understood than those of congestion. Research suggests that congestion worsens the pollution problem in areas that do not meet the national ambient air quality standards established by the Clean Air Act.

Charging for Other Externalities. Vehicles using gasoline and diesel fuel emit such air pollutants as oxides of carbon and nitrogen, hydrocarbons, volatile organic compounds, and particulate matter; they are also very noisy. To sensitize motorists to the social costs they are imposing and to induce them to cut back, charges could be imposed that reflect the cost of air and noise pollution. Authorities could charge for polluting in conjunction with charges for congestion, by means of automatic vehicle identification and scanning units. Because emissions and noise characteristics vary significantly by vehicle, pollution charges should vary by type of vehicle.[28] They also should vary by time of use, location, and ambient air quality.[29]

28. One Colorado study found that 10 percent of the automobiles passing a monitoring site emitted 50 percent of the pollution. See Donald H. Stedman, "Automobile Carbon Monoxide Emission," *Environmental Science and Technology*, vol. 23, no. 2 (1989), pp. 147-149.

29. Economist William Vickrey has suggested that vehicles be given a pollution rating at time of delivery, which would be adjusted over time. Charges could be varied according to vehicle rating, location of use, and weather conditions. On days when inversion or other adverse conditions threaten, increased pollution charges could be announced via news media and individuals would be given a strong incentive to postpone nonessential trips. Incentives would be offered to transfer vehicles with high emissions away from the most polluted areas.

As with congestion, the pricing theory is simple but applying it is difficult. Scientists disagree about the harmful effects of air pollutants on the environment and on the health of people who breathe polluted air. Similar disagreement exists on the damage noise causes. Estimates of the costs of pollution are therefore uncertain.

The *HCAS* Appendix E's estimates of efficient charges for air pollution and noise are shown in Table 5. The authors caution that these estimates are rough and rely on a number of simplifying assumptions. Of particular interest here is that they are small in relation to efficient charges for pavement damage and congestion.

What Should Be Done with Revenues from Pollution Charges? The economic rationale for air and noise pollution charges is that they would induce motorists to reduce their use of highways and the resulting social costs. It would therefore defeat the purpose of the charges for the proceeds to be earmarked for more highway spending, unless it was committed specifically to reducing social costs. Until 1990, motor fuel taxes were earmarked mostly for highways, with a small amount allocated to mass transit. The Omnibus Budget Reconciliation Act of 1990 set a precedent by allotting 2.5 cents a gallon to the general fund of the U.S. Treasury rather than the Highway Trust Fund. This option should be considered if pollution charges are imposed.

Other Considerations in Adopting New User Charges

To obtain efficient use of highways, users should pay a price equal to the marginal social cost of using them. Theoretically, pavement, congestion, and environmental charges could be designed to achieve this result. Moreover, technological advances are making it increasingly feasible to do so. The foregoing consideration of fuel and other existing federal taxes suggests that they do not measure up well against the efficiency criterion, since they do not closely reflect the marginal social cost of road use by various types of vehicles at various locations and times.[30] What, then, are the obstacles to moving from fuel taxes to pavement, congestion, and environmental charges?

Charges based on congestion costs send strong signals about the demand for new roads.

Gasoline and diesel fuel taxes are proven revenue raisers. Although estimates suggest that a combination of charges based on congestion, axle weight, and distance could raise as much or more revenue, they do not have a proven track record. Fuel taxes have been in existence for so long that they are well understood and generally accepted. Motorists find them more predictable than new types of charges with which they have had no experience.

The effects of taxes and charges imposed by the federal government cannot be evaluated without also considering state and local government policies. The benefits of efficient charges set by the federal government could be diluted or defeated by state policies that work at cross purposes.

This study has focused on pricing policies as a way to improve the productivity of the nation's roadways and the efficiency with which they are used. But many other federal policies

30. Fuel taxes would be suitable if they could be designed to reflect the social costs of pollution and energy consumption.

affect efficiency in highway use and design. Some of them could be reexamined if efficient pricing policies were imposed. For instance, many highway users complain that the roadways are not as durable as they should be. If highway users were charged explicitly for the pavement damage they cause, they would be motivated not only to reduce axle loads, but to argue vigorously for thicker, stronger pavements that would bear up better under heavy loads.[31] Small, Winston, and Evans estimate that if roadway investments, as well as prices, were at the optimal level, highway users would enjoy net benefits of $13 billion annually.[32] Given the demand signals sent by users' choices of load sizes, highway officials might reexamine existing design standards for highways and bridges, looking for more ways of obtaining greater net benefits from highway investments.

Similarly, charges based on congestion costs send strong signals about the demand for new roads and additional lanes on existing roads. Congestion costs have implications for pavement durability, since delays caused by road maintenance would translate directly into higher congestion prices.

Conclusion

Existing federal taxes on highway users yield about the same amount of revenue as the federal government spends each year on highways. Alternative financing options are available, however, that could raise enough revenue to cover spending and promote greater efficiency in highway use. Charges for pavement that reflect the damage caused by heavy loads on each axle would encourage more efficient distribution of these loads and reduce the damage to roadways. Charges that reflect congestion costs would discourage nonessential travel on the busiest roads at the busiest hours and stretch existing capacity. Charges based on environmental costs would discourage travel that generates significant pollution and would probably measure up well against many of the alternative policies being considered to reduce pollution.

31. Thicker pavements are not necessarily a panacea. In some cases, construction techniques that allow better drainage or use materials less susceptible to freeze-and-thaw damage may be as effective in reducing life-cycle costs as adding another inch of pavement.

32. Small and others, *Road Work*, p. 7. The authors estimate that combining pavement charges and optimal investments in road durability could generate $8 billion in annual net benefits, and congestion charges could yield an additional $5 billion in net benefits. The estimates are in 1982 dollars.

Chapter Three

Airways

The federal government provides numerous services to owners and operators of aircraft to ensure safe flights through the nation's airspace. In 1991, the Federal Aviation Administration (FAA) spent an estimated $4.8 billion on air traffic control and related services and on supporting facilities, equipment, research, engineering, and development.[1] Revenues from taxes on passenger tickets, international departures, cargo, and fuel generated about $4.9 billion in 1991.[2]

The air traffic control system has been under increasing pressure in the past decade. Airline traffic has burgeoned under deregulation and overwhelmed the capacity of increasingly antiquated equipment used for tracking and communicating with aircraft. The FAA forecasts that takeoffs and landings by major air carriers and regional airlines will increase from the current level of 22 million annually to almost 30 million by the year 2000.[3] The result could be delays caused by congestion when the airports and air traffic control are unable to handle demand at peak periods. Assuming that the demand for aviation services continues to grow at current rates and that capacity or new technology does not, by the year 2000 congestion and bad weather together will account for 20,000 hours or more of delay annually at each of the nation's 41 major airports.[4]

In 1981, the FAA embarked on a major investment program to replace outmoded air traffic control facilities and equipment. The object was to achieve more efficient use of the nation's airspace by 1991. This program, originally called the National Airspace System (NAS) Plan and now called the Capital Investment Plan (CIP), is expected to expand the capacity of the air traffic control system and alleviate delays. But until the new equipment is in operation, the air traffic control system will face increasing challenges in handling the rising volume of traffic.[5]

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1. Total FAA spending in fiscal year 1991 was $7.2 billion. The difference of $2.5 billion includes grants to airports and funding for aviation safety regulations, aviation security, and management programs.

2. Aviation excise taxes are levied on users in the private sector only. Public-sector users such as the military are not charged for using the air traffic system, although they contribute to its costs. These costs are covered by the general fund of the U.S. Treasury. In this chapter, unless otherwise noted, public-sector users are treated on an equal footing with other users so that the FAA costs referred to include both private- and public-sector costs.

3. Committee for the Study of Long-Term Airport Capacity Needs, *Aviation System Capacity*, Special Report 226 (Washington, D.C.: Transportation Research Board, National Research Council, 1990), Table 1-1.

4. Delays are based on the difference between the time that a flight would take if it did not have to wait at gates or runways and the actual flight time. Air traffic controllers make judgments about the cause of delay and report delays that exceed 15 minutes. Schedule delays that occur because of mechanical problems are not counted as delays. For more on the two ways in which the FAA measures delays, see Committee for the Study of Air Passenger Service and Safety Since Deregulation, *The Winds of Change*, Special Report 230 (Washington, D.C.: Transportation Research Board, National Research Council, 1991), pp. 210-215; and Department of Transportation, Federal Aviation Administration, *1990-91 Aviation System Capacity Plan*, DOT/FAA/SC-90-1 (September 1990), pp. 1-11 to 1-16.

5. The Capital Investment Plan is a continuing series of projects and does not have a single completion date. Several major components of the plan are scheduled for completion by the year 2000.

Congestion can be considered a shortage; it occurs when more services--of the air traffic control system or airport landing space--are demanded than can be supplied at a given time and place. When there is a shortage of a good or service, the economic solution is to raise the price. Charging a higher price forces users to reevaluate their demand, and only those who value the good or service enough to pay the price will continue to demand it. If aviation users were charged extra for peak-hour use, some would shift to less busy times, thereby alleviating congestion at the peak periods.

Some observers argue that aviation system users should cover the entire costs of the FAA.

Pricing can do more for efficiency than just alleviate congestion. Even when the airways are not congested, each flight imposes costs on the air traffic control system. If users recognize these costs and factor them into their operational decisions, the air traffic system as a whole can become more efficient. The prices that users are willing to pay for air traffic control services can also serve as signals indicating which additional investments will have the greatest payoffs. These signals can help the FAA set priorities in phasing in new equipment.

In response to perceived inadequacies in the air traffic control system, some observers have proposed privatizing it. Although examining the merits of privatization is beyond the scope of this study, the discussion in this chapter of alternative pricing mechanisms suggests some of the problems.

The proposals for privatization indicate how much the aviation system has advanced since the days when the federal government's policies were chiefly designed to promote air travel. The federal government continues to subsidize aviation from the general fund of the U.S. Treasury. Revenues from taxes imposed on aviation users over the past five years contributed about 60 percent of the FAA's total annual spending--including safety regulation and grants to airports--and 80 percent of estimated spending for air traffic control services. In light of the large federal budget deficit, there appears to be increasing sentiment for aviation users to pay the entire cost of the services they receive.

One argument in favor of continuing subsidies to aviation is that the safety of the aviation network can be considered a public good because even nonusers of planes face catastrophic consequences if there are accidents. It is difficult to charge users for the well-being of communities located below their flight path; therefore, a federal subsidy to help airlines and other users minimize the dangers to nonusers on the ground may be justified.

Background

The airway system, also called the air traffic control system, is designed to ensure the safe movement of aircraft through the nation's airspace. It includes traffic control at and between airports, weather advisories, and other services to help pilots plan their routes. Excluded from consideration in this study are federal aid to airports and such nontraffic-related FAA activities as certifying aircraft and pilots, setting safety standards, and other headquarters activities.

Why Are Airports Not Included?

Airports are not generally considered part of the air traffic control system. They are run by

state or municipal governments, and the federal role is limited to providing grants-in-aid.

Federal actions can affect efficiency at airports, however. Terminal congestion can be reduced by expanding capacity and using existing capacity more efficiently. In addition, air traffic control (ATC) services are linked with runway capacity, so if that capacity is inadequate, ATC will also be constrained. It is more likely, however, that the greatest payoff from federal activity lies with efforts to improve air traffic control technologically and to find appropriate prices for ATC services.

The Users of the Air Traffic Control System

For purposes of this study, the direct users of the air traffic control system are the operators of commercial and private aircraft, not the passengers or freight carried by the aircraft. The aircraft is the element whose safe movement is of concern to air traffic controllers, regardless of who or what is on board. A study of airport costs would have to consider passengers (as well as pilots and other employees) as users, since they impose demands directly on airport facilities that entail costs to the airports.

The Services that the Federal Government Provides to Aviation

The major components of FAA spending include operations and capital improvements (see Table 7). About 55 percent of the FAA's outlays in 1991 were spent on operations. The largest component of that spending was for the air traffic control system. The FAA's capital spending is divided almost evenly between the Airport Improvement Program, which provides grants to airports, and facilities and equipment (F&E) used to keep track of aircraft and guide them safely to their destinations. A small amount of capital spending goes for research, engineering, and development (RE&D) to find ways of improving the FAA's air traffic control services.

The FAA's outlays for air traffic control services include all expenditures for F&E and RE&D plus spending on five categories of operations that seem most directly related to operating the air traffic control system: operation of the traffic control system, National Airspace System logistics support, design and management, maintenance of traffic control, and leased telecommunications services. The federal budget does not show outlays for these individual components of ATC. It does, however, show obligations, and since outlays track obligations over time, they can be used to

Table 7.
Federal Aviation Administration and Air Traffic Control Spending, Fiscal Year 1991
(In millions of dollars)

	Amount	Percentage of Total
Capital Account		
Airport Improvement Program	1,541	21
Air traffic control		
Facilities and equipment	1,512	21
Research, engineering and development	179	2
Subtotal	3,232	45
Operations Account		
Air traffic control share of operations[a]	3,063	42
Non-air traffic control share of operations[a]	950	13
Subtotal	4,013	55
Total	7,241[b]	100
Memorandum:		
Spending on Air Traffic Control	4,754	66[c]

SOURCES: *Budget of the United States Government, Fiscal Year 1993*, Appendix One, p. 746 and Table 12, p. 128.

a. Estimate from Table 12 on p. 128.

b. Includes a credit of $3 million for the Aviation Insurance Revolving Fund.

c. Percentages may not add up to subaccount totals because of rounding.

show the composition of spending on air traffic control. The estimated amount spent by the FAA on air traffic control in 1991 is shown in Table 7.

Some observers argue that aviation system users should cover the entire costs of the FAA. But the costs that are relevant to this study are those that relate directly to air traffic control. Therefore, federal grants to airports, administration of safety regulations, and headquarters services are excluded for the purposes of this analysis.

The services provided by the FAA for a typical flight begin well before takeoff and continue until the pilot has turned off the "fasten seat belts" sign at the airport gate. Air traffic controllers and other skilled personnel perform these services at a variety of facilities including:

- Flight service stations;
- Airport traffic control towers;
- Terminal radar approach control facilities; and
- Air route traffic control centers.

Flight Service Stations (FSS). FAA personnel at flight service stations help pilots plan their flights. They provide weather predictions, maps, and other information that helps pilots select the best routes and altitudes for their particular aircraft. The flight service stations are especially useful for general aviation--corporate jets and pleasure aircraft--which relies heavily on the FAA. Large commercial air carriers typically have their own sources of information and use their own computer models to determine the best flight paths. Airlines file flight plans electronically with air route traffic control centers. Therefore they do not use many FSS services.

Airport Traffic Control Towers. Airport tower traffic controllers are responsible for the safe movement of aircraft on the ground and in the air within a few miles of an airport. They direct departing aircraft from gates, along taxiways, to runways, and give permission for takeoff. After an aircraft is airborne, the tower controller relinquishes control to another controller who then tracks it by radar in the terminal radar approach control facility (TRACON). For incoming aircraft, the process is reversed; the tower controller directs the aircraft from the time it is relinquished by the TRACON controller until it is parked at the arrival gate.

Tower controllers observe the movements of aircraft from glassed-in enclosures high enough for them to see the airport's runways and taxiways. Thus, they can track aircraft both in the air and on the ground.

The FAA is buying new equipment to monitor aircraft on the ground more effectively and to provide warnings of potential collisions. For instance, better equipment might have prevented recent accidents in Los Angeles, where a commercial jet and a small commuter aircraft collided on a runway, and in Detroit, where a pilot lost in fog taxied onto a runway from which another jet was taking off.

In 1989, the FAA operated control towers at about 400 airports, including all major commercial terminals. Many small airports used primarily by general aviation do not have towers.

Terminal Radar Approach Control Facilities. Once an aircraft is airborne, the tower controller hands it over to the controller in the TRACON, who monitors it on radar, guides it some 30 to 50 miles out from the airport, and then relinquishes responsibility to a controller at an air route traffic control center (ARTCC). For incoming flights, the TRACON controller receives control of an aircraft from an ARTCC controller and guides it until it is close enough for the tower to take over.

At hub airports, many aircraft arrive at about the same time from one direction, and after an interval for unloading and loading passengers, depart en masse on continuing flights. For example, a number of flights from

the East Coast may arrive at a hub within minutes of each other, give passengers three-quarters of an hour to catch connecting flights, and take off for the West Coast. At such times, TRACON controllers face tremendous pressures in lining up the aircraft on approach paths and keeping them safely separated. In areas with several fields, one TRACON is usually responsible for aircraft approaching and leaving all the airports. For instance, the TRACON at Chicago's O'Hare International Airport is also responsible for traffic at Midway, Meigs, and several other smaller airports in the region.

There are 188 TRACONS in the continental United States, all of which employ highly sophisticated tracking and communications gear. The FAA is trying to upgrade the facilities and equipment at all TRACONS as part of its long-term capital investment plan.

Air Route Traffic Control Centers. Controllers at ARTCCs monitor and guide aircraft until they near their destination and are handed to the local TRACON. The FAA operates 22 ARTCCs throughout the country, and together they cover virtually all of the nation's airspace.[6]

An aircraft may be handled by more than one ARTCC in the course of its flight.[7] A flight from Washington to Chicago, for example, is passed from the local TRACON to the Washington ARTCC at Leesburg, Virginia. From there it is passed along to controllers in the Cleveland, Indianapolis, and Aurora, Illinois, ARTCCs before being directed by the TRACON at O'Hare.

Commercial carriers constituted about half the operations handled by ARTCCs in 1988. The balance were general aviation, commuters, and government (mainly military). General aviation pilots may elect not to use the services of ARTCCs when flying in good weather under visual flight rules.

As sophisticated as ARTCC radar and communications equipment is, it is still inadequate under certain conditions. When the system begins to get overloaded, traffic controllers must juggle demands, directing aircraft to change altitude or course, or asking neighboring ARTCCs or TRACONs not to send any more aircraft to their sector until congestion eases. With better equipment, provided under the FAA's capital investment plan, the ARTCCs can handle more operations without sacrificing safety. At some facilities the newer equipment will require fewer controllers, thereby lowering operating costs as well. (See Table 8 for the traffic associated with each type of facility organized by class of user.)

In addition to airport towers, TRACONs, and air route centers, the FAA operates a central flow control facility that monitors aviation activity nationwide. Its purpose is to smooth the flow of traffic from sector to sector across the country. If, for instance, late-afternoon thunderstorms in New York City bring operations to a standstill even for a short period, waiting aircraft queue up in the air and on the ground. In order to minimize the number of circling airplanes, the FAA's flow control facility issues instructions to keep on the ground those bound for New York until they can be safely accommodated at their destination.

The Federal Aviation Administration's capital investment plan was launched in 1981 as the National Airspace System Plan to modernize the FAA's equipment and facilities. As it replaces outmoded and overloaded computers and communication equipment, the FAA will be able to manage many more operations than it can now. But the program has encountered numerous technical difficulties and

6. Some airspace used for testing aircraft or conducting training missions is under military control.

7. As used by air traffic controllers, a "handle" consists of an instrument flight rules entry and departure from a sector and the guiding of an aircraft over the sector controlled.

Table 8.
Operations Conducted by the Federal Aviation Administration in 1990, by Facility and Class of User (In millions of operations)

	Operations by User Class									
	Commercial Carriers		Commuters and Taxis		General Aviation[a]		Public Sector		Total	
Facility	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Operations	Percent
ARTCC	18.5	49	5.6	15	7.9	21	5.5	15	37.5	100
ATCT[b]	12.9	20	8.8	14	39.0	21	2.8	4	63.5	100
FSS[c]										
Pilot briefs	n.a.	n.a.	n.a.	n.a.	11.5	47	n.a.	n.a.	n.a.	n.a.
Instrument flight plans	n.a.	n.a.	n.a.	n.a.	5.3	22	n.a.	n.a.	n.a.	n.a.
Visual flight plans	n.a.	n.a.	n.a.	n.a.	1.6	7	n.a.	n.a.	n.a.	n.a.
Air contacts[d]	n.a.	n.a.	n.a.	n.a.	6.1	25	n.a.	n.a.	n.a.	n.a.
Total	n.a.	n.a.	n.a.	n.a.	24.5	100[e]	n.a.	n.a.	n.a.	n.a.

SOURCE: *FAA Aviation Forecasts, Fiscal Year 1992-2003*, (February 1992) Chapter X, Tables 27, 32, 34, and 35.

NOTES: ARTCC = air route traffic control centers; ATCT = air traffic control towers; FSS = flight service stations; n.a. = not applicable.

a. Data on flight service stations, pilot briefs, instrument flight plans, visual flight plans, and air contacts apply only to general aviation.

b. The FAA has consolidated the information from air traffic control towers and terminal radar approach control facilities in recent years.

c. These services are used predominantly by general aviation. No breakdown by user class is given.

d. An air contact is a radio communication between an aircraft and a controller at the flight service station.

e. Total may not equal 100 because numbers are rounded.

is well behind its original schedule.[8] Although originally expected to cost $12 billion, the cost of the plan is now estimated at $27 billion.[9]

While the CIP is being carried out, charging users according to the costs they impose on the traffic control system could serve two purposes: it could help alleviate congestion and could suggest which elements of the plan would yield the greatest benefits and should be given top priority.

8. The General Accounting Office has published a series of reports on the NAS Plan, including *Air Traffic Control: Challenges Facing FAA's Modernization Program*, GAO/T-RCED-92-34 (March 1992); *Air Traffic Control: Status of FAA's Effort to Modernize the System*, GAO/RCED-90-146FS, (April 1990); *Issues Related to FAA's Modernization of the Air Traffic Control System*, GAO/T-RCED-90-32, (February 1990); and *Continued Improvements Needed in FAA's Management of the NAS Plan*, GAO/RCED-89-7 (November 1988).

9. Committee for the Study of Air Passenger Service, *The Winds of Change*, p. 297.

Current Financing Policy

The FAA gets its money from two sources: the general fund of the U.S Treasury and a set of aviation excise taxes. Almost all of the revenues from the aviation excise taxes are deposited in the Airport and Airway Trust Fund (AATF), from which the FAA makes all

capital and some operations expenditures.[10] The AATF serves as a dedicated source of funding for the aviation system and facilitates comparing the amount of tax revenues collected from aviation sources and the amount of federal spending on aviation activities.

When the trust fund was established in 1970, it was intended to finance investments in aviation and, if funds were available, to help finance operations. Early attempts by the Nixon Administration to restrict capital spending while using the trust fund to finance operations led the Congress to impose limits on the amount of spending on operations that can be financed by the trust fund.[11] This study is concerned with both capital and operations spending for air traffic control; however, it does not consider the current legislative and institutional constraints on sources of financing for the different activities.

The Tax on Passenger Tickets

The federal government taxes passenger tickets at 10 percent of the ticket value for domestic flights on commercial airlines.[12] In 1991, revenues from the ticket tax were $4.3 billion and accounted for 88 percent of total revenues from aviation taxes (see Table 9).

Although the tax on passenger tickets raises substantial amounts of revenue, it does not effectively promote efficiency. To begin with, it does not correspond closely to the FAA's cost of handling a passenger aircraft through the air traffic control system. The cost to the FAA is linked to the movement of the airplane, not the passenger. To air traffic controllers, it does not matter whether an airplane is empty or full; they handle it the same way and it imposes the same costs on the system. With the wide variety of discount fares available to passengers, moreover, ticket prices--and the resulting taxes--paid by different passengers on the same airplane may vary widely.[13]

Table 9.
Aviation Excise Taxes, 1991
(In millions of dollars)

	Amount	Percentage of Total
Passenger Ticket Tax[a]	4,341	88
Freight and Waybill Tax[b]	222	5
Fuel Tax[c]	140	3
International Departure Tax[d]	217	5
Refund of Taxes	-10	[e]
Total	4,910	100[f]

SOURCE: *Budget of the United States Government, Fiscal Year 1993*, Appendix One, p. 749.

a. Tax rate of 8 percent in 1990 on the value of domestic passenger tickets. The rate changed to 10 percent on December 1, 1990.

b. Tax rate of 5 percent in 1990 on the value of air cargo shipments. The rate changed to 6.25 percent on December 1, 1990.

c. Twelve cents per gallon of aviation fuel and 14 cents per gallon of jet fuel used by general aviation in 1990. The fuel charges changed to 15 cents and 17.5 cents per gallon on December 1, 1990.

d. Six dollars per person on international flights effective January 1, 1990.

e. Tax refunds were less than one percent of taxes collected.

f. Percentages do not add up to 100 because numbers are rounded.

10. The revenues from the increase in taxes on aviation fuels enacted in the Omnibus Budget Reconciliation Act of 1990 for the period December 1, 1990, through December 31, 1992 remain in the general fund. Thereafter, these revenues are dedicated to the Airport and Airway Trust Fund.

11. The AATF is described in detail in a Congressional Budget Office special study, "The Status of the Airport and Airway Trust Fund" (December 1988), and a CBO Staff Memorandum, "The Effects of Alternative Assumptions about Spending and Revenues of the Airport and Airway Trust Fund" (July 1990).

12. Title 26, U.S. Code, Section 4261(a). The rate increased from 8 percent to 10 percent on December 1, 1990, under provisions of the Omnibus Budget Reconciliation Act of 1990.

13. In April 1992, airlines began experimenting with simplified fare structures. The smaller variation in ticket prices implies passenger ticket taxes for the same flight will not vary so widely in the future.

A commercial airliner departing from Washington National Airport imposes the same demands on airport tower and TRACON personnel regardless of whether it is carrying business passengers paying full fare and bound for New York, vacationers paying discount fares and bound for Florida, or a mix of passengers bound for Dallas. But the total fares and taxes paid may vary greatly among those flights. For these reasons, the passenger ticket tax is not likely to serve as a good index to the FAA's cost.

It would be only coincidental if the aviation excise taxes equaled marginal costs.

There are, however, some factors that affect air traffic control costs, ticket prices, and ticket taxes in the same way. Ticket prices are usually higher for long flights than for short ones; correspondingly, air traffic control costs are higher for flights that pass through many sectors of airspace and make intermediate stops that require extra handling by controllers. Airplanes that operate when the air traffic control system is busiest and congestion costs are highest are likely to be filled with business travelers paying full fares--and correspondingly high taxes. These effects are coincidental, however; they do not reflect an intentional effort to tie passenger taxes to costs imposed on the aviation system.

International Departure Tax

The federal government levies an international departure tax of $6 a passenger on every international flight originating in the United States. The tax applies to commercial flights on both domestic and foreign carriers.[14] Revenues in 1991 were $217 million, about 4 percent of revenues from aviation-related taxes. Because the international departure tax, like the passenger ticket tax, is imposed on passengers rather than on aircraft, there is no reason to expect that it would closely reflect the FAA's costs for handling international flights. The cost to the FAA of handling a large jet is the same regardless of whether it is carrying 300 passengers, paying a total of $1,800 in departure taxes, or just 150 passengers, paying a total of $900 in taxes. In addition, the tax does not reflect congestion costs.

Freight Waybill Tax

Freight transported within the United States by commercial air carriers is subject to a tax of 6.25 percent of the waybill.[15] Revenues were $222 million in 1991, about 5 percent of total revenues from aviation excise taxes. The waybill tax does not necessarily correspond to the services provided by the air traffic control system, but it comes closer than the taxes on passengers. Air freight rates typically depend on the size, weight, distance traveled, and time sensitivity of the shipment. Some freight is carried in the cargo holds of passenger aircraft, while other freight moves on dedicated planes. Often the dedicated aircraft, such as those of Federal Express or United Parcel Service, operate at night. This pattern eases the demands imposed on the air traffic control system by peak-hour passenger flights, but it may increase the number of controllers on duty at night.

Aviation Fuel Tax

Fuel used by general aviation is subject to an excise tax of 15 cents a gallon for aviation gas-

14. Title 26, U.S. Code, Section 4261(c). The tax increased from $3 on January 1, 1990.

15. Title 26, U.S. Code, Section 4271. Until December 1, 1990, the rate was 5 percent.

oline and 17.5 cents a gallon for jet fuel.[16] Revenues from these taxes were $140 million in 1991, about 3 percent of total revenues from aviation excise taxes.

Of all the aviation excise taxes, fuel taxes are most likely to correlate closely with costs imposed on the airway system, since fuel use is linked with distance traveled. Still, a small airplane flying between two small airports serving only general aviation and lacking control facilities would place few demands on the system--the pilot might check the weather with the flight service station and file a flight plan--but the same airplane flying the same distance (and using the same amount of fuel) between congested airports would cost the system much more. The fuel taxes paid would be the same for both flights.

The relationship between fuel taxes and costs is even more important. Although fuel taxes may be more closely correlated with costs than other aviation excise taxes, taxes do not necessarily cover costs. Total revenues raised from passenger ticket taxes may come much closer to covering the ATC costs associated with commercial airline transportation than do fuel tax revenues to covering ATC costs associated with general aviation. As for marginal costs, it would be only coincidental if the aviation excise taxes equaled marginal costs--a condition for efficiency.

The Relationship of Taxes to Costs of ATC

In 1991, aviation tax revenues were $4.9 billion, while spending to equip, operate, and maintain the air traffic control system was estimated to be $4.8 billion. The FAA's airport improvement program received $1.5 billion of aviation tax revenues. During the last five years, FAA outlays for the ATC system averaged $4.2 billion annually, while revenues from aviation excise taxes were $4 billion.

Cost allocation studies by the FAA estimate that the public sector is responsible for about 15 percent of FAA costs.[17] If aviation activity by the public sector is considered separately from that of private users, FAA costs to private users would be reduced by 15 percent. Assuming that private-sector users were responsible for 85 percent of estimated ATC costs (about $4.1 billion in 1991), aviation excise taxes would have been sufficient to cover ATC expenses. But it should be kept in mind that the excise taxes are used for other expenditures such as grants to airports. In 1991, private users imposed total costs of about $6.2 billion on the FAA. The result was a shortfall in cost recovery of about $1.3 billion.

Taxes Paid and Costs Imposed, by User Class

Different classes of users are taxed in different ways and impose different costs on the air traffic control system. Some studies have been undertaken to determine the relative costs and tax revenues and to discover whether some users are subsidizing others. As with highways, two approaches have been taken. One is the top-down approach, which allocates all FAA costs--including those not directly associated with air traffic control--among the various classes of users. An alternative, bottom-up approach has been taken by Gellman Associates (Richard Golaszewski in particular), who estimated the marginal costs of individual operations by users from different

16. Title 26, U.S. Code, Section 4041(c). Until December 1, 1990, the rates were 12 cents a gallon for aviation gasoline and 14 cents a gallon for jet fuel. In 1991, $14 million of revenue from the fuel tax--the projected amount attributable to the tax increase--will remain in the general fund, as provided by the Omnibus Budget Reconciliation Act of 1990.

17. Daniel Taylor, *Airport and Airway Costs: Allocation and Recovery in the 1980s*, FAA-APO-87-7 (Washington, D.C.: National Technical Information Service, February 1987), p. 8.

Table 10.
Marginal Costs of Air Traffic Control Services in 1985 (In 1985 dollars)

Facility Type	Activity Measure	Air Carrier	Commuter	General Aviation	Public Sector
Air Route Traffic Control Center	Total handles[a]	13.93	13.93	12.63	21.30
Terminal Radar Approach Control	Operation, seconds and over[b]	12.80	12.80	3.44	12.80
Air Traffic Control Tower	Operation[c]	7.91	1.86	1.44	4.45
Flight Service Station[d]	Pilot briefs	6.86	6.86	6.86	6.86
	IFRFP	6.86	6.86	6.86	6.86
	VFRFP	13.68	13.68	13.68	13.68
	Air contacts	3.87	3.87	3.87	3.87

SOURCE: Richard Golaszewski, "The Unit Costs of FAA Air Traffic Control Services," *Journal of the Transportation Research Forum*, vol. 28 (Arlington, Va.: Transportation Research Forum, 1987), pp. 13-20.

NOTE: IFRFP = instrument flight rules flight plan; VFRFP = visual flight rules flight plan; air contacts = a radio contact between the pilot and the flight service station.

a. In a "handle," a controller receives an aircraft operating under instrument flight rules from a terminal radar approach control facility (TRACON). The controller then guides the aircraft through airspace that the air route traffic control center is monitoring, and hands it over to a TRACON.

b. A TRACON operation occurs when the plane lands at the primary airport associated with the TRACON. Seconds and overs refers to aircraft that have traveled to another airport and were handed over to another TRACON or airport control tower.

c. An air traffic control tower operation is defined as a landing or takeoff by an aircraft.

d. The costs of the various flight service station services were the same for all users.

classes.[18] The marginal cost approach is more relevant to this chapter, since the focus is on efficiency.

Marginal Costs: The "Bottom-Up" Approach

Understanding the costs associated with use of the air traffic control system entails breaking down aircraft operations into the parts that use FAA services.

18. Richard Golaszewski, "The Unit Costs of FAA Air Traffic Control Services," *Journal of the Transportation Research Forum*, vol. 28 (Arlington, Va.: Transportation Research Forum, 1987), pp. 13-20.

Marginal Costs to the FAA. It is difficult to determine the marginal costs of services provided by the air traffic control system. A typical flight makes use of a variety of services, each of which imposes a marginal cost on the FAA. The study by Richard Golaszewski estimated the marginal costs of various FAA services provided to different classes of users (see Table 10). In some cases, the estimates of marginal costs were identical for different classes of users, such as handlings by TRACONs of air carriers, commuters, and government flights, because the available data did not distinguish among them statistically. (See Box 3 for an explanation of how Golaszewski used econometrics to estimate the marginal costs.)

Golaszewski's estimates do not distinguish between peak and offpeak marginal costs. The FAA is likely to incur greater costs at peak hours because more controllers are needed to direct additional traffic, but it is not clear whether peak traffic raises marginal costs to the FAA. It is clear, however, that in peak periods additional aircraft impose additional marginal costs in the form of delays on other users of the system.

Box 3.
Using Econometrics to Measure Marginal Costs

The relationship between costs and units of FAA service can be estimated by linear regression techniques.[1] One study by airline analyst Richard Golaszewski used sites as his reference points: an air route traffic control center, a terminal radar approach control center, an airport traffic control tower, or a flight service station. For each type of facility, he regressed the cost of operating the site against the numbers of operations of the different classes of users--air carriers, commuters, general aviation, and the public sector. The estimated coefficient for each class of users is the marginal cost of that class, and the constant term in each estimated equation represents the fixed cost--not specific to any individual class of users--of the facility. The marginal costs of facilities are estimated, although because of data limitations, capital costs (buildings and air traffic control equipment) are not represented in the marginal cost coefficients. Underlying the cross section statistical analysis is the assumption that each facility is the optimal size for the work it does.

Although Golaszewski's estimates of marginal costs are somewhat out of date--they are based on 1985 data--his work provides a methodology that can be used to calculate marginal costs and show roughly the size of marginal costs compared with total costs of the air traffic control system. Golaszewski estimates marginal costs to be between 20 percent and 40 percent of total costs; the other 60 percent to 80 percent of costs include joint costs at the various sites, equipment maintenance not allocated to the sites, general overhead, and capital spending on facilities and equipment and research and development.

1. Richard Golaszewski, "The Unit Costs of FAA Air Traffic Control Services," *Journal of the Transportation Research Forum*, vol. 28 (Arlington, Va.: Transportation Research Forum, 1987), pp. 13-20.

Marginal Costs to Other Users. When the aviation system is not congested, the marginal cost is the addition to the total cost to the FAA of handling one additional user. Alternatively, the marginal cost is the cost that could be avoided if the additional use was forgone. With congestion, however, the marginal cost includes additional costs of delays experienced by other users. When the airways system is congested, each additional user increases the time that others must wait before being served.

Congestion Costs. When the system is congested, the costs of delay may be large. At these times, only users who value the service very highly, such as aircraft carrying a couple of hundred business passengers, will be willing to pay the high social marginal cost. Users who place less value on flying into a congested airport at a busy time will be encouraged to make alternative arrangements. For example, general aviation users can shift to a less congested airport, and general aviation or commercial aircraft carrying a high proportion of vacation travelers whose time is more flexible than that of business travelers can choose other travel times. In that way, congestion at peak hours will be alleviated.

Congestion can also impose high costs on the airlines if delays are severe enough to interfere with their schedule of operations. Late arrivals into hub airports, for example, can produce a domino effect, spreading delays throughout the system.

Numerous studies have estimated the value that travelers place on their travel time--or, in other words, how much they would be willing to pay to get to their destinations more quickly. On the basis of these studies and its own research, the FAA estimates that the average value of time for business trips is $44.24 an hour. For nonbusiness trips, the estimated value is $38.03 an hour.[19]

19. These values are expressed in 1991 dollars and are derived from FAA's estimates of $37.06 for business and

(Continued)

Consider, for example, a flight departing from a busy airport during the late afternoon peak. Each aircraft added to the queue awaiting clearance for takeoff contributes to delays for aircraft behind it in line. If there are five aircraft in the queue, each carrying 100 passengers who value their time at $40 an hour, and if the average delay is 6 minutes (0.1 hour), the first aircraft imposes a delay cost of $1600 on the other four. Similarly, the second aircraft in the queue causes congestion costs of $1200, the third $800, and the fourth $400. If surcharges corresponding to these amounts were imposed for takeoffs at the peak hour, some aircraft--particularly those with fewer passengers or more vacationers with discounted fares--would probably shift their flights to less congested, less costly hours.

The delay time is the same regardless of the type of user; a corporate jet would impose the same delay cost on others as a larger airplane.[20] To promote efficiency, the congestion charge should be the same regardless of aircraft type or user class. At offpeak hours, when there are no queues, the delay cost and congestion charge would be zero.

Bad weather heightens delays. Maintaining an extra margin of safety when visibility is low requires keeping aircraft farther apart than in clear weather. This step reduces the number of aircraft that the air traffic control system can handle in a given period of time. Pricing for congestion would highlight the cost of delays at specific locations and would help locate places where improvements in the air traffic control system would reduce delays.

The FAA has estimated that congestion and delays add about $5 billion annually to the airline operations. It is unlikely that charging users for the congestion they cause would raise that much in revenues. The revenues that could be expected from congestion pricing are more likely to be between $1 billion and $2 billion.[21]

Environmental Costs. Pollution is another social cost that should be taken into account. Noise pollution is an important factor in an airport's decision to increase the number of runways and operations. Air pollution from jet fuel may need to be priced as traffic expands. At present, however, there is stronger agreement among analysts about the practicability of pricing for congestion than for other social costs.

To achieve efficient use of the system, users should be charged the sum of the marginal cost to the FAA and the marginal cost of delays and pollution. This total is called the marginal social cost.

Comparison of Revenues Raised from Taxes and Marginal Costs for Selected Types of Flights

The FAA's Cost Allocation Study concluded that some classes of users pay more than their

19. Continued

$31.86 for nonbusiness trips (in 1987 dollars), using the consumer price index. The estimates from studies reviewed by the FAA ranged from $20 an hour for military business travelers to $140.47 an hour for general aviation travelers using turbine powered aircraft, and from $26.97 an hour (for domestic passengers on commercial air carriers) to $210.71 an hour (for general aviation travelers using turbine powered aircraft) for nonbusiness trips. The high-end estimates accounted for a very small percentage of all users. See Stefan Hoffer and others, *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, FAA-APO-89-10 (Federal Aviation Administration, October 1989), p. 11.

20. There may be some differences in delay time for various types of aircraft because of the need to provide proper spacing between aircraft.

21. This range of revenues from pricing for congestion at crowded airports is based on some assumptions. The FAA found that in 1988, commercial airlines experienced delays of more than 20,000 hours at each of 21 airports. The passengers on these aircraft (about 100 passengers per aircraft) might have been willing to pay for reducing the amount of delay. Depending on how much congestion is deemed optimal, how much congestion is due to weather, and how much time is worth to passengers, the revenues from charging these passengers could vary from $1 billion to $2 billion. For the FAA estimates of the value of time to passengers, see footnote 19 in this chapter. In 1989, bad weather accounted for 57 percent of all delays.

share of costs and some pay less (see Box 4).[22] One can also ask whether individual aircraft are paying enough to cover the marginal costs they impose on the system. The most efficient use of the system occurs when the price is equal to the marginal cost.

There is, of course, no typical flight with which marginal costs and tax revenues may be compared, but a commercial airline flight from Washington, D.C., to Chicago will serve as an illustration. As it moves through various portions of air space, the flight imposes marginal costs on each ATC facility it traverses. Using Golaszewski's 1985 estimates, if those costs rose at the same rate as the gross national product (GNP) deflator, the cost would be about $135 in today's dollars. If the aircraft carried 100 passengers paying an average of $150 apiece, the passenger ticket tax (10 percent of the ticket price) would yield revenues of $1,500 for the trip.[23] If the flight were filled with full-fare business passengers, the tax revenues would be much higher; if it were carrying mostly tourists paying deep-discount fares, revenues would be lower.

If the aircraft carried freight instead of passengers, tax revenues would depend on the size of the waybill, which in turn would depend on such shipment characteristics as volume, weight, fragility, and priority.

A general aviation aircraft flying from Washington to Chicago would make somewhat different demands on the air traffic control system, depending on whether it went by instrument (IFR) or visual flight rules (VFR). If the aircraft followed IFR, the cost to the air traffic control system would be about $105. If it followed VFR rules, the cost would drop to $30. A small plane for transporting executives might use about 250 gallons of aviation fuel, paying a tax of 17.5 cents a gallon, thus yielding about $45 in total revenues.

22. Taylor, *Airport and Airway Costs*.

23. Most passenger carriers also carry freight, in addition to passengers' baggage. Revenues from the waybill tax should be included in total revenues.

It is therefore possible that a general aviation aircraft, not maintaining much contact with the ATC, may pay more in aviation excise taxes than its marginal cost. But if it operates under IFR, it could pay much less.

Although there is no average or typical experience, these examples help illustrate that the existing tax structure does not reflect marginal costs to the FAA. As a result, users of the system get no signals encouraging efficient use.

Alternative Financing Mechanisms

As the preceding discussion suggests, the present system of aviation excise taxes does not provide strong incentives for efficient use of the airways. The taxes imposed on each user group do not reflect marginal costs, and total revenues from all aviation taxes are insufficient to cover the FAA's costs for air traffic control services. Moreover, cost allocation studies suggest that some classes of users pay more of their share of the costs than others. Are there alternative financing mechanisms that would provide incentives for efficient use of and investment in the airways?

Marginal Cost Pricing

One option is to charge each user the marginal cost of using the airways. Charging users the social marginal cost provides incentives for efficient use of the system. Users who value the service enough to pay the costs associated with it will use it, while those who do not will find alternatives.

The marginal costs estimated by Golaszewski could serve as a starting point for setting efficient prices for users of the air traffic control system. Users could be charged a price equal to the marginal cost of each service they received. Charges could be based on the

Box 4.
The "Top-Down" Approach

FAA Cost Allocation Study

The Federal Aviation Administration periodically conducts studies to allocate costs among users. (See the table at right for the findings of the FAA's most recent cost allocation study.)[1] The main user classes are air carriers, general aviation, and the public sector. The air carrier class as a whole did not pay all the costs for which it was responsible. Passengers on domestic airlines paid more in ticket taxes than the air traffic control costs caused by the planes carrying them. But the commuter subclass had a deficit per operation of $108.82, and the deficit per operation for international flights was $32.33.[2]

The general aviation deficits and deficits per operation are substantial. Turbine-engine aircraft generated the largest deficit per operation ($111). Piston-engine aircraft flew a large number of operations--more than three times the number of domestic commercial flights--thereby generating the largest overall deficit.

Since the revenues for the public sector come from the general fund, revenues from aviation charges cannot be compared with the costs generated by the public sector. An alternative approach assumes that taxpayers pay for two kinds of aviation costs: the cost of public sector aviation and the cost of making up the deficit of the other users. About $704 million is associated with public-sector users. The remaining $887 million (shown as the surplus of the public sector in the table) is a subsidy by the general taxpayer to the other users of aviation infrastructure.

To summarize, the FAA found that in 1985 taxes paid by all users of the aviation system did not cover the FAA's cost of providing aviation services. But tax revenues from domestic air carriers exceeded their FAA costs. Commuter carriers and all categories of general aviation contributed substantially less in tax revenues than their costs.

Methodology of the Study

The FAA study analyzed all aviation system costs--including the airport grant program, regulatory activities, and administrative overhead--not just air traffic control, since the purpose was to determine how much users of the entire aviation system pay and how much the FAA spends on their behalf. The study is thus concerned more with equity than efficiency--whether users are paying their fair share of the costs they impose.

The FAA study's general approach was to determine which costs were attributable to each user group. If a given FAA activity was directly linked to just one user group, such as commercial passenger carriers, the study assigned all the costs of that activity to that user group. If an FAA activity was performed for all types of aviation, the study allocated the joint costs according to several criteria, including each group's use of the aviation system, the marginal costs associated with each group, and a markup based on the elasticity of each group's demand. Overhead and other indirect costs not associated directly with operations were assigned to users in much the same way as direct joint costs.

The FAA study used two methods of allocating joint costs--that is, those that cannot be directly attributed to any individual user group. The first--the "full-cost allocation method"--allocated joint costs among all the user groups. The second--the "minimum general aviation allocation method"--allocated joint costs only among commercial and government users. This method regarded general aviation (GA) as marginal users of a system that would be in place anyway to serve commercial aviation, and so it allocated to GA users only the costs directly attributable to them. The costs attributed to GA under the minimum GA allocation method correspond to the marginal costs of GA as a class.

The costs reported in the table reflect the full-cost allocation method. Even under the minimum general allocation method, however, none of the categories of general aviation was found to contribute more revenues than its costs. That is, even under this method, which minimizes the costs attributed to it, general aviation does not pay its way.

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1. Daniel Taylor, *Airport and Airway Costs: Allocation and Recovery in the 1980s*, FAA-APO-87-7 (Washington, D.C.: National Technical Information Service, February 1987).

2. When analyzing tax revenues, the FAA classifies air taxis as general aviation because they are subject to the fuel tax imposed on general aviation. Passengers who hire air taxis are not subject to the passenger ticket tax. When counting numbers of operations, however, the FAA includes air taxi operations with commuter air carriers.

Allocating Aviation Infrastructure Costs to Users and Revenues Collected from Users, 1985

	Cost (Millions of dollars)	Revenues (Millions of dollars)	Deficit (Millions of dollars)	Number of Operations (Millions)	Cost per Operation	Tax per Operation	Surplus or Deficit per Operation
Air Carrier							
Domestic	2,176.0	2,419.0	243.0	9.03	240.88	267.78	26.90
International	121.2	108.3	-12.9	0.40	303.75	271.42	-32.33
Freight	122.9	134.1	11.2	0.70	175.46	191.45	15.99
Commuters	713.0	89.8	-623.2	5.73	124.50	15.68	-108.82
Total	3,133.1	2,751.2	-381.9	15.86	197.55	173.47	-24.08
General Aviation							
Air Taxi	131.7	12.7	-119.0	2.96	44.56	4.30	-40.26
Piston	683.0	23.5	-659.5	30.48	22.41	0.77	-21.64
Turbine	520.2	60.9	-459.3	4.14	125.70	14.72	-110.98
Rotor	63.8	3.0	-60.8	2.12	30.03	1.41	-28.62
Total	1,398.7	100.1	-1,298.6	39.70	35.23	2.52	-32.71
Commuter and Air Taxi	844.7	102.5	-742.2	n.a.	n.a.	n.a.	n.a.
Air Carrier and Air Taxi	3,264.8	2,763.9	-500.9	n.a.	n.a.	n.a.	n.a.
Public Sector	703.8	1,591.0	887.2	3.09	228.01	228.01	287.42
with No Subsidy	703.8	703.8	0.0	3.09	227.77	0.0	0.0
Total (Carriers plus general aviation plus public)	5,235.6	4,442.3	-793.3	58.65	89.27	75.75	-13.53
Without Subsidy	5,235.6	3,555.1	-1,680.5	58.65	89.27	60.62	-28.65
Alternative Cost Allocation: Minimum General Aviation Allocation							
General Aviation							
Air Taxi	48.3	12.7	-35.6	1.53	31.61	n.a.	-23.30
Piston	323.6	23.5	-300.1	30.62	10.57	n.a.	-9.80
Turbine	186.1	60.9	-125.2	4.10	45.34	n.a.	-30.50
Rotor	21.8	3.0	-18.8	2.21	9.86	n.a.	-8.50
Total	579.8	100.1	-479.7	39.64	14.62	n.a.	-12.10

SOURCES: Congressional Budget Office calculations and Daniel Taylor, *Airport and Airway Costs: Allocation and Recovery in the 1980s*, FAA-AP087-7 (Washington, D.C.: National Technical Information Service, February 1987).

n.a. = not applicable.

operation of the aircraft and the expected use of the control facilities. But charging for each contact with the ATC may be costly to audit, and operators might skimp on such contacts, thus decreasing the safety of the airways.

Examples of Attempts at Marginal Cost Pricing

Although the FAA could, in principle, impose charges for congestion as a way of allocating scarce capacity of the air traffic control system, in practice such charges have been attempted only by airport authorities in connection with landing fees. From the economic standpoint of allocating scarce resources efficiently, it does not appear to matter which unit--the airport or the FAA--imposes the congestion fee, although both would be concerned about who gets the revenue.

Two attempts to impose congestion charges have had very different receptions. In 1968, the Port Authority of New York and New Jersey (PANY) imposed surcharges for peak-hour use by small aircraft at Newark, Kennedy, and LaGuardia airports.

PANY raised the peak-period minimum takeoff or landing fees for aircraft with fewer than 25 seats from $5 to $25, while keeping the off-peak fee at $5. Larger aircraft did not have to pay the fee but continued to be assessed according to their weight. Peak hours were defined as 8 a.m. to 10 a.m. on Monday through Friday and 3 p.m. until 8 p.m. on all days of the week. The PANY case demonstrated that peak/off-peak pricing differences were administratively feasible.

As a result of the surcharges at the New York and Newark airports, general aviation activity decreased by 19 percent overall and 30 percent during peak hours. The percentage of aircraft operations delayed more than 30 minutes declined markedly.[24]

The Aircraft Owners and Pilots Association (AOPA) took legal action in 1969 to have the fees canceled. The core of AOPA's argument was that the fee was openly discriminatory and infringed on the equality of access to air facilities. AOPA argued that PANY could not distinguish among aircraft from the point of view of their right of access to these public airport runways for landing and taking off, and that even if PANY had such a power, the present fee system was discriminatory.

The United States District Court found in favor of the Port Authority, ruling that the defendants were justified in distinguishing different classes of aircraft, on the grounds of safety and efficient use of landing facilities.[25] The court further recognized that the fee was meant to induce aircraft operators to use other times of the day or other facilities.

The PANY experience contrasts with that of an attempt by the Massachusetts Port Authority (Massport), the agency in charge of Boston's Logan airport, to reduce congestion by increasing landing fees for smaller aircraft. In 1988, Massport proposed a new formula for calculating landing fees. The formula was intended to reduce use by general aviation aircraft that were contributing to congestion. The main difference between the PANY surcharge and Massport's fee was that Massport's applied during both peak and off-peak periods. The authority's old fee was based solely on landing weight--$1.31 per thousand pounds with a $25 minimum. The new formula consisted of a relatively high base charge for landing--$88--and a smaller charge based on weight--47 cents per thousand pounds. The new fees resulted in smaller aircraft paying more than before and larger aircraft paying less (see Table 11).

The state of Maine and several associations complained that the new fee structure discriminated against general aviation. The U.S. Department of Transportation filed a suit

24. Office of Technology Assessment, *Airport System Development* (August 1984), pp. 118 and 131-132.

25. *Aircraft Owners and Pilots Association v. Port Authority of New York and New Jersey*, 305 Federal Supplement 93, S.D.N.Y. (1969).

Table 11.
Old and New Fees at Boston's Logan Airport for Selected Aircraft

Type of Aircraft	Weight (Pounds)	Old Fee (Dollars)	New Fee (Dollars)
Beechcraft Bonanza F33 A/C	3,400	25.00	89.60
Boeing 737-200	107,000	140.17	138.29
McDonnell Douglas DC-10	421,000	551.51	285.87
Heaviest Aircraft Paying Minimum Under the Old Fee	19,000	25.00	96.93

SOURCE: *Investigation into Massport's Landing Fees, Opinion and Order.* Federal Aviation Administration Docket 13-88-2; and Federal Trade Commission, *Proposed Comment on Massport's Program for Airport Capacity Efficiency,* Memorandum (February 18, 1988).

against Massport charging that the new fee structure unduly discriminated against small aircraft. An administrative law judge found that the new fee structure was unreasonable and contrary to federal statute and ordered Massport to revert to its old fee schedule. The judge also commented that "it would have been more credible for Massport to have adopted the surcharge type fee that the Port Authority of New York has imposed for peak hour small aircraft usage at Newark, LaGuardia, and Kennedy airports . . ."[26]

Revenues from Marginal-Cost Pricing

Since charging users their marginal costs is economically efficient, the next issue is how much revenue can be raised from marginal-cost pricing. In 1985, if users had been charged the marginal costs estimated by Golaszewski, revenues would have been about $1.1 billion.[27] The corresponding revenues in 1991 would have been about $1.4 billion.[28] The estimated revenues could be less if airlines raise ticket prices to pass on some of the marginal costs to consumers. This could reduce the demand for flights and hence the revenues.

How do these revenues compare with total spending on the air traffic control system? FAA spending on air traffic control services is broken down in Table 12 into operations, facilities and equipment, and research, engineering, and development; the table also shows the estimated revenues from marginal cost pricing and total outlays during 1985 and 1991.

Table 12 shows that marginal-cost pricing would have failed to recover costs of operations or total air traffic control costs in 1985 and 1991. The estimates of spending on ATC were derived from the amounts obligated, and spending for operations was based on assump-

26. *Investigation into Massport's Landing Fees, Opinion and Order,* FAA Docket 13-88-2 (1988), p. 9.

27. Golaszewski, *The Unit Costs of FAA Air Traffic Control Services,* Parts I-III.

28. This estimate was calculated by converting the 1985 marginal cost for each service to 1991 dollars using the GNP deflator. The costs were then multiplied by the number of operations, pilot briefs, air contacts, times the aircraft was handled, and so forth, for each user class at each type of facility in 1991. The estimate assumes that public-sector users are paying the marginal costs for their use of the air traffic control system. This assumption is valid here because the intent of this section is to compare total ATC expenditures with the possible revenues from marginal-cost pricing. The information on air traffic control activity for 1991 is contained in various tables in the *FAA Aviation Forecasts,* 1992-2003.

Table 12.
A Comparison of Spending on Federal Aviation Administration Air Traffic Control with Revenues from Marginal-Cost Pricing (In millions of 1991 dollars)

Category	Amount 1985	Amount 1991
Total Federal Aviation Administration Outlays	5,061	7,241
FAA Spending for Air Traffic Control[a]		
Operations	2,671	3,063
Facilities and equipment	523	1,512
Research, engineering, and equipment	322	179
Total	3,516	4,754
Estimated Revenues from Marginal-Cost Pricing, Excluding Congestion Pricing	1,308	1,399
Difference (Between FAA spending on air traffic control and revenues from marginal-cost pricing, excluding congestion revenues)	2,208	3,355
Estimated Revenues from Marginal-Cost Pricing, Including Congestion Pricing	n.a.	2,900
Difference (Between FAA spending on air traffic control and revenues from marginal-cost pricing, including congestion revenues)	n.a.	1,854

SOURCES: Budgets of the United States Government, Fiscal Years 1987 and 1993; FAA Aviation Forecasts, February 1992; FAA cost allocation model; and CBO calculations.

NOTE: n.a. = not applicable.

a. Estimated spending on air traffic control operations, research engineering, and development and facilities and equipment. The calculations were based on FAA's cost allocation model and number of operations at FAA facilities in 1985 and 1991.

tions about which operational activities are most closely related to the ATC system.[29] The FAA budget does not explicitly separate spending for air traffic control from such other spending as programs for safety, activities at headquarters, and other aviation activities that do not impinge directly on air traffic control.

The difference between FAA spending on ATC and revenues from marginal-cost pricing, excluding congestion revenues, increased from $2.2 billion in 1985 to $3.4 billion in 1991. The rise is partly explained by the increase in capital spending by the FAA during this period. Since capital expenditures are not usually counted as part of marginal costs, revenues would not have increased correspondingly.

Problems with Marginal-Cost Pricing

The advantages in efficiency of marginal cost pricing must be weighed against several drawbacks. First, estimating marginal costs is not easy. Although Golaszewski has shown one way to estimate marginal costs, he cautioned that he had to make certain assumptions about use of capacity and other specific characteristics of the various facilities be studied. He apparently was unable to obtain enough data to distinguish between peak and off-peak periods, to determine whether marginal costs to the FAA varied by time of day.

29. Obligations for ATC operations are fairly close to outlays. Obligations for facilities and equipment, which can be commitments to spend on capital for many years into the future, can differ greatly from outlays, which are monies paid out during the year to contractors, possibly for work obligated in the past.

It is likely, however, that congestion costs have a stable component that can be used to set fees that do not vary unpredictably. Users would benefit from stable fees when making their decisions about when to use the system.

A second problem is how to administer a system of marginal-cost charges. Although the FAA keeps detailed records of aircraft handled, a system of billing commercial air carriers and general aviation for their use of FAA services would have to be devised.[30]

Finally, the estimates made by Golaszewski and the FAA's cost allocation study suggest that if users were charged only the component of marginal costs incurred by the FAA, revenues would not cover the FAA's costs of operating the air traffic control system. With additional charges for congestion, revenues might be sufficient to cover total costs, but distributional problems might arise if excess revenues from congested locations were used to cover costs at those that were not congested. Thus, it could be argued that the commercial air carriers and their passengers, who would pay the lion's share of congestion charges, would be subsidizing owners of private aircraft.

Congestion charges could be levied on aircraft at airports. Using the average value of time for aviation users, and the FAA's estimates of delays at congested airports, the revenues from congestion fees would be around $1 billion to $2 billion, an amount that could increase estimated revenues from marginal-cost pricing to between $2.4 billion and $3.4 billion.[31]

This estimate is subject to several qualifications. If congestion is a local phenomenon--that is, a crowded airport at New York can coexist with an uncongested airport in Iowa--the fees would be collected only at congested airports.[32] In addition, if airlines are required to pay these charges, they will pass on some of the costs to consumers, reducing congestion, demand for flights, and, consequently, the revenues from congestion charges. Finally, if the FAA is successful in making needed improvements at airports, congestion at the major airports would decline, reducing the estimated revenues from congestion fees.

If the purpose of congestion fees is to reduce congestion to an acceptable level, revenues from pricing for congestion could be used to finance improvements in capacity at congested airports. It has been estimated that increases in IFR arrival capacity at the top 25 airports (by number of operations) will require about $825 million.[33] The expected revenues of $1 billion to $2 billion from congestion fees could be used to finance these improvements and air traffic control as well.

Whether marginal-cost pricing covers total costs does not matter for the efficient allocation of resources in the short run, but it has long-run implications for investment decisions. Revenues greater than cost add strength to arguments that more spending is warranted on air traffic control. The excess of revenues over costs is likely to be greatest where the most congestion delays are experienced--and thus where investments to reduce delays would be most valuable.

If marginal-cost pricing would never yield enough revenue to cover the total costs of some activities, additional investment may or may not be justified. Cost-benefit analysis might help guide the investment decision. The gen-

30. The countries in the European Community are trying to put in place a single air traffic control system. It appears that collecting user fees in this system is administratively feasible. See Gellman Research Associates, *Towards a Single System for Air Traffic Control in Europe* (Jenkintown, Pa.: Gellman Research Associates, September 1989).

31. Department of Transportation, *1990-91 Aviation System Capacity Plan*, Table 1-5, p. 1-16.

32. Delays at a hub airport can cause delays throughout the system.

33. Committee for the Study of Long-Term Airport Capacity Needs, *Aviation System Capacity*, Table 3-5. These projects should lead to about 230 additional hourly IFR arrivals at those airports.

eral rule is that if users would be willing to pay for the investment--whether or not they are actually charged to cover its total cost--the investment is worth undertaking.

Charging to Recover Total Costs

Even if charging all users the marginal cost of air traffic control services does not yield enough revenue to cover costs, there are several ways to make up this shortfall:

- Ramsey pricing;
- A subsidy from the general fund;
- Raising existing aviation excise taxes; and
- Raising marginal costs proportionately to the percentage of total costs.

Ramsey Pricing

Applying Ramsey pricing to air traffic control services entails lowering or raising charges according to the reactions of users to price changes. Classes of users who would cut back sharply on their consumption of ATC services in response to a price increase would be charged either the marginal cost or only a small markup over it. (If charged the marginal cost, they would not fly less; a small markup would cause them to cut back.) Price markups would be higher for those users who were less sensitive to price increases--those who would continue to fly nearly as much as before, even if prices rose considerably. The difference between the price they would pay and the marginal cost for each unit would help cover the overhead costs.

This approach has different distributional consequences from simply charging marginal costs because some users would face higher prices than others. Commercial airlines probably would be less responsive to price changes than general aviation.[34] If so, under Ramsey pricing they could be expected to pay more for ATC services than general aviation.

Charging Marginal Cost and Making Up Revenue Shortfalls from the General Fund

Another way to cover the costs of air traffic control while maintaining the advantage of marginal-cost pricing is to draw on the general fund of the U.S. Treasury to make up any difference between total costs and revenues from marginal cost pricing. In 1991, as Table 12 shows, the estimated contribution from the general fund would have been about $3.4 billion. If congestion charges had also been levied, the subsidy would have been about $1.9 billion.

Charging Marginal Cost and Making Up Revenue Shortfalls with Existing Aviation Excise Taxes

In 1991, marginal-cost pricing would have yielded revenues of about $1.4 billion. Aviation excise tax revenues were about $4.9 billion. Thus, a combination of revenues from marginal-cost prices and taxes would have more than covered the $4.8 billion spending on FAA air traffic control. Revenues would be even higher if congestion charges were included in marginal costs. The surplus would then have been available to cover some of the FAA programs outside of ATC, primarily the Airport Improvement Program, which required outlays of $1.5 billion.

34. In its cost allocation study, the FAA assumes that general aviation users are twice as sensitive to price changes as commercial airline users. See Department of Transportation, Federal Aviation Administration, Office of Aviation Policy and Plans, *Allocation of Federal Airport and Airway Costs for FY 1985* (December 1986), Appendix A, pp. 5-9.

These numbers assume that users of the air traffic control system would not have cut back on use after paying the user fees. If they did cut back significantly, both fees and expenses would be less than the amounts given above. This option also assumes that the various aviation groups would agree to pay both the taxes and user fees for ATC when they had been paying only taxes for such services.

Increasing Current Taxes Proportionately to Cover All Costs

This option dispenses with the efficiency of marginal-cost pricing; its sole objective is cost recovery. What aviation tax rates in 1993 would cover estimated total FAA outlays (FAA spending on both ATC and airports) for the private sector? Assuming that public-sector users account for 15 percent of FAA costs, total FAA outlays on the private sector in 1993 are estimated to be $7.3 billion. The tax rates in 1993 and the rates needed to recover these outlays are shown in Table 13. It is assumed that the ratio of each tax collected to the total tax collected remains the same. For example, since the passenger ticket tax receipts are about 88 percent of total taxes collected in 1991, the new rate of 13 percent yields about the same percentage of FAA outlays on the private sector.

The advantage of financing all costs through aviation excise taxes is that subsidy of private-sector users by the general fund would be eliminated. In addition, the misleading surplus in the trust fund would no longer grow. This surplus makes it appear that total FAA outlays have been less than aviation excise tax revenues. In fact, operations costs have been partly subsidized by the general fund, and therefore such a conclusion is unwarranted.[35] Finally, the federal deficit would be reduced by the amount now coming from the general fund to finance the costs imposed by private users.

If one of the objectives of the government is to promote aviation, the main disadvantage of raising aviation excise taxes is that levels of use could decline. Also, the commercial air carriers may object to an increase in the tax on passenger tickets when they are already paying more than the costs they impose on the FAA.

It should be emphasized that this option is at variance with the other approaches that aim at efficient use of the aviation network. It is mentioned primarily as a logical addition to the option of raising aviation taxes to cover the revenue shortfall from marginal-cost pricing.

Table 13.
Tax Rates Needed to Recover Estimated Federal Aviation Administration Outlays for Fiscal Year 1993[a]

	1991 Rate	Rate Needed to Recover Outlays
Passenger Ticket Tax (Percentage)	10	13
Freight and Waybill Tax (Percentage)	6.25	8.125
Fuel Tax (Cents per gallon)[b]	16.8	22
International Departures Tax (Dollars)	6	7.80

SOURCES: *Budget of the United States Government, Fiscal Year 1993*, and CBO calculations.

a. Assumes all rates are raised proportionally so that revenues collected from aviation taxes equal FAA outlays for the private sector, which are estimated to be $7.3 billion in fiscal year 1993.

b. The fuel tax in the table is a weighted average (weighted by amounts of aviation fuel and jet fuel consumed by general aviation) of the aviation fuel tax of 15 cents per gallon and the jet fuel tax of 17.5 cents per gallon.

35. For an analysis of the aviation trust fund, see Congressional Budget Office, *The Status of the Airport and Airway Trust Fund* (December 1988).

Marking Up Marginal Costs Proportionately to the Percentage of Total Costs

Total costs of the ATC system may also be recovered by charging each group a multiple of its marginal costs. The value of the multiplier is determined by the ratio of marginal costs to total costs incurred by each group. For example, in 1985, the marginal costs incurred by air carriers were about 21 percent of their total costs.[36] Thus, under a cost recovery scheme in which marginal costs form the base, air carriers would be charged about five times the marginal cost for services offered at ATC facilities.

For example, an air carrier flight from Washington, D.C., to Chicago imposes marginal costs of about $135 on the air traffic control system. If all ATC costs (including capital equipment and overhead) were to be covered by raising this marginal cost in proportion to the costs caused by air carriers, the total cost of the Washington, D.C., to Chicago trip would rise to $985. This total cost is greater than the proportionate increase in marginal costs mentioned above because of the high capital costs attributed to an IFR departure; such costs were not included in the marginal cost of a "handle," which is defined as two IFR departures plus guidance by air route traffic control centers.

If costs are allocated by a proportionate increase in marginal costs as in the example above, air carriers may pay less on an average flight than the revenues currently being collected through the passenger ticket tax. However, commuter air carriers would probably raise prices to defray the new costs, thereby causing a decrease in demand for their services. General aviation users would also be adversely affected by this procedure since they would have to pay more on a typical flight than the fuel taxes they are currently paying.

For example, a corporate jet now pays about $43 in fuel taxes for a flight from Washington, D.C., to Chicago. If all ATC costs were to be covered by raising the marginal cost in proportion to the costs generated by general aviation for an IFR flight, the fee would be about $445. If it flew under visual flight rules and avoided contact with ATC centers en route, the fee would drop to $140. (This example merely serves to illustrate the difference between user fees for IFR and VFR. For efficient operation, a jet would have to cruise above 25,000 feet; thus, in practice it would fly IFR.)

Since users would pay more than marginal costs under this mechanism, levels of use would be lower than the efficient levels associated with marginal-cost pricing. There is also no attempt to tailor prices to demand while recovering costs, as under Ramsey pricing. The advantage of this method is that once costs have been allocated to the different classes of users, it is easy to administer.

Average-cost pricing is similar to the above method with the additional advantage that it does not require a determination of marginal costs. Under average-cost pricing, total costs to a service used by each group in the previous year are divided by the number of operations associated with that group in that year to get the fee.

Conclusion

Existing federal taxes on users of the air traffic control system and other parts of the aviation system do not promote the efficient use of aviation infrastructure. Charging users their marginal cost could improve efficiency. The data for determining such fees is readily available.

Aviation taxes also do not raise enough revenues to cover the total expenses of the FAA. If the aim is to recover all costs of air

36. Golaszewski, *The Unit Costs of FAA Air Traffic Control Services*, Table 2.

traffic control, two main options are available. Existing taxes could be increased proportionately for each class of users. Alternatively, a combination of new fees that correspond to additional costs caused by users and existing aviation taxes could also make the air traffic control system self-financed. Neither of these options is as efficient as charging aviation users the marginal costs they impose on the air traffic control system.

Chapter Four

Inland Waterways

In 1990, the federal government spent $776 million to build, operate, and maintain the nation's inland waterway system for navigation purposes.[1] The inland waterway system is used primarily by commercial barges, although recreational and commercial passenger boats are common in some sections. Like users of the highway and aviation systems, commercial waterway users pay fuel taxes that are intended to cover some of the system's costs. But revenues from fuel taxes yielded only $63 million in 1990, or about 8 percent of the amount spent in support of the inland waterway system. Since no other charges or taxes are imposed for using inland waterways, the general fund of the federal government paid the rest of the expenses.

Some rivers would be navigable even without investment by the Army Corps of Engineers. But such work as dredging, removing obstacles, and widening and straightening channels can enhance their value by accommodating larger barge tows and enabling the vessels to move faster. Without locks and dams to regulate the flow of water, some river segments would be too shallow, rapid, dangerous, or unpredictable to accommodate the reasonably regular or predictable flow of traffic that is essential to efficient scheduling of the flow of commerce. Spending to improve the waterways, then, enhances the productivity of the users of the waterway system. It is an investment in infrastructure that, like other investments, can be evaluated on the basis of its returns.

Charging users in keeping with the costs of providing the waterway system significantly affects the efficiency and productivity of the nation's transportation resources. If users pay less than their share of the cost, they tend to overuse the system, sometimes to the detriment of competing modes, such as rail and truck. Moreover, users who do not pay their share of costs may demand excessive additional investment in the waterway system.

There may be an economic rationale for not charging users of navigable waterways the full cost of the system. If the waterway system promotes economic development or national defense capabilities, economic equity might justify having the general public pay for those external benefits. The substantial imbalance between costs and user taxes, however, suggests that it is desirable to explore ways of placing a larger share of the burden on the users.

Background

The inland waterways of the United States are a major component of the nation's transportation system. They are especially important in the transportation of heavy, low-value, bulk commodities such as coal, petroleum, chemicals, construction materials, and grain.

1. The data presented in this chapter are the most recent available for comparative purposes. In general, aggregate budget data are available for 1991, disaggregated spending data for 1990, and data on traffic for 1989.

In calendar year 1989, inland waterway traffic consisted of 606 million tons of freight carried an average of 450 miles to yield a total of 272 billion ton-miles.[2] This amount was about 10 percent of the nation's freight and 2 percent of the freight bill. About 55 percent of the tonnage carried on inland waterways is crude petroleum, petroleum products, and coal. Inland waterway transportation plays an important role in export trade; about one-half of U.S. grain exports and one-fifth of U.S. coal exports are carried on the inland waterways.

Description of Waterways and Their Users

Barges are an efficient method of moving bulk commodities that have a low value-to-weight ratio. Water transportation is especially energy-efficient in transporting large loads over long distances. Barges carrying grain, coal, and similar dry bulk commodities on the Mississippi River-Gulf Coast system are typically 195 feet long, 35 feet wide, and have a draft of nine feet. Barges have an average capacity of about 1,500 tons. Tank barges carrying liquid cargo--petroleum, petroleum products, fertilizers, and industrial chemicals--are nearly 300 feet long and can carry 1 million gallons. A tow consists of a towboat pushing a number of barges, typically eight to 17, three abreast, on large and medium-size waterways with locks. The number of barges in a tow on the lower Mississippi River is usually 30 to 40. The magnitude of these tows accounts for their efficiency.

About 1,800 companies are involved in the barge, towing, and related support businesses in the United States. Some firms own only one or two towboats, while others own fleets. Together, these organizations operate some 5,000 towboats, 27,000 dry cargo barges, and 4,000 tank barges.

The shallow-draft inland waterway system consists of about 11,000 miles of navigable channels and is maintained by the U.S. Army Corps of Engineers as part of its civil works program. (The Army's civil works program is included in budget function 300, water resources.) Most inland waterways are less than 14 feet deep, and commercial vessels traveling on them are subject to a fuel tax. The waterways subject to a fuel tax are specified in the Inland Waterways Revenue Act of 1978 and the Water Resources Development Act of 1986 and are listed in Table 14. (See Figure 4 for a map of the waterways with a fuel tax.) Traffic in deep-draft channels and ports is generally subject to the Harbor Maintenance Tax, a tax on the value of cargo. The system includes 167 lock sites, with 216 lock chambers. Where there is more than one chamber at a site, one main chamber handles most of the traffic, and an auxiliary chamber--typically smaller than the main one--is used for recreational boats and small amounts of commercial traffic at peak times or when the main chamber is undergoing maintenance or repair. The oldest locks still in use were built in 1839, and the newest was opened to traffic in 1991. The median age is about 35 years.

Cost Elements

In addition to the tow operators' private costs of labor, fuel, facilities, and equipment, waterway navigation imposes numerous resource costs, many of which are borne by the federal government. Making waterways navigable entails building and renovating locks and dams, and dredging, widening and straightening channels. These activities may impose environmental as well as direct construction costs. Operating and maintaining locks and dams and ensuring a smooth flow of traffic along the waterways also consume considerable resources. Tow operators impose and incur delay costs when waterways become congested and traffic must wait to go through locks. At the few locks and dams where

2. Army Corps of Engineers, *1990 Inland Waterway Review* (draft). The total includes some traffic on nontaxed portions of the inland waterways. Traffic on the fuel-tax waterways was 250 billion ton-miles in calendar 1989, the most recent year for which data are available.

Table 14.
Operation and Maintenance (O&M) Costs and Traffic by Waterway, 1989

Waterway	Ton-Miles (Thousands)	O&M Costs (Thousands of dollars)	O&M Costs per Ton-Mile (Cents)
Mississippi (Ohio River - Baton Rouge)	112,908,248	52,486	0.047
Ohio	51,595,916	52,184	0.101
Gulf Intracoastal Waterway	22,202,858	28,387	0.128
Mississippi (Missouri-Ohio Rivers)	17,515,644	22,414	0.128
Black Warrior-Tombigbee	4,862,584	12,213	0.251
Tennessee	6,512,433	17,383	0.267
Green-Barren	476,515	1,297	0.272
Illinois Waterway	7,870,314	24,746	0.314
Atchafalaya-Old	475,783	1,683	0.354
Kanawha	1,269,365	4,973	0.392
Mississippi (Minneapolis-Missouri River)	15,760,281	82,361	0.523
Columbia-Snake	1,437,536	9,134	0.635
Red	546,594	3,597	0.658
Monongahela	1,523,674	11,911	0.782
Missouri	796,735	7,373	0.925
Cumberland	1,215,034	11,573	0.953
Arkansas System (McClellan-Kerr)	1,788,528	26,569	1.486
Kaskaskia	97,896	1,817	1.856
Tennessee-Tombigbee Waterway	791,309	18,040	2.280
Atlantic Intracoastal Waterway	461,104	13,507	2.929
Ouachita-Black	123,884	4,315	3.483
White	58,628	2,294	3.913
Willamette	12,711	619	4.870
Alabama-Coosa	181,909	9,710	5.338
Apalachicola-Chattahoochee-Flint	93,059	7,795	8.376
Kentucky	14,695	1,480	10.072
Allegheny	52,168	7,304	14.001
Pearl	a	866	a
Total	250,645,405	438,031	0.175

SOURCE: Army Corps of Engineers.

a. The Pearl River had no traffic in 1989.

hydroelectric power is generated, each movement may cause a small loss in generating capacity--still another resource cost.

This study is concerned primarily with costs associated with navigation, but navigation projects sometimes have other purposes, such as flood control, recreation, and generation of power. When this is the case, it is difficult to determine how much of the costs to attribute to each of the different uses or purposes. Often, much of the cost is joint: a given expenditure serves more than one purpose, such as building a levee that aids navigation and controls flooding. By definition, joint costs cannot be attributed to individual users or categories of users. Still, a system for recovering joint costs from users may be desirable. One accepted principle is to allocate costs according to the benefits received by each user or class of users. The Corps of Engineers has adopted cost-allocation regulations that describe procedures for assigning joint costs to project purposes. The corps has also extensively studied alternative methods of allocating costs that could serve as a basis for setting user charges. This study uses the corps's existing allocation system. Although serving adequately for current purposes, however, this system could be refined, based on

Figure 4.
Fuel-Tax Waterway System

SOURCE: Army Corps of Engineers.

NOTE: Tenn-Tom = Tennessee-Tombigbee; ACF = Apalachicola-Chattahoochee-Flint.

work already completed by the corps, to provide better information for imposing charges on waterway users.[3]

Federal Spending on Waterways

The Army Corps of Engineers, under the Army's civil works budget, carries out most of the federal government's spending on inland waterways. In 1990, the corps spent $384 million to operate and maintain the fuel-taxed waterway system and $392 million on construction.[4]

Spending for Operation and Maintenance

Funds for operation and maintenance (O&M) are used for dredging channels; operating locks; repairing locks, dams, revetments, and other structures; removing channel obstructions; and similar activities. Among the factors that affect the costs of operating and maintaining navigation channels are water flow, weather, and the passage of time. Some rivers need to be dredged more often than others to maintain a certain depth. In years of drought, the corps may have to do extra dredging throughout the system to maintain navigable depths. Critical to the problem of charging users of waterways is whether and how the passage of tows affects O&M costs on a waterway. The corps's data suggest that traffic is not an important determinant of O&M costs on a waterway.

Data on O&M costs and traffic on each waterway subject to the fuel tax for 1989 are presented in Table 14. The corps uses the amount of ton-miles carried on a waterway as the measure of output. Alternative measures, such as the number of tows or barges, could also be used and might be more useful in showing the effects of traffic on costs. The various measures are likely to be highly correlated for barges carrying loads. The main difference is that the ton-mile measure does not reflect the flow of tows containing empty barges.

In 1989, the systemwide average O&M cost per ton-mile was 0.17 cents. There was wide variation among waterways: O&M costs per ton-mile ranged from less than 0.05 cents on the lower Mississippi River between the Ohio River and Baton Rouge to 14 cents on the Allegheny River.[5] Because costs and traffic fluctuate somewhat from year to year, it is also useful to look at an average of several years. Over the 1977-1988 period, average O&M costs per ton-mile ranged from 0.04 cents on the lower Mississippi to 12.6 cents on the Kentucky.[6] The cost per ton-mile tends to be low on those waterways with a large amount of traffic and on those with few or no locks.

Average costs are one important factor in determining efficient investment and pricing levels, and marginal costs are another. Marginal costs--the costs of one additional unit of traffic--are difficult to determine using available data. But CBO ran a linear regression relating O&M costs to ton-miles and water-

3. See, for example, Office of the Chief of Engineers, Directorate of Civil Works, Office of Policy, U.S. Army Corps of Engineers, *Navigation Cost Allocation Study--A Feasibility Case Study* (October 5, 1980).

4. These are preliminary estimates of spending on the shallow-draft segments subject to the fuel tax. Including spending on nontaxed waterway segments and on deep-draft channels and harbors on which traffic is generally subject to the harbor maintenance tax would yield total outlays of $718 million for operation and maintenance and $534 million for construction in 1990.

5. The corps spent $866,000 in 1989 on the Pearl River, but reported no traffic. The last year for which traffic was reported on the Pearl was 1985, when the cost per ton-mile was 95 cents.

6. These averages are based on nominal dollars for each year. No attempt was made to adjust for inflation, since the purpose was to make comparisons among waterways rather than to understand trends over time. The average O&M cost per ton-mile on the Pearl River for 1977-1988 was 34.9 cents.

way length and found that one additional ton-mile would raise O&M costs by less than 0.04 cents.[7] This low marginal cost, which is less than the average cost on even the lowest-cost waterway, suggests that most O&M costs can be regarded as fixed and do not vary with output. The marginal-cost estimate applied systemwide.

It is important to note that availability of data limited this analysis. A more thorough analysis would include all relevant factors, such as the number of tows, number of lockages, and variables reflecting unusual weather conditions or other characteristics that might affect costs, and would test alternative specifications of the relationships among the variables. The limited objective here was to see whether there was any statistically significant relationship between costs and use, and if so to estimate an approximate marginal cost.

It may be easier to associate costs with use for lock operations than for dredging or other channel maintenance. Each operation involves wear and tear on the lock. Moreover, each lockage entails labor, although if an operator must be on duty (and paid) regardless of whether any tows pass through the lock during that operator's shift, the cost would not depend on the number of operations. Another type of cost, for the few locks and dams at which hydroelectric power is generated, occurs because each lock operation reduces the water flow and thus diminishes generating capacity slightly.

Congestion at locks also imposes costs. Because the costs of these delays are borne by tow operators rather than the federal government, they raise somewhat different issues about imposing user charges to improve efficiency and productivity. (See the discussion below on alternative mechanisms for charging users.)

Spending on Construction

The Army Corps of Engineers spent $392 million on construction and major rehabilitation projects on the inland waterway system in 1990. Since these projects typically take many years to complete, the spending in any single year consists of partial payment for a number of projects. A list of construction and major rehabilitation projects under way or proposed in the fiscal year 1991 budget is contained in Table 15.

Waterway construction projects are generally undertaken in response to a traffic impediment, such as when a lock and dam have become congested because of increases in traffic or breakdowns resulting from age. Replacing the lock, and perhaps expanding it, may substantially benefit barge operators. Dredging a channel deeper to allow transit by more heavily loaded barges, or widening channels, or turns in channels, to facilitate transit by more and larger tows, are other examples of improving waterways.[8]

Construction projects generally have long lives. Locks and dams are designed to last 50 years or more. The largest recent lock and dam construction project is the $950 million Melvin Price Locks and Dam (Locks and Dam 26) on the Mississippi River above St. Louis. Its 1,200-foot-long and 110-foot-wide main chamber should help alleviate congestion at the smaller (600-foot long) lock and dam it has replaced. The new main lock was opened to traffic in 1990. A 600-foot by 110-foot auxiliary lock is under construction. Another recent project is the Oliver Lock and Dam on the Black Warrior River, which was completed in 1992 and cost $120 million.

7. Both factors were statistically significant. The coefficient on the ton-mile variable, which indicates by how much O&M costs increase as a result of one additional ton-mile of traffic, was less than 0.0004. Regressions of O&M costs by waterway against ton-miles and length of waterway were run using data from 1985, 1988, and the 1977-1988 average. The number of lock sites in each segment was also included as a variable. All of the regressions gave similar results.

8. A distinction should be made between dredging to deepen a channel, which is an investment aimed at increasing capacity, and dredging to maintain a given depth, which is properly classified as O&M.

The largest channel construction project completed in recent years is the 234-mile Tennessee-Tombigbee waterway, which was built to link the Tennessee and Tombigbee rivers in Mississippi and Alabama. The channel is nine to 12 feet deep and 300 feet wide in most places, and there are 10 locks and five dams. Completed in 1985, the Tennessee-Tombigbee took 13 years to build and cost the federal government $1.8 billion. With regular maintenance, this addition to the waterway system is expected to last at least 50 years and probably longer.

Investment decisions are guided by benefit-cost analyses, which estimate the expected benefits and costs over the life of the investment. Estimating the benefits of a project can be difficult, however, especially if market prices do not reveal the value of a project to its potential beneficiaries. A system of charging users could help illuminate which investment

Table 15.
Construction and Major Rehabilitation Projects (Costs in millions of dollars as of October 1991)

Waterway/Project	Completion	Total Cost
Upper Mississippi River Locks and Dams		
Melvin Price, 1st lock	1997	737
Melvin Price, 2nd lock[a]	1993	213
No. 3, 5A-9 (6 sites)	1999	50
Upper and Middle Mississippi		
System environmental management program[b]	2002	259
Middle Mississippi River		
Regulating works	2000	215
Lower Mississippi River		
Channel improvement	2010	3,622
Atchafalaya River	2010	1,648
Arkansas River System	2000	646
Red River, mouth to Shreveport, Louisiana	c	1,847
Ohio River System Locks and Dams		
Ohio River, Gallipolis[a]	1999	384
Ohio River, Olmsted[a]	2006	1,110
Monongahela River, Grays Landing[a]	1995	174
Monongahela River, Point Marion[a]	1994	99
Kanawha River, Winfield[a]	1997	236
Gulf Intracoastal Waterway		
Mississippi River-Gulf Outlet, Inner Harbor Lock[a]	c	500
Mobile River and Tributaries		
Black Warrior River, Oliver Lock and Dam[a]	1992	120
Columbia-Snake Waterway		
Columbia River, Bonneville Lock and Dam[a]	1994	331

SOURCE: U.S. Army Corps of Engineers, *1991 Inland Waterway Review* (draft), Tables 6-3, 6-4, and 6-5.

a. Funded in part by the Inland Waterways Trust Fund.

b. Except recreation.

c. Completion date is indefinite.

projects were likely to generate the greatest increases in productivity and efficiency.

Current Financing Policy

All of the federal government's spending for operation and maintenance and part of its spending for construction on the inland waterway system is financed by general tax revenues. Revenues from a tax on fuel used by commercial vessels on the waterways cover a share of new construction spending. (See Box 5 for a description of financing by the Inland Waterways Trust Fund.) The Inland Waterways Revenue Act (IWRA) of 1978 as amended by the Water Resources Development Act (WRDA) of 1986 imposed the fuel tax as a way of shifting some of the costs from the general taxpayers to users of the waterway system. The fuel tax does not apply to deep-draft (more than 12 feet) oceangoing ships, passenger boats, recreational craft, or government vessels.[9] The schedule for phasing in the fuel tax, which began at a rate of 4 cents a gallon in 1980 and will rise to 20 cents a gallon in 1995, is shown in Table 16. Under current law, it will remain at that level.

Section 206 of the 1978 IWRA designated 26 waterways on which traffic would be subject to the fuel tax. The 1986 WRDA (Section 1404 (b)) added the newly completed Tennessee-Tombigbee Waterway to the list. The fuel tax is uniform on the 11,000 miles of shallow-draft waterways on which it applies.[10]

Table 16.
Phase-In Schedule of Fuel Tax Rates

Time Period	Fuel Tax (Cents per gallon)
October 1, 1980, to September 30, 1981	4
October 1, 1981, to September 30, 1983	6
October 1, 1983, to September 30, 1985	8
October 1, 1985, to December 31, 1989	10
January 1, 1990, to December 31, 1990	11
January 1, 1991, to December 31, 1991	13
January 1, 1992, to December 31, 1992	15
January 1, 1993, to December 31, 1993	17
January 1, 1994, to December 31, 1994	19
January 1, 1995, and Beyond	20

SOURCE: Internal Revenue Code, 26 USC 4042(b).

Revenues from the Fuel Tax

The fuel tax generated $60 million in 1991 and is expected to yield $460 million during the 1992-1996 period. Increases in tax rates and traffic are expected to raise revenues each year. But the higher tax rates may not yield proportional increases in revenues. Many tow operators are using fuel more efficiently. They have been running at slower, fuel-conserving speeds since excess capacity in the industry has diminished the need to deliver a load quickly and return for another. Replacing older towboats with new ones that have more fuel-efficient engines also reduces fuel consumption.

Effects of Fuel Taxes on Efficient Use of Resources

Fuel taxes--and other user taxes or charges--should be judged not only on the amount of revenue they raise but also on the incentives or disincentives they provide for efficient use of resources. The question raised in this section is what effect (if any) the fuel tax has on the use of waterways by tow operators.

9. Inland Waterways Revenue Act of 1978, Section 202, codified at 26 U.S.C. Section 4042(c)(1).

10. Shallow-draft waterways other than the 27 designated, shallow-draft harbors and channels, and deep-draft harbors and channels are excluded from the fuel tax. Their traffic is subject to the harbor maintenance tax, established to pay 100 percent of their O&M costs. Local sponsors of improvements to these projects must pay a share of construction costs.

Short-Run Efficiency: Does Price Equal Marginal Cost? From the standpoint of a tow operator, the fuel tax is only one component of tow operating costs. Because the tax rate is expressed in terms of cents per gallon of fuel, the amount of the tax varies directly with the amount of fuel used. The industry reports achieving an average of 500 ton-miles per gallon of fuel, although the actual amount of fuel used varies with such factors as weight, speed,

Box 5.
The Spending Side of the Current System: The Trust Fund Mechanism

The Inland Waterways Revenue Act of 1978 established the Inland Waterways Trust Fund, into which the Congress appropriates amounts equivalent to the revenues received in the Treasury from the tax on fuel used by commercial vessels. Section 1405 of the Water Resources Development Act of 1986 authorizes appropriations from the trust fund for construction and rehabilitation projects on those waterways that are subject to the fuel tax. In general, the trust fund and the general fund of the U.S. Treasury have split the costs of such projects evenly.[1] The same legislation specifies that operation and maintenance (O&M) costs are to be paid entirely from the Treasury's general fund.

The unspent balance of the trust fund earns interest. Interest payments made a relatively large contribution to total trust fund receipts in the fund's early years, when tax revenues were accumulating but outlays were not being made, because the Congress did not authorize expenditures from the fund until fiscal year 1985. Interest accounted for $32 million in 1990 and is projected to decline somewhat as balances are drawn down to pay for new projects.

The anticipation that one-half of the costs of construction will come from the trust fund imposes a constraint on new construction projects. The fuel tax does not provide enough revenue to fund half the costs of all the projects that users have been seeking. As a result, there is a need to set priorities and to fund only projects that have the greatest support. If this translates into funding only those projects for which the net benefits are greatest--and only those for which net benefits are greater than zero when an appropriate discount rate is used--the result will be increased efficiency in investment. Efficiency is maximized when all projects with positive net benefits at an appropriate rate of interest are undertaken. Budget constraints may make this impossible, however.

The requirement that the trust fund can be used only for construction and major rehabilitation, but not for operating and maintenance costs, has several implications. First, it means that the general taxpayer subsidizes waterway users. If users do not have to pay for benefits received, they are likely to demand more services. That is, they would tend to demand more spending on O&M--for example, a higher quality of service--than if they were paying for it themselves. Second, if users pay a share of construction costs, but not O&M, there may be a skewing of demands from the most efficient mix of construction and O&M spending.

The 1986 Water Resources Development Act established the Inland Waterways Users Board to advise on spending from the trust fund. Experience suggests that the board may have a beneficial effect on efficiency in the selection of projects, since it serves as a forum for users to express their needs and advise on their priorities. The board seeks to ensure that the taxes paid by users into the trust fund are spent wisely. Without direct user fees, this mechanism is quite useful in shaping investment decisions. But with price signals as well to serve as a guide, resources could be allocated even more efficiently.

The trust fund serves the accounting function of showing receipts and outlays related to inland waterway spending. If user charges or taxes in addition to the fuel tax were enacted, depositing them in the trust fund would help maintain that accounting function. Receipts and outlays do not necessarily have to be equal. If waterways provide benefits other than to direct users, then users should not bear the full cost. Moreover, all prospective spending projects should be evaluated and only those yielding net benefits should be undertaken, regardless of the size of the trust fund balance.

1. The 1986 act does not specify the split between general and trust fund financing; it is covered in the authorization of each project. To date, the split has been 50-50, but the law does not require this.

strength of current, whether or not the tow is moving upstream or downstream, congestion and delay time at locks, the amount of maneuvering needed to get through locks and other narrow passages, and the size of the tow. At the 1992 tax rate of 15 cents a gallon, the tax adds about 0.03 cents per ton-mile to operating costs. For an eight-barge tow traveling an average distance of 450 miles and getting 500 ton-miles per gallon of fuel, the tax would be about $1,600. A 17-barge tow traveling the same distance would incur fuel taxes of about $3,400. A large 40-barge tow--commonly found on the open lower Mississippi River--traveling 450 miles would incur about $8,100 in taxes. A profit-maximizing tow operator takes these factors into account, trading off fuel use with other operating considerations, such as crew costs and prompt service.

How do fuel taxes relate to the government's cost of providing waterways? The analysis of the Army Corps of Engineers' O&M costs reported in the previous section suggested that the marginal cost to the government of one additional unit of traffic along a waterway is small. The O&M costs of one additional ton-mile are estimated to be slightly less than 0.04 cents. This amount can be compared with the estimated fuel tax of 0.03 cents per ton-mile. These numbers should be treated with caution, since they are based on a number of simplifying assumptions and aggregate data. But if the estimates are reasonably accurate, they indicate that the price (based on the 1992 fuel tax rate of 15 cents a gallon) is slightly less than the marginal cost of O&M, a condition that would lead to some uneconomic use of the system.

In light of the simplifying assumptions under which the marginal-cost estimates were made, a more reliable conclusion is that the fuel tax paid by tow operators and the marginal cost to the federal government of operating and maintaining the waterways are of essentially the same order of magnitude.[11] If this is so, the fuel tax may not distort tow operators' incentives for efficient use of the waterways in the short run, at least on a systemwide basis. If marginal costs vary across waterways as average costs do, however, there would be greater divergence between the fuel tax and marginal cost and consequently less efficiency. Fuel could be taxed at different rates on different waterways, but this might cause administrative and enforcement problems.

The foregoing discussion assumes that the fuel tax is intended to cover only the costs of using the waterway system's physical plant. If all or part of the fuel tax is intended as an environmental protection or energy conservation measure, the issue becomes more complicated. As with highways and airways, the marginal costs of pollution and energy consumption would have to be estimated and added to the marginal cost of waterway use to arrive at a price for inducing efficiency.

Long-Run Implications for Corps Spending Decisions. In the private sector of the economy, if a firm cannot cover its total costs, including replacement of capital, over the long run, it goes out of business. The failure is a signal in the market that users are unwilling or unable to pay the cost of resources used to produce a specific good or service and that those resources would be more highly valued elsewhere.

In 1990, the fuel tax raised less than one-sixth of the revenues needed to cover construction spending; the U.S. taxpayers paid the remaining construction costs and all of the costs of operating and maintenance.[12] Since waterway users are not being asked to cover the full cost, the Corps of Engineers receives insufficient economic information about users' priorities for alternative corps projects, despite the corps's claim that it gets ample in-

11. The 20-cent per gallon fuel tax rate scheduled for 1995 and beyond would be equivalent to 0.04 cents per ton-mile, slightly higher than the estimated marginal cost to the government of O&M. The marginal cost may also rise, however.

12. Fuel tax revenues pay for one-half the cost of construction projects authorized under the Water Resources Development Act of 1986. General funds pay the other half, plus all the costs of construction projects authorized before the 1986 act.

formation from users about their priorities and preferences.

Fairness Considerations and Benefits Received. Fuel taxes may act as a proxy for the benefits received by tow operators, since they are correlated with use of the waterway system. This should be considered in comparing the fairness of the fuel tax with alternative ways of charging users of waterways. The correlation between fuel taxes paid and benefits received on the waterway system is diminished by a number of factors, however. The fuel used by a towboat is taxed at the same rate throughout the waterway system. But the federal government's spending varies considerably from waterway to waterway. Thus, under a uniform tax, users of high-cost waterways enjoy much higher subsidies than users of low-cost waterways.

When the marginal cost of an additional tow is very small, a user charge based on marginal cost would recover only a small portion of total costs.

Alternative Financing Options

A fuel tax may lead to greater efficiency--and equity--in waterway investment than no taxes at all because it presents a way of compelling all waterway users to bear some of the costs of the system. It sends only weak signals, however, about the desirability of specific investments.

General Principles and Criteria for Assessing Alternative Charges

The prescription for efficiency, as set forth in Chapter 1, is to charge users a price equal to the marginal social cost. The preceding discussion suggests that waterways are characterized by economies of scale, however, meaning that marginal-cost pricing will not cover total costs. There are, of course, alternative ways of dealing with the trade-off between economic efficiency and cost recovery.

Systemwide Charges Versus Charges Based on Factors Specific to Each Waterway

The various ways of charging users could be imposed on a systemwide basis or vary by waterway. Charges based on factors specific to each waterway, referred to here as waterway-specific charges, have some advantages since, as shown in Table 14, operation and maintenance costs per ton-mile vary tremendously among waterways. Users of waterways whose costs per ton-mile are relatively low would not be forced to subsidize users of waterways whose costs per ton-mile are high, as they would under a plan imposing a systemwide average charge. Some shipments for which barge transportation would be economic under a charge equal to the O&M cost on a low-cost waterway would not be economic at a higher charge, based on the systemwide O&M cost per ton-mile. Under a systemwide fee, these shipments might go by another mode (rail, pipeline, or truck) or might not be

shipped at all. For this reason, charges tailored to specific waterways could lead to greater efficiency than a systemwide approach.

The waterways most likely to be affected by a waterway-specific charge are those with relatively little traffic. Any decline in traffic would necessitate raising fees because fixed O&M costs would be spread over fewer users. Such an increase could cause further declines in traffic, possibly to the point of no traffic at all on a high-cost waterway. This would be inefficient in the short run, because once the O&M costs are incurred, there is no reason to discourage traffic as long as it covers its marginal cost. The result could be economically efficient, however, if plans were made to cope with it; that is, if in advance of incurring O&M costs on a waterway, the corps determined that doing so would yield an insufficient return. Such a waterway probably would not fall into disuse immediately; more likely, operating adjustments would be made in the short run, such as running less heavily loaded barges on waterways that, without dredging, became shallower.

Pricing each waterway on the basis of its cost and traffic would help highlight the fact that some waterways are much more costly than others to maintain in relation to the number of ton-miles they serve. If levying a relatively high fee--but one that accurately reflects the costs of maintaining a particular waterway--causes users to find it no longer economic to use that waterway, its disuse would suggest that the waterway is not worth the expenditures for operation and maintenance. Reallocating expenditures to other waterways could benefit users. But the fact that users of high-cost waterways also use lower-cost waterways complicates the assessment. Closing high-cost waterways would probably reduce traffic on lower-cost waterways as well.

Charging fees on a systemwide basis has some advantages over charging on a waterway-specific basis. First, O&M costs and traffic tend to fluctuate from year to year, and the fluctuations are more pronounced for individual waterways than they are for the system as a whole. Without a good estimate of charges they might incur, it would be difficult for operators to plan how much use they would make of the waterways. Second, it would be easier administratively to base charges on a systemwide flat rate than to keep track of each waterway's use.

Charging to Recover Operation and Maintenance Costs

Set Price Equal to Marginal Cost. The regression discussed above (see pp. 57-58) estimated the marginal cost of operation and maintenance associated with an additional ton-mile to be about 0.04 cents.[13] If multiplied by the 250 billion ton-miles of traffic in 1989 (the last year for which data are available), the result is $100 million compared with total operation and maintenance costs that year of $438 million for fuel-tax waterways. When the marginal cost of an additional tow (or other unit of output, such as a ton-mile) is very small, a user charge based on marginal cost, although efficient in the short run, would recover only a small portion of total costs. Therefore, the Corps of Engineers would learn little about how much total spending on O&M would be efficient. In addition, the marginal cost-based charge does not distinguish between high-cost and low-cost waterways.

Impose an Annual License Fee. One way to cover the fixed component of O&M costs is to impose an annual license fee equal to the cost divided by the number of towboats or barges using a waterway in a given year.[14] The advantage of this approach is that once the annual fee is paid, it does not affect incentives for use. As a result, resources would be allocated

13. As noted, this regression made use of available data to produce illustrative results, but more thorough analysis including variables expressing output in tows or tow-miles and other factors affecting total costs would be needed to provide the statistical confidence about the marginal-cost relationship to base user charges on it.

14. Alternatively, a more sophisticated system based on cargo capacity or horsepower could be used.

efficiently at the margin. One disadvantage is that a license fee for barges might lead operators to use fewer barges than would be most efficient (and likewise with a license fee for towboats). The same traffic might be carried by using barges more intensively, at some additional cost in terms of speed or fuel consumption, or traffic might be cut. Another drawback is the difficulty of estimating O&M costs and user demand, especially on a prospective basis. A reasonable approximation might be reached, however, using an average of several recent years, perhaps combined with information about trends in costs and usage.

An annual fee could be imposed on either a systemwide or waterway-specific basis. Systemwide, the total amount of fixed O&M costs would be divided by the number of vessels using any part of the system. Under a waterway-specific plan, users of each waterway would share the costs on that waterway. A user of more than one waterway would pay a share of the costs of each waterway used. A drawback to a license fee specific to each waterway is that it is complex, since most vessels operate on more than one waterway. If a systemwide fee had been in effect in 1990, the charge per towboat would have been about $115,000; alternatively, the charge per barge would have been about $13,000.[15] The approach can be varied by giving users a choice between paying an annual fee or a charge per use that would be set so as not to deter occasional use.

Impose a Charge Equal to the Operation and Maintenance Cost per Ton-Mile. A proposal that has received attention in recent years is to establish a charge equal to the total O&M costs divided by the number of ton-miles transported. As discussed in Chapter 1, average-cost pricing will cover total costs, but with a loss in efficiency from marginal-cost pricing. Trips for which marginal benefits exceed the marginal cost but fall short of average cost will not be made.

If O&M costs remain roughly constant regardless of the amount of traffic, O&M costs per ton-mile depend solely on the number of ton-miles. Charging a price per ton-mile that exceeds the marginal cost would be likely to cause traffic to decline further and could set off an upward spiral of costs per ton-mile.

A charge equal to O&M costs per ton-mile could be made on either a systemwide basis--using total O&M costs divided by the total ton-miles of inland waterway traffic--or a waterway-specific basis--using the O&M costs and traffic on each waterway.

Impose a Per-Lockage Charge. Using lock operations as the basis for a user charge is another option.[16] For each lockage, the operator is charged an annual amount equal to the total O&M cost for the waterway divided by the total number of lockages handled on it.

Like the O&M charge for cost per ton-mile, a lockage fee structured in this way would represent a kind of average cost. It would reflect the expenses of operating and maintaining channels, such as dredging costs, and those of operating and maintaining locks and dams. In order to assess the efficiency of this or any other lockage-related charge, one would need to know the marginal and average costs of operating and maintaining each lock. An additional factor to consider in determining an efficient lockage fee is whether there is congestion and what the costs of congestion delays are. Congestion pricing is discussed in a later section.

Charging by lock operation would be relatively easy to administer. Lock operators would simply keep track of lock use. A lockage charge exceeding the marginal cost,

15. This estimate is based on the fleet for the heavily traveled Mississippi River and the Gulf Intracoastal Waterway region, which includes most of the fuel-taxed waterways.

16. See Rusidan Lubis, Michael V. Martin, and B. Starr McMullen, "The Impacts of Waterway User Fees on Grain Transportation on the Snake-Columbia River," *Water Resources Bulletin*, vol. 23, no. 4 (August 1987), pp. 673-680.

however, might reduce efficiency by inducing tow operators to use less efficient ports that avoided lockages or tow configurations that minimized lockages while raising other costs.

CBO calculated examples of this kind of charge for three waterways, using 1989 data for O&M costs and numbers of lockages. The costs per lockage were about $215 on the Monongahela River, $555 on the Illinois Waterway, and $1,285 on the Red River. If recreational lockages are excluded, the costs rise to $250, $780, and $1,515, respectively. These estimates are based on total O&M costs for each waterway. For greater efficiency, it would be preferable to charge according to the cost of operating each lock and dam individually.

Increase the Fuel Tax to Cover All O&M Costs. Some analysts have suggested raising the fuel tax high enough to generate enough revenue to cover the federal government's waterway costs. The administrative mechanisms to collect and enforce it are already in place. To cover O&M costs, however, the fuel tax rate would have to rise substantially, to about 85 cents a gallon, assuming that tow operators did not respond to a tax increase by cutting back on their use of fuel. At 85 cents a gallon, the rate would be 65 cents a gallon higher than the level the fuel tax is scheduled, under existing law, to reach in 1995. In the more likely event that demand for fuel would decline with an increase in the tax, the tax rate would have to rise still higher to generate enough revenue to cover costs.

On a waterway-specific basis, fuel tax rates would range from about 24 cents a gallon on the lower Mississippi River to $69 a gallon on the Allegheny River.[17] A tax greater than $5 a gallon would be required on a dozen waterways if O&M costs were to be covered. The high numbers reflect the small amount of traffic on these waterways.

Raising the fuel tax rate would undermine efficiency if the tax rate exceeded the marginal cost to the government. Analysis based on limited data available suggests that the present tax rate closely reflects the marginal cost. At a much higher rate, tow operators would face a price greater than the marginal cost and would thereby be discouraged from making trips.

Charges Based on Demand Factors. All of the types of charges discussed above are applied uniformly. In other words, all users would face the same charge per ton-mile, per gallon, per towboat, or per barge. This type of charge might affect different barge operations in quite different ways. Some commodity shipments may be more sensitive to increased prices than others, since some shippers have more alternative forms of transportation at their disposal. Even a small increase in barge rates could lead some shippers to use railroads or pipelines instead of barges. Their shift would raise the average cost for remaining users of waterways. To minimize uneconomic diversion of traffic, charges could be set lower for those who have more alternatives available and higher for those with fewer alternatives.[18]

This approach, called Ramsey pricing, is discussed in Chapter 1. It calls for charging each user according to the sensitivity of demand to the price.[19] Ramsey pricing is efficient because each use is charged a price that is as close as possible to the marginal cost of supply.[20] Ramsey pricing allows total costs to be covered while meeting the efficiency cri-

17. Similar calculations using 1985 data produced results ranging from 24 cents a gallon on the lower Mississippi to $62 a gallon on the Kentucky and $475 a gallon on the Pearl River. By 1988, there was no traffic reported on the Pearl.

18. Diversion of traffic is an economic problem only if it entails moving to a mode for which resource costs are higher.

19. Frank Ramsey, "A Contribution to the Theory of Taxation," *Economic Journal*, vol. 37 (March 1927), pp. 47-61. See also William J. Baumol and David F. Bradford, "Optimal Departures from Marginal Cost Pricing," *American Economic Review*, vol. 60 (June 1970), pp. 265-283.

20. For exposition, it is easier to refer to a user than a unit of use, which is the more precise term. A single user--for example, a barge company--might value some uses, such as when transporting a shipment on which it can charge high rates, more highly than others.

terion of setting the price equal to the cost of the marginal unit.

This approach causes two practical problems. First, it requires information that is not readily available, in particular the sensitivity of different demands to different prices. This problem is not insurmountable--the barge companies themselves must have a good grasp of what rates they can charge for carrying different commodities at different locations, and Ramsey pricing could be applied using a percentage markup over the rates charged.

The second practical problem is the acceptability of this scheme. The idea of charging higher prices to those with fewer alternatives may seem inherently unfair. Indeed, the railroad industry has for many years been criticized for charging different rates for different commodities, and for charging higher rates where there is no alternative rail or barge transportation. There are benefits to such pricing schemes, however, not only to shippers who enjoy lower rates but also to those facing higher rates. As long as the lower-rate shipments pay even a small amount more than their marginal cost, they contribute to the coverage of fixed costs that otherwise would have to be borne by higher-rate shipments. Thus, they also benefit higher-rate shippers.

Use Combination Tolls. There also have been proposals for combining the existing systemwide fuel tax and a waterway-specific ton-mile charge.[21] The objective of these proposals seems to be to increase efficiency by taking advantage of the vast difference in costs among waterways while retaining the revenue-raising capability of the nationwide fuel tax.

The fuel tax component of the combination toll could serve as a rough proxy for marginal cost, as discussed above. As described previously, there are potential problems associated with using a ton-mile charge to recover fixed costs. The most serious practical problem would be the short-run effect of driving traffic away from waterways with high costs per ton-mile. Still, this kind of policy provides gains over the long run from shifting O&M spending from little-used waterways to those that carry large volumes of traffic.

Charge for Congestion at Locks and Dams. Delays at locks and dams are costly to users. Some delays are caused by mechanical or other operating problems; others result from too many tows waiting to use the locks at the same time. In any case, tow operators, not the federal government, bear the costs of delay, such as higher labor and fuel costs associated with extra operating time. With congestion, each tow not only incurs a cost of delay but also imposes such a cost on other tows.

Pricing to alleviate congestion follows the same principle described in the previous chapters: set the price equal to the marginal social cost, so that users bear the cost of delays they impose on others. The social costs will be recognized and factored into tow operators' decisions about using the waterway system only if charges are imposed to reflect the costs. Such charges would give users an incentive to use waterway resources more economically.

At present, lock operators generally deal with congestion by accommodating tows on a first-come, first-served basis.[22] This approach is not necessarily the most efficient solution from the standpoint of resource use. Efficiency would dictate giving priority in use to the tows willing and able to pay the highest price for it. Tows for which the costs of delay are lower would fall back in the queue.

21. See Department of Transportation and Department of Commerce, *Inland Waterway User Taxes and Charges*, a report of the Secretary of Transportation to the U.S. Congress pursuant to Section 205, Public Law 95-502, the Inland Waterway Revenue Act of 1978 (February 1982), p. 36.

22. There are some exceptions. For instance, if two small tows can fit together in a lock chamber, the second, smaller one may be allowed to move ahead of the larger. Also, if tows are waiting in both the upbound and downbound directions, the lock operator may allow several to pass in one direction before processing several in the other direction, since this reduces total transit time.

Congestion at locks and dams is somewhat different from congestion on highways and at airports. Highways and airports typically are congested at certain times of day--generally at the beginning and end of the workday--when people are most likely to take trips. By contrast, once a trip is under way, a tow generally keeps operating, with crew members on duty 24 hours a day. Congestion at a lock occurs when several tows arrive at about the same time, although that time could as easily be 5:00 a.m. as 5:00 p.m. It is possible, then, that simply scheduling lockages, or providing traffic information to tow operators, could reduce delays caused by congestion. If this is so, tow operators might be willing to pay a relatively small fee to cover the cost of administering a reservation system. If two or more tows arrived at a lock at the same time, the one with the reservation would be given priority. Under this system, tow operators might choose not to make a reservation and to take their chances of a delay when traffic is light to moderate, but to pay for a reservation to avoid delay at peak times.

There may be times, for instance if an unusually large harvest results in a sizable increase in the number of grain-carrying barges, when the lock capacity is insufficient to handle all the traffic. Under such circumstances, efficiency and productivity are enhanced if there is a way of allocating the scarce capacity to the tows that place the highest value on it. That result could be achieved by selling time slots to the highest bidder. By contrast with the normal situation, when a reservation would cost a nominal fee to cover administration costs, the peak-period reservation would carry a premium charge to reflect the scarcity of capacity. The existence of a premium would help signal the demand for additional capacity.

Under any kind of reservation system, efficiency could be gained by allowing tow operators holding reservations to sell them to others who want to go through the locks first.

The key to economic efficiency is that the benefits of a prospective project equal or exceed the costs.

Commercial barge traffic constitutes the predominant flow at most locks, but some serve a large number of recreational craft as well. Currently, lockmasters usually follow the first-come, first-served rule, although they have discretion in setting the order and pattern of lockage transits. If, for example, a recreational boat can fit in a lock chamber with other recreational boats or with a small commercial tow, the lockmaster may allow it to move ahead of a larger tow in the queue. In some areas, recreational use has been steadily increasing and could cause delays for commercial traffic. Under a reservation system, the same rules could apply to all users.

Other External Costs. Use of locks and dams may entail other social costs. Where hydroelectric power is generated, each lock operation may reduce the water flow and slightly diminish generating capacity. Efficient pricing would place the burden of this loss on boat operators using the facilities.

Charging to Recover Capital Costs of Specific Projects

For generations, economists have struggled with the problem of finding an efficient way to

cover the cost of major capital investments.[23] Once a canal or a lock and dam has been built, the marginal cost of one additional tow is minimal. If users were charged the marginal cost, revenues would be insufficient to cover total costs. But the revenue shortfall could be made up through the types of pricing mechanisms discussed above.[24]

The key to economic efficiency is that the benefits of a prospective project equal or exceed the costs.[25] The construction cost generally is incurred in one or a few years--depending on the size of the project--but the project is expected to provide services over a much longer period--50 years or longer for a lock and dam. Requiring users to pay for the project as soon as costs are incurred would be undesirable because the investment will continue to provide returns over many years. Instead, project costs can be annualized, like a mortgage, on the basis of the initial cost, the number of years the project is expected to provide benefits, and an interest rate that reflects the time value of money. This expresses the cost as if money for the investment were borrowed to finance it and then paid back over a period of time.

Impose an Annual Fee Based on Annualized Capital Costs Divided Equally Among Users. Annualized capital costs could be divided by the number of users or the number of units of use. For example, tow operators could be required to purchase annual permits entitling them to operate on the waterways. A permit's price in any year could equal the annualized total capital outlays divided by the number of users. Alternatively, the unit on which charging could be based might be the towboat (possibly with gradations according to horsepower) or the barge. As discussed above, a fixed fee would minimize negative effects on economic efficiency because once paid it would not affect incentives for additional use.

Capital costs could be charged solely to users of new construction (or major rehabilitation) projects, to all users of the waterway system, or to all users of the major waterway on which the investment is located.

The way a charge is imposed has implications for distribution as well as for efficiency. Charging the same fee to big and small companies would place a greater burden on the small ones. Charging per towboat or barge would alleviate this problem to some extent. But this might create incentives to reduce the number of towboats or barges operated, perhaps to an inefficiently low number.

Impose a Per-Use Charge. Alternatively, a charge could be based on the amount of use. Suppose, for instance, that the charge was calculated by dividing capital costs by the number of tows, with each tow being charged the average annualized cost. This method might induce operators to increase the size of each tow--for instance, doubling the number of barges in each tow, so as to cut in half the number of tows and thus the tow charge. Of course, the tow charge would be just one of many cost factors--labor, fuel, and possibly other charges such as for lockages--and the tow operator also would need to take into account such demand factors as whether shippers would tolerate delays caused by assembling more barges for each tow. In any event, because it would affect operations in ways not related to costs, this form of charge is likely to be less efficient than a fixed annual fee unrelated to operations.

23. See Jules Dupuit, "On the Measurement of the Utility of Public Works," written in 1844 and reprinted in D. Mundy, ed. ,*Transport* (London: Penguin Books, 1968), pp. 19-57; Ramsey, "A Contribution to the Theory of Taxation"; Baumol and Bradford, "Optimal Departures from Marginal Cost Pricing"; and Clifford Winston, "Conceptual Developments in the Economics of Transportation: An Interpretive Survey," *Journal of Economic Literature*, vol. XXIII (March 1985), pp. 57-94.

24. Besides the loss in allocative efficiency from charging fees to recover the costs of past investments, there is the risk of still more inefficiency if the past investment was larger and costlier than optimal.

25. The Corps of Engineers uses shipper surveys and data on traffic trends and congestion to estimate the benefits of waterway investments. Charging users (or announcing plans to charge) and observing their willingness to pay for new projects can provide additional useful information in setting investment priorities.

Charges Based on Demand Factors. Capital costs could be covered by Ramsey pricing, as discussed above in the section on covering O&M costs. The same considerations apply.

Without pricing considerations as a guide, some investments have been criticized as being larger and more expensive than the benefits would warrant. This problem is currently being addressed in part by the Inland Waterways Users Board, which advises the federal government on investment priorities. The Users Board has an incentive to support investments with high returns and to oppose less worthwhile investments. Its recommendations are merely advisory, however.[26]

Because past investments are sunk--that is, the resources needed to build them have already been spent--and because some may have been inefficiently large, imposing charges to cover the historical costs would not improve the efficiency of resource allocation. From an equity standpoint, however, there might be justification for attempting to recover at least a portion of these costs.

Examples of Capital Cost Recovery

The two largest projects in recent years are the Tennessee-Tombigbee Waterway and the Melvin Price Locks and Dam.

Tennessee-Tombigbee Waterway. The Tennessee-Tombigbee Waterway, completed in 1985, cost $1.79 billion.[27] (See Table 17 for a comparison of the annualized payments under alternative assumptions about the appropriate discount rate and the expected lifetime.) At a discount rate of 3 percent and expected life of 100 years, the annual payment would be $57 million; at a discount rate of 10 percent, the annual payment over 100 years would be $179 million. Divided by the 1.8 billion ton-miles carried on the Tenn-Tom in 1988, these costs amount to 3 cents to 10 cents per ton-mile, at discount rates of 3 percent and 10 percent respectively.

Table 17.
Payments Needed to Recover the $1.79 Billion Investment in the Tennessee-Tombigbee Waterway Under Alternative Assumptions

Discount Rate (Percent)	Life (Years)	Annual Payment (Millions of dollars)	Payment per Ton-Mile (Cents)
3	50	69.6	3.8
3	100	56.6	3.1
7	50	129.7	7.2
7	100	125.4	6.9
10	50	180.5	9.9
10	100	179.0	9.9

SOURCE: Congressional Budget Office calculations.

Melvin Price Locks and Dam. The new main chamber of the Melvin Price Locks and Dam was opened to traffic in 1990, replacing the old Locks and Dam 26 on the Mississippi River above St. Louis. The main chamber is 1,200 feet long and 110 feet wide, and cost $737 million.[28] An auxiliary chamber, 600 feet long and 110 feet wide, is under construction and scheduled to open in 1993 at a cost of $213 million. If these costs are combined and amortized over periods of 50 years to 100 years at discount rates of 3 percent to 10 percent, the annual payment would range from $30.1 million to $95.8 million.[29] At traffic levels reported at the lock site in 1989,

26. See Section 302 of the 1986 Water Resources Development Act.

27. These are nominal dollars spanning the 13-year construction period from 1972 to 1985. It would be preferable to convert the spending each year into constant dollars for the year 1985.

28. U.S. Army Corps of Engineers, *Justification for Appropriation Estimate, FY 1993*, Book 2, Lower Mississippi Valley, pp. 38-43.

29. As with the Tennessee-Tombigbee example, this assumes that all costs were incurred in the same year and that there is no inflation. The numbers are intended merely to give a very rough idea of the implications of alternative cost recovery schemes. More accurate estimates would require refinement of the calculation.

these costs translate into a range of $2,020 to $6,440 per lockage, or 44 cents to $1.40 per ton, as shown in Table 18.

Table 18.
Annual Payments Needed to Recover the $950 Million Investment in the Melvin Price Locks and Dam, Under Alternative Assumptions

Discount Rate (Percent)	Life (Years)	Annual Payment (Millions of dollars)	Payment (Dollars per lockage)	Payment (Dollars per ton)
3	50	36.9	2,480	0.54
3	100	30.1	2,020	0.44
7	50	68.8	4,630	1.01
7	100	66.6	4,480	0.97
10	50	95.8	6,440	1.40
10	100	95.0	6,390	1.39

SOURCE: Congressional Budget Office calculations, based on 1989 traffic.

Conclusion

Existing taxes imposed on users of the inland waterways do not raise enough revenue to cover operation and maintenance costs, let alone the costs of new construction. Economic theory suggests efficient ways of charging waterway users to reduce the demands on the Treasury's general fund. Developing a schedule of efficient charges would require more information than is currently available about the specific factors influencing waterway costs. If operation and maintenance costs are unaffected by an additional tow, then O&M costs should be treated as fixed costs, and any user charge should not vary with use. If costs do vary with use--at a congested lock and dam, for instance--then efficiency would require users to be charged the marginal cost.

Appendix

"Top-Down" Cost Allocation Studies of Pavement Costs

The *Final Report on the Federal Highway Cost Allocation Study (HCAS)*, published in 1982, is the most comprehensive effort to allocate pavement costs to classes of highway users and compare the costs and revenue of each class.[1] Because several changes have been made since 1982 in federal taxes on highway users, the findings are out of date. Still, the study provides a general picture of various user groups' costs and revenues and the cross-subsidies between them. More recently, the *Heavy Vehicle Cost Responsibility Study (HVCRS)* focused on shares of pavement costs and revenues by vehicles with gross weights of 80,000 pounds or more.[2] Together, these studies shed light on the question of which users are paying more than their share of pavement costs and which are paying less.

***HCAS* Findings**. The *HCAS* found that certain classes of vehicles were paying more than their share of pavement costs and some were paying less. Single-unit trucks paid 30 percent to 75 percent more than their share of costs in 1977, but combination vehicles--power units pulling one or more trailers or semi-trailers--paid 15 percent to 55 percent less

1. Department of Transportation, Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study*, Report of the Secretary of Transportation to the United States Congress Pursuant to Public Law 95-599, Surface Transportation Assistance Act of 1978 (May 1982).

2. Department of Transportation, *Heavy Vehicle Cost Responsibility Study*, Report of the Secretary of Transportation to the United States Congress Pursuant to Section 931 of the Deficit Reduction Act of 1984 (November 1988).

Table A-1.
Comparison of Pavement Cost Responsibility and User Taxes Paid, by Class of Vehicle

Vehicle Class	Ratio of User Taxes Paid to Cost Responsibility[a] 1977	1985[b]
Passenger Vehicles	1.11	0.98
Autos	1.10	0.97
Large	1.21	1.16
Small	0.70	0.71
Motorcycles	0.46	0.58
Pick-ups and vans	1.23	1.08
Buses	0.51	0.03
Intercity	1.16	0.15
Other[c]	0.33	0.00
Trucks	0.79	1.03
Single unit	1.51	1.99
Under 26,000 pounds	1.31	1.71
Over 26,000 pounds	1.74	2.21
Combinations	0.59	0.80
Under 50,000 pounds	0.84	1.23
50,000 to 70,000 pounds	0.85	1.25
70,000 to 75,000 pounds	0.60	0.78
Over 75,000 pounds	0.45	0.59
All vehicles	1.00	1.00

SOURCE: Department of Transportation, Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study* (May 1982), Tables VI-10, p. VI-33, and VI-13, p. VI-36.

a. Ratio of user charge payments to cost responsibilities under the approach recommended by the Federal Highway Administration. A ratio of less than 1.0 indicates underpayment.

b. Projections for 1985, assuming the 1982 tax structure.

c. Transit and school buses are exempt from most user taxes.

than their share (see Table A-1). Large automobiles paid about 20 percent more and small automobiles about 30 percent less than their shares, with this difference reflecting variations in fuel tax revenues arising from differences in fuel-efficiency between large and small cars, though their costs were about the same.

The *HCAS* made a similar comparison for 1985 using projections based on the 1977 tax rates but taking into account such factors as expected changes in the fuel economy of various vehicles and effects of inflation on revenues from various taxes. Taxes based on value, such as the excise taxes on vehicles and tires, were projected to bring in rising revenues because of inflation. The fuel taxes, which are based on physical units, were not expected to rise. The ratios of revenues to costs are shown in Table A-1.[3]

***HVCRS* Findings.** *HCAS's* findings that heavy trucks generally paid less than their share of costs led to demands for more detailed information about variations in shares among different weights and configurations of heavy trucks. In the Deficit Reduction Act of 1984, the Congress directed that the Secretary of Transportation "conduct a study of whether highway motor vehicles with taxable gross weights of 80,000 pounds or more bear their fair share of the cost of the highway system."[4] The resulting *Heavy Vehicle Cost Responsibility Study* found sizable differences among weight groups in the ratio of revenue shares from user taxes to cost shares, as shown in Table A-2. Note that the shares presented are shares of costs and revenues of trucks weighing more than 50,000 pounds rather than shares of costs and revenues of all highway users.

Table A-2.
Ratio of Shares of User Tax Contributions to Shares of Highway Costs Caused by Trucks Over 50,000 Pounds Gross Weight

Operating Weight Group (Thousands of pounds)	Ratio of User Tax Shares to Cost Shares
50 to 70	1.32
70 to 80	0.81
80 to 90	0.49
90 to 100	0.37
100 to 110	0.50
110 to 120	0.59
Greater than 120	0.94

SOURCE: Department of Transportation, *Heavy Vehicle Cost Responsibility Study* (November 1988), Table IV-7, p. IV-17.

There are several differences between the *HCAS* and the *HVCRS*. The *HCAS* grouped vehicles by registered weight, but the *HVCRS* grouped them by operating weight. Revenues estimated in the *HVCRS* were based on the taxes in effect at the time of the study, which differed from those in the earlier *HCAS*.[5] Still, the methodology for cost allocation was essentially the same, and both the *HCAS* and the *HVCRS* show that heavy vehicles impose disproportionate costs on the highway system.

There are even greater differences between the studies on cost allocation and studies of marginal costs. The approaches differ in both techniques and objectives. The top-down ap-

3. A recent review of cost allocation methodologies is contained in *Rationalization of Procedures for Highway Cost Allocation Studies*, prepared by the Urban Institute and Sydec, Inc., for the Trucking Research Institute, ATA Foundation, Inc. (October 1990).

4. Section 931 of the Deficit Reduction Act of 1984 (98 Stat. 494).

5. The tax changes included a 5-cents-a-gallon increase in fuel taxes, plus an additional 6 cents for diesel fuel (the so-called "diesel differential"), to make diesel fuel taxed at 15 cents a gallon and gasoline at 9 cents; repeal of taxes on motor oil, tread rubber, inner tubes, and truck parts; an increase in the heavy vehicle use tax; and a change in the structure of the excise taxes on trucks and tires.

proach is motivated by questions of equity, whereas the marginal-cost approach is motivated by questions of efficiency. This is not to say that there is no element of efficiency in the top-down approach, nor that equity is ignored in the marginal-cost approach. Indeed, the concept of equity adopted in the *HCAS*--at the behest of the Congress--is cost-based: users should pay according to the costs they cause.

The top-down approach allocates all costs, including joint costs associated with any and all users, whereas the marginal-cost approach does not. Another difference is that the top-down studies allocated only the costs to the government, but the marginal-cost studies also included external costs of congestion, pollution, and noise. Because the marginal-cost estimates are particularly important from the standpoint of economic efficiency, they are the focus of Chapter 2.

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