TRANSPORTATION RESEARCH RECORD
494

Formerly issued as Highway Research Record

Problems in Implementing Roadway Pricing

5 reports prepared for the 53rd Annual Meeting of the Highway Research Board

subject areas
15 transportation economics

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
Washington, D. C., 1974

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TRR 494
ISBN 0-309-02282-7
LC Cat. Card No. 74-12521
Price: $2.00

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CONTENTS

FOREWORD

The papers in this record examine the problems related to roadway pricing. Legal issues, collection problems, and parking taxes are discussed.

The first paper examines legal issues—federal statutes, court decisions, state statutes, and local ordinances—involved in congestion pricing. The author focuses on 2 schemes: placing a commuter tax on central city streets and adjusting bridge tolls to meet congestion pricing goals. One conclusion drawn by the author is that the federal prohibition against tolling on federally aided roads is not an obstacle to taxing city street use.

The second paper discusses methods for restraining city traffic by pricing. A variety of methods and systems of localized pricing are examined including an electronic point-pricing system; a pattern of zones with peak and off-peak prices for crossing the cordons around them; and parking charges, which could be varied according to location and time of day. To compare the performance of different pricing systems the author suggests that a model similar to those presently in use in traffic and public transport studies be used with some modifications. The author suggests that a simulation model be run through the computer to set standard levels and match individual costs with marginal social costs all over the network.

The third paper examines the collection problems associated with congestion pricing and the use of automatic vehicle identification (AVI). The author discusses developments in AVI, which is like an electronic license plate, with a transponder (a small device carried on a vehicle) and an interrogator (an electronic element in or near the roadway). AVI technology offers greater fairness and responsiveness in allocating road-use charges than can be obtained with other means existing today. If gas tax revenues decrease because of the scarcity and high cost of gasoline supply and the introduction of new forms of energy, AVI can fill an important need in maintaining equitable taxation for road use.

The fourth paper discusses a time-calibrated self-canceling ticket (timer-ticket) for collecting motor vehicle user charges. The paper emphasizes that the administrative simplicity of timer-tickets and their ease of sale are profitable to local governments. The last part of this paper discusses the categories in which these timer-tickets may be used: overnight parking, where charges are low and parking long term; historic area parking, where aesthetic considerations rule out street hardware; toll collecting; and congestion pricing.

The fifth paper presents an after the fact analysis of the effects of a 25 percent parking tax that was in effect in San Francisco from October 1, 1970, to June 30, 1972. The author develops parking price elasticity estimates for various types of parking facilities.

LEGAL ISSUES SURROUNDING ROADWAY PRICING ON CITY STREETS AND BRIDGES

Rosanne J. Coit, The Urban Institute, Washington, D.C.

Economists and transportation planners have been talking for years about congestion pricing of roads and bridges, primarily to ration traffic and secondarily to produce revenue. Most of the research in this field has centered on the technological options for carrying out pricing schemes and their effect on the motoring public. Little has been said about the legal issues of congestion pricing—federal statutes, court decisions, state statutes, and local ordinances. This paper focuses on the legal issues of two schemes: placing a commuter tax on central city streets and adjusting bridge tolls to meet congestion pricing goals. It suggests that, in spite of federal regulations, substantial power to implement congestion pricing lies unused.

•ASK a highway builder what he or she thinks about roadway pricing and you are likely to get a response that is not enthusiastic—roadway pricing is seen as contrary to providing unlimited mobility. Ask what he or she thinks about road tolling and you will be told that it is illegal.

TAXING CITY STREET USE

Legal Obstacles: Real or Illusory?

Road tolling is illegal only if you are talking about roads built with federal money. Section 301 of Title 23 of the United States Code (23 U.S.C. §301) set forth in 1916 the federal highway laws of the nation: "All roads constructed under provision of this title shall be free from tolls of all kinds." The section 301 prohibition against tolling (with some exceptions for bridges and tunnels) remains in force today on all federally aided roads, despite the timeliness and attractiveness of roadway pricing as a clean air strategy, a traffic rationing device, and a revenue producer. This flat prohibition might be enough to make some pricing enthusiasts want to pack their briefcases and go home. But the apparently certain refusal to allow tolling on roads built with federal aid should not be taken literally. The law is not so simple nor so discouraging to road pricing as it might first appear.

The conditions placed in the 1916 legislation on the granting of federal aid are interesting. The money was to be used only for construction of rural post roads. Cities of more than 2,500 people were ineligible, except for certain undeveloped areas. Yet, despite increasing urbanization of the nation and twice-daily traffic crushes for city dwellers, the prohibition against tolling still holds, affecting a federal highway program that has changed drastically in nature and scope.

Many toll roads exist today. Most were built as intercity routes just before the development of the Interstate system. Toll financing was chosen because federal- and state-aid systems of the time did not meet the expense of construction. There has been only one attempt to modify or remove the section 301 prohibition from the federal highway laws. In the first session of the 92nd Congress, Rep. Les Aspin (D.-Wisc.) introduced H.R. 9813, which would have allowed cities of more than 200,000 to impose tolls on segments of the Interstate system within their boundaries. The money was to be used for public transit. The bill died in committee.

The Courts' Construction of Section 301

The courts normally refuse to overturn, except on constitutional grounds, a statutory law. Judge-made law (case law), though, is overturned or remade without such reluctance. Notwithstanding judicial reluctance to remake statutory law, the courts do interpret statutes to give them varying degrees of effect. Roscoe Pound described this as ranging from "receiving the law not only as a rule to be applied but a principle from which to reason," to "refusing to reason from it by analogy and apply it directly only... give to it a strict and narrow interpretation, holding it down rigidly to those cases which it covers expressly" (1). In another article on statutory interpretation, Karl Llewellyn noted a difficulty that the courts seem to have encountered in the construction of section 301: "Increasingly as a statute gains in age, its language is called upon to deal with circumstances utterly uncontemplated at the time of its passage." In such a situation, the court seeks to enforce not merely the sense intended at the time of passage, but the sense that "can be quarried out of it in the light of the new situation" (2).

State governments and the courts had to face years ago the dampening effect of section 301 on the states' ability to raise money for road maintenance. Judicial interpretation narrowed section 301 considerably. Today, as the side effects of automobile use raise serious problems for governments at all levels, the antitolling provision must again be interpreted in the light of changing circumstances. Possibly, pressure may mount to delete the section from the law.

Tolls Prohibited—User Taxes Allowed

The problem originally caused by section 301 for state and local governments was that of money to maintain the roads. The federal-aid highway program has always left to the states the task of securing funds for road maintenance. State legislatures, in the early 1900s, enacted various types of fees or taxes based on the operation of automobiles and common carriers on public roads. These included gasoline taxes, vehicle registration fees, fees on businesses operating common carriers, and taxes on the mileage and revenues of common carriers.

Individuals and businesses, to avoid payment of these fees and taxes, challenged their validity in the courts, contending that the state statutes violated the antitolling provision of the federal highway law. Through the adjudication of more than a dozen cases in the late 1920s and early 1930s, the courts without exception upheld the specific fees and user taxes in question, as not constituting tools within the meaning of section 301 (3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16). Later, in a case in New York State, the courts decided that tolls are allowable on roads built with federal aid if the state has arranged to repay the federal government (31). Although these cases related specifically to the validity of the fees, the courts in general language affirmed the right and duty of the states to maintain public roads for the people and to demand recompense for the use of the roads.

These cases are interesting today, because they represent the only series of judicial interpretation of the states' ability to levy user charges on federally aided roads since the passage of the Federal Highway Act. The precedents they set outline the boundaries for determining what user charges on federal roads will be allowable. The user charges in this series of cases were passed by state legislatures primarily for raising money to maintain the roads. Some of the decisions are based on the states' need to raise revenue to fulfill their maintenance obligations (14). The road pricing measures being considered today, though, are for rationing or regulating use. Although some court decisions would allow general regulation of road use with reference to raising revenue, to the extent that earlier courts were influenced by revenue needs, the outcome might be different today.

Legal Difference Between Toll and Tax

We have seen the courts allow user taxes for the maintenance of public roads. Suppose that a city wished to impose a commuter tax on motorists entering the congested downtown area during peak hours. If such a tax were imposed and were challenged in court as violating section 301, would the courts reach a similar holding of its validity? The answer to that question may be found in the courts' reasoning in the referenced cases.

Consider how the courts have defined toll. The Florida Supreme Court in Cahoon v. Smith (12) found the state mileage tax not a toll, "it not being collected for mere passage over the roads and exacted when and as the privilege of passage is exercised." The Georgia Supreme Court in Inter-City Coach Lines v. Harrison (13) reasoned the mileage tax cannot be a toll "in the commonly accepted sense of a proprietor's charge for the passage over a highway or bridge exacted when and as the privilege of passage is exercised." And the New Hampshire Supreme Court in one of the narrowest constructions of the word toll said in Tirrell v. Johnson (16), "The only charges prohibited by the federal statute are tolls in the accepted sense of a proprietor's charge for passage over a highway or bridge exacted when and as the privilege is exercised."

So, congestion pricing to charge the user on the spot at toll booths probably is not allowable on federal roads. However, two collection methods—automatic vehicle identification (AVI) and self-canceling tickets—might be allowable because collection is separate from time of passage. The AVI system monitors cars in designated areas by electronic devices and sends bills to users at the end of the month. The ticket system requires prepurchase of tickets to be displayed on automobile windshields in designated areas.

The courts also acknowledged that a large percentage of the roads for which the maintenance fees were collected were not federally aided and that there is no statutory prohibition against tolling on nonfederally aided roads. In the 20 largest cities in the United States, the percentage of road-miles built entirely with state and local funds ranges from 76.8 percent in Cleveland to 94.7 percent in Los Angeles-Long Beach (17).

Authority to Tax City Streets Comes From State

So, it is possible to devise a tax on city street use and a method of collecting it that would not violate the federal highway law. But who has legal authority to impose the tax? Rep. Aspin's bill would have allowed certain cities to impose tolls on their segments of Interstate highways. This bill, without additional legislation from the states, though, could not have granted authority to these cities to collect tolls. The 10th amendment to the U.S. Constitution, in granting to the states all powers not specifically delegated to the federal government, gives the states exclusive power to decide what taxes will be collected within their jurisdictions. The power of a city to impose a tax, including a tax for road use, must come from the state. (A commuter tax in Washington, D.C., would have to be authorized by the House District Committee, in its role as substitute for the state legislature.)

States sometimes give certain cities broad taxing powers, and, in at least 2 large U.S. cities, authority to impose a city road-use tax probably has been delegated. The vehicle and traffic law of the state of New York [section 1642(4)] permits the city of New York to charge tolls, taxes, fees, licenses, or permits for highway use when so authorized by law. The authorizing legislation would be an amendment to existing local law expanding the powers of a city agency to collect a commuter tax. A 1970 revision of the Illinois state constitution gave Chicago partial home rule in the selection of revenue devices. Revenue cannot be raised by taxes on income or occupations. Home rule units otherwise have complete taxing powers. The Chicago city council could apparently enact a commuter tax if it so desired (18).

Equal Protection Problem

Whom to tax and whom to exclude is an important administrative problem because it raises the issue of equal protection under the law. City authorities might want to exempt various classes of vehicles from a use tax. Police, fire, and other emergency vehicles might be excluded. Buses and other public transit vehicles might also be excluded to encourage transit ridership. Owners of commercial vehicles serving the central city would probably argue for exemption on the basis of necessity. The problem is where to draw the line.

This problem is illustrated by the fate of a recent Arlington County, Virginia, ordinance that banned on-street parking during working hours in Crystal City except for residents (19). A state court held the ordinance invalid as violating the due process clause in the 14th amendment of the U.S. Constitution, which states: "No state shall deprive any person of life, liberty or property without due process of law; nor deny to any person within its jurisdiction the equal protection of the laws." Laws containing exemptions must have a reasonable justification for the differing treatment in terms of the purpose of the law. The exemption of Crystal City residents from the parking ban, said the Virginia court, "bears no reasonable or rational relationship to the quality of the air, the noise level, the visibility, or the general safety in the area. The requirement that a permit holder be a resident of the area is an unreasonable classification when viewed in the light of the objectives of the ordinance."

But, in another case contesting classifications in a local traffic ordinance, the New York State court and the U.S. Supreme Court held differently (20). The ordinance allowed delivery vehicles to carry display advertising of the products of the vehicle owner only. An express company whose vehicles carried advertising for other companies contested the classification, alleging denial of equal protection of the laws. In refusing to invalidate the classification, the Supreme Court said, "We would be trespassing on one of the most intensely local and specialized of all municipal problems if we held that this regulation [and its classification] had no relation to the traffic problem of New York City. It is the judgment of the local authorities that it does have such a relation." The Court thus deferred to local judgment that there was a valid purpose for the classification.

But, if one class of persons or vehicles is to be exempted from the road-use tax, there must be a valid state purpose capable of being demonstrated for the exemption, no matter how much courts defer to local judgment. If there is not, the tax might be struck down as violating the equal protection clause. It is easy to prove a valid state purpose for exempting police, fire, and possible buses from the road-use tax. Exemptions for taxis and other commercial vehicles might be more difficult to justify.

Burden on Interstate Commerce

Article I, section 8, clause 3 of the U.S. Constitution, the commerce clause, provides that the Congress shall have the power to regulate interstate commerce. Although this clause neither extends to the states nor takes from them the power to tax interstate commerce, courts have upheld the states' right to tax interstate commerce when consistent with national objectives.

The primary objective of the commerce clause is protecting the free flow of commerce from state to state. But in each case where an unfair burdening of interstate commerce is alleged, the courts apply a balancing test. They measure the detriment to the national interest and the difficulty in complying with the regulation against the merit of the state interest (21). For example, if it were found that the interference with interstate commerce was more important than the need to raise revenue, the use tax system could be struck down as being an unconstitutional burden on interstate commerce.

Generally, the courts will give a more sympathetic reading to state statutes that seek to further health, safety, or social welfare interests than to state statutes that seek to protect local economic interests (22). On this basis, taxing congested city streets would be acceptable, because the purpose would be to further health, safety, and social welfare interests. Local economic benefits would be a side effect, not a purpose of the tax. However, a state regulation that has as its purpose the protection of local health, safety, or welfare could be struck down if it were found to impose an unreasonable burden (21, 23, 24). Also, state regulations will be held invalid under the commerce clause if they discriminate against interstate commerce in favor of intrastate commerce (25, 26).

The due process requirement has been interpreted by the courts to mean that there must be "sufficient contacts" between the taxing state and the commerce taxed to justify the charge. If there are sufficient contacts, the commerce is said to have a "taxable situs"; an agency is said to have a taxable situs in a state if it receives benefits or protection from the taxing state (27).

Do trucks carrying goods into or through a metropolitan area where there is a use tax have a taxable situs in the state or states traveled through? The benefits received by commercial vehicles traveling into or through the area differ from the benefits received by workers or shoppers who use the roads. However, the benefits to commercial entities from use of city streets are real and cannot be completely paid for by state gasoline taxes and other such charges. Commercial travelers, therefore, whether interstate or intrastate, may have a sufficient taxable situs to subject them to a use tax on city streets. Furthermore, equal protection considerations may dictate that commercial travelers not be exempted from the charge.

REGULATING BRIDGE TOLLS AS A PRICING DEVICE

Federal Regulatory Power

Although it is legally possible to make some upward peak-hour adjustment in bridge toll rates for traffic rationing purposes, there are both statutory and economic limitations which, taken together, make bridge toll adjustments less desirable than city street taxes.

Let us review the federal regulatory power over bridge toll rates. The federal power comes from 2 separate titles of the U.S. Code. Title 23, which contains the federal highway laws, in section 129 sets the permissible rate structure formula for federally aided bridges. Title 33, which deals with navigable waters, in sections 494, 503, 526, and 529 sets provisions for tolls on bridges built over navigable waters according to where and when the bridge was constructed, the extent to which the water is navigable, and the bridge ownership, whether public or private.

The ultimate discretion over rate making under both titles has been granted to the Secretary of Transportation and delegated to the Federal Highway Administrator. Toll rates are not set or even supervised, except in rare instances, by the Administrator or his staff. Rate making is done locally by the bridge's commission or board of directors. It is the limits on the rates that are set and enforced in Washington.

The federal limits on local rate-making powers may be usefully divided into 2 types. The first, of which 23 U.S.C. §129 and 33 U.S.C. §529 are examples, might best be described as a formula limitation. Tolls on bridges under these statutory provisions must be set to amortize capital costs and pay for maintenance and operation and must be lifted when amortization is complete. The second type is that exemplified by 33 U.S.C. §§494, 503, and 526. These statutes for bridges over navigable waters require that the toll rates be "reasonable and just."

It is important to note that the exercise of the federal power over bridge rate making is an extraordinary and locally initiated event. The usual procedure is that, following an increase in a toll rate, someone files a complaint with the Federal Highway Administrator who sends his staff to conduct local hearings. If the Administrator determines that the rates are excessive according to the statutory limitations and no rollback comes, a suit may be filed with the Administrator against the bridge commission or board.

State and Local Regulatory Power

Who are bridge owners? They include states, counties, various other political subdivisions, corporations, associations, partnerships, and individual businessmen. Their authority to operate and set rates comes from a charter from the state government in which the bridge is located. (If the bridge connects two states, the charter will be a bistate agreement.) Charters vary in their provisions, but have one common characteristic: They emphasize financial responsibility to the bondholders. Most charters do not set strict limits for toll rates but embody a concept known as a coverage ratio. Most bridge commissions want a coverage ratio (revenues over expenses) of 1 or more (1.2 is a commonly mentioned desirable coverage ratio) to ensure that they retire their bonds on schedule.

What about diverting bridge revenues to other purposes? Some charters forbid this and require that extra revenues be used to retire the debt earlier. A few charters, particularly for publicly owned bridges, allow excess funds to be used for quite diverse purposes. An example of the latter type is the Delaware River Port Authority, which operates the Benjamin Franklin, Walt Whitman, and Betsy Ross bridges. Its charter allows revenues to be diverted to support the Lindenwold Line commuter railroad. Another provision is even more liberal, allowing revenue diversion for "improvement and development of the [Philadelphia] port district." The Delaware River Port Authority charter is an example of a tristate compact; its governing board draws members from Delaware, New Jersey, and Pennsylvania. As an illustration of the divergence of charter provisions, the Delaware River and Bay Authority, which controls the Delaware Memorial Bridge, does not have any charter provisions for revenue diversion.

Bridge owners tend to be wary of revenue diversion, whether for public transit or some other purpose. The reason is that their first obligation is to their bondholders. A program of revenue diversion might prompt a suit by the bondholders or bridge users. For the same reason, bridge owners can be expected to react unfavorably to pricing experiments. To the extent that demand for the bridge facility is elastic (that is, to the extent that other routes or modes of travel are available), pricing would reduce the number of vehicles using the bridge. Although this is in accord with road pricing objectives, it would be contrary to the bridge proprietors' interests if numbers decrease such that total revenues fall. Road pricing experiments would be acceptable to bridge owners only when no great trip diversion is possible or when the rates would be increased only to the point that would not decrease total revenues, thus defeating the purpose of the pricing experiment.

Special Treatment for Bridges and Tunnels Built With Federal Aid

Because of the great expense of bridge construction, a special section was added to the highway laws to allow the collection of tolls to repay the state's share of a bridge financed with federal funds. That section is 23 U.S.C. §129 (28). One of its conditions is that the bridge or tunnel must be publicly owned and operated. Section 129 requires that all revenues, less operation and maintenance costs, must be applied to repayment of the state's contribution to the construction cost. After the state's share has been repaid, the tolls must be lifted and the bridge operated as a free facility. Tolls may not be charged after that time even for maintenance and operating expenses; maintenance is to be provided out of other state funds.

On federally aided bridges then, under the provisions of section 129, road-pricing experiments would be allowable, as long as the state's share has not been repaid. Because tolls would be higher during a road-pricing experiment, the date when the state's share would be repaid and the tolls would have to be lifted would be brought closer. No diversion of toll revenues, for public transit or any other purpose, would be possible. Nor would any road-pricing experiments be permissible when the state's share has been repaid.

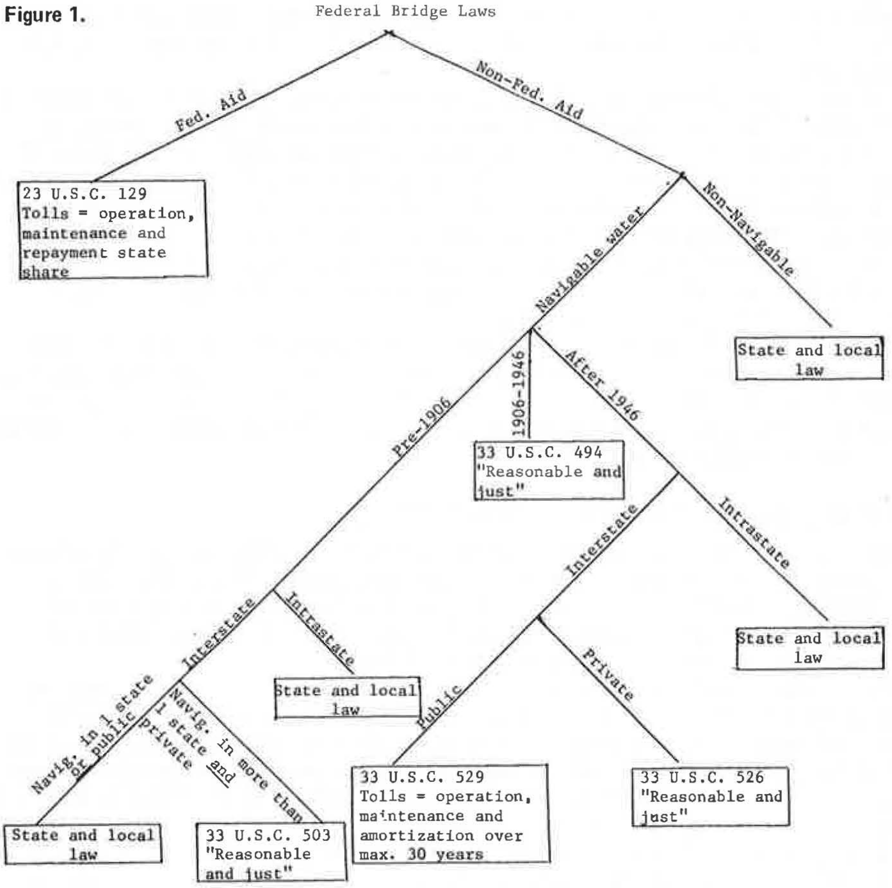
A Statutory Quagmire

In 1906 and 1946 Congress enacted major bridge legislation, which was supplemented by several smaller pieces of legislation over the years. The result has been described as a "hodgepodge of confusing and inconsistent statutes," characterized by "anachronistic omissions" (29). The provisions of Title 33 concerning toll rates are indeed confusing. But a basic understanding of them is necessary to determine to what extent pricing experiments might be undertaken.

The first question to ask ourselves about a bridge is whether federal money was used in its construction. If the answer is "no," we must ask whether the water crossed by the bridge is navigable. If it is not, the provisions of Title 33 are of no concern because the Title 33 regulatory power is derived from the constitutionally granted power over interstate commerce. If the water is navigable, we then must determine when the bridge was constructed.

Figure 1 shows the inconsistencies in the law. Loopholes, or the absence of federal control over bridge rates, are indicated by the squares entitled "state and local law." If the bridge was constructed after 1946, and does not cross state lines, only state and local law (i.e., the bridge charter) need be considered in setting toll rates. If the bridge

Figure 1.



is interstate and privately owned, the section 526 "reasonable and just" standard applies. If it is interstate and publicly owned, tolls must be set to provide for amortization of capital costs, maintenance, and operation over a maximum period of 30 years, under section 529.

If the bridge was constructed between 1906 and 1946, only the "reasonable and just" standard of section 494 applies. If the bridge was built before 1906, more questions must be asked. If the bridge does not cross state lines, only state and local law applies. If the bridge is interstate, is over water that is navigable in more than one state, and is privately owned, it is subject to the reasonable and just standard of section 529. But, if an interstate bridge is publicly owned or is over water that is navigable in only one state, the loophole appears and only state and local law applies.

The analysis of the Title 33 bridge statutes is not complete, without an inquiry into the meaning of the phrase "reasonable and just". When does a bridge toll become unjust and unreasonable and subject to action by the Federal Highway Administrator? This is a question that has been rarely adjudicated. In the words of one court, "There has been neither contemporaneous nor continuous" interpretation of that portion of the statute (30). Burlington v. Turner (30) is one important recent case interpreting the reasonable and just requirement. After complaints about tolls on the MacArthur Bridge over the Mississippi River at Burlington, Iowa, the Federal Highway Administration (FHWA) held an investigation and hearings and concluded that the tolls charged were unjust and unreasonable because they "exceeded the level necessary for operation, maintenance, repair, amortization of the debt, and administration of the bridge, and therefore must be reduced to that level." In other words, the Administrator was attempting to apply a formula-type interpretation to the phrase reasonable and just. The city of Burlington filed an action in federal district court asking for review of the Administrator's decision.

In upholding the city's toll structure, the district court said, "A reasonable and just rate, at least in other areas of regulation, is one that is fair to the public, yet gives a fair return to the provider of the service in question, though perhaps varying with different economic situations and input factors." More specifically, the court rejected the Administrator's contention that tolls should be limited to an amount sufficient only to defray bridge costs. "Intended differences in statutes must be given effect," the court said, "and the very fact that the 1906 Bridge Act has been allowed to stand without amendment... can only indicate a Congressional intent that the 1906 Act be given a different reading than subsequent legislation...."

Thus, the court upheld the independence of the Title 33 statutes. A bridge subject to the section 494 reasonable and just standard is subject to that standard alone and the vagueness of the phrase does not allow the Administrator to apply a formula-type standard. In the same opinion, the court found that the use of bridge revenues for nonbridge purposes was not unjust and unreasonable.

Department of Transportation Recommends Bridge Pricing

The MacArthur Bridge decision has been criticized as an example of the "main failing of a vague, general standard as the basis for rate regulation" (29, p. 6). The Department of Transportation (DOT) received a congressional mandate to recommend revisions to existing bridge laws because of FHWA criticism that existing laws were not adequate for it to carry out regulatory responsibilities.

Section 133(a) of the Federal-Aid Highway Act of 1973 authorized the Secretary of Transportation to undertake a "full and complete investigation and study of existing federal statutes and regulations governing toll bridges over the navigable waters of the United States for the purpose of determining what action can and should be taken to assure just and reasonable tolls nationwide." The Secretary submitted a report to Congress, including recommendations for major change to the bridge laws, on July 1, 1974 (32).

Instead of the expected tightening of loopholes and greater formula-type regulation, the report of the Secretary of Transportation recommended a major policy change to allow adjustments in bridge tolls to meet road-pricing objectives.

Specifically, the report recommends amendments to 23 U.S.C. §129 and relevant sections of Title 33, to achieve more efficient use of existing transport structures. Cities of more than 400,000, the report recommends, should be allowed to vary bridge tolls in accordance with road-pricing principles. Legislation on this matter, sponsored by the Secretary, will be introduced soon. It will recommend that bridge-pricing initiatives be subject to approval by the Secretary of Transportation and developed by the DOT-approved urban transport planning agency. Tolling proposals must also be approved by local officials including bridge management and the governor.

Revenues under the proposed tolling scheme could be used for a variety of transport needs. They might pay for highway or transit capital improvements, transit operating assistance, exclusive bus and carpool lanes, metering systems, and transit service improvements.

Future Directions

This study represents the first formal endorsement by DOT of road-pricing principles. If changes are eventually to be made to section 301 itself, allowing roadway pricing on a general, system-wide basis, the proposed change in bridge toll restrictions is a good beginning. For geographic reasons, bridge pricing is only a partial solution to urban congestion. (For example, in Washington, D.C., access from Virginia is via bridges, but access from Maryland is not.) Bridge pricing will be most effective in producing more efficient use of transport resources only when combined with pricing on other access routes and city streets. Perhaps the day is coming when legislation to allow road pricing on a system-wide basis will be introduced and passed.

CONCLUSIONS

The 23 U.S.C.§301 prohibition against tolling on federally aided roads does not present a real obstacle to taxing city street use. This is because tolls have been narrowly defined as being collected at the time and place of passage. Most charges for road use have been termed user charges and allowed by the courts. Thus, a charge levied separately from the time and place of passage would fit into the allowed user charge category. A tax on city street use would probably be upheld because most city streets were not built with federal aid.

A city, to tax city street use, would have to be granted the power by the state legislature. Certain groups of vehicles might be exempted from the tax, but there must be a valid purpose for the exemption; otherwise, the ordinance would be in danger of being struck down as violating the equal protection clause of the U.S. Constitution. In interstate commerce the tax must not discriminate in favor of intrastate commerce, and the benefits accorded by the taxing entity must have a sufficient relationship to the commerce taxed.

Bridges are subject to various federal statutes according to their date of construction, funding, and other factors. Many bridges, however, are not subject to any federal regulation or only to a vague reasonable and just standard. A recent report by the Secretary of Transportation recommends changes in bridge regulation to allow for congestion pricing. But on the local level, bridges are subject to individual character provisions, which often stress responsibility to shareholders. If pricing experiments are likely to lower total revenue, they will not be well received. On the other hand, if revenues can be kept high, there is little that would block bridge-pricing experiments.

ACKNOWLEDGMENTS

This paper was produced under a grant from the National Science Foundation. The opinions expressed are those of the author and do not necessarily represent the views of The Urban Institute or the research sponsor.

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APPROACHES FOR EVALUATING ALTERNATIVE METHODS OF RESTRAINT

Edward P. Holland, International Bank for Reconstruction and Development

This paper examines various methods for restraining city traffic including an electronic point-pricing system; peak and off-peak prices for crossing boundaries of a few large zones; and parking charges, which could be varied according to location and time of day. It is necessary to devise specific design patterns for a particular city and analyze the costs, problems, and performance in a specific network rather than try to choose among different methods of pricing in terms of abstract characteristics. A model similar to those presently in use in traffic and public transport studies is examined in comparison with the performance of other suggested pricing systems. The simulation model would set standard levels and match individual costs with marginal social costs all over the network.

•IN SPITE of "firm congressional guidance" that recently blocked plans for parking surcharges in Washington and 7 other cities in the United States (1), an increasing number of professionals agree that restraining city traffic by some form of pricing restraints is desirable. However, experts differ widely on the methods that should be used. Some still believe that urban congestion can be dealt with by high taxes on the purchase and ownership of automobiles and high prices including taxes for fuel. But this paper addresses restraining by price the operation of automobiles in certain localities during times when congestion exists.

Various systems of localized pricing have been proposed, and there is a need for ways to select a good combination for application in a particular urban area. Each of the following approaches has its advocates:

1. An electronic point-pricing system designed to equate individual cost with marginal social cost on each link of the street network at all times;
2. A less elaborate electronic system providing a set of cordons around many small areas with different prices for crossing different cordons and changes in the set of prices for different times of day;
3. Peak and off-peak charges, which might be registered electronically or collected at toll booths, for crossing the cordons around a few large zones;
4. Charges, which would be implemented through a daily license, for operating within a similar zone pattern rather than for crossing boundaries; and
5. Parking charges, which could be varied according to location and time of day.

Some of the discussion on the merits of these approaches has focused on the hardware requirements and the difficulties of administration and collection for different systems. Some say that the best system is that which is simplest to administer and enforce and uses the least sophisticated hardware. In contrast, proponents of complex systems, like the first one listed, say that their difficulties and costs would be minor when compared with their potential benefits. Theoretically, if individual cost could be made equal to marginal social cost everywhere at all times, trip-makers would be induced to make the decisions that would yield an economically efficient allocation of road space. The closer the actual system approaches the ideal pattern of unit costs the better.

But these statements are oversimplified. What is best for a city will depend on many characteristics including size of the city; geographical distribution of residences, shopping districts, and workplaces; corresponding densities of population, sales, and employment; street layout; ownership of private cars; characteristics of public transportation; and behavior of the people. In the complicated patterns of land and street use in a city, different methods of pricing restraint will have distinctive effects. The use of high parking charges in a zone will inhibit trips ending in that zone but not trips passing through it. Charges for crossing a cordon around a zone would affect trips both into and through the zone but not those that take place entirely inside it.

Rather than choose among different methods of pricing in terms of their abstract characteristics, it is better to devise design patterns for a particular city and analyze the costs, problems, and performance in a specific network. Some instructive simulation experiments have been done, comparing several pricing methods and levels in a purely hypothetical network. The results offer some insights that could be helpful in guiding the designer, but they do not lead to general rules that would do away with the need for studying real cities individually (2). It is desirable to compare a large number of alternatives and refine each design through trial and modification, but techniques for doing this quickly and cheaply have yet to be developed. The only valid way to compare the performance of different pricing systems is to simulate traffic flows for different price levels in each system by using a suitable model that also computes travel times and costs, financial revenues, and other information for evaluating economic benefits.

What is a suitable model for simulating the effects of different pricing patterns? Probably the best answer is a model like those currently being used in traffic and public transport studies where vehicle ownership, trip generation and distribution, modal choice, and route assignment are simulated sequentially with some repetition. But some models of this type would not do the job; certain sophisticated features are required. Because congestion is part of the problem, it must be a model in which speeds are adjusted and traffic is rerouted as individual links reach capacity. The model must include the realistic effects of prices on trip-makers' decisions. Trip-generation functions should provide for some trips to shift from peak to off-peak periods if prices are made higher during peak periods. Trip distribution and route assignment should respond to central-zone pricing by diverting some trips to different destinations or around certain zones to avoid higher costs. Modal choice for any trip should be influenced by cost. Even car ownership should be affected because car purchase decisions are influenced by the relative costs of commuting by car and by public transport. Thus the sort of model that is needed for comparing the effects of different restraint systems is one in which congestion feeds back to modify speeds, trip times, and costs and in which changes in trip time and cost affect all stages of the trip-makers' decisions. This requires a lot of repetitive adjustment, and it is important that the procedures yield convergent solutions.

Of course, price-responsive decision functions have not been well established and are difficult to estimate empirically. One of the first tasks will be to look through other researchers' empirical studies for evidence on the price elasticities of various elements of trip decisions. But price variations are usually correlated with other changes so that it is hard to separate the effects. A certain amount of judgment will have to go into determining some of the coefficients.

Once we have a model that can simulate trips by public and private transport and the corresponding vehicle flows under different pricing systems, how shall we use it? The easy answer is that we try out alternative schemes and see what happens. But there must be some rational order in the experimentation and the "what happens" part must be put in terms that are meaningful for making comparisons. Before we can say that one system performs better than another, we must define criteria by which performance can be assessed. The objectives of a traffic restraint policy are usually congestion and air pollution reduction. But if congestion and pollution were reduced by making it costly and inconvenient for anyone to go anywhere, that would not be satisfactory. Transportation itself must be recognized as a component of social and economic welfare, and if a reduction in congestion does not result in better transportation at lower social cost, why should we want to reduce congestion? Let us beware of the unconscious assumption that we are going to have easier driving because other people will be forced to stay off the road.

It is possible to derive economic values for transportation differences in different systems including congestion costs and disbenefits to those who, because of the pricing system, do not travel, change destinations, or use a less convenient mode of travel. The point is that there is a way to use information generated by the model to arrive at a number representing the economic benefits of a tested design pattern and restraint level. The initial and continuing costs of hardware installation and administration have to be estimated in conventional ways and considered against the benefits.

There are also benefits from reduced air pollution and reduced noise. The differences in pollution and noise can be estimated quantitatively by physical measures and could be considered with the economic criteria. But, rather than assigning them values and adding them in with economic benefits, it is better to consider them as extra dimensions.

Other dimensions that should be considered include the financial costs and revenues of each system (these may be quite different from the economic costs and benefits) and the effects on operations and finances of the public transit system. All this information can be computed in the model and printed out so that different systems and different price levels can be compared.

When systems are compared, total figures are useful indicators; but, because they could mask some important local problems or opportunities for improvement, the more detailed results should be available for analysis. The research analysts should have access to all the information they want. Most likely this would include maps of volume-to-capacity ratios on each street at different times of day, details of bus and other public transit ridership on particular routes, and numbers of cars parked in different areas. On the basis of such information, price differentials between different zones might be adjusted, boundaries might be moved, and other improvements might be made to each system tested.

Now that we have a suitable simulation model and have included in the computer program provisions for printing out the chosen criteria of performance and more detailed outputs, what we need is a testing strategy. We must choose a future year that the simulations will represent. Contemplated changes in streets, freeways, busways, and other transit facilities have to be included in the model. Data related to trip generation and distribution, such as populations, retail stores, jobs in each zone, income levels, and family sizes, must be projected for the future year. Then each restraint system to be tested must be coded into the network in terms of trip-end parking fees and tolls on links that cross cordon lines or pricing points. These charges should be programmed so that prices at different points can be readily changed by putting in new data.

Now that everything is ready, one of the first runs has to correspond to the situation without special restraints. This does not mean without ownership or annual taxes, fuel taxes, or parking fees. Those should be set at standard levels—those levels set by authorities if they were not trying to restrain traffic—or higher levels corresponding to components of the restraint program and complemented by locally variable charges. Because either definition of standard requires a subjective judgment, it may be necessary to vary them in sensitivity tests but, for most of the other comparisons, they should be held constant. This run is the base relative to which costs and benefits of all other systems will be measured as differences.

The next set of runs should use a finely spaced point-pricing system to match individual costs with marginal social costs all over the network. This process would have changes at one point causing repercussions elsewhere, so I am not sure it can be done within a reasonable number of trials, but I would attempt it for two reasons. First, to have some idealized standard with which to compare the performance of the practical systems is helpful to indicate whether there is room for improvement in the performance of the latter. Second, the resulting geographical pattern of price levels may be useful for the layout of zones and cordon lines and the choice of patterns and initial levels of prices for the other systems that are the objects of the rest of the experiments.

Finally there is a need for comparing restraint systems in more than 1 year and at several times of day. To run such a complex model through all these conditions for every change in price level and every pattern of restraint methods would be cumbersome, costly, and unnecessary. A good deal of exploration, refinement, and preliminary comparison can be done in terms of a single year and peak period. These partial comparisons must be done, however, without forgetting that the relation of all-day effects to peak-period effects will be different for a time-varying meter-recorded change than for a daily sticker system and that a method aimed too sharply at dealing with congestion in a predefined peak period may create secondary peaks just outside that time period. These and other differences between different approaches must be brought out and analyzed.

This outline should help get us started in studying traffic restraint measures. Carrying out such a study will simultaneously serve to help design a system for a particular city and add to our general understanding of traffic restraint systems.

ACKNOWLEDGMENT

This paper expresses the views of the author and is not an official publication of the International Bank for Reconstruction and Development.

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COLLECTION PROBLEMS AND THE PROMISE OF AUTOMATIC VEHICLE IDENTIFICATION

Robert S. Foote, The Port Authority of New York and New Jersey

Because traditional toll collection cannot be used as a congestion pricing method on federally aided roads, another equitable method needs to be found. Three types of automatic vehicle identification presently available—optical systems, radio frequency systems, and microwave systems—are discussed. Field test results of radio frequency equipment are given for a study done by the Port Authority of New York and New Jersey in 1971. The accuracy of the technology tested shows that it will be possible to charge people for road use in close proportion to their actual use. An automatic vehicle identification system can achieve greater fairness in allocating road use charges than other means existing today.

•ORIGINALLY I had felt that the problems in implementing a congestion pricing scheme would be like those in conventional toll collection. But in doing some homework for this session, I discovered a paper by Coit that caused a change in the approach I had been planning to follow. This paper states (1, p. 9):

> Clearly, congestion tolling in the traditional conception, with the use of collection booths to charge the users on the spot, is not to be allowed on federally-aided roads. However, use of the more sophisticated AVI systems or the simple self-cancelling ticket (à la Sumner Myers), sold in books at a time and place separate from the passageway, would seem to place the congestion pricing experiment safely on the "tax side" of the line, rather than the "toll side."

So the specific problems of traditional toll collection are not pertinent here, because traditional toll collection cannot be used for congestion pricing.

PRICING SCHEMES

Transferring funds from a driver to a collection agency separate from the passageway requires establishment of proof that payment has been made, and destruction of that proof when it is no longer valid. There are two places this proof can be held—by the collection agency or by the driver. For example, if the pricing scheme requires that all vehicle drivers entering the central business district (CBD) between 8 a.m. and 9 a.m. on weekdays pay the city $10 per month, the payment record for a particular vehicle could be carried on a sticker and be checked on a sampling basis. Or it could be carried in a computer maintained by the city that would be accessed on line in real time on a sampling basis by an observer reading license plates.

This form of congestion pricing would be simple from the collection standpoint, especially if a time-dependent sticker were used. Time dependency might be achieved by an expiration date, color code, or automatic sharp change in color after some interval "à la Sumner Myers" (2). Automatic vehicle identification (AVI) installation for this type of collection would be a case of technological overkill and would be uneconomic too.

But such a simple pricing scheme may be unsatisfactory for redistributing traffic, which the proponents of congestion pricing want to accomplish. The goal is to achieve more efficient use of roads by inducing motorists who have only a marginal need for congested highways to travel instead on noncongested routes or at off-peak times. The marginal user then should be defined by the particular congestion existing at the time and by the route he or she would travel. Otherwise either too few or too many people will be diverted to other routes. This could be a serious problem because of the variability in day-to-day and route-to-route traffic conditions. For example, congestion at 7:59 a.m. and 9:01 a.m. could be major.

So if the congestion pricing scheme requires charging the marginal motorist on the route he or she uses and the time he or she uses it, then the sticker system will not be fair because the monthly sticker cost per trip to a motorist traveling to the CBD 4 times a month would be 5 times more than the cost per trip to a regular commuter. That is, the deterrent effect would be weakest for the motorist contributing the most to congestion. A sticker good for only 1 trip would avoid this, but the costs to monitor the stickers would be too high. And if the charge were made proportional to the length of the trip or how late in the peak period it was made or the type of vehicle it was made in, then the number of stickers and monitors would be too high. Here, AVI may be the answer.

AVI PROPERTIES

Automatic vehicle identification is a type of electronic license plate, with a transponder (a small device carried on a vehicle) and an interrogator (an electronic element in or near the roadway). A complete AVI system may also be tied into a computer, have a local printer, and have additional peripheral elements downstream. But the key components are the transponder and the interrogator.

There are 3 forms of AVI techniques that are now available: One sends information in the visible light spectrum by optical technology, another sends information by low-power radio frequency, and the third by microwave energy. An AVI transponder can be powered by a vehicle source, by a part of the transponder, or by roadside circuitry.

The results desired indicate which AVI form would be most suitable. Some of the key elements to be considered are accuracy, amount of information capable of being transmitted, transponder appearance, counterfeiting difficulty, service life of the transponder, and cost.

If accuracy is required, then optical systems may not be suitable. Optical systems have the most field experience—they have been adopted by the Association of American Railroads as standard for identifying railroad freight cars and more than 80 percent of railroad freight cars are equipped with multicolored stickers. However, the accuracy of these transponders, as reported by the Association of American Railroads, is from 70 to 80 percent. The main problem is keeping the labels clean. Collection accuracy must be in the 99 percent range because the cost of handling inaccurate collection information is very high. The microwave systems are not nearly so dependent on the cleanliness of the transponders as the optical systems are, so the microwave approach should offer higher accuracies. But there has not been enough field experience to permit a true judgment of their accuracy. The low-power radio frequency (rf) systems have been tested, and they have demonstrated accuracies from 98 to 99 percent. By more precise coding and other data protection techniques, accuracies of 99.9 percent appear attainable.

Although accuracy is a key element in deciding among various forms of AVI, the amount of information capable of being transmitted by the transponders is also important. The amount of information that can be transmitted from optical stickers on the side of a vehicle is small compared to what can be transmitted with rf and microwave transponders. Optical systems now in use, with stickers 18 in. (457 mm) long, transmit 6 to 8 decimal digits. Systems with rf transponders suitable for a national collection system can transmit 14 decimal digits. Microwave systems have comparable capacity. Both rf and microwave capacity values may be increased without significantly altering the size of the transponder.

Transponder appearance is a problem that depends on how widely used the system will be and whether the equipping of vehicles with transponders will be voluntary. It seems that automobile owners would object to placing 18-in. (457-mm) multicolored stickers on the side of their vehicles far more than they would object to adding a small box underneath their vehicles.

Another inportant factor is the need to protect against counterfeiting. It is easy to counterfeit the optical sticker but not rf or microwave devices.

The service life of the transponder is another point for consideration. An optical sticker has a limited life, and, if the sticker will be renewed at short intervals, this could be advantageous. In the case of the railroad application, however, the identification is for the life of the freight car and label maintenance is a problem. The rf transponder is expected to have a service life of 15 years. These devices use solid-state components and are sealed.

Cost is another major consideration. The attractiveness of the optical system depends primarily on the low cost of the transponder. The installed cost of the multicolored sticker on a railroad car is about $8. The cost (uninstalled) of a rf transponder in production quantities is expected to be $35 to $40. The cost of a microwave transponder would probably be less than rf transponders, but because the technology is still being developed there is no firm information yet.

The costs of interrogators, a significant part of a total system, are reversed. An optical interrogator is considerably more expensive than a rf interrogator, which costs from $4,000 to $7,000.

STATUS OF AVI

Several years of experience with optical transponders on railroad cars in the United States have produced results that are not encouraging—the labels or stickers cannot be kept clean enough to achieve an accuracy of better than 70 to 80 percent. The optical system is also being used widely on containers and on a pilot basis for toll collection at the Baltimore Harbor Tunnel and Philadelphia's Walt Whitman and Ben Franklin bridges. When the stickers are sensed the driver can deposit a reduced rate of toll. But these are systems with limited information capability.

The U.S. Department of Defense is funding the development of a microwave system that will be adapted for identifying containers, freight, and packages. Until this system is field tested, though, we will not know much about it. Microwave systems have been demonstrated as laboratory components but not for unattended field use. Although accomplishing identification using microwave technology is technically feasible, performance questions like the effect of ambient electrical noise can only be resolved through extensive field testing.

The distance required between the interrogator and the transponder may be a potential difficulty in using microwave techniques for identifying highway vehicles. Locating the transponder under the vehicle would subject it to the least amount of interference, but the consequent close distance between the interrogator and transponder would require more precise positioning of vehicles over the interrogator head than is feasible in many highway applications.

FIELD TEST PERFORMANCE

Radio frequency equipment has been rigorously tested. The Port Authority of New York and New Jersey, in the fall of 1971, invited potential manufacturers of AVI devices to demonstrate their equipment by supplying 40 transponders to be mounted on 40 buses and be tested for several months in rigidly controlled field conditions. Although discussions were held with suppliers of all types of AVI systems, only the suppliers of low-power rf systems participated in the field test. Entering the test, which required that the manufacturer provide 40 transponders and an interrogator without cost to the project, represented a commitment on the part of the manufacturer of many thousands of dollars. Thus, only the most serious prospective suppliers took the test. Agreements were concluded with GE, WABCO, North American Philips, and Glenayre Electronics. All but North American Philips were powered inductively from the roadway; the Philips systems used a 3- to 5-year battery in the transponder.

The transponders were mounted on commuter buses that operate between Maplewood, New Jersey, and the Port Authority bus terminal in midtown Manhattan. Interrogator locations were about 4½ miles apart at New Jersey Turnpike interchange 16 leading to the Lincoln Tunnel and the Port Authority bus terminal. The interrogators were connected over leased telephone lines to a computer in the Lincoln Tunnel administration building halfway along the route.

The test was conducted in 2 phases. In the first phase the stress was on the ability to measure travel times for individual buses passing through the road network. In the second phase interrogators for all of the 4 systems being tested were located on the Port Authority bus terminal ramps, and data from each were used to cross-check the others.

Because buses using the suburban level enter the terminal by only 1 lane and leave by only 1 lane, accuracy can be checked by 1 interrogator in the inbound lane and another in the outbound lane. This was done for GE, which provided 2 interrogators. But any errors arising from the failure of the system to detect buses at both the entrance and the exit would pass unnoticed in this system. However, when interrogators from the other 3 manufacturers were placed alongside the inbound GE interrogator, the chance of all failing to detect an inbound bus was remote.

The 4 transponders were mounted on a rig in front of 1 of the test vehicles to determine the accuracy of each system at varying height, lateral placement, and speeds. The maximum speed possible in this restricted location was 30 mph (48 km/hour).

Although the transponders used in this test differ from each other, typical dimensions would be $1\frac{1}{2}$ by 5 by 9 in. (38.10 by 127.00 by 228.60 mm). When the transponder is mounted underneath the vehicle, brackets must separate by 4 in. (101.60 mm) the transponder and the nearest metal on the vehicle because, if the transponder is too close to vehicle metal, its weak signal can be diverted. Based on more than 2 years of experience with buses, no difficulty has been encountered because of the transponder being struck, but mounting similar devices on small cars may be a problem. Most standard-sized cars, though, offer suitable locations for AVI transponders. In large-scale production, large-scale integration (LSI) circuits will undoubtedly be used. Although the primary reason for using LSI components is to reduce transponder costs, they will also make the transponder more compact and make mounting easier.

The interrogator loop cut into the pavement is similar to that required for an induction-loop vehicle interrogator, except that for the GE system 2 overlapping loops are needed—one to start power and the other to receive transponder signals. Typical dimensions are 2 ft (0.6096 m) in the direction of travel by 8 ft (2.4384 m) across the lane. The test on the bus ramp was especially rigorous because of the large amount of reinforcing steel and heating tubes in the ramp and the radio frequency noise from nearby commercial radio stations. These factors proved not to be a problem, however.

The interrogators for the various systems differed considerably in the amount of circuitry provided. But in a typical final installation the interrogator would be enclosed in a box measuring 2 by 2 by 3 ft (0.6096 by 0.6096 by 0.9144 m). With LSI circuitry, the size could be reduced greatly.

The 4 systems were performance tested on the bus terminal ramp for 3 months and were checked against each other. The GE system had the most transactions (because there were 2 interrogators). Out of a total of 13,814 bus passages, all but 181 were measured correctly; the accuracy of the GE system was 98.69 percent. The WABCO system was on line for the longest time for this test, with its 1 loop sensing a total of 9,199 transactions, all but 48 of them correctly, for an accuracy rate of 99.48 percent. The highest accuracy was attained by the North American Philips system. Once initial tuning was completed, which delayed the placement of this system on line, the Philips interrogator sensed 5,226 vehicles, all but 8 of them correctly, for a performance rate of 99.85 percent. The smallest amount of experience was gained with the Glenayre system. During the test Glenayre sensed 1,416 passages, missing only 22—a performance rate of 98.45 percent.

APPLICATION PLANS

What applications are being planned now, based on this experience? The Golden Gate Bridge, Highway and Transportation District has been testing the GE equipment for several years using its own vehicles. Performance of the system has now reached the level where the district has developed plans to make equipment available to the public in the near future.

The Port Authority of New York and New Jersey is now purchasing GE transponders and interrogators to develop an AVI-based toll collection system for nonstop movement of buses. When the toll system is demonstrated, funds will be sought from the Urban Mass Transportation Administration to equip most of the buses using the Port Authority bus terminal with transponders. Because rf systems can display variable as well as fixed data, this installation being planned by the Port Authority of New York and New Jersey could relay such information as the route number of a bus and the number of passengers it is carrying. This information would contribute to the efficiency of bus-fleet management. One purpose of the next Port Authority test is to evaluate such potential benefits.

The New Jersey Turnpike Authority, in conjunction with the Port Authority, is considering the purchase of 250 transponders and 6 interrogators to evaluate AVI on automobiles commuting between interchanges 14 and 16 in the New York metropolitan region. The turnpike test will be particularly valuable in determining the public interest in AVI.

So the development of AVI is proceeding step by step on a limited scale. There are still many important elements to be evaluated, now that the basic performance of the AVI technology itself has been confirmed. Although there are few technical questions about the feasibility of processing nonstop toll collection (or road user pricing) data on line in real time, the best equipment use and configuration and the costs for maintaining accounts for AVI customers need to be defined.

CONCLUSION

It will be possible to charge people for road use in close proportion to their actual use. Automatic vehicle identification technology offers the possibility of greater fairness in allocating road use charges than can be obtained with other means existing today. For example, although a gasoline tax is relatively simple to administer, it is not equitable. Those who must use the poorest quality roads, with many interruptions along their route because of intersections and traffic signals, consume more gas per mile. They pay more for using poor roads than do motorists using costly limited-access facilities. If gas tax revenues decrease because of the scarcity and high cost of gasoline supply and because of the introduction of new forms of energy, AVI can fill an important need in maintaining equitable taxation for road use. However, in simplifying road use pricing, AVI may not be the deterrent that some economists look to for reallocating traffic.

It should be stressed that, in conducting AVI research, the Port Authority of New York and New Jersey is not advocating deterrent pricing. The purpose of highway traffic operations is to serve as efficiently as possible the transportation needs of the people consistent with environmental and other constraints. The availability of employment and, more generally, the quality of life in an urban area depends in part on the availability of efficient and economical transportation. Automatic vehicle identification hopefully can contribute to improving the quality of transportation. But the rate at which AVI is accepted will depend entirely on the judgment of the people. Acceptance of AVI on a broad scale will undoubtedly take much time, but essential work is being done.

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COLLECTION PROBLEMS AND THE PROMISE OF SELF-CANCELING TICKETS

Sumner Myers, Institute of Public Administration, Washington, D.C.

This paper discusses collecting motor vehicle user charges by time-calibrated self-canceling tickets (timer-tickets). In a designated area, a timer-ticket, about the size of a 3- by 5-in. (76- by 127-mm) card, would be displayed on the windshield of an automobile to show whether the driver paid for the vehicle to be in the area. The timer-ticket, when bent or scratched, changes color to red. This shows that the ticket has been activated. It also starts a chemical reaction that, after a preset time, results in a second color change, to blue. This shows that time is up. The ticket has canceled itself. The paper emphasizes that the administrative simplicity and the ease of sale of timer-tickets would be profitable to local governments. It also discusses the categories in which timer-tickets may be used: overnight parking, historic area parking, toll collecting, and congestion pricing.

• IN THIS era of big science many people do not understand that small technologies have a large effect on the system to which they are applied. For example, the invention of carbon paper made it possible to design an endless variety of administrative systems based on shared information. These are sometimes called "linchpin" technologies. I am going to discuss a new linchpin technology for collecting motor vehicle user charges that would offer great flexibility and would be a necessary first step in the implementation of user-charge systems. This new technology is a time-calibrated self-canceling ticket (timer-ticket). The ticket, about the size of a 3- by 5-in. (76- by 127-mm) card, would be displayed on the windshield of an automobile to show whether the driver paid for the vehicle to be in a designated area.

The timer-ticket, when bent or scratched, changes color immediately to red to show that the ticket has been activated. It also starts a chemical reaction that results in a second color change, to blue after a preset time. The blue shows that time is up. The ticket has canceled itself. Here is how a 25-cent timer-ticket would be used to pay for 1 hour of parking:

The motorist, after parking, pulls out a 25-cent timer-ticket that was bought earlier. The driver rubs the card with a coin and the ticket begins to turn red. After more rubbing, more red appears and the ticket is activated. The driver notes that it is 1:30 p.m. and puts the ticket on the dashboard so that it shows through the windshield. The ticket stays red until 2:30 p.m. when the hour is up. Then it changes to blue.

A sharp color change when time is up is important because the ticket must tell enforcing officers on a "yes or no" basis whether the vehicle is permitted to be in a restricted area. A ticket that gradually changes from one color to another will not work because it would be difficult to tell whether it was valid.

A wide variety of administratively simple user-charge systems can be designed around self-canceling tickets. One feature that contributes toward simple administration is that tickets can be sold undated in advance. Tickets could also be sold one at a time or in books, over the counter, from slot machines, at gasoline stations, or by mail. And, because of the convenience, many motorists may keep books of prepaid tickets on hand, and the local governments that issue the tickets could borrow larger sums of money on their larger capital income.

PARKING

Because timer-tickets are cheap and require no street installation or maintenance, they could be used where mechanical parking meters are inappropriate—for example, overnight parking where charges are low and parking is long-term; historic area parking where aesthetic considerations rule out street hardware; or truck parking where different charges for time, space, or type of vehicle will be made.

Overnight Parking

The self-canceling ticket might be particularly useful in charging for overnight parking on city streets where charges are low and parking long-term. Timer-tickets for 12 hours would be presold to motorists as overnight parking permits for designated streets. The motorist, after parking his or her car, would "pay" for the space by activating the ticket and placing it against the inside of the windshield. While the ticket showed fluorescent red, the car could park all night on streets designated for all-night parking. After 12 hours, the ticket would cancel itself by turning blue. To park the next night, the motorist would have to use another timer-ticket.

New York, Philadelphia, Baltimore, Boston, and Minneapolis have considered charging for overnight street parking to generate revenue more than to allocate street space. Although their financial need was great and potential revenues were substantial (the Office of the Administrator in New York City estimated that an overnight parking charge would net approximately $60 million per year), there was no suitable way to collect overnight charges. Overnight parking charges could have been collected by conventional meters. But parking meters, particularly in residential areas, have several drawbacks: Some neighborhoods object to them for aesthetic reasons and in some neighborhoods they are vandalized. Overnight charges also could have been collected by a monthly or annual permit system. This avoids the aesthetic and vandalism problems, but a prepaid permit is so inflexible that it is likely to be politically unacceptable because it requires payment in advance whether or not the motorist actually gets to use what he has paid to use. At worst, a permit system works like a nuisance tax—at best, like a hunting license. A city that has an overnight charge in residential areas should charge for space only when it is used. Otherwise, the public response might be what it was in Philadelphia some years ago. In that city, motorists who could not find parking spaces under the "hunting license" scheme were so angry that they actually stoned the mayor's house to emphasize their displeasure. The scheme was dropped.

Under a timer-ticket scheme, a motorist would pay for a parking space only if it was used. If the motorist did not find a space on the street and parked in a garage, he or she need not use a permit. So the timer-ticket system may be politically more acceptable than other prepaid systems.

Historic Area Parking

Timer-tickets might also be used for making space available to short-term parkers in historic or other aesthetically sensitive areas where mechanical meters are unsightly or otherwise inappropriate. In these areas timer-tickets could be used to attract visitors rather than commuters. For example, tourists could buy tickets for parking on the Mall in Washington, D.C.

Truck Parking

Timer-tickets of different values could be used to levy special charges against trucks making deliveries or pickups during peak hours. Similarly, timer-tickets could be used to charge for and thereby discourage unnecessary double-parking where measures to completely prohibit double-parking are unreasonable.

TOLLS AND CONGESTION PRICING

Timer-tickets offer a wide variety of parking options, but they really come into their own when it comes to collecting charges in congestion-prone areas.

Economists and others have long urged that highway congestion be controlled through the application of user charges. While in the past this has had little prospect of being carried out, pressure has built up lately for the application of user charges to control air pollution and to reduce energy consumption. A good deal of attention has been given to the costs and benefits of road user charges. But, except for the British, nobody has really considered the methods by which charges could be collected. Most people simply take it for granted that road user charges can be collected on a large scale because tolls are collected on a smaller scale at highways, bridges, and tunnels. But toll facilities are poor models for collecting user charges on a broader scale.

Current technology for collecting tolls is inadequate for collecting charges in congestion-prone areas. Toll facilities use too much space with plazas and booths that create traffic bottlenecks. Automated electronic collection might reduce this problem, but the cost-effectiveness of automatic vehicle identification (AVI) systems depends on requiring all vehicles using the controlled areas to be equipped with electronic devices. It will be difficult for any government to charge motor vehicles for something that is now free. This difficulty will be compounded if user charges depend on electronic surveillance of all vehicles in the system. Many people might consider this an invasion of privacy. A more flexible user charge collection system should be used as a supplement to or a substitute for electronic devices. The timer-ticket is such an option.

Timer-tickets could be used to collect entrance charges to bridges and tunnels, especially those without room for toll plazas (e.g., New York City's East River bridges) or where toll plazas would spoil the environment (e.g., Washington's Memorial Bridge). The motorist would activate a timer-ticket before reaching the check point of the bridge or tunnel. The activated ticket showing fluorescent red would be displayed on the windshield where it can easily be spotted as cars move past the check point. At the end of a preset time, the ticket would cancel itself. The motorist might have to use another timer-ticket for his next trip through the facility. The timer-ticket could be used in conjunction with AVI. Regular users who prefer to be billed could voluntarily equip their vehicles with AVI devices. Occasional users or those who prefer not to be identified could prepurchase timer-tickets.

Area Access

The timer-ticket is a simple way to levy a 1-day charge on motor vehicle users who drive into or through congestion-prone areas. The area might be a central business district (CBD), a transportation corridor, or even a particular street or highway. Timer-tickets would permit local governments to control the area all the time or some of the time. There could be different prices for different parts of the city. For example, it might cost the motorist 2 tickets to be within the CBD but only 1 ticket to be on its fringes.

Local governments might also use the timer-ticket with either an AVI system or a prepaid monthly sticker system such as that proposed for London. In the sticker system, regular travelers would prepurchase semiannual stickers. In an AVI system, regular users would be equipped with electronic units. Occasional users such as sales representatives and shoppers, would buy a 1-day timer-ticket to save money. This option makes the administratively efficient sticker system workable because the occasional traveler can be easily accommodated.

ADMINISTRATION

Vehicles in a timer-ticket system do not have to be checked at fixed observation points. They can be checked randomly within the control area. The system also lends itself to a statistical sampling type of enforcement.

Some people will try to cheat the system, but total compliance is not necessary for the system to be economical if the number of cheaters can be kept to within acceptable limits. This can be done by cracking down whenever statistical samples show that it is necessary.

Cracking down would involve checking for forgery. Although the timer-ticket is designed to make forgery impossible, some people will undoubtedly attempt it. Although forgeries would be impossible to spot in moving traffic they can be spotted easily when the vehicle is standing still. Police can also check for forged tickets as a routine matter whenever they stop a vehicle for a traffic violation.

One political question remains to be answered: Are people willing to pay for a public facility that has always been free? Most likely the answer is no. We should, therefore, consider other methods for allocating road space. One method is lotteries. Another is rationing. Timer-tickets could make either system work.

In a lottery system, vehicle owners wishing to try for a monthly set of daily timer-tickets would send in an application form along with a nominal fee. The fee would be set high enough to discourage people with marginal needs. Winners of the lottery would receive 1 month's supply of daily timer-tickets. Because the tickets would not be coded for specific days, the winners could use them as needed or they could sell their unused tickets.

A road rationing scheme, such as the Israelis are using, would operate similarly. Vehicle owners would receive a ration of 1-day timer-tickets that would limit vehicle-days of use. Because the tickets would be open-dated, owners could decide when to use their tickets or they could decide to sell them.

All the systems discussed have their advantages and disadvantages. The point is that timer-tickets would make them all administratively simple and thereby more likely to succeed.

PARKING TAXES AS ROADWAY PRICES: A CASE STUDY OF THE SAN FRANCISCO EXPERIENCE

Damian Kulash, The Urban Institute, Washington, D.C.

This paper analyzes the effects of a 25 percent parking tax in San Francisco from October 1, 1970, to June 30, 1972. It develops parking price elasticity estimates for various types of parking facilities. Commuters were more sensitive to price changes than were shoppers, but the overall effect on the number of parking stall occupancies was slight. The effect on parking lot profitability was severe. The parking tax also had little influence on congestion, air pollution, and energy consumption. Downtown businesses other than parking lots were not harmed by the tax.

•ON OCTOBER 1, 1970, a 25 percent tax on parking went into effect in San Francisco. It was the largest citywide jump in parking prices ever experienced in the United States. All parking with the exception of residential, hotel, and metered parking was subject to the tax. The San Francisco parking tax was instituted not because of concern about traffic congestion, air pollution, or energy consumption but because the city and county of San Francisco needed revenue. A parking tax provided a convenient way of raising it. It was introduced in a package with a utility tax and a gross receipts tax. These were expected to raise $15 million for the city. One-third was expected to come from the parking tax.

The parking tax generated the amount anticipated—$5.5 million per year. An increase of 27 cents on the 1970-71 tax rate of $12.82 would have been required to raise the same funds. The tax was for all parking operations throughout the city and county, except residential and metered parking. Metered parking was exempt because of the difficulties in refitting meters for odd rates. Residential parking facilities that were rented to tenants were also exempt. Parking station operators were responsible for collecting the tax and paying it to the government. Exemptions were later added for hotel guests and long-term storage by military personnel.

Support for the tax came from persons who wanted to avoid raising the personal property tax and from environmental groups who wanted to reduce the role of the automobile downtown. They argued that the tax would cause commuters to shift from automobiles to public transportation and would have little effect on shoppers; thus it would reduce traffic-related problems without damaging the economic life of downtown San Francisco.

Opposition to the tax came from parking operators who argued that the tax was excessive and put unfair hardships on the industry; from downtown merchants and businessmen who were concerned that retail activity would be reduced in the central business district (CBD); from citizens who were without ways other than the car for getting to work; and from doctors, lawyers, and other professional people whose offices were in the taxed area. In spite of these objections, the San Francisco Board of Supervisors voted to institute the tax, though some supervisors stated that they would reconsider their position as the effects of the tax became clear. On August 28, 1970, Mayor Joseph L. Alioto signed the tax package into law, noting:

> Both the Supervisors and the Mayor are well aware of specific defects pointed out by critics of these new taxes. However, the significant thing is that these same critics offer no substitute whatever, despite the fact that San Francisco has the most narrow tax base of any big city in the entire country. In my conferences with the business community and other critics of the

> new tax package, it finally became clear that they really advocated saddling all increased governmental costs onto the already overburdened property taxpayer. That approach we must reject, simply as a matter of fairness and equity. The property taxpayer cannot continue to be the only source for increased revenue.

On October 1, 1970, the parking tax went into effect. This paper will describe its effects on the parking industry, on traffic generally, and on the downtown area. Because it is a study after the fact, it is limited by the availability of data. Furthermore, these data permit a variety of interpretations because of other changes in transportation. Particularly significant was that construction on the Bay Area Rapid Transit (BART) System hindered traffic flow on Market Street and in some areas around it. This construction interfered with automobile, bus, and trolley travel. Other transport changes that may have had a bearing on the experience are

1. The San Francisco Municipal Railway (MUNI) fare increases from 15 to 20 cents on June 30, 1969, and from 20 to 25 cents on August 31, 1970;
2. The passenger ferry service between San Francisco and Sausalito that began on August 15, 1970; and
3. The increased transit service and patronage when Golden Gate Transit replaced Greyhound as the bus line from the Marin County corridor on January 3, 1972.

These developments, except the MUNI fare increase, which occurred 1 month before the parking tax took effect, increased the attractiveness of public transportation and may account for changes in travel behavior that appear to have resulted from the parking tax.

The 25 percent tax was eventually lowered to 10 percent effective July 1, 1972, because of opposition from affected individuals and business interests. The 25 percent tax had been in force for 21 months; the 10 percent tax is in force now.

EFFECT ON PARKING

Data given in Table 1 on parking in downtown San Francisco in 1966 indicate that equal quantities of lot and garage parking were available (1). Off-street parking provided nearly 50,000 spaces in San Francisco and on-street parking just over 11,000, most of which was for short-term use. Not all of the off-street parking was open to the general public; 20 percent of it, mostly in lots, was reserved for private purposes such as employee parking.

Garages tend to be located in central areas and command higher rates than lots. The city and county of San Francisco are heavily involved in this high-rent segment of the parking market, owning about half of the garage parking in downtown. There is considerable variation in parking rates and use patterns. The highest rates are charged in the financial district and on the northwest side of the retail district. In 1965 these rates were about $2.00 per day compared to 25 cents per day in lots near the Central Skyway (1). Parking properties also vary greatly in the types of trips they serve. The parking study reported that 9 percent of all vehicle-trips to the area were shopping trips, although it has been claimed that as many as 90 percent of the parkers in some garages are shoppers. It is misleading to speak of a single parking industry in San Francisco. Operations differ markedly in the rates they charge and the types of traffic they attract. Reports concerning the effects of the parking tax on parking operations therefore were varied.

Municipal Garages

Although construction financing for municipal garages often comes from private sources, the properties are operated under agreements with the city and county governments. Because these operations are public, they have the most complete data for past patronage and revenues. And, because rates at municipal garages are fixed by the city and county governments, they reflect only those price changes from the tax. Operators not bound by these rate controls frequently lowered their base rates and absorbed part of the tax themselves in order to lower patronage losses.

Table 1. Parking in downtown San Francisco, 1966.

Type	Number of Automobiles
Off-street parking	
Public lots	18,612
Public garages	21,558
Private lots	7,774
Private garages	1,670
On-street parking	
Metered	4,951
Unmetered	6,221
Total	60,786

Table 2. Parking price elasticities for municipal properties.

Property	Automobiles Parked 1969-70	1970-71	1970-71 (adjusted)	1971-72	Elasticity[a] 1969-70 to 1970-71	1969-70 to 1971-72
Civic Center Auto Park	121,599	123,132	123,642	103,842	-0.05	-0.96
Civic Center Plaza Garage	423,243	438,662	443,797	428,791	0.09	-0.19
Ellis-O'Farrell Garage	446,826	450,905	452,263	455,108	-0.07	-0.17
Fifth and Mission Garage	1,195,467	1,266,244	1,289,813	1,214,386	0.02	-0.18
Golden Gateway Garage	366,605	340,260	331,487	366,934	-0.58	-0.24
Japanese Cultural Center Garage	135,247	122,570	118,349	155,106	-0.72	0.36
Marshall Square Parking Plaza	54,298	49,998	48,566	44,697	-0.62	-1.12
Mission-Bartlett Parking Plaza	217,200	190,309	181,354	185,943	-0.93	-0.94
Portsmouth Square Garage	598,187	603,896	605,530	623,969	-0.07	-0.06
St. Mary's Square Garage	419,132	361,311	352,056	333,497	-0.91	-1.27
Seventh and Harrison Parking Plaza	149,484	101,143	85,045	101,753	-2.65	-1.97
Sutter-Stockton Garage	743,538	779,123	790,972	792,520	0.15	0.03
Union Square Garage	890,195	855,582	844,055	873,038	-0.36	-0.34
Total	5,761,021	5,683,135	5,666,929	5,679,584	-0.20	-0.31

[a]Secular trend extracted.

Table 3. Parking price elasticities by type of garage.

Fiscal Year	Basis of Estimate	Parking Price Elasticity: Commuter Garages	Shopper Garages
1970-71	Automobiles parked	-0.27	-0.08
1971-72	Automobiles parked	-0.26	-0.25
1970-71	Gross income	-1.50	-1.23
1971-72	Gross income	-1.29	-1.22

Table 4. Parking price elasticities during price reductions.

Basis of Estimate	Parking Price Elasticity[a]: Commuter Garages	Shopper Garages	All Garages
Automobiles parked	-0.91	-0.23	-0.38
Gross income	-2.19	-1.45	-1.63

[a]Fiscal year 1972-73 compared to fiscal year 1971-72.

During the 6-year period before the parking tax, the gross income of city garages rose by 33 percent and the number of autos parked rose by 18 percent. These correspond to annual growth rates of 4.9 percent for gross incomes and 2.8 percent for the number of autos parked.

Parking price elasticities have been computed for each of the municipal garages by using secular growth factors. The results, given in Table 2 (12, App.) indicate a wide variation among properties. Because of this variation, the discussion will center on averages for various parts of the parking industry to avoid fluctuation at the individual property level. Parking price elasticities based on the number of automobiles parked for total municipal properties are -0.20 for fiscal year 1970 to 1971 and -0.31 for fiscal year 1971 to 1972. These values are close to those observed during large-scale parking price changes in other areas (2). They support the idea that parking demand is inelastic and that only drastic parking price increases will create a sizable reduction in parking traffic. Revenues and profits, however, were found to be very sensitive to price changes.

If parking demand really is inelastic, it certainly would be profitable for parking operators to make substantial rate increases of their own. But parking space rental is a unique service—it can be purchased in quantities from several minutes to an entire day or more; and the price per unit varies with the quantity purchased. Parking rate increases can cause 2 types of reaction: discontinuing use of the service or shifting to a cheaper facility or a shorter term of occupancy.

Net revenues (revenues minus the parking tax) are good for determining occupancy patterns for municipal garages because the relationship between net revenues and duration of occupancy remained fixed for these garages during the study period. The average net revenues per parked car dropped during the period of the 25 percent tax and then rose again when the tax was lowered to 10 percent at the start of fiscal year 1972-73. The drop in net revenues could be because of a decrease in long-term parking relative to short-term parking; for example, a greater reduction in commuter parking than in shopping and other short-term parking.

Prices were assumed to rise by 25 percent, the amount of the tax. But, because of shifts in the types of parking, the average price for parking fell slightly, even though rates rose. Thus a very different set of elasticity estimates results from computations based on revenues or gross incomes. Revenue-based parking price elasticities are η-1.44 for fiscal year 1970 to 1971 and η-1.63 for fiscal year 1971 to 1972. These estimates, then, indicate that the parking market is in an elastic range, a finding in agreement with observed behavior.

When 2 different approaches to estimating parking price elasticities yield different results, a single elasticity measure is too simple an index to describe the changes that result from parking price changes. Discrepancies might be reduced by analyzing separately the behavior of commuters, shoppers, and other groups of parkers. But this study is severely limited in this area because it was done after the fact.

One step that was possible was separating garages whose patrons are commuters from garages whose patrons are shoppers. This was done by using the observations of parking personnel and an index of stall turnover. Parking price elasticities were computed on this basis; the results are given in Table 3. Shopper facilities show lower price elasticities in all cases than do commuter garages. However, there is still a large difference between elasticities based on the number of automobiles parked and those based on the gross income of parking facilities.

When the parking tax in San Francisco was reduced from 25 to 10 percent in July 1972, it was possible to examine changes resulting from prices being lowered. Elasticity estimates were computed for the price drop, and the results, given in Table 4, follow the same pattern as that of the previous findings. And, the gap between commuter and shopper elasticities is even wider than that observed during the price increase. These facts indicate that commuters were more likely to discontinue parking in municipal properties than were shoppers. A breakdown of parking by trip purpose and by duration of stall occupancy should be made if similar parking price changes are enacted elsewhere to gain a deeper understanding of traveler behavior.

Other Parking Operations

Municipal parking properties, which comprise mostly garages near key retail and employment concentrations represent a choice segment of the parking industry. Data on the rest of the parking industry in San Francisco are limited. In response to a request by the San Francisco Board of Supervisors, several parking operators furnished statements of revenues from parking operations before and after the tax. The properties accounted for about 20 percent of nonmunicipal garage operations in San Francisco and had revenue-based elasticities of -1.66 to -0.78 with a median of -0.97. These estimates are less elastic than those for municipal garages. One reason could be rate cutting, which would cause estimates of elasticities to be lower (in absolute value) than true values. Lots located several blocks away from areas of high activity showed the most elastic response. Analysis of all commercial operations is complicated by rate cutting, frequent lot openings and closings, and data limitations.

The simple elasticity computations made here assume that prices rose by the amount of the tax. Some operators, in an effort to keep revenues as large as possible after the tax, lowered their rates and absorbed part of the tax themselves. A few of these, though, had raised rates before the tax to recoup some of their future losses. In these cases, rate cutting is deceptive because rates had been unusually high. Fringe lots and lots located within walking range, but some distance from the CBD, appear to have cut rates the most; central garages, the least.

Many parking lots, especially low-rent ones, require very little capital investment over the costs of acquiring the land; and often the land is leased. Some operations exploit conditions such as short-term land vacancy before a planned building is constructed or a temporary change in zoning restrictions. These factors and changing demand patterns make low-rent parking a business where lot openings and closings are common. It is difficult, therefore, to make comparisons at different times.

The flexibility in rates and the opening and closing of lots create a need for a large volume of operating data on rates, occupancy, and revenues. Some data were available from parking operators in material sent to the Board of Supervisors. Obtaining additional information is difficult. For the most part, parking operators claim that detailed information for a period 2 or 3 years ago does not now exist.

Even if rate cutting is ignored, lots showed more elasticity than garages. If better rate-cutting information were available and estimates were revised accordingly, the differences would be even larger. Ten self-park lots operated by Savoy Auto Parks and Garages, Inc., showed a revenue-based elasticity of -1.72. Eight lots operated by S. E. Onarato Garages showed -2.23. Statistics on the number of automobiles parked in 30 lots and garages operated by Metropolitan Parking Corporations showed elasticity of -0.82—much more elastic than patronage-based estimates for garages. The greater price elasticity in lot operations derives from the location of facilities, not the types of facilities.

FINANCIAL EFFECT

Parking space rental is only part of the parking industry. Other services such as car washes and minor repair and maintenance work are offered. The downward trend in parking volumes and a shift to shorter parking created a decline in the demand for these extra services. Numerous parking operations reported reductions in the number of persons they employed following the tax. The union representing parking lot employees claimed that their membership fell by 22 percent because of the tax.

The revenue data for the years before and after the tax indicate that the effect on the industry was severe. A typical parking price elasticity based on these data is about -1.6, which indicates a 13 percent per year loss of gross revenue. Of this, 5 percent represents a loss of the usual growth in annual gross revenues and 8 percent represents a decline in gross revenues over the previous year. Thus a typical operator would make only 92 percent of what was made before the tax was instituted. After the tax was deducted, only 69 percent of the former net income would be left. This is 36 percent lower than what would have been expected without a parking tax.

EFFECT ON TRAFFIC

Transportation agency officials and businessmen in the San Francisco area agree that the parking tax had no noticeable effect on traffic. This is hardly surprising—automobile-based elasticity estimates indicate that a 25 percent parking price increase would reduce by 10 percent the number of vehicles parked at off-street, priced facilities. This represents 2 percent of the vehicular traffic in San Francisco. But, this reduction would be difficult to observe because vehicle-miles of travel on urban streets across the country increased by 74 percent from 1960 to 1970 (3, p. 20). At this rate of growth, the price elasticities demonstrated in San Francisco indicate that a parking tax of 100 percent would offset just 1 year's expansion in vehicle-miles of travel. But, because commuting parkers showed greater elasticity than shoppers, traffic reductions during peak hours would be noticeably larger. Furthermore, most paid parking is in the CBD, so that most of the traffic reduction from the tax would be in the congested downtown areas.

Statistics on annual traffic across the Golden Gate Bridge, which carries 1 out of every 6 vehicles entering San Francisco (4, Table 3.1), are shown in Figure 1 (5). They indicate a rise in bridge traffic in 1968 followed by a decline in 1969. The following 3 years show a similar decline in growth. Changes in the parking tax did not appear to create any noticeable changes in annual bridge traffic. The slower growth in traffic during the tax began almost 2 years before the tax. The timing of the slowdown and the lack of change when the tax was imposed and later reduced suggest that the parking tax was not the cause of the slump in traffic growth. Construction on the Bay Area Rapid Transit (BART) system caused some traffic disturbances during this period, and substantial improvements were made in transit services to the Golden Gate Bridge corridor. The decline in growth of annual bridge traffic which began in 1968 may have resulted from these factors rather than the parking tax.

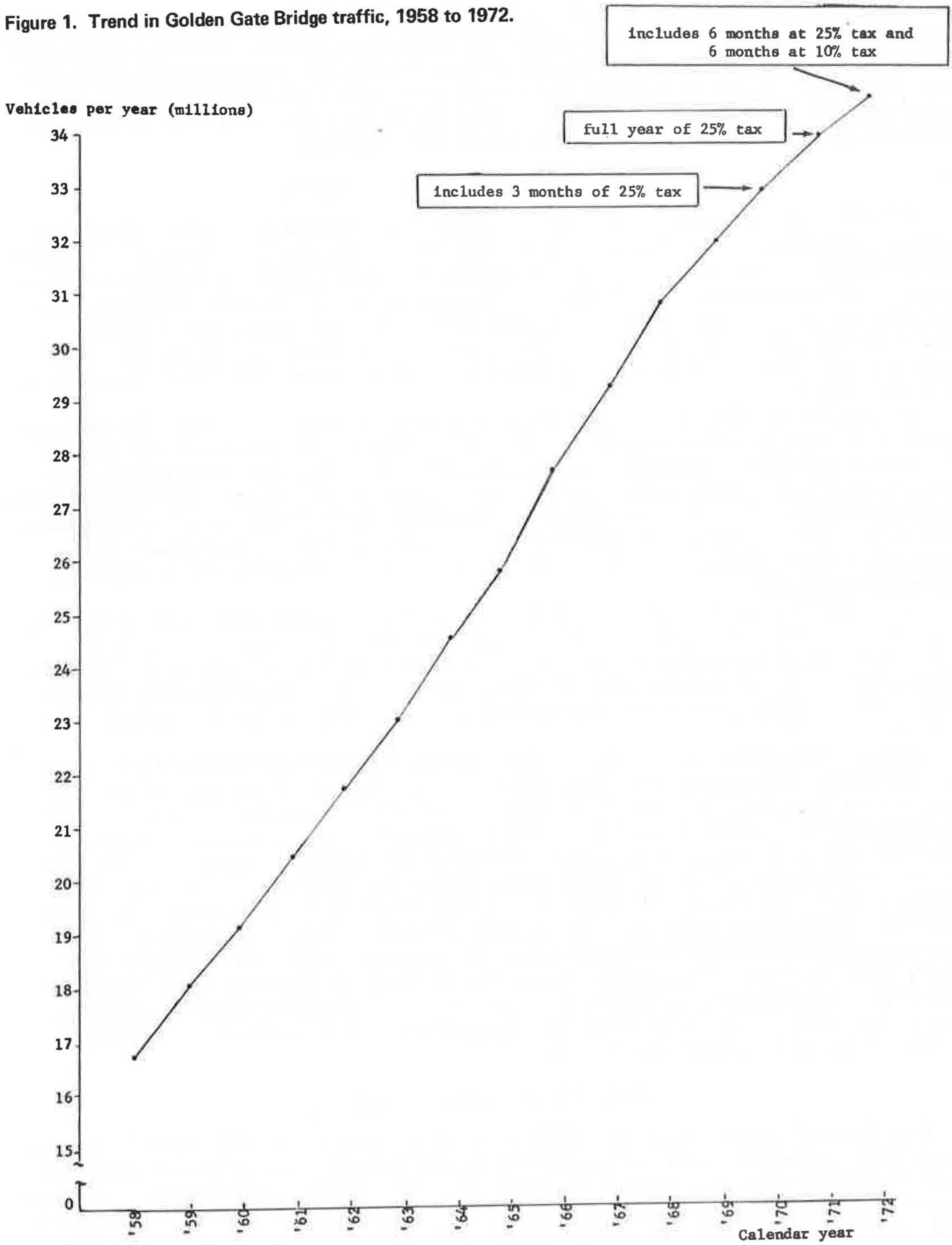
A reduction in peak-hour traffic was noted on the Golden Gate Bridge after the first month of the tax, according to the general manager's report (6, p. 4):

> October traffic figures showed an increase of only 1.6 percent over the same period the previous year. We also note that the average number of vehicles during the 3-hour morning commute period was 16,194 cars. Had the same increase occurred that had prevailed from 1958-1968, this average number would have been expected to be 17,337.
>
> It is difficult to be sure what has accounted for this reduction in the rate of growth for all traffic for the month of October and also for the morning commute hours, but we believe the main reasons to be:
>
> 1. The increase in parking rates in San Francisco.
> 2. The general slow-down in business activities.
> 3. The increased numbers now riding the Sausalito and Tiburon Ferries, particularly during the commute hours.

Peak-period traffic across the Golden Gate Bridge has remained roughly constant since the parking tax went into effect. If this were due solely to the parking tax, it would indicate that the effect of the tax on traffic volumes during commute hours was much greater than at other times of day. However, there were 2 significant changes in transit service during this period that throw doubt on the importance of the parking tax in halting peak-period bridge traffic growth. The first drop in peak traffic corresponds to the institution of the tax and to the establishment of the Sausalito and Tiburon ferry service. The second drop corresponds to a reduction in the parking tax as well as the takeover of bridge bus operations by Golden Gate Bus Transit. The bus takeover added 1,500 passengers per day during commute hours, accounting for much of the drop in peak-period vehicles per day that occurred between 1971 and 1972 (7, p. 4).

It is impossible to isolate the effect of the parking tax from the effect of transit service improvements, but their combined effects have a distinct pattern: Overall bridge traffic continued to grow and peak-period traffic growth stopped. Because transit services in the Golden Gate Bridge corridor are commuter operations, their effect on peak-period traffic would be greater than on other traffic. Whether the parking tax exerted an equally strong influence on peak-hour travel remains unanswered.

Figure 1. Trend in Golden Gate Bridge traffic, 1958 to 1972.



The impression that the tax had no noticeable effect on traffic volumes appears to be accurate. Overall daily vehicular traffic on the Golden Gate Bridge continued to grow, bringing with it increases in fuel consumption and pollution. Peak-period congestion held constant, but mostly because new transit services absorbed the growth in peak-hour automobile use. The 25 percent parking tax appears to have slowed, but not reversed, the growth trend in automobile use in San Francisco.

EFFECT ON DOWNTOWN BUSINESS

A number of downtown retail establishments and professional offices in San Francisco complained that the parking tax was harmful to business (8). However, in letters to the Board of Supervisors asking that the tax be reduced, officers of downtown stores argued their point indirectly by referring to lower patronage in neighboring garages, by pointing to differences in suburban versus city sales statistics, and by simply claiming that the tax was harmful. Store managers were reluctant to quote actual dollar sales volumes before and after the tax. In some cases they admitted that these had increased.

Because of inflation, the number of sales transactions may be a better indicator of retail activity than dollar volume. Only 1 store reported statistics on the number of transactions and the average amount of each sale. That store experienced a 9.5 percent drop in transactions and an 11.6 percent increase in the average sale following the imposition of the tax (between January 1 to October 30, 1970 and January 1 to October 30, 1971). The net growth of about 2 percent that it experienced is probably more than offset by inflation, but it is doubtful that this experience is typical of downtown business generally.

Sales statistics show that total retail sales, excluding automotive expenditures, for only the city, declined in 1969, the year before the tax. They stabilized at the 1969 level and are at that level now. The San Francisco metropolitan area as a whole also showed a drop in retail sales in 1969, but returned to a normal growth pattern after that. City retail sales showed no improvement in 1972 even though the tax was reduced in June 1972.

Department store sales are a good indicator for determining whether the parking tax influenced downtown sales. Unlike food and drug stores, department stores are apt to draw customers who pay for parking. Logically, this segment of overall retail sales would be expected to be sensitive to a parking tax. Again statistics show the city and county of San Francisco had a substantial decrease in growth during the first 9 months of the tax (9), while the remainder of the metropolitan area enjoyed steady growth. By mid-1971, the downward effect seems to have been overcome, and sales were at a record high in the city during the Christmas season. Paradoxically, department store sales fell from their usual pattern when the tax was lowered to 10 percent in July 1972. This pattern suggests that downtown San Francisco has indeed been having trouble keeping pace with department store sales growth in the suburbs, but the timing of the sales declines does not indicate that the parking tax is a major cause for the lack of downtown success.

SUMMARY AND CONCLUSIONS

For almost 2 years beginning in October 1970, the city and county of San Francisco imposed a 25 percent tax on parking within its jurisdiction. This step was taken primarily to raise revenue for San Francisco. This tax was the most stringent, areawide economic control ever placed on automobile usage, and the experience gained may contain lessons for other areas that are considering similar policies to conserve fuel, reduce congestion, or improve air quality.

The San Francisco experience highlights 2 themes that are central to contemporary transportation problems. One is the extreme popularity of automobile transportation—the love affair between the American and the automobile. The other is the growing disillusionment with the side effects of the highway explosion—concern about air pollution, energy conservation, land use, congestion, and urban aesthetics. The 2 themes are partly in conflict because controlling the side effects of automobile use implies controlling the use itself.

If public attachment to the automobile is strong, then it is unlikely that transportation controls such as parking taxes would diminish undesirable side effects, but they would generate substantial revenues. On the other hand, if the attachment to the auto is weak, imposing a parking tax would discourage traffic and reduce the unwanted effects of automobile use. At first glance, then, a parking tax would appear to yield either tax revenues or desirable relief from the unpleasant automobile side effects, and possibly both. The surprising moral of the San Francisco experience is that a narrowly conceived parking tax will do neither. Overall, San Francisco's 25 percent parking tax served to reduce traffic levels by the equivalent of about 3 months of normal growth, and the revenues paid to the government were more than offset by parking operator losses.

Most available information on areawide parking price changes has shown that the level of demand for parking is inelastic—a large price change results in a small reduction in the number of vehicles parked. Examination of vehicle parking counts in San Francisco supports this conclusion. An overall price elasticity of about -0.3 was found to be consistent with observed behavior.

On the other hand, estimating parking price elasticity on the basis of the change in gross revenues suggested that the market was more elastic, where an increase in price was offset by a drop in dollar sales volume. A revenue elasticity of about -1.6 was estimated on the basis of the revenue change.

The incompatibility between these 2 sets of estimates has been explained by a shift in the mix of parking before and after the tax. Statistics on net parking fees and a comparison of garages catering predominantly to shoppers and commuters indicate that after the tax there was a sizable decline in long-term parking relative to short-term parking. Commuters, more than shoppers, shifted to new travel patterns to avoid the increased parking fees. This pattern, together with the fact that parking operations are concentrated near the CBD, suggests that traffic conditions at the most congested times and places may have benefited the most from the imposition of the tax, but there are no traffic data available to support or rebut this.

The tax had little effect on traffic in the city as a whole. At most, the reduction of vehicles in San Francisco was 2 percent. Because the annual growth in urban automobile usage has been nearly 8 percent over the last decade, the contribution of the tax toward solving congestion, air pollution, and fuel conservation problems would be swallowed up by 3 months of normal growth.

If the behavior observed in response to a 25 percent tax can be taken as an indication of what would happen if a 100 percent tax were imposed, then such policies are not effective instruments for alleviating pollution and energy problems. Parking charges would have to be doubled each year just to preserve the status quo.

The effect of the parking tax on the level of downtown retail activity also was minimal. Other than the parking industry, downtown business continued with no noticeable disturbance.

The only sizable effect of the tax was on the parking industry itself, where it dealt a major blow to profits. Gross revenues were estimated to be 36 percent below the level projected under normal growth, and 31 percent under those observed the year before the tax. These losses exceeded the revenues that the city and county governments collected from the tax. Had parking operators in San Francisco been fully compensated from tax receipts for the financial damage due to the tax, the tax would have caused a net loss of revenues for the city and county. This poses a serious question about the fairness of using a parking tax to control unpleasant effects of private automobile use, especially when taxes and surcharges larger than the San Francisco tax are contemplated.

That traffic did not respond to the San Francisco parking tax should not be surprising because each paid off-street parking space in the city is used by about 2 cars a day. The entire commercial parking industry, comprising 50,000 spaces or 100,000 daily occupancies, accounts for 200,000 one-way trips per day. Roughly 1 million vehicle-trips per day are made within San Francisco, so only 1 trip in 5 uses paid off-street parking.

The off-street parking industry is predominantly located within the downtown area. In a metropolitan area the size of San Francisco, less than 5 percent of all auto trips are made to or from the CBD (10, p. 97). Any traffic control directed at the center alone will have only a small effect on areawide traffic, air pollution, and energy use.

If parking controls are to be used to combat problems of traffic congestion, air pollution, and fuel consumption, they need to be applied to a broader base than current paid parking operations. Controls on other forms of parking, notably on-street parking, could help to compensate off-street parking operators by maintaining the existing garage patronage levels while reducing overall automobile usage. However, controls on the high turnover on-street segment of the parking market might lead to a slowdown in downtown business activity.

Perhaps a more promising avenue for reducing automobile-related problems lies in controlling employee parking. In the United States, an average of only 7.3 percent of persons driving to work pay for parking. Seventy-five percent have parking provided by employers and 12 percent park on the street (11, p. 90). Pricing or restricting employee parking could contribute to reducing the undesirable side effects of automobile use, because most work travel occurs when congestion is at its worst and when transit service is frequent and widespread.

Parking controls, to be effective, need to be more broadly based than those in San Francisco. If parking prices are to be effective in altering travel behavior on a large scale, dramatic changes will be necessary in the supply of free parking and in the setting of prices.

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