policies by using a MIS strategy, e.g., micro, mini, and main-frame computers and alternative programming languages;

4. Evaluation of the suitability of implementation strategies for alternative fare policies under various constraints, e.g., fleet size, labor rates, and decentralized or centralized dispatching;
5. Evaluation of the effects of alternative fare policies on consumer behavior, e.g., ridership, trip lengths, and travel patterns; and
6. Evaluation of the feasibility of alternative fare policies from a public policy standpoint, e.g., rider acceptability, acceptability to policymakers, acceptability to funding agencies, overall effect on subsidy requirements, and efficient use of available subsidy funds.

The research of such topics could be extended through consideration of such concepts as demand elasticity, utility maximization, social benefit, market segmentation, service coordination, and funding coordination.

It should be noted that the existence of the computer-based MIS now serving CCRTA's b-bus program presents a tremendous opportunity for the research efforts recommended above. Grant funds would not be required for purchase of hardware and could be spent entirely on the research recommended.

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REFERENCES

1. R.P. Warren and J. Collura. Data Recording and Evaluation: The Barnstable County Experience. TRB, Transportation Research Record 696, 1978, pp. 58-65.
2. R.P. Warren, A.D. Rogers, and J. Collura. Coordination Through Consolidation: The Barnstable County Experience. Proc., 21st Annual Meeting of Transportation Research Forum (Philadelphia), Richard B. Cross Co., Oxford, IN, 1980, Vol. 21, No. 1, pp. 21-29.
3. J. Collura and D.F. Cope. Applications of the Concept of Equity to Cost Allocation. Civil Engineering Department, Univ. of Massachusetts, Amherst, 1979.
4. Cape Cod Regional Transit Authority: Accounts Receivable System Feasibility Study. Crosbro, Inc., Brockton, MA, Aug. 1980.

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Income Equity of Two Transit Funding Sources

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Currently, a number of funding sources are used to subsidize public transit. These originate at all levels of government, and their mix differs greatly among regions. Each source or combination has implications for equity that are often overlooked since each has a unique incidence, i.e., pattern of who pays by income group. The purpose of this paper is to examine the incidence of two commonly used sources: a sales tax and a motor fuel tax. Previous studies of the incidence of these taxes are not comparable; what is necessary is a single source of data on which to examine them. Suitable data to calculate incidence are available from the 1972-1973 Consumer Expenditure Survey of the Bureau of Labor Statistics, a comprehensive source of information on consumption expenditures by detailed items and income for 40 000 U.S. families. These data allow the relative percentage of income paid as sales or motor fuel tax to be calculated. The results indicate that both sources are regressive. Use of the S-index of progressivity for comparison suggests little short-run difference in income equity between the two (although exactly what items are subject to the sales tax can affect the results). The study points out that the equity impact of potential funding sources should be understood, available, and part of the decision-making process.

Transit systems throughout the United States have become increasingly dependent on subsidies from various levels of government. Each system tends to have a unique set of funding sources that is usually determined by law and politics in a particular geographic area. As new and expanded sources of transit funding are sought, the equity issue of who is paying from each source (the incidence) is often overlooked.

In addition, great concern is placed by federal agencies to ensure that their funded activities comply with Title VI of the Civil Rights Act of 1964. As an example of this concern, the Urban Mass Transportation Administration (UMTA) issued Circular 1160.1 (December 1977). A number of the objectives of this circular relate to this issue of equity of federally funded activities. Although most of the emphasis of Title VI has been on the distribution of benefits, a less obvious but related potential inequity involves the distribution of burdens. That is, Who pays for transit and what are the equity implications of different funding sources? A complete examination of equity would thus involve analysis of both who pays and who benefits. This paper attempts to shed light on a portion of the former aspect of this issue, recognizing that it is only a piece of the total equity problem.

Recent legislastion has changed the funding mechanism used to provide subsidies for public transit in the Chicago area. The essence of the change was that a 5 percent tax on motor fuel was eliminated; a general sales tax increase was substituted (1 percent in Cook County, 0.25 percent in the adjacent five counties). The main purpose of this change was apparently to generate more funds. In addition, an issue of geographic equity (the relationship between the funds raised and the funds expended in an area) was addressed. However, very little analysis has been undertaken to determine the income equity (who pays versus who benefits by income groups) of the funding switch.

The purpose of this paper is to explore the equity of two common sources of transit subsidies suggested by the Chicago Area Regional Transit Authority's funding switch from a sales tax to a motor fuel tax. A recent survey by the American Public Transit Association (APTA) (1) listed 24 regions that use a sales tax and 5 areas that obtain transit funds through a gasoline tax. It will be assumed that the revenue raised under each source would be structured to be similar. Since the basic groups that benefit from the subsidy funds remain the same, only the groups that pay for the subsidies will be examined. In economic terms, one wishes to compare the differential tax incidence of one source (e.g., motor fuel tax) with the incidence of the other source (general sales tax). Incidence refers to who (ultimately) bears the burden of the taxes, i.e., who pays.

Obviously, different sources will have different incidence. The initial distribution of liabilities (statutory incidence) can differ significantly from the final distribution (economic incidence). This will be true to the extent that a chain of adjustments by consumers or firms ensues. For simplicity as well as data limitations, it will be assumed that the sales and motor fuel taxes fall totally on the consumer. In fact, consumers may make some adjustments, such as the amount or location of gasoline or taxable goods purchased. However, previous studies of incidence have allocated sales and excise taxes to those who purchase the taxable products. Since these taxes are assumed to fall completely on consumers, incidence can be determined by noting the amount of each tax paid by consumers in each income level. It is noted that the incidence of multiple funding sources can be determined by combining and weighting the data from the individual sources used. Detailed discussion of theoretical issues in tax incidence can be found in most texts on public finance, e.g., Musgrave and Musgrave (2).

PREVIOUS STUDIES OF SALES AND FUEL TAX INCIDENCE

A number of previous studies have examined the incidence of the sales tax under different bases (i.e., items that are subject to tax). Although most of the studies took place in the 1960s, their conclusions were similar: The sales tax is regressive; that is, the tax paid by a lower-income family represents a larger percentage of income than that paid by a higher-income family. For example, Musgrave and Musgrave (2) used 1968 data to estimate that families in the lowest annual income bracket (under $4000) paid 3.4 percent of their income for general sales taxes; as incomes rose, this percentge fell continuously (to 0.3 percent in the $92 000 and over bracket). A second study by Pechman and Okner (3) reached the same conclusion. By using 1966 data, they found that families in the lowest annual income bracket (under $3000) paid 9.4 percent of their income for general and specific sales and excise taxes. Families in the highest income bracket ($1 000 000 and over) paid 1.0 percent for these taxes. Similarly, a study by the Advisory Commission on Intergovernmental Relations (4) used allowances by the Internal Revenue Service for sales tax deductions to obtain like results.

A handful of studies have looked at the incidence of a motor fuel tax. Most lump this tax together with other goods that are selectively taxed, such as cigarettes, alcohol, and public utilities [e.g., Musgrave and Musgrave (2)], or combine all sales and excise taxes together [e.g., Pechman and Okner (3)]. Probably the most comprehensive analysis of gasoline tax incidence was reported by Freeman (5). Freeman used 1972 household data provided by the Brookings Institution and an assumed tax of $0.20/gal (although the results would be representative of any tax that would be proportional to usage) and obtained a pattern that is slightly progressive except at either end of the income distribution [(5, p. 189); relative incidence compares the implicit tax rate of all income brackets with that of the highest income bracket]:

1972 Income ($000)	Relative Incidence	1972 Income ($000)	Relative Incidence
<2	4.16	10-15	3.45
2-4	2.71	15-20	3.52
4-6	2.68	20-26	3.42
6-8	3.00	26-50	2.94
8-10	3.23	<50	1.00

Zupnick (6) used a four-step process to examine the 1971 incidence of a tax-induced $0.10/gal price rise. Starting with average fuel use by automobile model year, he combined data on average miles driven by income group with ownership of each automobile model year by income class. The results indicate progression in the lower-middle brackets but regression in the income brackets above this (6, p. 412):

1971 Income ($000)	Relative Incidence	1971 Income ($000)	Relative Incidence
<3	1.53	6-7.5	1.85
3-4	1.33	7.5-10	1.54
4-5	1.56	10-15	1.26
5-6	1.76	>15	1.00

Finally, the Institute of Public Administration (7) examined incidence in a much less detailed manner by using data from the Motor Vehicle Manufacturers Association. For five income-bracket quintiles, the incidence of gasoline expenditures (and therefore taxes that would be proportional to expenditures) was found to be extremely regressive.

Other potential sources of data on gasoline expenditures are deficient or duplicative in some manner. For example, the U.S. Department of Energy (8,9) offers data on the distribution of gasoline consumption for households that own vehicles or that use gasoline (but not for all households). Their model employs a synthetic data base; the distribution of gasoline expenditures implied is quite similar to that reported in the Consumer Expenditure Survey used below. The old Federal Energy Administration had a Household Energy Expenditure Model; however, the basic data input source was the 1970 census, and mean income in each income bracket was not reported (10). The Survey Research Center of the University of Michigan has also analyzed household behavior for a number of years. However, incidence of gasoline expenditures was calculated by assuming the same miles per gallon for all vehicles, which clearly would bias the results (11).

The problem with previous studies is that it is very difficult to compare the incidence results of one tax source with the results of any other source. Each study used a different set of data, different time periods, different definitions of income, etc. In order to effectively compare the incidence of two or more taxes, a single set of data is necessary.

INCIDENCE OF SALES VERSUS MOTOR FUEL TAX

In order to draw an income profile of who pays the motor fuel tax and compare it with the impact of a sales tax, a suitable single source of data must be obtained. One source that will allow this to be undertaken is the 1972-1973 Consumer Expenditure Survey of the Bureau of Labor Statistics (BLS). This survey describes itself as the only comprehensive source of detailed information on expenditures and income related to socioeconomic and demographic characteristics of U.S. families. For a sample of 40 000 families, consumption expenditures by detailed items (i.e., the average dollar amount spent by a family on good or service X) were compiled and classified by income bracket. The BLS data sources are the interview survey (20 000 families) (12) and the diary survey (20 000 families (13). The former provided the primary data for this study; the latter supplemented and expanded the available categorization. Although the BLS data and the empirical analysis below used a national focus, it would be straightforward to adapt the technique to a study of incidence in a particular region. The BLS has recently released data that are drawn from and reported by particular standard metropolitan statistical areas (SMSAs).

To determine incidence of the sales tax, it would be necessary to total the consumption expenditures on items that are subject to a general sales tax (by income group). For the motor fuel tax, the amount spent on motor fuel needs to be noted. Since different regions subject different items to a sales tax, two cases were tested. In variant 1, each consumer expenditure item was considered as to whether it was subject to the Illinois Retailers' Occuption Tax (general sales tax). Illinois (and 7 other states) tax both food purchased for home consumption and prescription drugs. A second variant was compiled for an area where food consumed at home and medicine and drugs were not subject to a sales tax, as is the case in 23 states.

The sample population was ranked by income deciles, from the families with the lowest 10 percent of income (decile 1) to those with the highest 10 percent (decile 10). The total dollar amount of spending on taxable items was estimated for each decile. Since the sales tax is included in this spending and represents a flat percentage of the total, it was not necessary to separate the tax out. That is, it is sufficient to look at spending on taxable items as a percentage of income by deciles to determine the incidence of the sales tax. This information is displayed in Table 1. The average consumption expense (expenditures) by income deciles is broken into consumption exempt from sales tax and spending subject to (and including) sales tax. The relative incidence compares taxable expenditures as a percentage of income for each decile with that of the highest decile. Since the sales tax would be a flat percentage included in taxable expenditures, the relative incidence for both total taxable expenditures and sales tax payments as percentages of income will be the same. The results confirm the conclusion that the general sales tax is regressive. That is, those in the lowest income decile pay 2.5-3 times as much of their income in sales tax as do those in the highest income decile.

To derive the incidence of the motor fuel tax is a somewhat simpler task. The BLS data report on dollar expenditures for gasoline (including tax) by income group. Since this tax would be proportional to use, it also does not have to be separated out in order to examine incidence. Table 2 displays this information: average consumer expenditures on gasoline and fuels for vehicle operations by income decile, this expenditure as a percentage of income, and the relative incidence. It reveals a regressive tax; consumers in the lowest income decile pay 3.5 times as much of their income in gasoline tax as those in the highest decile do.

There appears to be some discrepancy between the previous studies of motor fuel tax incidence (text tables above) and the results presented in Table 2. This may be due in part to the choice of income brackets used in the previous studies, which do not match closely either the income of the population deciles of Table 2 or the definition of income. In addition, some of the previous studies' assumptions (e.g., fuel economy being the same for a model year for all cars) could lead to biased results.

A number of caveats exist in the empirical analysis above. First, since each regional sales tax includes or excludes a unique set of goods and services, sales tax incidence can differ somewhat between regions. Next, it is not possible to be completely accurate in excluding those expenditures that are not subject to a general sales tax (or in including those that are) since some expenditure categories listed by the BLS include both taxable items (e.g., parts) and nontaxable items (e.g., labor). However, these ambiguous categories are relatively small compared with those that are unambiguous (e.g., housing expenses), and the bias is apt to be minimal. Third, the data were collected in 1972-1973. To the extent that consumer expenditure patterns have changed, the incidence could change, e.g., How have different income groups responded to the large price increase in gasoline? The use of a single year's income can be criticized as unrepresentative of a longer-run view of income. Unfortunately, no data are readily available to correct this. Finally, it is assumed that all gasoline purchases are made by households or, alternatively, that the tax is levied only on consumer purchases of gasoline. In fact, approximately 68 percent of motor fuel was consumed by automobiles in 1976; most of the remainder was used by trucks.

It is also assumed that, in response to any change in tax levels, households continue to buy gasoline and consumption goods subject to the sales tax in the same proportion and geographic area that they did before. Any other assumptions would vastly complicate empirical calculations. In effect, these assumptions look at short-run incidence, assuming that the price elasticity of demand (sensitivity of quantity demand to price changes) is zero. The price elasticity of gasoline is fairly low (-0.2 to -0.4). A couple of tax studies have attempted to ascertain the impact of competition from firms in areas not subject to a particular tax in proximity to firms in areas that are subject to a tax. This could alter the burden of the tax by affecting how much of the tax gets shifted to the consumer. Unfortunately, these studies did not attempt to determine who bears the unshifted portion of the burden. They did suggest that proximity to a political border where no (additional) tax is levied does reduce the ability to shift the burden to the consumer.

DISCUSSION OF RESULTS

When the relative incidences of both taxes are compared, the following conclusions become apparent. First, both sources are regressive. The motor fuel tax is roughly as regressive as variant 1 of the sales tax; variant 2 is somewhat less regressive. A glance at the lower-middle income deciles of variant 1 and the fuel tax (second through fifth decile) shows that the relative incidence of the latter is close to proportional; the former is more regressive in this range.

A second way of comparing the incidence of different funding sources is to use the S-index developed by Suits (14). The S-index is a quick, convenient, one-number way of comparing incidence. There is no other generally accepted index of progressivity. This index, similar to the Gini ratio of income distribution equality/inequality [cited in Mendershausen (15)], ranges from +1 (extreme progressivity) to -1 (extreme regressivity). A proportional source would have an S-index of zero. Use of this index requires that families be ranked by income percentiles, from lowest to highest, and have their contribution to each source

Table 1. Expenditures and sales tax incidence.

Item	Income Decile 1	2	3	4	5	6	7	8	9	10
Variant 1										
Expenditures ($)	3037	4026	5161	6299	7417	8348	9472	10 578	12 168	16 015
Tax exempt	1630	2054	2560	3037	3491	3846	4333	4704	5503	7339
Taxable	1407	1972	2601	3262	3926	4502	5139	5874	6665	8676
Average income ($)	1559	3268	5081	7063	9112	11 244	13 466	16 116	19 747	31 974
Taxable expenditures divided by income (%)	90.3	60.3	51.2	46.2	43.1	40.0	38.2	36.4	33.8	27.1
Relative incidence	3.33	2.23	1.89	1.70	1.59	1.48	1.41	1.34	1.25	1.00
Variant 2										
Expenditures ($)	3037	4026	5161	6299	7417	8348	9472	10 578	12 168	16 015
Tax exempt	2214	2871	3537	4098	4680	5131	5749	6221	7139	9168
Taxable	823	1155	1624	2201	2737	3217	3723	4357	5029	6847
Average income ($)	1559	3268	5081	7063	9112	11 244	13 466	16 116	19 747	31 974
Taxable expenditures divided by income (%)	52.8	35.3	32.0	31.2	30.0	28.6	27.6	27.0	25.5	21.4
Relative incidence	2.47	1.65	1.50	1.46	1.40	1.34	1.29	1.26	1.19	1.00

Note: Consumption and income figures are from the 1972-1973 Consumer Expenditure Survey (11, 12).

Table 2. Motor fuel expenditures and income.

Item	Income Decile 1	2	3	4	5	6	7	8	9	10
Expenditures for gasoline ($)	98	132	208	270	336	394	449	480	525	561
Gasoline expenditure divided by income (%)	6.3	4.0	4.1	3.8	3.7	3.5	3.5	3.0	2.7	1.8
Relative incidence	3.50	2.22	2.28	2.11	2.05	1.94	1.83	1.67	1.50	1.00

Note: Source of gasoline expenditure figures is the 1972-1973 Consumer Expenditure Survey (11, 12).

noted. The S-index for any tax can be estimated (for 10 income deciles) as

$$S \approx 1 - (1/5000)\left\{\sum_{i=1}^{10} (1/2)\,[T_x(Y_i) + T_x(Y_{i-1})]\,(Y_i - Y_{i-1})\right\} \tag{1}$$

where

x = given funding source x,
Y_i = income decile i, and
T = cumulative percentage of funding source paid by cumulative percentage of total income represented by income decile i.

Computation of the S-index for the two variants of the sales tax and the motor fuel tax reveals that all three are regressive. Surprisingly, the motor vehicle tax registers slightly greater regressivity (S = -0.16) than either variant 1 (S = -0.13) or variant 2 (S = -0.09) of the sales tax. However, due to the caveats mentioned above, the differences among S-indices are probably not significant. Previous studies that used 1966 and 1970 data have computed S-indices for sales taxes of -0.15 to -0.16. To give an idea of the S-index range for typical taxes, the variation is from about -0.40 to +0.40.

CONCLUSIONS

The results suggest little short-run impact on the distribution of income from changing funding sources between sales and motor fuel taxes. In addition, the magnitude of these taxes collected from transit is not particularly large. For example, a 1 percent sales tax would cost a first-decile family around $9-15/year or a tenth-decile family $74-93/year (Table 1). A levy of 5 percent on motor fuel usage would cost a family $5-28 in tax. In addition, the data suggest that to exempt food purchased for home consumption and drugs and medicine (variant 2) would be less regressive than one that taxes these items.

A change from a sales to fuel tax (or vice versa) affects not only income groups but also the sectors of society that pay the subsidy. If a motor fuel tax is imposed, redistribution stays within the transportation sector; automobile users pay and transit users receive primary benefits (others may benefit as well). If a general sales tax is used, however, the redistribution involves other sectors: from all consumers to transit users.

Governments have a wide menu of sources available to obtain funds. Although issues such as the revenue-raising potential of each source or how much would be raised in each geographical area by source are important, the income incidence of different taxes should not be overlooked.

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REFERENCES

1. A Survey of Local Mechanisms for Financing Transit Operating Costs. American Public Transit Association, Wasington, DC, 1979.
2. R.A. Musgrave and P.B. Musgrave. Public Finance in Theory and Practice, 3rd ed. McGraw-Hill, New York, 1980.

3. J.A. Pechman and B.A. Okner. Who Bears the Tax Burden? Brookings Institution, Washington, DC, 1974.
4. Significant Features of Fiscal Federalism. Advisory Commission on Intergovernmental Relations, Washington, DC, 1974.
5. A.M. Freeman III. The Incidence of the Costs of Controlling Automotive Air Pollution. In The Distribution of Economic Well-Being (F.T. Juster, ed.), National Bureau of Economic Research, Ballinger Publishing Co., Cambridge, MA, 1977.
6. J.W. Zupnick. The Short-Run Incidence of a Tax-Induced Rise in the Price of Gasoline. Journal of Economic Issues, Vol. 9, No. 2, June 1975, pp. 409-414.
7. Institute of Public Administration. Financing Transit: Alternatives for Local Government. U.S. Department of Transportation, DOT-I-7916, July 1979.
8. Distributional Aspects of Alternative Energy Price Scenarios. Energy Information Administration, U.S. Department of Energy, Service Rept. DOE/EIA-0182/3, April 1979.
9. Distributional Aspects of Standby Gasoline Rationing Plan. Energy Information Administration, U.S. Deprtment of Energy, Service Rept. DOE/EIA-0176/1, April 1979.
10. Task Force on Distributive Impact of Budget and Economic Policies. Distributive Impacts of Proposed Changes in National Energy Policies. Committee of the Budget, U.S. House of Representatives, 1977.
11. Survey Research Center. Five Thousand American Families: Patterns of Economic Progress. Institute for Social Research, Univ. of Michigan, Ann Arbor, Vol. 3, 1975; Vol. 4, 1976; Vol. 6, 1978; Vol. 8, 1980.
12. Bureau of Labor Statistics. Consumer Expenditure Survey: Interview Survey, 1972-1973. U.S. Department of Labor, Bull. 1997, 1978.
13. Bureau of Labor Statistics. Consumer Expenditure Survey: Integrated Diary and Interview Survey Data, 1972-1973. U.S. Department of Labor, Bull. 1992, 1978.
14. D.B. Suits. Measurement of Tax Progressivity. American Economic Review, Vol. 67, No. 4, Sept. 1977, pp. 747-752; Vol. 70, No. 1, March 1980, p. 211.
15. H. Mendershausen. Changes in Income Distribution During the Great Depression. National Bureau of Economic Research, New York, 1946.

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Economic Analysis of Transportation Pricing, Tax and Investment Policies

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In response to the ad hoc nature of current transportation user charges and cost allocations, a rigorous analytical framework is presented based on economic welfare theory. A multimodal transportation system model that has explicit price and tax, investment maintenance, service quality, and externality variables is formulated; the optimal decision rules of equating marginal social benefits and marginal social costs are derived and given operational interpretations. Optimal and administratively feasible aggregate prices by user class and mode are derived in terms of aggregate marginal social costs that are not impractical to estimate. An optimal cost allocation is defined as marginal social-cost pricing followed by general taxation of consumer goods (excluding transportation) to cover any deficit.

Considerable confusion exists about economic principles as they are applied to transportation policy analysis. Although a correct operational definition of marginal cost is hard to find in the literature, it is widely assumed that the marginal-cost pricing principle is not relevant to transportation facilities for a number of alleged reasons, e.g., there is no feasible way to (a) cover full costs or (b) implement ideal marginal cost pricing. The principles that find their way to practitioners suggest ad hoc rules of thumb rather than deduced results from a unified theory.

The purpose of this paper is to present an integrated economic transportation model that will clear up some of the confusion and serve as a basis for policy analysis. The model is set in the framework of welfare economics, and the results can be interpreted as the well-known principle of equating marginal social benefits with marginal social costs. Moreover, these concepts and principles are brought in touch with reality by the detailed structure of the model. All relevant investment and maintenance variables of a multimodal transportation system are incorporated in the model; service quality attributes and externalities are made explicit.

The results reported here are a summary of several aspects of an extensive working paper (1). Optimal decision rules for investments, maintenance programs, and prices are derived and interpreted. "Second-best" issues are discussed. An original contribution is the derivation of optimal and administratively feasible aggregate prices by user class and mode. Finally, an optimal cost allocation is defined as marginal-social-cost pricing followed by optimal taxation of consumer goods (which excludes transportation) to cover any deficit.

INTEGRATED MODEL

The task of this section is to model the transportation system and its effects in a manner that facilitates the application of economic welfare theory to transportation policy issues. The level of detail is sufficient for addressing the issues of investment and maintenance policy, service quality and externalities, pricing and cost allocation, and intermodal effects.

The welfare optimization problem can be stated in operations research terms as maximizing a social