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Benefit-Cost Analysis of a Proposed Rail Line Relocation: A Case Study

RICHARD S. TAYLOR and RALPH D. SANDLER

ABSTRACT

Although the economic principles associated with conducting a benefit-cost analysis of a proposed rail project have been discussed in the literature, there are few articles that demonstrate these techniques within the context of a practical case study. An attempt is made herein to demonstrate one particular approach that was taken to evaluate the economic feasibility of a proposed rail line relocation. In 1984 the Florida Department of Transportation completed a study of the feasibility of constructing a railroad bypass of the Pensacola-Milton, Florida, urbanized area. This paper is a report on that portion of the study concerned with the benefit-cost analysis. The results of the benefit-cost analysis indicate that, from the standpoint of pure economic efficiency, the project is not desirable. The benefit-cost analysis reveals that only between 69 and 83 percent of project costs are offset by quantified benefits. In addition, an evaluation of the distribution of present value benefits demonstrated that the Seaboard System Railroad would be the prime beneficiary of the project.

Section 5 of the Department of Transportation Act of 1966, as amended by the Local Rail Service Assistance Act of 1978, requires states to include a benefit-cost methodology, to be used in evaluating rail projects, in their State Rail Plans. Benefit-cost guidelines, which were intended to suggest how a state might conduct such an economic analysis, were produced by the Federal Railroad Administration (FRA) (1). A subsequent article (2) was written to further aid the analyst in estimating the true economic benefits and costs of proposed state rail projects. Although both of these publications focus on the difficult theoretical issues associated with conducting a benefit-cost analysis, there are few articles that demonstrate these techniques within the context of a practical case study. Aside from the theoretical complexities of such an analysis, there are also difficult measurement problems that must be overcome. According to the FRA (2), branch-line benefit-cost studies submitted to its Office of State Assistance by state transportation agencies have been filled with analytical flaws that have produced misleading results. This paper is an attempt to illustrate, through a case study, one particular approach that was taken to evaluating the economic feasibility of a proposed rail line relocation. In addition, the application of benefit-cost analysis under realistic (and less than ideal) conditions of incomplete information is demonstrated. Time and budgeting constraints did not allow the environmental effects of the project to be addressed. Nevertheless, every reasonable effort was made, including the use of a special train performance calculator and a grade crossing delay computer program, to consider all significant effects of the project.

BACKGROUND

In 1979 the Florida Department of Transportation (FDOT) completed a study (3) to evaluate the possibility of establishing a main-track bypass of the urbanized areas of Escambia and Santa Rosa Counties in Florida. The document contained several alternative alignments for a main-track bypass of the urban area and a recommendation that one alignment be implemented. This alignment, however, was not well received by the public and implementation was not pursued.

In early 1983 the Seaboard System Railroad (SBD) notified the FDOT that it was initiating steps to replace its Escambia Bay trestle and inquired about the status of the bypass. Implementation of the bypass would eliminate the need for the trestle and the SBD would avoid the expense of a replacement structure estimated to cost $23 million.

Subsequently, the Pensacola Urbanized Area Metropolitan Planning Organization requested the FDOT to reexamine the feasibility of a railroad bypass of the Pensacola-Milton, Florida, urbanized area. Although there are a number of problems or issues presented by the location of the existing SBD main track in the urbanized area, these issues principally relate to the dense population along the route and associated vehicular delay and safety considerations at local rail-roadway grade crossings and the transportation of hazardous material.

Preliminary investigations were made to determine if the potential existed for a corridor that had not previously been examined and that would permit the location of a main-line railroad operation with minimum interference with existing and planned development in the two-county area. The 1979 effort failed in large part because of citizen concern over the recommended location, which was close to existing and potential population centers. A new corridor was identified (Figure 1), which offered the best possibility of meeting the criteria necessary for community acceptance and was adopted for this evaluation. In 1984 FDOT completed a study (4) on the economic feasibility of the proposed project. This paper is a report on that portion of the study concerned with the benefit-cost analysis.

Included in this paper is a description of the economic principles considered, analytical techniques used, and primary conclusions reached in evaluating

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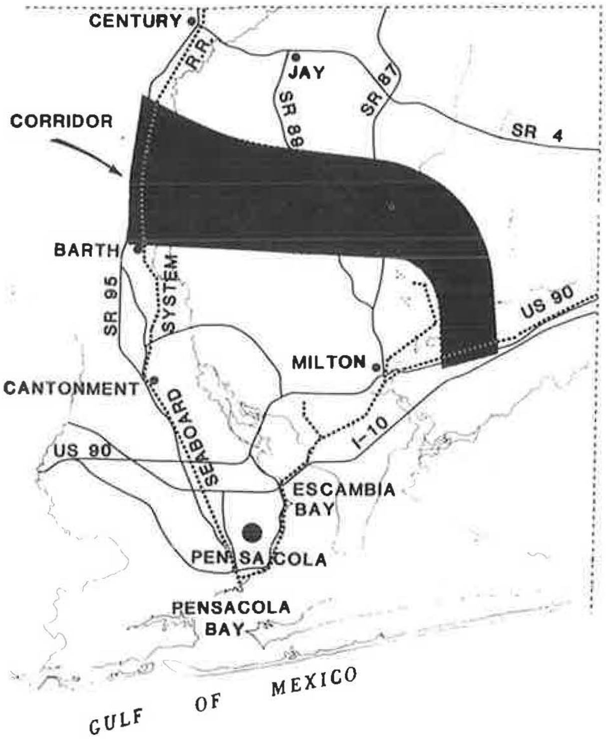

FIGURE 1 Study corridor.

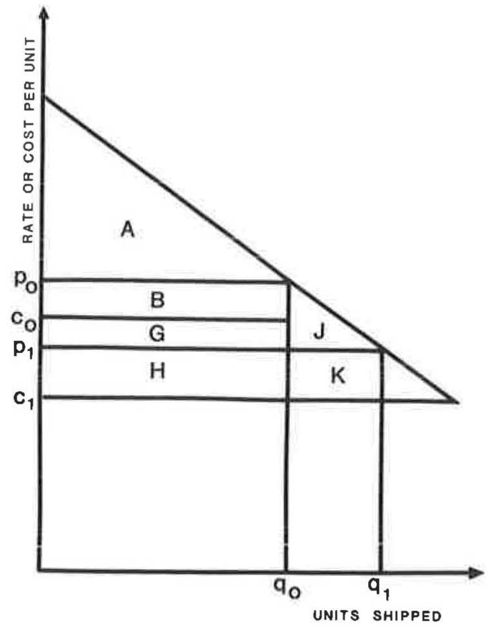

FIGURE 2 Demand curve for freight transportation (from U.S. Department of Transportation).

the project. Even though other factors may also be important, maximizing economic efficiency was the primary decision criterion used in the analysis. The analytical framework proposed by the FRA (1) was used as a point of departure in the study. Although these FRA guidelines were primarily produced to aid in the evaluation of railroad branch-line projects, most of the economic principles and techniques are equally relevant to this proposed main-line relocation. The benefits derived from changes in transport rates and cost as a result of the proposed project are best illustrated with the aid of Figure 2, a demand curve for freight transportation, and the following formula:

$$(B_1 - B_0)_t = Q_0(C_0 - C_1) + 1/2(P_0 - P_1)(q_1 - q_0) + (P_1 - C_1)(q_1 - q_0) \quad (1)$$

where

P = unit rate,
C = unit cost,
q = quantity shipped,
$(B_1 - B_0)_t$ = gain in economic benefits associated with implementation of the proposed project (Alternative 1) over the null alternative of no action (Alternative 0),
$q_0(C_0 - C_1)$ = cost reduction on existing traffic (Areas G + H),
$1/2(P_0 - P_1)(q_1 - q_0)$ = consumer surplus on new traffic (Area J), and
$(P_1 - C_1)(q_1 - q_0)$ = producer surplus on new traffic (Area K).

Consumer surplus, in the illustration, is the difference between what a consumer is willing to pay for some quantity of a product, as defined by his demand curve, and what he has to pay as defined by the price he pays for that amount. Producer surplus is the excess of total revenue over total avoidable cost that accrues to a seller as economic profit. Areas A and B in Figure 2 represent consumer and producer surpluses for the null alternative of no action.

Areas G, H, J, and K show the increase in producer and consumer surpluses that result from implementation of the project. According to the FRA analytical framework, the benefits of a project can be divided into three subcategories: first, actual resources saved or costs avoided on existing traffic (Areas G and H); second, consumer surplus on new traffic (Area J); and, finally, producer surplus (economic profit) on new traffic (Area K).

PRESENT VALUE ANALYSIS

Benefits and costs will occur at different times during the life of the project; consequently, a discount rate was used to convert all benefits and costs to a present value. The authors believe that the appropriate discount rate is the average rate of return that is expected on private investment before taxes and after inflation. Those funds expended for a government project are not funds that would otherwise stand idle. They are obtained by the government from the private sector, either by taxation or by borrowing, or from the government itself by diverting funds from other purposes. If left in the private sector, the funds would be put to use there and would earn a return that measures the value society places on the use of the funds. If the funds are diverted to government use, the true cost of the diversion is the return that would otherwise have been earned. This cost is the opportunity cost of capital and is the correct discount rate to use in benefit-cost analysis.

In recognition that discount rates may reflect both the effects of inflation and the true opportunity cost of money, all costs and benefits were expressed in constant 1983 dollars and the real discount rate reflecting only opportunity costs was used in the analysis. It is believed that the true social opportunity cost of capital, before taxes and after inflation, is approximately 7 percent and this is the correct discount rate to use in an economic analysis. Predictably, the selection of a discount rate has generated a diversity of opinion, although 4 and 10 percent real discount rates appear to represent the extreme upper and lower range of current professional opinion (5,pp.14-15; 6-9). Because the results of the benefit-cost analysis may be sensitive to the discount rate used, calculations were also performed at discount rates of 4 and 10 percent for comparative purposes.

The net present value (NPV) criterion was used to evaluate the stream of costs and benefits over time:

$$NPV_k = \sum_{t=1}^{n} (B_{kt} - C_{kt})/(1 + r)^t \qquad (2)$$

where

NPV_k = net present value of project k,
B_{kt} = benefits from project k in year t,
C_{kt} = costs of project k in year t, and
$1/(1 + r)^t$ = present value discount factor at rate of discount r for t years.

The proposed rail line relocation project would be considered desirable from an economic efficiently standpoint if the present value of all project-related benefits exceeded the present value of all project-related costs.

ANALYSIS PERIOD

The benefit-cost analysis was performed for a period of 32 years beginning in 1983 when the study commenced and ending in 2015, 25 years beyond the estimated date the bypass would be available for operations. The interim period represents the elapsed time to arrange for funding, perform detailed engineering, obtain the necessary approvals and permits, and complete construction of the bypass. The 25-year period beyond project completion was selected as a representative project life. Although many components of the project have an economic life well beyond this period of time, cross-ties used in the bypass main track will have reached the end of their useful life and will require replacement. In addition, the mathematics of discounting to arrive at present worth are such that a longer period of time should not produce any significant difference in net present value.

IMPLEMENTATION COSTS

A preliminary bypass route was located within the corridor defined in Figure 1. This route was established following the same general criteria that were used in selecting the corridor itself, minimizing population and activity conflicts, while following sound railroad engineering practices to minimize railroad operating costs.

The bypass route selected extends 29.9 mi from the vicinity of Bogia in Escambia County to the vicinity of Harold in Santa Rosa County. A description of the bypass is given and the manner in which it was selected and designed are fully discussed in the complete study (4). The implementation cost of the bypass project was estimated to be $64,098,446 in 1983 dollars and is summarized by work item for all components in Table 1.

In addition to the cost of construction, there were other costs that the railroad would have to incur because of the project. The condition of the existing Escambia Bay trestle dictates constant maintenance on the part of SBD, which is estimated by the railroad to approximate $1 million per year. These costs will continue to be incurred by the SBD as long as the structure is required for railroad operations (i.e., until the new structure is completed or the bypass implemented). The SBD plans to build a new structure, which could be completed by November 1986, in order to avoid these costs. Thus the $1 million per year must be considered as an additional cost to the SBD for any action that requires continued use and maintenance of the existing trestle beyond the estimated completion date of the new bridge (1986) and before the bypass can be implemented (1990).

TABLE 1 Summary of Estimated Project Costs by Work Item (1983 dollars)

Work Item	Cost ($)
Right-of-way	1,240,000
Grading, drainage, and erosion control	13,869,500
Bridges and grade separations	21,060,000
Track construction	17,860,756
Crossings and crossing protection	98,625
Utility adjustments	323,900
Shops, scales, office, and other yard facilities	1,285,000
Subtotal	55,737,781
Engineering and contingencies at 15 percent	8,360,665
Total estimated cost	64,098,446

DERIVATION OF BENEFITS

Implementation of the project would result in benefits accruing to both the railroad and the public. An examination of potential categories revealed that many benefits of an economic nature could be quantified following the principles related to the freight transportation demand curve shown in Figure 2. Others could not, however, given time and budget constraints. Reductions in transport costs in the form of railroad savings on existing traffic as well as public savings, which would accrue from alteration of use of the railroad main track, were expected.

Railroad savings were found to result from reductions in operations, derailments, and capital expenditures with additional benefits derived from liquidation of facilities no longer needed. Public benefits were related to decreased exposure to railroad operations, consumer and producer surplus on new rail traffic, and residual value of the project's assets. These benefit categories and their derivation are more fully described in the following sections.

BYPASS BENEFITS--RAILROAD

The proposed bypass would result in positive benefits for the SBD based on a revised operating scheme and removal of the Escambia Bay trestle. Figure 3 shows the existing main track and related facilities as well as the proposed bypass.

Operating Impacts

A forecast of anticipated traffic levels, based on historical trends, and the revised operating scheme were used to estimate the impact of the bypass on SBD operating factors. The analysis was performed, in large part, using a train performance calculator,

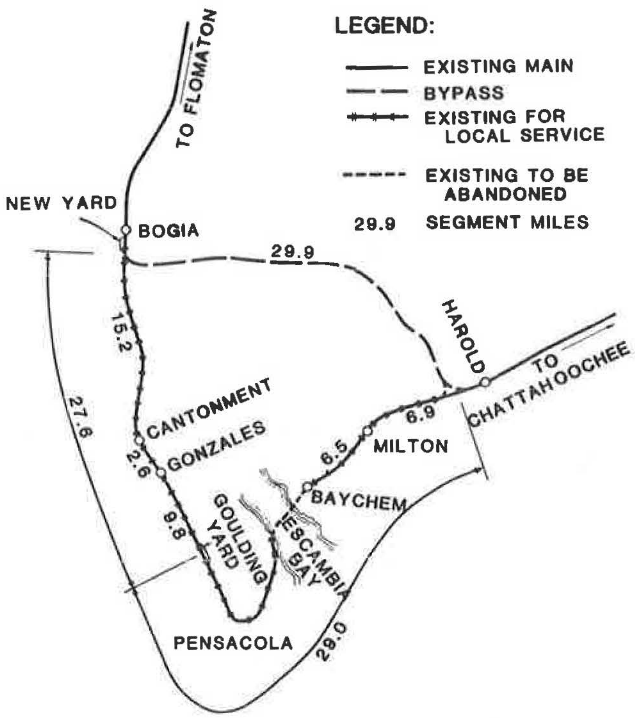

FIGURE 3 Proposed bypass and existing main track.

a computer model that simulates train operations (10). The configuration of the trains and the track alignment and gradients were used as input. In this manner train operations in and through the two-county area were simulated for both the existing main track and the bypass.

A number of operating factors were considered in the analysis. Time and fuel consumption factors were determined using the train performance calculator. Mileage impacts--cars, trains, and locomotive units--were determined from calculations using local traffic origins and destinations and through-car counts. In general, the operating factors examined and quantified on an annual basis increased for local train operations with the revised operating scheme but declined significantly for through and way trains. The latter train categories benefit from the reduction in main-track mileage and improved track geometry. Details on SBD operating impacts are provided in the complete study (4).

The operating impacts that would result from implementation of the bypass and Bogia yard equate to $970,847 in estimated annual SBD savings. These savings are comprised of cost reductions--freight car miles, fuel consumption, and locomotive repair and maintenance--that can be directly attributed to the reductions in operating factors previously discussed and given in Table 2.

Although time savings would be produced with implementation of the bypass, these savings cannot be directly translated into reductions in expenses. Because of local work rules, time savings for train crews cannot be readily converted into wage changes; thus there would be no reduction in each crew's assignment. Time savings for equipment, locomotives and freight cars, will not equate to savings unless there is an improvement in utilization of the equipment. Unless the time savings can be shown to actually improve utilization, such as making a connection with another train at a distant terminal that could not have been made otherwise, the time saved cannot be viewed as an economic benefit. Although there might be some improvement in utilization some-

TABLE 2 Annual SBD Operating Savings with Bypass Implementation

Item	Quantity	Unit Cost[a]	Annual Savings ($)
Fuel	523,400 gal	0.92 per gallon[b]	481,528
Car-miles	3,543,600	0.0848[c] per car-mile	300,497
Locomotive repair	21,753,680 locomotive gross ton-miles	0.00868[d] per locomotive gross ton-mile	188,822
Total			970,847

[a] 1983 dollars.
[b] Average cost including labor over last 4 years based on Louisville and Nashville Railroad 1982 costs and the American Association of Railroads (AAR) fuel index.
[c] SBD unit costs for 1981 based on typical car types used or transported through the study area and AAR Railroad Cost Recovery Index.
[d] SBD unit cost for 1981 and AAR Railroad Cost Recovery Index.

where on the SBD, it would be difficult to ascertain and quantify.

Derailment Impacts

Another factor to be considered in relation to SBD main-line operations is the reduced potential for derailments if the bypass route were used. This consideration involves not only the number of derailments but the consequences of those that do occur. Derailments affect both the railroad and the public and pose the potential for the severest consequences of all factors considered. This discussion therefore covers benefits that are attributable to both the railroad and the public and is further developed later in the section on public benefits.

Between 1975 and August 1983, 31 derailments occurred in the two counties on lines of the SBD. Of the total number recorded, 15 occurred on the existing main line within the limits affected by the proposed bypass route. The derailments, which comprised all of the injuries and fatalities reported, resulted in 11 injuries and 2 fatalities.

Railroad derailments usually result from problems related to one of three major factors--track, equipment, or human error. Relating these factors to estimated reductions in railroad operational measures (track, main-line mileage; equipment, car- and locomotive-miles; human error, operating hours and train-miles) indicates that a 39 percent weighted reduction in derailments could reasonably be expected as a result of the reduced exposure. The calculations on which the weighted reduction in derailments was based, are provided in the complete study (4).

Main-line derailments reported in the area resulted in estimated costs to the railroad (property damage and clearing wrecks) ranging between $7,830 and $861,212 per occurrence. The costs do not include some perhaps more far-reaching costs such as settlement of lawsuits. The average cost per derailment was $178,932 in 1983 dollars. Based on the frequency of occurrence of 1.7 derailments per year over the main-line segment affected by the bypass, the reduction in derailment potential of 39 percent, described previously, and the average historical cost of derailments, annual SBD savings of $118,632 ($178,932 x 1.7 x 0.39) could be anticipated with use of the bypass.

Liquidation of Assets

The revised scheme of operations resulting from use of the proposed bypass would enable SBD to liquidate some of its assets that would no longer be needed. The new yard at Bogia would render approximately 77 acres of land at Goulding yard available for use for purposes other than railroad operations. With removal of the Escambia Bay trestle, a section of the existing main line (Figure 3) would no longer be needed for train operations because of the elimination of through trains and the absence of rail users. On the basis of the market and net liquidated values of the properties and track materials, resources equal to $957,100 would be available for other uses.

Escambia Bay Trestle

The largest benefit of the bypass to the SBD is the expenditure saved by avoiding the need to construct a new trestle across Escambia Bay. The new trestle is estimated to cost $23 million.

BYPASS BENEFITS--COMMUNITY

There are community benefits associated with the proposed project that include the residual value of the project's assets and costs avoided by reducing derailments, grade crossing delays and accidents, and the community's vulnerability to hazardous material transported in and through the urban area.

Residual Value

It is estimated that the residual value of the project's assets, primarily right-of-way, rail, and structures, will have a market value of $14,922,000 in the last year of the analysis period (2015).

Derailment Impacts

Injuries and fatalities associated with derailments occurred at the rate of 1.25 and 0.23 per year, respectively, from 1975 to 1983. The reduction in derailment potential of 39 percent, described earlier, can be equated to lowering the annual injury and fatality rate to 0.49 and 0.09, respectively.

The National Safety Council (NSC) estimates that the average cost per injury was $8,000 in 1983 (11). The problem of placing a value on human life has been extensively addressed in the literature (12-14). Some economists have argued that the relevant benefit measure of an endeavor that affects human life should be based on an individual's willingness to pay for a marginal change in the probability of survival (13). Thaler and Rosen (15) analyzed a sample of individuals and, using risk compensating wage differences to estimate risk premiums, estimated the value of life in 1983 dollars at $612,627. Using these estimates, the total value to be placed on lowering the annual injury and fatality rate is $59,056 per year. These calculations are given in Table 3.

TABLE 3 Calculation of Community Derailment Impact Savings with Bypass Implementation

Item	Description	Value
a	NSC average cost per injury ($)	8,000.00
b	Thaler and Rosen estimated value of a life ($)	612,627.00
c	Injuries per year 1975 to 1983 in the study area	1.25
d	Fatalities per year 1975 to 1983 in the study area	0.25
e	Reduction in injuries per year = 39 percent reduction in derailments x c	0.49
f	Reduction in fatalities per year = 39 percent reduction in derailments x d	0.09
g	Value to be placed on lowering annual injury rate = (a x e) ($)	3,920.00
h	Value to be placed on lowering annual fatality rate = (b x f) ($)	55,136.00
i	Total value of reduced injuries and fatalities per year = (g + h) ($)	59,056.00

Impacts of Grade Crossings

From a public viewpoint, elimination of through and way train operations from the existing main line, leaving only local trains and switch engines whose operation is limited to local service, results in a tremendous reduction in potential grade crossing conflicts. Although the existing crossings would remain, the majority of them would only be subjected to a few train movements per day if the bypass were implemented. This reduction in train movements would decrease person and vehicular traffic delay at the crossings, reduce the potential for vehicle-train accidents at the crossings, and reduce the need for additional crossing signal protection and grade separations. Because the proposed bypass alignment would be grade separated at all arterials, no significant adverse impacts would be generated along the new main-line route.

Delays at Grade Crossings

The cost savings (benefits) associated with the reduction of train movements at the crossings affected by the bypass were estimated using a grade crossing delay computer program (16) in association with the train performance calculator. The two-step procedure consists of, first, estimating the times and durations of grade crossing blockages due to train operations and, second, calculating the highway vehicle delays that would occur as a result of these crossing blockages.

The crossing blockage records produced by the train performance calculator and individual grade crossing average daily traffic and number of roadway lanes are then used by the Grade Crossing Delay Model to calculate the vehicle and person delay resulting from train operations. Average daily traffic was distributed by hour of day using generalized daily traffic hourly percentages. Standard queueing formulas were then used to calculate the vehicles stopped, queue lengths, and total vehicle delay arising from each train blockage. Person delay was calculated using assumed vehicle occupancy rates.

Total person and vehicle delay was calculated by summing the delays resulting from all crossing blockages throughout the travel day. Local wage rates and family income were then used along with the procedures available in the AASHTO publication, A Manual on User Benefit Analysis for Highway and Bus-Transit Improvements (17), to determine average unit costs. A detailed presentation of all calculations is provided in the complete study (4). The results of the analysis indicate that savings with an estimated value of $220,460 would be achieved annually with the revised operating scheme resulting from use of the bypass. These savings are comprised of $87,600 in annual vehicle stop and idle costs and $132,860 in annual person delay.

Accidents at Grade Crossings

The reduction in train movements also reduces the potential for train-vehicle accidents at area grade crossings. The grade crossings of the existing main track, within the limits being evaluated for the bypass, comprise 79 percent of the main-track crossings in the two counties and handle 74 percent of the vehicular average annual daily traffic (AADT). A weighted value based on train movements over these crossings, with and without the bypass, indicates that the probability of a main-track grade crossing accident should be reduced by 54.6 percent. Recent grade crossing statistics equate to 10.5 accidents, 1.4 injuries, and 0.34 fatalities per year. FRA data indicate that the average property damage per grade crossing accident was $1,892 for automobiles and $5,143 for trucks (18). Based on these incident rates, the reduced probability of main-track grade crossing accidents, and the associated costs per incident (accident costs are proportioned from the percentage of the AADT comprised of trucks), grade crossing accident cost savings are $133,474 per year as given in Table 4.

Protection of Grade Crossings

Although the number of grade crossing protection devices currently in use could conceivably be reduced with the reduction in train movements, this is not envisioned. Grade crossing protection upgrading, however, is planned by the FDOT for 14 crossings in the area during the next 5 years. These improvements will require a total expenditure of $578,000, which could be avoided if the bypass were implemented. Also avoided would be maintenance costs associated with these protective devices. Maintenance costs are estimated to total $21,000 per year after installation of all of the devices.

Transportation of Hazardous Materials

The transportation of hazardous materials over the SBD main line through the urbanized areas is a major safety concern of local citizens. Although increases in regulations and technical improvements in railroad tank cars have mitigated the risk and consequences associated with derailments involving hazardous materials, the potential for a major disaster in the urbanized area still exists. A major criterion in selecting the bypass route was a reduction in community vulnerability to hazardous material accidents through decreased exposure of population and property.

Six of the 31 derailments previously discussed required the evacuation of an estimated 3,505 people because of the release of hazardous material. Of the six, five occurred on the existing main line within the limits affected by the bypass. Injuries and fatalities resulting from these derailments were discussed and quantified under railroad derailments. Public costs such as emergency service (overtime), lodging and food, rental equipment, time lost by residents, and volunteer help were not. Although precise information of this type was difficult to obtain, the data available from a variety of sources did indicate that time lost by residents and public emergency service costs that might be avoided by reducing the population exposed to potential derailments amount to $19,285 per year. A much more comprehensive discussion of these estimates may be found in the complete study (4).

The savings do not include consideration of property exposure. Given the improvements and investments in some of the developed property, derailments involving fire or explosions, or both, could prove to have large consequences in the urban areas. Needless to say, the factors that were quantified are at best rough estimates and, if anything, reflect the lower range of potential community savings resulting from reduced exposure.

So far, the economic benefits attributed to the proposed project have been based on actual resources saved or costs avoided on existing traffic (Areas G and H). A summary of the benefits is given in Table 5. The analytical framework proposed by the FRA also suggests that, if possible, the benefits attributed to consumer and producer surpluses on new traffic be addressed. There are, however, significant problems associated with these concepts.

Consumer and Producer Surplus on New Traffic

It is reasonable to consider the possibility that railroad cost savings may lead to lower freight rates, which would then generate new traffic. Consumer surplus on new traffic is the familiar welfare triangle shown in Figure 2 (Area J) and part of Equation 1, which, for simplicity, may be recast as

$$w = 1/2 \Delta P \Delta Q \tag{2}$$

where

w = consumer surplus on new traffic,
$\Delta P = (P_0 - P_1)$, and
$\Delta Q = (q_1 - q_0)$.

Unfortunately, it is difficult to estimate ΔP and ΔQ directly, so a crude approximation will be used and then checked to see how sensitive the results are to any change in assumptions. It has been assumed that all of the railroad's annualized cost savings of $2,205,737 (SBD cost savings in this example were taken from Table 5 and annualized using a 7 percent discount rate) will be passed through to

TABLE 4 Calculation of Grade Crossing Accident Cost Savings

Item	Description	Value
a	NSC average cost per injury ($)	8,000.00
b	Thaler and Rosen estimated value of a life ($)	612,627.00
c	FRA average property damage per grade crossing accident for automobiles ($)	1,892.00
d	FRA average property damage per grade crossing accident for trucks ($)	5,143.00
e	Estimated reduction in grade crossing accidents	0.546
f	Total accidents per year 1975 to 1983 in the study area	10.50
g	15 percent of AADT is trucks, thus truck accidents per year = 15 percent x f	1.58
h	85 percent of AADT is automobiles, thus automobile accidents per year = 85 percent x f	8.93
i	Injuries per year 1975 to 1983 in the study area	1.40
j	Fatalities per year 1975 to 1983 in the study area	0.34
k	Value to be placed on lowering annual truck accidents (property damage) per year = (d x g x e) ($)	4,437.00
l	Value to be placed on lowering annual automobile accidents (property damage) per year = (c x h x e) ($)	9,225.00
m	Value to be placed on lowering annual injury rate = (a x i x e) ($)	6,115.00
n	Value to be placed on lowering annual fatality rate = (b x j x e) ($)	113,728.00
o	Total value of reduced property damage, injuries, and fatalities per year = (k + l + m + n) ($)	133,505.00

TABLE 5 Summary of Benefits Based on Costs Avoided on Existing Traffic with Implementation of Project

Benefit	Amount ($)	Occurrence
SBD		
Operating savings	970,847	Annual
Derailment cost reduction	118,632	Annual
Asset liquidation	957,100	1991-1994
New Escambia Bay bridge construction avoidance	23,000,000	1985-1986
Public		
Derailment injury and fatality reduction	59,056	Annual
Grade crossing delay reduction	220,460	Annual
Grade crossing accident reduction	133,505	Annual
Grade crossing protection installation and	578,000	1984-1988
maintenance avoidance	21,000	Annual
Hazardous materials derailment reduction	19,285	Annual
Residual value of project's assets	14,922,000	2015

shippers in the form of lower freight rates. Although this is an unlikely assumption in a market in which there are so many captive shippers, it should give an upper bound on the estimate. Given the average number of rail cars that has recently either originated or terminated in Pensacola, Florida, each year (34,650), this amounts to a price reduction of $64 per year or approximately 9 percent of the average freight rate per car on the SBD system.

George Wilson (19,pp.15-19) has estimated the aggregate price elasticity of rail transport demand at -0.696. This means that a 9 percent decline in price will lead to a 6 percent increase in quantity demanded or 2,079 cars per year. With ΔP and ΔQ now available, the consumer surplus on new traffic can be estimated at $66,528 per year (1/2 x $64 x 2,079). When the railroad's cost savings in Table 5 are annualized at 4 and 10 percent, the consumer surplus on new traffic is $48,524 and $87,336 per year, respectively.

There are theoretical problems associated with the use of producers' surplus as an economic benefit in this study. Producers' surplus (Figure 2, Area K), the excess of total revenue over total avoidable cost that accrues to a seller as profit in the short run, is transformed into a cost, or otherwise eliminated, in the long run. Therefore, even if there were excess factor payments generated by the proposed project, their value as an economic benefit would only extend over a comparatively short period of time relative to the anticipated life of the project. Mishan (20,pp.55-64) and Anderson and Settle (12) have argued forcefully that the concept of producers' surplus in an increasing-cost industry is not applicable in the long run. For these reasons, estimates of producer surplus have not been included in this study.

BENEFIT-COST RESULTS

Estimated benefits and costs take place at various points in time and must be appropriately discounted to evaluate the relative merits of the proposal. The results of the present value calculations are given in Table 6.

The proposed project would be considered desirable from an economic efficiency standpoint if the present value of project-related benefits exceeded the present value of project-related costs. Clearly this is not the case because discounted costs exceed discounted benefits at all three discount rates. The results of the benefit-cost analysis indicate that from the standpoint of pure economic efficiency the project is not desirable. The benefit-to-cost ratios reveal that only between 69 and 83 percent of project costs are offset by quantified benefits.

TABLE 6 Project's Net Present Values ($000s) and Benefit-to-Cost Ratios at Various Discount Rates

Item	Discount Rate (%) 4	7	10
Benefits	45,568	34,273	27,820
Costs	54,691	46,707	40,102
Net present value	-9,123	-12,434	-12,282
Benefit-to-cost ratio	0.83	0.73	0.69

In estimating consumer surplus, it was assumed that all of the railroad's annualized cost saving would be passed through to shippers in the form of lower freight rates. Although this was a fragile assumption, it did provide a useful upper bound on the estimate. Clearly, because the cost of the proposed project far exceeds its benefits, the conclusions are not affected by a change in this particular assumption, which would only reduce the benefit-to-cost ratio.

DISTRIBUTIONAL CONSIDERATION

Benefit-cost analysis, as described here, focuses on the economic efficiency aspects of the proposed rail line relocation. However, policy makers are often as interested in the distributional aspects of a project. Because funding sources have not been identified, it is not possible to determine how the project's cost would be distributed. Nevertheless, a distribution of present value benefits is given in Table 7 and demonstrates that, depending on the discount rate used, the SBD is the beneficiary of between 76 and 85 percent of the quantified benefits.

TABLE 7 Distribution of Present Value Benefits ($000s)

Beneficiary and Benefits	Discount Rates (%) 4	7	10
SBD			
Operations	11,525.5	7,045.7	4,522.2
Derailments	1,408.3	860.9	522.6
Asset liquidation	654.4	497.7	382.1
Bridge construction	22,893.0	19,491.7	18,222.8
Subtotal	34,481.2	27,896.0	23,679.7
Public			
Grade crossings			
Delays	2,617.7	1,600.2	1,027.1
Accidents	1,584.8	968.8	621.8
Protection	832.4	685.6	587.5
Derailments			
Hazardous materials evacuations	229.1	140.1	89.9
Injuries and fatalities	701.1	428.6	275.1
Project residual value	4,253.7	1,712.2	706.7
Consumer surplus	867.5	841.4	832.0
Subtotal	11,086.3	6,376.9	4,140.1
Quantified total	45,567.5	34,272.9	27,819.8

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Employment Impacts of the Surface Transportation Assistance Act of 1982

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ABSTRACT

The Surface Transportation Assistance Act (STAA) of 1982 was primarily a legislative response to growing concern about the condition and performance of the nation's highways. There was also a widely held belief that implementation of the act would generate additional employment. Thus the specific purpose of this study was to estimate the employment consequences of (a) increases in highway and transit expenditures and (b) increases in highway user taxes attributable to the STAA. Because of the large number of economic variables that had to be analyzed and the complex interrelationships among these variables, the research was conducted with the aid of multiequation econometric models. The results of the study indicate that the STAA of 1982 has no significant impact on the gross national product, although sectors linked closely to highway construction benefit from the act and those sensitive to higher gasoline prices, lower disposable income, and higher interest rates suffer. However, the net effect on employment is not zero because of different labor intensities among industries. Thus total employment was predicted to drop slightly in 1983 but to increase from 1984 through 1986 as the stimulus of increased highway spending gradually overtook the inhibitive effects of the tax increase. Regional variations are primarily the result of differences in the number of new construction jobs created, differences in construction wage rates, and geographic concentration of manufacturing and trade in general and motor vehicle manufacturing in particular.

The Surface Transportation Assistance Act (STAA) of 1982 was a legislative response to growing concern about the condition and performance of the nation's highways, the tax structure supporting the Highway Trust Fund, and several other related issues. Increased federal aid to the states was deemed necessary to maintain the highway system. Thus, when financing for the Highway Trust Fund was extended, the level of funding was increased. This was accomplished primarily by raising the tax rate on motor fuels by 5 cents per gallon. Other highway taxes were restructured, but the intent of those changes was to redistribute the burden of highway user taxes, not to increase revenues. In addition, a portion of the increased funding was dedicated to public transportation assistance.

Although the STAA of 1982 was introduced primarily as a transportation infrastructure improvement measure, the commonly held opinion that implementation of the legislation would generate employment provided additional support for enactment. The FHWA has responded to widespread interest in the employment issue by undertaking a study to monitor the employment trends resulting from the act. The study consists of several research efforts, including surveys of actual construction projects, an analysis of effects on transportation projects funded solely by state revenues, and an econometric assessment of the employment impacts of the legislation. In this paper the research of the third phase of the study, the econometric analysis, is summarized.

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The purpose of this research effort is to estimate the employment consequences of (a) increases in highway and transit expenditures and (b) increases in highway user taxes that are attributable to the STAA of 1982. A priori, it was not clear what effect these increases would have on total employment. Obviously, the increased expenditures would tend to create jobs. However, the higher user fees would be expected to dampen employment because consumers and business firms would have less money to spend on nonhighway goods and services. The net effect on employment over time would depend critically on the rate at which the newly created funding would be spent relative to the rate at which the increased user fees would be collected. The net effect would also be a function of the labor intensities of the affected industries.

Because all of these factors had to be considered in a way that captures their interrelationships, the research was conducted with the aid of large, multiequation econometric models. Computer-based models available from Data Resources, Inc. (DRI) were chosen for this project because they permit the national, regional, and industry aspects of the problem to be addressed within a single analytical system. In addition, the DRI macroeconomic model contains spending and tax variables that can be changed in ways that closely reflect the actual implementation of the STAA of 1982. Working within an analytical framework developed by the Transportation Systems Center, the DRI Interindustry Service and the DRI Regional Information Service prepared reports on national and industry employment effects and regional employment effects, respectively. In this paper the methodology is outlined and the results of these reports are summarized. For more technical detail, the reader is referred to the individual DRI reports.

The general approach of the research is to simulate the behavior of the economy in two scenarios, one with the STAA of 1982 in effect and the other without. The differences in the values of economic variables in these two cases are estimates of the impacts of the act. As with other research of this type, it is the changes between scenarios, not the absolute levels predicted for either scenario, that are important.

When the project was initiated in the fall of 1983, the fuel tax and spending provisions of the STAA of 1982 had already been implemented. The FHWA determined that the employment consequences of the act should be estimated for 1983 and also forecast for the years 1984 through 1986. Because the standard DRI macroeconomic forecasts already incorporated the relevant provisions of the STAA of 1982, the November 1983 forecast, with historical information for the prior months of 1983, was used as the baseline scenario. This is the "with-STAA" scenario. A "without-STAA" scenario that models the performance of the economy under the assumption that the act was not passed has also been developed; this includes estimates for early 1983 as well as for the remainder of the study period.

The methodology and results of the macroeconomic, interindustry, and regional simulations are summarized in the next three sections. The development of the without-STAA macroeconomic scenario is given prominence because it is the basis of the subsequent interindustry and regional work. The critical assumptions, consequent limitations, and data are noted in the methodological discussions.

MACROECONOMIC ANALYSIS

Two sets of estimates had to be made to develop the without-STAA macroeconomic scenario. These were the changes in spending on highways and transit and the changes in tax receipts that resulted from the STAA of 1982. The legislation sets forth only increases in apportionments to the states and the 5-cent increase in the federal motor fuels tax. Decisions had to be made about how these changes could best be represented in the DRI macroeconomic model.

For the spending changes, both the dollar amounts and their timing had to be estimated. Estimation of the increased highway spending attributable to the act was complicated because the federal government does not pay for highway and transit construction directly. Instead, it provides aid to the states, which in turn let the construction contracts. In addition, the federal-aid program requires the states to provide some percentage of project costs from their own revenues. Thus the increase in spending could be greater than spending from federally provided funds if state matching funds were new state revenues. Alternatively, states could provide matching funds by shifting state funds from other highway or transit projects to federally aided projects. In the current economic climate, it appears unlikely that states would raise taxes solely to match new federal funds; therefore it was assumed that matching funds would come from existing state revenues. [A third possibility is that states would use federal funds for projects that would have been funded entirely from state-only revenues. In this case, which has been judged less likely to occur, the total change in spending would be less than the change in federal aid.] State highway and transit spending from the states' own revenues has been held constant, and the total change in spending is, therefore, equal to the increase in federally provided money. An implication of this assumption is that changes in state motor fuel tax rates that have occurred would have occurred even if the STAA of 1982 had not been passed.

The time pattern of highway spending by the states relative to the apportionment process is determined by two lags and by obligation ceilings. First, there is a lag between the apportionments at the beginning of the fiscal year and the point at which states obligate some part of the apportionment for a specific project. Generally, states are allowed 3 or 4 years in which to obligate a specific year's apportionment. State obligations in any year are constrained not only by the level of apportionments but also by obligation ceilings. There is also a lag between the obligation of funds and payments to contractors. This lag depends on how long it takes to let construction contracts and the pace of the construction or repair project itself.

Because no data on the apportionment-obligation lag are readily available, the changes in obligation levels that result from the STAA of 1982 have been estimated solely from data on obligation ceilings before and after enactment of the act. The aggregate obligation ceiling, which had been binding for the past several years, was raised by the STAA. Preliminary data indicate that the new ceiling was binding for FY 1983. At the suggestion of the FHWA, it was assumed for the purpose of this study that states would continue to obligate funds up to their ceilings, adjusted to include authorizations for programs not covered by the ceilings. Thus the change in obligations is estimated to be the difference between ceilings. It should be noted that, even though an obligation ceiling is reached in a particular year, the obligated funds are not necessarily solely from that year's apportionment; the increases in highway spending that occur as a result of the STAA are due not only to increases in federal aid per se but also, and perhaps especially, to the change in the obligation ceiling. If there is a bias in the impact estimates because of the assumption that the ceiling is reached, it is upward. If the states as a whole obligate less than the ceiling in future years, highway expenditures will be less than predicted, and the spending impacts will be somewhat smaller.

The new funding ceilings provided by the STAA of 1982 are given in the first row of Table 1. It was assumed that, in the absence of the act, the funding ceilings would have been \$8 billion. The incremental obligations for highways, the differences between the ceilings, are given in Row 3.

TABLE 1 Estimated Incremental Obligations Under the STAA of 1982 (fiscal year, billions of dollars)

	1983	1984	1985	1986
Highway obligation ceiling under STAA[a]	12.449[b]	13.421	14.427	15.319
Highway obligation ceiling without STAA	8.000	8.000	8.000	8.000
Incremental highway obligations	4.449	5.421	6.427	7.319
Incremental transit obligations[c]	0.572	1.351	1.175	1.106

[a]Adjusted by FHWA to reflect programs not covered by ceiling.
[b]Actual obligations for FY 1983.
[c]Provided by UMTA.

Because construction on highway projects begins only after funds are obligated, the lag between obligations and expenditures must be estimated. An expenditure, from the federal government's point of view, is a reimbursement from the federal government to a state for payments to contractors. FHWA data on expenditures, therefore, most closely approximate the flow of funds into the economy. FHWA has developed a payout table that reports the rate at which

TABLE 2 Estimated Incremental Expenditures Under the STAA of 1982[a] (fiscal year, billions of dollars)

	1983	1984	1985	1986
Incremental highway expenditures	0.747	3.243	4.597	5.624
Incremental transit expenditures	0.030	0.205	0.507	0.803
Total incremental expenditures	0.777	3.448	5.104	6.427

[a]Payout patterns provided by FHWA and UMTA.

funds obligated in a given year are expended in that year and subsequent years. This table was applied to the estimates of incremental obligations to develop estimates of the incremental highway expenditures attributable to the STAA. These are given in Table 2.

The transit program is characterized by an obligation lag and an expenditure lag analogous to those in the highway program. No published data on the length of the lags are available. Estimates of incremental obligations by the states for transit improvements were provided directly by UMTA to FHWA. These are reported in Row 4 of Table 1. UMTA also provided information on payout rates for transit expenditures. The notable point about the transit payout pattern is that, although payout rates are initially lower than those for highways, the payout period is shorter. The estimates of increased transit expenditures are given in Table 2.

The second major set of issues in the without-STAA macroeconomic scenario involves the estimation of (a) tax revenues that would not have been collected had the STAA not been passed and (b) the incidence of the tax rate increase. The Bureau of Economic Analysis had made forecasts of tax revenues generated by the 5-cent increase in the gas and diesel tax through the end of FY 1984. DRI extrapolated this series to the end of calendar year 1986, using the baseline forecast of refined petroleum production as a proxy for the tax base. The revenue estimates, which are consistent with estimates provided by FHWA, are given in Table 3.

TABLE 3 Estimated Incremental Revenue Under the STAA of 1982[a] (fiscal year, billions of dollars)

1983	1984	1985	1986
2.9	5.5	5.5	5.6

[a]1983 and 1984 estimates from Bureau of Economic Analysis; 1985 and 1986 estimates by DRI.

The federal gasoline tax is levied on gasoline production and is, therefore, paid by refiners or, in some cases, primary distributors. The actual incidence, or burden, of the tax will differ, however, as producers pass the rate increase backward to labor and capital or forward to highway users. It was assumed that producers would pass the entire tax increase along to highway users, thereby raising the retail price of gasoline. This assumption is supported by actual price increases that occurred on or about April 1, 1983. The treatment of gasoline prices in the DRI model reflects this assumption.

These spending and tax changes have been incorporated into the alternative macroeconomic simulation by making changes in several exogenous spending and tax variables. The baseline scenario is the with-STAA case, so construction of the without-STAA case involved reducing the level of spending and taxes. Because highway and transit construction is directly financed by state governments, the levels of the variables for state and local purchases of goods and services and of construction were reduced to reflect spending changes reported in Table 2. The flow of funds from the federal government to the states in the model was altered by reducing the amount of grants-in-aid. The magnitude of the change equaled that of the change in state spending because the federal government reimburses the states for their payments to contractors.

Changes in tax revenue were introduced into the model by reducing the level of the variable for federal government indirect business tax and nontax accruals by the amounts given in Table 3. Because the producer price index for gasoline in the DRI model is estimated net of the federal tax, the change in the tax rate was reflected by reducing the level of the gas tax variable. This adjusts the retail price index and thus implements the assumption that the incidence of the tax is on highway users. Because reductions in tax revenues exceed reductions in federal grants-in-aid in the without-STAA scenario, there will be an increase in the federal deficit. However, it was assumed that the increase would be too small to induce changes in monetary policy and that the Federal Reserve would continue the policies implied in the with-STAA scenario.

The impacts of the STAA on key macroeconomic variables are estimated by comparing the with-STAA and without-STAA simulations. The variables of interest are the real gross national product (GNP) and its components, disposable income, prices, and interest rates. Table 4 gives the percentage differences in these variables.

TABLE 4 Macroeconomic Impacts of the STAA of 1982 (percentage differences between with-STAA and without-STAA scenarios by calendar year)

	1983	1984	1985	1986
Real GNP	0.0	0.0	0.1	0.0
Real consumption	−0.1	−0.1	−0.1	−0.1
Real nonresidential fixed investment	0.0	−0.1	−0.1	−0.2
Real residential fixed investment	0.0	−0.1	−0.3	−0.4
Implicit price deflator	0.1	0.2	0.3	0.3
Three-month treasury bill rate	0.01	0.05	0.09	0.10
New high-grade corporate bond rate	0.02	0.04	0.06	0.04

The results indicate that the stimulus of increased government spending is largely offset by the negative effects of the tax increase so that there is no significant impact on real GNP (measured in 1972 dollars). This is so even though the time patterns of increased spending and increased tax revenues are markedly different. The increase in spending does result in a 0.1 percent rise in real GNP in 1985 above what it would have been if the STAA had not been enacted, but GNP in other years is unaffected.

More significant changes occur in the primary components of real GNP. Government spending is, of course, up, but both real consumption and real residential and nonresidential investment are lower in the with-STAA simulation. Residential investment is the most adversely affected sector, declining by 0.4 percent in 1986 from the without-STAA level. The decline in personal consumption expenditures is largely the result of a decline in real expenditures on gasoline and oil and on motor vehicles and parts, and the decline in residential investment reflects the decline in housing starts caused by higher interest rates.

These changes are attributable directly and indirectly to the increase in the retail price of gasoline caused by the tax. Most important, the price increase not only affects fuel consumption; it also increases the cost of operating a motor vehicle. Furthermore, it is reflected in an increase of 0.1 percent to 0.3 percent in the general price level as measured by the GNP price deflator, which has a small negative effect on real disposable income and thus on other consumption categories. An increase in interest rates prompted by the general price increase reduces interest-sensitive purchases such as housing starts and consumer durables (e.g., furniture and vehicles).

INTERINDUSTRY ANALYSIS

The purpose of the interindustry analysis is to assess the employment impacts of the STAA in greater detail than would be possible with a macroeconomic analysis alone. Use of the DRI input-output-based industry model permits identification of both the total (net) employment effect and specific industry employment effects. The industry impacts include both direct and indirect effects, where indirect effects are those on suppliers to the directly affected industries.

Both the with-STAA and without-STAA interindustry simulations are derived from their companion macroeconomic simulations. Development of the without case, however, requires additional model manipulation to fully reflect the nature of particular final demand changes. The interindustry model by itself captures the lower level of state and local construction spending, but it is necessary to target these spending changes to specific industries to ensure that sectors such as sewer and water facility construction are not affected.

The necessary adjustments were made in a two-stage process. The first was to identify the types of construction projects that are expected to be undertaken and to estimate the incremental funding for each type. The second was to develop a mapping between project types and the relevant industries in the DRI model. FHWA and UMTA each supplied information on expenditures by project type. DRI developed the mapping between projects and the industries classified in the model; 6 of the 400 industries in the interindustry model were judged to be affected. Table 5 gives expenditures by project type, and Table 6 gives the targeted industries by project type. The outputs of the industries listed in Table 6 were reduced by the amounts in Table 5 in the creation of the without-STAA simulation.

The direct effects are the result of final demand shifts forecast by the macroeconomic model, and the indirect effects are determined by the technological coefficients of the interindustry model. The final demand shifts include both the increase in government spending on construction and the reduction in personal consumption and housing investment. Employment is expected to increase in the six sectors designated as recipients of increased state and local expenditures and to decline in (a) consumption categories that are vulnerable to price and interest rate increases and (b) the housing construction industry. These industries, particularly the six targeted ones, can generally be characterized as having a large number of suppliers, each accounting for a relatively small amount of input costs. The indirect effects are likely, therefore, to be widespread but minor in terms of industry output. The indirect employment impacts will likewise be small, particularly in capital-intensive industries. Although the net effect on GNP is insignificant, the net employment effect need not be zero because of differing labor intensities among industries.

Comparison of the two simulations indicates that the net employment effect is in fact not zero. Table 7 gives the net employment changes. Total employment declined slightly in 1983 below what it would have been without the STAA but is expected to increase in

TABLE 5 Incremental Expenditures by Project Type (billions of 1972 dollars)

Project Type	1983	1984	1985	1986
Highway				
Repair	0.472	1.485	2.019	1.812
New construction	0.052	0.65	0.224	0.201
Bus facility construction	0.002	0.008	0.020	0.023
Railroad				
Repair	0.007	0.037	0.088	0.102
New construction	0.007	0.034	0.080	0.093
Buses	0.002	0.008	0.020	0.023
Railroad vehicles				
Existing systems	0.002	0.009	0.022	0.026
New systems	0.000	0.000	0.001	0.001

TABLE 6 Industries Affected by Incremental Expenditures in the 400-Sector Interindustry Model

Project Type	No.	Industry
Highway		
Repair	44	Maintenance and repair, other
New construction	37	New highways and streets
Bus facility construction	42	New construction, NEC
Railroad		
Repair	44	Maintenance and repair, other
New construction	31	New railroads
Buses	333	Motor vehicles
Railroad vehicles		
Existing systems	340	Railroad equipment
New systems	340	Railroad equipment

TABLE 7 Employment Impacts of the STAA of 1982 (thousand employees)

No.	Industry	1983	1984	1985	1986
Change in Total Employment		–9	29	98	43
Change in Industries Directly Affected by Increased Construction					
31	New railroads	0	1	2	2
37	New highways and streets	2	7	9	8
42	New construction, NEC	0	0	1	1
44	Maintenance and repair, other	23	75	103	91
333	Motor vehicles	–1	–1	–1	–1
340	Railroad equipment	0	0	0	0
Change in Selected Industries Directly Affected by Decreased Consumption Expenditures and Investment					
21	New residential single-family housing	0	–1	–2	–3
376	Retail trade	–12	–16	–7	–6
389	Automobile repair	–1	–1	–1	–1
Change in Selected Supplier Industries (indirect effects)					
19	Stone and clay mining	0	1	1	1
181	Petroleum refining and related products	–1	–1	0	–1
202	Concrete products, NEC	0	1	1	1
248	Metal stampings	0	–1	0	–1
264	Construction machinery	0	1	1	0
334	Motor vehicle parts and accessories	–1	–1	–1	–1
375	Wholesale trade	–4	–6	–3	–6
385	Miscellaneous business services	–1	–1	1	–2
386	Advertising	–1	–1	0	–1

1984 through 1986. This is because the government spending stimulus increases gradually over the period but the inhibitive effects of tax increases occur immediately.

Table 7 also gives employment effects for selected industries. Of the six industries designated as recipients of incremental construction funds, only one, maintenance and repair, experiences a major increase in employment over the entire period. Much smaller increases occur in the other three construction categories. The pattern of increases over time reflects the pattern of the anticipated spending changes. Interestingly, employment in the motor vehicle industry actually declines slightly. This is due to the reduction in automobile sales occasioned by the fuel tax increase, which outweighs increases in bus purchases. The additional expenditures for rail equipment are not sufficient to cause an increase in employment in that industry. The most significant decline in employment occurs in the retail trade industry, primarily as a result of the drop in consumption expenditures but also as a result of indirect impacts. The decline in automobile repair employment is also representative of the adjustments that follow from the reduction in consumption. The employment reduction in housing construction employment is directly linked to lower levels of residential investment.

The indirect employment effects fall into two categories: changes for construction industry suppliers and changes for consumption-related industries. These groups are not mutually exclusive, and the results given in Table 7 are net. The indirect construction impacts show up in industries such as stone and clay mining, concrete products, and construction machinery. The negative indirect effects are experienced by industries supporting fuel and motor vehicle sales sectors, such as petroleum refining and related products and motor vehicle parts and accessories, and by those providing general business services, such as wholesale trade, miscellaneous business services, and advertising. Industries in this latter category also support the construction sector, so the net negative effect is due to the dominance of the shifts in consumption expenditure industries.

REGIONAL ANALYSIS

The employment impacts of the STAA for the nation as a whole were presented in the preceding section. In this section, these national impacts are disaggregated by census region.

The DRI Regional Information Service (RIS) model was used in carrying out this analysis. The RIS model is directly linked to the macroeconomic and interindustry models used in the analyses described previously. This linkage made it possible to run the macroeconomic and interindustry with-STAA and without-STAA results through the RIS model in a simple, straightforward way. The regional model then allocated the national impacts to the nine census regions on the basis of the extent to which each region's economy is dependent on motor vehicle sales, oil refining, construction, and other major sectors affected by the act. In addition, as discussed later, the regional distribution of highway spending had to be taken into account.

The RIS model uses employment as the principal indicator of economic activity in each sector. For this reason, the direct impact of increased highway spending was introduced into the model in the form of a change in construction employment. Because the national macroeconomic analysis had already estimated the total direct impact on construction employment nationwide, all that was needed was the regional shares of this total impact. These regional shares are not precisely the same as the shares of the increased federal funds because construction wages vary from region to region. Thus the same dollar expenditure will create more jobs in lower-wage regions than in higher-wage regions.

The regional shares of national highway spending were estimated from data on each state's share of total obligation limitations for the nation as a whole. These shares were then divided by average construction wages by state. In this way, each state's share of the new highway construction employment created by the STAA was estimated. The results, aggregated by census region, are given in Table 8. These results show that the South Atlantic region ranks first in gains in highway construction employment created by the act, with almost twice as many new highway construction jobs as the second-ranking Pacific region.

TABLE 8 Estimated Census Region Shares of Highway Construction Employment Generated by the STAA of 1982 from 1983 to 1986

Rank	Census Region	Average Annual No. of New Highway Construction Jobs (000s)	Share of New Construction Employment (%)
1	South Atlantic	17.0	22.0
2	Pacific	9.1	11.8
3	East North Central	8.8	11.4
4	Middle Atlantic	8.3	10.8
5	West South Central	8.3	10.8
6	West North Central	7.4	9.6
7	East South Central	7.1	9.2
8	Mountain	6.9	8.9
9	New England	4.3	5.5
	U.S. total	77.2	100.0

However, the ranking of regions by gains in highway construction employment differs markedly from the ranking by total employment impacts, given in Table 9. For example, the South Atlantic region, which ranks first in highway construction gains, ranks only third in total employment gains. This might reflect, among other factors, relatively low construction (and other) wages and incomes in this region.

More generally, the data in Table 9 indicate that implementation of the STAA will create more jobs than it destroys in each of the nine census regions. The largest net average annual increases will be realized in the West North Central and West South Central regions, with gains of 7,700 and 7,600, respectively. The East North Central and New England regions, with gains of only 700 and 1,300 jobs, respectively, show the smallest increases. Consistent with the macroeconomic and interindustry analyses, in all nine regions the largest gains occur in construction. This, of course, reflects the increases in highway construction employment. All of the regions also show employment declines in manufacturing, transportation, and trade. For other sectors, the results are mixed across census regions.

The most adversely affected sectors nationwide are manufacturing, trade, and, to a lesser extent, services. The combined impacts of the STAA on these three sectors offset 45 percent of the increase in construction employment. After all impacts are considered, there is a net increase in total nonagricultural employment of 38,100 jobs.

The impacts on manufacturing employment, given in

TABLE 9 Average Annual Number of Jobs Created (net) by the STAA of 1982 from 1983 to 1986 Ranked by Census Region (000s)

Rank	Census Region	Construction	Manufacturing	Transportation	Trade	Finance	Services	Federal Government	State and Local Government	Mining	Total
1	West North Central	8.8	-0.8	-0.1	-0.3	-0.1	-0.3	0.0	0.4	0.1	7.7
2	West South Central	9.5	-0.3	-0.1	-1.5	-0.1	-0.2	0.0	0.2	0.1	7.6
3	South Atlantic	12.2	-2.6	-0.4	-2.6	-0.3	-0.8	-0.1	0.4	0.4	6.2
4	East South Central	7.8	-1.9	0.0	-0.6	0.0	0.1	0.1	0.4	0.3	6.2
5	Mountain	6.3	-0.4	-0.1	-1.0	-0.1	-0.3	0.1	0.2	0.2	4.9
6	Pacific	7.6	-1.3	-0.3	-2.5	-0.3	-0.9	-0.1	-0.3	0.0	1.9
7	Middle Atlantic	8.4	-1.3	-0.3	-2.9	-0.4	-1.2	-0.1	-0.7	0.1	1.6
8	New England	4.0	-0.7	-0.1	-1.1	-0.2	-0.5	0.0	-0.1	0.0	1.3
9	East North Central	9.5	-3.1	-0.4	-3.2	-0.4	-1.4	-0.1	-0.4	0.2	0.7
	U.S total	74.1	-12.4	-1.8	-15.7	-1.9	-5.5	-0.2	0.1	1.4	38.1

Table 10, are important because of their relatively large multiplier effects on other sectors. This is caused by the relatively high average wages in this sector. The most significant impacts of the act on manufacturing are felt by the transportation equipment industry, which is adversely affected by the increased cost of automobile ownership. A smaller, opposite impact occurs in the stone, clay, and glass sector as a result of increased highway construction activity. The regional distribution of these changes is primarily a matter of where these industries are concentrated. The largest reduction in manufacturing employment thus occurs in the region in which transportation equipment is most heavily concentrated, the East North Central region. The South Atlantic region shows the second largest decline in manufacturing employment. As is the case in the East North Central region, a significant part of this is explained by negative impacts on transportation equipment. Even more important are the negative impacts, caused by reductions in gasoline demand, of the act on chemicals, which affect the price and production of petrochemical feedstocks.

Reductions in employment in nonmanufacturing sectors of the economy--trade, services, communications, utilities, and so forth--are brought about primarily by reductions in real disposable personal income caused by the 5-cent tax increase. The impact on services is relatively large (see Table 9) because the service sector itself is large. Here, unsurprisingly, the geographic distribution of impacts is fairly even. The employment losses in trade are larger than those in services because this sector includes the retail sale of gasoline by service stations. Like those in services, the employment losses in trade are fairly evenly distributed across census regions, except in the West North Central region. In this region, a relatively large proportion of gasoline is purchased for agriculture, which is largely exempt from fuel taxes, and long-distance trucking, whose demand for gasoline is less responsive to price changes than is the demand by most other sectors of the economy.

The regional employment impacts of the STAA discussed thus far have been measured in absolute numbers of jobs gained or lost. Additional insights into the employment consequences of the act can be obtained by measuring these gains and losses as percentage changes from employment in the without-STAA scenario. When the absolute changes presented in Table 9 are converted to percentage changes, the results are those given in Table 11.

Perhaps the most forceful point indicated by the data in Table 11 is that all of the regional sector employment impacts are quite small relative to the without-STAA employment levels. The largest absolute change in regional sector employment shown in Table 9 is the 12,200 gains in construction jobs in the South Atlantic region; in Table 11, this translates into an increase of 1.4 percent.

Another point brought out by the data in Table 11 is that the percentage gains are largest for the three smallest regions in terms of population: East South Central, West North Central, and Mountain. It is no coincidence that the East South Central and West North Central regions rank first and second, respectively, in percentage gains in construction and that the Mountain region ranks fourth. An excep-

TABLE 10 Average Number of Jobs Created in the Manufacturing Sector by the STAA of 1982 from 1983 to 1986

	New England	Middle Atlantic	South Atlantic	East North Central	East South Central	West North Central	West South Central	Mountain	Pacific	U.S. Total
Food processing	160	195	140	-103	-75	-359	-31	3	37	-35
Textiles	30	50	-398	41	-177	-41	21	0	46	-429
Apparel	-23	-65	-129	-92	-108	-10	-3	-1	15	-417
Lumber	59	88	-53	28	-127	62	-6	-108	-455	-511
Furniture	-18	-64	-158	-86	-34	-34	-20	-2	12	-403
Paper	-47	-83	-66	-90	-24	-17	-35	-4	-39	-405
Publishing	-75	-125	21	-98	121	2	-24	-11	-39	-228
Chemicals	42	-246	-804	178	-756	161	154	153	839	-277
Petroleum	1	-10	2	-9	-1	0	-25	-4	-14	-59
Rubber and plastics	-64	-92	-34	-237	-40	-16	-36	-8	-85	-611
Leather	-82	-54	-11	-4	-4	-8	1	3	33	-126
Stone, clay, and glass	19	292	199	302	107	136	172	0	81	1,308
Primary metals	5	36	88	-395	-33	-144	-118	-97	-225	-883
Fabricated metals	168	252	-258	26	-277	29	194	-21	-128	-15
Nonelectrical machinery	-105	-367	-342	-418	-279	-111	-300	-52	-194	-2,169
Electrical machinery	-401	-689	-175	-746	147	-122	-72	-172	-343	-2,573
Transportation equipment	-170	-262	-355	-1,302	-113	-253	-172	-68	-609	-3,302
Instruments	-100	-171	-31	-74	-9	-37	-20	-23	-145	-610
Miscellaneous	-36	-64	-17	-71	-6	-34	-16	-11	-57	-312
Total	-663	-1,342	-2,598	-3,148	-1,880	-827	-335	-434	-1,263	-12,487

Note: Columns do not add to totals because changes in "other" (unclassified) manufacturing employment are not shown.

TABLE 11 Average Annual Percentage Changes in Employment Caused by the STAA of 1982 from 1983 to 1986 Ranked by Census Region

Rank	Census Region	Construction	Manufacturing	Transportation	Trade	Finance	Services	Federal Government	State and Local Government	Mining	Total
1	East South Central	3.11	–0.14	–0.01	–0.06	0.00	0.01	0.05	0.05	0.29	0.12
2	West North Central	3.07	–0.06	–0.03	–0.02	–0.03	–0.02	–0.01	0.04	0.20	0.11
3	Mountain	1.92	–0.07	–0.04	–0.08	–0.04	–0.03	0.03	0.02	0.15	0.10
4	West South Central	1.63	–0.02	–0.02	–0.06	–0.02	–0.01	–0.01	0.02	0.02	0.07
5	South Atlantic	1.41	–0.08	–0.05	–0.07	–0.04	–0.02	–0.01	0.02	0.36	0.04
6	New England	1.96	–0.04	–0.05	–0.09	–0.04	–0.04	–0.01	–0.02	0.19	0.02
7	Middle Atlantic	1.59	–0.04	–0.03	–0.09	–0.03	–0.03	–0.02	–0.03	0.19	0.01
8	Pacific	1.28	–0.05	–0.04	–0.08	–0.04	–0.03	–0.03	–0.01	–0.03	0.01
9	East North Central	1.61	–0.07	–0.05	–0.09	–0.04	–0.04	–0.02	–0.02	0.19	0.00
	U.S. total	1.75	–0.06	–0.04	–0.07	–0.03	–0.03	–0.01	0.00	0.12	0.04

tion to the correlation between percentage increases in construction and total employment is New England, which experienced greater than average losses in trade and services and did not make up for them in mining.

The East North Central region experiences the lowest gain in employment, in both absolute and percentage terms. Although this region ties for second place in the number of new construction jobs, these gains were offset to an unusual extent by losses in the manufacturing sector, which is heavily concentrated in motor vehicles, and by the relatively large multiplier effects of the manufacturing losses on the trade and service sectors. This is in contrast to the neighboring West North Central region, whose manufacturing sector is relatively small and not especially dependent on motor vehicles. In this region, even though it gained only an average number of construction jobs, the negative impact on trade is quite small.

SUMMARY

Although the Surface Transportation Assistance Act of 1982 was passed primarily in response to concern about the nation's transportation infrastructure, the act was also expected to generate increased employment. The results of this analysis indicate that, with respect to aggregate GNP, the stimulus of increased government spending is largely offset by the negative effects of the tax increase. Thus there is no significant impact on real GNP. However, there are changes in the components of the GNP. As would be expected, those sectors linked closely to highway construction benefit from the act and those sectors sensitive to higher gasoline prices, lower disposable income, and higher interest rates suffer.

Although the aggregate GNP impacts are not significant, the net effect on employment is not zero because of differing labor intensities among industries. Thus total employment was predicted to drop slightly in 1983 but to increase in 1984 through 1986 as the spending stimulus gradually overtook the inhibitive effect of the tax increase.

Finally, the regional effects of the act were found not to be borne uniformly. This is also as expected. Regional variations are primarily a result of differences in the number of new construction jobs, differences in construction wage rates, and the geographic concentration of motor vehicle manufacturing in particular and manufacturing and trade in general.

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Time-Series Analysis of Interactions Between Transportation and Manufacturing and Retail Employment

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ABSTRACT

Using data on state highway expenditures and employment from 30 Minnesota nonmetropolitan counties over a 25-year period, possible interactions between transportation and employment are investigated. Although cross-sectional analysis suggests no significant interactions, causality tests and time-series analysis indicate that highway expenditures affect manufacturing and retail employment, and employment influences expenditures. Although increases in expenditures cause employment improvements in the short term, long-term effects are less favorable. Highway expenditures respond quickly to increased needs caused by retail improvements.

Federal budget deficit increases and spending reductions are likely to significantly restrict the flow of federal aid to regional economic development programs during the next several years. As such programs are phased out, state assistance to economically distressed regions will become increasingly important. Responding to this challenge, states will be encouraged to seek efficient ways to stimulate regional economic development in distressed areas. Although there exists a wide range of policy options for providing stimuli directly within the economic sector, the effectiveness of such policies depends, in part, on the availability of a supporting infrastructure. Transportation investment has long been an important factor contributing to the condition of the infrastructure nationally and at the state level.

Use of resources in transportation investment may, of course, preclude their concurrent use in other types of investment. Similarly, transport investment in a particular region may deprive other regions of useful resources. Therefore, although a given investment may be beneficial when viewed from a strictly local perspective, its net contribution to the economy of the state or a larger region may be negligible. On the other hand, the reallocation of resources accompanying the investment may lead to improved efficiencies and net gains within the larger system as well. Such effects play an important role in project evaluation and should be taken into account in the short-term and long-term assessment of transport policies. To accomplish this, state decision makers should identify and measure any possible impacts of transportation projects on economic development.

Identification of such impacts in nonmetropolitan areas is the major objective of this paper. By employing state trunk highway expenditures and county employment indicators in Minnesota over a 25-year period, this work investigates the existence and direction of causality between expenditures and employment for counties both near and far from large cities. Where causality may exist, time-series analysis develops relationships that explain any possible interactions between expenditures and employment.

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BACKGROUND

Despite the wealth of literature analyzing ways to improve the economy, relatively little of it has examined whether such improvements can be accomplished through selection of appropriate transportation policies. Yet, the literature has recognized (1,2) the quality and cost of transportation as one of the primary barriers to economic development. Most of the literature on transportation and economic development is descriptive or empirically oriented and has been undertaken to address the potential interactions between the two fields in the course of assessing specific project and policy impacts in both freight and passenger transportation. Such interactions include, for instance, the potential influence of transportation costs and accessibility to inputs and markets on the location of firms. Transportation may also permit or make economical the development of certain resources that otherwise would not have been developed. In addition, passenger transportation improvements may increase the labor pool that is available and attract more firms to an area.

Recent empirical evidence about whether changes in freight transportation can have impacts on economic development is mixed. Several studies claim to have found such influence, whereas others conclude that any impacts are insignificant. Even when these effects occur, the industries affected are not manufacturing firms but firms whose function is to service highway users. These firms often are merely relocating from areas where such users previously stopped. The literature points out, for example, that counties with Interstate highways consistently have an advantage over other counties with regard to population and employment growth (3-5). Further, the effect on population growth varies inversely with the distance from a metropolitan area and does not exist in areas farther than 25 mi from a metropolitan area. The effect on employment is primarily with regard to service (tourist-related) employment and is not found in manufacturing and wholesale activities. Research in the Atlantic Region of Canada (6) concluded that increased investment in transportation infrastructure and freight subsidies would attract very few industries because "a reasonably mature transportation system [is] properly in place and maintained." Similarly, a study of the region around the Ozark Plateau (7) concluded that there is little correlation between highways and economic development. Even if there is a correlation, the direction of causality could be economic development leading to highway investment rather than highway investment leading to economic development.

Whereas the research reviewed thus far did not reveal any significant links between highways and economic growth, other sources claim to have found such links. For instance, a strong relationship between regional employment growth rate and transportation cost resulted from motorway investments in North England (8). In Connecticut manufacturing employment and population increased more in the towns close to the new turnpike than in towns farther away (9).

Freight transportation may directly affect enterprise location, and passenger transportation can do so indirectly through its effect on labor conditions. For instance, transportation costs and accessibility can affect where jobseekers look for work (9-11), and firms are affected by the size of the labor pool available to them (11-13). As a hypothetical example, a public transport system from a region with few job opportunities to nearby centers with an excess number of job openings may decrease the unemployment rate (14,15), but the cost of providing the service may not make the investment attractive. Transportation changes may also affect local sales (16), but upgrading transit between communities of different sizes tends to siphon sales away from the smaller communities toward the larger ones.

To summarize, the empirical literature on transportation and economic development is contradictory. However, the majority of the studies indicates that, as long as today's well-developed transportation system provides good accessibility, transportation improvements no longer contribute significantly to economic development. Nevertheless, the literature on large-scale regional models presents a different picture.

Large-scale regional models have been used for regional economic forecasting and policy analysis (17-23). Most are based on the input-output method and several include a transportation sector that plays an important role in the analysis. Although the small-scale empirical studies on freight transportation conclude that transportation has little effect on today's economy, the large-scale regional models indicate that transportation can affect the economy. There are three possible explanations for this apparent contradiction.

- The large-scale regional models estimate transportation coefficients for specific sectors, whereas the small-scale studies are more generally oriented. With different sectors of the economy changing in different directions as a result of transportation changes, the net overall effects may be insignificant even though, by sector, the transportation effect is significant. The few small-scale studies that conclude that freight transportation has economic effects do specifically define a particular part of the economy for study.
- Because different sectors of the economy affect each other, an identification problem, which the large-scale models take into account, may exist in the small-scale models.
- The effect identified by the large-scale models may be passenger-transportation related; if so, they would not contradict the small-scale empirical studies on freight transportation.

Although these are plausible explanations for the apparent contradiction among past findings, a rigorous analysis is needed to resolve this issue. The results from such an analysis of the manufacturing and retail sectors in nonmetropolitan areas are presented in this paper.

DATA ANALYSIS METHODS

Although many methods exist for analyzing the data, here two major methods are distinguished according to the manner time is treated in the analysis:

1. Cross-sectional analysis employs data from different areas but for the same point in time. The analysis assumes that all variables are in equilibrium during the planning period. Any delayed interactions (e.g., between transportation and the economy) are overlooked. Results are applicable to long-term assessment.
2. Time-series analysis employs data from one area but for different points in time. The analysis makes no assumption about long-term equilibrium. Results can point to relations among variables as they occur through prespecified time increments and, therefore, this method is applicable to short-term analysis.

Both methods, by definition, exclude a large part of the available data from the analysis. In particular, the cross-sectional method excludes any data collected over time and the time-series method excludes data from all areas except the one under study. As a result, with either method the analysis may not benefit from additional information, even when such information exists. Nevertheless, this limitation can be overcome by combining the two methods via use of panel data. In particular, when it is desired to consider effects as they occur through time, as is the case here, time-series analysis with panel data can be used. Following this method, data from different time periods and areas are pooled together; however, the cross-sectional differences are eliminated from the data before analysis.

DESCRIPTION OF DATA

Two major sets of data were developed, one for cross-sectional and one for time-series analysis. For each type of analysis, data on both transportation expenditures (only state trunk highway expenditures are analyzed in this paper) and the economy of the areas targeted by these expenditures were collected. The economic indicators included county manufacturing employment, retail sales, unemployment, and family income for cross-sectional analysis and manufacturing and retail employment for time-series analysis.

Before analysis, the data were transformed in two ways. The gross national product (GNP) deflator was employed to adjust the sales and income data for inflation. Further, the data were normalized (however, the normalized variables kept their original names) in order to make the counties comparable. Without such normalization, larger counties would naturally be expected to have more employment and sales and receive more highway expenditures. The resulting high correlations would mask any causal effects between highway expenditures and the economy and, therefore, would make assessment of such effects impossible. To avoid such problems, highway expenditures and sales were normalized by population, and manufacturing employment by employment for cross-sectional analysis. For time-series analysis, county highway expenditures and employment were normalized by total state highway expenditures and employment, thus representing the fraction of the state expenditures and employment in a county, respectively. Normalized time-series data from two representative Minnesota counties, Freeborn and Kandiyohi, are shown in Figures 1 and 2, respectively.

Thirty of 87 Minnesota counties were randomly selected for this analysis. Several criteria led to the selection of the appropriate economic indicators and data source. In particular, to include time explicitly in the analysis, the selected indicators had to be available in the form of a time series, the longer the better. In addition, because state highway expenditures are only available on a yearly basis, there was little need for economic data on periods shorter than a year. Further, to determine whether transportation affects individual economic sectors, easy access to economic data by sector was necessary, at least for the sectors of the economy that are of greatest interest. Of course, the data needed to be reliable. A summary of the different data and their sources is given in Table 1. The reasons for using the employment figures from the County Business Patterns are their ease of access, their availability yearly since 1964, and their existence by county and by sector (or better) for almost all sectors. This study employs both manufacturing and retail employment.

CROSS-SECTIONAL RESULTS

No significant or consistent correlation between state highway expenditures and either manufacturing or retail employment could be determined from the cross-sectional analysis of the data. This result was not surprising and, indeed, was in agreement with findings from previous analyses of this nature mentioned earlier. Such a conclusion refers to absence of relationships in the long term (e.g., at equilibrium beyond a 20-year horizon); it does not consider possible interactions occurring within this

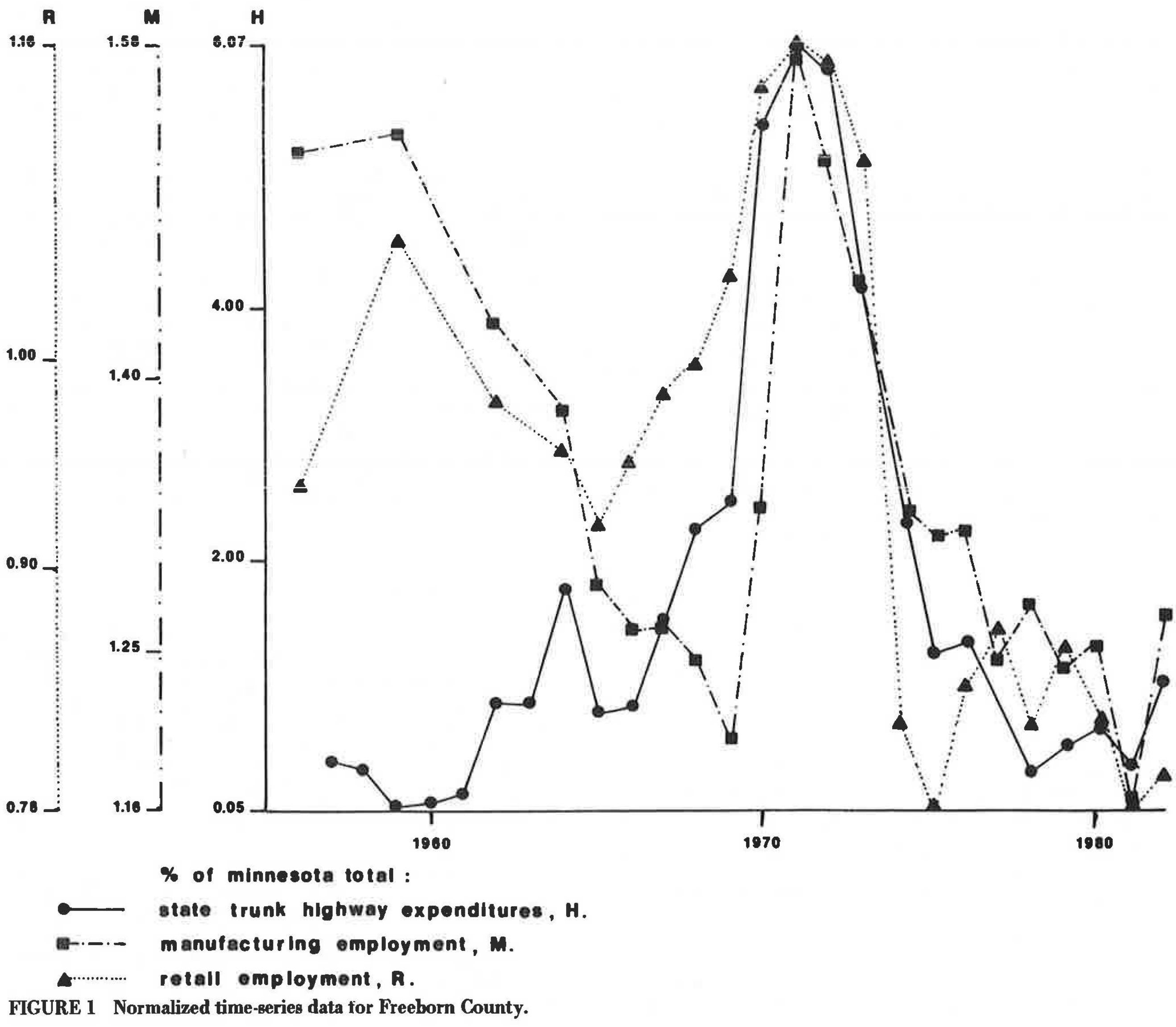

FIGURE 1 Normalized time-series data for Freeborn County.

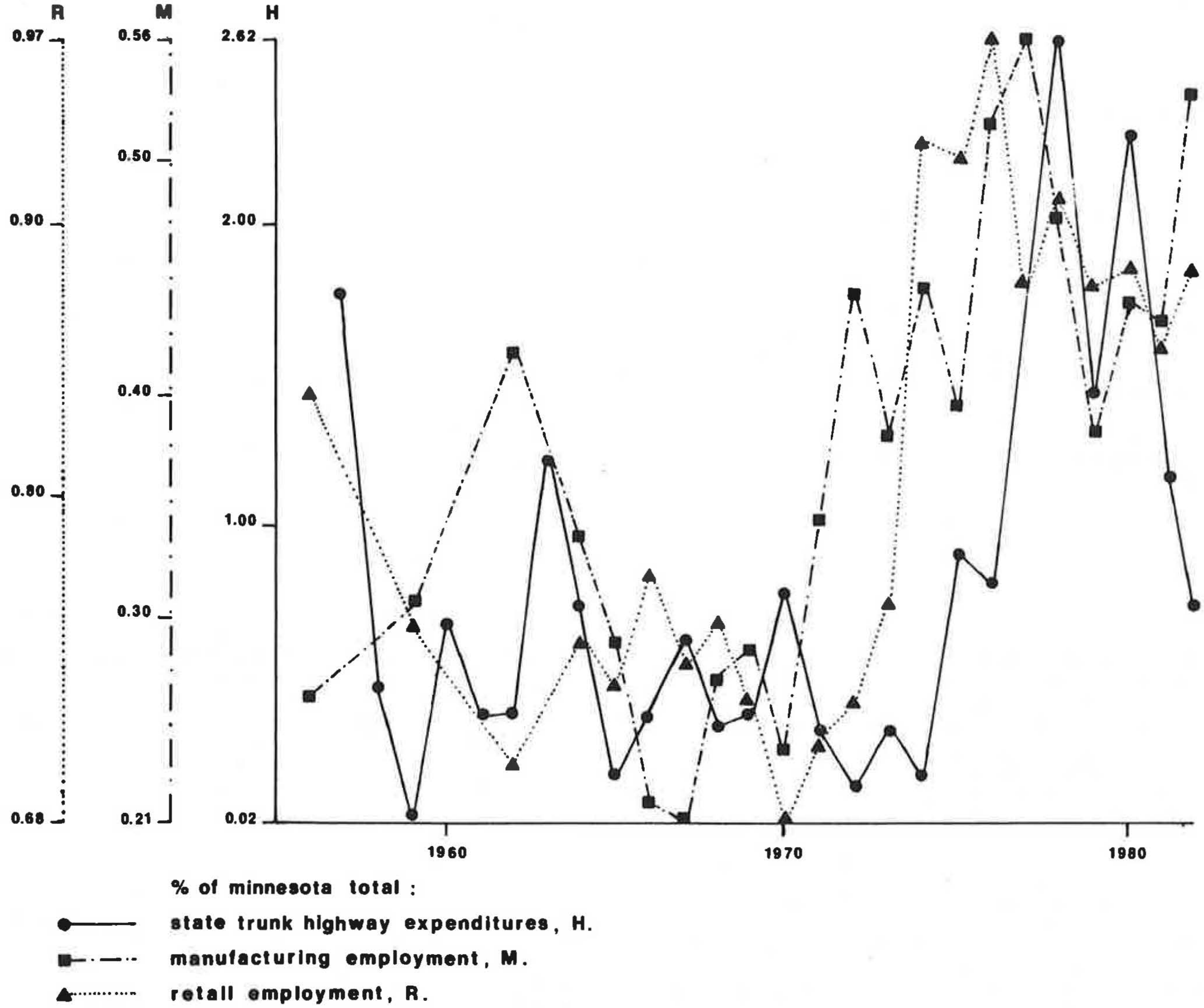

FIGURE 2 Normalized time-series data for Kandiyohi County.

period. Because evidence exists that any possible effects of transportation on the economy may occur within shorter time periods, such as in 1 to 8 years (11,12), time-series analysis of the data was performed next.

To fully use the available data, the data were paneled before the time-series analysis by eliminating the cross-sectional element for each variable and for each county i over all years t. The transformed manufacturing (M_{it}) and retail employment (R_{it}) and state highway expenditures (H_{it}) were derived from the raw data $\bar{M}_{it}$, $\bar{R}_{it}$, and $\bar{H}_{it}$ following the general formula:

$$V_{it} = \bar{V}_{it} - \left[\sum_{s=k}^{s=m} \bar{V}_{is}/(m - k + 1) \right] \qquad (1)$$

TABLE 1 Data Characteristics

Characteristic	Employment CBP[a]	Employment DES[b]	Unemployment DES	Median Family Income
Access	Very good	Poor	1966-1978, very good 1978- , poor	Very good
Time series	1964-	Unknown	1966-	Unknown
Time basis	Yearly	Monthly	Monthly	Yearly
All counties	Yes	Unknown	No; excludes counties with cities above 30,000 population	Yes
By sector	Yes except agriculture, mining; may also include 3- and 4-digit SIC	Yes except agriculture, mining; no additional SIC detail	No	No

[a]County Business Patterns.
[b]Department of Economic Security.

where V is any variable and k = 1957 (for employment data, k = 1964), m = 1982, and i = 1, . . . , 30.

CAUSALITY TESTS

Two hypotheses were tested, as the previous section suggests:

Hypothesis 1: $M_{it} = M(H_{it})$ (2)

Hypothesis 2: $R_{it} = R(H_{it})$ (3)

where M_{it} and R_{it} represent the county-to-state employment ratio using data reported by employers on FICA reports (excluding the self-employed) for 1 week in the middle of March each year and H_{it} represents the county-to-state ratio for expenditures on state trunk highways for that year. Regressing the employment on the same year's highway expenditures leads to the following simple specifications (t-statistic in parentheses):

$$M_{it} = \underset{(8.9)}{0.05} H_{it} \quad \text{correlation} = 0.36 \qquad (4)$$

$$R_{it} = \underset{(14.6)}{0.10} H_{it} \quad \text{correlation} = 0.53 \qquad (5)$$

For the average Minnesota county, the coefficients 0.05 and 0.10, respectively, represent the elasticities of manufacturing and of retail employment with respect to highway expenditures. If highway expenditures in the county increase by 1 percent ($25,600), these coefficients imply that manufacturing employment will increase by 0.05 percent (2.0 employees) and retail employment will increase by 0.10 percent (3.6 employees).

It is important to note that, even with such strong correlation between the variables, Equations 4 and 5 do not indicate causality in either direction. A high correlation between employment and expenditures could equally well imply that changes in employment cause changes in expenditures or that both employment and expenditures change in response to a third variable.

To determine the existence and direction of causality between employment and expenditures before formulating any relationships between the two, a series of causality tests was performed. The methodology for these tests was developed by Sims (24) following the concept of Granger (25).

The first step in determining whether a variable x "causes" a variable y consists of formulating the null hypothesis that x does not "cause" y. Next, x is regressed on past, present, and future values of y. Under this hypothesis, all future coefficients of y should be zero. If they are all zero by an F-test, no causality is likely. On the other hand, if even one future coefficient is not zero, then x is said to cause y. To be sure, even this test cannot replace the experimental demonstration of a causal relationship. The test only implies that changes in one variable precede, in a statistical sense, changes in another variable; such precedence is necessary but not sufficient for true causality. It should be noted that spectral analysis, as described by Box and Jenkins (26) is inadequate for the determination of causality because the cross spectrum of x and y can be composed of two cross spectra, one representing x causing y and the other representing y causing x (25). The Granger causality test, as applied here, goes beyond spectral analysis.

Using the 30-county time-series data, causality was tested between state trunk highway expenditures and manufacturing and retail employment. Six causality tests were performed. Each test was repeated three times: (a) for the whole data set, (b) for that part of the data set that included counties within 25 mi of a "large city," (defined here as one with more than 30,000 population), and (c) for the remainder of the data set. A summary of the test results is given in Table 2. The data in the table indicate that

TABLE 2 Causality Tests

	Probability Hypothesis is Correct		
Hypothesis	Complete Set	Near Large City[a]	Far from Large City
Manufacturing employment does not affect expenditures	0	0	0.37
Expenditures do not affect manufacturing employment	0.09	0.05	0.47
Retail employment does not affect expenditures	0	0	0.32
Expenditures do not affect retail employment	0.09	0.13	0.77

[a]Defined here as one with more than 30,000 population.

- For the complete data set, all causalities are accepted. However, the significance of employment changes causing changes in highway expenditures is much higher than that of changes in expenditure causing changes in employment.
- The set of counties near a large city behaves similarly to the complete data set.
- There exist no causalities in counties more than 25 mi away from a large city.

TIME-SERIES RESULTS

On the basis of the results from the causality tests, the vector autoregressive method (26) was used to develop three specifications for the complete data set. The three specifications can express (a) manufacturing employment as a function of state highway expenditures, (b) retail employment as a function of state highway expenditures, and (c) state highway expenditures in terms of manufacturing and retail employment. Following this analysis, a second set of three specifications was developed for areas within 25 mi of a large city, as discussed hereafter.

The vector autoregressive method employed is of the general form

$$\hat{y}_t = \theta_n(B)x_t + \phi_p(B)y_t + c \qquad (6)$$

where

y_t = the dependent variable in year t;
x_t = the independent variable in year t (x_t and θ_i can be vectors);
$\theta_n(B) = \theta_0 B^0 + \theta_1 B^1 + \theta_2 B^2 + \ldots + \theta_n B^n$;
$\phi_p(B) = \phi_1 B^1 + \phi_2 B^2 + \phi_3 B^3 + \ldots + \phi_p B^p$;
B = the lag operator (i.e., $B^s x_t = x_{t-s}$);
n and p = the number of lags for x_t and y_t, respectively; and
c = a constant.

Note that following certain transformations (see earlier discussion) the highway expenditure and employment data used in developing the following specifications are stationary. For each specification, the parameters for three time lags for the dependent and independent variables were identified and are presented together with the standard error, the R^2, and the mean square error (MSE) where

$$MSE = \sum(y_t - \hat{y}_t)^2/K \quad (7)$$

where

y_t = the observed dependent variable in year t,
$\hat{y}_t$ = the estimated dependent variable in year t, and
K = the number of observations.

Time-series analysis of the county data led to the following specification for the manufacturing employment county-to-state ratio (M_t) as a function of the expenditures ratio (H_t):

Lag t	Parameter	Standard Error
	H_t	
0	θ_0 0.011	0.0072
1	θ_1 0.020	0.010
2	θ_2 -0.019	0.010
3	θ_3 0.013	0.0078
	M_t	
1	ϕ_1 0.76	0.048
2	ϕ_2 0.0021	0.059
3	ϕ_3 0.021	0.048
Constant	0.000097	0.000053

$R^2 = 0.64$
$MSE = 1.23 \times 10^{-6}$ (8)

This specification can be written as an equation as follows:

$$M_t = 0.011\ H_t + 0.020\ H_{t-1} - 0.019\ H_{t-2} + 0.013\ H_{t-3} + 0.76\ M_{t-1} + 0.0021\ M_{t-2} + 0.021\ M_{t-3} + 0.000097 \quad (9)$$

Similarly, time-series analysis of the data on retail employment (R_t) as a function of H_t resulted in the following specification:

Lag t	Parameter	Standard Error
	H_t	
0	θ_0 0.017	0.0053
1	θ_1 -0.0036	0.0071
2	θ_2 -0.019	0.0071
3	θ_3 0.0139	0.0056
	R_t	
1	ϕ_1 0.92	0.046
2	ϕ_2 0.23	0.062
3	ϕ_3 -0.25	0.047
Constant	0.000066	0.000038

$R^2 = 0.88$
$MSE = 6.14 \times 10^{-7}$ (10)

Finally, the results on expenditures (H_t) as a function of M_t and R_t were

Lag t	Parameter	Standard Error
	M_t	
1	θ_1 0.31	0.34
2	θ_2 0.29	0.40
3	θ_3 -0.23	0.33
	R_t	
1	θ_1 0.82	0.44
2	θ_2 0.64	0.59
3	θ_3 -0.27	0.47
	H_t	
1	ϕ_1 0.88	0.048
2	ϕ_2 -0.082	0.065
3	ϕ_3 -0.22	0.050
Constant	0.00027	0.00034

$R^2 = 0.72$
$MSE = 4.93 \times 10^{-5}$ (11)

Additional time lags (i.e., more than 3 years) could have been included in the analysis. However, because such inclusion would not have improved forecasting accuracy significantly, it was decided to adopt the simpler specifications.

APPLICATION

The purpose of this section is to demonstrate how the specifications developed in this work can be used to forecast the effects of highway expenditures and county employment on each other. Because the analysis employed time-series data from Minnesota counties to develop the specifications, the forecasts deal with the varying effects that highway investment options would have on county employment in that state. This application uses the complete Minnesota data set. A simple example follows.

Let highway expenditures in a typical Minnesota county change by a one-time 10 percent increase this year (i.e., at t = 0). Use Equation 9 to forecast the resulting changes in manufacturing employment this year (t = 0), next year (t = 1), and in the years beyond.

If the equation did not contain any autoregressive (i.e., lagged values of the dependent variable M) terms, the answer would be that, in year zero, manufacturing would be 1.1 percent higher than the initial base, in year 1 it would be 2 percent higher than the initial base, and so forth. However, because of the additional M terms, the calculations become cumbersome and are completed in a microcomputer. The manufacturing forecasts are shown in Figure 3. As the figure indicates, county manufacturing employment increases by a maximum of 0.3 percent in the year following the 10 percent investment increase. Manufacturing employment drops to approximately its original value in the third year but then increases to an intermediate range and falls back to its original level in the long term. Thus the data indicate that state highway expenditures within a county favorably influence manufacturing in that county but the effect occurs in two stages. The primary, and more substantial, positive influence occurs the year after the highway funds are spent. A less substantial, long-term secondary effect implies that manufacturing employment in the county is still better off with the transportation improvement; the duration of this effect is approximately 10 years.

The effects of highway expenditures on county retail employment, determined with the specification given by Equation 10, are shown in Figure 4. As the figure suggests, a 10 percent increase in highway expenditures results in a maximum 0.17 percent retail increase that same year. However, retail drops 0.04 percent below its initial base by the third year, and, although it later recovers, it falls back to its initial level in the long term, probably drained by better access to metropolitan areas, an effect that is in agreement with previous findings (12).

In the final example, the specification given by

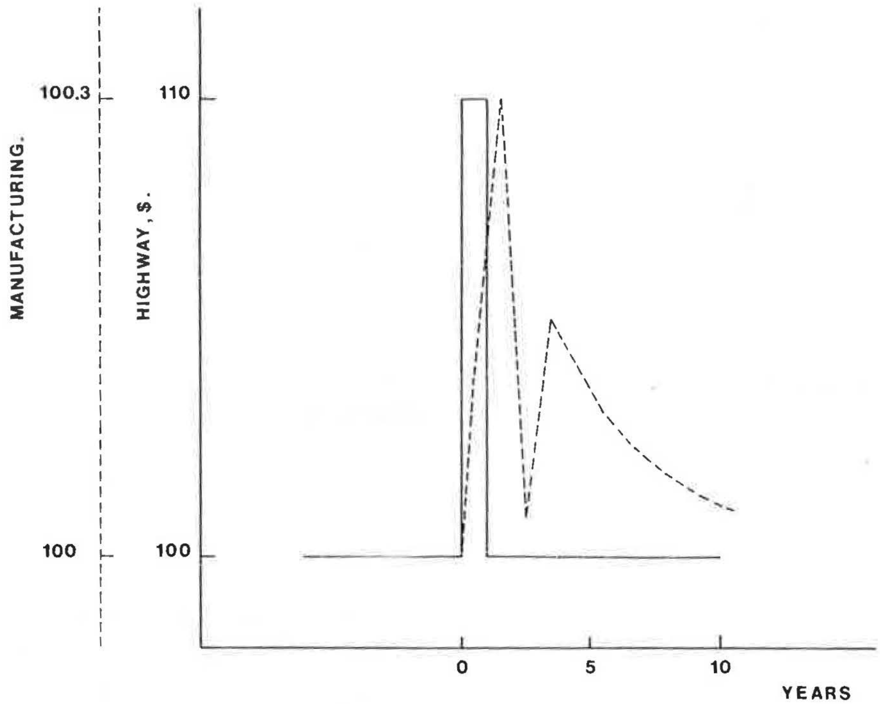

FIGURE 3 Influence of transportation on manufacturing employment.

Equation 11 is used to determine how a 10 percent increase in county manufacturing and retail employment will influence state highway expenditures in that county. The results, shown in Figure 5, indicate that highway expenditures respond to the higher needs of the county by beginning to increase a year after the employment increase. The expenditures peak in the fourth year with a 49 percent increase and then drop but still remain at a level well above the initial base. Although the expenditure increase is higher than the employment improvement in percentage terms, highway funding may be responding to changes in additional economic sectors, such as services, that usually improve with the retail sector.

Using the data set from counties near a large city (as defined earlier), the analysis developed three new specifications that correspond to those developed with the complete data set. In summary, although the results were similar to those for the complete set, manufacturing and retail employment dropped severely following their short-term peak, which indicates that the long-term draining effect

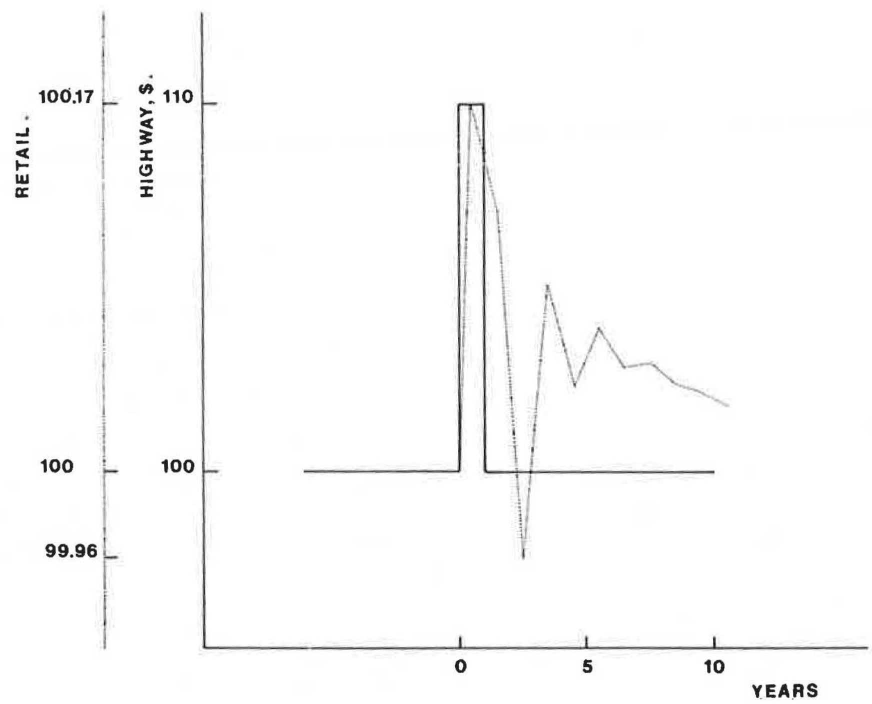

FIGURE 4 Influence of transportation on retail employment.

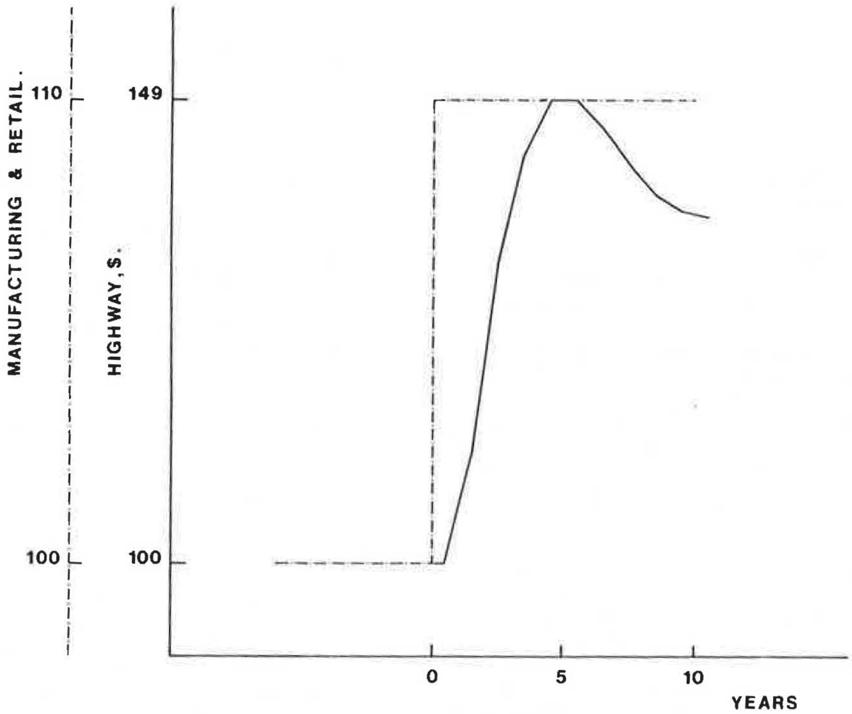

FIGURE 5 Influence of manufacturing and retail employment on transportation.

caused by better access to metropolitan areas is more substantial when a county is near such an area.

CONCLUSIONS

State trunk highway expenditure and employment data from 30 Minnesota nonmetropolitan counties are analyzed and possible interactions between highway expenditures and employment are investigated. In agreement with some previous research, cross-sectional analysis of the data suggests no significant interactions. However, more rigorous causality tests identify such interactions (i.e., highway expenditures influence manufacturing and retail employment, and employment affects highway expenditures). Nevertheless, causality is not indicated for counties located more than 25 mi from large cities (defined here as cities with more than 30,000 population).

Using time-series data from the period 1957-1982, the vector autoregressive method developed specifications for the cases in which causality existed, both for the complete data set and, separately, for the counties located near large cities.

From the specifications it is concluded that, although state trunk highway expenditures influence both manufacturing and retail county employment, the short-term effects differ from the long-term ones. In particular, although employment increases in the first 2 or 3 years following highway improvements, it then drops and, by approximately the 10th year, is back to its initial base, possibly drained by better access to metropolitan areas. Further, highway expenditures respond to county needs by improving service within a year after employment begins to increase. Finally, it is found that counties within 25 mi of a large city behave much like the complete data set except that, in their case, the draining effect to metropolitan areas is more severe.

Although these findings shed some light on the existence, direction, and size of causal effects between highway investment and the regional economy, several questions still remain unanswered and are currently under investigation. For instance, the possibility of interactions between transportation and additional sectors of the economy, such as the service sector, must be investigated, and more economic indicators can be employed to complete such assessment. Further, large highway construction projects, such as the Interstate program, can be distinguished from the rest of the projects and each set evaluated separately. Finally, more work in isolating the effects of large cities on their surrounding regions will aid in clarifying the interactions between highway expenditures and the economy of those regions.

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The Economics of Transporting Solid Wastes

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ABSTRACT

The problems associated with the management of solid wastes in today's society are complex and challenging. Transportation of solid waste is an important component of the management system. In this paper an attempt is made to identify the various economic components of transporting solid wastes. A methodology for justifying the construction of transfer stations is suggested, and the impacts of population growth and distance to landfill on the economics of transfer stations are evaluated. The analysis concludes that the location of the transfer station with respect to the waste generators and the landfill has a direct and significant impact on the economic analysis and a detailed approach to the problem is strongly recommended. It is also concluded that the cost saving due to constructing a transfer station increases with the increase in distance between the waste generators and the landfill--a break-even point was observed at around 10 mi. Finally, it was observed that should the population of generators increase unexpectedly, the cost saving would increase.

Solid wastes are wastes that arise from human and animal activities and that are normally solid and discarded as useless or unwanted products. They encompass the heterogeneous accumulations of agricultural, industrial, and mineral wastes. The accumulation of solid wastes is a direct consequence of life, and the management of these wastes is a monumental task.

The problems associated with the management of solid wastes in today's society are complex because of the diverse nature of the wastes and the development of sprawling urban areas. Two critical activities associated with the management of solid wastes from the point of generation to final disposal have been identified: collection, and transfer and transport.

The functional element of collection, generally, includes the gathering of solid wastes and the hauling of these wastes to a location where the collection vehicle is emptied. This location may be a transfer station, a processing station, or a landfill disposal site. Collection accounts for close to 80 percent of the total annual cost of urban solid waste management (1). The functional element of transfer and transport involves the transfer of wastes from the smaller collection vehicle to larger transport equipment and the subsequent transport of the wastes over long distances to the disposal site. In small cities where the final disposal sites are nearby, the hauling of wastes is not a serious problem. In large cities, however, where the haul to the point of disposal is long, the haul may have serious economic implications. The solution to the problem of long-distance hauling is complicated because the motor vehicles that are well adapted to long-distance hauling are not well suited or particularly economical for house-to-house collection. Consequently, supplemental transfer and transport facilities and equipment are needed.

In this paper an attempt is made to identify the various economic components of transporting solid wastes, a methodology for justifying transfer stations is suggested, and the impacts of population growth and the distance to landfill on the economics of transfer stations are evaluated.

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BACKGROUND INFORMATION

Transfer and transport operations become a necessity when haul distances to available disposal sites or processing centers increase to the point that direct hauling is no longer economically feasible. Transfer stations are used to accomplish the removal and transfer of solid wastes from collection and other small vehicles to long-haul transport equipment. Transfer stations may be classified with respect to rate as follows: small, less than 100 tons per day; medium, between 100 and 500 tons per day; and large, more than 500 tons per day. Factors to be considered in the design of transfer stations include type of transfer operation, capacity requirements, equipment requirements, and sanitation requirements (1).

A typical large-capacity transfer station is composed of collection vehicle unloading area, storage pit, platform scales, stationary hydraulic clamshell, auxiliary equipment (cranes and bulldozers), and transfer vehicles. All incoming collection trucks are routed to the platform scales where each truck is weighed. Then the contents of the vehicle are emptied into the storage pit. Bulldozers are used to crush uncompacted wastes and move them through the pit to the loading hoppers. Articulated cranes are used to distribute the load in the transfer vehicles before the vehicles leave their loading position (2).

Transfer stations should be located as close as possible to the weighted center of the individual solid waste production areas to be served, within easy access to major highway routes, and where construction and operation are most economical.

A recent survey, performed jointly by Waste Age and the Association of State and Territorial Solid Waste Management Officials, of 1,278 transfer stations in 42 states reported that only 70 handled more than 300 tons per day (3). Of the total identified transfer stations, the following breakdowns by type were available:

- Enclosed stations with compaction: 396
- Enclosed stations, no compaction: 56
- Open stations with compaction: 103
- Open stations, no compaction: 291

Reports from different cities have revealed small to moderate savings due to the use of transfer stations. In Tucson, Arizona, city administrators claim that their transfer facilities net up to $185,000 per year in direct operating and maintenance savings (4). In Chicago, Illinois, a 900-ton per day transfer station, operated by a private company, reported a successful story. Larry Groot, the owner of C. Groot Disposal, concluded that the direct return on a transfer station investment may be small. However, the indirect benefits should flow in a wide and profitable stream (5). Other reports from Hempstead, New York, Tampa, Florida, and Montgomery County, Maryland, indicated that a well-designed and managed facility could result in a profitable operation (6-8). The question that remains unanswered at this juncture is: At what level of long-haul distance and solid waste generation rate may a transfer station be justifiable? This study will attempt to answer that question.

FEASIBILITY OF TRANSFER STATIONS

In this section, an incremental economic analysis is presented to evaluate the feasibility of transfer stations. Five major components of the economic analysis were identified, and the proposed analysis was applied to five localities within the Phoenix metropolitan area in Arizona.

The five major components of the economic analysis include:

1. Transportation costs without a transfer station from the waste generation area to the candidate landfill site;
2. Transportation costs with one transfer station from the local waste generators to the transfer station; these are called short-haul costs;
3. Transportation costs with a transfer station from the transfer station to the candidate landfill; these are called long-haul costs;
4. Capital costs for constructing the facility; and
5. Operation and maintenance costs of the transfer station.

Transportation Costs Without a Transfer Station

A review of the literature related to collection trucks showed that their capacity ranges between 6 and 45 yd^3 per loading. For this study, it was assumed that the average truck has a hauling capacity of 35 yd^3 at a waste compaction rate of 1,000 lb per cubic yard. The average number of trips per year was calculated from

No. of trips per year = (total tonnage x 2,000)/(1,000 x 35)

Trip mileage to a candidate site was measured from the center of each locality to the landfill site. Multiplication of number of trips per year times trip length gave the average annual mileage for any given landfill site. A cost per mile factor of $3.91 was used to calculate the annual transportation cost from the average annual mileage. This cost per mile factor was determined on the basis of data collected in Phoenix, Arizona, and the following assumptions:

- A typical collection truck costs $80,000 and has a life mileage of 65,000 mi; the replacement cost, therefore, amounts to $1.23 per mile;
- Collection trucks travel at an average speed of 30 mph, and an average operator wage of $12.40 per hour amounts to $0.41 per mile; and
- A typical collection truck costs around $2.27 per mile in operation and maintenance.

Although the $3.91 per mile cost rate includes replacement costs, it does not include the collection down time for waste trucks while they are traveling to a distant landfill. A separate analysis was conducted to estimate the annual cost for down time using the following assumptions:

- 250 working days per year;
- 20-min loading and unloading period;
- 8 working hours per day with 3 hr covering the peak period;
- Average running speed of 30 mph; and
- The cost per mile rate increases by an inflation rate of 6 percent annually, and capitalization was financed at 8 percent over a 30-year period.

Short-Haul Transportation Costs

Short-haul transportation represents the transportation of solid waste from the generation area to the transfer station. The assumptions made for the transportation cost without a transfer station were applied to the short-haul analysis. The only difference is that short-haul movements have relatively shorter hauling distance than does direct haul from the collection area to landfills. It is critical to locate transfer stations at strategic sites close to major waste generators to minimize the total short-haul transportation cost.

Long-Haul Transportation Costs

Long-haul transportation represents the transportation of compacted waste from the transfer station to the landfill using appropriate transfer trucks. The following assumptions were made for this analysis:

- Transfer trucks, of 72 yd^3, are used, each at a cost of $110,000 and with a life mileage of 65,000 mi;
- Waste is compacted at a rate of 1,000 lb per cubic yard;
- Because transfer trucks travel mostly on highways, their maintenance and fuel consumption cost is significantly lower per unit traveled than is that of collection pick-up waste trucks; a cost rate of $2.00 per mile was used for replacement, labor, and maintenance of trucks; and
- An inflation rate of 6 percent and an interest rate of 8 percent were used over the 30-year analysis period.

Capital Costs of Transfer Stations

The capital cost of a transfer station generally consists of four components: (a) land cost, (b) building cost and other related components, (c) in-station equipment, and (d) transfer trucks. The land cost is assumed to be $50,000 per acre, and the area needed is a function of the daily activities of the station. The second cost category includes administration building, scale, scale house, storage pit, transfer building, earthwork, landscaping, paving, fencing, insurance, and contingency. In-station

TABLE 1 Capital Cost ($000s) Categories for Six Levels of Facility Output

	Facility Output (TPD) of					
	600	1,100	1,400	1,800	2,200	3,200
Building and other costs	2,500	2,500	2,500	3,500	3,500	7,000
Land cost	500	750	750	1,000	1,000	1,000
In-station equipment cost	120[a]	160	160	160	320	320

Source: Information provided by the Sanitation Divisions of the cities of Phoenix and Glendale.

[a]Two bulldozers and one crane at $40,000 each.

equipment includes bulldozers and cranes, and the number of these is also a function of the ton per day (TPD) rating of the station. Table 1 gives the first three capital cost categories as a function of six levels of TPD (600, 1,100, 1,400, 1,800, 2,200, and 3,200).

For the fleet size determination, the following assumptions were made:

• 250 working days per year, 20 percent for peak day higher than the average day, and 3 peak hours per day and

• Average operating speed of 35 mph.

Cost of Transfer Station Operation and Maintenance

The cost of operating and maintaining a typical transfer facility normally includes the following items:

• Labor costs for crane operators, bulldozer operators, scale operators, clerks, and supervisors;
• Maintenance and parts;
• Fuel and oil;
• Utilities;
• Building and site maintenance;
• Insurance; and
• Contingency.

The cost of operation and maintenance is a direct function of the total TPD. Surveying transfer stations currently in operation and making appropriate assumptions resulted in operating costs of $480,000, $750,000, $800,000, $900,000, $1,140,000, and $1,440,000 for the same six TPD levels listed in Table 1 (namely: 600, 1,100, 1,400, 1,800, 2,200, and 3,200 TPD). These estimates were developed using personnel costs and other information provided by the Sanitation Divisions of the cities of Phoenix and Glendale, Arizona.

Application of Model to Arizona Sites

A feasibility study for constructing a transfer station to serve five localities in Arizona (El Mirage, Surprise, Peoria, Youngtown, and rural county) was conducted. These localities are located within the Phoenix metropolitan area.

The first step in the analysis was to develop waste projections for the five localities. The 1980 Maricopa Association of Government (MAG) projections on waste generation for Maricopa County were used to develop population projections and waste projections (Table 2). These projections were based on a generation rate of 4.10 lb per capita per day increasing annually at a rate of 0.10 lb per capita per day until reaching 6.10 lb per capita per day.

For purposes of the study, two sites were considered for constructing a transfer station. The first site (TS 1) is located in El Mirage, and the second site (TS 2) is located in Sun City West. Land cost, zoning constraints, and the location of the landfill were the main criteria used in selecting the sites. Table 3 gives the hauling distances between the collection sites and both the landfill and transfer stations.

TABLE 2 Population Projections and Waste Production

Year	El Mirage	Surprise	Peoria	Youngtown	Rural[a]	Total
Population						
1985	6,050	5,670	23,480	2,310	51,110	88,620
1990	8,390	7,600	35,740	2,400	62,420	116,550
1995	10,540	9,380	51,270	2,500	73,840	147,530
2000	12,900	11,430	71,230	2,500	82,940	181,000
2005	15,050	13,420	92,620	2,500	90,990	214,580
2010	17,420	15,350	117,100	2,500	99,500	251,870
2015	20,240	17,170	146,430	2,500	109,400	295,740
Waste (tons)						
1985	4,527	4,243	17,569	1,728	38,243	66,310
1990	7,043	6,380	30,004	2,015	52,402	97,844
1995	9,810	8,730	47,720	2,327	68,727	137,314
2000	13,184	11,681	72,797	2,555	84,765	168,466
2005	16,754	14,940	103,109	2,783	101,295	199,720
2010	19,393	17,088	130,362	2,783	110,768	280,394
2015	22,532	19,115	163,013	2,783	121,790	329,233

[a]Sun City and Sun City West.

TABLE 3 Haul Distances (mi) Between Collection Sites and Both the Landfill and the Transfer Stations

	El Mirage	Surprise	Peoria	Youngtown	Rural
Landfill	14.50	14.00	23.00	17.50	19.00
Transfer station (TS 1)	3.00	3.50	8.50	1.50	4.75
Transfer station (TS 2)	5.25	2.75	4.75	2.75	2.00

Note: TS 1 to landfill = 10.75 mi and TS 2 to landfill = 9.00 mi.

All the costs estimated in the analysis were annualized over a 30-year analysis period (1985-2015) and discounted at 8 percent to present worth. The short-haul transportation cost, long-haul transportation cost, transfer station capital cost, and operating costs were summed using the appropriate economic factors to determine the equivalent discounted annual cost associated with the two station alternatives. The net annual cost, namely the equivalent annual cost without the transfer station minus the equivalent annual cost with the transfer station, was used as the justification measure. It was assumed that the station is designed for the year 2015.

Microcomputer spreadsheet software (LOTUS 123) was used to conduct the analysis. This program permitted a fast and easy assessment of different planning scenarios that will be discussed in the next sections of the paper.

Impact of Station Location

Economic analysis was conducted first for site TS 1. The hauling distances were measured from an approximate location in the center of the locality to either the transfer station or the landfill depending on the cost category. For short haul, as an example, the distance is measured to the transfer station. The results of this analysis are given in Tables 4-6. Table 4 gives the results of the transportation cost without a transfer station. The first line in

TABLE 4 Transportation Cost Without Transfer Station

Year	Item	El Mirage	Surprise	Peoria	Youngtown	Rural	Total
1985	Yd^3/yr	9,053.83	8,485.16	35,137.82	3,456.92	76,486.12	132,620
	Loads/yr	258.68	242.43	1,003.94	98.77	2,185.32	3,789
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	17.39
	Cost ($)	25,286	22,750	164,867	11,972	290,516	515,391
1990	Yd^3/yr	14,086.81	12,760.40	60,007.46	4,029.60	104,803.16	185,637
	Loads/yr	402.48	364.58	1,714.50	115.13	2,994.38	5,591
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	17.55
	Cost ($)	39,342	34,212	281,555	13,955	398,072	767,137
1995	Yd^3/yr	19,620.21	17,460.87	95,439.11	4,653.75	137,453.16	274,627
	Loads/yr	560.58	498.88	2,726.83	132.96	3,927.23	7,846.49
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	17.73
	Cost ($)	54,796	46,815	447,800	16,117	522,086	1,087,615
2000	Yd^3/yr	26,367.60	23,362.92	145,594.12	5,110.00	169,529.36	369,964
	Loads/yr	753.36	667.51	4,159.83	146.00	4,843.70	10.570
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	17.92
	Cost ($)	73,641	62,639	683,128	17,697	643,921	1,481,025
2005	Yd^3/yr	33,508.83	29,879.63	206,218.43	5,566.25	202,589.24	477,762
	Loads/yr	957.40	853.70	5,891.96	159.04	5,788.26	13,650.35
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	18.08
	Cost ($)	93,585	80,112	967,577	19,277	769,492	1,930,042
2010	Yd^3yr	38,785.63	34,176.78	260,723.15	5,566.25	221,536.75	560,798.56
	Loads/yr	1,108.16	976.48	7,449.23	159.04	6,329.62	16,022.53
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	18.23
	Cost ($)	108,323	91,633	1,223,313	19,277	641,460	2,284,005
2015	Yd^3/yr	45,064.36	38,229.01	326,026.39	5,566.25	243,579.10	658,465.11
	Loads/yr	1,287.55	1,092.26	9,315.04	159.04	6,959.40	18,813.29
	Distance (mi)	12.50	12.00	21.00	15.50	17.00	18.37
	Cost ($)	125,858	102,497	1,529,716	19,277	925,183	2,702,531

Note:

N	PWF	PW ($)
0	1.000	515,391
5	1.000	3,627,782
10	0.681	3,500,453
15	0.463	3,244.087
20	0.315	2,877,259
25	0.215	2,317,339
30	0.146	1,866,144

Total present worth $17,948,455
Annual transportation cost $1,594,315
Adjustments for down time

Year	RTT	EDS	EHS	EFS	EFS5Y	PW
1990	1.84	7.21	0.90	1.65	0.56	30,394.48
1995	1.85	9.02	1.13	2.08	0.71	24,327.39
2000	1.86	10.90	1.36	2.53	0.87	22,025.18
2005	1.87	12.32	1.54	2.88	1.00	17,204.55
2010	1.88	9.49	1.19	2.23	0.78	9,140.20
2015	1.89	11.16	1.40	2.64	0.93	7,411.57

PW down time cost $112,503
Annual down time cost $9,993

RTT = round-trip time (hr), EDS = extra daily shipment, EHS = extra hourly shipment, EFS = extra fleet size, EFS5Y = extra fleet size over 5 years, PW = present worth, RTT = (one-way distance/30 + 0.33) · 2, EDS (forecast yd^3 - original yd^3/(250 · 35), EHS = EDS/8, EFS = RTT · EHS, and EFS5Y = EFS · (one-way distance · 250 · 5)/65,000.

the table represents the total annual waste in cubic yards taken from Table 2. The second line shows the number of loads per year calculated from line 1 (line 1 divided by 35). The distances shown in the third line are taken from Table 3, and the distance shown under the heading "Total" represents an average weighted distance. This average weighted distance was used only in the down time calculation as will be discussed later. The annual cost was simply calculated by multiplying the number of loads times the distance times $3.91. PWF stands for series present worth factor, and PW is the present worth of cost.

For the adjustments for down time, the round-trip time was calculated knowing the distance (average weighted distance), the speed, and the extra time at either end for loading and unloading. The extra daily shipments (EDS) were calculated for 5-year increments of yearly yardage. For example, the extra daily shipment for 1990 is calculated from the difference between 1990 and 1985 divided by 35 cubic yards per shipment and by 250 working days per year. Furthermore, it was assumed that a typical day contains 8 working hours and that the truck should be replaced every 65,000 miles. These parameters were used to calculate the extra fleet size needed over a 5-year period.

Transfer station capital and operations costs, in dollars, are as follows:

Total yd³	132,620
Daily peak	8.84
Hourly peak	2.95
Speed (mph)	35
Round trip (mi)	0.64
Fleet size	2
Building cost	2,500,000
Land cost	750,000
In-station equipment	160,000
Trailer cost	206,550
Total capital	3,616,550
Annual cost	321,249

TABLE 5 Transportation Cost with Transfer Station (short haul)

Year	Item	El Mirage	Surprise	Peoria	Youngtown	Rural	Total
1985	Yd^3/yr	9,053.83	8,485.16	35,137.82	3,456.92	76,486.12	132,620
	Loads/yr	258.68	242.43	1,003.94	98.77	2,185.32	3,759
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	5.46
	Cost ($)	6,069	6,635	66,732	1,159	81,174	161,768
1990	Yd^3/yr	14,086.81	12,760.40	60,007.46	4,029.60	104,803.18	195,687
	Loads/yr	402.48	364.58	1,714.50	115.13	2,994.38	5,591
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	5.63
	Cost ($)	9,442	9,979	113,963	1,350	111,226	245,960
1995	Yd^3/yr	19,620.21	17,460.87	95,439.11	4,653.75	137,453.16	274,627
	Loads/yr	560.58	498.88	2,726.83	132.96	3,927.23	7,846.49
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	5.79
	Cost ($)	13,151	13,654	181,252	1,560	145,877	355,495
2000	Yd^3/yr	26,367.60	23,362.92	145,594.12	5,110.00	169,529.36	369,964
	Loads/yr	753.36	667.51	4,159.83	146.00	4,843.70	10,570
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	5.98
	Cost ($)	17,674	18,270	276,504	1,713	179,919	494,079
2005	Yd^3/yr	33,508.83	29,879.63	206,218.43	5,566.25	202,589.24	477,762
	Loads/yr	957.40	853.70	5,891.96	159.04	5,788.26	13,650.35
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	6.13
	Cost ($)	22,460	23,366	391,638	1,865	215,005	654,335
2010	Yd^3yr	38,785.63	34,176.78	260,723.15	5,566.25	221,536.75	560,788.56
	Loads/yr	1,108.16	976.48	7,449.23	159.04	6,329.62	16,022.53
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	6.26
	Cost ($)	25,997	26,726	495,151	1,865	235,114	784,853
2015	Yd^3/yr	45,064.36	38,229.01	326,026.39	5,566.25	243,579.10	658,465.11
	Loads/yr	1,287.55	1,092.26	9,315.04	159.04	6,959.40	18,813.29
	Distance (mi)	3.00	3.50	8.50	1.50	4.75	6.39
	Cost ($)	30,206	29,895	619,171	1,865	258,507	939,644

Note:

N	PWF	PW ($)
0	1.00	161,768
5	1.00	1,163,142
10	0.68	1,144,148
15	0.46	1,082,248
20	0.32	975,467
25	0.21	796,308
30	0.15	648,840

Total present worth $5,971,921
Annual transportation cost $530,470

Adjustments for down time

Year	RTT	EDS	EHS	EFS	EFS5Y	PW
1990	1.03	7.21	0.90	0.93	0.10	5,469.06
1995	1.04	9.02	1.13	1.17	0.13	4,849.67
2000	1.05	10.90	1.36	1.43	0.16	4,156.77
2005	1.07	12.32	1.54	1.64	0.19	3,318.62
2010	1.08	9.49	1.19	1.28	0.15	1,794.62
2015	1.08	11.16	1.40	1.51	0.19	1,477.29

PW down time cost $21,066
Annual down time cost $1,871

For explanation of abbreviations see Table 4.

Operating and maintenance (O&M) costs of the facility are as follows:

Year	Total O&M ($)
1985	480,000
1990	480,000
1995	480,000
2000	480,000
2005	480,000
2010	750,000
2015	750,000
PW of first 15 yr	$4,108,550
PW of second 15 yr	$1,295,187
PW of last payment	$74,533
Total present worth	$5,478,270
Annual O&M cost	$486,621

Cost without transfer station = $1,604,309. Cost with transfer station = $1,578,308. Cost savings = $26,001.

It was concluded from the analysis that a cost saving of around $26,000 can be achieved with site TS 1. The analysis of the second site, TS 2, revealed that the cost savings can amount to $298,800. As expected, the second site is centrally located with respect to the five localities; consequently, the total hauling distance is shorter. Two observations can be made: (a) down time cost is small compared with the transportation cost (Table 3) and (b) the analysis is sensitive to the location of the transfer station. The second observation brings out the need for a refined and detailed approach to determining the optimal location of transfer stations. Such an approach would require detailed data with respect to the collection routes in each locality and more information related to traffic flow in the region.

Impact of Landfill Location

To assess the impact of landfill location on the justification of the transfer station, the analysis

TABLE 6 Transportation Cost with Transfer Station (long haul)

Year	Item	El Mirage	Surprise	Peoria	Youngtown	Rural	Total
1985	Yd^3/yr	9,053.83	8,485.16	35,137.82	3,456.92	76,486.12	132,620
	Loads/yr	125.75	117.85	488.03	48.01	1,062.31	1,842
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	5,407	5,068	20,985	2,065	45,679	79,204
1990	Yd^3/yr	14,086.81	12,760.40	60,007.46	4,029.60	104,803.18	185,687
	Loads/yr	195.65	177.23	833.44	55.97	1,455.60	2,718
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	8,413	7,621	35,838	2,407	62,591	116,869
1995	Yd^3/yr	19,620.21	17,460.87	95,439.11	4,653.75	137,453.16	274,627
	Loads/yr	272.50	242.51	1,325.54	64.64	1,909.07	3,814.27
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	11,718	10,428	56,998	2,779	82,090	164,013
2000	Yd^3/yr	26,367.60	23,362.92	145,594.12	5,110.00	169,529.36	369,964
	Loads/yr	366.22	324.48	2,022.14	70.97	2,354.57	5,138
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	15,747	13,953	86,952	3,052	101,247	220,951
2005	Yd^3/yr	33,508.83	29,879.63	206,218.43	5,566.25	202,589.24	477,762
	Loads/yr	465.40	414.99	2,864.14	77.31	2,813.74	6,635.59
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	20,012	17,845	123,158	3,324	120,991	285,330
2010	Yd^3yr	38,785.63	34,176.78	260,723.15	5,566.25	221,536.75	560,788.56
	Loads/yr	538.69	474.68	3,621.15	77.31	3,076.90	7,788.73
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	23,164	20,411	155,710	3,324	132,307	334,915
2015	Yd^3/yr	45,064.36	38,229.01	326,026.39	5,566.25	243,579.10	658,465.11
	Loads/yr	625.89	530.96	4,528.14	77.31	3,383.04	9,145.35
	Distance (mi)	10.75	10.75	10.75	10.75	10.75	
	Cost ($)	26,913	22,831	194,710	3,324	145,471	393,250

Note:

N	PWF	PW ($)
0	1.00	79,204
5	1.00	552,671
10	0.68	527,872
15	0.46	483,978
20	0.32	425,363
25	0.21	339,803
30	0.15	271,546

Total present worth $2,680,437
Annual transportation cost $238,096.

was repeated assuming different long-haul distances. For site TS 1, the distance between the transfer station and the landfill was increased and decreased on either side of the original value by 1-mi increments. The new distances caused changes in the long-haul transportation cost and the transportation cost without a transfer station, and all other cost items remained essentially unchanged. Table 7 gives the results of this analysis. Closer examination of the results reveals that, as expected, as the landfill moves farther from the transfer station, the net saving increases. A break-even point does exist between distances of 9.75 and 10.75 mi. This is because, as the landfill moves farther away, the total cost without the transfer station increases faster than the increase in the long-haul cost. Furthermore, it is observed that the capital cost increase due to moving farther out. This is due to the increase in down time experienced by transfer trucks. It is interesting to conclude that a break-even distance of about 10 mi exists for this case study.

Impact of Unexpected Population Growth

The last analysis was conducted to evaluate the impact of unexpected population growth. Rural county was assumed to have growth factors of 1.25, 1.50, 1.75, 2.25, and 2.50 with respect to the forecast population as reported by the MAG. It was concluded that, as the population of this locality increases, the cost saving due to constructing a transfer station increases and the results are given in Table 8. The savings are attributed to the sharp increase in the cost without a transfer station. It was assumed that population growth will take place within the existing land use pattern and that the hauling distance from the localities to the landfill will remain essentially unchanged.

SUMMARY AND CONCLUSIONS

A review of the different economic components of transporting solid wastes was attempted. An incre-

TABLE 7 Landfill Location Results—Annual Cost Items ($)

Distance Between Transfer Station and Landfill (mi)	Without Transfer Station	Short Haul	Long Haul	Capital Cost	Operating and Maintenance Cost	With Transfer Station	Cost Saving
7.75	1,334,508	532,341	171,651	318,781	486,621	1,509,394	−174,885
8.75	1,424,402	532,341	193,799	319,603	486,621	1,532,365	−107,963
9.75	1,514,335	532,341	215,948	320,426	486,621	1,555,336	−41,001
10.75[a]	1,604,309	532,341	238,096	321,249	486,621	1,604,309	26,001
11.75	1,694,322	532,341	260,245	322,072	486,621	1,601,279	93,044
12.75	1,784,376	532,341	282,393	322,894	486,621	1,624,250	160,126

[a]Base case.

TABLE 8 Results of Population Growth Impact

Unexpected Population Growth Factor	Cost Without a Transfer Station ($)	Cost With a Transfer Station ($)	Cost Saving ($)
1.0	1,604,309	1,578,308	26,001
1.25	1,780,644	1,658,145	122,499
1.50	1,956,984	1,802,258	154,725
1.75	2,133,326	1,881,660	251,666
2.00	2,363,670	2,072,979	290,691
2.25	2,486,017	2,164,367	321,650
2.50	2,662,365	2,243,772	418,592

mental economic analysis to justify transfer stations was formulated, and a computer program utilizing LOTUS 123 was developed. The proposed approach was applied to five localities and two proposed station sites. The following conclusions were drawn:

1. The results of the analysis are highly sensitive to the location of the transfer station.
2. As the landfill gets farther away from the localities, the cost savings due to constructing a transfer station increase. A break-even point was observed at a distance of around 10 mi.
3. As the population unexpectedly increases, the cost saving due to constructing a transfer station increases.

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Transportation Network Investment Problem—A Synthesis of Tree-Search Algorithms

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ABSTRACT

In this paper tree-search algorithms that are particularly adept at solving network-design problems in transportation planning are surveyed and synthesized. A unified view of the underlying principles of these tree-search algorithms is presented. Two methodologies--branch-and-bound and branch-and-backtrack--have been identified as promising techniques for solving typically nonlinear and ill-behaved network-design problems, particularly when they are coordinated with the postoptimality procedures of link lengthening and link shortening in minimum-path computation. The two algorithms are then compared, and a third algorithm--based on double bounding--is synthesized to solve transportation network-design problems more efficiently.

A number of problems in transportation planning deal with network investment or network design. An example may be the improvement of a rail or highway network where the heavy capital investment involved necessitates a careful configuration. A body of literature exists on this type of analysis, which is often referred to as the link-addition problem. This paper is written to summarize the pertinent techniques that address the problem.

The plan of presentation is as follows: First, the essential elements of the mathematical formulation of a transportation network-design problem are identified. Second, a brief review of the solution methods, which lead to the potential of the tree-search technique, is presented. Third, examples of the upper- and lower-bound tree-search techniques are given, compared, and their key features uncovered. The comparison helps to arrive at a generalized bounding technique to solve network-design problems.

PROBLEM STATEMENT

The substantive problem of this paper can be stated as follows: The transportation planner is given a fixed budget, B, to improve a multiple origin-destination network. Each link in the network is associated with a level-of-service function $C_{ij}(X_{ij})$, which is a monotonically increasing function of flow, X_{ij}. Investment projects are defined for a link (i,j), where $\Delta C_{ij}(X_{ij})$ denotes the improvement on link (i,j). It is assumed that the project candidates have been identified (i.e., ΔC_{ij}'s are exogenously defined for a subset of the links). The problem is remotely similar to a knapsack problem in the sense that an attempt is made to fit a number of projects, each with a nonzero cost of b_{ij}, into the budget:

$$\sum_{(ij)} b_{ij}\,\delta_{ij} \leq B \tag{1}$$

where δ_{ij} is a 0-1 variable that denotes whether project ΔC_{ij} is rejected (0) or accepted (1). A shorthand form for Equation 1 is $\underline{b}^T\underline{\delta} \leq B$.

This is a multicommodity network flow (1). Each "commodity" is defined as the vehicles, passengers, or cargo that start from an origin (O), k, heading for destination (D), ℓ. There are as many commodities as the number of origin-destination (O-D) pairs. The constraints can be written as a tableau of a block diagonal form; each block is a "copy" (2) of the node-arc incidence matrix, $A^{k\ell}$, representing the flow between k and ℓ. The flow between k and ℓ using link (i,j) is denoted by $X_{ij}^{k\ell}$'s, which are grouped into a vector $\underline{X}^{k\ell}$. Each copy $A^{k\ell}$ models an amount of flow $V^{k\ell}$ originating at k and terminates at ℓ. The node-arc incidence matrix $A^{k\ell}$ is composed of the following elements:

$$\sum_i X_{ip}^{k\ell} - \sum_j X_{pj}^{k\ell} = \begin{cases} -V^{k\ell} & \text{if } p = k \\ V^{k\ell} & \text{if } p = \ell \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where the O-D demand $V^{k\ell}$'s are functions of the level of service from k to ℓ [i.e., $V^{k\ell}(C^{k\ell})$]. If $\underline{d}^{k\ell}$ is used to denote the right-hand vector of Equation 2, each copy of commodity flow can be written as

$$A^{k\ell}\underline{X}^{k\ell} = \underline{d}^{k\ell}(\underline{C}^{k\ell}) \tag{3}$$

The flow on a link comes from diverse O-D pairs:

$$\sum_{k\ell \in R_{ij}} X_{ij}^{k\ell} = X_{ij} \tag{4}$$

where R_{ij} is the set of O-D flows that utilizes link ij.

The objective function minimizes the individual vehicle's travel cost (i.e., user optimizing instead of system optimizing) (3) for highway travel:

$$\text{Sup } Z = G\left\{\sum_{R^{k\ell}} \min \sum_{(ij)\in R^{k\ell}} [C_{ij}(X_{ij}) - \Delta C_{ij}(X_{ij})\,\delta_{ij}]\,X_{ij}^{k\ell}\right\} \tag{5}$$

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where

$R^{k\ell}$ = the set of links contained in the routing from k to ℓ,
$G(\underline{\delta})$ = monotone function of the project vector $\underline{\delta}$, and
$Sup(\cdot) = \overline{max}(\cdot)$ or $min(\cdot)$.

For scheduled transportation services such as trains and airplanes, vehicular flow can be more appropriately modeled by a system-optimizing objective function (4,5), which is Equation 5 without the minimization operator between the summation signs. Notice that the amount of travel cost each project saves (henceforth called the "value" of a project) is not explicitly stated. The reason is that each time a project ΔC_{ij} is implemented, the flows X_{ij} may change because of a possible change in the minimum cost flow paths. The implementation of a particular project would affect the minimum cost flow pattern in a different way (and hence its value is different) depending on whether and what other projects have been implemented. The link-travel-time-reduction projects are termed dependent (6) because the value of a project depends on whether and what other projects have been implemented.

Obviously, variants of this "classic" formulation are found. Instead of minimizing the system or user cost, the total budget expenditure for a given level of effectiveness may be minimized (7). Furthermore, maximization of consumers' surplus and a system-equity measure (8) may be employed. Instead of a single period problem, a staged-investment formulation (8-11) can be used. Finally, a hierarchical approach to network investment (7,12) can be employed. The important point is that the tree-search method is flexible and robust enough to tackle all of these variants.

REVIEW OF SOLUTION METHODS

It is well recognized that there are serious limitations of the formal developments in mathematical programming for solving the typically ill-behaved transport network-design problem (13-15). Here a set of network-design methodologies, which combines the versatility of the enumerative-type algorithm with some analytical niceties of the algebraic formulations, is presented. These algorithms are referred to as tree-search solution algorithms in which the geometric configuration (the network synthesis problem) is structured by the enumerative mechanism and the passenger or commodity flow problem is solved by an algebraic formulation (the network analysis problem). In this way, a problem is decomposed into subproblems (4,16). The tree-search algorithms as defined here have the following additional advantages: First, the network-flow algorithms--such as traffic assignment--are computed only as needed and often involve postoptimality procedures in minimum-path computations. Second, the tree-pruning criteria are often stronger, thus delimiting the computational space. Finally (but probably most significant), the tree-search strategy as defined in this fashion indicates adaptability to the many more "real-life" issues encountered in transport network design--a point that will be elaborated.

TREE SEARCH

Included in the synthesis of tree search is a class of enumerative solution methods such as branch-and-bound and implicit enumeration (branch-and-backtrack) (7,8,17-30). Tree search derives its name in part from the way the solution procedure is graphically displayed as a directed tree (see example in Appendix). The solution strategy is to break up (or decompose) the original difficult problem into easier, auxiliary problems, each of which constitutes a network analysis problem.

An auxiliary problem is defined at the nodes of the directed tree. The first node of the tree is the root. In the directed tree, there is branching from a predecessor node to two or more successor nodes. Thus in the network-design problem cited previously $Z(\underline{\delta})$ is minimized or maximized by an optimal choice of $\underline{\delta}^*$. The solution strategy involves dividing the set of all feasible and infeasible solutions D into the combinatorial space of q subsets, where

$$D_1 \cup D_2 \cup \ldots \cup D_q = D \qquad (6)$$

A partial solution is defined as one in which only a subset of the n decision variables has been assigned 0-1 values. Those decision variables not yet assigned a binary value are called the free variables. A completion of a partial solution is obtained by specifying binary values for the free variables.

In the directed tree, each auxiliary problem can be written as $Z_k(D_k)$ at node k. Among the current successor nodes, a lower bound can be computed for the corresponding network-analysis problem, yielding $Z_k^L(D_k)$ with

$$Z_k^L(D_k) \leq Z(\underline{\delta}) \qquad \underline{\delta} \in D \qquad (7)$$

Such a bounded node is where branching takes place in the next step in the branch-and-bound algorithm. Likewise, an upper bound U is computed for the optimal solution $\underline{\delta}^*$.

A node is said to have been dominated if its objective function cannot be made better (than the objective function of a feasible solution already obtained) by further branching. Fathoming a node is the process of completing (explicitly or implicitly) the partial solution at that node. Inactive or fathomed nodes are nodes that have been considered and need not be investigated further because of dominance, feasibility, or end-of-branch considerations. In other words, if $Z_k^L > U$, the successor D_s cannot include the optimal solution $\underline{\delta}^*$. Hence these successors need not be examined further.

Active or unfathomed nodes, on the other hand, are nodes that still can be branched from. More precisely, if $Z_k^L \leq U$, the successor D_s may include $\underline{\delta}^*$. Active nodes that are not yet branched from are called terminal nodes.

Backtracking refers to "climbing up" the directed tree through the predecessor nodes to some terminal node and further branching from the terminal node. In the branch-and-bound procedure, typically, branching takes place from the best bound of all terminal nodes. In the branch-and-backtrack procedure, on the other hand, branching is done from the set of nodes that has been reached last (i.e., branch from the newest active node). Because all terminal nodes are considered (explicitly or implicitly) candidates for branching, this branching process is called flooding.

There are two types of branching strategy: either free decision variables are sequentially fixed in a predetermined order or they are chosen in a variable manner. These are called fixed-order and variable-order branching, respectively. Branching stops when the optimal solution $Z(\underline{\delta}^*)$ = is found or when

$$Z_k^L \geq U \quad \forall k \qquad (8)$$

In these network-analysis problems, the works of Loubal (31), Murchland (32), and Halder (33) on minimum-path recomputation are often used to solve the auxiliary, algebraic problem--aside from the regular minimum-path traffic assignments (34,35). In a network in which link (m,n) is shortened from C_{mn} to C_{mn}', the auxiliary problem of tree search is to find the new shortest distance $C_*^{k\ell}$ and its corresponding route. Murchland suggests the following method of updating an existing $C^{k\ell}$ and the routing matrix in minimum-path computation:

$$C_*^{kn} = \min_m (C^{kn}, C^{km} + C_{mn}') \qquad \forall k, k \neq n \tag{9}$$

and

$$C_*^{k\ell} = \min_n (C^{k\ell}, C_*^{kn} + C^{n\ell}) \qquad \forall k \text{ and } \ell, \; \ell \neq k, \ell \neq n \tag{10}$$

Loubal's algorithm (31) can be thought of as a special case of the Murchland method generalized to more than the matrix minimum-path computation.

Neither Loubal's nor Murchland's algorithm is particularly efficient for link lengthening (or when a link is deleted from a network). Halder's method (33) of competing links specifically addresses this problem. Assume that N^m stands for the set of nodes contained in a tree built from m as the root and N^n is the set of nodes in the tree with n as the root. Now, in the general case, define L^D as the set of links the removal of which would disconnect every node of N^m from N^n. This means a minimum path from a node k in N^m to a node ℓ in N^n will contain one of the (competing) links of L^D. Updating the minimum paths after lengthening link (m,n) in L^D involves

$$C_*^{k\ell} = \min_{(rs)\epsilon L^D} (C^{kr} + C_{rs} + C^{s\ell}) \tag{11}$$

It can be seen that this link-lengthening procedure is not as efficient as the link-shortening one. One thing remains clear, however: minimum-path updates normally involves η^2 instead of η^3 arithmetic operations, where η is the number of nodes in the network. The computational savings achieved by updating is obvious.

UPPER VERSUS LOWER BOUNDING TECHNIQUES

The project vector, $\underline{\delta} = (\delta_{ij})$, whose entries δ_{ij} are 0-1s, denotes the rejection or acceptance of project ΔC_{ij}. Thus $\underline{\delta}$ = (0110) denotes the rejection of the first and last link project and acceptance of the second and third. As suggested previously, the branch-and-bound tree with a 0-1 branching rule defines the combinatorial space of $\underline{\delta}$. An interesting relation is observed between the project vector $\underline{\delta}$ and the objective function, Z:

(01) If $\underline{\delta}'$ is identical to $\underline{\delta}$ except that $\underline{\delta}'$ has more entries of 1's, then $Z' \leq Z$ or $Z' \geq Z$, corresponding to a minimizing or maximizing objective, respectively.

To see this, let us consider three states in the network-design problem as shown in Equations 1-5: (a) link (i,j) carries no flow, or (b) it carries the flow on one O-D pair k-ℓ only, or (c) it carries the flow of multiple O-D pairs. Link (i,j) belongs to one of the three states. A reduction in travel cost in (i,j) would result in link (i,j) staying in state t or going to a higher state t+k; k = 0,1,2. The change to a higher state is caused because some O-D flows find it less costly to use the reduced cost link on their paths from k to ℓ. In the case of perfectly inelastic demand, for example, the total travel cost Z can either stay the same, Z'=Z, corresponding to staying in state (a) before and after, or decrease, Z' < Z, when one or more O-D pair flows find it less costly to traverse link (i,j), corresponding to states (b) and (c). On the other hand, in the case in which demand is a function of level of service, the total amount of O-D movements will be increased because of network improvement, at a nondecreasing cost. Hence system user cost will be increased (i.e., $Z' \geq Z$) as a result.

A second observation is given between the project vector $\underline{\delta}$ and the constraint $E(\underline{\delta})$ [where $E(\underline{\delta}) = \underline{b}^T\underline{\delta} \leq B$ in the classical formulation given in Equations 1-5]:

(02) For a monotonically decreasing function $E(\underline{\delta}^T\underline{\delta})$ and a monotonically increasing function $E'(\underline{\delta}^T\underline{\delta})$, suppose $E(\underline{\delta}) \leq E_o$ or $E'(\underline{\delta}) \geq E_o$. Then a vector $\underline{\delta}'$, which is identical to $\underline{\delta}$ except that $\underline{\delta}'$ has more entries of 1's, is an infeasible solution.

To see this, take the budget $E(\underline{\delta}) = \underline{b}^T\underline{\delta}$, which is a monotonically increasing function of $\underline{\delta}^T\underline{\delta}$. At optimality, the dot product of $\underline{\delta}$ is at its maximum value consistent with the budget constraint $E(\underline{\delta}) = \underline{b}^T\underline{\delta}^* \leq B = E$. Because the cost of implementing any project is nonnegative, adding another project to a subset of projects that already uses the budget to its limit would certainly exceed the budget and become infeasible.

These two observations, together with the branching strategy, make it possible to bound and fathom. Each auxiliary problem is to update a multiple O-D minimum-path computation by an algorithm suggested by Murchland (32) or Halder (33). Because the number of candidate project links is typically only a minor fraction of the number of all links in the network and a subset of the candidate links is defined at a node (say κ of them), the number of calculations is on the order of $\kappa\eta^2 << \eta^3$. This inequality becomes quite significant when η is large, as is the case with most real-world problems. Depending on the actual tree-search algorithm, however, the size κ may vary significantly.

For the sake of clarity, the tree-search method will be illustrated in its detailed algorithmic steps, in which the following procedures are used to solve the classical minimization network-design problem outlined in Equations 1-5.

Branch-and-Bound Algorithm

Step 1

Generate the active root node, r = 1. Define for this node $\underline{\delta} = (\underline{1})$ and label it with objective function Z_1. Go to Step 4.

Step 2

If an active node j has $b_j = \underline{b}^T\underline{\delta}_j \leq B$ (i.e., node j is feasible), set upper bound $U = Z_j$. Put node j on inactive status. All active, feasible nodes i with $Z_i \geq U$ are dominated [by (01)]. Put these dominated nodes on inactive status. If there are no more active terminal nodes, terminate the algorithm. The optimal solution, or solutions, $Z_j^* = U$ has been found.

Step 3

Branch: Branch from the bounded node ℓ, creating node r + 1 to the right and r + 2 to the left. Set a free variable $\delta_{ij} = 1$ on the right branch and $\delta_{ij} = 0$ on the left branch. At node r + 1, add δ_{ij} to the set of variables with assigned values, I. Calculate $\hat{B}_{r+1} = \sum_{i \in I} b_i$. If $\hat{B}_{r+1} > B$, node r + 1 has been fathomed [by (02)] and termed inactive. Otherwise, set $Z_{r+1} = Z_\ell$. At node r + 2, solve the auxiliary problem corresponding to $\underline{\delta}_{r+2}$ to obtain Z_{r+2}.

Step 4

Bound: Out of the set of active (i.e., the lower bound Z^L_ℓ) nodes, find the node ℓ with the smallest objective function Z_ℓ. Node ℓ is the bounded node. If $r \neq 1$, set r = r + 2. Go to Step 2. An example of this algorithm is shown in the Appendix.

Branch-and-Backtrack Algorithm

Step 1

Generate the active root node 1 and set counter r = 1. Set $U = \infty$. Define $\underline{\delta} = (\underline{0})$. The set of free variables, F, consists of all δ_{ij}'s. The problem as defined here has exactly the flow pattern of the original network before any project implementation. Call the present objective function Z_1.

Step 2

Backtrack: Out of the set of active terminal nodes, find the node with the largest node number (i.e., the latest active terminal node). If $r \neq 1$, set r = r + 2.

Step 3

Branch: Branch from the latest active node. Create node r + 1 to the right and node r + 2 to the left. Set a free variable $\delta_{ij} = 1$ on the right branch and 0 on the left branch. At node r + 1, compute $\underline{b}^T \underline{\delta}_{r+1} = B_{r+1}$. If $B_{r+1} \geq B$, node r + 1 has been fathomed [by (02)] and termed inactive. Otherwise, declare node r + 1 active. At node r + 2, let F be the new set of free variables after δ_k has been fixed. If $\sum_{i \in F} b_i = B_{r+2} \leq B$, then node r + 2 is feasible. Solve the auxiliary problem corresponding to setting the free variable in the current $\underline{\delta}$ to unity and obtain Z_{r+2}. If $Z_{r+2} \leq U$, modify the upper bound to be $U = Z_{r+2}$. Declare node r + 2 inactive. All feasible nodes with $Z_i > U$ are dominated [by (01)]. Put these dominated nodes on inactive status. If there are no more active terminal nodes, terminate the algorithm. Optimal solution U has been found. On the other hand, if $B_{r+2} > B$, declare node r + 2 active. Go to Step 2. An example of this algorithm is also contained in the Appendix.

Parametric Branch-and-Bound

In the branch-and-bound scheme proposed previously, a parametric analysis (8,22,36) can be performed on the budget level. Sensitivity analysis can be carried out to find the range within which the budget B can vary, and the solution obtained still remains optimal.

First is discussed the procedure for finding the lowest budget B (henceforth called the budget "floor") at which the solution still remains optimal. A solution is shown to be optimal in the branch-and-bound procedure by establishing its feasibility and that it occurs at a bounded node. Suppose the optimal solution occurred at the bounded node ℓ, incurring a cost of $\underline{b}^T\underline{\delta}_\ell$, which is less than B. B can conceivably be decreased to $\underline{b}^T\underline{\delta}_\ell = B^L$ without affecting the feasibility of solution $\underline{\delta}_\ell$. Therefore B can be decreased by ΔB and the former solution would still remain optimal:

$$-(B - \underline{b}^T\underline{\delta}_\ell) \leq \Delta B \leq 0 \tag{11}$$

Second, a question can be posed: How large could B be and the solution still remain optimal? This upper limit is called the budget "ceiling," B^U. Determining the budget ceiling is more complicated than determining the budget floor because the feasibility dominance rule has been employed. Recalling the way the bounding operation was carried out, the partial solution with an objective function value $Z_{\ell'}$ closest to the optimal one $Z_\ell (Z_{\ell'} \leq Z_\ell)$ is obtained at the bounded node in the iteration just before the one that provides the optimum. The solution at ℓ', $\underline{\delta}_{\ell'}$, is clearly infeasible because, if it were feasible, it would have been accepted as the optimal solution (remember $Z_{\ell'} \leq Z_\ell$). To note this, $\underline{b}^T\underline{\delta}_{\ell'} > B$ can be written. Therefore the budget could have been expanded up to (but not set at) $B_{\ell'} = \underline{b}^T\underline{\delta}_{\ell'}$ and the current optimum would still be optimal. The amount ΔB by which B can be increased is expressed as

$$0 \leq \Delta B \leq (\underline{B}^T\underline{\delta}_{\ell'} - B) \tag{12}$$

If it is guaranteed that all the other nodes dominated due to feasibility reasons (call it the set G) have partial solutions $\underline{\delta}^P_i$, incurring budgets greater than $B_{\ell'}$, that is,

$$\underline{b}^T\underline{\delta}^P_i > \underline{b}^T\underline{\delta}_\ell \quad i \in G \tag{13}$$

then Z_ℓ would be the first optimal solution encountered as B is incrementally expanded. For this reason, to maintain optimality for the current solution, B definitely cannot be increased by more than ΔB as prescribed in Equation 12. On the other hand, if Equation 13 is not guaranteed, a second-best solution could conceivably be found in the set G. Under these conditions, only a weak upper bound could be obtained by taking $\underline{b}^T\underline{\delta}_\ell$. This section can be summarized by saying that

$$-(B - \underline{b}^T\underline{\delta}_\ell) \leq \Delta B \leq \min \left[(\underline{b}^T\underline{\delta}_{\ell'} - B), \min_{i \in G} (\underline{b}^T\underline{\delta}^P_i - B) \right] \tag{14}$$

Discussion of Solution Methods

Two solution methods, branch-and-bound and branch-and-backtrack, were outlined in the previous sections to solve the network investment problem. The branch-and-bound scheme adopts a strategy of branching from the lowest bound. The root node accepts all projects $[\underline{\delta} = (\underline{1})]$ and "rejects" projects one by one during branching. Computationally, each auxiliary problem may involve using the link-shortening algorithm quite a few times (up to κ times, where κ is the number of 1's in $\underline{\delta}$). For this reason, Halder's method of lengthening links may be more applicable here because only one additional link needs to be lengthened at a time.

The computer storage required to retain the intermediate information may have to be quite large. Programming the branch-and-bound algorithm may not be easy either. It requires a sophisticated data structure to jump efficiently from one node to another and to regenerate solution information at nodes not recently visited. But the greatest difficulty lies in controlling the number of terminal nodes. Storage space, rather than solution time, is the key constraint on this method. Because of the greater complexity of programming, data manipulation, and branching node choice, the execution speed is slower than for the branch-and-backtrack method.

The branch-and-backtrack method keeps on branching from the latest active node. In the present algorithm, a root node of all zeros [$\underline{\delta} = (\underline{0})$] is used to start and projects are accepted one by one during branching. Computationally, this branching rule saves solving quite a few auxiliary problems (five compared with nine in the problem worked out in the Appendix) because the auxiliary problem at a left-hand node need not be evaluated until feasibility is encountered. Also, each auxiliary problem defined in a branch-and-backtrack tree typically has fewer entries of 1's. The number of calculations in a link-shortening algorithm, κn^2, is smaller because κ is not as big as most of the κ's found in the branch-and-bound auxiliary problems.

Inside the computer, a pushdown list can be used. The entry on the top would correspond to the most recent active element. Each time branching is carried out, the new problems are placed on top of the stack. Each time branching is to be performed, elements from the top of the stack are examined. If active, new elements will be added to the stack, corresponding to the new problems generated by branching. If not active, the element will be discarded until an active element is encountered. The length of the stack will be proportional to the length of the longest path directed away from the root of the tree.

The branch-and-bound procedure of branching from the lowest bound obviously gives the best criteria for choosing the next node to branch from, in that the node chosen is more likely to have an optimal solution at its successor than the node automatically chosen by branch-and-backtrack. The scheme of branch-and-bound thus allows sensitivity analysis to be performed on the budget as outlined earlier, and this author finds it infeasible to perform an equivalent sensitivity analysis on the solution obtained by the branch-and-backtrack method. On the other hand, branch-and-backtrack tends to arrive at a feasible solution fast, even though it may be far from optimal.

There is a certain similarity between the tree-search scheme proposed here and the unimodal function search discussed by Mitten (25). In Figure 1 is depicted the trade-off relationship between optimality and feasibility. On the left end of the z-axis are solutions with low Zs, yet most of them are infeasible solutions. On the right portion of the axis are high Zs, but they tend to be feasible solutions. In the center portion will lie the optimum solution that satisfies optimality and feasibility. The branch-and-bound procedure generates solutions from the lowest bound. It approaches the solution from the left portion of the z-axis. The branch-and-backtrack method emphasizes getting feasible solutions fast. It operates from the right portion of the z-axis, edging onto the center portion. If the computer time available does not permit the execution of the tree-search scheme to completion, chances are that branch-and-backtrack will give at least a feasible solution and an upper bound. Branch-and-bound may just give an infeasible solution and a lower bound.

A DOUBLE-BOUNDING TECHNIQUE

The branch-and-bound and branch-and-backtrack algorithms are flexible enough to address a generalized cost function; a demand function; and a user- and system-optimizing, minimization, or maximization objective. There is one unsatisfying element about the solution method, however, and that is the difficulty of finding strong bounds, particularly both an upper and a lower bound. A strong upper and lower bound are critical to improving computational efficiency. Preliminary research has led to an algorithm that is discussed hereafter. Again, a minimization objective of the network-design formulation is assumed for convenience in the algorithmic steps. The design of the algorithm is motivated by works of Chan (37), Billheimer and Gray (38), Magnanti and Wong (39), and Ruiter (40).

Preliminary Step

Set up a state-stage diagram, as shown in Figure 2, in which the rows correspond to the O-D pairs and the columns correspond to the number of algorithmic iterations. The O-D demands corresponding to level of service m are also sketched in as $\pi^m_{k\ell}$, corresponding to the amount of induced demand increments. Initialize m = 0. Solve the first auxiliary problem by performing a traffic assignment for the network (if one is not already available), yielding the upper bound objective function $U^m = Z_U$. A parallel assignment is

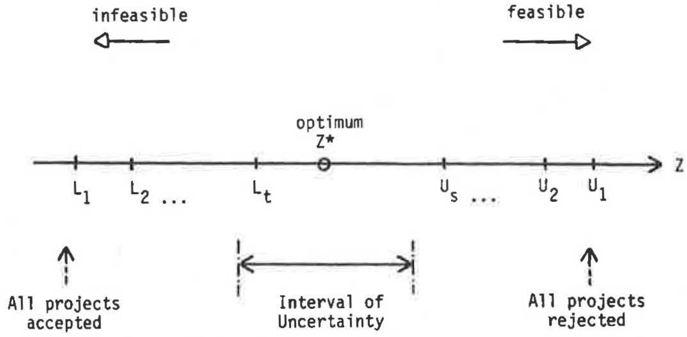

FIGURE 1 Bounding from above and below.

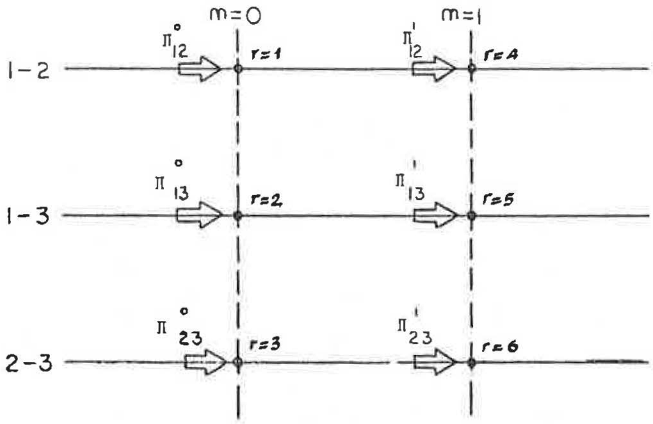

FIGURE 2 Demand function as represented in the state-stage diagram.

performed on a network where all the projects in the specified set R have been implemented, yielding the lower bound objective function $L^m = Z_L$. Set S = R and T = R.

Step 1: Link Insertion

Set $m \leftarrow m + 1$. Take each node m-r in the state-stage diagram as the active node, starting from the top in a fixed-order sequence. From the set of project candidates, S, a subset of projects $I = [\delta_i]$ is selected. The improvement in the objective function $\Delta Z_j^U(m)$ over the upper bound is obtained by updating the traffic assignment for each of the $\delta_j \varepsilon I$. The project that results in the best improvement δ_j is accepted and set to unity. The corresponding objective function $U_m = U_{m-1} - \Delta Z_j^U(m)$ and budget level $B_U(m) = \sum_{j \varepsilon S} \delta_j b_j$ are then computed. Project δ_j is then removed from the set S for further consideration.

Step 2: Link Removal

For the same nodes m-r, a project δ_k (if any) is selected from the subset I if the elimination of it from the network (i.e., setting δ_k = D) results in the minimal (but nonzero) degradation of the objective function, and the degradation $\Delta Z_k^L(m)$ has to be less than the improvement $\Delta Z_j^U(m)$ [i.e., $\Delta Z_k^L(m) < \Delta Z_j^U(m)$]. The corresponding objective function, $L_m = L_{m-1} + \Delta Z_k^L(m)$, and the budget level, $B_L(m) = \sum_{k \varepsilon T} \delta_k b_k$, are computed. Project δ_k is then removed from T.

Step 3: Termination Criteria

When both the upper and lower bound solutions are feasible [i.e., $B_L(m)<B$ and $B_U(m)<B$] or both sets S and T are empty, stop. A local optimal solution $Z^* = \min (U_m, L_m)$ has been found, with the corresponding projects S or T and budget level. Otherwise, after all the nodes m-r have been scanned and become inactive, go back to Step 1. An example of this double-bounding algorithm, to accompany the branch-and-bound and branch-and-backtrack examples, is shown in the Appendix.

CONCLUSION

This paper serves as a brief review of tree-search methods as applied to transportation network design. The example problem is formulated as a user-optimizing, nonlinear, multicommodity, fixed-charge-type integer program. The integer program is solved by two approaches, branch-and-bound and branch-and-backtrack. Postoptimality procedures are used to solve the auxiliary problem generated by the tree-search schemes. The concept of parametric branch-and-bound is sketched, showing that sensitivity analyses can be performed as part of the algorithm. Finally, a comparison is made between the two solution methods. This results in the design of a double-bounding algorithm.

It is observed that from the computation and computer programming point of veiw, the branch-and-backtrack algorithm is more efficient than the branch-and-bound algorithm. Branch-and-backtrack provides feasible solutions quite early in the computation. It approaches the optimal solution via an upper-bound pruning rule. Branch-and-bound gives feasible solutions only at the final phase of the algorithm, approaching the optimal solution mostly from the lower bound. Parametric sensitivity analysis can be performed with the branch-and-bound algorithm, whereas the author sees no way to do the same with branch-and-backtrack.

The proposed double-bounding algorithm has the promise of being computationally more efficient. The solution so obtained is, nevertheless, merely a local optimum. More research is needed in its refinement. Available information substantiates the value of tree-search methods in solving a number of transportation network-design problems with typically ill-behaved nonanalytical properties.

It should be noted that the tree-search algorithms presented here are based on the monotonicity properties (01) and (02), which essentially assume that travel congestion in vehicle-minutes is reduced for perfectly inelastic demands as links are added to the network. Likewise, it is assumed that the number of O-D movements is increased on an improved network for downward-sloping demand functions. Recent findings about the Braess' paradox by Steinberg and Zangwill (41) show that, should all routes used before the addition of the new link continue to be used, travel congestion for the inelastic demand case may be worsened as a result of link addition. This would in some cases violate the first of the two monotonicity properties on which tree-search solution algorithms are built and raises serious doubts over the wealth of literature on tree-search.

However, another recent finding is of interest. Pearman (42) found out that network-design problems are "rich in suboptimal solutions." Because there are other concerns in transportation planning aside from an "optimal" solution to the network-design problem, any improved network design, even though only locally optimal, may be useful in practice. Following this line of argument, a strong case can still be made for using the tree-search algorithms presented here as a computational tool to get better network designs; although the researcher would necessarily have to be humble in claiming that the algorithms are panaceas for solving all transportation woes.

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APPENDIX--SOLUTION OF AN EXAMPLE PROBLEM

Consider the following example problem with perfectly inelastic demands (Figure A-1):

$$\min Z = \sum_{k=1}^{4} \sum_{\ell=1}^{4} (4 - \delta_1)\, x^{k\ell}_{12} + (2 - \delta_2)\, x^{k\ell}_{41} + (2-\delta_3)\, x^{k\ell}_{24} + (4 - \delta_4)\, x^{k\ell}_{34} + 4x^{k\ell}_{23} + 7x^{k\ell}_{42} + 7x^{k\ell}_{14} + x^{k\ell}_{43}$$

such that

$$\sum_i x^{k\ell}_{ip} - \sum_j x^{k\ell}_{pj} = \begin{cases} -1 \text{ if } p = k \\ 1 \text{ if } p = \ell \\ 0 \text{ otherwise} \end{cases} \quad k \neq \ell, \forall p$$

$$\delta_1 + 2\delta_2 + 2.5\delta_3 + 1.5\delta_4 \leq 4$$

$x^{k\ell}_{ij} > 0$ only if (i,j) is on the shortest path from k to ℓ

$x^{k\ell}_{ij}$ = positive integers; $\delta_r = (0,1)$ where a shorthand notation δ_1 has been used to denote δ_{12}, δ_2 for δ_{41}, δ_3 for δ_{24} and δ_4 for δ_{34}.

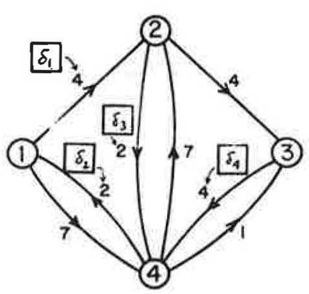

FIGURE A-1 Example network.

Branch-and-Bound

For this network design problem, the branch-and-bound algorithm is stepped through in detail as a directed tree. The reader should refer to Figure A-2 as he goes through the algorithm, where the node numbers correspond to the sequence in which the algorithm is carried out.

Branch-and-Backtrack

The same network design example will be used to illustrate the branch-and-backtrack algorithm. The reader should refer to the directed tree shown in Figure A-3 when he goes through the algorithm steps.

Double-Bounding Algorithm

Again, using the same example, these algorithm steps are performed

$m = 0$

In this preliminary step, a state-stage diagram is generated with 12 rows and an indefinite number of columns. Traffic assignments yield U° = 55 vehicle-minutes when all projects are rejected and L° = 37 with all projects implemented. $S = \{\delta_1, \delta_2, \delta_3, \delta_4\}$, with all δ's equal to 0. $T = \{\delta_1, \delta_2, \delta_3, \delta_4\}$, with all entries set at 1.

$m = 1$

Link Insertion

From the entire set of link-improvement candidates, links are improved by setting each δ_k to 1 in the upper-bound network. The corresponding system travel cost (Z) in vehicle-minutes is calculated using a link-shortening procedure such as Murchland's.

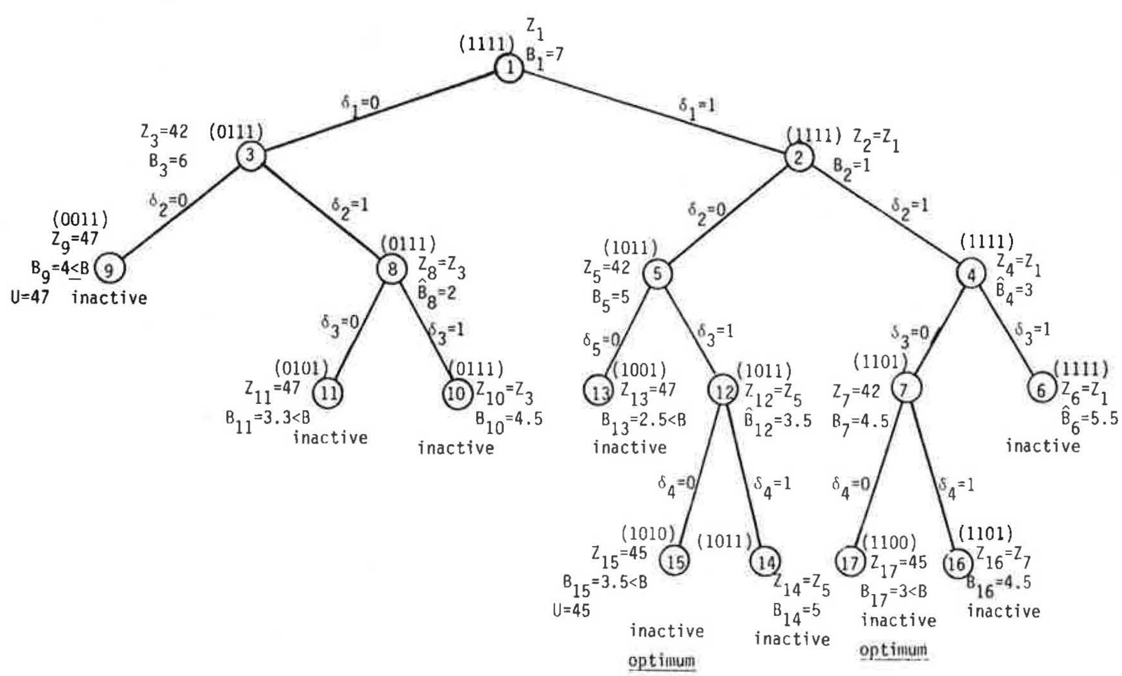

FIGURE A-2 Branch-and-bound example.

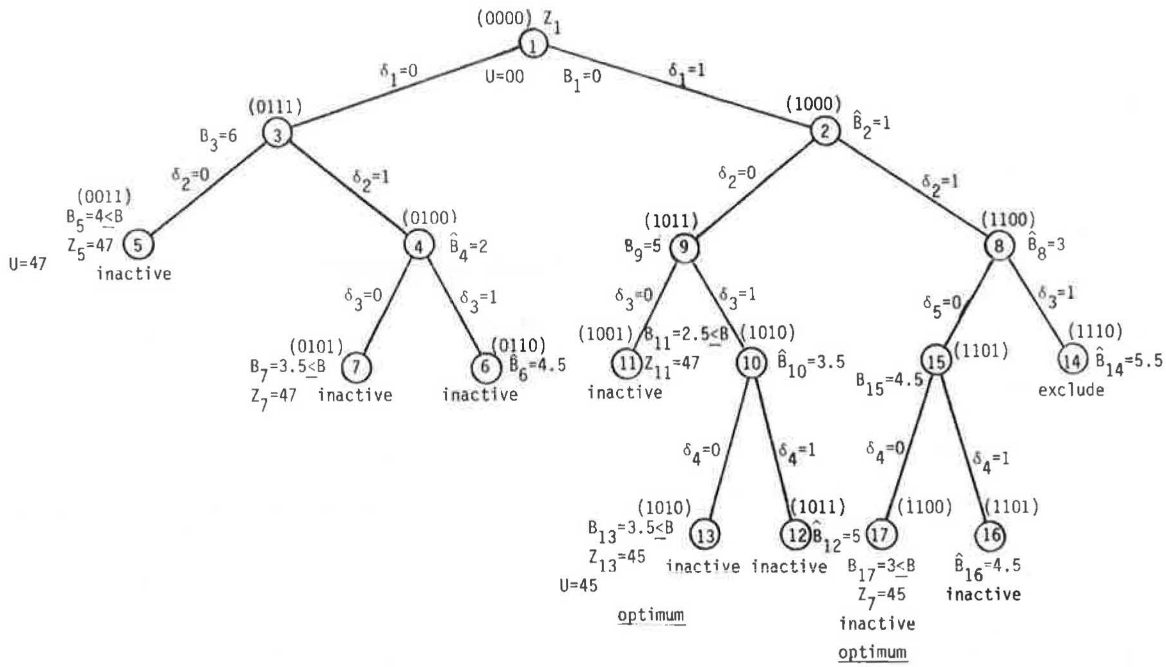

FIGURE A-3 Branch-and-backtrack example.

δ_2 results in the best improvement in Z of 7 vehicle-minutes. Hence $U_1 = 55 - 7 = 48$, $B_U(1) = 2 < B = 4$. δ_2 is then removed from the candidate set S.

Link Removal

Similarly, link-improvement candidates are removed from the network by setting each δ_k to 0 in the lower-bound network. The corresponding system travel cost (Z) is computed using a link-lengthening algorithm such as Halder's. The removal of candidate δ_2 results in the minimal degradation of Z, with the amount of degradation $\Delta Z_2^L(1) = 5 < \Delta Z_2^U(1) = 7$. Now $L_1 = 37 + 5 = 42$ and $B_L(1) = 5$ and project δ_2 is removed from T.

m = 2

Link Insertion

This second iteration inserts δ_1 into the upper-bound network, resulting in $U_2 = 44$, $B_U(2) = 3$, which is less than B = 4. Also, S now consists of δ_3 and δ_4 only, both at values of zero, with δ_1 and δ_2 set at unity.

Link Removal

Similarly, δ_4 is removed from S_2, resulting in $L_2 = 45$, $B_L(2) = 3.5 < B = 4$. Now T consists of δ_1 and δ_3 only, both at unity, and δ_2 and δ_4 are set at zero.

Termination

Because both upper- and lower-bound solutions are feasible, a local optimum Z* = min (44,45) = 44 vehicle-minutes is obtained with the corresponding projects, δ_1 and δ_2, implemented. Comparing the results with those of tree search, it is found that the solution is, indeed, a global minimum.

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Alternative Responses to the Need for Intercity Buses in Rural Areas

MARY KIHL

ABSTRACT

The impacts of the Bus Regulatory Reform Act of 1982 on service to residents of small communities must be viewed not just in terms of numbers of abandonments but also in terms of the level and type of replacement service available to such communities since 1982. This paper focuses on service to independent small towns in nonmetropolitan areas and the following are considered: (a) the level of replacement service directly stimulated by the act, (b) the nature of publicly sponsored alternative service, and (c) broader based programs that deal with the more fundamental questions regarding the nature of public demand for intercity bus service in rural areas. The adequacy and consistency of these various responses are then assessed. Research based on a review of available reports and hearings and supplemented by a series of telephone interviews conducted in June and July of 1985 with representatives of state transportation departments and state public regulatory agencies led to the following conclusions: (a) the potential for using publicly funded rural transit as an alternative form of service or as a feeder service has not been consistently explored by the states, nor has there been sufficient determination to use state programs to bolster the federal Section 18 program; (b) if effective intercity service is to continue in rural areas, a clear indication of public demand for that service and a public willingness to help meet that demand will be required; and (c) avenues for public-private partnerships are available, but in a deregulated environment they will not be explored unless communities can demonstrate demand and private companies can perceive the potential for profit.

The intercity bus has long been associated with the need for affordable transportation among residents of small communities. According to one study, 71 percent of the bus stops in a 12-state sample were in communities with populations under 2,500. The flexibility and relatively low start-up costs associated with bus operation were largely responsible for its introduction in the early 1900s as a means of filling gaps between rail lines and its rapid expansion in the 1920s as a substitute service for rail in low-density areas (1,pp.36-38). Efforts of the Interstate Commerce Commission (ICC) to regulate the expanding bus industry on the federal level in the 1930s stimulated concern about whether regulation would affect service to small communities. As one opponent of regulation commented in 1930, "Competition on various bus routes should be allowed for some time to come so that . . . bus service may be established in every district, rural as well as urban, throughout the country for the benefit of the public at large" (2,p.7). The Motor Carrier Act of 1935 did limit competition but did not impede the expansion of service to small communities. By the 1940s those communities were linked by a national network (3,p.27).

When cuts in bus service to small communities came in the 1960s and 1970s, they came in response to declines in ridership precipitated by the rise in availability of the automobile. Despite the complexities in exit requirements instituted by the Motor Carrier Act of 1935, service to an increasing number of small communities was terminated. Between 1969 and 1979 more than 185 locations lost service and new stops were only added in the suburbs (1,p.42). One case study noted that by 1978 only 42 percent of the small towns sampled had access to intercity bus service (4,p.4). Even with these cuts, bus industry profits continued to decline and the repeal of federal regulations was urged to permit route reorganization and open competition. Again, discussion revolved around potential impacts on service to small communities. "Loss of this service could prove to be devastating not only to individual bus riders who depend on the service, but to communities at large who are finding themselves increasingly isolated particularly in light of diminishing airlines and Amtrack availability" (5). Others countered with, "in the near term service to small towns seems no more threatened than to larger cities," and on the basis of available financial data, "the bus industry is healthier in rural areas than in highly urbanized areas" (6). The impact of bus deregulation has been carefully monitored since the Bus Regulatory Reform Act (BRRA) was passed in 1982. [The Motor Carrier Ratemaking Study Commission was requested to monitor the impacts on the aged and small towns. AASHTO has also monitored site abandonments as has a team of researchers from Indiana funded by the U.S. Department of Transportation. Private studies have also attempted analyses of deregulation.]

Abandonments of stops have apparently been distributed indiscriminantly in terms of the proportion of senior citizens or low-income residents in the towns losing service, but they have been concentrated disproportionately in smaller communities with populations below 2,500. During the first year following implementation of the BRRA, 82 percent of all abandonments were in communities in this population class (7,p.33). Seven hundred seventy-six points

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outside metropolitan areas were abandoned in the first year of deregulation. These abandonments were not unexpected because the intention of the BRRA was to grant private providers the right to reorganize their routes and maximize profits or at least cut losses. The BRRA also held out the hope of alternative service for small communities. During the hearings in 1982 Cornish Hitchcock, Director of the Transportation Consumer Action Project, pointed out, for example, that since there are no economies of scale in the bus industry, small companies can compete adequately with large (1,p.85). Economists agreed that the dominance of two large firms in the busy industry was not a result of market forces but rather an artifact of regulation (1,pp.34-35).

The impacts of the BRRA on service to residents of small communities must, therefore, be viewed not just in terms of numbers of abandonments but also in terms of the level and type of replacement service available to such communities since 1982. This paper focuses on service to independent small towns in nonmetropolitan areas and considers, first, the level of replacement service directly stimulated by the act; second, the nature of publicly sponsored alternative service; and, third, broader based programs that deal with the more fundamental questions regarding the nature of public demand for intercity bus service in rural areas. An attempt will then be made to assess the adequacy and consistency of these various responses in meeting the need for continuing service in rural areas. Information was gathered through a review of available reports and hearings and supplemented by a series of telephone interviews conducted in June and July of 1985 with representatives of state transportation departments and state regulatory agencies.

For purposes of this paper, intercity bus service will be defined to include regularly scheduled line-haul service open to the fare-paying public traveling between two or more contiguous cities outside a metropolitan area.

REPLACEMENT SERVICE

Regular-Route Carriers

As indicated, the expectation with the passage of the BRAA in 1982 was that small bus companies that had been prevented from moving in on routes already served by larger carriers would begin operations between smaller cities in rural areas. The experience of the 2 years after deregulation did not confirm that expectation but rather indicated a continuation of trends established long before 1982. There were approximately 21 percent fewer communities receiving service in 1982 than in 1975 and 20 percent fewer communities receiving service in 1984 than in 1982 (7,p.28). The record on replacement service has also not shown a dramatic increase. In the first year after deregulation an AASHTO survey noted that only 60 cities in nine states had received regular intercity bus replacement service. Forty-five of those cities were in the under-5,000 population class. When these figures are compared with the 480 cities losing all service in that year, 405 of which were in the under-5,000 population class, the record is not impressive. Only 7.8 percent overall and 7.3 percent of the under-5,000 population group received replacement service. In addition, 280 cities, 207 of which had less than 5,000 population, had their service cut by 50 percent or more. The record is only partly mitigated by the fact that 128 cities, 69 in the under-5,000 population class, that had not had bus service before gained regular-route service in 1982. In the second year, as Figure 1 indicates, the record improved somewhat to 13 percent replacement overall (117 out of 899) and 11 percent replacement (81 out of 713) for places with populations under 5,000. In addition, 159 new cities (102 in the under-5,000 group) gained service in the second year. [Statement of Francis B. Francois, American Association of State Highway and Transportation Officials, for submittal to the Subcommittee on Surface Transportation of the Senate Committee on Commerce, Science and Transportation relating to Oversight of the Bus Regulatory Reform Act of 1982, Nov. 1983, Nov. 1984.] This record certainly does not represent any improvement over the replacement record from 1975 to 1982 when service initiations equaled 26 percent of terminations (7,p.29).

The Official National Motor Coach Guide (8) lists 54 new bus companies in June 1985 compared with November 1982, but that must be balanced against the 72 bus companies that were listed in 1982 but no longer listed in 1985. This represents a net loss of 25 percent. Granted a quick review of Russell's Guide cannot account for mergers or small companies that

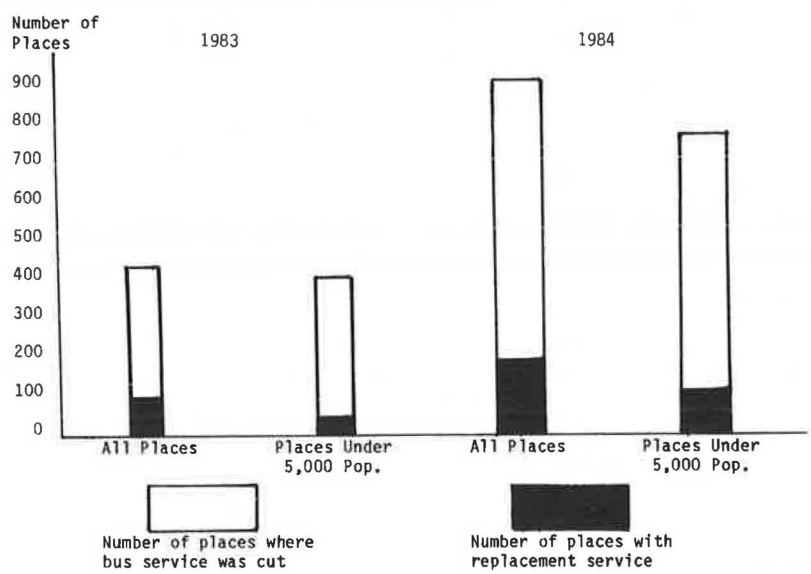

FIGURE 1 Replacement record.

do not choose to be listed, but it does indicate the lack of any abrupt change in the established pattern of bus company entrance into regular-route service.

Most of the places listed in the AASHTO survey as having acquired replacement service were served by expanded routes of existing carriers (9,table 7). Although 225 applications for regular-route authority to operate a total of 46,686 route miles were filed in the first year after bus deregulation, it is difficult to determine the extent to which those applications represented the potential for replacement service to points abandoned by another carrier. Such information is not included on the application forms (9,pp.13-14).

Charter Service

The big gains since deregulation have been in charters. Even in the period before deregulation small non-Class I carriers carried 89.4 percent of the charter and special services (1,p.9). In some states charters had served to compensate for operating non-revenue-producing routes in rural areas. Now that it is no longer necessary to run a regular route in order to be approved for charter service, new charter companies are entering the field at a rapid rate. According to one study, 1,706 applications (88.4 percent of all applications) were for charter authority in the first year of deregulation, 764 by existing firms, and 942 by first-time applicants. This represented a 511 percent increase over the average of the previous 5 years (1,p.75;9). In Ohio, for example, 80 percent of the requests for contract permits were for charter rather than for regular-route service. Indeed, 64 of the 70 bus companies operating in Ohio are charter companies (interview with a spokesman for the Ohio Utility Commission, June 14, 1985). North Carolina has had no requests for service permits except for charters (interview with spokesman for the intercity bus section of the North Carolina DOT, June 13, 1985). New low-cost charter operations with as few as three buses can easily undercut traditional companies trying to balance out losses on a regular route with revenues from a charter service. As a result, small traditional bus companies are apparently being forced to exit from their regular-route services. This observation was made in interviews with representatives of transportation departments in several eastern states but cannot yet be verified by independent data (interviews with spokesmen for rural transportation services and Section 18 in Ohio, Pennsylvania, North Carolina, and West Virginia, June 12-16, 1985). Such developments would certainly have a negative impact on regular-route service to small communities. Increased charter service does not compensate for the loss of intercity bus service in rural areas.

Increased Intermetropolitan Service

The other major trend since passage of the BRRA has been increased service between metropolitan areas over Interstate highways. Almost all state department of transportation representatives underscored this trend, which is understandable given the spirit of the BRRA in which a major thrust is the reduction of cross subsidies between routes or types of service (9,p.22). Nevertheless, it would direct regular-route service away from small self-contained communities. Even if intercity bus service is retained in a neighboring community or out on the highway, there is typically no local transit system linking the points (1,p.83). Fortunately, the Motor Carrier Rate Making Study Commission, directed by the BRRA to study the impact of the act on intrastate services, found that this trend is more noticeable among larger than among smaller bus companies. Because it faces severe competition on its better routes, a small company is not as likely to eliminate marginally profitable rural routes where it has an effective monopoly (9,p.24). Moving into unprofitable routes abandoned by another carrier, however, would certainly provide more of a challenge for a small operator, a challenge that few have accepted.

Industry-Initiated Replacement Service

In April 1985 Greyhound Lines, the giant of the U.S. intercity bus industry, launched a franchise program that it hoped would stimulate greater interest among small operators in assuming marginal rural routes. From 1974 to 1984 Greyhound's ridership plummeted 40 percent and 1984 profits were half the 1974 levels. Faced with these declining profits, Greyhound developed a plan to spin off 10 percent of its routes in the hope that lower cost operators might be able to make money on them. The approach would emphasize short-haul routes of less than 500 mi rather than cross-country through bus service; would provide service at more convenient travel times, albeit with increased transfers; and would potentially serve the needs of residents of smaller communities (10). Franchisees would have the benefits of the Greyhound name, insurance, advertising, sales outlets, driver training programs, management assistance, and maintenance and service. In exchange they would agree to pay a franchise fee of from $5,000 to $10,000 over a period of 5 years for a two- or three-bus fleet, respectively; pay royalties of $200 or 10 percent of profits each month; and contribute to the cost of advertising (Greyhound System Franchise Agreement Packet, pp. 15-18).

It is too soon to determine the success of the franchise program as a stimulant to replacement or retention of service in nonmetropolitan areas. As of July 10, 1985, however, five franchisees were on board and seven franchisees were to be added shortly. One of these was a new bus company; the others represented expansions of existing companies. Because requests for information about the franchise program were coming in at the rate of 15 a day, Greyhound executives were hopeful that other applications would be filed soon (interview with Greyhound representative, July 10, 1985).

Whereas the franchise concept is new to Greyhound, Trailways was encouraging independent non-Class I carriers even before the passage of the BRRA. Between 1982 and 1984 Trailways transferred operating authority to 20 nonaffiliated carriers. More than 50 independent, non-Trailways-affiliated carriers were members of the National Trailways Bus System by 1984. This coordinated network provides the potential for feeder runs to larger carriers and helps supply replacement service to a number of smaller communities. Although 13 marginal route independent affiliates with the Trailways Bus System have abandoned service since 1982, eight new companies have replaced them, according to Russell's Guide (8).

These private industry efforts at generating replacement service are well intentioned but their success must be measured by their ability to generate sufficient profit for all involved, and in the bus industry profits are dependent on ridership. The ability of small communities to generate sufficient ridership to support even the minimum replacement service now provided to them remains to be seen.

PUBLICLY FUNDED ALTERNATIVES TO INTERCITY BUS SERVICE

Publicly funded alternatives to intercity bus service have the advantage of surviving with deficits and consequently have been an approach used extensively in low-density areas. Unfortunately, there is no common or consistent source of information about publicly funded or assisted approaches to intercity bus service. In some cases, only local service providers are familiar with the type and extent of replacement service provided by rural public transportation. In an effort to generate such information a telephone survey was conducted of rural public transportation coordinators and intercity bus coordinators in 15 states. States selected for inclusion in the study had lost a disproportionately large number of bus stops after deregulation. The sample was also intended to reflect a broad geographic distribution and a range of state-sponsored responses to the need for intercity buses in rural areas. Where the coordination of rural and intercity bus services was distributed among two or more individuals, all were interviewed. The interviews were intentionally open ended but followed the general outline indicated in the Appendix. Unfortunately, specific quantitative service data were not available to test the relative success of the programs discussed.

States vary widely in their responses to the need for replacement intercity transportation. Emphases range from state subsidies for replacement service to specialized safety or marketing programs. For other states replacement service is a matter of local prerogative, which is left up to the rural public transportation providers. Among the 15 states surveyed, for example, 3 emphasized a continuing extensive state subsidy system available for intercity service and 3 stressed specialized state programs focused on marketing or safety. In addition, two other states indicated use of federal Section 18 money to assist with operating replacement service and specific routes. The remaining eight states have determined that local communities or counties are closest to the needs of their residents and consequently are best able to determine the extent of the need for replacement service or other rural public transportation services. The local community can then operate feeder lines, stimulate the construction of cooperative terminals, or foster public-private cooperation.

Section 18 as Replacement Service

The one federal program that all states rely on for basic funding of operating assistance for rural intercity transportation providers is the Section 18 funding authorized by the Urban Mass Transportation Act of 1964, as amended. This program, which is funded only at $70 million to $75 million per year, is administered differently in each of the states surveyed. Each of the states submits an annual project plan to UMTA, which reviews the plans only to ensure that they are in keeping with the general purpose of Section 18--to provide transportation to the general public living in rural areas. The directive is so broad as to include the possibility of subsidies for intercity carriers as well as county van service. To date, both capital and operating expenses are allowable although there has been an effort to eliminate operating subsidies much as has been proposed for urban areas. All state public transit coordinators surveyed applauded the Section 18 program and would urge increased funding levels for it. They viewed reports of elimination of operating subsidies with alarm and believed that any failings of the program were due to inadequate funding.

Because of the limited amount of funding available, few states have changed their Section 18 focus since bus deregulation. Among the states surveyed, only two had made changes in their allocations since 1982. Table 1 gives a summary of state Section 18 programs.

Distribution between small urban and rural projects differed among the states although most of the states surveyed allocated about one-third of the funding available to projects in small urban areas and the rest to projects in rural areas. Because awards were based on the merit of specific proposals,

TABLE 1 Section 18 Programs

State	No. of Projects	Area Served	County/Multicounty	Provision for Specific Trip	State or Local Subsidy for Intercity Bus Service	Encourage Linkage with Other Systems
California	100+	Rural and small urban	In county	Some	State subsidy	Not formally
Tennessee	16	11 rural, 5 towns	9 multicounty, remainder intracounty	Not so specified	Only at county level, if at all	Not formally but local effort
North Carolina	12	1 town, remainder rural	Intracounty and multicounty, 1 covers 5 counties	Yes	2 subsidized intercity routes	Not formally but local effort
Georgia	40	Rural	In county	Yes, subscription	No	Not formally
West Virginia	12	Rural and small urban	Most in county, 2 in 5 counties	Not specified	No	Not formally but local effort
Michigan	50	Rural	In county	Not specified	Yes, purchase buses	Initiative by project, local effort
Wisconsin	27	5 cities, 12 rural and rural intercity	Multicounty	Not specified	Yes, some state match	Not formally
Ohio	29	Most rural	In county except special purpose	Not specified	No	No
Pennsylvania	19	Most rural, 5 smaller urban	2 multicounty, remainder in county	Not specified	Yes, state; some piggybacking of funds	Limited, 1 project cooperates with private bus
Louisiana	35	Rural and suburban	2 multicounty, most in county	2 intercity work trips	No	Formal encouragement
Wyoming	5	Mostly rural	Local	University route and ski route	No	No
Kansas	125	Mostly rural	Most in-county, 1 serves 11 counties	Not specified	No	Up to locals
Minnesota	38	Mostly rural	Multicounty, 1 serves 30 counties	Not yet, but working with employees	State needs assessment program	No
Illinois	18	Rural and 5 urban	Multicity, county	Not specified	No	No
Iowa	46	Rural	Multicounty	Not specified	Special UMTA funding with state match	Yes

however, the ratio varied both among states and over time within individual states. Only one state, Wisconsin, was considering establishing a category priority system for distribution of operating subsidies. One plan under consideration in Wisconsin would rank projects as follows: (a) small urban services, (b) rural and Indian services, and (c) intercity services. UMTA is currently reviewing the concept of states setting priorities for distribution of Section 18 funds.

As with any priority-ranking system, there would certainly be protests from those who represent projects with a lower rank. The Wisconsin scheme would assign both intercity and rural projects a lower priority than projects that provide operating funds for small urban areas. This would use scarce resources to benefit the largest number of people and, at the same time, put less emphasis on intercity travel in rural areas. By so doing, the state would mirror preferences of private providers. Only 2 of the 15 states have directly subsidized private intercity service providers using Section 18 funds, and one of these (Wisconsin) is now insisting that private companies present their requests through a local public agency. In three of the other states, funds were distributed to counties that then had the discretionary power to subcontract with private carriers if they believed that was the best way to meet service objectives. The remaining states distributed Section 18 funds to public agencies only on the basis of project proposals. The number of projects funded ranged from 5 in Wyoming to 125 in Kansas with the average about 25. In 10 of the 15 states one or more of the projects served a multicounty area, thereby providing the potential for an alternative to intercity bus service. The other states distributed funds for services that operated primarily within a county. Most of these services did run dedicated trips across county lines but only for such purposes as visiting a health facility, for example, in the Cincinnati and Dayton areas of Ohio. Such specialized services of rural public transportation are, however, more akin to charter services than a substitute for intercity bus service.

The intracounty systems funded through Section 18 include both dial-a-ride and fixed-route systems and provide primarily for nearby shopping, personal business, and medical trips. Although open to the general public, as required in the legislation, most serve primarily senior citizens. In only three of the states were the rural transit coordinators aware of Section 18-funded services being used extensively for work trips.

In North Carolina work trips in rural areas are being accommodated by two subsidized intercity routes that were threatened with abandonment in 1983. One route transports workers from the eastern part of the state to the Outer Banks. This service carries maids and cooks from lower income sections of the eastern shore cities to their places of employment in hotels and restaurants on the Outer Banks. Ridership, which had declined, is now increasing with this regular service. In the western part of the state a route providing the only form of transportation for a rural mountainous area was cancelled and then replaced by a subsidized service now operating with one trip a day at better hours. The operating subsidy in both cases is matched by revenue generated by package express.

Similarly, in Louisiana two intercity projects provide for work trips in otherwise unserved areas, but in this case both routes are directed to New Orleans. One route, which serves low-income workers in the southern part of the state, has an increasing ridership. The other route serves workers from the more affluent suburbs. Section 18 funds pay 50 percent of the deficit of both routes, but, even with this help, the suburban route is soon to raise fares in order to help cover costs.

In Georgia, one county service operates a Section 18-funded subscription service for workers across the Clay County line into Alabama. Other counties also operate intracounty work trip routes in Georgia. In Wyoming, Section 18-funded projects serve two other target groups--college students and skiers.

Where Section 18-subsidized projects serve a multicounty area, there is the potential that they can serve as feeders to bring riders from rural areas to the remaining intercity bus stops along the Interstates. However, only four rural public transit coordinators actually noted formal efforts to generate such transfer points. In Pennsylvania one five-county system was coordinating with Trailways to arrange for a feeder service. Considerable effort was expended on feeder services in Iowa, albeit as a special demonstration using an UMTA grant rather than Section 18 funds. A special state effort is now being made to encourage Section 18 project recipients to include feeders and transfer points in their Transit Development Plans. In Louisiana, also, parishes that are having financial difficulty in running ser ices are advised to cut out service to urban areas and instead link up with Greyhound or other private carriers. In Illinois some rural public transit van programs act as short-distance feeders. In the other states, there were no formal efforts to encourage transfer points, although all surveyed thought that informal connections were possible particularly for outgoing passengers traveling through a county seat that still had intercity bus transportation.

In at least three locations in the sample states public transit providers with strong community support took stronger steps toward cooperation with intercity bus lines. In Cadillac, Michigan; Clarksville, West Virginia; and Wilson, North Carolina; local dial-a-ride systems encouraged transfers by building garages to serve both local and intercity public providers. In Clarksville, Greyhound used the Central West Virginia Transit garage, while Wilson, North Carolina, is using some Section 18 funds with a substantial local match to build a multimodal terminal facility to serve as the central transfer point for the local city bus system as well as intercity bus and taxi. Cadillac, Michigan, secured a $200,000 grant to build a combined terminal for the local dial-a-ride system, intercity bus, and taxi.

The small urban system in Johnson City, Tennessee, made the same type of offer to Trailways. When Trailways threatened to abandon their stop in Johnson City, the city offered to build a terminal that would serve both Trailways and the small 10- to 11-bus city transit company.

Little else has been done to encourage more general feeder programs. Most of the rural public transit coordinators thought that the transfers connected with feeders would discourage rather than encourage additional riders. All but the transit dependent would find transfers most inconvenient. In one location in northern Michigan, however, a substantial group of transit-dependent people continues to transfer buses at 2 a.m. even in the winter.

State Subsidy Programs

According to the Joint Survey on Changes in State Intercity Bus Programs and Policies conducted by AASHTO and the National Association of Regulatory Utility Commissioners in October of 1983, 10 of the 48 states responding indicated that they had an existing state subsidy program for intercity bus transportation. These subsidy or state operating assistance programs helped to ensure alternative intercity bus service when private intercity bus companies accelerated their retreat from rural areas. Among the states sampled in the current study, California, Michigan, and Pennsylvania had the most comprehensive state programs and all were sufficiently uncommon to warrant further discussion.

In California, the state operating assistance program was well established before the Bus Deregulation Act of 1982. One-quarter of 1 percent of the state sales tax is returned to the counties according to a population-based formula for use for public transit. Only 25 of the 80 intercity bus companies in California are private. When Greyhound announced plans to cancel service to 99 stops, 91 percent of the people affected already had access to public transit. Even had Greyhound withdrawn, the average distance to an intercity bus stop would still have been only 10 mi, which is the national average (11,p.383). Instead of undercutting Greyhound on the same routes, however, some counties provide a user-side subsidy system so that individual riders pay the same price to ride on Greyhound as on the county-sponsored public vehicle. Greyhound then bills the county for the rest of its usual fare.

Similarly, in Pennsylvania, a state subsidy is available for intercity buses. Eleven routes are currently subsidized--four Greyhound, three Trailways, and four independent. To be eligible for a state subsidy, a carrier must serve routes longer than 35 mi, go through at least two counties, and serve a rural population base. For example, Greyhound at first filed to abandon the Philadelphia to Scranton route in 1982. It then withdrew its request in favor of a subsidy of $2.48 a mile to help defray operating costs. The subsidy was to be granted to help cover operating costs as long as the route's revenues did not drop below 40 percent of costs. Currently, Greyhound operates three runs a day over the route.

A complementary Pennsylvania state program, "Section 203," funded through state lottery funds, provides user subsidies for senior citizen trips up to 35 mi in length. Beginning with planning money in 1980, the program has expanded to include 81 transit companies from across the state. It now provides up to 90 percent of the costs of a senior citizen's trip. The additional 10 percent of the fare is usually picked up by an area agency on aging. The program has been most successful at increasing the use of public transportation by the target groups: 95 percent of the riders on the participating services are senior citizens. Other passengers pay up to $10 for unsubsidized trips on the same service. Although the 35-mi limitation does not allow this program to substitute for most intercity travel, it is possible for a senior citizen to use a local cooperating service to travel to an intercity bus stop. In at least one small city, Lancaster, Pennsylvania, schedules are coordinated to encourage such transfers.

In Michigan, the state actually purchases service on intercity routes abandoned by private carriers, provided that the abandoned route was the only form of intercity service for rural residents. These routes are then contracted out on a bid basis to operators who are expected to meet specific safety requirements and to build up patronage within a 2-year period. Because the primary objective is to provide service, the state will pull out of a route if a private operator wishes to serve the same area without any state funding. To date, the program has worked well in sparsely populated areas like the thumb area of the state.

PROGRAMS FOCUSED ON RURAL SERVICE NEEDS

Operating subsidies, whether federal or state, may not necessarily be the long-term answer to the problems of providing intercity bus transportation in rural areas. Continued subsidies may, indeed, only temporarily prop up services that need more serious attention.

As indicated previously, the critical requirement for effective rural intercity bus service is sufficient ridership. As long as ridership continues to decline, continued service cannot be assured. Three of the states surveyed, Michigan, Minnesota, and Iowa, are attempting to address factors that may be contributing to declining ridership. Again, their approaches are sufficiently uncommon to warrant more extensive discussion.

In Michigan, state efforts have concentrated on bus safety and upgrading equipment. The concept is that people are reluctant to ride on old vehicles that may be of questionable quality and potentially unsafe. Consequently, the state department of transportation has launched a program that provides new vehicles to intercity bus lines serving rural areas within the state, in the hope of improving not only safety records but also the image of the system and thereby building confidence in it and encouraging greater ridership.

Participating companies are provided with new buses and a safety certificate that requires them to have safety inspections at a state-operated maintenance facility twice a year. In exchange for the new equipment, the operator agrees to serve particular areas on a regular schedule at least 5 days a week and agrees to pay back the state for the buses over a 6-year period at 5 percent interest. At the end of the 6 years, the title to the vehicle is turned over to the operator. The target group for the program is clearly small intercity bus operators in rural areas. New operators who want to operate along major highways have not been permitted to participate because of limited funds. The program has been credited with retaining continued safe service for workers in northern Michigan where three small companies now operate new buses over scheduled intercity routes. Ridership has increased in northern Michigan and stabilized elsewhere in Michigan.

Another approach to declining ridership has been developed in Minnesota where the department of transportation has launched a targeted market analysis to test for potential ridership in rural areas. The objective is to discuss potential needs for intercity bus transportation with those who are most likely to be affected--the rural residents themselves. Considerable effort is expended through newspapers, radio, and visits to senior citizens' centers to generate group discussions focusing on a number of bus-related issues ranging from changes in schedules and routes to needs for alternative types of service providers and equipment. Reactions of the groups, which range in size from 2 to 40 people, are taped and assessed.

To date, the analysis along one rural route indicated insufficient potential ridership to justify continued service. Efforts are being continued to build focus groups of current and potential riders to consider expanding service on some specific routes and service alternatives on other routes. Currently, the state DOT is also working with private employers and chambers of commerce to generate focus groups of potential riders. The approach has the benefit of gaining information on level of need before an operator invests in a specific route. Naturally, no system can accurately predict ridership, but having a prereading of the potential and the appeal of specific alternatives appears to be preferable to investing time and energy in a pilot, which would test only one alternative.

Iowa also is moving toward a market analysis approach to determining needs for intercity bus service. In a 6-month period ending in May 1985 the Iowa DOT, assisted by an UMTA 4-I project grant, tested five types of feeder service ranging from taxi and van to connecting bus service. The program featured aggressive marketing of the feeder services including radio and television spots, local newspaper features, and presentations in senior centers and service clubs. Handouts and television spots announced an 800 toll-free number for free information on connecting services and towns. Despite all efforts, however, the program generated only about 125 riders per month. Envisioned as an opportunity for rural riders to reexperience bus travel, the feeders actually only served as a replacement service for one town. For other towns the feeders reintroduced the intercity bus to residents who had not had that option for as long as 15 years. The disappointing responses may have been attributable in part to this introduction of a "new form" of travel after residents had become accustomed to automobiles or shared-ride travel.

Unlike the Minnesota program, these pilot feeders were expected to generate their own demand. No needs studies or focus groups preceded their introduction. The experiment showed the need for such pretests and Iowa now plans to develop focus groups and market analysis as a preliminary step in determining interest in specific feeder routes.

Local Efforts

Efforts to stimulate ridership are not limited to the state level. A number of local efforts sparked by chambers of commerce have been noted as well. In Georgia, the DOT reported numerous promotions organized by local merchants to encourage riding county buses. One of the most determined and thoughtful efforts was in Fort Bragg, California, where the city effected a positive schedule change. The bus had run from Fort Bragg to San Francisco in the morning and returned in the evening, a schedule that was most agreeable with workers and shoppers, but layover costs for the driver led the company to reverse the schedule and ridership from Fort Bragg plummeted. Community interest was sufficiently high that the chamber of commerce agreed to pay the driver's layover cost so that the original schedule could be restored.

Unfortunately, no before-and-after ridership reports are available to compare the relative success of these various programs or to compare the level of ridership on these services with that on similar systems in areas without a major effort to improve ridership.

ASSESSMENT

The lack of comparable quantitative data on ridership by route clearly limits the depth and accuracy of assessment of the adequacy of responses to the need for continuing intercity bus service in rural areas. With deregulation, requirements for regular consistent record keeping have been reduced, which makes the task of analysis even more complex. Nevertheless, some observations may be derived from the foregoing descriptive account of private and public efforts to provide replacement service to small communities. These observations include first, a prognosis for replacement service; second, a review of the potential for rural public transit as an alternative; third, an overview of the potential for public-private partnership; fourth, a request for more information on the demand for rural service; fifth, a review of the role of federal subsidies; and, finally, an overall conclusion.

Replacement Service

Clearly, it is unrealistic to expect that bus companies can be forced to retain unprofitable stops. The belief that easing requirements for entry into service will generate large numbers of replacement carriers to pick up marginal stops also appears to be unrealistic given the experience of the past 2 years. Replacement levels will probably remain about as they are. Spinning off unprofitable or marginal routes in the hopes that other firms with lower costs will be challenged to and be able to make them profitable also appears to be a rather unrealistic solution to replacement service, although there has not been sufficient time to test this concept. Local companies might be able to operate at more convenient times thereby generating a somewhat higher ridership, but most intercity routes in rural areas are destined to operate with relatively low ridership and marginal profits. The BRRA removes much of the incentive for cross subsidizing such rural routes through charters because small companies can enter the more profitable charter service without any obligation to also run a rural intercity route. It is not surprising that a major development since the BRRA has been the increase in new charter companies. With BRRA there is also little incentive for companies to enter the rural intercity market when a combination of charters and express or subscription service holds a far greater possibility of profit with the same capital investment as for a rural intercity route. In some areas small companies that had used charters to cross subsidize rural routes have found that with BRRA new firms that are exclusively charter are undercutting their traditional charter business and jeopardizing their efforts to continue unprofitable rural routes.

Publicly Funded Alternative Systems

The experience of the last 2 years has indicated that continuing to provide intercity service in many rural areas is more of a public service than a target for private enterprise. That would indicate the need for publicly funded forms of alternative service. However, rural public transit as provided in most areas cannot substitute for intercity bus service. In most areas it is operated by a social service agency within a specific county and serves the needs of a specific clientele. As required by federal Section 18 funding, most such services also carry the general public on a space available basis, but operating times and routes make that provision of limited utility to the general traveling public. Rural public transit can only meet the needs for intercity bus service if it travels in sufficiently large multicounty regions and has schedules and routes that appeal to a broad base of the general public.

Public-Private Cooperation

Linking rural public and continuing private service would appear to be a natural solution. This study, however, indicates few efforts to provide feeder programs that would link rural public transit with private intercity buses at continuing stops. In most states there is no encouragement for feeder programs and transfers are arranged only on an informal basis for specific passengers. Such systems work to some degree for outgoing passengers but make a return trip almost impossible. Only in Iowa was there a major state-initiated effort to encourage feeder programs linking local services with private intercity carriers at locations along an Interstate. The Iowa experience pointed out that feeder systems will not self-generate passengers. A considerable effort in publicizing the program is essential to reassure passengers, especially about the return trip. Any reports of unsuccessful transfers or long waits between vehicles can undo months of effort in generating riders. Only with the full cooperation of all parties including the operators of the transfer stop (restaurant owners, gas station owners, etc.) can such a system work effectively and then only by building a tradition of success can it generate riders. The complexity of operating such a system is enough to discourage some. To expect successful feeder programs to develop on an ad hoc basis by local initiative is unrealistic.

Public-private cooperation in building joint terminals has eliminated a major problem in facilitating transfers through cooperative scheduling and providing a safe, convenient location for the wait between buses. This venture worked successfully in Clarksville, Wilson, and Cadillac, when private companies and the public saw mutual benefit in the cooperative venture. Opportunities for such cooperation are, however, limited.

Level of Demand for Service

Other examples of local initiative working to continue or modify intercity bus service speak to a major factor in providing either replacement or alternative service--extent of demand. Where communities have mobilized efforts to retain service, bus companies have responded positively. It is much more difficult for bus companies or even publicly sponsored services to monitor informal protests or to respond to the needs of individuals.

In general, what is needed is a clearer picture of what type of service is needed and the level of demand in specific rural areas. Ridership surveys have characterized bus riders as primarily those either over 65 or under 18, those with lower incomes, and those embarking on relatively short trips. In general, 16 percent of bus riders are 65 or older, and 33.6 percent are under 18. In 1977, 19.3 percent of bus travelers had incomes under $5,000 and 69 percent traveled less than 600 mi (11). These proportions differ in studies conducted in different states.

Although no separate surveys were conducted of intercity travelers in rural areas, the expectation is that the characteristics of rural residents riding buses mirror the national average, except for perhaps a larger proportion of senior citizens because rural areas are home to a sizable senior population. Studies have focused on proportions of aged and low-income individuals in rural areas with abandoned bus services (7,11), but they can do no more than indicate the level of a pool of intercity bus riders. They do not indicate the level of demand for service. Past ridership figures appeared to indicate a low level of demand, but it is unclear whether those figures represented a response to the type of service provided in the past or to intercity buses in general. The Minnesota effort and the parallel program in Iowa are viable approaches to gaining insight into the level of demand for intercity buses in rural areas--a factor critical to the interest of any replacement service. The Michigan bus loan program is an indication that rural workers will ride a safe, convenient service when offered. The experiment in the Outer Banks of North Carolina reconfirms the popularity of convenient well-scheduled service among low-income rural workers. Efforts in rural areas with less well-defined work destinations have not fared as well.

Farebox charges are another important consideration in determining demand. Both Pennsylvania and California have minimized this factor for senior citizens through state subsidies. Ridership among the rural elderly in those states is relatively high. The Minnesota study, however, indicated that some members of the general public would be willing to pay $1 more than the existing fare if service were reliable and schedules convenient. Obviously, fare levels as well as other considerations must be assessed for each area.

Federal Subsidies

The level of federal subsidy is limited. All states surveyed emphasized the need to continue the Section 18 program. Nevertheless, this program cannot begin to meet the needs of all rural residents. A scattershot effort all over a state is unlikely to create much of an impact. If viable alternative service is to be generated or existing service is to be effectively subsidized, it is important to use the federal money where there is a demonstrated need or demand for service. Only one state, Wisconsin, is attempting to set up a formal priority-ranking system for allocating Section 18 funds. Such a system may well be beneficial as long as priorities are regularly reviewed and are sufficiently flexible to respond to demonstrated needs. Because federal money is limited, it is also critical that it be reinforced by state and local funding if adequate service is to be provided.

CONCLUSION

Two years after the BRRA went into effect it is safe to say that the act has not benefited small rural communities. The hope that ease of entry requirements would generate replacement service was generally ill-founded. What has happened since BRRA in terms of replacement service is similar to what happened before. The potential for using publicly funded rural transit as an alternative form of service or as a feeder service has not been consistently explored in the various states, nor has there been sufficient determination to use state programs to bolster the federal Section 18 program. If effective intercity service is to continue in rural areas, it will take a clear indication of public demand for that service and a public willingness to help meet that demand. Avenues for public-private partnerships are available, but in a deregulated environment they will not be explored unless communities can demonstrate demand and private companies can perceive the potential for profit.

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APPENDIX--RURAL BUS REPLACEMENT SERVICE SURVEY

I. What was the statewide impact of deregulation of intercity buses particularly in rural areas?
   1. How many routes were cancelled in rural areas?
   2. Were there any formal or informal protests? If so, what was the result of the protest?
   3. Have cancelled routes been replaced? If so, how?
   4. Have new companies entered the field? What type? How many?

II. Have there been any efforts to use rural public transportation to replace abandoned routes?
   1. Have Section 18 funds played a role in replacement? If so, how?
   2. Are there any efforts to use rural public transportation systems as feeders?
   3. Are there other efforts to replace intercity bus service?

III. Are there any state programs that have been developed to assist with rural intercity bus travel?

IV. Are you aware of any local efforts to assist with intercity travel?

V. Are there other examples of public-private cooperation in providing for intercity travelers in rural areas?

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Michigan Intercity Bus Study: Comparison of 1985 and 1977 User and Ticket Surveys

ROBERT L. KUEHNE and DOUGLAS C. HOLLANDSWORTH

ABSTRACT

The characteristics and origin-destination patterns of Michigan intercity bus service passengers in 1977 and 1985 are compared. One question addressed is whether the 1982 federal and state deregulation of the intercity bus industry resulted in any change in these characteristics and patterns. Intercity bus users in 1985 are somewhat older, have more operating automobiles per household, have a higher family income, and have made fewer intercity bus trips during the past 12 months than their 1977 counterparts. The predominant user continues to be female, but the female-male percentage gap has narrowed. The percentage of employed users has increased, that of college students has decreased, and that of retirees has remained about the same. User rating of intercity bus services is presented. Users are generally satisfied with the courtesy of employees, the condition of buses, schedule information, and adherence to schedule; they are generally dissatisfied with frequency of service and condition of terminals. Detroit continues to be the hub of Michigan's intercity bus system; nine of the top ten city pairs have Detroit as one terminus. The top corridor is Detroit-Chicago.

Significant changes have occurred nationwide in the intercity bus industry, the population, and the economy in the more than 8 years that have passed since the last Michigan intercity bus survey. Even when regular-route service is cross subsidized with charter revenues, it is becoming increasingly difficult for revenues to cover operating costs (the 1984 operating ratio was 98.3 percent), the number of operating companies has tripled (1,2), the number of employees has increased by more than 10 percent, and the number of bus-miles has decreased somewhat. At the same time, the number of passengers has increased by 10 percent and revenue passenger-miles by 5 percent.

Deregulation is linked to some of these trends. Passage of the Motor Bus Transportation Act of 1982 in Michigan and the Bus Regulatory Reform Act of 1982 at the federal level triggered changes, which are still taking place 3 years later, in the delivery and cost of intercity bus transportation. These include discontinuance and reduction of service, franchising services, a move away from terminal ownership to terminal leasing, cross subsidizing, anemic operating ratios, and a proliferation of intercity bus companies that provide a variety of services (e.g., regular-route, airport, work commuter, charter).

Michigan's population decreased during the early 1980s, although it recovered somewhat in 1984, and remains substantially below its 9.3 million 1980 census figure (3,p.5). The state continues to have a decreasing percentage of the nation's population: 4.4 percent in 1970, 4.1 percent in 1980, and an estimated 3.9 percent in 1985. The population of Wayne County (comprised primarily of Detroit), as a percentage of that of Michigan, has experienced a more rapid decline.

The employment picture in Michigan is uncertain. On one hand, the state's 1984 employment was higher than that of any year in the past two decades, except 1978 and 1979 (3,p.131). On the other hand, the 1984 unemployment rate of 11.2 percent, although lower than that of 1980, was more than 1.5 times the national average (7.1 percent), and it fluctuated between 10 and 11 percent in 1985.

Consequently, with the advent of deregulation, changes in the intercity bus industry, and a variable socioeconomic climate, the need existed to survey users of intercity bus service in Michigan. Some of the study objectives were to

1. Measure the effect of intercity bus deregulation on intercity bus users and service levels in Michigan,
2. Determine if the profile of the intercity bus user has changed since 1977 when a similar study was conducted,
3. Identify changes in the trip-making patterns of intercity bus users since 1977, and
4. Determine the users' perception of intercity bus service in Michigan.

1977 STUDY

Two surveys were conducted in Michigan during May 1977 to provide socioeconomic and travel information about intercity bus passengers. These were an on-board user survey and an intercity bus ticket survey (4).

The user survey was conducted in 12 travel corridors (Figure 1). Nearly 75 percent of the approxi-

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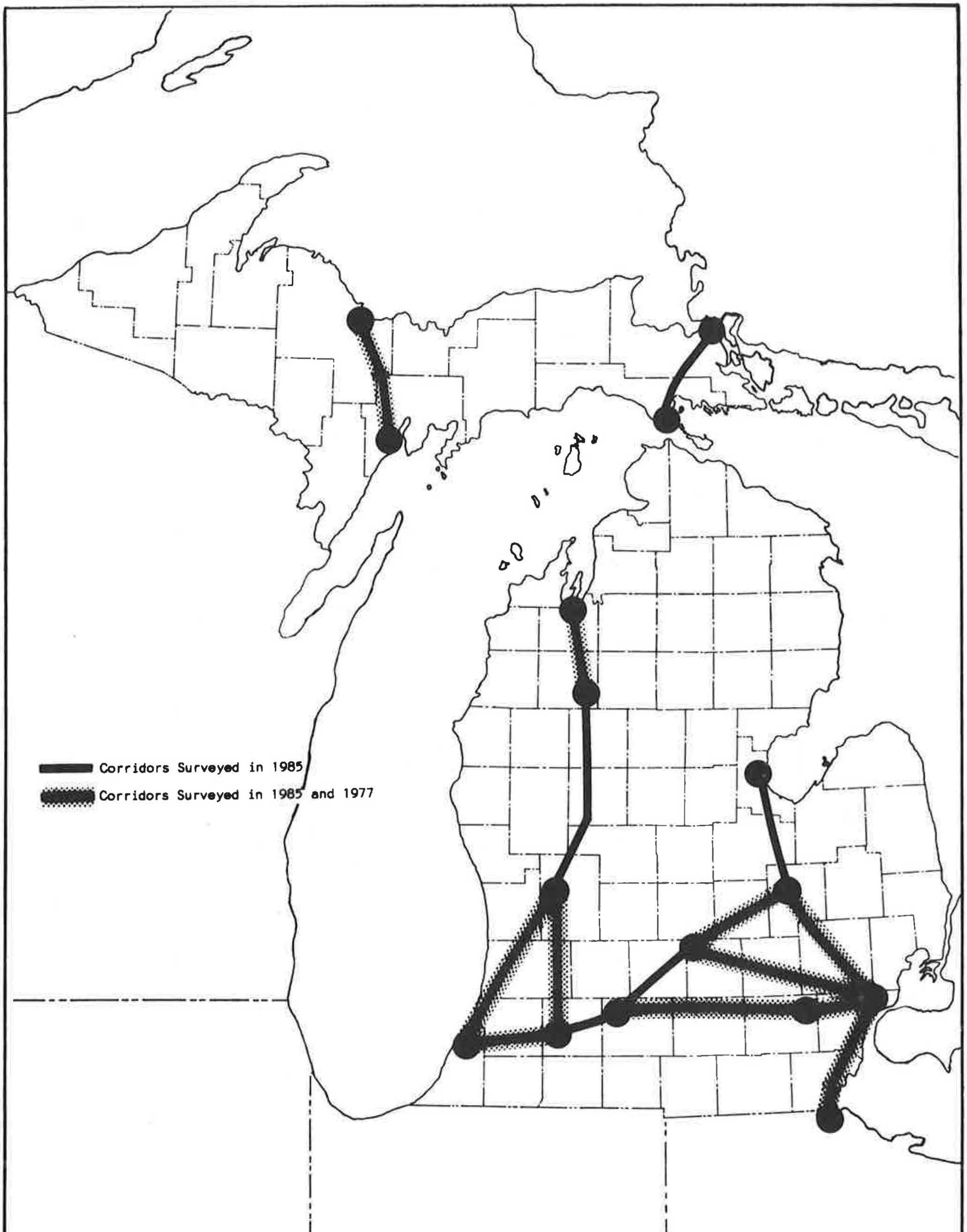

FIGURE 1 User survey corridors.

mately 3,300 questionnaires distributed were usable. Major findings of this on-board survey included:

- Somewhat more than half of the users (53 percent) traveled by automobile at the origin and destination ends of their intercity bus trip. The exception to this was at stations located adjacent to college campuses where an above-average number of riders walked to and from the station.
- Half of the users (50 percent) were riding the bus to visit friends or relatives; one in six (17 percent) was riding for personal business reasons.
- Nearly half (47 percent) of the users were 18 to 29 years old, and one in four (25 percent) was 50 or older.
- College students constituted the largest group (22 percent) of users.
- Approximately 60 percent of the users were female.

The ticket survey consisted of counting tickets for at least 7 consecutive days (May 9-15) at 36 intercity bus stations located throughout Michigan (Figure 2). The following were among the findings of the ticket survey.

- A daily average of 2,033 tickets was sold at the 36 surveyed stations.
- Detroit was the most frequent Michigan destination, generally followed by Michigan's larger urbanized areas. It was also the most frequent origin of trips destined out of state.
- Chicago was the largest out-of-state attraction for trips originating in Michigan (116 trips daily).

1985 SURVEY

May 1985 appeared to be an appropriate time to measure the effect of intercity bus deregulation. More than 2 years had passed since passage of the deregulation legislation at the state and federal levels. Although more changes in intercity bus services could be expected, many had already occurred.

To maximize comparability, the 1985 survey was conducted during the same time of year as the 1977 survey. The 1977 survey was conducted during the second full week in May, so May 12-18, 1985, was selected as the time for tabulating all tickets sold and conducting most of the user survey.

The same corridors and stations included in the 1977 study were surveyed in 1985. This was done to improve data comparability. Twelve corridors and 36 stations were surveyed in the 1977 user and ticket surveys, respectively. In 1985, 15 corridors were included in the user survey and 40 stations in the ticket survey.

OPERATING ENVIRONMENT AND MODAL CHOICES

The study area was the entire state of Michigan: 83 counties and 13 urbanized areas on the upper and lower peninsulas. Michigan has

- 9.3 million residents (eighth largest state) with 80 percent living in 13 urbanized areas plus those portions of two out-of-state urbanized areas (South Bend and Toledo) that extend into Michigan; some 85 percent reside in the southern half of the lower peninsula as defined by an imaginary line from Muskegon to Bay City (Figure 3);
- Approximately 1,600 employers with 250 employees or more;
- More than 90 percent of its 4-year college enrollment attending schools located in the southern half of the lower peninsula; this amounts to more than one-quarter million students;
- Approximately 9,500 mi of Interstate freeways and trunk lines that accommodate 31.9 billion annual vehicle miles of travel (8 percent of the roads carry nearly 50 percent of the traffic); and
- A maximum driving distance of approximately 640 mi from boundary to boundary (New Buffalo to Ironwood); this is farther than it is from Detroit to St. Louis or to Philadelphia.

Several changes have occurred in Michigan's intercity passenger transportation system since May 1977. Intercity bus route mileage, communities served, and use have decreased; intercity rail passenger route mileage, communities served, and use have increased; air service departures and use have increased; state trunk-line mileage and use have increased.

The highest level of intercity bus service in 1985 was east-west between Detroit and Chicago and north-south between Detroit and Toledo with more than 10 daily round trips (Figure 4). This was also the case in 1977. Eleven of Michigan's 13 urbanized areas are connected by routes that have at least five daily round trips. There is no service in the thumb, most of the northeast lower peninsula, and between Sault Ste. Marie and Marquette. In addition, service was discontinued in December 1985 along Michigan's western shoreline between Holland (35 mi south of Muskegon) and Petoskey. There is reduced service, compared with 1977, south of the Detroit-Chicago corridor (I-94).

At the time of the 1977 survey (5,p.III-113), most population and employment centers in Michigan, both in the lower and the upper peninsulas, had direct intercity bus service (Figure 5). In 1985 some of these places had either no service or inconvenient routing and schedule times. However, rail passenger transportation served three more population centers in 1985 than in 1977, commercial air service departures had increased, and Michigan's highway system had increased by 68 mi.

The number of average daily intercity bus passengers in Michigan in 1985 had decreased 44 percent since 1977 (6,p.46). Meanwhile, rail passengers increased by 6 percent, commercial air passengers by 22 percent, and state trunk-line traffic by 8 percent.

USER SURVEY

The user survey was designed to profile the intercity bus user in the current deregulated environment and to compare that profile with the 1977 profile. The survey was conducted in 15 corridors (Figure 1). In addition, riders rated the service.

Procedures

It was recognized that any such survey needed the full consent and cooperation of the intercity bus carriers serving Michigan and needed to generate data comparable to the 1977 survey results. Finally, it was decided to use a mail-back survey form in an

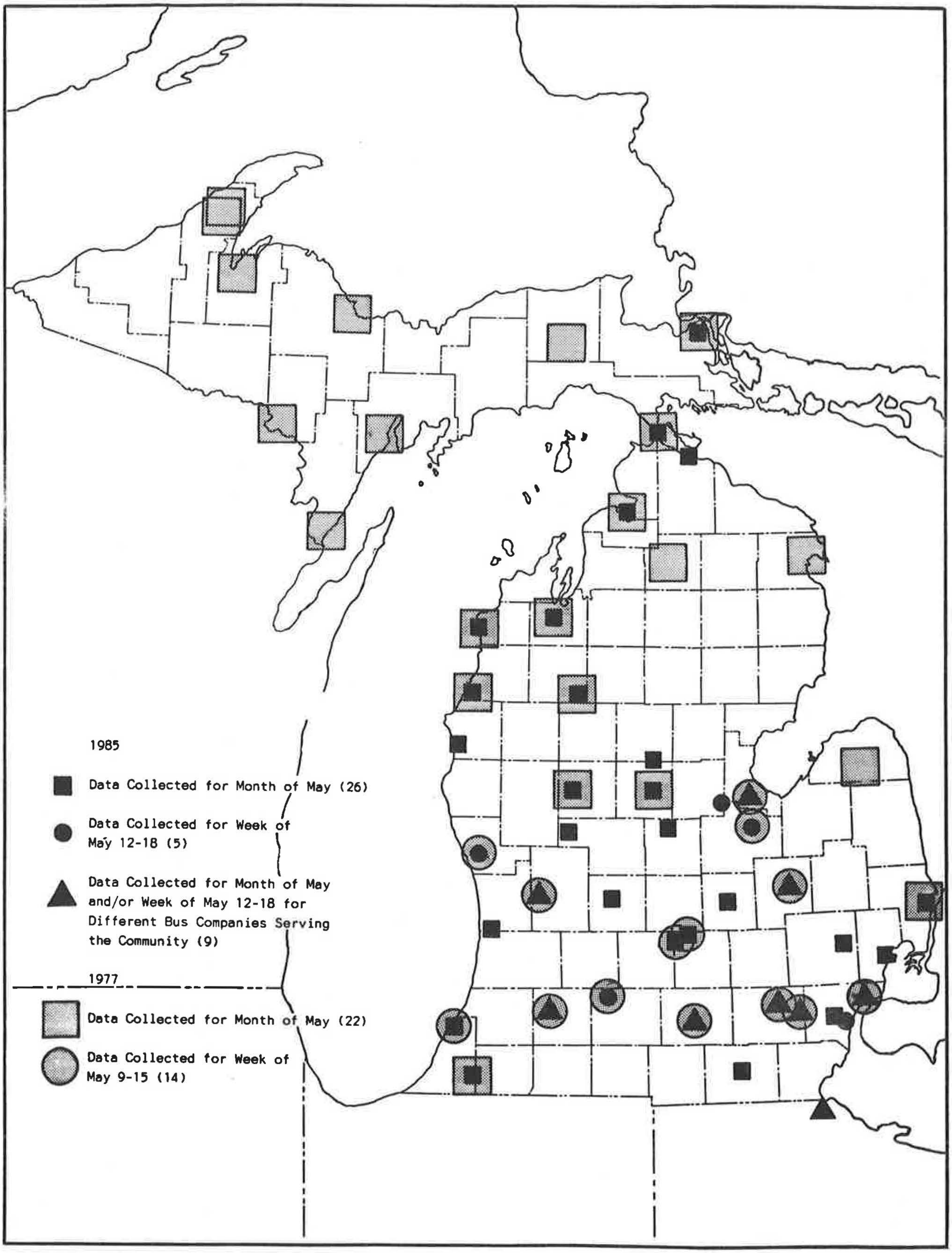

FIGURE 2 Intercity bus ticket survey stations.

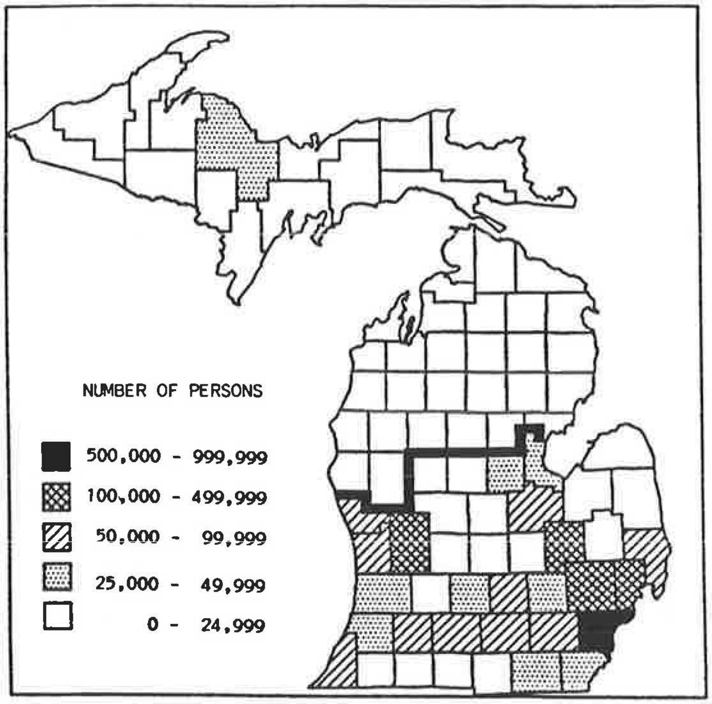

FIGURE 3 1980 population.

attempt to obtain user data for more routes without using additional survey personnel.

Some salient points regarding the procedures include (a) the intercity carriers offered their complete cooperation; (b) the 1985 survey was conducted in May, the same month as the 1977 survey; (c) more corridors were included in 1985 than in 1977; and (d) most routes with five or more daily intercity bus round trips were surveyed.

Sample Size

Careful attention was given to sample size when evaluating the data collected in the user survey. For the survey, 1,187 questionnaires were distributed. Of these, 437 were usable returns. This constituted a 36.8 percent return rate, which is an 18 percent sample of the approximately 2,400 daily intercity bus users in Michigan. It is not as large a return rate as was desired, nor was it as large as that obtained in the 1977 survey (74.5 percent), which did not use the mail-back technique. The 36.8 percent return rate is, however, acceptable and fairly standard for mail-back surveys conducted by the Michigan Department of Transportation (a 30 percent return rate is average).

Findings and Conclusions

Access

Fewer people walk to the intercity bus station to begin their bus trip. Approximately 10 percent did so in 1985 compared with 17 percent in 1977. At the same time, more passengers access bus stations via the automobile (64 versus 54 percent). This is somewhat less than Texas' 68 percent and North Carolina's 74 percent (7). This shift away from walking and toward the automobile may be partly attributable to the higher number of automobiles per household and family income of 1985 users. This trend could continue if more bus terminals are relocated to improve bus travel times (such as near freeway interchanges) and terminals are shared with other transportation modes.

Use of local public transit going to and from intercity bus terminals remains about the same. About 11 percent of passengers used local public transportation to reach a terminal and 9 percent used it to reach their destination from a terminal in both 1985 and 1977.

There continues to be little interconnecting of intercity bus and Amtrak trips. That is, few people (less than 1 percent) use intercity bus service to reach an Amtrak terminal.

Fewer than 5 percent of the users transferred from one intercity route to another to complete their trip, either in 1985 or 1977.

One conclusion to be drawn from the access data is that, because the automobile is used more now than in 1977 between intercity bus terminals and trip origins and destinations, adequate off-street parking, drop-off, waiting, and pick-up space should be assured. A second conclusion is that, because use of local public transit remained the same (about 10 percent), local transit to and from intercity bus terminals should be maintained or improved. A third conclusion is that, because walking to terminals has declined substantially, catering to the walk-in intercity bus user may not be as important a criterion for station location as it was in the past. For instance, a recent passenger survey in one of Michigan's urbanized areas revealed that more than 85 percent used an automobile to go to and from the downtown bus terminal. A full 79 percent of these intercity bus users lived outside the community in which the terminal was located (8). A fourth conclusion is that, because few people use intercity bus service to access Amtrak (1 percent) and not many more transfer to another intercity route (5 percent or fewer), intercity bus services that feed Amtrak trains and other intercity buses should be reevaluated.

Trip Purpose, Frequency, and Travel Options

Visiting friends and relatives continues to be the dominant trip purpose (approximately 5 of 10 trips) although to a lesser extent than in 1977 (44 percent versus 51 percent). When vacation trips are added, the 1985 and 1977 percentages are approximately the same.

Personal business trips continue to rank second, comprising one-fourth of all trips. This is significantly higher than the 1977 figure of 18 percent. This change is tempered by a possible lack of understanding of what "personal business" connotes to the respondent.

Work or business trips continue to constitute about 1 of 10 trips made by intercity bus. Urban

FIGURE 4 Intercity bus regular-route system, 1985.

areas are the origin or destination for 9 of 10 trips, and Detroit is the urban area in 3 of 10 cases. This percentage has increased slightly since 1977, from 8 to 10 percent. The 9 percent figure of those using intercity bus services 20 or more times in the past 12 months corroborates the 10 percent work trips figure.

Users are making somewhat fewer trips by intercity bus. Nearly 3 of 10 users had made more than 10 trips in the past year in 1977 compared with fewer than 2 of 10 in 1985.

More than 8 of every 10 passengers use intercity bus service fewer than 10 times a year. Nearly 2 of these had not used it at all previously, and another

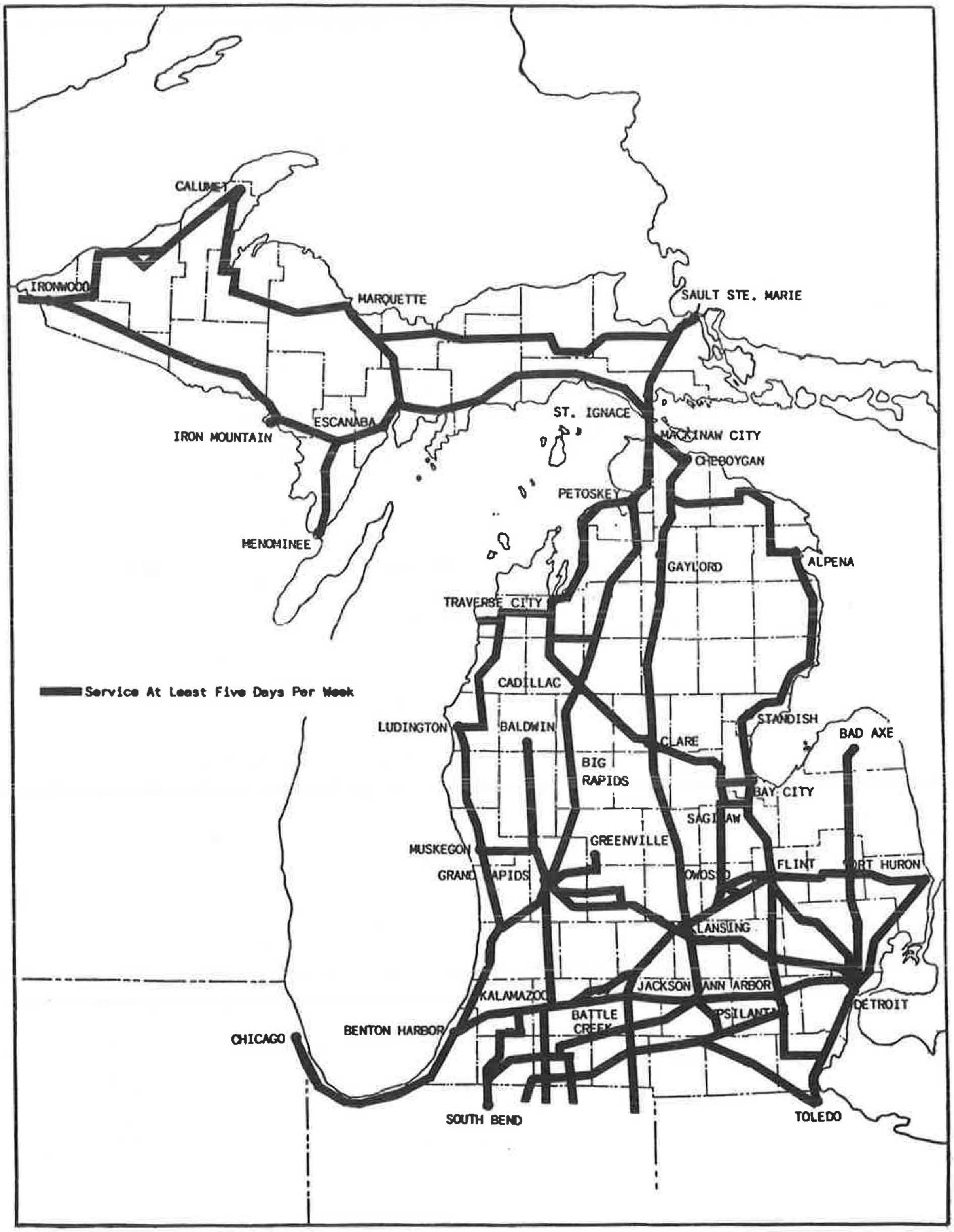

FIGURE 5 Intercity bus regular-route system, 1977.

3 had used it only once or twice in 1985. The 1977 report did not provide a breakdown of the 0 to 9 category.

If intercity bus service were discontinued, nearly one-half of the passengers would drive an automobile or ride with a friend, 35 percent would use another mode of public transportation (rail and air were equally popular), and 16 percent would not take the trip. The latter might be due to nonavailability, high price, or fear of the alternate travel options.

One perception is that older Americans have fewer alternatives than do younger bus riders. A cross tabulation of retirees and travel options yields percentages similar to those for all intercity bus users with one exception: more would take Amtrak (25 versus 16 percent) and fewer would fly (10 to 11 percent versus 16 to 17 percent). The conclusion is that retirees would make the trip as often as any other user although they would be more likely to take Amtrak than fly. A second conclusion is that although older Americans who use intercity bus service have fewer automobiles and less income (more than half have incomes of less than $10,000), they would make the trip as often as any other user.

Household Size and Operating Vehicles per Household

The user's household size is slightly smaller than that of the overall Michigan population (2.7 versus 2.8). Two of 10 users are single, which is similar to the state's percentage; however, fewer than the state's percentage are from two-person households (18 versus 30 percent) and more come from households of five or more persons (28 versus 20 percent). This data item was not obtained in the 1977 survey. One conclusion is that intercity bus travel is not a family affair. Eight of 10 users are traveling alone, yet only 2 of 10 are from one-person households.

There are significantly fewer intercity bus users from no-car households. A reduction of 12 percent from 36 to 24 percent was experienced from 1977 to 1985. The number of no-car households in Michigan decreased by 2.5 percent from 12.2 percent to 9.7 percent.

There has been a similar percentage increase in the groups with one, two, and three or more operating vehicles per household. This increase is 5 percent for the groups with one and three or more vehicles per household and 2 percent in the group with two vehicles per household. The pattern for all Michigan households was dramatically different: one vehicle per household (decreased 13 percent); two vehicles per household (increased 4 percent); three or more vehicles per household (increased 12 percent).

The number of employed (full- or part-time) users has increased substantially. More than 4 of 10 users were employed in 1985 compared with fewer than 3 of 10 in 1977. It should be noted that employment in Michigan, and the nation, was higher in 1985 than in 1977.

The number of unemployed users remained about the same (10 versus 9 percent) during a time when the unemployment rate in Michigan increased by 37 percent from 8.2 percent (1977) to 11.2 percent (1985).

College students decreased as a percentage of total users from nearly 3 of 10 to fewer than 2 of 10 during a period when Michigan's college enrollment was stable. Enrollment at 4-year universities and colleges in Michigan was 284,947 in 1977 and 282,413 in 1984. A survey of Michigan rail passengers indicated a similar decline, from more than 25 percent in 1975 to 18 percent in 1985.

Retired users remained about the same as a percentage of total users (15 percent). At the same time, senior citizens (65 and older) are constituting an increasing percentage of Michigan's population (8.2 percent in 1960, 8.5 percent in 1970, and 9.6 percent in 1980). One conclusion is that services to major 4-year universities should be evaluated to better accommodate weekend student travel. A second conclusion is that a fare structure, marketing program, and image should be created that will increase use of intercity bus service by retirees.

Sex, Age, and Family Income

The majority of intercity bus users continues to be female, although decreasingly so. The 1977 percentage differential of male to female passengers of 22.2 percent had been narrowed to 7.0 percent in 1985. The differential for Michigan's total population in 1980 was 2.5 percent.

The age distribution of users has not changed markedly since 1977 although the average age has increased from 28 to 33 years. This is similar to all Michigan residents and to the population of the nation as a whole. In Michigan, the median age increased from 1970 to 1980 to 1985 from 26.3 to 28.8 to 30.5 years; nationally, it increased from 1970, to 1980 to 1985 from 28.1 to 29.9 to 31.6 years.

A somewhat surprising finding is that most riders are neither younger nor older. Nearly half the users are in the 25 to 64 age range. This is consistent with the 1981 Indiana (55.1 percent) and 1980 New Mexico (51.7 percent) survey findings (7).

No major shift in the income distribution of users is discernible, although the median family income (in 1985 dollars) increased about $1,000 from 1977 to 1985. The median family income of bus passengers in both years was considerably below the median family income of Michigan's residents in 1980, which was $24,200. The median family income (in 1985 dollars) of intercity bus users was $18,100 in 1985 and $16,900 in 1977. The $10,000 to $19,999 group decreased by 28 percent whereas all other income groups increased slightly.

Users' Rating of Service

Users are generally satisfied with employee courtesy, condition of buses, schedule information, and adherence to schedule. They are generally dissatisfied with frequency of service and terminal conditions, although even these percentages are in the high sixties as the following tabulation indicates.

Rank	Feature	Very Good and Good (%)
1	Courtesy of employees	84.9
2	Condition of buses	83.8
3	Schedule information	80.1
4	Adherence to schedule	79.6
5	Frequency of service	69.5
6	Condition of terminals	67.0

When asked "What one thing would you change about the bus service?" approximately 38 percent stated level of service. Suggestions included (a) improve frequency of service, departure and arrival times, and connections and (b) reduce number of stops and travel time. Condition of the buses received 24 percent of the comments. Eliminate smoking, improve seating, provide cleaner bathrooms and cleaner buses, and provide music were mentioned. More than 7 percent indicated that no changes were needed. Approximately 40 percent did not comment.

The perception that intercity bus terminals are generally undesirable because of their location or condition, or both, was somewhat confirmed by the users surveyed. Approximately one-third of the users rated bus terminals as being in fair or poor condition. Twenty of the users' comments pertained to the condition of terminals.

TICKET SURVEY

The ticket survey was designed to profile current travel patterns, some of which have emerged in the postderegulation period, and compare them with 1977 travel patterns. This survey provided data for every trip made from 40 intercity bus stations located throughout the state (Figure 2). Information at lower volume stations was collected for 1 month, at higher volume stations, for 1 week. These data have been incorporated into a trip table of intercity bus passenger travel patterns that represent an average day.

Procedures

Several steps were followed in developing and conducting the ticket survey. Many of the procedures are the same as, or similar to, those followed for the user survey. Selected steps were done simultaneously for both surveys. Some salient features of these procedures are that (a) the two surveys were conducted during the same time frame, (b) the week of May 12-18 was used to determine average daily passenger volumes, and (c) tickets sold at 40 intercity bus terminals (compared with 36 terminals in 1977) throughout the state were counted.

Sample Size

Virtually all tickets issued at 40 intercity bus stations throughout the state were included in the ticket survey. Four assumptions, which are important when determining the validity of the ticket data, were made in obtaining ticket information. The first assumption was that most tickets would be used within 1 week of purchase. The second assumption was that the return portion of a round-trip ticket would, in the majority of instances, be used within 1 week as well. The third assumption was that round-trip tickets would be mirrored in paired cities. This means that the same number of round-trip tickets would be purchased from Lansing to Jackson as were bought from Jackson to Lansing. The fourth assumption was that all tickets to out-of-state or other nonsurveyed stations would be mirrored.

The sample size, based on tickets sold at stations surveyed, was more than 95 percent. That is, although the percentage of stations surveyed was small, the percentage of tickets surveyed exceeded 95 percent of all tickets sold in Michigan. Only if the month of May or the week of May 12-18 were completely atypical could the data be unrepresentative of intercity bus trip characteristics throughout the state.

Findings and Conclusions

During the week of May 12-18, 1985, some 9,364 tickets were sold at the stations included in the ticket survey. This is an average of 1,338 tickets per day. Approximately one-third of these were sold in Detroit (2,919). More than 500 were sold at three additional Michigan terminals.

The 1985 survey week ticket sales were significantly lower than the 1977 figure: 9,364 versus 14,233. Correspondingly, the average number of tickets sold daily at surveyed stations was 1,338 and 2,033, respectively. This constituted a decrease of 34.2 percent during the 8-year period. Because the 1985 figure is based on ticket counts at more stations in a system that is smaller than the 1977 system, the actual decrease in ridership exceeds 34.2 percent and may possible be as high as 44 percent.

The 10 most productive stations changed somewhat (Table 1). Detroit continued to be the highest in weekly ticket sales. The only change in the top five was that Ann Arbor replaced Kalamazoo in the number-five position. In the second five, some shuffling occurred and Jackson bumped Saginaw from the top 10.

TABLE 1 Top 10 Michigan Intercity Bus Communities (based on weekly ticket sales) 1985 and 1977

Community	1980 Population	1985 Rank	1985 Tickets	1977 Rank	1977 Tickets
Detroit	1,203,339	1	2,919	1	4,865
East Lansing	48,309	2	805	2	1,376
Grand Rapids	181,843	3	770	3	1,103
Flint	159,611	4	578	4	877
Ann Arbor	107,316	5	497	6	664
Kalamazoo	79,722	6	467	5	817
Lansing	130,414	7	447	8	631
Battle Creek	35,724	8	284	7	654
Ypsilanti	24,031	9	241	9	470
Jackson	39,739	10	237	12	357

Note: The 1985 survey week was May 12-18 (Sunday through Saturday). The 1977 survey week was May 9-15 (Monday through Sunday).

Source: MDOT, Bureau of Transportation Planning, Passenger Transportation Planning Section.

The top 10 Michigan (intrastate) city pairs in 1985 had 18 or more bus passenger trips between them, and the highest volume was 62 (Table 2). The highest number of intercity bus passenger trips (82) occurred between Detroit and Chicago, which is Michigan's gateway to the west and southwest. Also one of the highest is the Detroit-Toledo city pair at 36; Toledo represents Michigan's gateway to the east and southeast.

TABLE 2 Top 10 Michigan Intercity Bus Corridors (based on daily passengers) 1985 and 1977

City Pair	Distance (mi)	1985 Rank	1985 Passengers	1977 Rank	1977 Passengers
Detroit-Chicago	280		82		92
Detroit-Ann Arbor	38	1	62	1	79
Detroit-East Lansing	80	2	60	3	59
Detroit-Flint	60	3	49	4	57
Detroit-Ypsilanti	30	4	43	2	68
Detroit-Lansing	85	5	40	5	42
Detroit-Toledo	58		36		66
Detroit-Jackson	73	6	29	6	36
Detroit-Grand Rapids	149	7	24	7	28
Ann Arbor-East Lansing	58	8	23	13	16
Detroit-Saginaw	96	9	20	10	23
Battle Creek-Kalamazoo	23	10	18	12	20

Source: MDOT, Bureau of Transportation Planning, Passenger Transportation Planning Section.

Ten of these city pairs have Detroit as either an origin or a destination. The top city pair is Detroit-Chicago, the second is Detroit-Ann Arbor, and the third is Detroit-East Lansing. It should be noted that Ann Arbor and East Lansing are the homes of Michigan's two largest universities (the University of Michigan and Michigan State University). One conclusion is that emphasis should be placed on frequent, on-time service in corridors that contain these city pairs.

The top five Michigan city pairs remained the same, although not in rank order, as in 1977. Detroit-Ann Arbor continued to be the number-one city pair. The order of the other four, however, changed. Two city pairs were new to the top 10: Ann Arbor-East Lansing and Battle Creek-Kalamazoo replaced East Lansing-Flint and Grand Rapids-Kalamazoo.

The predominant distance defined by the top 10 Michigan city pairs was in the 50- to 100-mi range. Six city pairs were in this category, and one was nearly 150 mi. Eight were in this group in 1977. These are truly intercity transportation distances. Three city pairs fall into the commuter service range with a distance of less than 40 mi; the shortest is 23 mi.

Several Michigan cities had more than 100 daily intercity bus passenger trip ends. These were Detroit (956), East Lansing (252), Grand Rapids (239), Flint (210), Lansing (159), Kalamazoo (154), and Ann Arbor (152).

SUMMARY

Users

The typical 1985 intercity bus passenger was from a household with 2.7 persons, 0.8 operating vehicles, and an average family income of $18,100 (in 1985 dollars); was employed, female, approximately 33 years old; and was not traveling with others in her household.

This means that intercity bus users in 1985 were somewhat older, had more operating automobiles per household, had a higher family income, and had made fewer intercity bus trips during the past 12 months than their 1977 counterparts. The predominant user continues to be female, but the female-male percentage gap has narrowed. The percentage of employed users has increased, that of college students has decreased, and that of retirees has remained about the same.

Users gave courtesy of employees, condition of buses, schedule information, and adherence to schedule high marks (approximately 80 percent or more ranked these very good or good). Frequency of service and condition of terminals received average or below-average marks. A significant number of users believe that no changes are needed.

Two dozen findings and nine conclusions have been made on the basis of the user survey data. There are, of course, additional findings and conclusions not explicitly identified that could affect the delivery and pricing of intercity bus service. These pertain to such items as terminals, buses, service, access to and from service, and fares.

Travel Pattern

A number of changes have occurred since 1977. These include a 44 percent decrease in Michigan-based intercity bus users, an increased percentage of users generated by Michigan's urban areas, and some shifts in the top 10 city pairs in terms of intercity bus passengers.

Detroit is the hub of Michigan's intercity bus system. Approximately one-third of all tickets sold in Michigan are purchased at the two Detroit terminals as was the case in 1977. The top corridor in Michigan is Detroit-Chicago, and most high-volume intercity bus corridors emanate from Detroit.

Intercity bus usage between urban areas is the strongest part of the intercity bus market. The number of passengers between communities that comprise the top 10 city pairs decreased significantly less than the total ticket sales of these communities. Whereas the number of passengers between these city pairs decreased by only 14 percent, total ticket sales declined by 39 percent.

Achievement of Study Objectives

The objectives of the Michigan Intercity Bus User and Ticket Study have been achieved to varying degrees. The 1985 user profile has been determined and compared with that of the 1977 user. Changes in trip-making patterns have been identified. The user's perception of intercity bus service has been described. Just how many of the changes are due to intercity bus deregulation, however, is subject to question. Certainly, service reconfigurations, reductions, and discontinuances have affected intercity bus trip-making patterns. However, economic conditions and alternate transportation modes also affect intercity bus use and the user profile, so all the changes noted are clearly not attributable to deregulation of intercity buses.

Intercity bus service in the United States is at a crossroad in its 60-year history. Deregulation and its concomitant competition, increasing costs and declining ridership, and continued competition from other intercity passenger transportation modes have brought the intercity bus industry to the threshold of major modification or collapse. A number of possible actions have been identified in this comparative study of 1985 and 1977. Some of these are being done; others warrant additional attention.

ACKNOWLEDGMENTS

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Differential Influence of an Interstate Highway on the Growth and Development of Low-Income Minority Communities

ROOSEVELT STEPTOE and CLARENCE THORNTON

ABSTRACT

The purpose of the research on which this paper is based was to measure the changes in land use and related economic and environmental variables that were attributable to the location and operation of a portion of an Interstate highway in the Scotlandville community of Baton Rouge, Louisiana. More specifically, the research was designed to determine the degree to which low-income minority communities experience unique highway impacts. The research was conducted in two phases--a baseline assessment phase and a follow-on, longitudinal phase. In the baseline phase, measures were taken of several significant variables including (a) land use on a parcel-by-parcel basis; (b) recreational patterns; (c) traffic volumes and residential densities; (d) number and variety of minority businesses; (e) housing types, quality, and conditions; and (f) street types and conditions. The follow-on phase was completed after the highway was completed and opened to traffic. A comparison of these two sets of data constitutes the assessment of the highway impacts on this community. The literature was carefully examined and the reported impacts on nonminority communities were summarized for comparison with the Scotlandville community. One conclusion reached was that many of the highway impacts identified in Scotlandville were similar to those reported in other communities. The major exception is that, whereas highways generally induced commercial developments around major interchanges in nonminority communities, the highway does not appear to attract new businesses in minority communities. Scotlandville has experienced no appreciable economic developments that can be attributed to the location and operation of the highway. Further, displaced minority businesses experience great hardships in relocating and often cease to operate when displaced.

A careful review of the available literature related to highway impacts on communities reveals that several studies have been conducted to determine the various influences of highways on the growth and development of communities throughout the United States. However, if planners and decision makers want to know how these influences apply to minority communities, they must draw inferences from what is known about majority communities. This study hypothesized that minority communities experience unique consequences of highway location and that these consequences affect community structure, growth, and development patterns. It is therefore valuable to document the growth and development trends occasioned by the location and operation of a major highway that displaced a significant portion of the households and businesses in a minority community.

DEFINITION OF PROBLEM

The location and operation of highways and other transportation facilities in economically disadvantaged minority communities have generally resulted in economic, social, and environmental consequences that have not been identified and reported in the existing body of research literature. Because disadvantaged minority communities frequently are chosen for the location of new transportation and redevelopment projects, there is a need to set forth the major structural, growth, and development consequences to these communities that must coexist with the new facilities. The major areas of influence are usually associated with land use, population and residential densities, growth and development of minority business enterprises, quality and type of housing, and numerous related neighborhood elements.

Current literature on the subject of impacts of transportation facilities indicates that much has been accomplished in this general area, but in no instance has there been an analysis of the effects in a black community on land use and its implications for minority businesses and recreational space. Most existing related studies cover a city-wide area or highway corridor, not a segment of the route to assess the impact on a population subset that has differentiated problems and characteristics. Because entrepreneurial, housing, and social and recreational opportunities are distinctly differentiated for blacks and most other minority groups, separate impact studies must be conducted at the neighborhood level if reliable empirical data are to be assembled. An attempt to do so and to compare the results with the documented experiences of other cities is presented here.

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OBJECTIVES OF THE RESEARCH

The purposes of the research were to measure the changes in land use that were attributable to the location and operation of a portion of an Interstate highway in the Scotlandville community of Baton Rouge, Louisiana, and to determine the degree to which low-income or minority communities experience unique impacts. A detailed analysis of the land use changes permits an assessment of the highway impact on minority business enterprises, population and residential densities, and recreational space. The research was aimed at assessing these impacts and comparing them with impacts reported for nonminority communities.

RESEARCH METHODOLOGY

This study documents the essential growth and development changes that occurred in Scotlandville, Louisiana, a minority community, as a result of the location of a major highway bypass in the community. It is not considered sufficient merely to ascertain the impacts in the study area; a comparison with findings in nonminority communities is also made.

This research was conducted in two phases--a baseline assessment phase and a follow-on longitudinal phase. In the baseline phase, measures were taken on several significant variables including (a) land use on a parcel-by-parcel basis; (b) recreational patterns; (c) traffic volume and residential densities; (d) number and variety of minority businesses; (e) types, quality, and condition of housing; and (f) types and conditions of streets. An assessment of the same variables was accomplished during the follow-on phase as a means of assessing the changes that occurred between 1974 and 1984. This follow-on assessment was made after the Scotlandville bypass was completed and opened to traffic (February 1984). A comparison of these two sets of data constitutes the assessment of the highway impacts on Scotlandville. The overall research design required that (a) the highway impacts in the study area be assessed and (b) the outcomes be compared with the findings reported in the literature on majority communities. The comparison permitted testing the hypothesis that the consequences of highway projects in minority communities are significantly different from those that occur in majority communities. The relevant literature was carefully reviewed and summarized to highlight impacts on communities throughout the nation.

The researchers recognized the limitations inherent in this study. Not all of the community changes that occurred or failed to occur could be attributed exclusively to the highway (the community could not be placed in a test tube), nor could all of the differences identified in the comparison with findings in majority communities be related to the minority characteristics of the area. Despite these inherent limitations, the research was believed to be extremely useful (a) in setting forth the probable differences and similarities with which future studies can make comparisons and (b) in highlighting the probable differences and similarities for planners, decision makers, and scholars. Thus, because the literature contained no studies on minority communities, such a study would be useful just as a case study, even if no comparisons were made or differences highlighted.

In addition to studying community impacts, the impacts on displaced households and businesses were assessed with the before-and-after relocation approach.

STUDY AREA

The study area is Scotlandville, an unincorporated, low-density, predominantly black residential community in an area of about 8 mi^2 north of the central business district of Baton Rouge, Louisiana (Figure 1). The residents of Scotlandville tend to be homeowners, which indicates a condition of economic independence and a potential for community improvement. This independence is continuously being reinforced by the interlocking family ties and the racial homogeneity in the area. Scotlandville is more than 95 percent black. Before the highway was built, it had a population of about 26,300.

The industrial areas to the immediate north and south and the residential areas to the far north and south of Scotlandville generated an immense amount of traffic on Scenic Highway and Scotland Avenue during the morning and evening rush hours. Because these two thoroughfares merge into one street (Scenic Highway) in the center of Scotlandville, the portion of Scenic Highway from the point of merger to Airline Highway was one of the city's greatest traffic bottlenecks. The Scotlandville bypass is that portion of Interstate 110 (begun in 197[illegible] and completed in 1984) from Airline Highway through the center of Scotlandville to Scenic Highway (Figure 2). This bypass is about 3.2 mi in length. It intercepts the traffic north and south of Scotlandville from both Scenic Highway and Scotland Avenue and channels it to the south and north via an elevated expressway, thus reducing local street congestion.

ASSESSMENT OF COMMUNITY IMPACTS

Between 1974 and 1984 a number of changes occurred in the Scotlandville community that were directly related to the construction of the bypass. Some of the important changes that occurred between 1974 and 1984 were in land use, quality and type of housing, street conditions and patterns, traffic patterns and volume, recreational facilities, and number of minority enterprises.

Land Use

Some changes in land use in Scotlandville were expected as a natural consequence of highway construction activities. One obvious change was the conversion of land, mostly vacant and residential, to transportation uses. Another expected change was the conversion of vacant and residential land to joint recreational and right-of-way use. Although there were 6,416 parcels of land in the study area in 1974, there were 6,002 after the highway was built. This meant that the highway right-of-way absorbed many parcels, even though additional parcels were created through the subdivision of larger parcels. Nevertheless, there were no substantial changes in the proportion of residential parcels recorded during this time period: residential parcels constituted about 81.5 percent of the total parcels in 1974 and 80.4 percent after completion of the highway in 1984.

On an acreage basis, the percentage of land devoted to residential use in 1984 was approximately the same as it was in 1974 (21.3 and 21.6 percent in 1974 and 1984, respectively). Thus the initial expectation regarding the possibility of increased overcrowding in the area was not realized. Part of the reason for this appeared to be the relocation to areas outside of Scotlandville of many residents who were directly affected by the highway. Another reason may be the relative unattractiveness of many

FIGURE 1 Scotlandville study area.

vacant parcels for residential construction because of the close proximity of these parcels to the highway. Whatever the reason, the proportion of land devoted to residential use was largely unchanged between 1974 and 1984, though the actual number of acres devoted to housing did increase somewhat.

The number of acres devoted to recreation, transportation, communication, and utilities increased during the study period. For transportation, the change was from 15 percent of the total acreage in 1974 to 18 percent in 1984. Comparable figures for recreation were 1 and 4 percent, respectively, for 1974 and 1984. Of course, such increases were not unexpected. Finally, that the proportion of acres devoted to residential use remained the same while many houses were eliminated to construct the right-of-way and some recreational facilities means that a significant amount of land was subdivided and, subsequently, used for the construction of dwelling units.

Types of Housing

The total number of residential structures was 5,039 in 1974 and 4,828 in 1984, which represents a 4.2 percent decline during the 10-year period.

There were changes in the types of housing units during the study period. There was a slight decrease in the percentage of single-family and two-family units. There was, on the other hand, a significant increase in the percentage of multifamily units.

A significant number of displaced households (more than 51 percent) relocated outside of Scotlandville, the conversion of vacant land to residential uses was not accompanied by new quality construction, and the upgrading of existing residences did not appreciably occur. Further, there has been an increase in the percentage of multifamily units and a decrease in the proportion of single-family units in a neighborhood that had a strong tradition of single-family units. For Scotlandville, "multi-

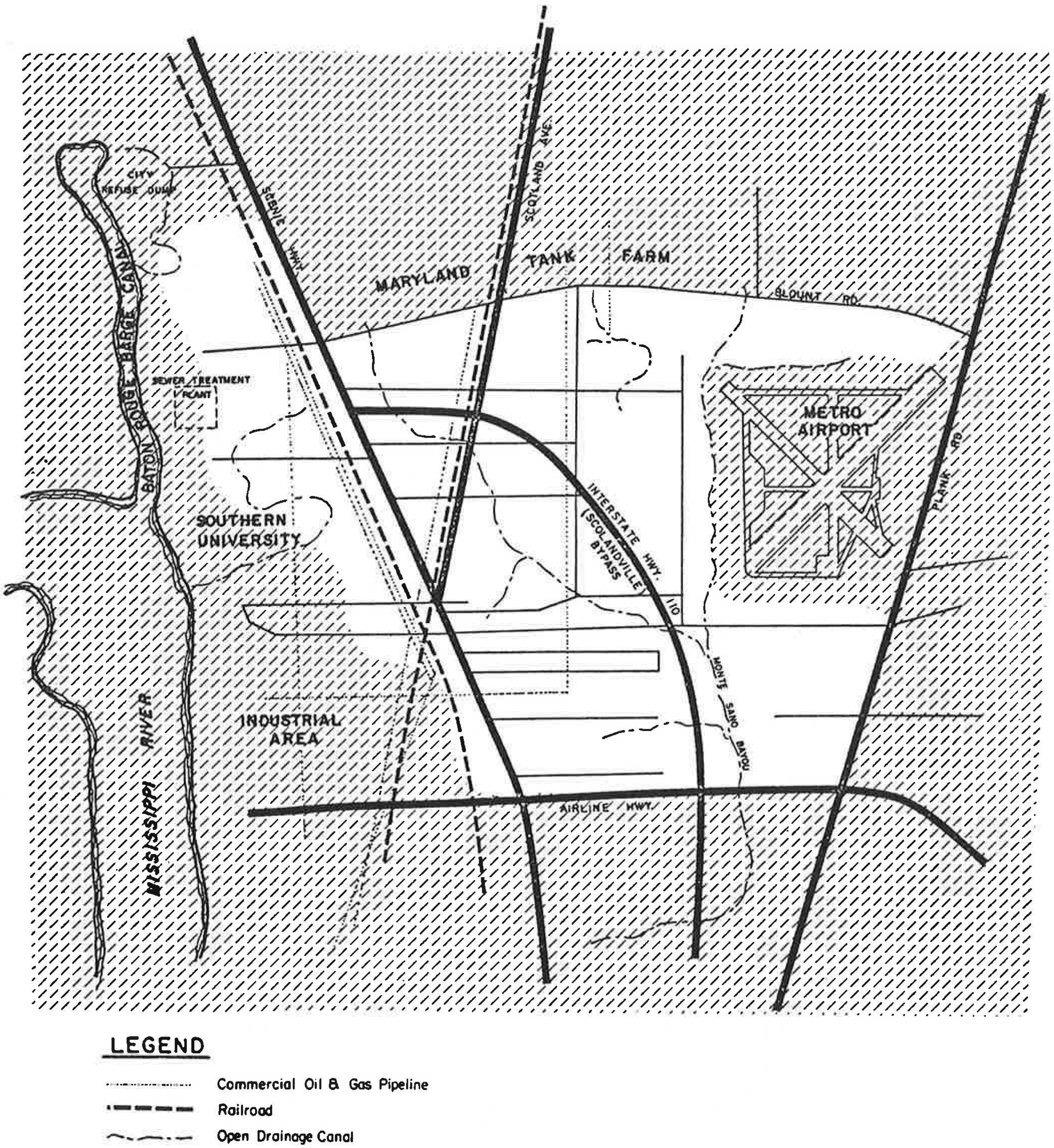

FIGURE 2 Boundaries and physical constraints.

family" may generally be equated with lower quality housing.

Though the location of the highway is not the only cause of these changes in housing type and quality, it was unquestionably a significant contributing factor. The displaced households are directly attributable to the location of the highway. Although higher population and residential densities were anticipated, household density actually decreased because a majority of the residents who were displaced moved outside of Scotlandville and have not been replaced as anticipated. The highway has also contributed to the unattractiveness and undesirability of some sections of Scotlandville as a neighborhood. This, among other things, means that the normal population growth has not been sufficient to increase the number of households in the area.

When the 1970 and 1980 census data are contrasted, several important differences can be noted: (a) there was a decline in the number of housing units, (b) the population of the study area declined significantly, (c) there was a decline in overcrowding, (d) there was a decline in the percentage of homeowners, and (e) there was a decline in the proportion of substandard units (based on plumbing and other internal facilities). There was an increase in the median rent and house value, which mostly reflects inflation during the decade.

Conditions and Patterns of Streets

In 1974 the streets in the Scotlandville area were plagued with many deficiencies. The system of streets was haphazardly designed, and streets were poorly maintained. Moreover, there were many open ditches and a noticeable lack of curbs and gutters in much of the area. Taken together, these deficiencies contributed to blight in the area and reflected the haphazard manner in which the community was originally developed and maintained.

Since 1974 there have been several important changes in street conditions in the community. Many of these changes relate directly to the location of the Scotlandville bypass. A survey of street conditions revealed that many streets, notably the major arterials and other streets linked to the bypass, have been significantly improved. The streets representing the major arterials were classified as poor in some areas, fair in other areas, and good along limited sections in 1974. However, each of the major arterials (Harding Boulevard, Scotland Avenue, and Scenic Highway) has been upgraded and is now classified as good (Figure 3).

Major improvements have been made to Airline Highway, Scenic Highway, and Harding Boulevard because they interface with the bypass through interchanges. Harding Boulevard, a major collector and through street in Scotlandville, and Airbase Avenue, the main access street to the local airport, have been resurfaced with concrete and widened into four-lane streets. Airline Highway between Plank Road and Scenic Highway has also been resurfaced as has Plank Road. These arterials are now classified as good, and the improvements cited are attributable to the location of the Interstate highway.

In 1974 portions of both Scenic Highway and Scotland Avenue were classified as poor in some sections and fair in others. These arterials represented the through streets for north-south traffic. (It was the traffic bottlenecks generated during peak-hour travel along these arterials that served as one of the major justifications for constructing the bypass.) In conjunction with completion of the bypass, these two arterials have been resurfaced and widened to four lanes. In addition, curbs, gutters, and sidewalks have also been added. These improvements, along with the operation of the bypass, have relieved rush-hour traffic congestion and caused improved local street conditions. These major improvements were intended to accommodate the increase in traffic volume generated by the bypass. Improvements have not been as significant for the other neighborhood and collector streets in Scotlandville.

A summary assessment of overall street conditions is given in Table 1. These data make it clear that the changes that have occurred have generally been improvements.

Despite the actual differences in total street mileage surveyed in the two studies, the data indicate some overall improvement in street conditions because the percentage of good streets (39 percent)

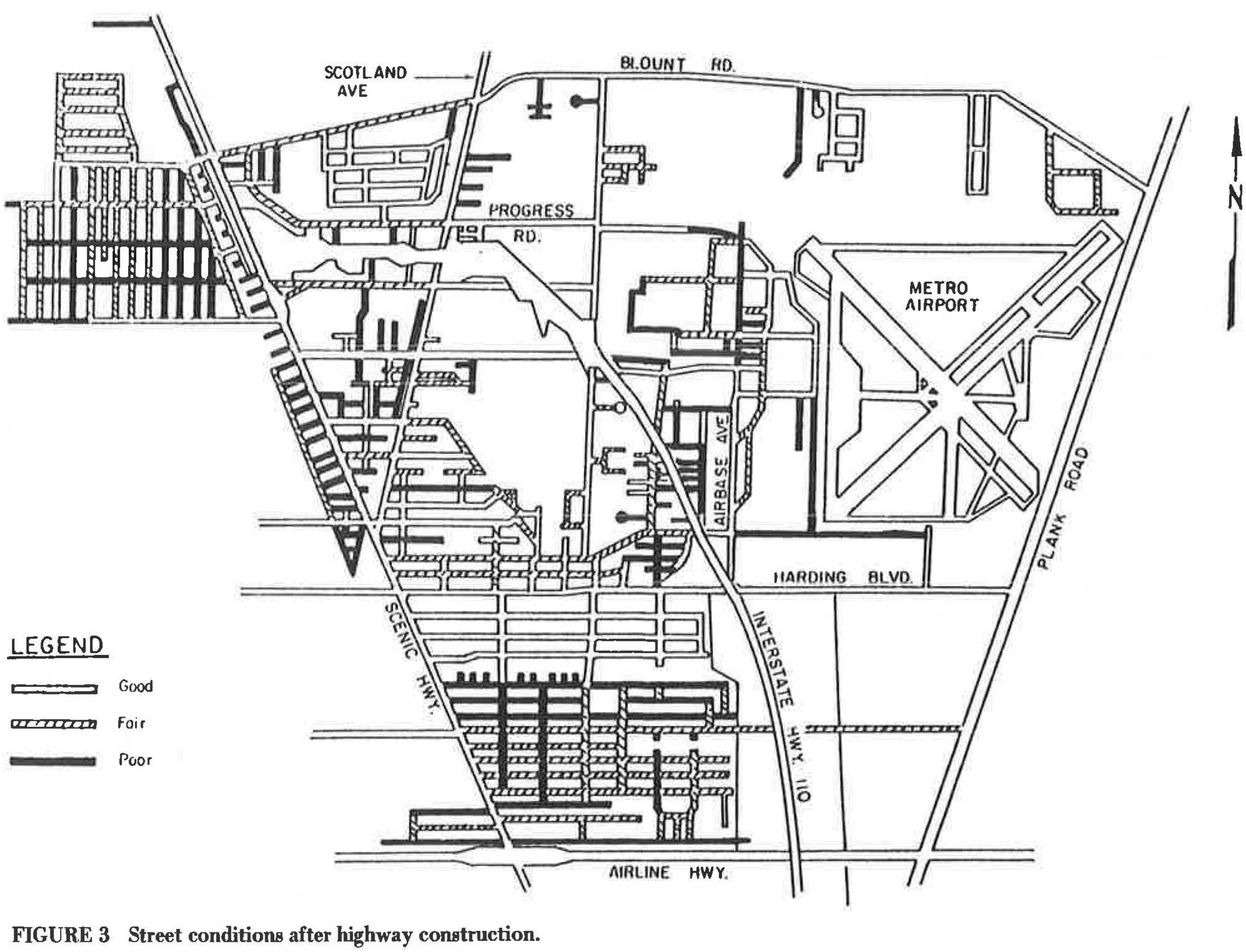

FIGURE 3 Street conditions after highway construction.

TABLE 1 Changes in Street Conditions, 1974-1984

	1974		1984	
Condition	Miles	Percentage	Miles	Percentage
Good	15.45	21.10	28.07	39.13
Fair	29.61	40.44	23.97	33.41
Poor	28.16	38.46	19.70	27.46
Total	73.22	100.00	71.74	100.00

in 1984 has increased over that reported in 1974 (21 percent) and the percentage of poor streets has declined from 38 percent in 1974 to 27 percent in 1984. The poor circulation resulting from dead-end streets in the area just north of Harding, where residential displacement was the highest, has improved somewhat as a result of the bypass. The presence of curbs and gutters along area streets and the general improvement of street drainage facilities since the baseline study are significant.

Traffic Pattern and Volume Changes

The purpose of the bypass was to relieve the major Scotlandville arterials of much of the through traffic. Thus the volume of traffic on Scenic Highway, Scotland Avenue, and Harding Boulevard was expected to decline after the completion of the highway, allowing for better circulation of local traffic.

Findings clearly confirm that, with the exception of Harding Boulevard, all arterials have significantly less traffic since the construction of the highway. However, the traffic that now uses Harding flows without serious problems because that street has been widened to a four-lane highway.

The relief of traffic congestion on Scenic Highway and Scotland Avenue has made internal vehicular circulation much easier than it was in 1974. However, the change in traffic patterns has resulted in a decline in business activities or growth for some businesses on Scotland Avenue and Scenic Highway.

Recreational Facilities

The total amount of land devoted to recreation has increased rather substantially during the study period. This has been largely due to the efforts of the highway planners to return to the community large portions of the unused right-of-way in the form of expanded recreational space and facilities (Figure 4).

Referred to locally as the Scotlandville Park System, these facilities are located between Airline Highway on the south and Rosenwald Street on the north. The system is located on both sides of the highway structure, with a substantial proportion directly beneath the elevated segment of the highway.

Through systematic observations, the number of recreational participants and the kinds of activities in which they engaged were determined. Facilities contained in the park system include areas for team sports, trails, picnic grounds, and related facilities adjacent to the highway.

Together, these designated areas appear, at least on the surface, to offer substantial recreational

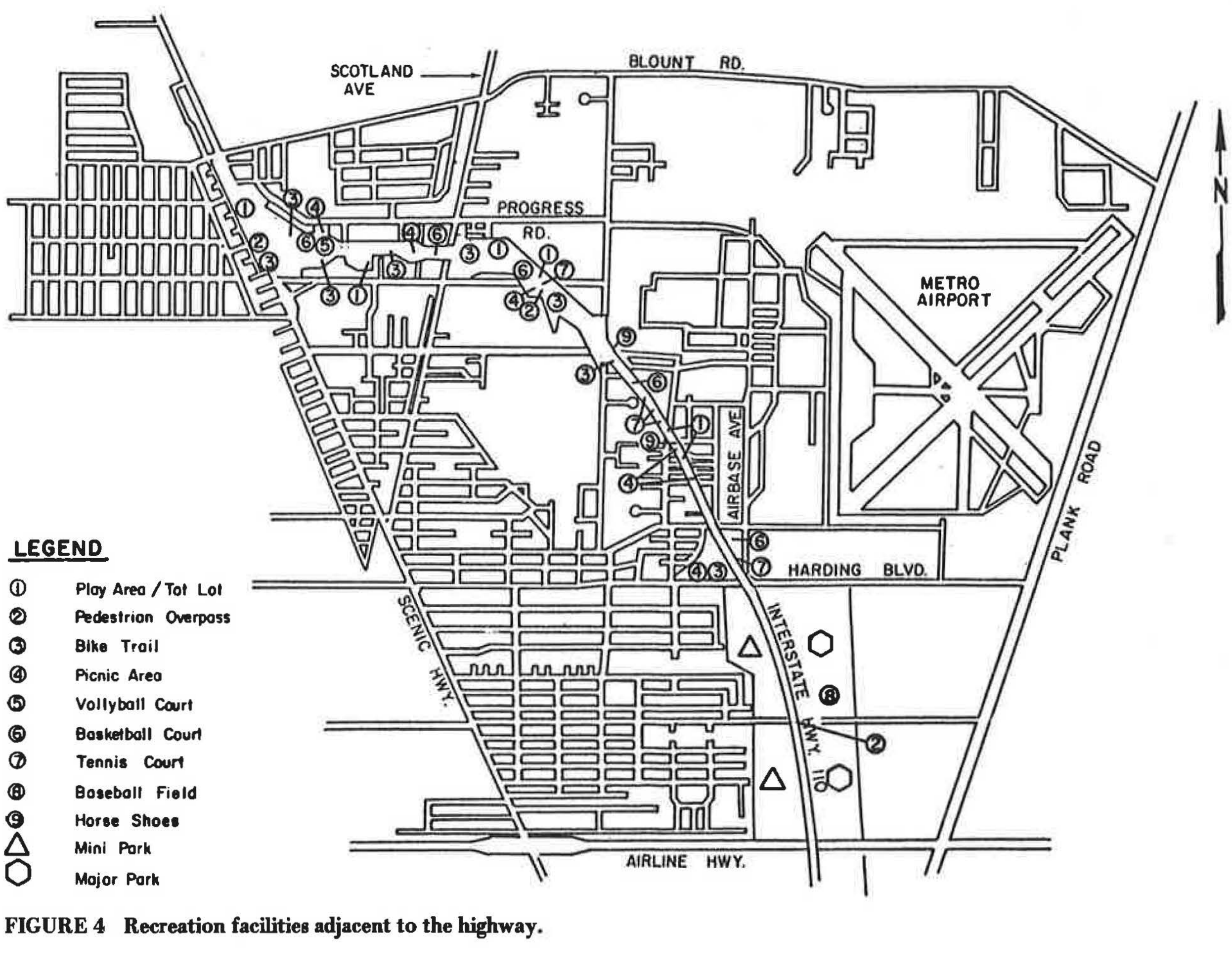

FIGURE 4 Recreation facilities adjacent to the highway.

opportunities where few existed in the past. Utilization of these facilities has been much less than expected. After having made head counts of park visitors on at least 20 different occasions in different areas and at different times (Table 2), researchers estimated that the entire park system was used by a fraction of 1 percent of the community's residents. Moreover, a vast majority of these users were teenage males.

TABLE 2 Current Activity Patterns in Park System

Type of Activity Observed	Average No. of Participants During 20 Visits
Outdoor games or sports	14
Trail use	4
Picnicking	18
Outdoor recreation by concrete stretch	15

Because of the expressed desire of community residents for more recreational facilities and the inference drawn that new facilities would attract more widespread usage, park utilization was expected to be high. [See Thornton (1) for results of a household survey describing use of recreational facilities, level of satisfaction with facilities, and suggestions for improvements as of 1979.] Recent discussions with park users and community leaders, however, revealed several reasons for underutilization of the park. The reasons include lack of toilets and running water, improper maintenance, inadequate lighting and supervision, and inadequate police protection in view of wooded locations and reported instances of crime in the area. In addition, it is widely known that traffic accidents pose a problem where parks have been located beneath expressways. Indeed, on numerous occasions, large trucks have managed to break through guardrails and land inside park areas. Perhaps this knowledge has added to the fear some residents have expressed about parks adjacent to portions of the Scotlandville bypass, which, in turn, may have contributed to the problem of underutilization. In sum, the addition of park space and facilities has served to enhance the area's physical environment and to increase the recreational opportunities for some community members, but the existing facilities do not readily lend themselves to frequent use by a significant segment of the community.

Impact on Minority and Other Businesses

The impacts of the highway on area businesses were of two broad kinds--businesses displaced by the Interstate facility and its effects on the remaining businesses (existing and prospective). There were 33 displaced businesses.

It was hypothesized during the highway planning phase that the transportation facility would affect local businesses in a number of ways. Important among the anticipated negative impacts were (a) the location of large chain store operations near the interchanges that would place the smaller, independent, community-oriented businesses at a competitive disadvantage and (b) changes in travel patterns after the highway was built that would negatively affect local traffic-dependent businesses. Though it is difficult to isolate the impact of the highway on minority business opportunities in Scotlandville because of the complexity of the changing environment in which these enterprises operate, the direction of selected highway influences on minority businesses can be underscored.

The highway has not had the anticipated impact of attracting large-scale, established chain store operations. Quite the contrary appears to be occurring: established chain store operations that constituted a nearby shopping center closed after the highway was completed. Although the highway was not a factor in its closing, its proximity to a four-way interchange did not prevent the cessation of operations. It can be argued that the entrance and exit ramps did not directly connect to the shopping center, but it is equally true that some advantage of this proximity to the highway could have been taken with additional streets. Significantly, only in one instance did the several interchanges in the study area generate a new business enterprise. A small local automobile repair and parts shop has located near an interchange and shows signs of great expansion potential. However, there is a complete absence of new retail outlets of the chain store variety taking advantage of the traffic volume in the area. Further, the highway facility has not significantly generated any new businesses--majority or minority--in the study area.

The tabulation of area minority businesses for 1974 and 1984 indicates that there were declines in a few types of businesses and increases in others. One factor that contributed to this slight change of business mix was the number of minority businesses displaced that did not continue operating in the Scotlandville community--they either ceased operations altogether or relocated outside of Scotlandville. The other causative factors were normal attrition and the organization and development of new enterprises. The total number of minority businesses in 1984 (213) was smaller than the number in existence in 1974 (244). This leads to the conclusion that this highway has not, on balance, encouraged the development of new minority business; indeed, when the displacement factor is considered, it has probably contributed to a slight decline in the number. There is no evidence available that the highway has had a positive impact on minority businesses. The change in the flow of traffic away from the black business district, the displacement of 33 minority businesses, and the development of only one minority business along the new Interstate facility lead to the conclusion that the facility has had a slight negative impact on these enterprises. Further, the normal growth of businesses along the streets of the heavily traveled black business district would probably have occurred in the absence of the highway. That fewer businesses exist after a 10-year period lends additional weight to the conclusion that the influence of the highway on the growth of this sector of the community was negative.

SUMMARY OF MAJOR HIGHWAY IMPACTS ON OTHER COMMUNITIES

Perhaps the most comprehensive and up-to-date assessment of highway impacts on population and housing characteristics was performed by Burkhardt et al. (2). This study included case materials from Baltimore, Cleveland, Hartford, and Wichita. Impact categories analyzed and compared across impact and control neighborhoods within these cities included population changes, changes in housing market conditions, business activities, and uses of local facilities. These researchers hypothesized that there would be decreases in total population, number of housing units, standard units, and owner-occupied units; they projected increases in minority households, vacancies, median rents, house values, and overcrowdedness in the affected neighborhoods. All of these were held to detract from the overall attractiveness of neighborhoods.

The findings of Burkhardt's study are noteworthy and reinforce some of the findings reported elsewhere in the literature. First, considerable variation in the magnitude and direction of highway effects from one city to another was found. For example, both Cleveland and Baltimore had large minority populations, but highway construction had a strong depressant effect on adjacent neighborhoods only in Cleveland. In Baltimore, most comparisons of impact and control neighborhoods revealed no statistically significant differences. Second, new highway construction neither stimulated nor detracted from aggregate improvements. Finally, this research showed that highway effects are much more discernible at the block level than at the census tract level and that such effects depend strongly on proximity to the highway.

Studies (3,4) suggest that limited-access highways are guarantors of neither community development nor community demise. Rather, they appear to reinforce trends that were in evidence before the highway program (5). In addition, although the impact of new highways in the aggregate appears to be minimal in most instances, the impact is much more noticeable in densely populated areas.

A brief summary of highway impacts and the cities in which they occurred is given in Table 3. These impacts will provide standards against which the results of the present investigation will be compared.

FINDINGS

Similarities with Other Communities

A number of highway impacts, which were quite similar to those found in other communities, were identified in the Scotlandville community. Specifically, housing relocatees were generally better off in terms of housing accommodations, though this was less true for tenant-relocatees than for homeowners. Also, although financial burdens were reported by a minority of relocated households, complaints were more likely to emanate from the ranks of tenant-relocatees. The tendency has been for smaller businesses located in a highway corridor to experience significant financial hardship or to cease operations, or both. This, too, was the pattern observed in Scotlandville. Further, as in other communities, the Scotlandville bypass resulted in an increase in multifamily units, a general increase in accessibility, and a minimal increase in housing vacancy rates.

Impacts Unique to Scotlandville

There were several impacts that appear to be unique to Scotlandville (and by inference to minority communities). First, there was no increase in neighborhood traffic volume directly attributable to the new bypass. This, however, was not unexpected, inasmuch as the bypass was designed to remove through traffic from the heavily congested streets in the local area. Second, unlike other areas, Scotlandville did not experience large increases in commercial or industrial development in the general vicinities of the new highway interchanges. This is true even though vacant and usable land exists at all three interchanges built in the community. Indeed, because of the loss of some minority businesses, the community has actually experienced a loss of jobs, a pattern that is quite the opposite of that observed in majority communities.

Other Impacts Not Reported in Studies on Other Communities

Street types and conditions, accessibility to various parts of the community, and internal circulation were significantly improved. Further, group recreational facilities were scarce in the community before the highway was built and significant improvements, which were attributable to the highway, were observed after it was built. Residents, however, make limited use of the newly constructed recreational facilities (which accompanied the highway) because of wooded or secluded locations, lack of security, and lack of proper supervision by the local government.

SUMMARY AND CONCLUSIONS

A majority of displaced businesses were small, community oriented, and not reestablished as were displaced households. Indeed, the majority of the displaced businesses ceased operations as a result of displacement. Though this finding parallels impacts

TABLE 3 Highway Impacts in Selected U.S. Cities

Variable	Baltimore, Md.	Cleveland, Ohio	Hartford North, Conn.	Hartford South, Conn.	Wichita, Kans.	Wilmington, Del.	Winston-Salem, N.C.	Charlotte, N.C.	Raleigh, N.C.	Durham, N.C.	Greensboro, N.C.	Allentown, Pa.	North Springfield, Va.	Bellevue, Wash.	Puyallup, Wash.	Kingsdale, Wash.	Grinnell, Iowa	Scotlandville, La.
Total population	0	D	D	0	0	D	0	I	I	0	I							D
Minority population	D	0	D	0	0	I												D
Multifamily units									I	I								I
Property value							I	I	I	I	I	I	I	I	0	I	I	0[a]
Housing vacancy	0	I	0	0	0	I												I
Employment							I	I	I	I	I						I	D
Substandard housing	D	D	I	I	0	D												I
Commerce and industry							I	I	I	I	I							D
Owner-occupied units	I	0	0	0	0	D												D
Accessibility							I	I	I	I	I	I	I	I	I	I	I	I
Traffic							I	I	I	I	I						I	D
Total housing units	0	D	0	0	0	D												I
House value	0	I	D	0	0	0												
Decentralization of business activity							0	0	I	0	I							

Note: D = decreased, I = increased, 0 = remained the same.

[a]After inflation is considered.

assessed in other areas, all of the businesses displaced in Scotlandville were small and minority owned; reestablishment is more difficult for such businesses, and the percentage of cessations is significantly higher. A general conclusion here is that small, community-oriented businesses require a more comprehensive relocation package, including greater compensation and more extensive reestablishment assistance, than was provided for those businesses displaced by the Scotlandville bypass.

The contrast between Scotlandville and other communities was perhaps the most salient with regard to the impacts of the new highway on economic sectors. Whereas new highway construction has typically aided the economic development of affected communities as new development projects have sprung up in areas surrounding Interstate interchanges, this pattern was absent in the Scotlandville area. A major and unique impact of the Scotlandville bypass is the general failure of the highway to generate the kind of industrial and commercial developments and accompanying employment opportunities observed in majority communities. Perhaps this could more accurately be termed a failure to result in a benefit than an adverse effect. Nonetheless, this failure has held true even though vacant and usable land is available at all three interchanges built in the community. Not only have there been no new development projects, but one medium-sized shopping center located near the largest Interstate interchange in the area closed between 1974 and 1984. In addition, the loss of 33 businesses, with an accompanying loss of jobs for local residents, was directly linked to the highway. Further, the failure of the highway to generate new business or industry also means that property values have not increased. It is theorized here that the racial characteristic of the neighborhood is the factor that accounts for the lack of significant commercial development.

Certainly, no limited-access highway can singlehandedly guarantee growth or demise of any community. On the whole, it may be said that the Scotlandville experience supports the premise that communities are generally better off with a highway than without one. Although there have been no significant differences in land use, no marked changes in housing quality, and no economic development resulting from bypass construction, the negative impacts have been minimal except for adverse effects on the business sector. Traffic reduction, better street conditions, improved internal vehicular circulation, increased access, reduced population density, and improved recreational facilities are among the benefits attributable to the bypass. This leaves room for only two important recommendations. The first is that special reestablishment assistance in the form of counseling and greater financial aid should be given small businesses that are displaced. These small businesses make an important contribution to their communities in terms of both economics and service; they should not be forced to close because of insufficient financial help or inadequate counseling. Black businesses have a special relocation and reestablishment problem. The second recommendation is that the location of recreational facilities adjacent to and under highways warrants further and careful study before future investments of this nature are made.

The permanent injury to a high proportion of displaced, small minority businesses and the general failure of the highway to generate the kinds of commercial developments observed in many majority communities are the significant differential impacts that must be noted.

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