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Application of the Highway Investment Analysis Package

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The Highway Investment Analysis Package is a computerized benefit/cost and cost-effectiveness model developed by the Federal Highway Administration to aid state, regional, and local governments in making the best use of limited highway funds. During the past year, a project evaluation and programming study has been conducted by the Wisconsin Department of Transportation and a team of consultants to improve the department's evaluation and program development capabilities. As part of this study, the Highway Investment Analysis Package programs have been installed in Wisconsin and used in two major analyses. The applications and the resulting evaluation of the package for inclusion in the improved programming procedure are the topic of this paper. The Highway Investment Analysis Package programs were found to be extremely useful in the efficient estimate and display of many of the consequences of alternative highway improvements and investment policies.

The Wisconsin Department of Transportation and a team of consultants have recently completed a project evaluation and programming study aimed at improvement of the department's procedures for making highway investment decisions. The study was initiated by the department in 1977 in response to widespread concerns that the old programming process (where many decisions were made at the nine highway district offices) could not respond effectively or consistently to new policy directives. Central guidance and review had to be strengthened if increasingly scarce highway funds were to be spent wisely.

The project evaluation and programming study was conducted in three phases:

1. Several planning and programming aids potentially of use to state and district offices were assembled or developed;
2. The existing, refined, and new techniques were applied on a trial basis in the course of the development of a highway program for the years 1980 through 1985; and
3. The experience gained in the applications was used to establish an annual cycle of programming activities at the department.

Certain principles were established at the start of the study. The programming process had to consider a broad range of technical data (e.g., service and safety measures) and subjective data (e.g., community impacts) if the product was to be widely accepted. The assimilation of this much information, however, requires consistency among the data and criteria used to define deficiencies and evaluate alternative design solutions. A final principle was that alternative policies and programs be evaluated to provide top management with sufficient information to make informed choices about the development of investment programs.

As a result of these requirements, a range of data presentation and analysis techniques were considered for complementary roles in the overall process. Benefit/cost analysis was found useful for describing some important implications of alternative project designs and investment programs. A number of benefit/cost packages were reviewed at the start of the project. The Highway Investment Analysis Package (HIAP), recently developed under the sponsorship of the Federal Highway Administration (FHWA) (1, 2), was selected as best fulfilling the requirements of the Wisconsin Department of Transportation.

HIAP is a computerized benefit/cost and cost-effectiveness package developed to aid state, regional, and local organizations in making the best use of limited highway funds. The package consists of two basic modules: project evaluation and program development. The project evaluation module uses microeconomic theory to analyze alternative improvements to individual roadway sections or limited networks of roadway sections, called project sites. The physical, operational, and traffic characteristics of each existing, improved, or new section are used to estimate both (a) highway user performance measures (i.e., travel times, vehicle operating costs, and accidents) and (b) public performance measures (i.e., pollutant emissions and noise levels) for the no-build condition and for each alternative improvement to a project site over a planning period of 15-20 years.

Aggregate economic and effectiveness measures for the evaluation of an improvement are produced by a comparison of the improvement's performance measures to those of the no-build alternative. The effectiveness measures include changes in accidents, emissions, and noise levels. The economic measures include the total present (i.e., discounted) value of user benefits summed over the planning period, the net present value (i.e., total present benefits minus the present value of improvement costs), and the benefit/cost ratio. The HIAP user specifies the key parameters, such as values of time (used to convert time savings into dollar benefits) and the discount rate (used to assign consistent weights to present and future benefits) applied in developing the economic measures.

The program development module of HIAP uses the aggregate measures calculated for project alternatives at all sites to develop candidate investment programs for as many as four periods. The selection process uses marginal analysis to allocate a budget among the sites to achieve the best program possible under the funding limitations specified by the user; the choice of sites that receive funds and the project scale or design at each site are made concurrently. The funding limitations can include minimum levels of investment in different funding programs, functional classes, or jurisdictions as well as the overall budget limits. The project selection criterion (specified by the user) can be the maximization of either accident reductions or economic benefits per dollar invested. By varying the economic parameters, the selection criterion, and the funding constraints, the HIAP user can easily generate a number of candidate investment programs that meet different program objectives, revenue forecasts, and allocation policies. The decision makers receive evaluation measures for alternative programs that may be combined with other considerations not easily handled by benefit/cost packages.

In the course of the project evaluation and programming study, HIAP has undergone an intensive evaluation involving five basic steps:

1. Adapting the programs to Wisconsin—Accident rates and pavement deterioration tables were developed

from Wisconsin data to replace those distributed with the project-evaluation module. The formats of some reports were also modified.

2. Acquainting senior staff with the program's capabilities—One-day orientations were conducted for over 70 senior district and headquarters staff to explain the operation of HIAP and the interpretation of its results. The first session was an overview of HIAP for potential users of its results; the second was a more detailed presentation for project managers who would be using HIAP to develop and analyze alternative project designs.

3. Applying HIAP to specific studies—Two major applications of HIAP were performed using data collected largely by district offices. The reports of these studies received wide distribution within the Wisconsin Department of Transportation.

4. Assessing the role of HIAP in the planning and programming process—The reactions of many study participants to HIAP's capabilities and usefulness were compiled to evaluate HIAP and determine its appropriate role in the continuing programming process.

5. Developing an applications guide—A workbook of instructions and guidelines for future users of the programs was assembled to supplement the more detailed user's guide distributed by FHWA (1).

APPLICATIONS OF HIAP

HIAP was applied in two major studies. The first application was an analysis of 13 reconstruction and 10 resurfacing projects under consideration as additions to the 1979 highway improvement program. Because of time constraints, only one improvement was considered at each site. Seven candidate programs were generated from these projections: one that used a base set of economic parameters developed by project staff (as shown below) and three pairs of programs in which the values of time, discount rate, and costs of accidents were alternately raised and lowered. The final selection of projects for the supplementary 1979 investment program was based on summaries of deficiency data for the three sites and a methodical view of existing conditions as shown on the department's photolog, together with the benefit/cost results obtained from HIAP.

Parameter	Amount
Value of time ($/vehicle-h)	
Automobile	3.20
Single-unit truck	7.00
Multi-unit truck	10.00
Accident cost ($/accident)	
Fatality	122 000
Injury	7 550
Property damage	600
Discount rate (%)	7

The more extensive application of HIAP was the analysis of alternative improvements at 30 sites where major investments had been proposed for the highway program in the years 1980-1985. The sites represent a good cross section of the major highway projects proposed for the state. In general, data were readily available for alternative improvements to the sites and a particular improvement had not yet been selected. Six of the sites were urban, 9 were suburban, and 15 were rural. Eleven of the sites included the improvement or construction of a bypass or a beltway.

The district offices supplied data on the 30 proposed alternative sites, which project staff then compiled and edited. Results of preliminary runs of a HIAP benefit/cost analysis of those data were distributed and discussed at the second HIAP orientation meeting. Besides providing measures of the proposed alternatives, the preliminary HIAP results indicated sites where additional, generally lower-cost, alternatives should be considered. Where improvements were proposed for more than one highway section, the HIAP results also indicated which sections should be the first step in a staged investment. The districts used this information to correct any data inconsistencies and to develop new alternatives for some of the sites. Essentially, the initial runs helped district staff clarify assumptions, make trade-offs, and propose better second-round alternatives. Final analyses considered a total of 107 project alternatives at the 30 sites and used both the project-evaluation and program-development components of HIAP.

In the project evaluation phase of the analysis, the performances of all existing highways and each improvement were examined over a 21-year planning period (specifically, years 1980, 1986, 1991, and 2001) under the assumption of generally increasing traffic conditions. The values shown in the preceding table were applied to translate time and accident savings into dollars so that these terms could be added to cost changes in vehicle operations and highway maintenance to form measures of total benefits. In calculating savings in travel time, a maximum speed of 90 km/h (55 mph) was used to reflect current state and federal policies. Except in special cases, specific accident rates were used for each existing section, and statewide averages by highway type were used for improvements.

HIAP performs its benefit and cost calculations in constant dollars. The assumption is made that all components to which dollar values are assigned will inflate uniformly in the long run, so an inflation rate need not be estimated. The discount rate of 7 percent given in the table measures the public's preference for present over future benefits, exclusive of inflation. In the analysis, 1977 cost values were used and a factor of 1.55 was applied to the 1969 vehicle operating costs internal to HIAP (3). This factor considered changes in fleet characteristics and fuel economy as well as increases in factor prices (e.g., cents per liter of gasoline).

Analysis of Project Evaluation Results

The preliminary analysis of improvements to the 30 major project sites focused on the results of the project evaluation phase of HIAP. At project sites where only one improvement was analyzed, the evaluation was simple. A positive net present value indicated that the improvement was worthwhile; a negative net present value indicated that it was not. At sites where more than one alternative had a positive net value, incremental analysis was used to evaluate the alternatives. For example, Table 1 lists the summary evaluation measures for the three alternatives analyzed for project site A. The alternatives are listed in order of increasing cost, which in this case is also the order of increasing benefits and net present value. The least-expensive alternative ($6.5 million) upgrades part of the existing route and replaces the remainder with a new expressway. This alternative yields $43.9 million in benefits, a ratio of 6.8. The additional or incremental cost of replacing the entire route with a new expressway is $3.3 million. This alternative yields $11.2 million in additional benefits, so the benefit/cost ratio of the incremental investment is 3.4. This incremental ratio, not the total ratio of 5.6, determines that the alternative is a worthwhile investment. Similarly, an incremental benefit/cost ratio of 2.1 can be calculated for the freeway alternative. This indicates that the additional investment needed to construct this alternative is also a worthwhile investment. Note that the incremental benefit/cost ratio is always greater than 1.0 if the net present value is increased by the additional investment.

From an economic perspective and in the absence of any budgetary constraints, the freeway alternative is the best investment at the site because it produces the highest net present value. If funds were limited and could be invested at other sites to produce benefits at a consistent rate of at least 3:1, however, the expressway alternative would be the best investment at site A.

At many sites none or few of the initial alternatives emerged as being economically worthwhile or competitive for limited program funds. At site B, for example (see Figure 1), the four-lane freeway initially proposed did not produce significant net benefits until the 1990s, when its additional capacity would be better used. Consequently, the alternative two-lane designs shown in Figure 1 were proposed for construction during the next six years. At site C (also shown in Figure 1) a lengthy bypass of two rural towns produced significant service improvements only on portions of its route. In this case revised alternatives that combine shorter bypasses with spot improvements to the existing roadway were developed to concentrate smaller investments at the problem areas.

In the final HIAP analyses, a total of 107 alternatives were examined at the 30 project sites. At only 3 of the sites did no alternative yield a positive net present value. Two of these were highways with few deficiencies, which carry low to moderate traffic volumes; the third could not be improved at a low cost because of the poor conditions of the existing roadway. At a fourth project site, where the upgrading of a four-lane expressway to a six-lane freeway was analyzed, the results showed an increase in net present value if the improvement was deferred beyond 1985 despite a benefit/cost ratio of 2.7. In this particular case most of the benefits occurred late in the planning period and were not lost by the deferral.

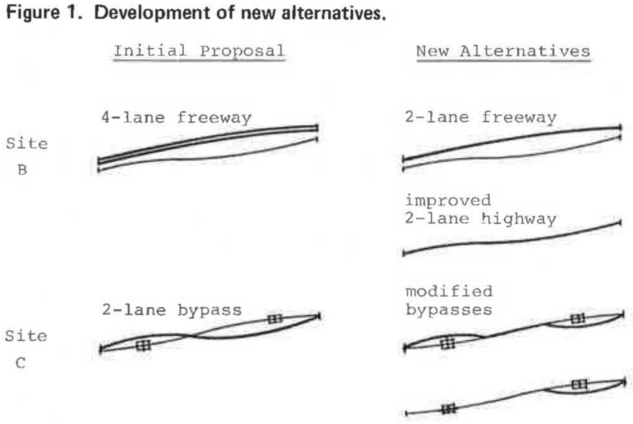
Analysis of Program Development Results

After new and revised alternatives had been developed, the program development module of HIAP was applied to the project evaluation results for the 107 alternatives.

Table 1. Site A analysis results.

Alternative	Capital Cost ($000 000s)	Total Benefits ($000 000s)	Net Present Value ($000 000s)	Incremental Benefit/Cost Ratio
Partial four-lane expressway	6.5	43.9	37.4	6.8
Four-lane expressway	9.8	55.1	45.3	3.4
Four-lane freeway	11.5	58.7	47.2	2.1

Figure 1. Development of new alternatives.



Several candidate investment programs were generated for different assumptions about budget levels and project selection criteria. These programs illustrated many of HIAP's capabilities in this area and provided information useful for the development of the 1980-1985 highway program.

Without Budgetary Constraints

Earlier we noted that, if sufficient funds were available, the project alternative at each site with the highest positive present value would be the best to implement from an economic perspective. A program of these alternatives forms an upper bound on worthwhile investment in the 30 sites (assuming the values of the economic parameters shown in the in-text table). In this benchmark program, $478 million would be invested in 27 of the sites to yield $2 billion in benefits—an average return of $4.20 on each $1.00 invested.

Alternative Funding Levels

HIAP's program development module was used to apply total six-year program budgets of $50 million, $100 million, $150 million, and $200 million (in 1977 dollars) to the 30 project sites. A summary of the results is given in Table 2. A major impact of the budget restrictions was to decrease the number of project sites at which investments are made. In addition, the scale of the project changed at 3 of the sites. At site A, for example, the three alternatives listed in Table 1 were funded in the $100 million, $150 million, and $200 million programs, respectively. The changes in project scale emphasized the need to examine a range of project alternatives when funding limitations exist. Essentially, no best alternative can be selected at any site on the basis of an independent project evaluation. The appropriate alternative design always depends on program funding constraints and on the merits of alternative projects at other sites in competition for the funds. Had more alternatives been examined at some site, additional changes in scale might have occurred as program funding increased from $50 million to $200 million.

Incremental Increases in Funding

Not all of the budgets listed in Table 2 could be spent because of the large incremental costs typical of highway investments. An examination of optional HIAP reports also indicates that, in choosing the last alternative in each of the programs in Table 2, except the unconstrained program, desirable projects that would just exceed the budget limit have to be skipped. In other words, when most of the available funds have been allocated, small investments with lower incremental benefit/cost ratios are selected to use up the remaining budget. For example, a 1 percent increase in the $50 million budget would allow a four-lane highway to be funded at project site E in place of widening part of site F to four lanes. The additional $1.4 million spent yields an increase of $9.1 million in the net present value of the program. The most striking change occurs when the $100 million budget is increased by 2 percent—the additional $2.5 million invested yields a $20 million increase in program net present value.

This analysis of small variations in program specification effectively compensated for HIAP's selection rules, which may select a low-cost project that produces only moderate benefits to complete the budget at the end of the selection process. In the major project application, a low-cost improvement at site G appeared in most programs generated because it had a relatively low cap-

Table 2. Impact of budget constraints.

Program Funding Level ($000 000s)	Number of Project Sites Funded	Program Cost ($000 000s)	Program Net Present Value ($000 000s)
50	6	49.1	730
100	12	98.7	1005
150	16	148.9	1225
200	22	199.7	1304
Unlimited	27	478.3	2025

ital cost and thus was a convenient budget filler. In view of this characteristic of the selection process, the $102 million program was probably a better preliminary program than the strict $100 million program. The uncertainties of cost and revenue estimates are probably significantly higher than the 1-2 percent variation examined here; larger variations in budget level should be considered to determine the impacts of these factors.

Allocation of Funds to Categories

HIAP allows the user to control the distribution of funds among categories by specifying minimum funding levels in each. To demonstrate this feature, we specified that at least 25 percent of the budget be spent in each of the urban, suburban, and rural categories at program funding levels of $100 million and $150 million. At both budget levels, funds were shifted to urban projects from at least one of the other categories; the greater shift occurred in the $100 million program. The shifting of funds to less beneficial projects decreased the net present values by $26 million for the $100 million program and by $7 million for the $150 million program. The size of the decrease provides a measure of the cost of the allocation policy.

Variation of Economic Parameters

The economic parameters used in the analysis are another realm of uncertainty. Additional programs were generated for budget levels of $100 million and $150 million (the most likely range of six-year investment in the 30 sites) to test the sensitivity of the investment program to changes in these key parameters. In two tests the discount rate was varied to 4 percent and 10 percent (i.e., future benefits were given more and less weight, respectively, than they received using the base set of economic parameters). In two other tests the values of time used to calculate automobile-user benefits were lowered and raised by 25 percent. In the latter test, truck values of time were also raised by 50 percent.

On the whole, the variation of the economic parameters had little effect on program composition; most sites were unaffected. At the lower budget level, the decrease of the discount rate to 4 percent or the automobile value of time to $2.40/h had no impact on program composition. The results of varying the parameters indicate that the sites and alternatives consistently selected by HIAP represent good investments.

Developing Programs with Alternative Criteria

Programs were generated at the $100 million- and $150 million-funding levels using accident reductions as the selection criteria. One program at each budget level considered all accidents and a second considered only serious accidents (i.e., fatality- and injury-producing accidents). With these selection criteria, HIAP uses the ratio of accidents saved by implementing an alternative to the capital cost of the alternative as a benefit/cost ratio, although no dollar value is assigned to the numerator, and future savings are not discounted. At both funding levels, there were significant changes in both project scale and project sites selected.

Synthesis of Programs

The various programs generated show that budgetary constraints and selection criteria affect the program development process. As a first step toward development of a final program, the staff grouped the project sites, alternative project designs, and specific improvements within projects on the basis of consistency of selection in the various $100 million and $150 million programs. This information, as well as deficiency summaries, scheduling constraints, and community and environmental considerations, was used in the development of the 1980-1985 highway program.

EVALUATION OF HIAP

Comments were solicited from district and central office staff who had reviewed and used the results of the two HIAP applications. Many responses dealt with assumptions made in the analyses, such as the values of key economic parameters, the uses of detailed and statewide accident rates, the definition of maintenance costs, and the definition of the no-build alternatives—all of which were addressed in the development of the applications guide. Other concerns, such as the use of nationally derived daily traffic distributions, suggested the possibility of a staff effort to develop new tables from Wisconsin's automatic traffic recorder data.

Still other concerns pointed to the need for additional research at the national level and the incorporation of the results in a revised version of HIAP. These concerns include the development of current vehicle operating cost tables (an effort currently sponsored by FHWA); the development of more refined traffic flow equations, which relate speed change and stop cycles to both congestion levels and a highway's physical characteristics; the explicit handling of recreational vehicles; the provision of greater flexibility for specifying alignment, profile, and cross-sectional characteristics, particularly of rural two-lane roads; and the development of improved techniques for estimating the impacts of pavement type and condition on the highway user, making HIAP more useful in the analysis of alternative resurfacing and reconditioning policies.

On the whole, HIAP was viewed as an efficient means for consistent quantification and display of many of the consequences of alternative highway improvements. It provides planners and designers with measures for evaluating alternative solutions to a specific problem or set of problems, and gives top-level staff measures for comparing among projects in developing investment programs. HIAP's ability to generate candidate investment programs quickly, using different criteria and parameters, proved particularly useful in the development of highway investment programs.

HIAP's roles in the ongoing programming process at the Wisconsin Department of Transportation will include

1. The early and continuing analysis of candidate projects to assist in the design of the most appropriate scales of improvement;
2. The periodic review of candidate projects for which significant cost changes, changes in alternative design, or delays or problems in project development have occurred; and
3. The annual review of the six-year investment program to determine the best responses to changes in

budget levels or allocation policies and to provide guidelines on appropriate scales for projects in the preliminary design stage.

In all cases, HIAP will be used as a design aid and not as a substitute for making decisions. This subservient role for the model was well received at the department of transportation during the trial applications—many had feared that benefit/cost analysis would be proposed and used as the final criterion for decision making. In fact, a major use of benefit/cost analysis in the project was in the identification of new alternatives. The need for professional judgment in preparation of data for HIAP and in analysis of the model results also became apparent in the applications. Once experience with the model was gained, HIAP became a very powerful tool for professional engineers and planners in the department.

ACKNOWLEDGMENT

The HIAP applications were performed as part of a contract between the Wisconsin Department of Transportation and Cambridge Systematics, Inc., to improve the department's programming capabilities. We wish to thank other participants in the Wisconsin project evaluation and programming study for their contributions in the installation and applications of HIAP. Edmund Byrkit, Joseph Dresser, and Robert Gerndt of the Wisconsin Department of Transportation; Richard D. Juster, Marie O'Brien, and J. P. O'Hare of Multisystems, Inc.; and Wayne Pecknold of Cambridge Systematics, Inc., deserve special credit. The staff of HIAP's sponsoring office in FHWA, the Program Management Division of the Office of Highway Planning, has been helpful in informing project staff of some minor problems uncovered in their ongoing testing of the computer programs.

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New York State's Approach to Highway Jurisdictional Realignment

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The New York State Department of Transportation is currently undertaking a study of the jurisdictional realignment of state and local highway systems based on functional classification. This paper describes the approach that is being taken. The current approach is based largely on the desire to correct existing misassignments of highway jurisdiction to the extent practical and is largely shaped by several recent efforts to accomplish realignment. Application of this procedure to many other states appears feasible. This paper briefly summarizes past highway jurisdictional realignment efforts within New York, outlines a series of short-term objectives and long-range goals for the study effort, highlights the present status of this effort, and discusses the preliminary observations and conclusions that may be drawn from study efforts.

In the past few years, state and local transportation officials have become aware that in the near future they will be unable to address a substantial portion of identified highway needs due to declining resources (in terms of real dollars) for both highway capital construction and maintenance. This has led to significant changes of emphasis in philosophy and program planning at the state and local levels. By necessity, many elements of transportation plans developed in the late 1960s and early 1970s are now being postponed, reduced in scope, or totally abandoned. Capital construction programs are now being redirected to recondition existing facilities rather than to plan for the development of new facilities. Such an approach increases the emphasis on the preservation of past investments and reduction of the cost of maintaining the existing highway system. Even at the federal level, which has traditionally emphasized new capital construction and reconstruction investments rather than aid for rehabilitation and operations, the tide seems to be changing.

This new direction has also drawn increased attention to a somewhat related area—highway jurisdiction. In some states the existing assignment of responsibility for maintenance and improvement of the public highway network may no longer be entirely logical or equitable. As a result, a number of states either have recently completed or are now undertaking studies that reexamine the validity of current jurisdictional assignments. In addition to eliminating inconsistencies, most states also hope that such an effort will result in potential cost savings through increased efficiencies. The New York State Department of Transportation is currently undertaking such an effort, via a somewhat unique yet straightforward approach.

BACKGROUND

New York's state highway system was created in 1898. Originally, only rural routes of major statewide significance were included in the system. As in most other states, initial route selection was based on a number of general concerns, including system continuity, nature and magnitude of travel carried, geographic equity, and ability to support the system financially. Gradually, routes were added on an incremental basis without any periodic and systematic review and revision.

The state highway system consists of about 24 140 km (15 000 miles) or approximately 13 percent of the public highways within the state. Of this total, approximately 19 310 km (12 000 miles) are in rural areas and about 60 percent of that total are classified as rural arterials. Of the more than 4830 km (3000 miles) of state highways in urban areas, about 70 percent are classified as connecting links of rural arterials. Responsibility for the majority of these highways is assigned to the New York State Department of Transportation.

The remaining 150 000 km (93 000 miles) of public highways in the state are under the jurisdictional responsibility of one of the state's 57 counties outside of New York City, 62 cities, 930 towns, or 556 villages—most of which have independent highway or public works departments. The total amount of federal highways in the state does not exceed 150 km (93 miles); therefore, it is ignored for discussion purposes.

In the mid-1960s a joint study to realign rural highway responsibilities was initiated by the New York State Department of Public Works (forerunner to the state department of transportation) and New York State County Highway Superintendents' Association. At that time it was agreed that a statewide approach to jurisdictional realignment was necessary and that such an effort should also consider financial needs of each level of government necessary to adequately maintain and improve the highway network.

An initial statewide realignment proposal was developed at that time, but implementation was not pursued because of the pending development of the 1968 and 1990 functional classification systems, the state's master plan for transportation (1), and local governments' desire to have increased state financial assistance accompany any state-local realignment.

In 1973 a second proposal for highway realignment was completed and documented in the statewide master plan. This proposal called for the realignment of both urban and rural facilities in accordance with their 1990 highway functional classification. The master plan recommended that only routes that have an arterial functional classification should be state highways. It proposed that a net transfer of 5150 km (3200 miles) be made to local jurisdictions in rural areas and, in urban areas, a net transfer to the state of 6759 km (4200 miles) be undertaken. The proposal would have had a significant financial impact on the state and a number of municipalities, so it was also proposed that, before any transfers were actually made, a study should be undertaken to determine the financial, administrative, and technical capability of the state and local governments to maintain and improve the realigned system.

To date, such a detailed financial study has not been undertaken and the master plan realignment proposal has not been implemented. Primary factors for this appear to be (a) the negative financial impact of the proposed realignment plan on most rural areas, which would result from the proposed transfer of a substantial amount of state highways to rural municipalities; (b) the fiscal problems that have faced all levels of government in New York State during the past few years; (c) limited department staff available to pursue implementation due to state-level budgetary reductions; and (d) the perception of state officials, legislators, and the public that a significant problem did not exist.

Completion of a 1980 highway functional classification study in 1976 once again focused attention on the present assignment of highway jurisdictional responsibilities within New York State. The 1980 functional system was developed initially by state and local officials to realign the federal-aid primary, secondary, and urban systems in accordance with the requirements of the Federal-Aid Highway Act of 1973. This system provided a convenient technical tool that could be readily used to identify apparent jurisdictional inconsistencies. Applying functional concepts to the existing state highway system identified approximately 1600 km (1000 miles) (nearly 7 percent of the total system) that do not primarily serve a statewide or regional travel function. Conversely, over 4000 km (2500 miles) of local highway appear to serve intercounty travel needs. The majority of the subject local highways that are outside of cities is currently under the jurisdiction of county governments.

Based on these overall findings and the recognition that state-local jurisdictional inconsistencies may be the cause of ineffective use of capital and maintenance resources, the New York State Department of Transportation revived its efforts to realign the state highway system during 1976.

APPROACH TO JURISDICTIONAL REALIGNMENT

Before an approach to jurisdictional realignment can be selected, a determination must be made as to the objectives that one wishes to achieve. A number of lessons learned from New York's realignment efforts of the past were used to establish the following short-term objectives and long-range goals:

Short-Term Objectives

1. Make state and local officials aware of the nature and magnitude of governmental jurisdictional inconsistencies;
2. Develop a fair and equitable solution that will not impact adversely on either the state or any of its municipalities (i.e., do not pit winners against losers);
3. Dispel the fears and negative attitudes that a number of municipalities in the state developed toward jurisdictional realignment as a result of previous statewide realignment efforts;
4. Develop a cooperative and open state-local realignment process;
5. Demonstrate to those officials that may be skeptical that it is possible to accomplish something, even if it is not the ultimate or maximum realignment solution;
6. Minimize the short-term costs of realignment; and
7. Improve the continuity, efficiency, and effectiveness of state and local highway systems.

Long-Range Goals

1. Establish logical and systematic assignments of highway jurisdiction at all levels of government that correspond to their general responsibilities;
2. Provide each level of government with the resources it needs to maintain and improve its highway system in an efficient and effective manner; and
3. Ensure that the residents of all levels of govern-

ment are treated in an equitable manner—in terms of service received and resources required to support the corresponding system.

Based on these goals and objectives, the New York State Department of Transportation selected a two-phase approach to total highway system realignment (see Figure 1). The first phase is directed at the realignment of the state highway system outside of cities. It is designed as a short-term trading effort, which principally involves the state and its counties and will have little or no adverse financial impact on any governmental unit. The efforts of the initial phase are intended to produce a more logical system that will provide the basis on which permanent solutions to several complex issues can be addressed in phase 2. These issues, which tend to require a longer-term effort because of their potentially significant socioeconomic impacts include

1. The possible extension of the state highway system within cities (currently few state routes other than expressways are continuous through cities),
2. Development of adequate state highway-aid programs to assist in the maintenance and improvement of local government highways, and
3. Realignment of highway systems at the municipal level as appropriate (optional).

Guidelines

The department has established a series of specific guidelines that explicitly relate to the achievement of the short-term objectives cited above. These guidelines, which have been established to facilitate the development of equitable state-local transfer proposals in each of the 57 counties, include the development of exchange proposals that utilize the 1980 functional classification system as the primary basis for identifying appropriate exchanges (2): "Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide." Functional classification criteria are available from other sources (2, 3). The state should be assigned the highest classified routes, the counties the next higher level routes, and the remaining routes should become the responsibility of cities, towns, and villages. Only limited involvement with cities, towns, and villages is required in the initial phase, since appropriate exchanges can generally be developed between the state and each county.

Contrary to the approach taken in the master plan (which assigned all arterials to the state and other routes to local government), no specific dividing line between state and local government jurisdiction within a county will be established. Instead, the split will be determined by the extent of the existing state system within that county. This approach is intended to ensure that the financial impact on all levels of government is minimal; however, it will not rectify past inequities.

Proposed exchanges between state and local government are to be developed on a lane-kilometer for lane-kilometer basis. This guideline presumes that the costs of highway maintenance and improvement relate directly to the length and width of the roadway. However, since a number of other factors also have a significant influence on costs (e.g., differing road conditions, standards, magnitude, and size of structures), adjustments in the extent of highways to be transferred in order to offset potentially significant financial imbalances are also to be accounted for.

No exchanges between the state and its counties will be pursued by the state unless appropriate local officials agree on the extent and timing of the proposed transfers and a resolution in support of the proposal is passed by the appropriate legislative body. Routes are to be exchanged in their present condition. Improvements will only be made when they can compete on their own merits for available resources.

A similar set of guidelines will also be developed for the longer-term effort. Although not yet final, guidelines for jurisdictional realignment within cities are expected to be based on the same general principles that are being applied in other areas of the state. Functional classification will be the primary tool used to identify a fair and equitable state highway system in each city. It is expected that the majority of such routes will have a principal arterial (connecting link) functional classification, indicating that they serve through travel. Because the extent of existing state highways within cities is limited, it will generally not be possible to exchange highways on a lane-kilometer for lane-kilometer basis, as was done during phase 1. However, existing state highways not on the selected state system will most likely be returned to their city.

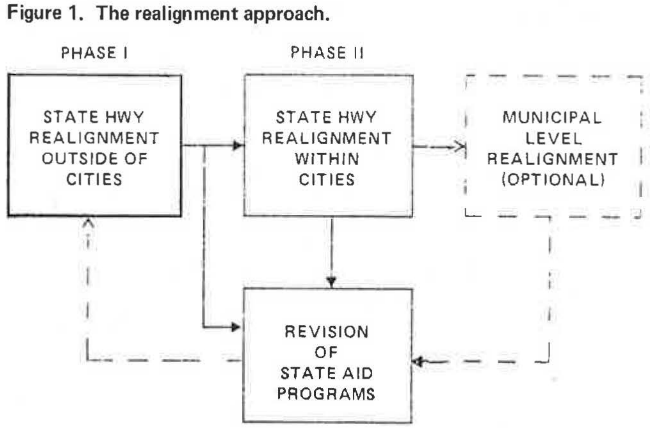
While it is anticipated that a system will be developed in each city to indicate routes for which the state should assume some level of responsibility, several options will be examined as part of the financial element of phase 2 to determine the most appropriate method to address this issue. Among these are

1. Outright state takeover of these routes for purposes of operations, maintenance, and capital improvement;
2. Outright state takeover but with contractual arrangements with each city for operations and maintenance purposes; and
3. Direct state assistance to cities to offset some of the costs associated with the designated state system.

Status

In the fall of 1977, the department selected Jefferson County to use the above guidelines as a pilot area for highway jurisdictional realignment. Jefferson County is principally rural, has a population of 90 000, and is located in northern New York. It contains the city of Watertown, which has a population of 30 000. After several months of negotiations between department, county, and city officials, agreement was reached on the exchange of approximately 116 lane-km (72 lane-miles) of state highway with minor collector and local functional classifications for 111 lane-km (69 lane-miles) of county highway having arterial and major collector classifications and

Figure 1. The realignment approach.



5 lane-km (3 lane-miles) of city streets having an arterial classification. Both local governments passed resolutions in support of this proposal. In the remaining 56 counties the department then developed preliminary transfer proposals and began to discuss them with appropriate local officials. A formal report (4) was prepared and distributed to state and local officials in support of this effort.

During 1978, preliminary agreements were achieved in about 30 counties and a decision was made in still another 10 counties that existing assignments of responsibility did not require modification. A major effort was undertaken to finalize phase 1 negotiations in the remaining 17 counties early in 1978 so that enabling legislation could be submitted to the state legislature for action in the spring of 1979 and phase 2 activities can formally commence.

PRELIMINARY OBSERVATIONS AND CONCLUSIONS

While jurisdictional realignment efforts are far from complete in New York State, some preliminary observations and conclusions can be drawn at this time from the experiences in phase 1.

The use of functional classification as a principal tool in highway system realignment is quite appropriate. The Federal Highway Administration (FHWA) has determined that many other states, including Arkansas, Colorado, Georgia, Indiana, Iowa, Michigan, Missouri, Nebraska, Washington, and West Virginia, are using it as a basis for system realignment (5, 6, 7). Although it is much simpler to equate specific functional classification levels to each level of government, it is also feasible to use the concepts of functional classification even though responsibility for routes in a certain classification level may be split between two levels of government after realignment. For example, in order to maintain a similar-sized rural state highway system in New York, the more important elements of the major collector system were assigned to the state and the remainder were assigned to the counties. After the existing extent of state highways and functional classification systems in other states is examined (8), a similar approach could probably be used.

While the lane-kilometer for lane-kilometer guideline was an effective rule of thumb for development of preliminary transfer proposals that have minimal financial impact, it should not be expected to supplant the need for careful evaluation of potential financial impact on a route-by-route basis. Because of variations in roadway and topographic conditions, geometric standards, travel demand, and structures, routes of equal length can have substantially different maintenance and capital needs associated with them. New York has found that a detailed needs analysis was not required to determine such differences. Rather, field inspections by state and local officials responsible for maintenance and improvement of these routes was sufficient to estimate such cost-related differences.

Jurisdictional realignment has always been a very sensitive issue in New York State, probably because past efforts would have created some winners and some losers. By adopting an approach that attempts to minimize the adverse financial impact of realignment, much of the controversy has disappeared. However, much of the incentive for placing a high priority on realignment has also evaporated. By its very nature, the initial phase will not address the question of past inequities. Solutions to such situations may, however, be incorporated in the second phase, when financial resources are to be reviewed and recommendations made for appropriate adjustments.

The principal concern expressed by state and local officials about New York's approach to realignment has been that the final product of phase 1 may not necessarily be a statewide solution since counties are not mandated to participate. Thus, a discontinuous state system may result. Adequate provisions have been taken, however, to ensure that this does not happen. Although the extent of system realignment may be less than it would be under a mandated plan, a number of significant advantages were achieved under the approach selected. These include the improved cooperation of local government and improved political feasibility for making many desirable changes that might not occur in an all-or-nothing approach.

The department has found that many of the routes in question do not cross county lines, and other candidates for exchange are obvious to all affected governmental units. The department insists that system continuity criteria be satisfied in all exchanges. Thus, proposals negotiated in one county are sometimes dependent on what happens in an adjacent county. This approach obviously requires a continual monitoring of realignment efforts in all areas and periodic adjustments to reflect changes made in adjacent counties. However, this has not caused significant problems.

The potential for cost savings due to realignment appears to be minimal. Some efficiencies will result from more direct routings and from a continuous system, but the principal advantages of realignment within New York appear to be in the following areas:

1. Improved planning and coordination,
2. More effective use of capital and maintenance resources, and
3. Improved equity through a more rational relation between highway assignments and general governmental responsibilities.

New York's approach, while not revolutionary in nature, appears to be appropriate to address jurisdictional realignment concerns in a timely manner that is mutually satisfactory to all affected governmental levels.

ACKNOWLEDGMENT

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Subarea Diagnostic and Evaluative Procedures for Programming Short-Range Transportation Improvements

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The emphasis on low-cost, short-range transportation system management actions implies the need for more detailed data to support decision making at a smaller scale. Ideally, such data would be developed efficiently and in a manner conducive to identification of problems and opportunities and, ultimately, formulation and programming of improvements. At the same time, such data must permit planners to perform the necessary trade-offs of traditional mobility objectives against the increasingly important objectives of improved air quality, reduced energy consumption, and responsible fiscal management. This paper describes the development and case-study application of a diagnostic framework for subarea-level identification of problems and delineation of improvements. The necessary level of detail is provided by use of the thoroughfare planning system, a subarea focusing methodology. A framework is set forth for using such a tool to develop diagnostic measures pertaining to environmental as well as mobility objectives. The diagnostic measures obtained in a case-study application are described. Further, the use of these measures to formulate an improvements program within the case-study setting is reviewed, with particular attention to the packaging of individual candidate projects into distinct alternatives for evaluation and selection.

An essential responsibility of a metropolitan planning organization is to assist local governments in making transportation investment decisions. In the past, however, it has been difficult to provide adequate information to support local decisions. Regionwide analysis and evaluations of major highway and transit facilities simply are not detailed enough to address problems at a subregional scale. Much thought has been given to the development of planning methodologies that are geared to cost-effective analysis of subregional problems, and several recent developments appear promising (1, 2, 3). One such methodology is the thoroughfare planning system (TPS), developed by the North Central Texas Council of Governments in close cooperation with member governments. The TPS features a rich, hierarchically structured data base and an automatic subarea focusing capability. It provides low-cost analyses of transportation systems in substantially greater detail than was previously possible. The mechanics of TPS are adequately described elsewhere (4, 5). The subject of this paper is the application of subregional analysis in decision-making contexts of increasing complexity.

Recent legislation and other considerations have created a situation in which the objectives of transportation planning, at all levels, are more complex and are often in conflict. Short-term, low-capital transportation system management (TSM) actions must be explored before resorting to capital-intensive alternatives. The implementation of TSM actions must consider the progress of long-range developments. Fiscal constraints and environmental concerns temper the traditional objective of increased mobility. These manifold objectives require a well-structured diagnostic and evaluative process to guide the identification of effective improvements to the transportation system.

This paper describes a framework for systematic and comprehensive review of a local transportation system. It focuses initially on travel patterns (rather than on specific facilities) in order to formulate a more cohesive and effective set of system enhancements, including systemwide actions as well as facility-specific improvements. A by-product of this approach is the ability to address questions of equity more readily—questions such as whether trips to and from a particular residential zone are adequately served in terms of mobility, energy efficiency, and other objectives.

TPS

TPS is designed to answer many of the needs that arise from a shift in planning emphasis—from large-scale, capital-intensive projects to low-cost subregional projects, typified by TSM strategies. The ability to analyze small-scale problems quickly and inexpensively is essential. In the formulation of a local capital improvements program, for example, information is needed on an adequate range of options within the time constraints imposed by the decision-making process. The principal elements of the TPS include the following:

1. An approved regional thoroughfare plan, complete with design standards;

2. A base inventory of the thoroughfare system with procedures for continuous updates;
3. A thoroughfare information system, which facilitates the storage and easy access of both inventory data and analysis results; and
4. A thoroughfare analysis process to evaluate the impact of alternative strategies.

To provide for cost-effective analysis of small-scale problems, the TPS features several innovations:

1. Computerized procedures build subfiles for analysis from base data files that describe the zones and networks of the region in much detail. Typically, these subfiles include detailed presentation for the area of interest, with detail decreasing gradually with distance from the area of interest.
2. The subarea focusing feature is supported by a rich, hierarchically structured data base. At the finest level of detail, approximately 5000 zones and 12 000 links are represented for a study region covering 6600 km^2 (2550 $miles^2$). Per-user specification for a particular problem, automatic aggregation of zones, and deletion of links in focusing may result in 100 to 300 zones and 1000 to 3000 links for analysis.
3. To facilitate the evaluation of alternatives, the outputs of the analysis process are input to a special module for an automatic accounting of major impacts. Several categories of impact measures are reported in concise format: system supply and mobility measures, socioeconomic data, energy consumption, and emissions calculations.

DIAGNOSTIC FRAMEWORK FOR SUBAREA IMPROVEMENTS PROGRAMMING

Listed below are impacts of interest and the associated measures used in the analysis.

Condition	Measures
Accessibility	Average length of trip from subarea
	Percent of subarea trip origins destined outside subarea
Mobility	Vehicle kilometers of travel on subarea links
	Speed in subarea (posted, free, final)
	Delay in subarea (due to traffic controls, due to congestion)
Route directness	Route distance ÷ airline distance
Propensity for diversion	Time via minimum-distance path ÷ time via minimum-time path
Energy	Fuel consumption
Air quality	Emissions

Although most of these are standard evaluation measures, some may bear further discussion.

The signal delay due to traffic controls is defined as the difference between average posted speed limit and average free-flow (zero-volume) speed. This measure is particularly useful for the formulation of TSM strategies to improve traffic circulation. Signal delay is often several times greater than congestion delay and is often less costly to reduce.

Route directness is calculated as the ratio of route distance to airline distance. This measure may indicate either sparseness of the transportation network or diversion to longer paths. The former may point to capital projects to improve network support of particular zones. The latter may point out possibilities for reduction of vehicle kilometers of travel through improved arterial circulation.

The propensity for diversion to longer paths is measured by a travel-time ratio, the time on the minimum-distance path divided by the time on the minimum-time path. Values greater than one indicate a propensity for diversion to longer but faster paths. Analysis using this ratio can point to opportunities for reduction of the vehicle kilometers of travel.

Calculation of Measures in Subregional Analysis

To isolate problems within a subarea of interest and to ensure that effects within the subarea are not drowned out by regionwide effects, the calculation of performance measures should pertain to the subarea network only. One would, for example, be concerned with average speed within the subarea, calculated as the ratio of subarea vehicle kilometers of travel to travel time. For such analysis, it is necessary to build special skim trees whose path impedances are summed only over links within the given subarea. Figure 1 illustrates the calculation of subarea travel time for a specific path.

When the scope is restricted to subarea effects, care must be taken to avoid suboptimization, i.e., improvement of a local system in a manner detrimental to adjoining localities or to the region as a whole. Closely related is the need to order by priority the improvement programs of different communities to ensure that funds are channeled toward the most urgent problems. Thus, a diagnostic framework is needed for evaluation of subareawide performance (for comparison to other subareas within a study region), as well as for detailed analysis of problems within the subarea.

Diagnostic Framework

1. Subareawide evaluation reviews the overall performance of the local transportation system. This evaluation can be used in setting the priorities of subareas or corridors and may also be directly applicable in identification of generalized TSM actions or control strategies (e.g., a communitywide carpool promotion program).
2. Detailed diagnostic analysis examines the local system in detail to identify specific problems and opportunities for improvement with respect to mobility, energy consumption, and air quality. A systematic procedure is set forth below, beginning with the trip patterns served by the subarea transportation system and working toward identification of specific problems and candidate improvements. A schematic of this procedure is shown in Figure 2.

Identification of problem zones comprises the calculation of zone-related performance measures, based on trips to and from each zone in the subarea. Zones that produce or attract a significant number of trips that are inadequately served with respect to such factors as mobility or energy efficiency are singled out for further analysis. An important by-product is that questions concerning equity in the service to different sectors can be frontally addressed by zone-related performance measures.

For each of the problem zones, problem pairs of zones are identified. These are the specific trip interchanges that most need improved service. The paths associated with problem interchanges are then examined and specific facilities are examined in relation to problem zones and zone pairs.

Facilities on and near problem paths are examined for opportunities to reduce signal delay, divert traffic from congested highway links, and provide more direct routing. Finally, possible improvements are specified, taking into account the availability of funds, the priority of various needs, and detailed identification of problems and opportunities.

CASE STUDY: ANALYSIS OF BASE CONDITIONS

To demonstrate the application of the diagnostic framework, a case-study analysis of 1980 conditions was performed within the subarea depicted in Figure 3, which is located between Dallas and Fort Worth. The performance of the highway network in the subarea was evaluated; the objective was to formulate a hypothetical improvement program. The subarea network is bounded on the north and south by freeways running east-west, and contains a partially complete freeway, which runs north-south. The focus of the analysis was the arterial system—its support of the freeways and the quality of service to local traffic.

To better analyze congestion effects, separate traffic assignments were run for morning peak, evening peak, and off-peak travel. The assignment results were then assessed by following the diagnostic framework previously set forth.

Figure 1. Calculation of subarea travel time.

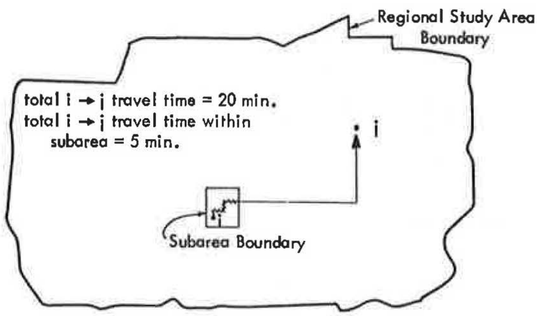
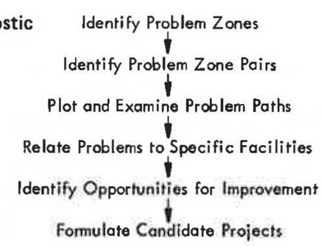


Figure 2. Detailed diagnostic analysis work flow.



Subareawide Diagnostics

Subareawide impact measures were calculated for the following classifications:

1. Roadway functional classification;
2. Trip purpose [home-based work (HBW), home-based nonwork (HNW), non-home-based (NHB), other];
3. Time of day (morning, evening, off-peak); and
4. Trip orientation [starting and ending within the subarea (I/I) starting within and ending ouside the subarea (I/E), starting outside and ending within the subarea (E/I), through traffic (E/E)].

As an example, the analysis of delay components is shown in Figure 4. On nonfreeway links, signal delay is several times greater than congestion delay. By trip purpose, HBW, HNW, and NHB trips experience less signal delay than do other trips (mainly truck and taxi trips). The time-of-day results show greater delay in the evening peak than in the morning peak. The E/E traffic experiences greater delay than do other trip orientations.

No attempt is made here to fully explore the subareawide results. It is difficult to draw conclusions from such results because little literature on subarea analyses is available for comparison and different subareas have different characteristics. Nonetheless, subareawide performance measures would clearly be useful for setting the priorities of investments within a study region and could also be used to identify subareawide TSM actions. For example, morning peak congestion delay in Figure 4 could perhaps be addressed by programs that promote staggered work hours or flextime. Since the evening peak period is already rela-

Figure 3. Case study: subarea boundary.

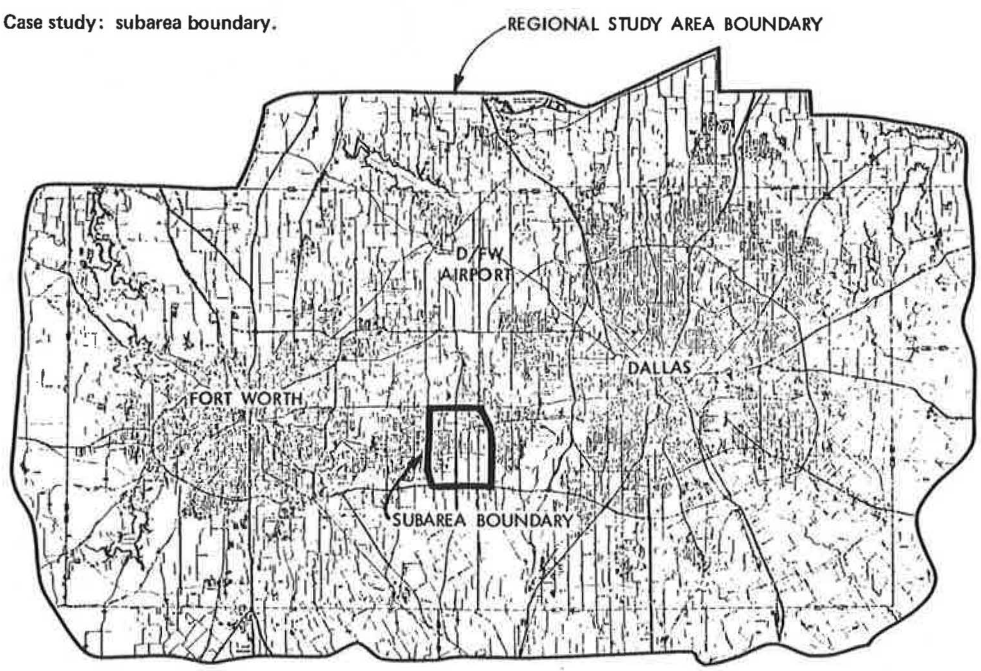


Figure 4. Case-study base condition diagnostics: delay components (percentage total free-flow travel time).

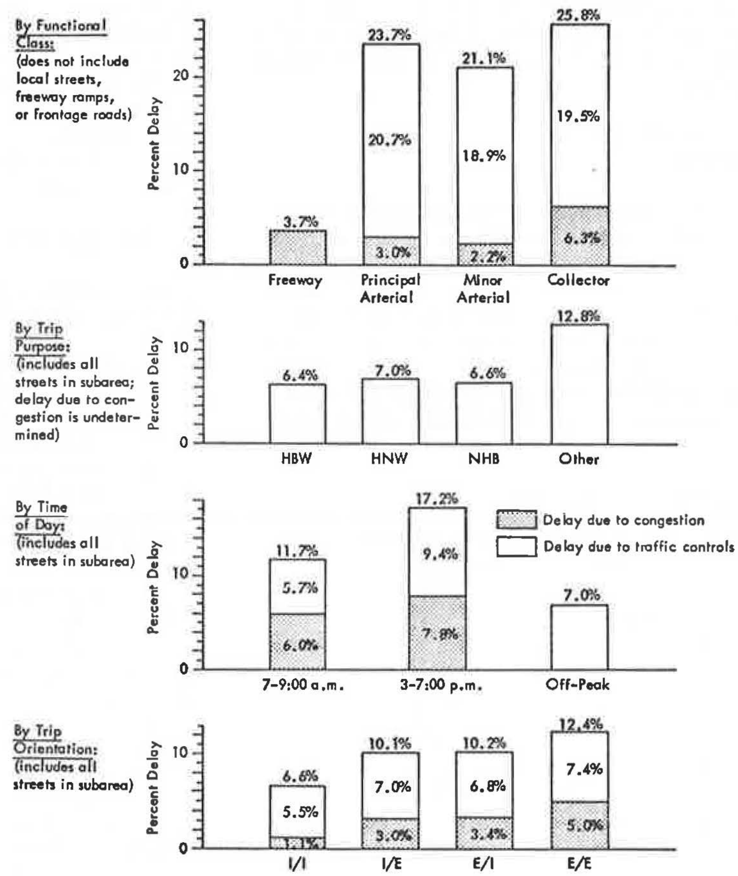


Figure 5. Subarea zones with signal delay.

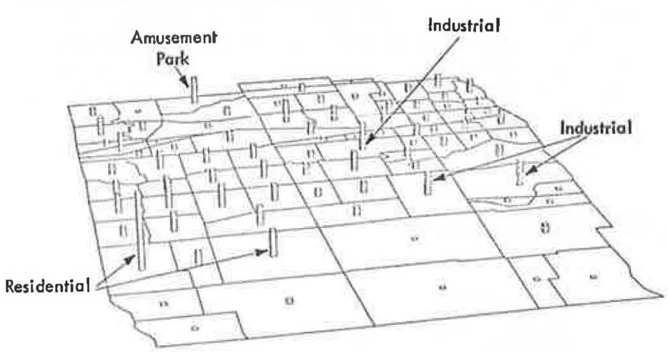
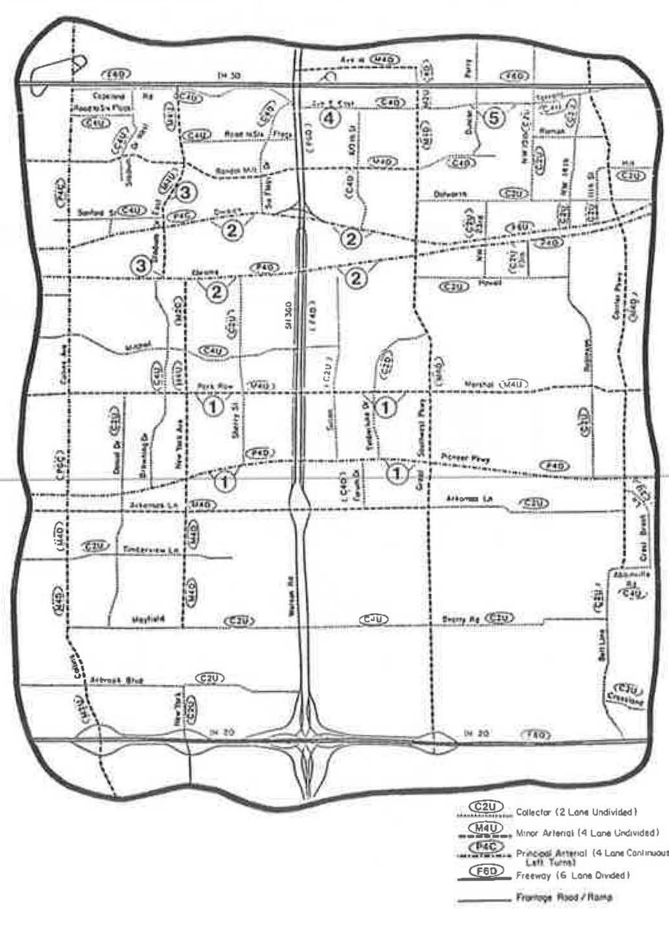


Figure 6. Subarea network: facilities contributing to signal delay.



tively broad and flat, however, promotion of a four-day work week might be more effective. The analysis of vehicle kilometers of travel by trip purpose, as another example, could point to opportunities for reduced vehicle kilometers of travel, emissions, and energy consumption through promotion of carpooling for work or nonwork travel.

Zone-Based Diagnostics

The detailed diagnostic analysis is trip based rather than link based, focusing initially on the trips served by the network rather than on specific facilities. The first step of the trip-based analysis (as illustrated in Figure 2) is the calculation of zone-related performance measures, which pertains to trips to and from each zone (rather than the links within each zone). Zones with subpar performance are then marked for further analysis. To illustrate, subarea zones that experience excessive signal delay are indicated in Figure 5. The zones in-

Table 1. Objectives and problem statements.

Objective	Statement of Problem
1. Improve north-south travel in western portion of subarea	North-south travel is circuitous; congestion delay makes up 16-25 percent of total travel time, a rate 8-12 times the subarea mean; traffic control delay makes up 15-20 percent of total travel time, a rate 3-5 times the subarea mean.
2. Improve east-west travel in northwestern portion of subarea	East-west travel experiences traffic control delay 14-20 percent of total travel time, a rate 2½ to 3½ times the subarea mean.
3. Improve east-west travel in southwestern portion of subarea	East-west travel experiences congestion delay 13-21 percent of total travel time, a rate 6-10 times the subarea mean; traffic control delay up to 20 percent of total travel time occurs at a rate 3½ times the subarea mean.
4. Improve transition from east-west travel to north-south travel in northeastern portion of subarea	Travel routes experience congestion delay between 20-40 percent of total travel time at a rate 10-20 times the mean for the subarea.

Table 2. Summary of improvement packages.

Objective	Package	Description	Cost Estimate ($)
1. Improve north-south travel in western portion of subarea	1-A	Provide a continuous north-south arterial route	2 200 000
	1-B	Provide freeway interchange and more direct arterial access	2 425 000
	1-C	Enhance traffic signal coordination and expand arterial capacity	1 101 000
	1-D	Construct additional freeway lanes and interchange	11 000 000
2. Improve east-west travel in northwestern portion of subarea	2-A	Provide new freeway interchange and coordinate arterial traffic signals	10 225 000
	2-B	Expand arterial capacity and eliminate an intersection	4 275 000
	3-A	Enhance design of an underutilized arterial roadway	1 800 000
3. Improve east-west travel in southwestern portion of subarea	3-B	Expand capacity along an existing arterial	3 600 000
	3-C	Restrict access to and from an existing arterial	550 000
	3-D	Construct grade-separated intersections along an arterial	6 550 000
4. Improve transition from east-west travel to north-south travel in northeastern portion of subarea	4-A	Provide freeway interchange and expand arterial capacity	4 610 000
	4-B	Provide a limited access interchange	2 000 000
	4-C	Construct a continuous arterial route and eliminate controls	3 650 000

dicated are those for which (a) the ratio of delay to travel time exceeded the subarea average by one standard deviation and (b) the delay for the zone constituted a significant portion of the total delay in the subarea.

For zones thus indicated, the next step is to determine the zone pairs that cause the problem. Standard urban transportation planning system (UTPS) software is used to calculate the impact measure in question for each trip interchange from these zones. Troublesome interchanges are then marked for the next step, which is to plot and inspect the paths traversed by traffic on these interchanges. From these plots it is then possible to relate problems to specific facilities or groups of facilities. Figure 6 is a map that identifies facilities contributing to signal delay. The circled numbers in Figure 6 correspond to the following problems:

1. Poor east-west mobility because of signal delay on arterials spanning the southern part of the subarea (since one of the facilities indicated already has a progressive signal system, the solution may lie in reducing the number of signals by limiting access),
2. Poor east-west mobility in the northern part of the subarea suggests the need for progressive signalling or limitation of access,
3. Poor north-south mobility in the northwest quadrant hinders access to the heavily residential zones in the southwest quadrant (simple realignment would eliminate one intersection and reduce signal delay),
4. Excessive signal delay at the freeway interchange to the north, and
5. Excessive signal delay getting onto the freeway in the northeast quadrant impedes access to industrial zones (more direct access to the freeway is needed).

Congestion delay, route circuity, and posted speed were also analyzed. Route circuity is indicative of excessive vehicle kilometers of travel and can point to opportunities for reduced emissions and energy consumption. Posted speed can be thought of as an upper limit on the accessibility to different sectors and, along with components of delay, determines operating speed.

Other auxiliary analyses of the network are useful in moving from diagnostic analysis to specification of improvements. Maps of currently underutilized links can be used to delineate alternative routes for diversion from congested facilities. Links where parking is currently allowed also have a potential for increased capacity.

FORMULATION OF TRANSPORTATION IMPROVEMENTS

The first step toward identification of specific improvements in the subarea was to use the diagnostic results to delineate a manageable number of distinct problems that should be addressed. Use of diagnostics in this manner often carries built-in justification for projects. Solutions to seemingly distinct problems often have interdependent effects; later, in the packaging of different combinations of improvements, an attempt was made to account for possible interrelationships.

Four generalized problem areas were identified for the subarea in question. For each area, an overall objective and a specific problem statement are provided in Table 1. Problems cited include circuity of travel, congestion delay, and traffic control delay. Although mobility objectives are a major thrust, programming goals are not restricted to mobility improvements only. The elimination of congestion and traffic control delay will often also reduce emissions and energy consumption, as a result of decreased travel time over a more uniform travel speed profile. In addition, the elimination of circuitous travel can reduce vehicle kilometers of travel for certain trips, further reducing energy consumption and emissions.

Initial Project Definition

Four types of projects were considered: new construction, existing road expansion, restriction of access, and traffic control improvements. Construction projects included interchanges as well as road segments. Projects to restrict access included turning-movement prohibitions and restrictions of midblock land access. The traffic control improvements included signal coordina-

Figure 7. Project packages: objectives 1 and 4.

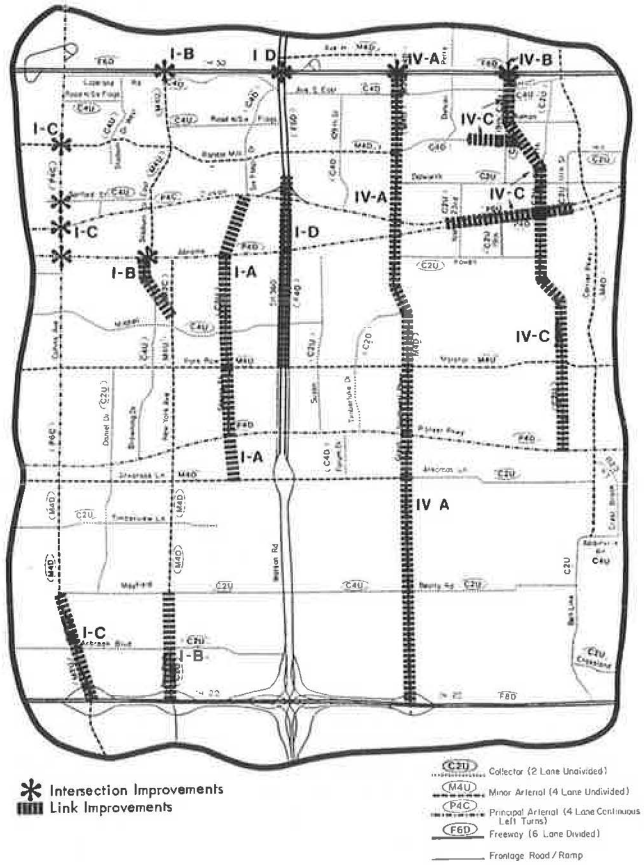
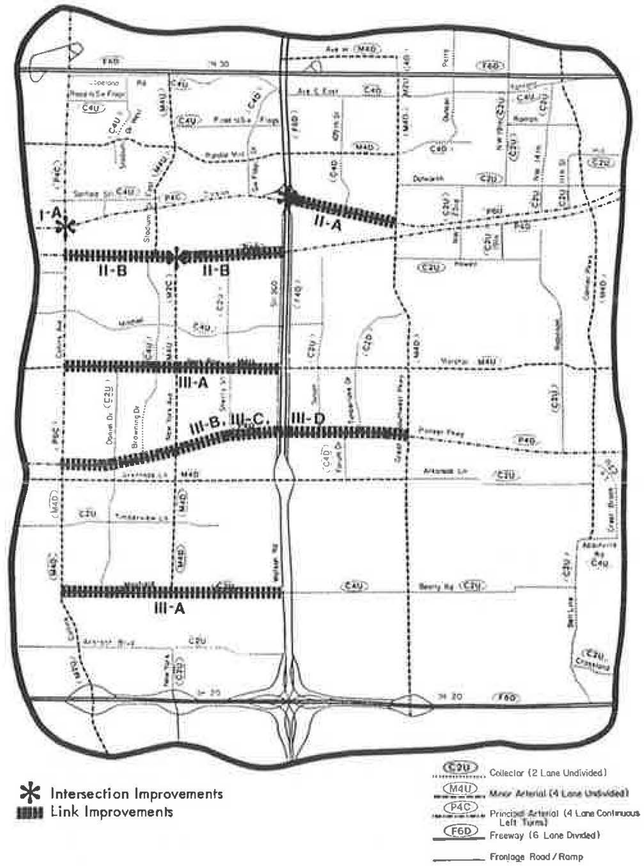


Figure 8. Project packages: objectives 2 and 3.



tion, traffic control removal, and traffic control modification. For the subarea in question, a total of 34 individual projects were initially considered. These projects were then combined into project packages before further consideration.

Individual projects are not always sufficient to produce desired increments in the objectives being measured. When grouped, projects can either reinforce one another or produce counterproductive results (6, 7). The next step, therefore, was to package individual projects together to form a manageable number of alternative solutions for each of the four problem areas in Table 1. In all, 13 separate packages were assembled from the list of possible projects proposed for the subarea. A summary of each package and its cost is provided in Table 2. The packages for objectives 1 and 4 are illustrated in Figure 7. Figure 8 shows the packages for objectives 2 and 3. The cost of the various packages ranges from $0.5 million to $11 million.

Selection of Improvements for Further Consideration

The initial identification and packaging of projects were based on the quantitative diagnostic analysis described previously. Final selection took into account additional qualitative arguments: political acceptance, economic feasibility, safety, and additional costs such as right-of-way and relocation.

A total of nine projects was selected, at an estimated cost of $9 925 000. For objective 1, package 1-A was selected. It is anticipated that this set of improvements will provide a much-needed continuous north-south arterial by means of improvements to an existing roadway in a non-politically sensitive area by using a variety of available funding sources. For objective 2, package 2-B was selected to improve east-west access to regional employment centers along the route because of available right-of-way and ease of construction. For objective 3, only a part of package 3-A was selected, to reduce cost and avoid duplication of benefits from package 1-A and to improve the access to a fast-growing sector of the subarea. For objective 4, a portion of package 4-A (the new freeway interchange) was selected to alleviate volumes at adjacent interchanges and to provide better access to industrial zones in the southeast sector.

The final selection of packages recognized that funding for individual projects could come from a variety of different sources, including federal aid, state aid, and local funding. Once a final selection is made, the remaining packages are tested as a group in order to see whether the results are valid and logical. The validity of projects can be tested in this manner, and thus a large portion of the guesswork is removed from the transportation programming process.

FUTURE WORK

This paper sets forth a diagnostic procedure for identification of problems and opportunities and delineation of candidate improvements. The features of this process are (a) orientation of the diagnostic measures to trip patterns rather than facility-specific measures, using zone-related performance measures as a starting point; and (b) assessment of performance in sufficient detail and breadth to support small-scale, short-range decision making in the face of multiple objectives. It would be difficult to prove that such analysis always leads to more effective improvements; however, in case-study application the analysis provided a comprehensive overview of the pattern by which specific facilities contribute to problems, guided the specification of improvements, and lent itself readily to the justification of proposed improvements in terms of trip interchanges and activity clusters being served. Areas requiring further work include the following:

1. The evolution, from future subarea studies, of suitable benchmarks against which to compare the subareawide diagnostics, so that these measures may be used to set priority subareas for funding and to specify subareawide strategies;
2. Development of more rigorous guidelines for what constitutes a problem zone or zone pair—the heuristic rules used in this paper call for further examination; and
3. Development of more rigorous guidelines for formulation of distinct objectives and packaging of individual projects into alternatives for addressing these objectives.

ACKNOWLEDGMENT

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Priority Programming for Highway Reconstruction

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An adequacy rating procedure was developed for use in priority programming for highway reconstruction. The procedure makes use of 15 roadway and traffic elements to rate highway sections in urban and rural areas based on a 100-point scale. Condition elements (35 points) include a subjective rating of highway foundation, pavement surface, drainage, and maintenance economy. Safety elements (35 points) are stopping-sight distance, highway alignment, skid resistance, accident experience, and traffic-control devices. Service elements (30 points) include shoulder width, passing opportunity, rideability, surface width, volume-capacity ratio, and average speed. Some of the advantages of the new procedure include computerized analysis of all input data and detailed output summaries. All highway sections are referenced by milepoints, reference points, and federal-aid route numbers. The procedure incorporates the 1978 design standards. New adequacy concepts include the use of the rate-quality control method for accident analysis, a formal rating scheme for traffic-control devices, and a rating of lane width based on design level of service. Other advantages include measured skid numbers and a roadway-condition rating guide for subjective evaluations of six different roadway elements.

Virtually every state has a systematic procedure for periodic evaluation of highway sections for improvement programming. The procedure, known as adequacy ratings (or sufficiency ratings), was first developed and implemented by the Arizona Highway Department in 1946 (1). The rating of highway sections is generally based on a 100-point scale, where 100 points applies to a new section.

The adequacy rating includes the evaluation of several highway and traffic elements, which may be classified as condition, safety, or service. Condition elements usually require subjective evaluation and may include foundation, surface, shoulder, and drainage. Safety elements may include more objective information, such as surface width, accident information, stopping-sight distance (SSD), alignment, and skid resistance. Service elements may refer to such descriptors as rideability, passing opportunity, shoulder width, traffic speed, or volume-capacity (V/C) ratio.

A nationwide survey was published in March 1973 of the most commonly used variables considered in adequacy rating of highways (2). The point values most often used were 40 for condition, 30 for safety, and 30 for service. More than 80 different highway and traffic elements were found to be in use in the United States in adequacy ratings. The 16 most common elements were recommended for use with either 5 or 10 points assigned to each. No distinction was made between ratings for rural and urban highways (2).

Adequacy rating of highways in Kentucky was developed primarily for the purpose of locating deficient highway sections on the state-maintained system. In using adequacy rating techniques, highway sections are assigned numerical ratings to indicate their relation to established design standards. Priorities for construction or reconstruction are then based, in part, on the adequacy rating (3).

Approximately 16 000 km (10 000 miles) of state primary and secondary routes are included in Kentucky's adequacy rating program. Because the adequacy rating methods and procedures were last revised in 1963, an in-depth evaluation was made of the procedure. The purpose was to incorporate the latest engineering principles, design standards, and computer techniques. In 1976, Kentucky developed a new adequacy rating procedure to more effectively rate sections of highway. Because of operational differences between urban and rural areas, the new procedure incorporates some descriptors that best suit the location. The procedure was developed to improve accuracy and reliability of the adequacy ratings and to help ensure optimal expenditure of safety-improvement funds.

CONDITION ELEMENTS

Subjective evaluation of many highway and traffic elements was made to determine those best suited for use in Kentucky. The variables used in other states and those currently used in Kentucky for rural and urban highways were considered. All elements are given in Table 1 along with corresponding point values. The condition elements include foundation (10 points), pave-

Table 1. Recommended adequacy rating elements.

Element	Rural Points	Urban Points
Condition		
Foundation	10	10
Pavement surface	10	10
Drainage	8	8
Maintenance economy	7	7
Safety		
Stopping-sight distance	8	-
Alignment	8	-
Skid resistance	7	-
Accident experience	12	20
Traffic-control devices	-	15
Service		
Shoulder width and condition	7	-
Passing opportunity	8	-
Rideability	5	-
Surface width	10	10
Volume-capacity ratio	-	12
Average speed	-	8
Total	100	100

Table 2. Roadway-condition rating guide.

Condition	Excellent	Good	Fair	Poor
Base	Base (as distinguished from surface) is considered to be in very satisfactory condition. Rare situations of imperfect smoothness but no evidence of base failure.	Occasional evidence of minor base failure, fully correctable by spot repairs. Extensive reworking not absolutely necessary.	Frequent evidence of base failure, correctable only by heavy maintenance. Road should be considered for reconstruction. Traffic speeds reduced somewhat.	Severe base failure throughout subsection, extreme washboard condition. Road must be reconstructed. Traffic speeds reduced substantially.
Surface	Surface (as distinguished from base) is considered to be in very satisfactory condition. Pavement smoothness very satisfactory. No surface failure.	Occasional spots of surface failure, spalling, or roughness, correctable to a satisfactory extent through maintenance and minor patching. Resurfacing not absolutely necessary.	Frequent spots of surface failure and spalling. Rough surface in need of heavy maintenance. Should be considered for resurfacing. Traffic speeds reduced somewhat.	Severe surface failure throughout subsection. Road must be resurfaced or rebuilt due to surface condition. Traffic speeds reduced substantially.
Drainage	Road surface drains satisfactorily during heavy rains; no ponding, no flooding.	Occasional ponding during heavy rains but drains quickly thereafter, no restriction to traffic operation, no flooding.	Substantial ponding during heavy and light rains. Some reduction to traffic speeds due to ponding. Should be corrected to avoid damage to pavement. Occasional flooding.	Excessive ponding to the extent that traffic on occasion must traverse ponds over 50.8- or 76.2-mm deep. Correction necessary to avoid base damage, frequent flooding.
Ditch drainage or urban drainage facilities	Ditch drainage (or urban drainage facilities) are completely adequate under conditions of heavy rainfall. No corrections needed other than normal light maintenance.	Ditch drainage (or urban drainage facilities) generally adequate except under conditions of very heavy rainfall. Frequent light maintenance required. No need for substantial improvement.	Ditch drainage (or urban drainage facilities) only partially adequate. Excessive maintenance required. Consideration should be given to substantially improve and extend ditches or other facilities.	Ditch drainage (or urban drainage facilities) completely inadequate, not correctable through maintenance methods. Drainage facilities must be provided.
Maintenance economy	No expenditures, other than strictly routine. Patching rarely required.	Some expenditures, but not excessive. Some patching required annually or at intervals. Resurfacing would help but not absolutely necessary.	Considerable expenditures of money and material. Considerable patching required annually or continually. Road should be considered for resurfacing or reconstruction.	Excessive expenditures. Great amount of patching required annually or continually. Road cannot be adequately repaired, must be rebuilt.
Rideability	No driver strain whatsoever under normal conditions. Crown, superelevations, and transitions provide for excellent operation of vehicles. No undue hazards or side-entrance friction. Smooth riding condition. No width or clearance restrictions.	Moderate driver strain due to minor geometric deficiencies, occasional side-entrance friction, and hazard. Good riding comfort. Operations or driver strain alone do not justify major improvements.	Considerable driver strain due to geometric deficiencies or side-entrance friction. Vehicle operation affected. May be some riding discomfort. Some improvements should be considered to improve quality.	Severe driver strain due to geometric deficiencies, side-entrance friction, maneuvering vehicle. Substantial riding discomfort. Improvements fully justified on this factor alone.

Note: 1 mm = 0.04 in.

Table 3. Points for condition rating.

Condition	Excellent			Good			Fair			Poor		
	H	M	L	H	M	L	H	M	L	H	M	L
Base	10	10	9	8	7	6	4	3	2	1	0	0
Pavement surface	10	10	9	8	7	6	4	3	2	1	0	0
Drainage	8	8	7	7	6	5	3	2	2	1	0	0
Maintenance economy												
Standard pavement	7	6	5	5	4	4	3	3	2	1	1	0
Substandard pavement	7	5	4	3	2	2	1	1	0	0	0	0
Rideability	5	5	5	4	4	3	2	1	1	0	0	0

Note: H = high, M = medium, L = low.

ment surface (10 points), drainage (8 points), and maintenance economy (7 points). The rating procedure and point allocation for condition elements are the same for rural and urban roads.

The condition elements are rated based on a subjective evaluation by planning personnel in each of Kentucky's 12 highway districts. Each of the condition elements is rated as excellent, good, fair, or poor. There are three possible levels (high, medium, and low) for each, or 12 possible ratings. A guide with word descriptions was developed for use by field personnel to describe what is excellent, good, fair, and poor (Table 2). The relation between rating and point value for foundation and surface condition was determined to be S-shaped. A similar relation was found for drainage condition (eight-point maximum). Maintenance economy refers to the needed annual expense each year in maintenance costs. Curves for standard and substandard pavement types were developed based on a seven-point maximum. A summary of point values for all subjective elements is given in Table 3.

SAFETY ELEMENTS

Rural Highways

For rural highways, the safety descriptors selected were SSD, alignment (vertical and horizontal), skid resistance, and accident experience. The rating for SSD is based on a maximum of eight points and is calculated by the formula:

$$\text{Rating} = 8 - N/L \quad (1)$$

Where N = number of SSD restrictions and L = section length.

Sight distance restrictions are based on traffic speed conditions for various types of highways as given in Kentucky's Basic Geometric Design Criteria (4). For example, for 65 km/h (40 mph) design speed, the minimum SSD is 83 m (275 ft). Design speeds of 80 km/h (50 mph) and 97 km/h (60 mph) correspond to SSD restrictions of 105 and 143 m (350 and 475 ft), respectively. On an 8-km (5-mile) section with 10-SSD restrictions, the rating would be six out of eight points.

The rating for highway alignment may receive a maximum of eight points. Vertical and horizontal alignment may each receive up to four points based on the following formula:

$$\text{Rating} = 4 - N/L \quad (2)$$

Curvature limits for various volume ranges and design speeds are given in terms of maximum degrees of curvature allowed, as listed in Kentucky's highway design standards. Allowable curvature ranges from 4° to 25°, depending on design speed and traffic volume. For the vertical alignment rating, if two deficient vertical curves exist in a 1.6-km (1-mile) section, the vertical alignment rating would be two points out of four.

In rural areas, skid resistance of the pavement was selected as a safety element and assigned a maximum of seven rating points. For survey and inventory purposes, skid tests are made at 65 km/h left wheel only, with two skid trailers meeting ASTM E 274 standards. Procedures also comply with ASTM E 274. Survey testing is limited to the period between July 1 and November 30. Frequency of repeated surveys or inventories may involve testing every two years (5, 6).

Skid resistance has been assessed in terms of skid number (SN) groupings. SNs above 39 are considered to be skid resistant; 33-39 is considered marginal; 26-32 is slippery (5, 6).

For use in adequacy ratings, a relationship was derived between SN and adequacy points. An SN of 25 or less was assigned zero points and an SN of 41 or more was assigned the seven-point maximum. A linear relationship was assumed between these SN values. For example, SNs of 31 and 35 would correspond to three and five points, respectively (5, 6).

Accident experience as a rating element of rural highway sections has received much attention within the Kentucky Bureau of Highways in recent years. A new method for identification of hazardous rural spots and sections is being implemented in Kentucky (7). One of the criteria used for evaluation of highways based on accident data involves the rate-quality control method.

Average statewide accident rates for highways of similar characteristics are needed to use the rate-quality control formula. The formula is based on the assumption that accident occurrences on an annual basis are approximated by the Poisson distribution (7):

$$CR = \lambda + k\sqrt{\lambda/m} + \tfrac{1}{2}m \quad (3)$$

where

- CR = critical accident rate for a particular highway section in accidents per 1 million vehicle-kilometers,
- λ = overall, average accident rate for sections of like characteristics in accidents per 1 million vehicle-kilometers,
- m = number of 1 million vehicle-kilometers on a highway section in a one-year period, and
- k = probability factor determined by the level of significance desired for the equation.

The value of k is determined by the level of probability that an accident rate above λ is abnormal, that is, large enough so that a high accident rate cannot be reasonably attributed to random occurrences (7). Examples of k values for various probability levels (P) are

P	k
0.995	2.576
0.975	1.960
0.950	1.645
0.925	1.440
0.900	1.282

Values of statewide average accident rates (λ) were determined for five types of Kentucky roads for 1971, 1972, and 1973 (8):

λ(two and three lane) = 3.84 accidents/1 million vehicle-km,

λ(four lane, undivided) = 5.01 accidents/1 million vehicle-km,

λ(four lane, divided) = 2.50 accidents/1 million vehicle-km, and

λ(Interstate and parkway) = 1.34 accidents/1 million vehicle-km.

The critical rate curves for two-lane and three-lane roads are given in Figure 1 and were prepared to illustrate the use of the formula. Each curve represents a highway section length of 1.6 to 32.2 km (1 to 20 miles). To apply the method, the accident rate for a one-year period is found by use of the formula:

$$R = (A)(1\,000\,000)/(365)(AADT)(L) \quad (4)$$

where

R = accident rate of the section,
A = number of accidents in one year, and
AADT = average annual daily traffic on the section.

This accident rate is compared with the critical accident level as given in Figure 1 for any AADT and section length. The actual rate is then divided by the critical rate to give the critical rate factor (CRF). Sections whose rates exceed their critical values have a CRF above 1.0, which signifies a very hazardous section.

Figure 1. Critical rate curves for rural two-lane and three-lane highway sections.

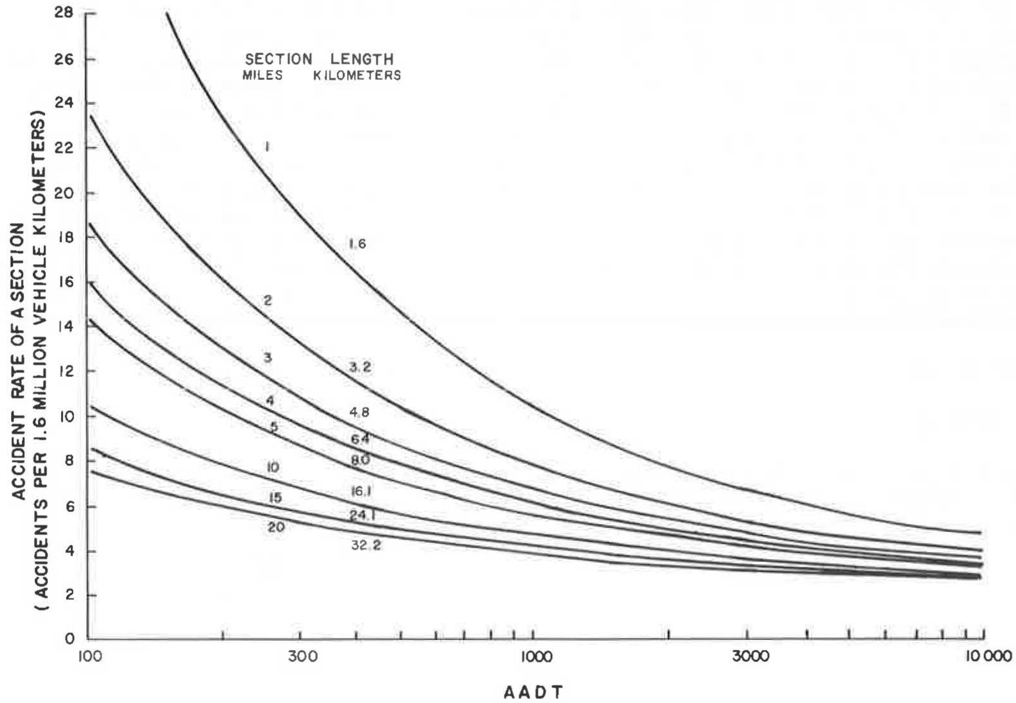


Table 4. Accident rate for arterial-collector locations.

Population	AADT Mid-Blocks	AADT Inter-Sections	Accidents Per Location Mid-Blocks	Accidents Per Location Inter-Sections	Accident Rate Per Million/Vehicles Mid-Blocks	Accident Rate Per Million/Vehicles Inter-Sections
Over 200 000	11 781	23 562	5.0	10.2	1.16	1.19
50 001 - 200 000	8 990	17 980	4.1	6.6	1.25	1.01
20 001 - 50 000	6 520	13 040	2.7	4.5	1.13	0.95
10 001 - 20 000	5 800	11 600	1.5	2.4	0.71	0.57
5 001 - 10 000	4 811	9 622	1.0	1.9	0.57	0.54
2 500 - 5 000	4 002	8 004	0.8	1.2	0.55	0.41

Table 5. Evaluation of traffic-control devices.

Criterion	Excellent	Good	Fair	Poor
Standardization	All existing traffic-control devices meet regulations in the MUTCD. Signal heads and indication displays are sufficient. Sign colors and symbols are correct. Proper sign distances exist. Color and type of pavement markings are correct and visible.	Most traffic-control devices meet MUTCD regulations. Signal heads and indication displays are sufficient in nearly all cases. Most signs and markings are correct. A few sign distances may be too short. Pavement markings are generally adequate.	Many traffic-control devices do not meet MUTCD regulations. Several signal heads and indication displays are inadequate. Sign colors and symbols are incorrect in many cases. Inadequate signing distances are often the case. Pavement markings are quite worn.	Traffic-control devices were installed with no regard to the MUTCD. Signal heads and indication displays are totally inadequate. Signs often are in conflict and unclear, and signing distances are inadequate. Pavement markings are misleading, incorrect, or worn.
Effectiveness	Existing traffic control devices convey sufficient information to the driver. No additional signs are needed. Destinations are clear. Regulations and warnings are adequately signed and marked. Traffic flows freely through signalized intersections.	Most traffic-control devices convey sufficient information to the driver. A few additional signs may be needed. Destinations are clear in most cases. Regulations and warnings are usually adequate. Traffic flows through signalized intersections with occasional congestion.	Many traffic-control devices do not convey sufficient information. Several additional signs are needed. Unclear destination signs exist. Regulations and warnings are often inadequate. Traffic flow is often congested through signalized intersections.	Traffic-control devices are unclear. More signing is needed, destinations are unclear, and regulations and warnings are unclear or conflicting. Traffic is greatly congested through the signalized intersections.
Maintenance	Signs and pavement markings are clearly visible, clean, and straight. All signal and streetlight bulbs are burning and lens faces are clean. Delineators are all in place and in good shape.	Signs are slightly weathered or dirty. Pavement markings are slightly worn or dirty. One or two bulbs in signals or streetlights may need to be replaced. Some delineators are missing, but they are still adequate for nighttime visibility.	Signs and pavement markings will soon need to be replaced. Several bulbs in signals or streetlights need to be replaced. Many signal faces need to be cleaned. No delineators exist and nighttime driving may be difficult.	Signs are weathered or dirty and need to be replaced. Several signal and streetlight bulbs need to be replaced. Delineators and pavement markers are mostly worn away or missing.

Curves for four lanes, divided and undivided, were also developed in a similar manner but are not given here. Values for λ were substituted into the formula with various AADT and section lengths to develop each set of curves. A probability level of 0.995 was used for all curves. Short sections must have a higher accident rate than long sections to have similar CRFs.

One use of the rate-quality control formula is to compare the degree of hazard of one section to another, regardless of length or highway type. For example, consider the data for two highway sections (1 km = 0.6 mile):

Factor	Section 1, Four Lane, Divided	Section 2, Two Lane
Section length	3.2 km	6.1 km
AADT	18 523	8391
Annual number of accidents (A)	24	27
Statewide average rate (λ)	2.50	3.84
Annual traffic exposure (m)	21.63	18.62
Accident rate (R)	2.83	3.72
Critical accident rate (CR)	3.95	5.78
CRF	0.72	0.64

Although section 1 had the lower accident rate, it had a greater CRF and is therefore more hazardous. Neither section is considered critical, since their CRFs are less than 1.00.

To apply this procedure to the adequacy rating of highways, a linear relation was developed between adequacy points and CRF. A point value of 0 (worst condition) represents a critical location for all sections with a CRF of 1.0 or greater. A point value of 12 (safest condition) was given to sections with a 0 CRF, which occurs when there are no accidents on a section in a one-year period (an accident rate of 0). A CRF of 0.50 (half of the critical level) corresponds to 6 points, and so on.

Urban Highways and Streets

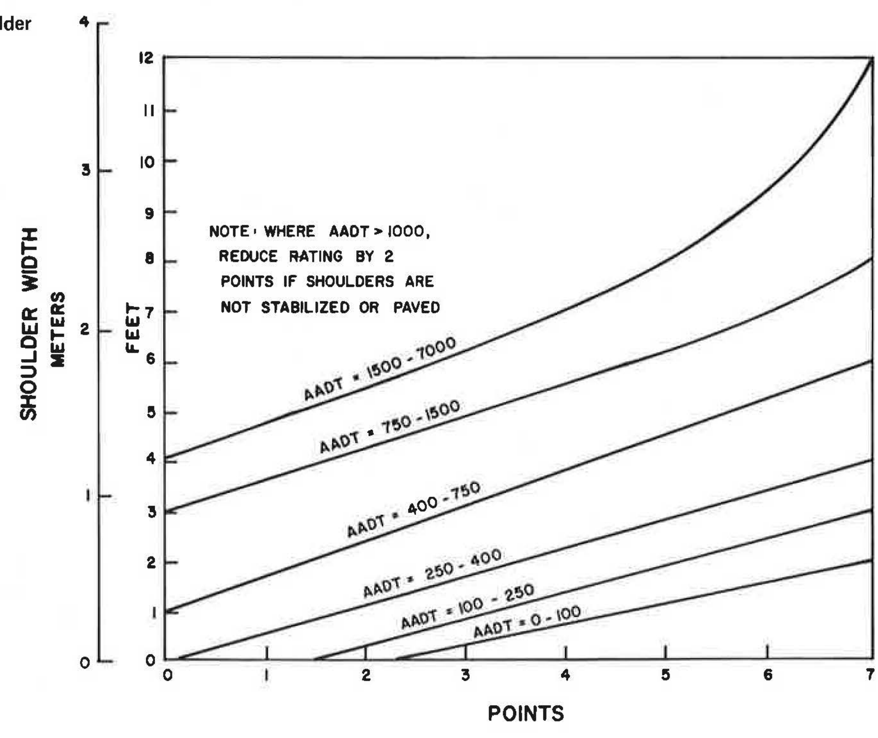
Although four different elements were selected for use in the evaluation of the safety of rural highways, only accident experience and traffic-control devices were chosen for urban safety rating. Skid-resistance data are often difficult or impossible to collect in urban areas due to low vehicle speed, high traffic volumes, and stop-and-go driving conditions. The evaluation of SSD and vertical and horizontal alignment is not applicable to city streets because of urban street networks and generally low vehicle speeds.

Accident experience was assigned 20 points because of the importance of this element. The method for the evaluation of accident experience for the adequacy rating uses the rate-quality control formula in a slightly different way than for rural highways. Urban streets, intersections, and midblocks are defined within each urban section. All rates are expressed in terms of accidents per million vehicles instead of accidents per million vehicle-kilometers. At intersections, volumes and accidents on both intersecting streets are used.

If locations in every city were considered under the same criteria, virtually no locations in small and medium cities would be identified as hazardous. Therefore, the rating procedure for cities was weighted according to population. Cities of over 2500 population were divided into six categories, as shown in Table 4. Average statewide accident rates were calculated for each city group for intersections and midblocks. Midblock average rates ranged from 0.55 to 1.25 accidents/1 million vehicles. Intersection rates ranged from 0.41 to 1.19 accidents/1 million vehicles. These values were calculated from 1974 accident data and volume counts (Table 4) (9).

Using the statewide average accident rates and the rate-quality control formula, a set of curves for critical rate were drawn for midblocks and intersections. They were based on a probability level (P) of 0.995 (k = 2.576) and give the critical accident rate for locations of a

Figure 2. Point values for rating shoulder width and condition.



given city group and AADT. There are 44 approved urban areas that fall under Kentucky's adequacy rating program.

To apply the procedure, CRFs are calculated and averaged for all intersections and midblocks within a study section. A linear relation was developed between CRF and rating points, as for rural roads. However, a maximum of 20 points is assigned for CRFs of 0 (accident rate of 0).

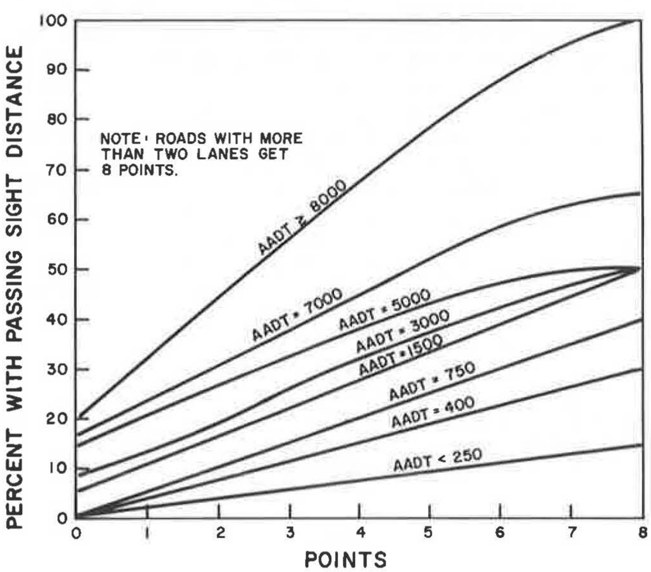
The condition and effectiveness of traffic-control devices are important in determination of the adequacy of an urban section. A maximum of 15 points was allotted to this element. A method was developed that consists of rating the standardization, effectiveness, and maintenance of signs, signals, and markings as shown in Table 5. Detailed definitions of condition evaluation are given for each of the three categories. The point allocation for each category is 5, 4, 2, and 0 points for excellent, good, fair, and poor ratings, respectively.

The standardization of a device is based on its compliance with the Manual on Uniform Traffic Control Devices (MUTCD) (10). Such items considered are sign color and symbols; proper sign location; color, type, and visibility of pavement markings; and adequacy of size and indications on traffic signals.

The effectiveness of traffic-control devices is the second category. This pertains to the clarity of information that is given to the driver related to destinations, upcoming dangers, and regulations (i.e., speed limits, stop signs, and no passing). The effectiveness of the traffic signals to promote smooth traffic movement through the intersection is also considered. Inappropriate signal timing, inconspicuous or small signal heads, or lack of coordination between adjacent signals would result in poor ratings in this category.

The maintenance of traffic-control devices requires that all signs and pavement markings be clearly visible, clean, and straight. All signal and streetlight bulbs should be burning and lens faces be clean. Pavement delineators should all be in place and in good condition. Weathered or worn-out traffic-control devices can create hazardous conditions to the out-of-state motorist, particularly in the rain or at night.

Figure 3. Point values for rating passing opportunity on two-lane roads.



SERVICE ELEMENTS

Rural Highways

The width and condition of the highway shoulder are important for adequate capacity and refuge for emergency stops. A relationship was developed between shoulder width and adequacy points based on AADT, as shown in Figure 2. Small values of AADT provide the most points for various shoulder widths. For example, for AADT ranges of 0 to 100, adequacy values range from two points for no shoulder to seven points for shoulder widths of 1 m (2 ft) or more. For AADT values of 1500 to 7000, shoulders of 1.2 m (4 ft) are assigned zero points, and seven points are given only for shoulders of 3.8 m (12 ft) and above. For roads over 1000 AADT, two points are deducted if shoulders are not paved or stabilized.

Figure 4. Point values for rating pavement width on two-lane roads.

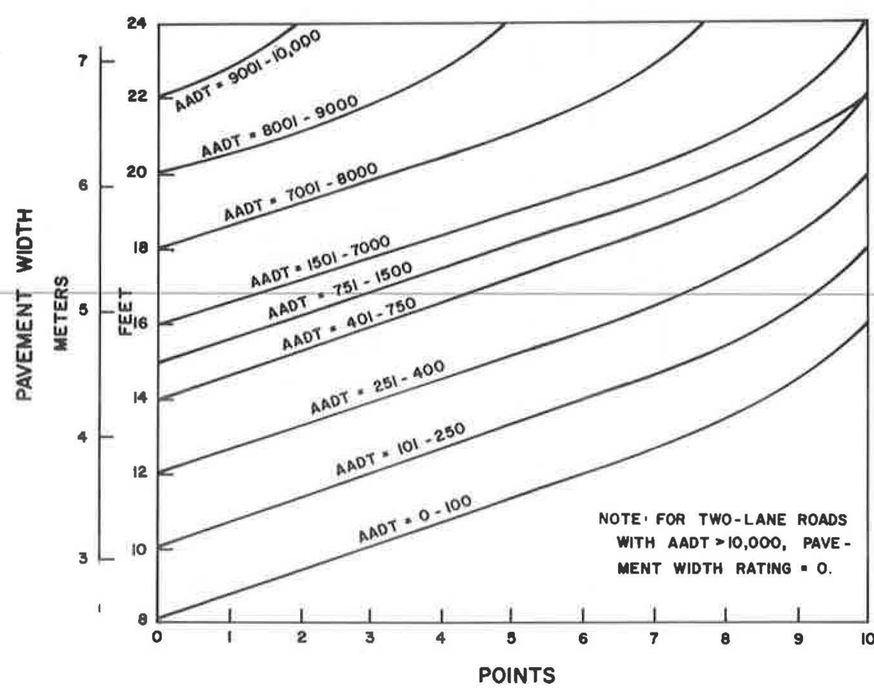


Figure 5. Point values for rating lane width on urban streets.

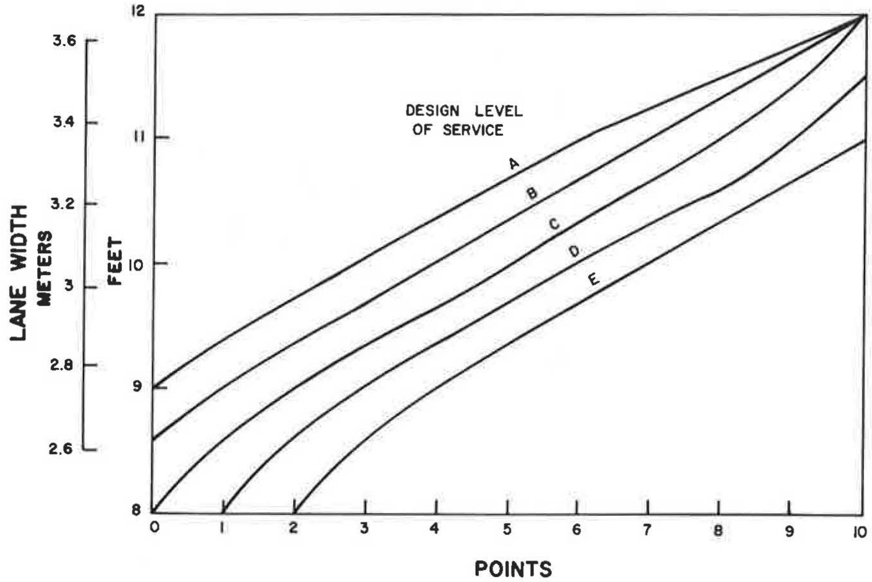
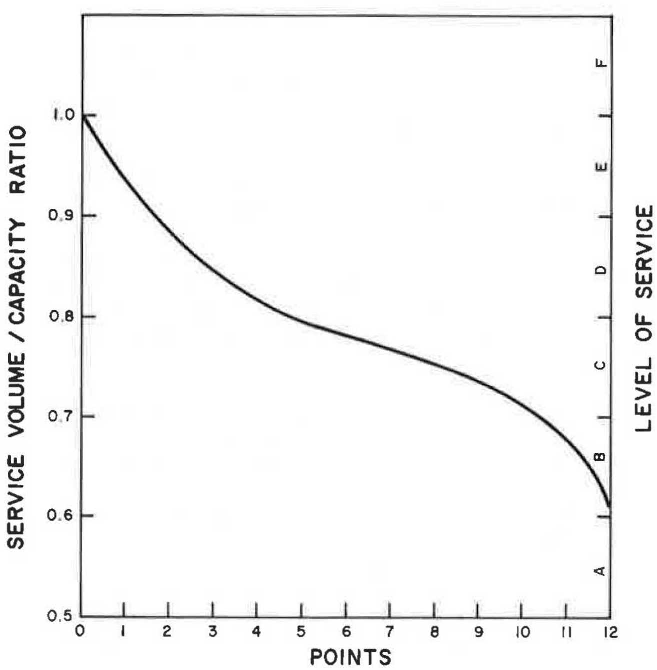


Figure 6. Point values for rating volume/capacity ratio on urban streets.



Another service element that was included for rural roads was passing opportunity (Figure 3). It is based on AADT and the percentage of passing-sight distance (PSD) on two-lane roads. Again, lower-volume roads are given more points than high-volume roads. For AADT values below 250, the maximum, eight points, is assigned for roads with a PSD of only 15 percent. Roads with AADTs above 8000 must have 100 percent PSD to obtain the eight-point maximum. Roads larger than two lanes get the maximum eight points, regardless of volume.

Rideability is a rural service element that is related to the road roughness and is a subjective rating made while driving over the section. The rideability rating is based on an S-curve, as was shown for foundation and surface condition, and carries a five-point maximum (Table 3).

Surface width is the most important service element (10-point maximum). Pavement widths of 2.5 to 7.2 m (8 to 24 ft) for two-lane roads were plotted against adequacy points as a function of AADT in Figure 4. A total of nine different volume ranges up to 10 000 were used for determining points. For two-lane roads with AADT values over 10 000, 0 points were assigned. For multilane, rural roads, another figure (not given here) was developed based on median width.

Urban Highways and Streets

As discussed previously, there are differences in driving conditions between urban and rural roads. On rural roads, desirable attributes include the opportunity to pass, adequate pavement width, wide shoulders, and a smooth pavement surface. On urban streets, the emphasis is on maintenance of acceptable speeds, avoidance of congested conditions, and an acceptable street width. The three service elements for urban areas include pavement width, V/C ratio, and average speed.

The relation between lane width and adequacy points on urban streets bears no resemblance to the curve for rural highways. The relationship was developed from level of service information provided in the Highway Capacity Manual (11). Up to 10 adequacy points are assigned to lane widths from 2.4 to 3.6 m (8 to 12 ft), as shown in Figure 5. Five different curves corresponding to levels of service A to E are provided. Kentucky's current design level of service is C for urban areas. Since design levels of service change, the figure provides for any such changes. As design level of service is lowered (such as from C to D), more adequacy points would be assigned for a given lane width.

The second service element for urban areas is the V/C ratio during peak traffic periods, which is worth up to 12 adequacy points (Figure 6). Again, information from the Highway Capacity Manual was used in the allocation of points (11). The S-shaped curve gives a high rating to V/C values below 0.7 (corresponding to levels of service A and B). Between 0.7 and 0.8, the points drop from about 10 to 4. When the volume equals or exceeds capacity (level of service E or F), no points are given.

Average traffic speed is the final urban service element and is based on eight points maximum (Figure 7). For business and downtown streets, speeds over 39 km/h (24 mph) correspond to the maximum eight points,

Figure 7. Point values for rating average speed of traffic on urban streets.

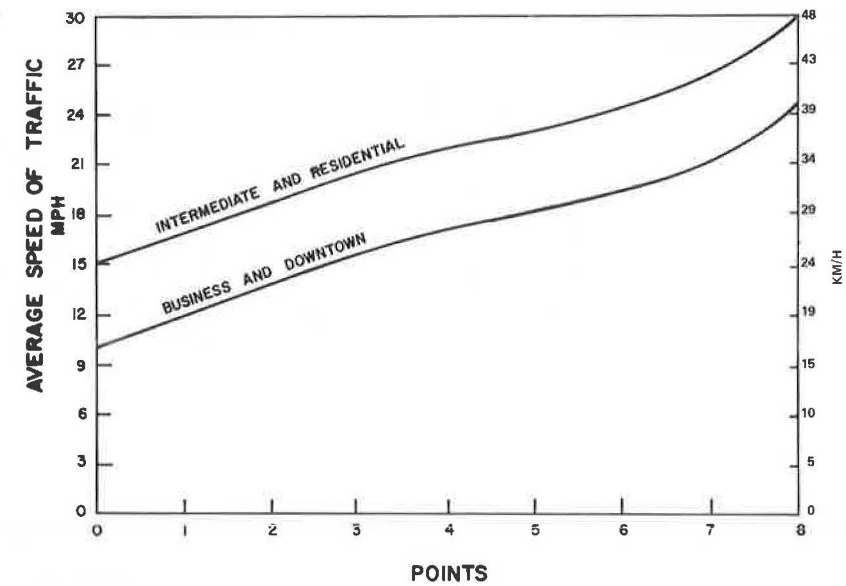


Figure 8. Example of computer output of adequacy ratings.

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CODE              ELEMENT                        POINTS

  A   FOUNDATION CONDITION (R, U )                 10
  B   SURFACE CONDITION (R, U)                     10
  C   DRAINAGE CONDITION (R, U)                     8
  D   MAINTENANCE ECONOMY (R, U)                    7
  E   STOPPING SIGHT DISTANCE (R)                   8
  F   ACCIDENT DATA (R, U)                     12 OR 20
  G   SKID RESISTANCE (R)                           7
  H   ALIGNMENT (R)                                 8
  I   SHOULDER WIDTH AND CONDITION (R)              7
  J   PASSING OPPORTUNITY (R)                       8
  K   RIDEABILITY (R)                               5
  L   SURFACE WIDTH (R, U)                         10
  M   TRAFFIC CONTROL DEVICES (U)                  15
  N   VOLUME/CAPACITY RATIO (U)                    12
  P   AVERAGE OVERALL SPEED (U)                     8

RURAL HIGHWAY SECTION

  6(10)A  + 5(10)B + 4(8)C + 3(7)D = 18(35)CONDITION
  2(8)E + 10(12)F + 4(7)G + 5(8)H  = 21(35)SAFETY
  6(7)I + 8(8)J + 2(5)K + 7(10)L   = 23(30)SERVICE

                                     62(100)TOTAL

URBAN HIGHWAY SECTION

  4(10)A + 8(10)B + 6(8)C + 7(7)D = 25(35)CONDITION
  18(20)F + 13(15)M               = 31(35)SAFETY
  11(12)N + 5(8)P + 10(10)L       = 26(30)SERVICE

                                    82(100)TOTAL

  R = RURAL, U = URBAN
  NUMBER IN FIRST POSITION INDICATES THE RATING
  NUMBER IN ( ) INDICATES MAXIMUM POINTS
    ALLOCATED TO THE ELEMENT
  LETTER INDICATES THE ELEMENT (SEE ABOVE AND
    TABLE 1)
```

while speeds of 16 km/h (10 mph) or less get no points. For intermediate and residential streets, average speeds of 48 km/h (30 mph) are necessary to receive eight points. Speeds of 24 km/h (15 mph) or below get no points.

OUTPUT FORMAT FOR ADEQUACY RATINGS

Computerization of all information appearing in the figures and tables was a major recommendation for improvement of accuracy and efficiency of the rating program. The only input into the computer program is the raw data collected for each highway section. The output consists of a listing of assigned and maximum points for each element of the section along with the final adequacy rating.

To facilitate the implementation of such a computer printout, each of the 15 highway elements was assigned a letter code (A to P), as shown in Figure 8. Examples of printouts for rural and urban highway sections include

1. Each element used (designated by letter code);
2. Assigned points for each element;
3. Maximum points for each element (number in parentheses);
4. Subtotal points for condition, safety, and service; and
5. Final adequacy rating.

The example for rural highways (Figure 8) shows that the section received 18 of the 35 condition points. The breakdown of the 18 points is 6 points for foundation, 5 points for surface, 4 points for drainage, and 3 points for maintenance. The section also shows 21 out of 35 points for safety and 23 out of 30 points for service. The final adequacy rating was 62.

The example of an urban highway section cited in Figure 8 shows a rating of 82. The point distributions show that most elements rated high except for the foundation element, which received only 4. A final adequacy rating of below 70 may indicate a need for highway improvement.

The capabilities for an additional computer printout, which would contain raw data used to compute adequacy points, were also recommended. Included would be such information as lane width, accident rate, AADT, SN, PSD, V/C ratio, average speed, annual maintenance cost, and a word description of all subjectively rated elements.

SUMMARY AND CONCLUSIONS

A number of advantages may be expected from the use of the adequacy rating techniques described in this report. Computerization of the procedures will permit the coding of numbers from forms without the need for tables, graphs, and charts. Traffic-control devices in urban areas can then be rated quickly and easily. The inclusion of accident and skid resistance data will be accomplished by merging computer tapes with those of the adequacy rating. The total cost of the rating program will be reduced; much of the work will be done more quickly and efficiently with the aid of the computer. Faster updates of adequacy ratings will be possible.

Improved reliability of the results can also be expected from the revised techniques. Conversion from tables, charts, and graphs will no longer be done by hand. Human error, therefore, will be reduced. Skid resistance will be a measured determination rather than a subjective rating. Several important elements, such as accident experience, traffic safety features, and traffic-control devices, add to the overall data base of the adequacy ratings and, therefore, improve reliability of the rating. Another improvement is the revision of the figures and tables to meet current design criteria in Kentucky. The revisions incorporate 1978 standards.

The revised procedure involves simple addition of numbers for each element to obtain the final adequacy rating. Maximum points and assigned points may be printed on the output format so that the specific deficiencies can be quickly noted. Another simplification is the use of mileposts, reference numbers, and federal-aid route numbers for each section. This will permit easier site identification. The revised technique uses only two classifications of highway instead of three, since intermediate highway sections are to be designated as either urban or rural.

The addition of accident experience, traffic efficiency measures, and traffic-control devices was judged to be important. Skid resistance data (measured values) will also be added to replace the subjective evaluations. The revision of the lane-width factor would allow for modification of the adequacy rating for urban sections if the design level of service were to be changed.

The recommended adequacy rating procedures in this paper are currently being implemented by the Kentucky Department of Transportation.

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Determination of Priorities for Incremental Development of the MARTA System

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The Urban Mass Transportation Administration has recently established a policy for the incremental development of fixed-guideway transit systems. This policy necessitates the evaluation of system components and the subsequent assignment of priorities to system components. The Metropolitan Atlanta Rapid Transit Authority undertook a comparative analysis study to determine the most appropriate order of construction for its "referendum" rail system. This paper reviews the study methodologies and final results. The referendum system, excluding that currently under construction, was divided into 13 operational segments (11 rail and two busway). Analytical information was compiled for each segment, including expected patronage, estimated construction and operating costs, annual revenue, travel time, and various nonquantifiable data. Three criteria were employed in the evaluation of segments: cost efficiency, travel utility, and an index representing nonquantifiable factors. The study was performed in a series of iterative analyses based on sequential decisions. The following conclusions are made: (a) the concept

of iterative analysis provides a reasonable method for determination of system extension priorities, (b) the analyses were sensitive to differences among segments, (c) wide variations of effectiveness were found among segments, and (d) the incremental development policy may adversely affect the ability of local areas to obtain local support for mass transit plans.

Recent federal policy has stressed the need for the incremental development of transportation improvements, specifically for fixed-guideway systems (1,2). The concept of incremental development raises an important issue for local planners: What methodologies can planners employ to evaluate not only the net impacts of a transportation plan but the comparative values of elements within the plan? These issues are of immediate concern to planners in those cities that are developing fixed-guideway transit systems (i.e., Miami, Baltimore, Detroit, Honolulu, and Atlanta).

In response to this federal policy and the uncertainties of federal funding, the Metropolitan Atlanta Rapid Transit Authority (MARTA) undertook a comparative analysis study, the MARTA phasing study (3), to determine the most appropriate order of construction of MARTA's 85-km (53-mile) "referendum" rail system.

BACKGROUND

MARTA was established in 1965. In 1971 a local referendum was passed that levied a 1 percent sales tax for transit use. The sales tax revenue is used to subsidize bus operations and for the local share of a new rapid transit system. The referendum system, including several minor revisions since 1971, includes 85 km (53 miles) of rapid-rail transit, 13 km (8 miles) of exclusive busways, and an extensive feeder-bus system. The fixed-guideway system is shown in Figure 1. (The figure is scaled in customary units as these were the units used in this study.) The 1971 referendum called for completion of the entire system by 1980. However, federal grants have not been sufficient to meet this schedule.

In 1975 the Urban Mass Transportation Administration (UMTA) committed a total of $800 million for the first increment of the MARTA system. Phase A includes the construction of 22 km (14 miles) of rail (see Figure 1) and will open in stages during the next two years.

Although no federal funds are currently committed to construction beyond phase A, funding is expected to be available within the next few years. However, enough funds are not expected at one time to finish the balance of the referendum system; grants will probably be awarded over an extended period of time. Therefore, the system will be constructed one or two segments at a time. Progress will depend on the amount of federal funds available and whether the 1 percent sales tax is extended beyond 1982. (The 1971 referendum calls for the tax to drop to 0.5 percent.) Since a considerable period of time could elapse before the last segment of the system is built, it is important to give careful consideration to the order of construction.

STUDY DESCRIPTION

The phasing study was a comparative analysis of all possible extensions of the system beyond phase A. When construction money becomes available, decisions will have to be made on which lines should be extended. Obviously, many political considerations are involved in this decision. The purpose of the phasing study was to provide technical direction about the advantages and disadvantages of each choice and to determine the most advantageous order of construction for all extension segments.

The referendum system beyond phase A was divided into 13 operational segments (11 rail and two busway). Each of the busways and 4 of the rail branch lines comprised segments, and the rail main lines were broken into segments that reflect logical end-of-line stations. Each of these segments contains one to three stations. The segments are listed in Table 1 and illustrated in Figure 1. Analytical information was compiled for each segment, including expected patronage, estimated construction and operating costs, annual revenue, effects on travel and travel time, and various nonquantifiable data.

Iterative Analyses

The phasing study was performed in a series of iterative analyses based on sequential decisions. In iteration one, the phase A system, now under construction, was used as the base rail-feeder-bus system. Each segment that could be added to the phase A system was analyzed as though it would be the only segment added to phase A. At the completion of the analysis stage in iteration one, the segments chosen as having the highest priority were added to the phase A base. The expanded system then served as the base for iteration two. These steps were repeated for iteration three.

The iterative methodology reflects the interdependency of segments for both operating costs and travel demand. For example, expected patronage on the Proctor Creek Branch varied depending on whether the North Avenue to Arts Center segment or any other segment was added to the base system. Each time a new segment was added to the system, new transit access was provided to the base system, and new transit destinations were provided for the base system. Therefore, if a segment was analyzed in iteration one but was not chosen for construction priority, its estimated operating costs and patronage forecasts in iteration two would be somewhat different. As a result, the priority rankings of segments in one iteration are sometimes reversed in subsequent iterations.

Patronage Forecasts

The operational segments were grouped into five test networks. These networks represent the phase A base system and four progressively larger networks, the last of which represents the referendum system. The networks beyond phase A each added about 16 km (10 miles) of rail to the previous network. The grouping of segments into networks was done in a logical manner, but, as can be seen by the conclusions of the study, this initial grouping was incidental to the results.

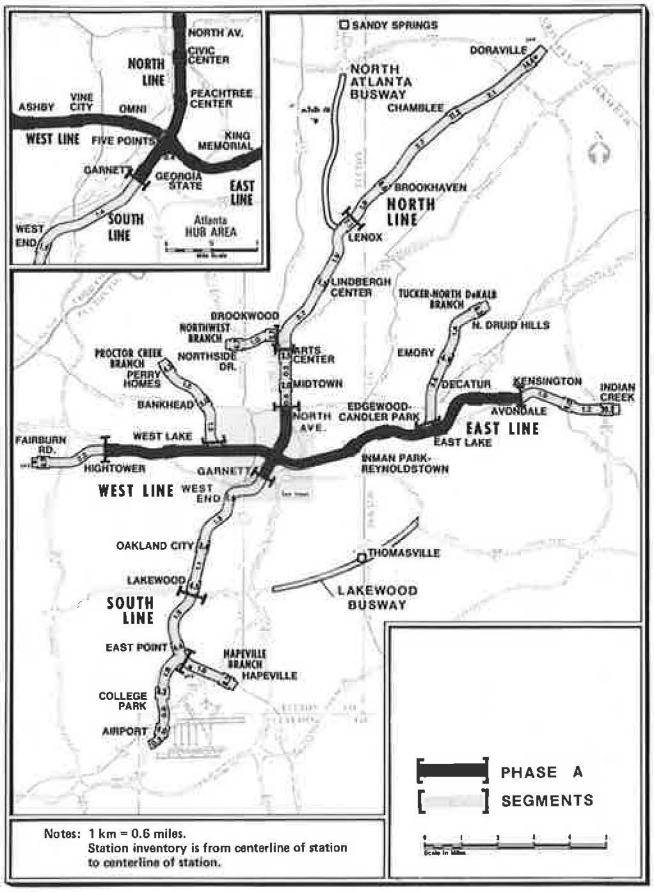
Patronage forecasts were based on conventional transportation planning techniques. This included the use of the urban transportation planning system (UTPS) programs. Highway networks for modal split analysis were built by the Georgia Department of Transportation, and population and employment forecasts for 1990 (the base year in the study) were supplied by the Atlanta Regional Commission, the metropolitan planning organization (MPO) for Atlanta.

Trip generation and distribution were common to each of the respective networks. Thus, for any zone-to-zone interchange, the total number of person-trips was constant for each network. Modal choice was simulated for each network. As the level of transit service increased among the successive networks, the portion of trips by transit also increased. The transit trips were then assigned to the bus or rail components of the transit network on the basis of shortest time paths. Manual adjustments were made to the network results to determine the patronage for each individual segment.

Three measures of patronage were estimated for each segment of the system. These measures were used in the analysis in order to assess the various transportation benefits that would be attributable to each additional segment of the system:

1. Total daily patronage on the segment—This is the number of passengers who would use any of the stations in the new segment. This measure of total use was used in the analysis of savings of travel time.
2. New rail riders—This is the number of persons who use a new segment who would not otherwise have used rail; thus, passengers who would switch from bus to rail when a new segment opens may be included. This measure is used to determine incremental operating costs of the rail.
3. Net systemwide patronage increases—This is the net increase in ridership on the total bus and rail system (i.e., trips diverted from automobiles). Induced trips were not included in this study due to the difficulty in estimating latent demand. This measure includes trips diverted directly from automobile to rail and trips diverted from automobile to bus that are the result of improvements to the bus system that are implemented in conjunction with rail extensions.

Figure 1. MARTA referendum system and phasing study segments.



This latter point deserves amplification. When a rail line is built or extended, the bus system in the corridor will generally be converted from radial to feeder configuration. This has two significant effects:

1. The bus-kilometers that are no longer required for radial corridor service can be reallocated to increase the level of service or the area covered by bus. In either case, new trips would be attracted to transit.
2. The implementation of feeder service also improves crosstown service. Many trips that would have required a downtown transfer in a radial system can be made directly in a feeder-crosstown configuration. Again, new trips would be attracted to transit.

About 70 to 75 percent of the new transit trips in this study were directly attributable to the new rail line. The other 25 to 30 percent were due to related improvements in bus service.

The net increase in overall transit patronage is not only an indicator of diversion from the automobile but also a good indicator of other related benefits, such as reduction of air and noise pollution, energy conservation, and savings in travel time for many individuals.

Table 1. Description of test segments.

Line	Segment	Test Network No.	Service (km) Rail[a]	Busway	Number of Stations
South	Garnett to Lakewood	2	6.9	-	3
	Lakewood to Airport	3	6.8	-	3
	Lakewood Busway	2	-	5-8	1
	Hapeville Branch	5	2.7	-	1
West	Proctor Creek Branch	2	4.8	-	2
	Hightower to Fairburn Road	5	3.5	-	1
North	North Avenue to Arts Center	2	1.8	-	2
	Arts Center to Lenox	3	7.4	-	2
	Northwest Branch	5	2.6	-	2
	North Atlanta Busway	5	-	8	1
	Lenox to Doraville	4	11.8	-	3
East	Tucker to N. DeKalb Branch	5	6.0	-	2
	Avondale to Indian Creek	4	5.0	-	2
Phase A		1	22.2	-	17
Total			81.5	13-16	42

Note: 1 km = 0.62 mile.
[a]Tail track excluded.

Cost Estimations

The phasing study considered both capital costs and operating costs. Each was evaluated to determine the relative expense associated with each new rail segment.

The capital cost estimates used in the phasing study analysis were based on 1974 estimates, which included escalation to the midpoint of construction. The construction schedule at that time called for completion of the full referendum system by 1980 at a capital cost estimated to be $2.1 billion. Construction costs were allocated by segment, and equipment costs (such as transit vehicles) were apportioned among segments based on expected operating patterns (see Table 2). Inflationary increases will occur in the costs of all segments, but these increases are immaterial in the phasing study since the comparison of various segments was made on a relative basis.

The operating costs of the system are composed of the costs of direct rail operations, direct bus operations, and common overhead and administrative costs. Rail operating costs were derived for each segment in each iteration. When a new segment is added to a base system, rail ridership increases and operating costs change, due to decreased headways and longer train circuit times. These costs are related to increased ridership, but they are also dependent on the configuration and operating characteristics of the base system, thus the marginal operating cost of a particular segment may change from iteration to iteration.

The total level of bus service provided was assumed to remain constant for the various test networks in the year 1990. As rail segments were added, bus kilometers were redistributed to new service areas. The bus fleet size and bus vehicle-kilometers provided annually remained constant, but the areas receiving bus service expanded as rail service was extended. Therefore, direct operating costs of buses and the percentage of common costs associated with bus operations were not considered in the comparative analysis.

Methodology

The comparative analysis for each segment included the following factors:

1. Total patronage on segment,
2. Total increase in rail patronage,
3. Total increase in transit system patronage,
4. Travel time to major generators,
5. Total capital cost,
6. Total increase in operating cost,
7. Improvement of transit service to special groups,
8. Impacts on land use and development, and
9. Environmental impacts.

From these, three summary evaluation criteria were derived: cost efficiency, travel utility, and nonquantifiable measures.

Cost Efficiency

One criterion of influence in decisions among alternatives is the greatest return per dollar spent. The total capital-cost and rail operating-cost increases associated with each new rail segment were compared to patronage increases to provide one basis for comparative analysis among segments.

Patronage forecasts provided estimates of total systemwide increases in daily patronage in 1990 for any given segment. Therefore, costs were also determined on a daily basis over the life of the project. The estimated construction cost for each new segment was divided by the service life of rail transit facilities, assumed to be 50 years. Systemwide equipment (i.e., vehicles, train control, and escalators) was assumed to have a 25-year life. An annualization factor of 285 was used. Daily operating costs were also determined for 1990. No assumptions were made regarding inflation and the future cost of money. This may affect the relative differences between capital and operating costs in future years.

The sum of daily operating and capital costs divided by the increase in total daily system patronage provided a relative measure of the efficiency of each segment in attracting new patrons. This figure is not a full measure of transit service cost per person and should not be misconstrued as such. Bus operating costs, for example, were not included. Also, many quantifiable benefits directly attributable to transit were not included, such as time savings for former bus riders.

Travel Utility Analysis

The travel utility analysis provided a second criterion for the comparative evaluation of segments. The travel utility analysis is based on the difference in travel time by transit to major destination points in the Atlanta area before and after the addition of a new segment. The travel time analysis compares transit travel time via each new rail segment to the previous transit travel times. An origin along the new segment is used for five sample major destinations: Five Points, Lenox Square, Fulton Industrial Park, Decatur, and the airport. The time saved in each case is multiplied by the number of estimated peak-hour riders in 1990 who will make those trips from the new segment's tributary area. The sum of peak-hour time savings to all of these destination points is divided into the total daily cost of providing the service. The resulting number is called travel utility.

Travel utility as discussed here is inappropriate for any purpose but the relative comparison between segments. This is because only a sample of trips and destination points was used. Because of this, and to simplify evaluation, the analysis results were converted to an index by dividing the value for each segment by the lowest segment value. Thus, the travel utility index for the most efficient segment is 1.00, and a value of 2.00 can be interpreted to mean that the associated segment is only half as cost effective in terms of travel time savings as the segment that has an index value of 1.00.

Nonquantifiable Factors

In addition to costs, patronage, and travel time (for which quantitative estimates were made), nonquantifiable factors were considered. These include community and environmental impact, effect on land use and development, and service to special groups of potential riders, such as handicapped, elderly, and other transit-dependent persons (captive riders). Some communities, for example, are opposed to MARTA alignments in their areas because the residents perceive property requirements and other undesirable effects. In those cases, a lower construction priority of that segment is indicated; a higher priority should be given to a segment whose overall impact is regarded as more beneficial by the community.

Nonquantifiable factors were summarized in a single nonquantifiable rating for each segment. The nonquantifiable ratings were represented by letter grades, with A being the most desirable and E being the least desirable. Segment ratings were determined by subjective weighing of the various factors. The rating for each segment was compared to the quantitative factors to determine the overall priority of a segment.

Table 2. Capital cost summary.

Line	Segment	Capital Cost[a] ($000 000s)
South	Garnett to Lakewood	109
	Lakewood to Airport	134
	Lakewood Busway	18
	Hapeville Branch	50
West	Proctor Creek Branch	73
	Hightower to Fairburn Road	48
North	North Avenue to Arts Center	63
	Arts Center to Lenox	136
	Northwest Branch	78
	North Atlanta Busway	20
	Lenox to Doraville	166
East	Tucker to N. DeKalb Branch	90
	Avondale to Indian Creek	113
Subtotal		1098
Phase A		1017
Total		2115

[a] 1974 estimate.

Table 3. Phasing study—iteration one.

Segment	Net Systemwide Patronage Increase[a]	Cost-Efficiency Analysis ($)	Total Daily Rail Ridership[b]	Travel Utility Index	Nonquantifiable Factors
Garnett to Lakewood	18 300	1.32	57 100	1.00	B
Proctor Creek Branch	4 390	2.14	17 700	4.51	B
Hightower to Fairburn Road	1 510	5.86	7 700	4.90	E
North Avenue to Arts Center	7 900	1.24	54 100	1.29	A
Tucker to N. DeKalb Branch	4 300	3.24	12 200	4.18	D
Avondale to Indian Creek	9 470	2.34	26 700	4.23	C

[a]Total daily transit ridership increase due to addition of segment.
[b]Total daily rail patronage per segment.

Table 4. Phasing study—iteration two.

Segment	Net Systemwide Patronage Increase[a]	Cost-Efficiency Analysis ($)	Total Daily Rail Ridership[b]	Travel Utility Index	Nonquantifiable Factors
Lakewood to Airport	21 260	1.16	59 600	1.39	B
Lakewood Busway	2 300	0.67	10 500	0.68	-
Proctor Creek Branch	4 590	3.13	18 500	3.49	B
Hightower to Fairburn Road	1 640	4.90	8 500	2.26	E
Arts Center to Lenox	20 000	1.43	80 600	1	B
Northwest Branch	4 450	4.02	17 500	3.45	D
Tucker to N. DeKalb Branch	4 710	3.50	13 800	2.58	D
Avondale to Indian Creek	11 700	1.95	33 100	2.31	C

[a]Total daily transit ridership increase due to addition of segment.
[b]Total daily rail patronage per segment.

Table 5. Phasing study—iteration three.

Segment	Net Systemwide Patronage Increase[a]	Cost-Efficiency Analysis ($)	Total Daily Rail Ridership[b]	Travel Utility Index	Nonquantifiable Factors
Hapeville Branch	4 250	2.63	19 000	1.28	B
Proctor Creek Branch	4 640	2.90	18 700	3.71	B
Hightower to Fairburn Road	1 720	3.84	9 100	1.68	E
Northwest Branch	4 500	2.45	17 900	2.54	D
Lenox to Doraville	12 700	2.53	39 300	1	B
North Atlanta Busway	1 880	0.93	9 500	0.16	-
Tucker to N. DeKalb Branch	5 020	2.93	14 700	2.63	D
Avondale to Indian Creek	12 380	1.94	36 500	2.51	C

[a]Total daily transit ridership increase due to addition of segment.
[b]Total daily rail patronage per segment.

COMPARATIVE ANALYSIS

Iteration One

The first iterative analysis considered the relative merits of the addition of each of six possible segments to the phase A system. The evaluation factors are summarized for each of the six segments in Table 3.

When net daily patronage (column 1) was divided by the total daily cost (cost-efficiency analysis), the resulting cost per new patron (column 2) was lowest for North Avenue to Arts Center and Garnett to Lakewood, followed by the Proctor Creek Branch and Avondale to Indian Creek. In the travel utility index (column 4), which relates travel time savings to cost, Garnett to Lakewood was estimated to be the best segment, and North Avenue to Arts Center was next best. In summary, the analysis of quantifiable factors found North Avenue to Arts Center and Garnett to Lakewood to be the highest priority segments.

The last consideration in the selection of priority segments in iteration one was the nonquantifiable factors (column 5). The Proctor Creek Branch will provide improved transit service in an area that is very transit dependent; however, disruption is associated with construction of the branch line and development potential is only expected to be fair. North Avenue to Arts Center has considerable development potential, and transit would be a catalyst for growth. The Garnett to Lakewood segment will cause some disruption and relocation but will stimulate southside development and provide service for many blue-collar workers. The overall effect of nonquantifiable factors is supportive of the quantitative data.

The results of the first iteration clearly show that the North Avenue to Arts Center and Garnett to Lakewood segments should be the first two segments to be added to phase A.

Iteration Two

The system base used as the beginning point in the second iteration was the phase A system plus the extensions to the Arts Center and Lakewood selected in the first iteration. Eight possible segments could be added to the new base system; data for these segments are summarized in Table 4.

In the cost-efficiency analysis, the Lakewood Busway proved to be the most cost-effective segment, followed by Lakewood to Airport and Arts Center to Lenox. One reason for the high efficiency of the busway was that bus operating-cost increases were not added to capital costs. This is because the overall level of bus service was assumed to be constant for all levels of system development. As a result, no operating costs were attributed directly to the busway segment despite the possibility that additional bus-kilometers may have been required. However, since the implementation of the busway is dependent on the construction of I-420, its priority in the phasing study is of limited value.

The segment from Arts Center to Lenox fared well in the travel utility index because the North Line would penetrate a major bottleneck in a highly developed and congested corridor. The segment from Lakewood to Airport also had favorable savings of travel times. Both segments also rate well in nonquantifiable factors.

The conclusion of iteration two was that Arts Center to Lenox and Lakewood to Airport were the next two priority segments. As in the summary of iteration one, these two segments were also very close in priority; the Arts Center to Lenox segment was slightly more favorable.

Iteration Three

The base system for iteration three included phase A plus the four segments selected in the previous iterations (East-West Line from Avondale to Hightower and North-South Line from Lenox to the Airport). All of the remaining segments of the referendum system were candidate segments in iteration three. For this reason and because the interdependency between outlying segments for trip-making and operating-cost considerations was not very significant, iteration three was the last iteration required. The relative rankings for net increase in total patronage, cost-efficiency, total daily ridership, travel utility, and nonquantifiable factors are in Table 5.

A comparison of the quantitative factors shows that the North Atlanta Busway appeared to be the most cost efficient. However, the same reasoning used in the discussion of the Lakewood Busway applies to the North Atlanta Busway. Since the busway is to be built in the median of the proposed North Atlanta Parkway, its construction depends on that of the parkway.

The final selection of rail segments was derived as follows: Lenox to Doraville had superior ratings in each of the quantitative factors. The projected patronage was very high, including many reverse commuters; travel-time savings were considerable, and the segment had a good nonquantifiable rating. Lenox to Doraville was, therefore, selected for the third priority category.

The Hapeville Branch had fairly good two-way patronage. Costs were moderate for both construction and operations. The Avondale to Indian Creek segment had considerably higher patronage but also higher costs. These two segments were ranked together in the fourth priority category.

The differences among the remaining four segments (Hightower to Fairburn Road, Northwest Branch, Tucker to North DeKalb Branch, and Fairburn Road) were relatively minor. Patronage increases were generally low due to high existing levels of transit use or too low densities. Since the construction of any of these segments is a number of years off and conditions could change in the interim, the assignment of exact priorities was not essential. Therefore, these last four segments were grouped together in the fifth priority category.

CONCLUSIONS

The concept of incremental development of extensions to the MARTA rapid rail system required the establishment of construction priorities. Such priorities were determined in the phasing study. The following conclusions were derived from a review of the methodology and the results of that study.

The cost-efficiency and travel-utility analyses are sensitive to differences among segments. Each iteration revealed a significant difference between at least some of the alternatives. This confirms the assumption, implicit in incremental development, that priorities among system segments can be determined with some degree of certainty.

The concept of iterative analysis provides a reasonable method for determining system extension priorities. With a series of networks, developed through conventional transportation planning techniques, patronage forecasts can be manually allocated to segments. Experience has shown that no network should contain more than one segment that extends from a given base line in the same direction. Also, the overall complexity of the study is a function of the number of segments and networks. This relation is more geometric than linear, particularly with respect to the projection of operating costs and patronage.

The feasibility of the MARTA referendum system has previously been established on a systemwide basis through an analysis of alternative systems and a benefit/cost analysis (4, 5). Until recently, the entire MARTA system was to be put into operation as fast as it could be built. However, the lack of sufficient federal funds to accomplish this has imposed an incremental development approach. The phasing study revealed a considerable variance in the cost efficiency of the various segments of the system. Therefore, after the completion of the higher priority segments, a reassessment of the weaker links in the system is called for. This process (a) would determine alternative configurations for building the weaker links to enhance their cost-effectiveness, such as more attractive or accessible station sites and shorter or cheaper line construction, and (b) would evaluate alternatives to the heavy rail mode.

An apparent conflict exists between the concept of incremental development and the reality of local politics. It is doubtful that many transit systems could gain local support under a strict policy of incremental development. In order to gain the widespread public support that is required to pass a referendum that calls for higher taxes, substantial benefits must be offered to all segments of the region within a relatively short time frame (5-10 years). MARTA's 1971 referendum passed by only 471 votes. Had any one of the branch lines that now appear to be weak links been omitted from the plan, the referendum probably would have failed.

The incremental analyses approach used for the MARTA phasing study proved to be workable and produced very satisfactory results. The most immediate applications to other cities, transit systems, and types of planning could be found in those cities that are in the process of developing fixed-rail or similar transit systems. Other applications could be the determination of priorities for major components of a regional transportation plan where several expressway and transit projects are proposed. Applications could also be found in any number of other planning endeavors where funding resources are limited and implementation of projects is additive (i.e., extensions to existing systems).

Since the phasing study was completed in late 1977, MARTA has developed a program for expansion of the system beyond phase A. In May 1978, MARTA submitted a grant application to UMTA for phase B of the system. Phase B consists of the North Line from North Avenue to Lenox [9.2 km (5.7 miles)] and the South Line from Garnett to Lakewood [6.4 km (4.0 miles)]. These segments follow the recommendation of the phasing study. Also, the next additional construction beyond phase B is expected to be the extension of the South Line to the airport. While political considerations played a major role in the selection of priority segments, the phasing study results had a significant effect on this decision.

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Potential for Multimodal Transportation Trust Funds on the State Level: A Recent Survey

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This paper presents the results of a recent study of the feasibility of multimodal transportation trust funds on the state level. Recent experience has shown that the slowdown in the growth of motor fuel tax revenues and rapid inflation in transportation construction and operations have created a serious challenge for states. The multimodal trust fund would provide a method that expands the fiscal base for transportation finance while it increases the flexibility for transportation planners in their short- and long-term decision making. The transportation departments of all 50 states were asked to respond to a survey of their present financial positions and policy stances on both the concept of a multimodal trust fund and a variety of other state and federal proposals for revising transportation financing and planning methods. Based on the 36 responses received at the time this article was written, the concept of such a trust fund is viewed favorably, but the problems that it might raise and the political battles that such a plan would face make its enactment in most states highly unlikely. The respondents expressed strong support for the continuation of the Highway Trust Fund and noted that (a) rapid completion of the Interstate highway system is not a very high priority in many states and (b) greater flexibility in the use of federal transportation assistance is needed. The respondents gave a strong mandate to the need for a stable, dependable source of federal mass transit assistance.

A number of recent political and economic factors have combined to create a minor fiscal crisis in the financing of the nation's transportation expenditures. The energy crisis of 1973-1974 and its repercussions brought a halt to the seemingly endless increases in vehicular travel and a decline in fuel sales. Although travel and energy trends have at least partially returned to their pre-1973 status, the threat of tighter and more expensive energy supplies will combine with the gradual increase in the energy efficiency of vehicles to level off and possibly reduce the sale of transportation fuels. This presents a serious challenge to transportation agencies, especially on the state level, that have traditionally depended on a variety of highway-user charges (principally gasoline taxes) to finance their highway construction and maintenance programs. The problem is worsened because the costs of providing adequate highways have increased tremendously in recent years. Betweeen 1967 and 1977 the nation's consumer price index increased by 85 percent; the index for highway construction rose by over 133 percent (1, 2). This fiscal squeeze has affected almost all states and was the force behind a survey in fall 1976 by the American Association of State Highway and Transportation Officials (AASHTO) and TRB of all state departments of highways or transportation. Two interrelated conferences in Denver and Washington, D.C., also addressed the need to find new sources for transportation revenues (3). The fiscal crisis was also a major reason for our request for funding to test the applicability of the multimodal fund concept as a possible approach to this perplexing problem.

There is an additional rationale behind the analysis of this type of fiscal mechanism. Many mass transit supporters, although pleased by the steady growth of federal aid to mass transit since 1970, think that transit will not be able to make meaningful inroads without a major source of guaranteed, continuous revenues similar to both the Federal Highway Trust Fund and the state gas tax revenues, typically earmarked for highway-related expenses and programs. Although a number of regional transit systems do have a variety of tax sources earmarked to support their capital and operating expenses, these funds have generally been well below the needed levels. Requests for additional state and local support through annual legislative approval become necessary; however, this support can easily fluctuate and is susceptible to political maneuvering.

Larger allotments of guaranteed annual funding would make possible the kind of coordinated, long-term construction and maintenance planning that the nation's highway systems have had up to this point. Supporters of the multimodal approach contend, however, that transportation decision making should be based on the merits of and need for a particular mix of services rather than a policy forced by revenues that are earmarked for a specific mode. Such a trust fund would provide an overall level of transportation support that could be depended on but which would offer the flexibility that one or more single-mode funds, by definition, deny. This same type of unified approach to future transportation planning and funding methods was presented recently by Secretary of Transportation Brock Adams in his legislative proposals to limit often artificial and inefficient modal separation.

STUDY METHODOLOGY

The major effort in the analysis of these trust fund questions was a survey of all state departments of transportation to assess their current positions on the multimodal trust fund idea and a variety of related fiscal concerns. Early in the project these matters were discussed with the persons within TRB and AASHTO who were responsible for the fall 1976 survey of the same state agencies on new sources for state transportation revenues. Copies of the questionnaires completed by the 46 states responding to that survey were provided for our review. The information was extremely helpful as an assessment of the states' views on a variety of fiscal topics. AASHTO-TRB forms and survey methodology were reviewed carefully to avoid any duplication and to use this earlier effort as a reference base on which to build the trust fund survey.

Our six-page survey instrument requested answers in the following six areas:

1. Sources and uses of funds in most recent department budget (e.g., amount of highway capital expenditures and the sources of these funds);
2. Types and assigned uses of any taxes earmarked for transportation expenditures;
3. Estimation of viability of multimodal trust fund in their state and actions and time required for enactment;
4. Taxes to be assigned to such a fund, and for what uses they should be assigned;
5. Expected impact of the enactment of such a fund on the state's financial relations with the federal and local governments; and
6. State's opinion on how seven actions recently proposed by the Carter Administration would affect their transportation operations and planning.

Questionnaires were sent to the 50 states plus Puerto Rico and the District of Columbia and 36 valid responses were eventually received at the time of this article, for a response rate of 69 percent. Numerous states also provided additional information about the organizations of their agency, the full text of their most recent budget, or an explanatory cover letter that discussed in greater detail various aspects of their state's opinions or present fiscal position. Although these materials, as well as those presented in some of the more open-ended questions on the survey form, were difficult to quantify, they provided important insights into the status quo of state transportation finance.

OVERALL REVIEW OF THE SURVEY RESULTS

The states that eventually responded to the survey provide a fairly representative sample of the national picture. Each of the 10 Urban Mass Transportation Administration (UMTA) regions was represented by at least half of the states in the region, and in 7 out of 10 regions, more than half of the states responded. The interface of the trust fund survey with the previous AASHTO-TRB effort made possible both the farily high response rate and the willingness of the agencies' representatives to complete a rather extensive and detailed form.

Table 1 outlines the present sources of funds for the five major areas of transportation expenditures. These results demonstrate something that was also clear from the analyses of the AASHTO-TRB survey—general fund revenues are much more likely to be used for nonhighway expenditures, but transportation user charges, paid almost exclusively by motor vehicle owners and drivers, are aligned with highway expenditures. This fact and the pay-your-own-way financial logic behind it seem combined to form one of the principal sources of resistance to the multimodal funding approach. Highways are popularly (and politically) viewed as self-financing; highway users are assumed to generate sufficient revenues to cover the expenses required to build, maintain, and operate the highway network. Although a number of studies have demonstrated that motor vehicles may actually be heavily subsidized in urban areas (4), and that certain classes of vehicles underpay substantially relative to the costs incurred in their behalf (5), the data in Table 1 show that vehicle and highway user charges are clearly the largest source of transportation revenues nationwide and virtually the exclusive source in numerous states.

Almost 92 percent of the states responding (33 out of 36) earmarked their gas tax revenues to various transportation sectors; highway construction and maintenance were the most frequent end uses. The responses to the

Table 1. Source of major state transportation.

Uses of Funds	States Response (%)[a]	Source of Funds: General Revenue	General User Charges[b]	Toll Road Revenue	Fuel Taxes	License and Registration Fees	Local Revenue	Other
General administration	97	37.1	37.1	-	14.3	2.9	-	8.5
Highway capital expenditures	100	38.9	41.7	-	16.7	-	-	2.8
Highway maintenance and operations	94	26.5	47.0	-	14.7	3.0	-	8.8
Public transportation capital expense	39	64.1	7.2	-	7.2	-	7.2	14.4
Public transportation maintenance and operations	53	62.9	10.6	5.3	5.3	-	5.3	10.6

[a] Some states had no expenditures in that area (e.g., no transit assistance).
[b] General user charges = fuel taxes, permits, and licenses.

AASHTO-TRB survey, however, show that this does not mean that portions of the fuel and vehicle taxes are not assigned elsewhere. Eighty-four percent of the states had at least part of the funds generated by the transportation sector earmarked for agencies outside of the states' highway department, although much of this was for transportation-related activities (e.g., highway patrol, department of motor vehicles, and driver education). Eighty-six percent of the states shared an average of 37 percent of their motor fuel taxes with cities and counties, usually through distribution formulae based on vehicle registration, the length of roadway, or population. The table below outlines the exact manner in which the states' motor fuel tax receipts were distributed (6) in 1975.

Uses of Funds	Percentage of Total Receipts
State-administered highways capital outlay, maintenance, and administration	49.1
Highway law enforcement and safety	5.0
Service of obligations for state highways	9.5
County and local roads and streets	30.8
Mass transportation	1.8
State general purposes	3.7
Local general purposes	0.1

Although a number of states (Alaska, Delaware, New Jersey, New York, and Rhode Island) assign all motor fuel revenues to their state's general fund, from which revenues must be appropriated by the legislature, the data in this table demonstrate the dominance of transportation uses of fuel tax receipts, especially for highway purposes.

The Present Status of Transit Funds on the State Level

The cover letter to the questionnaire included the following definition of what a multimodal transit fund stood for in the context of this survey.

> A multimodal trust fund is defined here as a fund to which part or all of the revenue from various transportation sector taxes (e.g., fuel tax) or general levies (e.g., payroll, sales, income taxes, etc.) are earmarked, with the fund's revenues used to support the capital operation or related expenses of several transportation modes versus a single mode fund (i.e., sales tax for transit expenses only).

This definition was included to avoid any misconceptions that might exist in the minds of the respondents concerning the meaning of the questions. The AASHTO-TRB survey had asked two brief questions on the state's opinions of "unified funding of state transportation programs," but, unfortunately, that term was not defined. Their questions were sufficiently open ended to provide some excellent insights into the fiscal positions and worries of state departments of transportation. All of this proved very useful in establishing the line of questioning for our trust fund survey.

The table below outlines actions that would be required to establish a multimodal trust fund in the respondents' states.

Action	Required (%)	Not Required (%)
Executive action	22	78
Legislative approval	89	11
Constitutional amendment	42	58
Public referendum	11	89
Other	8	92

Although the two surveys' populations were somewhat different, our results tend to support those reported for a similar question on the AASHTO-TRB form. The basic, generally long-standing traditions of highway financing in many states makes necessary the fairly high percentage of state departments of transportation that listed a constitutional amendment as a requirement for enactment, which would make the shift to such a trust-fund mechanism a rather tedious and time-consuming process. Even in those states where legislative action alone was sufficient, the probability of passage of such a proposal seems rather small. When asked whether this trust fund concept was a "politically viable alternative in your state," no states responded yes, definitely, and only 38 percent thought that it was possibly viable. Materials attached to the forms, including official state documents and departmental opinions as expressed by the respondents, gave the overall impression that there was very little legislative or executive push for this change in the financing of transportation.

A number of states thought that their opinions on this matter would either definitely or possibly change if there were a major shift at the federal level toward a multimodal trust fund format; however, over three-fourths saw their decision as independent of any federal changes in this area. Roughly 22 percent did, however, feel that a state's switch to a multimodal format would complicate financial relations with the federal government, mainly because federal funding mechanisms tend to dictate state actions, whether merely in the choice of state funds used for matching purposes or as a strong inducement in the actual selection of transportation plans and programs. A unified state fiscal approach might, therefore, create some difficulties when interfacing with the diverse funding mechanisms at the federal level.

The impact on relations with local governments was thought to be somewhat more serious. Over 38 percent perceived that the switch to a multimodal fund would complicate state-local financial arrangements. The concerns most frequently mentioned dealt with the impact of such a move on the funds regularly shared with local governments through established formulae. This would also heighten the competition for funds among both transportation and other agencies at the local level. Local agencies might require expanded financial and transportation planning expertise that they now often lack.

Consequences of Trust Funds

The tables below present the states' responses concerning the perceived benefits and handicaps of a multimodal trust fund (note that the percentages given may not total 100 due to rounding.)

Perceived Benefits	Percent
Coordinate, simplify, stabilize transportation planning	25
Increase financial flexibility and efficiency to meet changing needs	11
Stabilize aid to local governments (e.g., mass transit funding)	6
Overcome statutory obstacles	6
Other	6
No expected benefits	39
No response	8

Perceived Problems	Percent
Increase competition for funds	31
Decrease overall funding	8
Reduce legislative flexibility	11

Perceived Problems	Percent
Divert funds from true needs	22
Other	8
No expected problems	8
No response	11

Roughly 47 percent thought that it would solve no problems at all and almost 80 percent saw new ones being created. The major benefits were those normally attributed to such a move—the coordination of transportation planning among modes, the stabilization of funding to modes (mainly mass transit) that have traditionally depended on legislative appropriations, and the greater financial flexibility to meet transportation needs as they occur, thereby increasing the efficiency and effectiveness of transportation expenditures. However, the loss of flexibility over transportation expenditures under the more earmarked trust fund arrangements was also listed as a possible problem area. In addition, almost one-third of the states feared that, with all modes thrown into a common fiscal arena to battle it out for trust fund revenues, modal competition would be fierce and keep any state of efficient financial distribution from ever being achieved. The statement about states' true needs being shortchanged is a reflection of the fear that highways (which have always depended heavily on earmarked transportation funds) would be further pressed if other modes were allowed a portion of these funds. Although a fair number of states did recognize some of the potential benefits of a switch to the revised financing format, almost one-half mentioned no benefits and over 80 percent expressed a variety of essentially prohighway concerns.

Table 2. Preferred sources of multimodal trust fund revenues.

Source	States Listing Source (%)
Transportation revenue	
Gasoline tax per liter	67
Gasoline tax (percentage)	54
Tire excise tax	45
Automobile purchase excise tax	61
License fees	79
Registration fees	88
Portion of transit fares	51
Tax on taxi and livery fares	30
Airline ticket tax	54
Tax on inland waterways[a]	30
Other	33
General revenues (nonuse related)	
Graduated income tax (or portion)	21
Payroll tax (or portion)	6
Transportation tax per person or per household	0
Sales tax (or portion)	48
Value capture property tax	15
Property tax	6
Other	21

[a]A number of states have no significant intrastate waterborne transportation, which would therefore make this levy inapplicable. Roughly 8 percent of the states did not respond to this particular question.

Table 3. Preferred uses of trust fund revenues.

	State Use	
Use (Mode)[a]	Capital Expenditures (%)	Operations and Maintenance Expenses (%)
Highways	100	94
Urban public transit	100	82
Commuter rail	39	30
Paratransit	51	30
Intercity passenger rail	36	30
Railroad freight	36	30
Airports	88	57
Waterways	45	39
Other	21	21

[a]Clearly the fact that a state did not list a particular mode may be due to the nonapplicability of that mode (e.g., no intrastate waterways or commuter rail services). However, other responses may also reflect approval for expenditures in an area (e.g., paratransit capital expenses) that are presently not funded by that state. Roughly 8 percent of the states did not respond to this question.

Preferred Sources and Uses of Trust Fund Revenues

Survey respondents were asked to check those tax mechanisms that seemed appropriate for a multimodal transportation trust fund and the expenditure areas that should be supported out of these revenues. The results, given in Tables 2 and 3, reinforce the role of motor fuel and vehicle excise taxes and license-registration fees as the primary transportation sector levies. They also show a rather strong reluctance to use any general revenues, except those from a sales tax. The idea of a special personal or household transportation tax on the state level was universally rejected, as were any uses of special payroll taxes or property taxes. This of course did not mean that such taxes could not be used at the regional or local level to support various modal expenditures. Although a general payroll tax for transportation, for example, received virtually no support, its use as a regional transit tax within a state's urban areas might be widely supported. The same would hold true for the value-capture concept that has recently received considerable support in many regions as a means of finance for specific transportation projects (e.g., highways, transit lines, and special transportation zones) (7).

On the uses side two factors are clearly evident:

1. Highway and mass transit modes are almost unanimously acceptable; and
2. For all modes, expenditures for capital needs are viewed as more appropriate for state subsidy than those for operating and maintenance.

The second factor reflects the traditional resistance of all levels of government (except local) to subsidize the operations of a specific mode (especially mass transit)—a fiscal stance that has changed considerably in recent years. The AASHTO-TRB survey, for example, revealed that 48 percent of the states responding provided some form of transit operating assistance (versus 58 percent for transit capital needs), although these amounts are only sizable in a few of the major transit states (e.g., New York, Massachusetts, and Illinois). In our survey, however, over half of the states had some form of transit operations and maintenance (O&M) assistance. The other area consistently listed for trust fund support was airport development and operations, although the average amount of funding actually included in the states' present budgets was usually rather small (only 1 percent of the average state's total transportation budget). The relatively high ranking that paratransit expenditures received seems to demonstrate the desire of many states to expand the application of these modes, including specialized taxi services, vanpools, dial-a-ride networks, and similar public transportation systems that the country's decentralized population requires as an alternative to both the automobile and conventional transit modes (8).

Table 4. Expected impact of selected federal proposals on states' transportation operations.

Proposed Actions	Distribution of Expected Impacts (%)[a,b] 1	2	3	4	5	Composite Index[c]
Equalize federal funding levels for public transportation and highway programs (i.e., both 90-10%)	46	29	17	3	6	197
Simplify existing funding categories and increase the flexibility of their use	71	23	6	-	-	135
Establish regular and predictable funding sources to finance the nation's public transportation needs	68	20	9	3	-	147
Extend the life of the Highway Trust Fund by four years	89	8	3	-	-	114
Create a single transportation planning program that treats all modes equally	32	26	6	24	9	243
Expedite the completion of the essential gaps in the Interstate highway system	50	3	12	26	9	241
Establish a rural and small urban area transportation program	15	33	15	18	18	288

[a] 1 = very favorable; 2 = somewhat favorable; 3 = no significant impacts; 4 = somewhat harmful; 5 = very harmful.
[b] Percentages may not total 100 due to rounding.
[c] Composite Index = weighted score of all responses [i.e., percent score x index value; example for Proposal A, value would be (46 x 1) + (29 x 2) +...+ (6 x 5) = 197]. A lower score means that the overall reception of a proposal was more favorable than one that receives a higher score.

OPINIONS OF RECENT FEDERAL PROPOSALS

In early 1978 Secretary of Transportation Brock Adams proposed a number of changes in the methods of planning and financing transportation systems. The major thrust of his revisions was to remove or correct any fiscal mechanisms that unjustifiably or arbitrarily determine the flow of federal funds among various modes. In addition, some of the institutional and operational divisions of transportation agencies along modal lines (e.g., separate planning for highway and transit modes) would be removed in somewhat the same spirit of overall financial and planning efficiency that is behind the multimodal trust fund concept.

For this reason, each state was asked to rank seven federal proposals according to "How the efficiency of your state's transportation operations and planning would be effected by (them)." The results, outlined in Table 4, present a rather mixed review of these proposals. The plan with the best score (i.e., lowest composite index value) is the one that suggests a continuance of the major mode-specific financing mechanism of the last 30 years—the Highway Trust Fund. Almost all states gave this the highest rating, and none felt that it would harm its operations in any way. However, the proposal to expedite the completion of the essential gaps of the Interstate highway system (the primary purpose for the trust fund's existence) received a fairly negative vote; over one-third of the states said that it would be at least somewhat harmful to their transportation plans. Additional information provided by a number of states helps to explain this seeming paradox:

1. Some states do not expect to ask for extensive Interstate funding but would still like to receive funds for alternative projects; and
2. Other states think that the federal gas tax, a producer of billions of dollars annually, should be more easily accessible for other projects (especially nonhighway plans).

This second opinion is also reflected in the second-best ranking, which was received by the plan for simplified, more flexible funding mechanisms. A more predictable public transit funding source (similar to the guaranteed nature of the Highway Trust Fund) also received a fairly strong mandate.

The concept of equal matching levels for highways and mass transit (i.e., 90 percent federal-10 percent state and local) was generally supported but viewed with somewhat more cautious optimism. However, the single surface transportation planning program and the establishment of a small urban area and rural transportation program were poorly received, especially the latter. Even some states that are decidedly rural in nature view this move as harmful to their planning. This leaves the impression (mentioned specifically by one of the respondents) that the mechanism selected and not the basic idea turned so many against it and so few saw it as a very helpful move.

The overall message provided by the states' responses seems to be that the Highway Trust Fund should definitely be extended, but that moves to simplify and increase the flexibility of existing funding mechanisms while also identifying a regular, guaranteed source for mass transit support should also receive close attention. Although a few were against it, three-fourths of the states saw the end of the federal matching differential between highway and mass transit projects as a positive move. The push to complete the Interstate system was given a top rating by half of the states, but the remaining respondents were either indifferent or against it from the perspective of their own planning and operations. The single program for federal transportation planning had roughly equal shares of the states strongly supporting it, feeling mildly positive to indifferent, and viewing it as at least somewhat detrimental. Responses to the special rural and small urban program were more slanted toward the negative.

CONCLUSIONS: THE PROBABLE ROLE OF MULTIMODAL TRUST FUNDS

The message provided by the responses of 36 states to this survey was one that generally accepts many of the ideas behind any multimodal fund concept. Stable, yet flexible, funding for all modes (but mainly highways and mass transit) is given strong support, whether it occurs on the state or federal level. The basic nature of major fiscal mechanisms and the ingrained habits and traditions of highway financing would make any change to a combined fund a complicated and time-consuming affair, as demonstrated by the legislative and constitutional actions required for such a move by the many states. The political and institutional drive clearly needed for the enactment of a fund is simply missing. Obviously, if many states are faced with a problem of highway costs exceeded by available user charge revenues, the idea of sharing these funds with other modes would not be viewed favorably. Even though intense modal competition for funding would not necessarily occur (especially if the present highway sources were augmented by other revenues to expand the total size of the newly combined fund), almost one-third of the states fear such an occurrence, and others predict that highway needs will inevitably be shortchanged. If such a fund were ever created, transportation sector charges are strongly favored over general taxes as the sources for the necessary revenues. Motor fuel taxes and license and registration fees are expected to continue in the leading roles they presently play in state transportation finance. On the expenditure side, highway and mass transit projects and operations receive the strongest mandate for inclusion in such a funding arrangement. Capital costs are generally considered more appropriate for state support than operations and maintenance expenses.

The overall response to the package of federal proposals for funding and administrative changes was mixed. The continuance of the Highway Trust Fund is strongly supported, but completion of the Interstate highway system was not given priority. Greater flexibility and categorical simplicity in federal financing, and a more steady, dependable source of mass transit aid are both received favorably, but the creation of a combined UMTA-Federal Highway Administration (FHWA) planning program and a new rural and small urban transportation program were generally rejected.

Although the passage of California's Proposition 13 and the associated flood of public attention occurred before most of the states responded, the feeling underlying the overall answers and related back-up materials seems to be that the creation of a new state funding mechanism, especially if it required any new taxation, would not be well received by the citizenry. One of the benefits of the states' gasoline taxes is that they are relatively hidden; (i.e., they are combined into the total pump price and are generally easily absorbed by the fairly inelastic demand of drivers for fuel). However, if this source were leaned on more heavily, made to grow with inflation (e.g., switch to a percentage versus cents per liter method), or augmented by other new transportation taxes, these expenditures and the sources of their funding would become much more visible—something that state agencies clearly want to avoid in the present political atmosphere.

In closing, the idea of a new trust fund that would combine the dependable flow of revenues that single-mode funds have had with the flexibility to define annual support for individual modes according to changing needs rather than inflexible, highly political legislative mandate is supported more in concept than in actual application.

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