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Predicting and Measuring Impacts of Transportation Systems

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Impact of Transportation-Facility Deterioration and Abandonment

Hays B. Gamble, Institute for Research on Land and Water Resources, Pennsylvania State University

Five studies of the effects of lack of funds for normal maintenance of transportation facilities were discussed in a conference session. In Pennsylvania, a fiscal-review task force has made recommendations in the areas of program, funding, and management and policy studies. The most important of these is that highway maintenance, rather than new construction, should receive first priority. A Federal Highway Administration survey has found that, although highway travel has increased in the last 6 years, the highway capital-improvement program has decreased, and new highway capacity will soon be needed. A system was developed in Ohio for measuring the condition (or stage of deterioration) of a highway and evaluating the effect of this deterioration on the highway and its users. The process used in New York State for expending available federal railroad subsidies, selecting the variables in the analysis, and evaluating their weights is described. Maintenance models that predict the demand for maintenance and maintenance impacts and a maintenance-management system were developed for the state of Massachusetts.

Many state highway agencies and many railroads are severely constrained by lack of funds for normal maintenance programs on their facilities. As a result, there is much deterioration, and some facilities have been abandoned. Five speakers addressed these problems in a conference session. The first speaker, Thomas Larson, discussed highway construction and maintenance policies in Pennsylvania, where future fiscal conditions are constrained. The second speaker, William Reulein, discussed trends in the changing physical conditions of highways in the United States. Gary Byrd discussed ways of measuring highway conditions, effects of deterioration, impacts of deferred maintenance, and the impacts of these on highway use. The fourth speaker, Michael Trentacoste, described an approach that is used in New York State to analyze the impacts of rail abandonment. Michael Markow described maintenance models that predict demand for maintenance and maintenance impacts and discussed maintenance-management systems. These papers are summarized below.

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION: POLICIES FOR A FISCALLY CONSTRAINED FUTURE

Thomas D. Larson, Pennsylvania State University

The Pennsylvania Department of Transportation (PennDOT) maintains more highways—74 500 km (44 700 miles)—than there are in the six New England states, New York, and New Jersey together. An important issue facing PennDOT is the allocation of revenue to meet maintenance needs and also new construction. At present, there are insufficient funds available, and unless conditions change, this shortfall will become increasingly more acute.

A fiscal-review task force has carefully studied the problem and developed recommendations that address three broad areas: program, funding, and management and policy strategies.

The principal program recommendation was that highway maintenance, rather than new construction, should receive first priority. This is a reversal of long-standing priorities, but it reflects the wishes of both the public and the state legislature. PennDOT should adopt a high standard of maintenance that provides for time-staged reductions of maintenance backlogs and preserves the existing highways. It cannot allow deterioration to increase. It must preserve the existing highways or someday face the exorbitant costs of total reconstruction. New construction programs should be limited to critical safety and structural deficiency problems on the entire system and to significant improvements on a core network of vital highways.

New funding will be extremely difficult to obtain. PennDOT is already in a serious fiscal condition that can only become worse, primarily because of the heavy debt-service payments that are required by past bonding practices. The bonded indebtedness of Pennsylvania for highway construction is larger than that of any other state because the legislature made no provisions for increased revenues to cover the costs of paying interest and principal on bonds. Because continued bond financing is untenable, the task force recommended that the construction program be financed by current revenues and federal aid. To accomplish this will require that the liquid fuels tax be increased 0.5 cents/L (2 cents/gal) and other funding sources, such as the automobile sales tax, the general sales tax, and increased motor license fees, be sought.

Recommendations directed toward management and policy strategies included the development of better public relations by performance standards and a department report card to communicate performance levels to the legislature and the public. PennDOT must improve its internal efficiency by identifying and implementing operating economies, including more effective use of personnel. Capital programs should be highly selective, with significant improvements concentrated on a 6700-km (4000-mile) core of highways. A significant recommendation was that about 21 700 km (13 000 mile) of roads now maintained by the state should be turned over to local municipalities. Those roads serve no statewide function, but are truly local roads. Such a return would save PennDOT a significant amount in maintenance and capital costs after the cost of upgrading has been met.

TRENDS IN CHANGING PHYSICAL CONDITIONS OF HIGHWAYS

William Reulein, Federal Highway Administration

Preliminary information derived from the National Highway Inventory and Performance Study of the Federal Highway Administration indicates that the growth in highway travel throughout the country is not being matched by the present highway program. Although demand increases, the highway capital program, in constant dollars, decreases. If the travel trend continues, and there is no reason to believe that it will not, a greater percentage of the capital program will be needed for the creation of additional capacity.

During the past 6 years, travel per lane kilometer has increased significantly in spite of a huge investment in additional capacity. At the same time, the condition of the pavement on both arterial and collector roads has deteriorated. Prior to 1970, many more highways were new or nearly new, and with this abundance of quality pavement, it was possible to place greater emphasis on providing improvements in highway service. In the next 10 years, however, increases in marginal and poor-quality pavements and unsafe bridges may force highway agencies to switch their emphasis away from improvements in service to increases in expenditures for improvements that maintain the existing facilities in a reasonable condition.

The addition of new capacity since 1970, although it has not matched the increased demand, has brought improved service and safety to highway users. This is evident from the shift in travel to higher quality pavement, more travel lanes, and divided or access-controlled facilities. These improvements have generally offset the deterioration to the physical plant so that, on the national level at least, systemwide travel conditions appear to have remained stable since 1970. This means that, while many highways and structures should be improved, there has not been a great increase in deficient highways in this period.

Changes in highway physical conditions do not necessarily result in similar changes in highway performance. The deterioration in pavement quality and the increase in travel per lane kilometer have taken place in the intermediate ranges with probably only minor changes in highway performance. Not until there are large increases in highway travel on poor-quality pavement or under congested conditions will performance decline. This may not occur until the surplus of high-quality highways that existed prior to 1970 has been absorbed.

These trends and conclusions were developed on the basis of only two points in time. This means that we may now be in the middle of a long-range trend or at the start of some new cycle. Because such information is vital at both state and national levels if the effectiveness of our highway programs is to be evaluated and a sound rationale for future funding levels is to be developed, the inventory of highway physical conditions should become an ongoing periodic activity for all highway agencies.

DIRECT AND INDIRECT IMPACTS OF DETERIORATION

L. Gary Byrd, Byrd, Tallamy, MacDonald, and Lewis

An awareness that the highway system is deteriorating at a rate that exceeds maintenance and rehabilitation efforts has generated a growing interest in moving this problem from a judgmental to a quantitative value system that can be used with confidence in resource-allocation formulas.

Measuring Highway Conditions

A study performed for the Ohio Department of Transportation in 1970 was directed toward (a) the development of a system for measuring the condition (or stage of deterioration) of a highway and (b) the evaluation of the effect (impact) of deterioration on the facility and its users.

Over time, various physical and environmental influences will cause deterioration of the various elements of a highway. At intervals, these elements can be examined and their condition measured. Assuming that the the element can be maintained, a good condition will show few unrepaired defects, i.e., a high level of maintenance quality, and a poor condition will show numerous unattended defects, i.e., a low level of maintenance quality.

The methods developed for measuring and evaluating the quality of maintenance on highways in Ohio were based on (a) a sampling of the highway system; (b) objective, qualitative measurements of physical conditions that could be obtained quickly by regular maintenance personnel; and (c) presentation of the measurements in a simple, easily understood format.

A series of highway conditions referred to as recordable conditions were surveyed by unit counts on various highway elements. The results of the survey were presented graphically in computer-generated plots that showed the cost per lane kilometer overprinted on the number of recordable conditions per kilometer.

Effect of Deterioration

The individual recordable-condition measurements are effective managerial tools for assessment of the performances of specific maintenance activities. However, highway management is concerned with the combined effect that maintenance quality has on (a) the physical integrity of the highway, (b) its safety, (c) its ridability, and (d) the aesthetics of the system. To permit this type of evaluation, four composite measurements were developed. Each used some or all of the individual recordable-condition measurements, which were weighted to produce a single value that is indicative of the maintenance quality within a specific area of influence. Each area of influence must be considered separately because the measurements suitable for inclusion in different areas vary.

The general steps taken to produce a unit value for each of the areas of influence were as follows: (a) The appropriate measurements were identified, (b) each measurement was weighted to reflect its relative impact on the area, (c) all of the weighted measurements were totaled, and (d) the total was divided by the total of the weighting factors to produce a single number (the weighted average value).

Management decisions or information developed in future studies may require changes in the weighting scales from time to time, but the procedures for developing the weighted values should not change. The weighting that was used to reflect the effect that maintenance quality has on physical integrity of the highway was based on the statewide average direct-maintenance expenditures for those activities being measured.

The basis for weighting safety conditions was an exposure measure that was developed to reflect the opportunity that a user has to encounter a recordable condition on the system. In structuring the safety weightings, the general areas considered were the pavement, the shoulder, and the appurtenances. The quality measurements associated with the pavement surface are deterioration, obstructions, and flushing. The quality measurement associated with the shoulder was developed by observing traffic on a typical two-lane roadway to establish the percentage of vehicles encroaching on the shoulder area. The two conditions of appurtenances evaluated were guardrail deterioration and sign deterioration.

The American Association of State Highway Officials (AASHO) has developed a present-serviceability index that rates the ability of a pavement to serve traffic. This is basically a ridability rating and can be adequately reproduced by using an objectively established roughness index.

The weightings used for aesthetics attempted to reflect the driver's visual perception, which is directed primarily to an arc of 2.5° around the primary line of sight. The roadside was assigned 10 percent of the value of the pavement that is in the direct line of sight of the driver. Full weight was given to deterioration of the pavement surface, obstructions, and auxiliary-marking deterioration. Because the guardrail is in the line of sight, it received full weighting. Sign deterioration was also given full weight because the driver is looking for and at signing. Shoulder obstructions are also in the line of sight and were given full weight. Factors associated with the roadside area, such as litter appearance and drainage-ditch obstructions, were given a weight of 10 percent.

Impact of Deferred Maintenance

Deferring certain maintenance activities may be more costly than performing them in a timely manner. For example, deferring ditch and culvert cleaning may cause water to back up and pond in roadside ditches, which will permit mosquito breeding and the sloughing off of slopes as fills become water-saturated.

In addition to studying the maintenance of the physical integrity of the highway, which is a principal concern of the maintenance engineer, this project also studied the impacts of deferred maintenance on the highway user. Deferred maintenance may affect the user in the areas of safety, operating costs, comfort, convenience, and aesthetics. These impacts may be measured qualitatively or quantitatively, but the latter is preferable. While it is sometimes more difficult to assign values to user consequences than to maintenance consequences, techniques exist for the calculation of these costs. Finally, any assessment of deferred maintenance should also consider the liability of the highway agency and its employees.

Impact on Use of Highway

In a 1974 study, the development of a rational approach to the establishment of warrants for the use of premium pavements that require reduced maintenance was attempted. As a part of that study, the influence of maintenance and rehabilitation work (roadway occupancy) on the motorist was assessed. By using field data collected under a wide range of roadway-closure conditions, costs to motorists as determined by lost time, accidents, and pollution were computed.

From these data, a computer program was developed to perform an economic analysis of roadway occupancy for maintenance and rehabilitation. The user specifies the pavement design and the traffic. The program generates hourly traffic volumes by trip purpose, direction, and year; vehicle-operation costs by vehicle weights, speeds, and project-design alignment; values of time by trip purposes, income levels, and time losses; and annual work loads by activity. The influence of roadway occupancy on the motorist is executed hourly for each activity and lane closure. The resulting impacts on operations, time, accidents, and pollution are combined for all feasible closures including traffic detours and crossovers. A 16-km (10-mile) section of eight-lane portland cement concrete was analyzed for a 20-year period. At an 8 percent interest rate, the present worth maintenance, rehabilitation, and motorist cost was $1 061 000. This was divided 38 percent maintenance and rehabilitation, 25 percent motorist operation cost increases, 35 percent value of time losses, and 2 percent increased accident costs.

It is apparent that the management of maintenance programs must include an effective tool under the category of maintenance quality (or deterioration). This tool must be developed to permit the setting of proposed maintenance quality standards based on a technical, quantifiable procedure and the measurement of the actual quality standards achieved by the maintenance program. With this important tool developed and used skillfully, managers can realize another important step in meeting their responsibilities to the highway users and taxpayers whom they serve.

NEW YORK STATE RAIL PLAN: ANALYSIS OF IMPACTS OF ABANDONMENT

Michael Trentacoste, New York State Department of Transportation

Because of extensive railroad bankruptcies, many kilometers of rail lines in the northeastern United States have been faced with service abandonment. Federal legislation in 1973 provided funds for continuation of subsidies, but left to the individual states the decision of whether the avoidance of the negative social impact of abandonment on individual lines justified public expenditures. The New York State rail plan was adopted in 1976 as the basis for expending the available federal subsidy funds. This paper briefly explains the process used by the New York State Department of Transportation in selecting the variables in the analysis, assigning the level of importance weights to these variables, computing a single impact index for each rail line, and ultimately ranking the lines by their respective impacts. Several hypothetical importance weights are then applied and the resultant line-priority implications discussed. Conclusions relative to the development of such a decision-assisting process, its sensitivity to values, and the proper interpretation of its results are presented.

The methodology used in this analysis of the impacts of particular rail abandonments was based on the selection by individual rail customers, whose rail line was being abandoned, of one of three courses of action: to go out of business, to relocate, or to change to an alternate mode of transportation. In general, the abandonment of rail lines leaves former users with no direct transportation facility except highways. In the past, some shippers faced with such a situation have chosen to use trucks only between their plant and an alternative railroad station, but others have diverted their traffic to trucks for the full length of haul. In the former alternative, the added costs of time and money associated with the transfer between modes are an essential consideration. It is the rail-dependent firms that must either close or relocate in the event of abandonment of rail service. In this study, each shipper was questioned as to his probable decision, and the impacts of that decision only were evaluated. No attempt was made to verify or second-guess the decision or to screen out survey-sophisticated responses.

Several assumptions were made to allow for consistent estimates and statewide comparison of the impacts of alternative actions on each line. All firms indicating that they would use an alternative means of transportation were grouped into a category called team tracking. The location selected as the proposed team-tracking facility was the nearest station on a rail line that was not threatened with abandonment. The commodities shipped were divided into two categories: bulk and nonbulk. The multiplier effect of business closings (as, for example, subsequent decreases in employment in non-rail-oriented firms) was not considered.

The social-impact factors selected for inclusion in the analysis were screened from guides published by the Rail Service Planning Office of the Interstate Commerce Commission.

A number of state and local officials, persons in industry, and members of special-interest groups were asked to weight the criteria by considering the nature and probable application of each of the five social-impact factors and assigning it a percentage weight that indicated how important they judged that factor to be in relation to the other factors listed. The results of this survey are shown below.

Criterion	Weight (%)	Impact Aspect or Measure
Employment	31	Railroad, shipper, and related-service employees
Consumer costs	19	Transportation costs and competition effects
Taxes and community economics	18	Income, sales, property, and corporate taxes
Pollution	12	Energy use, air quality, esthetics, and traffic congestion
Community cohesion	13	Population shifts, urban versus rural composition, land use or zoning disruption, and public investment
Other	7	

Since the number of returns in the survey was small (66) and the sampling procedure was noncontrolled, the statistical significance of the results could not be ascertained.

Five factors were quantified in the analysis. These were

1. Consumer costs, which were estimated on the basis of increased transportation costs to firms on terminated rail lines;
2. Employment, which was the net of jobs lost in firms closing or reducing operations minus additional jobs created in trucking firms;
3. Tax effects, which include property taxes and sales taxes;
4. Sales effects, which were losses of sales by firms closing or reducing operations; and
5. Environmental effects, which included changes in energy use and the incremental air pollution associated with alternative transportation modes.

Computation of the impacts is shown below (1 kg = 2.2 lb).

Factor	Impact	
	Mean	Standard Deviation
Consumer costs, $	81 650	77 000
Employment, jobs	87	274
Tax effect, $	27 200	50 700
Sales effect, $	11 900	19 600
Environmental effect, kg	-2090	2160

Because the measures are not similar, they are not additive. To combine them into a single impact index, the standard deviations of each impact were scaled so that an input of one standard deviation was equivalent to five units on the scale. Figure 1 shows the scaling relationships, and the table below shows how the scaled values of the variables are pooled to give an impact index (1 kg = 2.2 lb).

Factor	Actual Social Impact	Scaled Social Impact	Final Weighted Impact
Consumer costs, $	4968	0.32	0.06
Employment, jobs	114	2.08	0.64
Tax effect, $	140 385	13.85	1.22
Sales effect, $	62 745	15.96	1.42
Environmental effect, kg	-1610	-3.75	-0.42
Composite index			2.92

Applications

The social impact-analysis can be used to identify those rail lines that, if abandoned, would have no negative social effect on the rail users and communities along the line. A second result of the analysis is an indication of the social benefits of each rail line relative to the others—an importance ranking. The lines having the more significant impacts can then be differentiated from other lines and ranked according to their perceived level of importance on the basis of the social-impact factors and criteria weights used in the analysis.

A third significant and useful result of this work is the use of the social-impact index to construct a benefit-cost relation or index for each line. This index includes not only the social impacts associated with each line but also an indication of the cost of maintaining the line, and is a cost-effective tool for the allocation of limited funds.

Sensitivity Tests

A test of the sensitivity of the ranking procedure that uses several different hypothetical weighting schemes, as well as the actual results of the opinion survey, was developed. The table below shows four distinct sets of importance weights that were used in the sensitivity tests. Set A uses the weights that were actually developed by the small survey and used in the state rail plan. The others were chosen to emphasize other factors.

Criterion	Weight of Set (%)			
	A	B	C	D
Employment	31	10	10	10
Consumer costs	19	50	10	10
Community economics	18	10	50	10
Environment	12	10	10	50

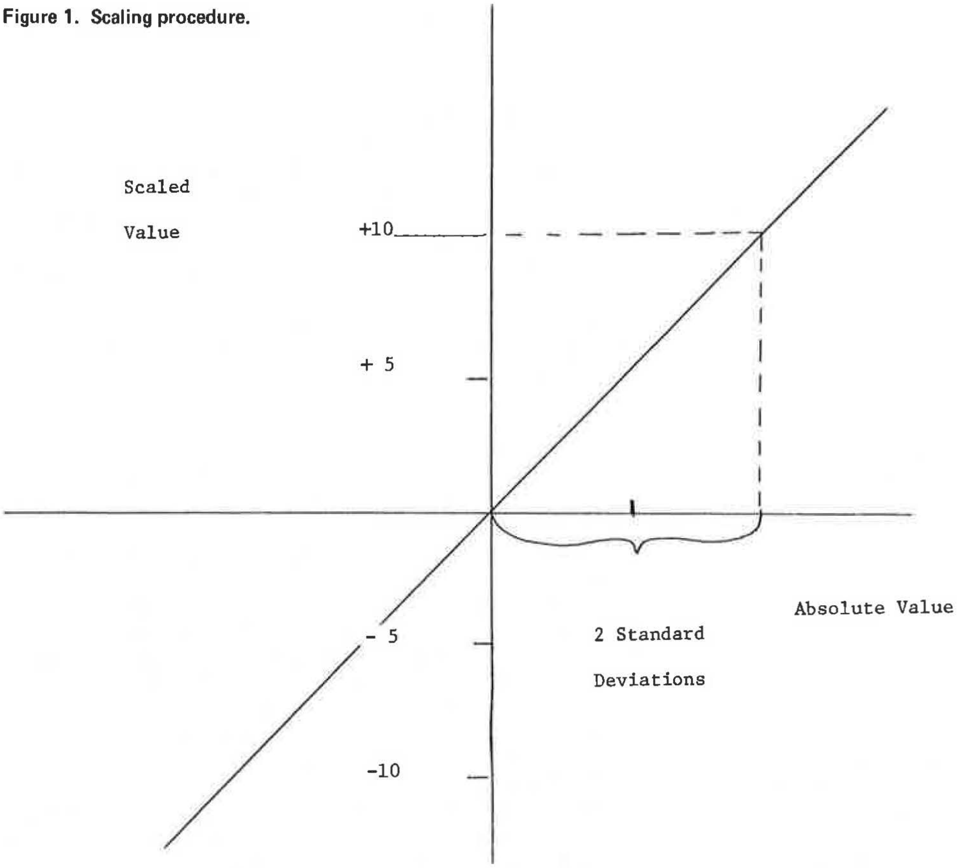
Twenty-five rail lines that were faced with possible service discontinuance as a result of the recent railroad reorganization provided the data for the sensitivity analysis. For each line, the composite social-impact index was calculated by each of the four importance sets. The results of these sensitivity tests showed that reasonable variations in the weights assigned to the various factors can produce changes in the relative ordering of the actions or projects being considered. The extent to which these changes are important depends on the intended application of the resultant rank-ordered list. At one extreme, such a list might be used to determine administrative priority for a single action decision. At the other extreme, each rank on the list might be associated with a different type of action.

Conclusions

Caution is necessary in both the development of the factor weights and the interpretation of the resultant rank-ordered list. To properly define the importance weights, the analyst must sense who the affected parties are. This is particularly important if actual weights are to be ascertained by an opinion survey. If the intended application is the decision of whether or not to subsidize rail freight service, the analyst could choose to survey the shippers who would benefit from the subsidy, the general taxpayers who would share the burden of the subsidy program (who generally react negatively to added public burdens and are uninterested in or unable to make trade-offs for the general welfare), or the responsible public officials who theoretically represent the consensus and appropriate balances. An awareness of and appreciation for the abilities and limitations of this type of structured decision-assisting process require that the analyst take the time to create and analyze sensitivity tests for specific applications.

In addition to the resultant ranking of potential actions or projects, the numerical values of the measures that the ranking is based on can provide useful guidance that

Figure 1. Scaling procedure.



should not be ignored. It would be difficult to defend cutoff points or subdivision of the list solely on the basis of the ranking, particularly when the cutoff discriminates between actions that differ very little in numerical measure. Moreover, the actual distribution of numerical values can support the selection of cutoff points.

MAINTENANCE MODELS

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The demands on state highway maintenance systems have been steadily increasing. Measured in annual dollars, average maintenance expenditures increased from 900 to 1800/km (1500 to 3000/mile) in the years from 1963 to 1973. When reduced to constant dollars, this still reflects a net increase of 20 percent. As a result, many highway departments have sought more efficient ways to provide maintenance services while sustaining desired levels of road service. This has led many states to the development of maintenance management systems that provide a systematic, formal, and objective approach to planning, scheduling, and performing highway maintenance.

Most state systems in use today are characterized by the fact that, in the budgeting process, their primary focus is on the supply of maintenance services in terms of labor, equipment, and materials used and budget money expended. There is, however, another side to maintenance management—the ability to predict the demand for maintenance. Maintenance demand arises through the combined actions of road use, the response of the physical road system, the desired or specified level of service, and the effects of the road environment. Knowledge of the need for road maintenance is essential for the evaluation of its impact.

Several states have incorporated various models within their management systems to attempt to predict annual maintenance requirements or costs. These models include quantity standards or work-load rates and are often developed within the state to include local physical, operational, and environmental conditions.

Because these relations are based on historical data or on regression analyses drawn from existing practices, they implicitly include a particular level of maintenance performance; i.e., the standards to which roads have been or are currently being maintained. However, to gauge the impacts of maintenance, different levels of performance must be investigated and compared to maintenance demand and the difference between the two then related to the impacts on the state and the motoring public.

Massachusetts Maintenance Management System

Recently the state of Massachusetts instituted a program to develop a maintenance management system that can quantify maintenance impacts. This will require the development of maintenance models that predict the demand for maintenance and relate demand versus performance to the probable impact.

The system introduces two basic mechanisms for the quantification of maintenance impacts. There are

1. The ability to express maintenance policy decisions in terms of quality standards—specific thresholds at which maintenance actions should be carried out [quality standards allow managers to (a) evaluate trade-

offs among different maintenance activities competing for limited resources and (b) tailor an annual maintenance program within current labor, equipment, and budget constraints] and

2. The use of maintenance models to estimate the demand for future maintenance as a function of the physical condition of the road, the traffic, and the environment [maintenance models allow managers to determine (a) the results of holding maintenance levels fixed for future years, (b) the results of varying maintenance levels to attempt to achieve a better maintenance program, and (c) similar strategy options for improvements].

Maintenance Models

The maintenance models predict the future demand for maintenance, both for budgeting purposes and for gauging the impact of policy decisions as expressed through changes in quality standards. In most cases, the models cover a time span approximately equal to that used for budget preparation in Massachusetts, which is generally 1 to 2 years.

Predicting Demand for Maintenance

The annual demand for maintenance is predicted for each of 15 to 20 groups of maintenance activities; e.g., the model for the flexible pavement group includes the maintenance activities of patching, surface treatment, and crack filling and the model for traffic lighting includes repair, washing, relamping, and repainting of traffic signals and luminaires.

The models operate under one of two modes. The first mode pertains to activities that can be classed as responsive maintenance; i.e., maintenance that is performed in response to a particular type of damage. Pavement maintenance is a good example of this mode: Cracks are filled when they have exceeded a certain width or extent and depressions are patched when they have exceeded tolerable limits in depth or extent. The level of maintenance that is actually performed—e.g., the percentage of cracks filled or the tolerance limits governing patching—can be controlled explicitly by the maintenance manager on a basis of established quality standards.

The models required to represent responsive activities contain explicit functions that relate the condition or deterioration of the road feature to the pertinent physical, environmental, and traffic-induced factors that are thought to affect the life and performance of the road.

The second mode pertains to activities that can be classed as scheduled maintenance, where it is assumed that the underlying physical relations governing the condition or deterioration of the road can be adequately represented by a linear time-dependent function. Pavement striping and lamp replacement are examples of this mode. The quality standards in these cases are simply the frequency with which the maintenance is performed.

Predicting Maintenance Impact

For each of the 15 to 20 groups of maintenance activities, models were also developed to predict (in a quantitative form where possible) the consequences of maintenance performance at a quality level specified. These impact models cover four basic areas:

1. Safety and legal or regulatory responsibility;
2. Effects on highway users: vehicle operating costs, travel times, user inconveniences and congestion effects;
3. Preservation of the road investment and preventive maintenance; and
4. Aesthetics and visual impacts.

The impacts of those activities classed as responsive maintenance can be expressed in either quantitative terms (e.g., user costs or benefits or increases or decreases in pavement life) or qualitative terms (e.g., an increase in riding comfort). The impacts of those activities classed as scheduled maintenance can be expressed in terms of their effect on the total maintenance inventory (e.g., the percentage falling below some minimum acceptable level) or overall maintenance trends (e.g., whether or not the frequency of maintenance matches the rate of deterioration) and quantitative or qualitative derivations of these.

Impacts of pavement maintenance are predicted in the areas of preservation of road investment, user consequences, and safety. For example, the beneficial effects of pavement maintenance in terms of preserving investments can be viewed in two ways. If the actual traffic volumes agree with the original projections, then maintenance extends the life of the pavement; i.e., it forestalls the time at which overlay or reconstruction is required. On the other hand, if the actual volumes are heavier than originally estimated, then proper maintenance can alleviate the effects of this additional damage and thus retain the originally planned life of the pavement. Both of these views can be quantified by using the pavement-deterioration relations derived from the AASHO Road Test.

Impacts in the area of user consequences are quantified by relating vehicle operating costs and travel times to road roughness or to congestion arising from the maintenance activities themselves. In the area of safety, accident data (e.g., the number and severity of accidents) can be correlated with pavement condition (measured in terms of both structure and skid resistance).

These impact data for all maintenance activities and the costs of maintenance performance are organized in a table that provides a convenient way to summarize the comparative costs and impacts of different maintenance policies, where each policy is defined by a particular set of quality standards. Managers may then judge the relative merits of proposed maintenance programs to adopt that one whose costs and impacts are most acceptable.

Summary

Maintenance-management systems are typically concerned with the management of maintenance supply, i.e., the labor, materials, and equipment used in maintenance operations. Recently the other side of the problem, the influence of maintenance demand on proper maintenance management, has been studied and a set of models has been developed with the following capabilities:

1. The ability to predict the condition or deterioration of specific road features as a function of relevant physical, environmental, and traffic factors;
2. The ability to compare this predicted condition with desirable or acceptable levels set by management—quality standards—to determine maintenance demand; and
3. Assuming that this maintenance demand is fulfilled, the ability to assess quantitatively the impacts of maintenance performance in the areas of safety, preservation of investment, user consequences, and aesthetics.

Automobile-Restricted Zones

Hays B. Gamble, Institute for Research on Land and Water Resources, Pennsylvania State University

The automobile-restricted zone, in which the free flow of traffic into a congested area is reduced, has been suggested as a potential solution to some of the problems of downtown business areas. This paper reports on a conference session that discussed problems, experiences, and opportunities of such zones. The following topics are considered: Recent experiences with automobile-restricted zones in Europe and in the United States are compared. The concepts, goals, and techniques for implementing automobile-restricted zones are discussed. A series of disaggregate, behavioral travel-demand models that were used to estimate the impacts of various automobile-restrictive policies on downtown retail and employment centers are described. The planning and design opportunities available in automobile-restricted zones are discussed. The economic approach to congestion problems, i.e., roadway pricing, is introduced, and its implementation in Singapore is described.

Restricting the free flow of automobile and truck traffic on downtown city streets is considered by an increasing number of transportation planners to be a means to reduce congestion, revitalize central business districts (CBDs), improve urban environments, and encourage more efficient use of mass transit facilities. Concepts, problems, opportunities, and experiences with automobile-restricted zones (ARZs) were discussed by seven speakers in a conference session. Joseph Goodman compared recent experiences with ARZs in this country and in Europe. Marvin Overway discussed the concepts, goals, and techniques for implementing ARZs. William Loudon discussed a series of disaggregate, behavioral travel-demand models that were adapted for the estimation of the impacts of various automobile-restrictive policies on travel demand to downtown retail and employment centers. Lajos Heder described the planning and design opportunities available in ARZs. Bert Arrillaga introduced the economic approach to congestion problems—roadway pricing and some of the factors affecting acceptance and implementation of the concept. Peter Watson and Edward Holland described the Singapore experience with congestion pricing.

EUROPEAN AND AMERICAN EXPERIENCES: RECENT COMPARISONS

Joseph Goodman, Urban Mass Transportation Administration

One of the major arguments in support of ARZs is the fact that the potential time savings of mass transit are lost in central business districts (CBDs) because of traffic congestion. In Europe, the immense growth in traffic on the narrow, medieval streets has become intolerable. In the United States, the motivations for ARZs are broader. Here, we are also trying to recapture some of the amenities of the cities and stem the decline in vitality of the CBDs. Decline in transit use and decline of downtown urban areas reinforce each other.

A 2-year study by the Urban Mass Transportation Administration (UMTA) has compared the European and American experiences and shown that there have been positive effects in Europe: ARZs have stimulated the use of downtown urban areas and increased business. The record in the United States, however, is uneven. Most of the experiences with ARZs in American cities have been with pedestrian malls, and the effects in terms of stimulating downtown retail businesses have been inconsistent.

In Europe, many of the ARZs are large and involve many downtown city blocks. They are also relatively clean and simple in design. In the United States, with the exception of one in Memphis, Tennessee, ARZs usually involve only a few blocks or a single street. We have relied heavily on street furniture, such as planters and benches, which are very expensive. On both continents, the placement of utilities underground can be very expensive.

AUTOMOBILE-RESTRICTED ZONES: CONCEPTS, GOALS, AND TECHNIQUES

Marvin Overway, Alan M. Voorhees and Associates, Inc.

In the past year or so, the idea of the ARZ has become increasingly prominent. The term is commonly used to cover a rather wide variety of situations, depending on the perspective involved, but the concept that is emerging may have significant potential for some existing city centers.

What Is an ARZ?

To begin with, it may be helpful to understand what an ARZ is or can be. Some examples of areas where automobiles are restricted (although not necessarily prohibited) include commercial superblock redevelopments, suburban shopping malls, new-town residential areas, recreation and amusement parks, and college campuses. The obvious benefits ARZs offer in terms of environmental quality and overall attractiveness are increasingly evident, particularly when they are compared to areas where the automobile continues to be dominant. The current interest in ARZ planning is an effort to achieve similar benefits within existing city centers by reducing the impacts of the automobile.

The concept of restricting traffic is not new. Traffic has always been subjected to a variety of controls, which have become increasingly restrictive with time. The degree of restriction that can be instituted varies. The measures used can be grouped into four basic categories: physical, operational, regulatory, and economic.

Objectives of ARZs

In the highly automobile-oriented society in which we all function, increasing the restrictions on automobile traffic is viable only if there are corresponding benefits. These benefits serve as trade-offs with the things that people perceive as the disbenefits, both real and imaginary, associated with the change.

The goals and objectives of ARZ concepts are distinct for different types of areas. For existing city centers, the goals are the vitality of the urban center, its environmental quality, and the stimulation of other travel modes. Specific objectives for realizing these general goals have been identified in four categories: transportation factors, economic factors, social factors, and functional and physical factors.

Clearly, the degree to which ARZ policies can attain these objectives is subject to a number of factors, some of which are only indirectly related to the ARZ concept. An ARZ can be a catalyst to give impetus to a direction and a commitment to the maintenance and enhancement of the city center by changing a situation of congestion and conflict to one of separation of function.

ARZ Techniques

While the actual design and implementation of an ARZ is closely related to the specific characteristics of the area, observation of a variety of existing ARZs suggests that there are a number of general techniques that are commonly used. These are

1. Traffic restriction—higher degrees of automobile restriction are realized through circulation controls with only limited interference to basic access;
2. Traffic circulation—through traffic is diverted out of the area, and local traffic is diverted around the area;
3. Transit service—a high level of transit service is provided to the area to serve as an attractive alternative mode;
4. Pedestrian orientation—pedestrian facilities are upgraded and linkages between facilities are provided;
5. Urban activity—existing spaces are reused for pedestrian-scale activities and to stimulate human interaction opportunities; and
6. Environmental quality—the area is made a nice place to be, with cleaner air, less noise, and improved urban design features.

The manner in which these issues are related to a specific site and the degree of their emphasis is tailored to the unique requirements of each local situation.

The following elements of an ARZ are interrelated to define a comprehensive ARZ scheme: the basic street element, the outer diversion element, the initial core element, the innercirculation element, the expanded core element, and the reinforcing element.

While the nature of the end product and the emphasis placed on particular elements are subject to substantial variation, the issues addressed and the techniques used are conceptually representative of most ARZ applications. Beginning with a basic grid system, four district ARZ plans might reflect, in turn, a pedestrian emphasis, a transit emphasis, an arterial-preference emphasis, and a traffic-operations emphasis. ARZs tend to be shaped over a period of time by the continuous implementation of specific measures that favorably accommodate pedestrian and transit functions and provide increasing disincentives to the use of the private automobile.

Existing Experience

At present, more than 70 cities of varying sizes in the United States have instituted some form of automobile restriction. The most commonly used technique has been the closure of a downtown shopping street and its conversion to a pedestrian area in which there is a high degree of emphasis on improved urban-design features.

An alternative scheme that is receiving increasing emphasis is the conversion of a downtown shopping street to a transit mall. Recently, a number of cities have moved toward a more comprehensive approach to traffic reorganization, transit emphasis, and environmental improvements. Boston, for example, has a number of completed projects that, when considered individually, have limited local impacts. But, as their number increases and linkages between the individual elements are formed, a comprehensive picture begins to emerge.

The concept of ARZs takes on an added dimension in the European context. Over 130 cities there have some form of automobile restriction. However, there are significant differences between European and U.S. cities in terms of the roles of public transit, land-use controls, and the importance of the CBD. The following highlights a number of relevant factors in the pattern of development of ARZs in Europe.

1. Most European programs are phased in over time.
2. Automobiles have not been totally eliminated from the restricted areas. Circulation within the area is severely restricted, but basic access by automobile to areas within walking and shuttle-bus distances of most destinations is generally maintained.
3. There has been a high degree of accommodation and compromise in most cities. Goods deliveries, service and emergency vehicles, and access to certain facilities have been suitably accommodated in a number of ways that are appropriate to the particular situation.
4. The pedestrian linkages that are created within the restricted areas serve the movement of people and create a pleasing shopping environment.
5. The severe opposition and the reservations that initially confronted these programs in most cities have generally been replaced with strong support after an initial 6 to 12-month period of adjustment.

Automobile restriction and environmental improvements cannot by themselves reverse the decay of downtown areas that are no longer viable centers for functions that have relocated elsewhere. However, they are an effective tool in protecting and enhancing downtown areas that are reasonably viable and serve as an impetus toward changing the image of the city center and the development of transit services that can compete more effectively with the automobile as a means of transport. This experience is common in both the United States and Europe.

Implementation Issues

The key issues related to implementing an ARZ are the following:

1. Urban activity—the area must possess some basic vitality and strength in its activity pattern;
2. Urban design—the purpose of automobile restriction is not simply to eliminate automobiles from city streets, but to create functional pedestrian and transit-preference networks;
3. Accessibility—the most critical factor in determining the success or failure of an ARZ is accessibility (if accessibility to and within an ARZ is not maintained, in the short term, there will be a decrease in the number of discretionary trips such as shoping and entertainment to the ARZ, and in the long run, many activities will relocate to more accessible sites);
4. Size of the ARZ—city size is only indirectly related to the success or failure of an ARZ, and the extent to which travel patterns will change is dependent on the size of the area subjected to automobile restriction;
5. Transportation policy—there is a wide range of options for automobile disincentives and for improvements in other transportation elements to maintain ARZ accessibility; and
6. Institutional and legal factors—institutional issues are the single most important factor, local leadership is of primary importance in the process of consensus building, and interagency cooperation is essential.

Conclusions

ARZs are not a concept that can be clearly categorized into a representative group of appropriate units to be conveniently matched to existing real-life situations.

Urban centers have many unique characteristics and constitute a conglomeration of special situations that must be dealt with on a site-specific, condition-specific basis. Automobile-restrictive policies must be tailored to local conditions.

Implementation of ARZ policies is not appropriate for all situations. Whether or not an ARZ is appropriate for a specific locality and what it might be like depends entirely on local conditions. An ARZ is not a cure-all: it is a means of encouraging and enhancing basic attributes that are already present.

MODELING THE TRAVEL-DEMAND IMPACTS OF AN AUTOMOBILE-RESTRICTED ZONE

Wayne M. Pecknold and William R. Loudon, Cambridge Systematics, Inc.

A series of disaggregate, behavioral, travel-demand models was used to estimate the impacts of various automobile-restrictive policies on travel demand to downtown retail and employment centers.

The models were used to predict the change in the following two major categories of travel demand for each policy:

1. Regional travel demand: work (mode choice among automobile drive alone, shared ride, and transit) and nonwork (frequency of travel, destination choice, and mode choice) and
2. Intra-CBD travel demand: worker (frequency of travel, destination choice, and mode choice) and nonworker (destination choice and mode choice).

The models predict changes in demand (frequency, destination, and mode choice) by using estimated changes in travel time and cost because of automobile-restrictive policies. They differentiate between trips made for work and nonwork purposes and also between regional trips—those into or out of the CBD—and intra-CBD trips—those having their origin and destination both within the CBD, such as trips made by shoppers, business people, and workers, during the day. The category of intra-CBD trips includes trips made in the morning and evening peak travel periods between parking lots or transit stops and places of employment, but the majority of intra-CBD trips occur during the midday (10 a.m. to 3 p.m.). Unlike the regional trips, the majority of intra-CBD trips are made on foot, and there are very few data available to aid in the analysis of the impact of automobile-restrictive or transit-improvement policies on them. A modeling approach developed recently is capable of simulating trips of this type from a very limited amount of data. These intra-CBD travel-choice models can also forecast the demand for new circulation modes, such as a shuttle bus service (either with or without a fare), which was recommended as a part of a number of ARZ projects.

The conclusions of the analysis of the travel-choice impacts of automobile-restrictive policies in a prototypical city and in Boston; Providence; Memphis; Tucson, Arizona; and Burlington, Vermont, are summarized below.

1. CBD trip patterns, both regional and intra-CBD, are diverse and complex, but a number of specialized travel-choice models can be used in an inexpensive and efficient manner to properly simulate each type of trip.
2. Because of the disaggregate and behavioral nature of the travel-choice models used in this analysis and because only changes in travel from existing patterns are being estimated, the models can be transferred, with only minor adjustments, to cities other than the one in which they were estimated.
3. The impact of automobile-restrictive policies depends on the extent of automobile restriction and the degree to which accessibility is maintained through other measures, such as transit and pedestrian improvements.
4. When implemented in conjunction with nontransportation policies, such as new construction, physical-design improvements, increased marketing, and improved maintenance, automobile-restrictive policies can induce travelers to change from automobile use to public transit and can increase the total number of shopping trips to the area.

PLANNING AND DESIGN OPPORTUNITIES IN AUTOMOBILE-RESTRICTED ZONES

Lajos Heder, Moore-Heder Urban Designers

Consider a familiar situation: A downtown shopping street becomes heavily congested and can no longer handle the automobile traffic. The conventional response has been to look for ways to improve the traffic flow. The moment a transportation planner decides to look instead for ways to eliminate or reduce the traffic and improve the street environment, he or she has entered a new world of planning concepts and working styles. The mechanistic ideas that relate to achieving the most movement for the least money must give way to complex ecological concepts of environmental capacity and the simple concept of the need to make places more attractive.

Those on a planning project team must constantly negotiate a balance among different disciplines. In the cities, they must look not only for solutions, but also for new opportunities. They must look about and walk the streets, because analytical studies do not reveal most of the opportunities. Urban designers must be able to invent new ideas for reusing older parts of cities.

The evidence from the automobile-restricted streets and zones that have been built in Europe and the United States shows that they do, in fact, help to bring new life into downtown areas. The indicators of pedestrian activity, retail sales, and building reconstruction all show major improvements. These places show a life that is in contrast to many dead downtowns. But it is also clear that to be successful, automobile restriction must be combined with improved streets for people, alternative transportation modes, imaginative promotion and management, and joint action with private developers. The following examples are drawn from five very different cities to illustrate the range of opportunities available in an ARZ.

1. Bringing the working population into the retail district is one of the opportunities available in Boston. Recent office construction has increased the number of workers in the downtown area to over 150 000, but it has also shifted much of this population just out of easy walking range of the old retail district. By shifting automobile traffic to the periphery of the retail area, the streets can become pedestrian-oriented and serve as connectors between the working population in Government Center and the financial district and improved shopping places. The upper floors of older buildings that are now vacant in spite of the intense business activity nearby could then become attractive again as living lofts or small specialty offices.
2. Keeping an old shopping street competitive with new developments is one of the opportunities in Burlington, Vermont. Creating a pedestrian orientation and providing shelters, heat in the winter, consolidated

parking, and other activities will help to maintain shopping on Church Street.

3. Building a city bus terminal and pedestrian arcades connecting the old downtown area to a renewal area is one of the proposals for Tucson. The terminal will provide convenient bus service and be the end point of a pedestrian-arcade system.

4. Building bus and pedestrian arcades along a declining shopping street in Tucson will accommodate waiting bus passengers, who will become pedestrians and customers. At present, the bus stops on the peripheral streets are crowded with people huddled on narrow sidewalks. The few pedestrians walk in 43°C (110°F) sun. The new arcades will provide continuous shade, occasional patios, seating areas, and evaporative cooling. The image of bus service will be improved.

5. A pedestrian-oriented downtown street as a stage for promotion and programmed entertainment is also proposed in Tucson.

6. A central place for city activities can be created in Providence by clearing away the traffic in front of the city hall and building a plaza and a sheltered transit terminal. The old Westminster Mall and proposed redevelopment of the Biltmore Hotel and Union Station can be tied together by a phased program of pedestrian improvements and bus facilities.

7. Locating a new transit center in a vacant building next to the main downtown bus stop is proposed for Memphis. Leasing the ground floor and opening it to the sidewalk and providing information, supervision, food vendors, shelter, and heat all become possible and may help to alter the image of buses as the transportation of last resort.

8. Creating pedestrian alleys and recycling buildings could be combined as a joint development program in the Cotton Row area of Memphis. The conversion of attractive, but run down and vacant, warehouses to apartments, restaurants, and specialty shops has begun and will be encouraged by the public contribution of repaving and lighting the alleys for pedestrian use.

The examples shown all concentrate on making the most of what the city already has and not on expensive reconstruction. The capital costs of the recommended improvement programs were in the range of $3 to 5 million for each city. While the issues may be typical, the solutions depend on the ability to discover the unique and often-neglected resources of the particular city. This is a discovery and design process that must go beyond quantitative analysis and requires the partnership of transportation planners and urban designers.

PRICING APPROACH TO AUTOMOBILE RESTRICTION: SUMMARY OF ACTIVITIES

Bert Arrillaga, Urban Mass Transportation Administration

Roadway-Pricing Concept

In roadway pricing, a fee is charged to low-occupancy vehicles that wish to use a designated area during highly congested periods, such as the morning peak hours. The fee is charged by selling a windshield license sticker on a daily, weekly, or monthly basis. The extent of the charge depends on the desired reduction in congestion and the needed revenue. High-occupancy vehicles, police, and emergency vehicles are exempt.

A collateral element is the implementation of significant transportation improvements in the months prior to implementation of the pricing scheme. These improvements may include the addition of conventional fixed-route buses or small vans. Service on these would be very low in price or free, and their headways would be 10 min or less. Park-and-ride lots could be strategically located around the restricted area so that automobile users could easily park and take a free shuttle bus to their destinations. Car pools, van pools, and shared-ride taxis would be encouraged. The reduction of traffic in some areas may free space in which to provide pedestrian amenities or physical improvements, such as sidewalk widening for cafes and shops.

Preliminary Analysis

Six cities expressed interest in a demonstration program, but only three (Berkeley, California; Madison, Wisconsin; and Honolulu) were willing to perform a preliminary analysis of alternative pricing schemes. A preliminary sketch design provided an opportunity to interact with local people and inform them about the concept and its possible impacts, and after this, a 6-month study dealt with the following key issues: public information, transit planning, project operators, cost estimates, and the development of an advisory group.

The table below summarizes the alternative pricing schemes studied for Madison. These schemes included a morning parking charge, several areawide charges on the downtown core area, and an urban-area permit for the entire city. The time of automobile restriction is the peak hours from 7:00 a.m. to 10:00 p.m.

Alternative	Fee ($)	Automobile Reduction	New Transit Riders	Annual Net Revenues ($000)
Parking surcharge	2.00	1 000	1350	-864
Core-area permit				
Drive alone	2.00	8 000	3300	-187
All automobiles	2.00	12 000	4500	+4 097
All automobiles	1.50	11 000	3500	+2 242
All automobiles	1.00	10 000	2930	+617
All automobiles	0.50	10 000	2475	-1 408
Urban-area permit	2.00	1 000	1100	+15 729

The alternative providing the greatest amounts of automobile reduction and transit increase is the $2.00 areawide license permit applied to all automobiles. This alternative results in an annual net revenue of over $4 million (the revenues from the license fees and the transit fares minus the costs of administration, enforcement, and transit operations). Care must be exercised in the selection of the charges because, in some cases, the costs of administration and operations are not covered by the revenues generated.

In Madison, the preferred strategy was a $1.00 core-area permit for all automobiles, which was close to break-even. The transportation improvements proposed for this alternative were 113 new buses running at a 7.5-min peak headway on all major transit routes and six or seven park-and-ride lots with shuttle service at 15 min or less headway.

Similar analyses for Berkeley and Honolulu led to similar results. In Berkeley, the initial reactions were positive, and a formal resolution to proceed with the more detailed study was passed. However, a press release on this action caused an unfavorable reaction from the public, which forced the study to be stopped.

In Honolulu, there was general interest, but business groups were concerned that the concept might be perceived as a tourist tax.

Additional Study Sites

Preliminary analyses are also being considered in Lake Tahoe, California, and Traverse City, Michigan, which have shown interest in the application of pricing schemes.

Lake Tahoe, where visitors outnumber residents four to one, has proposed a parking pricing scheme to restrict trip ends but allow through traffic. Parking permits would be sold at the rates shown below.

Time	Cost ($)
3 d	5
10 d	10
1 year	20

The major purpose of this scheme is to raise revenue to pay for the numerous transportation improvements planned for the area. It is expected that the parking charge would generate $13.8 million for fiscal year 1978.

At present, UMTA is studying the impact of the proposed Lake Tahoe plan on revenues and traffic congestion as compared to parking differential rates and areawide charges. The legal issues are also being studied, and an enabling legislation permitting the regional authority to enact a variety of pricing schemes is hoped for.

Factors Affecting Concept Acceptance and Implementation

The use of pricing schemes to control travel behavior in favor of high-occupancy vehicles is not a readily acceptable concept. Numerous factors affecting the implementation of the concept were perceived through personal contacts and visits made to the selected cities. These include the following:

1. The realism of a daily use fee;
2. Disbelief in proposed transportation improvements and their success in providing good mobility;
3. The inconvenience of obtaining a permit;
4. Effects on business;
5. Association of the concept with a commuter tax or a tourist tax;
6. Effects on low-income groups; and
7. Legal issues such as (a) whether the charge is a toll and whether it can be implemented on federal-aid roads, (b) the right to travel and the right to equal protection under law, (c) the availability of local enabling legislation, and (d) enforcement problems.

Future Directions

The experience gained by the initial interactions with city officials and local transportation planners and engineers convinced the UMTA study team that new directions must be taken to provide a better basis for the acceptability of the concept and its future implementation. These are

1. Ensure that the detailed feasibility-study phase is quite broad and considers not only the application of areawide charges but also parking strategies;
2. Deal fully with existing and planned transportation improvements;
3. Include other amenities, such as closing streets or lanes for expanded sidewalks for restaurants and shops;
4. Provide financial support for developing a comprehensive community-interaction program;
5. Develop an informative package to be used in citizen workshops or public hearings and for press conferences;
6. Be ready to accept a case-study site for performing detailed studies; and
7. Have a larger and more widely publicized site-selection process so that many cities will become acquainted with the program and have an opportunity to express their interest.

CONGESTION PRICING: EXAMPLE OF SINGAPORE

Peter L. Watson and Edward P. Holland, World Bank

The concept of road pricing and the details of its implementation in Singapore in the form of the area license scheme have been described previously. In this paper, the explanation of the design of the scheme is limited to a brief summary; the main purpose is to report the impacts of the scheme as measured in an extensive monitoring program.

Area License Scheme

The government of Singapore, having decided to take preventive action before traffic congestion grew to serious levels, instituted the world's first area license scheme in June 1975. The essence of the scheme is that a special supplementary license must be purchased and displayed on any automobile entering a designated restricted area during the peak commuting period in the morning. The license scheme is supplemented by increased downtown parking charges, and a park-and-ride service is provided as an alternative to driving downtown or using the standard bus service all the way.

The restricted zone was designed to include areas with congestion problems, leave diversion routes for motorists who do not have destinations in the zone, minimize the number of entry points that must be monitored, and take advantage of existing facilities for use as fringe car parks. The zone has an area of about 5 km^2 (2 $miles^2$) and has 22 entry points. The license fee was set at S$60/month (S$1 = U.S. $0.43) or S$3/day.

To focus the impact on peak commuting traffic, the license was initially required only for vehicles entering the restricted zone between 7:30 and 9:30 a.m., but later the period was extended to 10:15 a.m. to eliminate a peak that developed just after 9:30 a.m. It was thought that applying restrictions during the morning peak would significantly reduce traffic both then and in the evening peak, but the latter reduction has proved much smaller than desired. However, the scheme has not been modified to deal with the evening peak.

The license is not required for buses or commercial vehicles, to favor public transportation and maintain commercial activity. To encourage higher vehicle occupancy and more efficient use of road space, car pools (defined as automobiles carrying at least four persons) are also exempt from the license requirements, as are motorcycles. These exemptions also counter the objection that driving into the center would become a luxury that only the rich could afford; others can also do so if they form car pools or ride motorcycles. Taxis are not exempt.

Park-and-Ride Scheme

A park-and-ride scheme was designed to complement the area license scheme. Ten thousand spaces in parking lots around the periphery of the restricted zone were opened to commuters, and special shuttle buses were introduced to carry commuters from these lots to the central area. The combined monthly cost of parking and using the shuttle bus was set at S$30. This service attracted very few patrons.

Parking Policy

Parking charges were sharply increased at public parking lots within the restricted zone. Previously, there had generally been a flat rate of S$0.40/h. The new rates are designed to favor short-term, as opposed to all-day parking. The rates for the most congested part of the restricted zone are shown below.

Time	Cost (S$)
First hour	0.50
Second hour	1.00
Each subsequent half hour	1.00

The monthly rate for all-day parking in the central area has been increased from S$40 to 60 to S$50 to 80.

Monitoring Impacts on Travel

The World Bank, in cooperation with the government of Singapore, and with support from the United Nations Environmental Program, the U.S. Department of Transportation, and the U.S. Environmental Protection Agency, set up an extensive monitoring program that consisted of traffic counts, household interviews, speed versus flow measurements, interviews with businessmen, observations of pedestrian and parking behavior, and pollution measurements. The monitoring was begun more than 6 months before the scheme was implemented, so that before-and-after comparisons would be possible. The scheme was implemented during the middle of 1975. The implementation was carried out very smoothly, and no serious problems were observed.

The most visible impact was a decrease of 44 percent in the number of vehicles of all types entering the restricted zone during the restricted period. This was primarily the result of a 73 percent decrease in the number of automobiles entering during those hours. Of those automobiles that did enter, about 40 percent qualified as car pools (this can be compared to about 7 percent before the scheme was implemented and from 5 to 10 percent during unrestricted hours after implementation).

With these reductions in flow, one would expect to find increases in average traffic speeds, at least within the restricted zone. Technical problems prevented a direct before-and-after comparison, but by comparing speeds during the congested evening peak with those during the restricted hours, it can be inferred that speeds during the restricted hours have increased about 20 percent inside the restricted zone and from 10 to 20 percent on various inbound radial roads. Increased congestion on some parts of the ring road, however, may have reduced speeds as much as 20 percent in those locations.

From the household surveys, changes in travel behavior were analyzed in detail. The principal impacts, of course, were on people making trips to work in the restricted zone, especially those who had formerly driven automobiles. For these people, the monthly cost of commuting by automobile during the restricted hours increased from S$153 to S$228. Because of this, the proportion of trips that members of vehicle-owning households made as automobile drivers decreased from 34 to 27 percent, and the proportion that these persons made as bus riders increased from 33 to 46 percent. In addition, the proportion of work trips that were begun before 7:30 increased from 27 to 40 percent for automobile drivers and from 17 to 28 percent for automobile passengers. About the same numbers of persons from vehicle-owning households chose the options of changing to the bus, joining or forming car pools, and making the trip at a different time. People from non-vehicle-owning households did not change their behavior—90 percent of them traveled by bus both before and after the introduction of the area license scheme. The changes in travel time reported by travelers who did not change mode were very small. The only categories for which the average reported time changed more than about a minute were automobile drivers who changed to the bus and bus riders who changed to the automobile (mostly as passengers). The former lost an average of 9 min, and the latter gained the same amount.

The second group to be significantly affected were workers who traveled to work through the restricted zone to destinations on the other side of the city. Among these persons, the proportion of trips made by automobile decreased from 53.5 to 50 percent, but the proportion of automobile trips made in car pools increased from 9 to 28 percent. The proportion of trips begun before 7:30 a.m. increased from 50 to 60 percent. These travelers also had the option of detouring around the restricted zone. Before the introduction of the scheme, 88 percent of their trips had passed through the zone, but afterward only 66 percent of them drove through the zone, and of these, only 13 percent drove through during the restricted hours. The remainder changed time to avoid the fee.

Impact on Business

Many persons have expressed concern that a scheme such as that in Singapore could hurt business in the central area of the city. In-depth interviews with selected leaders in the business community, including store managers, bankers, wholesalers, and property agents, showed a consensus that the area license scheme has not had a serious adverse impact on the business climate. It is believed that the increased parking charges have further depressed retail sales in the central area but that these were already suffering from recession and decentralization. It is also believed that the restrictions on automobile travel to the center are accelerating the existing trend toward decentralization. In both cases, the area license scheme and the increase in parking charges are viewed as adding slightly to existing problems, but not as creating new ones.

Effects on Pedestrians

Before and after implementation of the scheme, time-lapse photographs were made at various times of day at different locations within the restricted zone to study the conditions for pedestrians. In general, there were more pedestrians at most locations after institution of the scheme, and they had less difficulty crossing the streets.

Air Quality

Although air pollution had not been considered as a problem, measurements made by the antipollution unit indicated an improvement, with changes in carbon monoxide levels that closely corresponded to changes in traffic flows.

Administration and Finance

Enforcement of the scheme has not been difficult. Distribution of licenses has gone smoothly. Revenues from license sales have exceeded operating costs (including the special police for enforcement) by a margin that was sufficient to pay off all the capital costs, including a gross overinvestment in fringe parking lots, in a little more than a year.

Evaluation

An opinion survey showed that residents of Singapore believe that the area license scheme has relieved congestion and improved conditions in central Singapore. Pedestrians, bus riders, taxi riders, and motorcyclists believe that they personally are better-off as a result of the scheme. Central area residents report that it is easier and safer to cross the streets, that general conditions in the restricted zone have improved, and that the amount of fumes has been reduced. Motorists report that they are worse-off, but not greatly so. All, including the motorists, believe that the effect on Singapore as a city is favorable.

In terms of the general objective of forestalling future congestion problems by forcing people to change their attitudes toward the use of automobiles for commuting, the area license scheme appears to be a success. Major modifications in travel behavior have taken place.

Whether these are simply short-term modifications or whether they represent fundamental changes in the attitudes of motorists cannot be determined at this point. It seems likely, however, that the continued use of such measures will result in a more widespread acceptance (rather than mere tolerance) of public transportation and car pooling.

Analyzing Indirect Impacts of Alternative Automated-Guideway-Transit Systems

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A computer methodology is described for analyzing at a sketch-planning level five types of indirect impact of automated guideway transit: right-of-way land consumption, community disruption, household and business displacements, aesthetics, and noise disruption. Application of the technique in a recent case study of dual-mode transit planning in Milwaukee is discussed. The methodology is also applicable to the preliminary analysis of other automated-guideway-transit systems. The procedures used in the inventory of potential link and station characteristics and in the analysis of network and corridor alternatives are reviewed. It is concluded that such analyses of neighborhood and environmental factors should be coordinated with other demand-and-supply-oriented, sketch-planning methodologies.

In the last 10 years, transportation planners have been introduced to a variety of new and proposed transportation technologies. Many of these technologies represent generic modes of travel for which there is no previous operational experience. Personal rapid transit and automated dual-mode transit are two examples of new transportation modes that, when viewed from the perspective of the traveler, offer performance characteristics that are significantly different from the more traditional, urban transportation modes. New planning methodologies and techniques are required to effectively analyze and determine the most appropriate role for a new transit technology within an existing mix of multimodal, urban transportation services. For simplicity, those new transit technologies that require some form of fixed facility or guideway are generally categorized as automated-guideway transit (AGT).

The Urban Transportation Planning System (UTPS) package of computer programs can represent the physical extent and operational characteristics of current and new transit technologies, for purposes of multimodal transportation-system, demand-and-supply analysis (13). The UTPS package can also be used for sketch-planning analysis—a procedure that can be used to rapidly iterate through alternative multimodal transportation systems and delineate feasible combinations of modes and service philosophies for more detailed, implementation-oriented studies. Sketch-planning has received increasing emphasis in urban travel-demand forecasting (1, 4, 11, 12), because it provides the following advances over the traditional urban-transportation planning process:

1. The ability to examine a much wider range and number of alternative systems to screen out concepts that can be shown to be less workable and delineate other designs for further, more detailed analysis;
2. The ability to analyze these alternatives relatively quickly and at low cost;
3. A selective focusing on major consequences and performance characteristics; and
4. The ability to perform parametric analyses that examine changes in these consequences because of variations in other system characteristics.

Sketch-planning programs are particularly useful at the system-planning level and may also be useful at more detailed levels, such as corridor planning (3, 9). They can be used in the planning and evaluation of both highway and transit systems, on a multimodal basis, and include the consideration of alternative transit technologies.

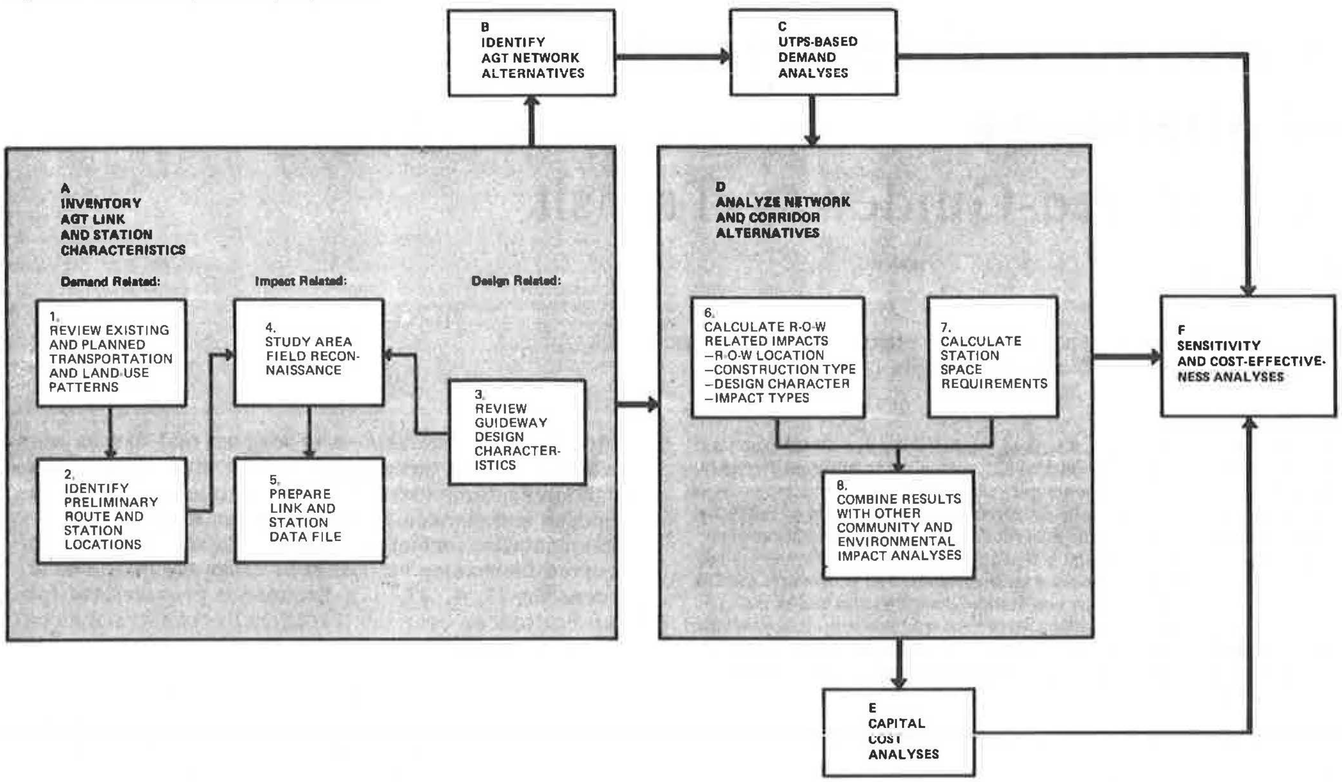
Much effort has been devoted to the development of sketch-planning procedures for analyzing travel demand and the related system-performance characteristics, but it is also important to develop methods for analyzing other, more indirect impacts of transportation-system alternatives (6, 7, 8, 10, 14). All too often, indirect impacts are not considered at the stage of alternative-

Table 1. Definitions of community and environmental-impact variables.

Category	Variable	Definition
User benefits	Consumer surplus[a]	Aggregate willingness to pay of transit users minus what they actually pay; this is an economic user-benefit measure
	Accident costs[a]	Number of accidents during peak period (highway and transit)
	Accessibility[a]	Indexes of transit accessibility to selected work, shopping, and recreation zones
	Disadvantaged[a]	Indexes of transit accessibility to selected work, shopping, and recreation zones, from primarily low-income-and-elderly zones
Environmental impacts	Air pollution[a]	Peak-period air-pollutant emissions
	Fuel[a]	Peak-period fuel consumption
	Noise	Residential neighborhoods traversed by guideway network
	Aesthetics	Types of neighborhoods traversed by elevated guideway
Neighborhood impacts	Land use for right-of-way	Land-use consumption (by type of neighborhood) for main line of guideway
	Community disruption	Community boundary orientation of guideway network
	Displacement	Number of modal-interchange stations adjacent to different types of land use
	Land values	Development potentials near several sample stations (subjective)

[a] Reductions or gains analyzed by comparison with 1990 conventional bus alternative; analyses of these impacts derived from computer-modeling outputs.

Figure 1. Indirect-impact analysis process.



systems conceptualization. Planners considering implementation of a new transit technology should be apprised of its potential for neighborhood, corridor, and regional disruption. Designs that perform well with respect to demand-and-supply considerations may ultimately succeed or fail on the basis of the indirect impacts that they generate. These indirect impacts can include, for example, potentials for community disruption or for right-of-way land-acquisition difficulties. Such impacts are rarely considered at the system-planning level and even less at the more generalized approach of sketch planning. However, the increased concern for a more comprehensive examination of social, economic, and environmental impacts at the system-planning level suggests that both demand-oriented and impact-oriented analyses are needed as the urban transportation planning process is broadened and extended.

The development of a simplified, computer-based approach for the analysis of indirect impacts, intended for application at a sketch-planning level, is the subject of this paper. The method was developed as a part of an analysis of alternative dual-mode transit systems, but can be extended to other AGT-system alternatives. Five basic impacts are considered: (a) right-of-way land consumption by type of land use; (b) community disruption; (c) household and business displacement; (d) aesthetics; (e) and noise disruption. The computerized portion of the methodology is simply an accounting procedure designed to permit the rapid analysis of many different AGT systems or networks and to facilitate parametric analyses. The method is base on a careful field reconnaissance of the study area and appears to save time and effort only if a fairly large number of alternatives (probably more than 10) are analyzed.

The technique was used in a recent case study of dual-mode transit-planning in the Milwaukee region (2). The 12 community and environmental-impact variables that were examined at a sketch-planning level are defined in Table 1. The analyses of the first 6 of those impacts were derived from UTPS-modeling outputs and are not to be discussed in this paper. The 5 impacts that are considered here were initially analyzed by hand. The information needed for a more systematic, computer-based analysis, which would permit consideration of a larger number of alternatives, gradually accumulated, but this kind of analysis was only partially implemented in the project. This paper consequently represents an extension of the methods actually used, and offers a recommended procedure for carrying out such analyses more efficiently.

Figure 1 summarizes the basic steps in the analysis procedure and suggests relationships with other steps in the sketch-planning process. These other steps include the design of alternative systems, travel-demand analyses, capital-cost analyses, and parametric analyses of demand, supply, cost, and impact trade-offs. The following sections of the paper will discuss each of these steps in turn, with some illustrative results from the Milwaukee study.

INVENTORY LINK AND STATION CHARACTERISTICS

The first major step shown in Figure 1 is the identification of the significant AGT-link and station characteristics to be analyzed. These characteristics fall into three categories: demand-related, impact-related, and design-related. These three types of characteristics provide inputs, in turn, to three subsequent steps in the process: (a) preliminary identification of probable AGT routes and station locations throughout the region under consideration; (b) field reconnaissance and inventory of impact-related characteristics of the most reasonable route and station locations; and (c) computer-based calculation of pertinent right-of-way-related impacts, based on the general design characteristics of the type of technology selected.

Preliminary Route and Station Locations

A preliminary examination of guideway location opportunities should be undertaken as an important site-related input to the design of the AGT-network alternatives and a subsequent input to the UTPS-based demand-and-performance analyses. In general, the identification of opportunities for multiple use of existing transportation or utility rights-of-way should be emphasized. In the Milwaukee case study, existing and planned non-transit transportation systems were examined for these location opportunities. Both route or link and station location opportunities were considered.

The following criteria were used to identify preliminary route locations. Potential AGT routes should

1. Follow existing freeway corridors to provide congestion relief;
2. Follow proposed freeway corridors to provide a modal alternative;
3. Follow major arterial streets (preferably but not necessarily those with available median rights-of-way) to provide service closer to residential trip ends;
4. Take advantage of other existing right-of-way opportunities, such as railroads, utility lines, drainage channels, and similar land uses; and
5. Cover all major urbanized and urbanizing subareas of the region with both radial and gridlike network configurations.

After preliminary, hypothetical AGT corridors were identified, the following criteria were used to identify potential AGT station locations. The stations should

1. Serve all major activity centers, including business and commercial, medical, university, governmental, recreational, and other trip-end concentrations;
2. Be interspersed according to station-spacing policies appropriate for the AGT technology under consideration [for example, 3 to 6 km (2 to 4 mi) for personal rapid transit]; and
3. Be located near major cross streets to facilitate modal transfers.

Field Reconnaissance of the Study Area

While this preliminary identification of potential AGT routes and stations can be conducted as an office activity by using the appropriate maps and plans, the development of the necessary impact-related data will require field inspections of each potential route alignment. From the analyses conducted in Milwaukee, it was concluded that the following six types of link data and four types of station-area data should be collected.

Link Data

1. Predominant right-of-way land-use: (a) freeway median or sidestrip, (b) arterial-street median or curb strip, (c) vacant (1974), (d) industrial, (e) mixed residential and commercial, (f) medium-density residential, (g) low-density residential, (h) railroad, and (i) utility;
2. Adjacent neighborhood land-use type: (a) low-density residential, (b) medium-density residential, (c) mixed residential and commercial, (d) commercial, (e) industrial, (f) vacant (1974), and (g) park and institutional;
3. Community boundary orientation: (a) follows boundary, (b) follows existing barrier (freeway), (c) follows existing spine (arterial street), (d) traverses low-density residential, and (e) traverses medium-density residential;
4. Guideway configuration (construction type): (a) at-grade, (b) open cut, (c) depressed, (d) cantilevered elevated, (e) straddling elevated, and (f) tunnel;
5. Right-of-way width; and
6. Unique features

Station Area Data

1. Right-of-way width: (a) freeway median or side-strip and (b) arterial-street median or curb strip;
2. Adjacent neighborhood land-use type: (a) low-density residential, (b) medium-density residential, (c) mixed residential and commercial, (d) commercial, (e) industrial, (f) vacant (1974), and (g) park and institutional;
3. Station configuration (construction type): (a) at-grade, (b) open cut, (c) depressed, (d) elevated, and (e) tunnel; and
4. Unique features.

(Links are defined as intervals between potential stations and may be further subdivided if significant land use changes occur. Link-data items 1, 2, 4, and 5 and station-area-data items 2 and 3 can be determined from field reconnaissance. Link-data items 1, 3, and 4 and station-area-data items 1 and 3 can be determined by analysis of appropriate maps and plans. Link-data item 4 and station-area-data item 3 should indicate minimum cost or disruption configurations. Link-data item 5 applies only to constricted route locations. Link-data item 6 and station-area-data item 6 are not coded.)

In the case study of dual-mode transit planning the existing urban development, land use, and transportation characteristics of the Milwaukee region were surveyed. Much of the data listed above were collected. The purpose of the field surveys was to become directly familiar with the potential locations for guideway alignment and right-of-way and for stations. Basic right-of-way characteristics for 20 different potential AGT-service corridors (including alternative alignments within some corridors) were inventoried, and more than 100 potential station areas were located along these hypothetical guideway alignments. The Milwaukee central business district and seven outlying commercial centers were visited to become familiar with activity-center characteristics. Detailed field notes and sketch maps were prepared. Each of the 20 potential guideway corridors was driven on.

ANALYZING ALTERNATIVE NETWORKS AND CORRIDORS

The next major step in the analysis process shown in Figure 1, the identification of alternative AGT networks and the associated station-spacing and service policies is largely external to the indirect-impact analysis. In the Milwaukee case study, only five basic networks were initially identified, and it was therefore possible to carry out much of the indirect-impact analysis by hand. However, after a series of additional networks was identified as a part of the parametric analyses and the number of networks increased, it began to appear that a more streamlined procedure for performing routine calculations would be useful. The more tedious portion of the impact analyses described below, the derivation of station-space requirements, was carried out by a simple computer program from the beginning.

Impacts Related to Right-of-Way

After the alternative networks have been identified in the overall sketch-planning process, it is possible to calculate and analyze the right-of-way-related impacts. As indicated in Figure 1, this requires four types of input data. The first involves the designation of an assumed right-of-way alignment within those corridors where alignment options—in terms of land-use requirements—have been defined, for each alternative AGT system to be analyzed. The second involves the designation of an assumed type of guideway construction for those links where more than one construction type appears applicable. In both cases, the purpose is to identify a single set of AGT links and their associated impact characteristics, from among all of the links that were inventoried, to unambiguously represent a single AGT system.

The third type of input data involves design-related location characteristics. These vary by type of AGT technology (for example, bus rapid transit, light rail transit, small-group rapid transit, and personal rapid transit) and, again, an unambiguous designation of guideway design features that may affect indirect impacts should be made. The pertinent design-related characteristics include

1. Guideway, right-of-way width requirements by technology and construction types (these width requirements need be verified only for those links where a constricted right-of-way has been indicated, to flag those locations where additional displacements might be created) and
2. Station-space requirements (preferably both width and total area), as related to passenger-flow volumes, by technology and construction types (these data should be in the form of a table or graph indicating changes in station-space requirements as a function of passenger flow and covering three station components: the mainline guideway-ramp connections, the station site itself, and the park-and-ride facilities).

The fourth type of input data involves the impact-related inventory characteristics collected in the field reconnaissance and office research activities. The impact-analysis process then involves no more than the summation of the indirect impacts for each particular set of links and station areas contained within each alternative system. A report can then be generated, either by hand or preferably by computer, that describes the length of the route or the number of stations in each right-of-way land-use category, neighborhood land-use type, and community boundary-orientation category and each station-location land-use category and neighborhood land-use category traversed by the guideway. Further interpretations and comparisons, particularly among the different systems, can then be made.

Analysis of Requirements for Station Space

In addition to developing generalized sketch-planning impact data by summing the link and station characteristics that fall in the different categories, analyses of the station-space requirements should also be made. Particularly for dual-mode transit stations where modal-interchange operations must take place, the relatively large station-space requirements can lead to significant dislocation impacts, so that even at a sketch-planning level of detail, some preliminary indication of the number and size of such stations is desirable. These analyses must be based on the station-design concepts and site plans that have been developed as a part of the hardware-oriented, AGT-system planning (5). A simplified computer subroutine was developed to process the demand-modeling outputs (as indicated in Figure 1) and the design-related data together to determine the average station-space requirements for each alternative system.

Two types of demand-analysis data are required for the determination of station-space requirements: (a) peak-hour person trips, inbound and outbound, by zone [covering walk-in, park and ride, on-board (no transfer), and transfer trips] and (b) number of stations per zone by station type (modal-interchange, walk-in only, transfer only, and possibly others).

The following analysis steps are then taken:

1. Allocate passengers per zone among stations per zone;
2. Use the total number of walk-in, park-and-ride, and transfer passengers per zone (peak direction) to calculate, by using station design and size requirements, the space requirements for each station; and
3. Calculate average station size and space requirements by station type (this step is important to emphasize that the space requirements calculated for any particular station or zone should not be taken too literally, since they are preliminary and generalized and that only average or total station-space requirements are pertinent at a sketch-planning level of detail).

Results of Milwaukee Case Study Illustrative

Tables 2 to 8 summarize the results derived in the Milwaukee case study of dual-mode transit planning. The results for the five initial dual-mode networks and the four networks defined as a part of the parametric analysis are given. The five basic networks were of two small-scale, two medium-scale, and one full-scale systems. The four parametrically-derived networks

Table 2. Dual-mode systems summary: guideway configurations.

	Length of Type of Construction (km)						
System	At Grade	Open Cut	Depressed	Elevated (cantilevered)	Elevated (straddling)	Tunnel	Total
A4	17.2	3.4	–	3.5	4.8	–	29.0
A1	7.4	5.6	2.7	10.8	2.6	–	29.1
A1 max	18.7	11.7	2.7	14.2	2.6	–	49.9
A1 min	1.8	3.4	1.6	6.9	2.6	–	16.3
B4	11.7	5.5	6.9	34.0	14.5	1.1	73.5
B1	9.7	5.5	6.9	25.3	12.9	–	60.2
B1 max	73.1	15.0	6.9	52.1	15.1	–	162.2
B1 min	5.1	5.5	6.0	21.6	7.6	–	45.7
C4	110.4	18.7	6.9	90.6	32.3	1.1	260.1

Note: 1 km = 0.62 mile.

Table 3. Dual-mode systems summary: land-use consumption (main line of guideway).

	Length of Guideway in Type of Land Use (km)								
System	Railroad	Low-Density Residential	Medium-Density Residential	Mixed Residential and Commercial	Industrial	Vacant (1974)	Median or Curb Strip of Arterial Street	Median or Side Strip of Freeway	Total
A4	7.4	–	–	–	–	–	5.8	15.8	29.0
A1	5.6	–	–	3.2	0.6	–	3.9	15.8	29.1
A1 max	5.6	–	–	3.2	0.6	–	3.9	36.5	49.9
A1 min	1.6	–	–	3.2	0.6	–	–	10.8	16.1
B4	7.4	–	–	–	1.8	–	35.1	29.3	73.5
B1	5.3	–	–	–	1.8	–	25.4	27.5	60.0
B1 max	18.8	–	–	–	1.8	–	45.4	96.1	162.1
B1 min	2.3	–	–	–	1.8	–	23.2	18.3	45.5
C4	32.7	–	–	–	2.6	20.0	93.3	111.4	260.1

Notes: 1 km = 0.62 mile.
Stations and intersections not included.

Table 4. Dual-mode systems summary: community-boundary orientation.

	Length of Guideway (km)					
System	Following Boundary	Following Existing Barrier (freeway)	Following Existing Spine (arterial street)	Traversing Low-Density Residential Area	Traversing Medium-Density Residential Area	Total
A4	–	23.2[a]	5.8	–	–	29.0
A1	–	20.6	8.5	–	–	29.1
A1 max	–	41.5	8.5	–	–	50.1
A1 min	–	11.6	4.7	–	–	16.3
B4	6.4	35.7	17.1	–	14.3	73.5
B1	6.4	31.9	7.4	–	14.3	60.0
B1 max	6.4	111.7	29.1	–	14.3	161.6
B1 min	6.4	19.6	5.1	–	14.3	45.5
C4	53.9	124.1	47.5	10.5	24.1	260.1

Note: 1 km = 0.62 mile.
[a] Includes portions where guideway follows railroad.

Table 5. Dual-mode systems summary: land use in station-area environs.

	Number of Stations Adjacent to Type of Land Use																											
	Low-Density Residential				Medium-Density Residential				Mixed Residential and Commercial				Commercial				Industrial				Vacant (1974)				Park or Institutional			
	Freeway		Arterial		Freeway		Arterial		Freeway		Arterial		Freeway		Arterial		Freeway		Arterial		Freeway		Arterial		Freeway		Arterial	
System	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W
A4[a]	–	–	–	–	1	–	–	–	–	–	1	–	1	–	–	–	5	–	–	–	2	–	1	–	2	–	–	–
A1	–	–	–	–	3	2	–	1	–	–	–	–	–	3	3	1	2	4	1	–	–	–	–	–	2	1	–	–
B4[a]	2	–	–	–	8	–	10	–	–	–	14	–	4	–	10	–	6	–	6	–	–	–	–	–	4	–	–	–
B1	–	–	–	–	5[b]	2[b]	3	5	–	–	–	–	2	6	3	3	4	7	1	–	–	–	–	–	2	1	1	1
B1 with shorter station spacing	–	–	–	–	5[b]	11[b]	3	15	–	–	–	–	2	12	3	8	4	14	1	2	–	–	–	–	2	3	1	1
B1 with longer station spacing	–	–	–	–	5[b]	–	3	1	–	–	–	–	2	3	3	1	4	1	1	–	–	–	–	–	–	2	1	1
B1 with minimum guideway	–	–	–	–	4[b]	–[b]	2	3	–	–	–	–	1	4	3	3	4	6	1	–	–	–	–	–	2	1	1	1
B1 with maximum guideway	1	5	–	–	6[b]	6[b]	7	14	–	–	–	1	3	6	5	6	6	7	1	–	15	8	1	–	3	4	1	1
C4[a]	3	–	–	–	11	–	15[c]	–	1	–	13	–	3	–	9[b]	–	6	–	4	–	13	–	14[d]	–	2	–	–	–

Note: M = modal-interchange station; W = walk-in-only station.
[a] Walk-in station locations were not investigated for the initial baseline systems. For these systems, modal interchange (or transfer) stations for both automated guideway and manual on-street operations were analyzed.
[b] One additional station located on railroad right-of-way.
[c] Includes 3 stations within railroad right-of-way.
[d] Includes 4 stations within railroad right-of-way.

Table 6. Dual-mode systems summary: neighborhoods traversed by elevated guideway.

System	Length of Guideway in Type of Neighborhood Traversed (km)							
	Low-Density Residential	Medium-Density Residential	Mixed Residential and Commercial	Commercial	Industrial	Vacant	Park or Institutional	Total
A4	0.6	-	2.3	0.6	1.3	2.1	1.3	8.2
A1	-	4.0	-	4.3	3.7	-	1.3	13.4
A1 max	-	5.8	-	4.3	4.7	-	1.9	16.7
A1 min	-	2.1	-	2.4	3.7	-	1.3	9.5
B4	-	28.0	2.9	9.5	7.7	-	0.3	48.4
B1	-	19.2	2.9	8.0	7.7	-	0.3	38.1
B1 max	-	30.6	6.8	14.6	8.7	2.1	1.4	66.9
B1 min	-	16.4	0.2	7.2	5.1	-	0.3	29.3
C4	9.3	56.0	13.4	21.4	15.4	3.4	4.0	123.0

Note: 1 km = 0.62 mile.

Table 7. Dual-mode systems summary: neighborhood environs traversed.

System	Length of Guideway in Type of Neighborhood Land Use (km)							
	Low-Density Residential	Medium-Density Residential	Mixed Residential and Commercial	Commercial	Industrial	Vacant (1974)	Park or Institutional	Total
A4	0.6	1.9	2.3	0.6	8.5	11.3	3.7	29.0
A1	-	8.4	1.4	4.3	11.1	0.2	3.9	29.3
A1 max	4.3	16.7	1.4	5.0	12.4	4.2	6.1	50.2
A1 min	-	2.7	1.4	2.4	5.6	0.2	3.9	16.3
B4	-	39.1	2.9	11.3	16.3	-	4.0	73.5
B1	-	29.1	2.9	8.7	16.3	-	2.9	59.9
B1 max	10.6	51.0	6.8	17.5	20.0	47.6	8.0	161.6
B1 min	-	23.2	0.2	7.7	13.7	-	0.8	45.5
C4	20.8	80.1	13.7	25.4	29.0	76.0	15.0	260.1

Note: 1 km = 0.62 mile.

Table 8. Dual-mode systems summary: station-space requirements.

System	Avg Station Size (m^2)			
	Modal-Interchange Station			
	Basic Station Facility	Park-and-Ride Area	Total	Walk-in-Only Station
A4[a]				
A1	11 812	5209	17 021	5266
B4	11 812	3427	15 239	6885
B1	11 812	3785	15 597	5194
B1 with shorter station spacing	11 812	3980	15 792	5176
B1 with longer station spacing	11 812	3022	14 834	5454
B1 with minimum guideway	11 812	3785	15 597	5184
B1 with maximum guideway	11 812	3785	15 597	5197
C4	11 812	2210	14 022	6900

Note: 1 m^2 = 10.7 ft^2.
[a]This initial baseline system was not analyzed.

were minimum and maximum alternatives of the small-scale and medium-scale systems. The following conclusions are derived from the results reported in Tables 2 through 8.

1. Because of relatively narrow guideway-width requirements, it appears possible to locate most of the main line of the guideway within existing transportation rights-of-way (freeways, arterial streets, and railroads). The system B4 network would require acquisition of about 2 or 3 percent of its land from land in current development, and the system C4 network would require acquisition of about 1 percent of its land from land in current development and about 8 or 9 percent from land that is currently vacant.

2. Community-disruption potentials would exist, but not in any major degree. Furthermore, the disruption caused by the relatively narrow, often-elevated guideway would probably be much less than that commonly associated with urban freeways. About 20 percent of the system B4 network and 12 percent of the system C4 network would traverse residential neighborhoods, not following existing boundaries, barriers, or (typically strip commercial) spines.

3. There are fairly significant residential and business displacement potentials associated with guideway-station-space requirements, especially for modal-interchange stations on arterial streets. For the system A4 network, 9 percent of the guideway stations would be in residential areas and none on arterial streets. For both systems B4 and C4, 30 percent of the stations would be in residential areas, and 15 percent would be on arterial streets. In each system, a smaller percentage of stations would be in commercial or industrial areas. While this would achieve close integration with surrounding urban land uses, which would maximize the potential

for walk-in patronage, the typical modal-interchange, station-space requirement of 3010 to 10 950 m^2 (32 500 to 99 000 ft^2) would create significant displacement problems. Further work in hardware design aimed at minimizing the space requirements of stations appears necessary.

4. Aesthetic-intrusion potentials were assessed primarily in relation to the land uses traversed by the elevated guideway. Even though there are fairly pleasing guideway and vehicle designs, the mere presence of an elevated guideway in a residential area, for example, could be aesthetically distracting. About 36 percent of the system B4 and 24 percent of the system C4 networks would be located in residential neighborhoods, where the disruption potential might be highest.

5. Noise intrusion potentials were related primarily to the extent to which guideways would pass through residential neighborhoods of varying density. Because the anticipated noise characteristics of dual-mode transit vehicles do not greatly exceed the ambient noise characteristics typically found in residential neighborhoods, the potential for serious noise intrusion does not appear very great. About half of the system B4 and 44 percent of the system C4 networks would be located in residential neighborhoods.

6. The minimum or maximum guideway networks (for systems A1 and B1) do not affect (reduce or increase) the right-of-way land requirements (for the main-line guideway only) for areas currently in urban development. For either variation of the system, guideways added or deleted would be located within existing transportation rights-of-way.

7. The minimum or maximum guideway networks would not affect (reduce or increase) the length of guideway traversing residential neighborhoods. For either variation of the system, guideways added or deleted would primarily follow existing boundaries or barriers (freeways or railroads).

8. The minimum and maximum guideway networks have some potential for reducing or increasing aesthetic intrusion in residential neighborhoods. For the system A1 network, the potential for such intrusion would be decreased from 4.0 to 2.1 km (2.5 to 1.3 miles) for the minimum guideway and increased from 4.0 to 5.8 km (2.5 to 3.6 miles) for the maximum guideway. For the system B1 network, the variations would be from 19.2 to 16.4 km (11.9 to 10.2 miles) for the minimum guideway and from 19.2 to 33.3 km (11.9 to 20.7 miles) for the maximum guideway. There are similar variations for commercial and industrial areas.

9. The minimum and maximum guideway networks have similar potentials for reducing or increasing the extent to which residential neighborhoods are exposed to some additional degree of noise intrusion. For the system A1 network, the length of guideway through residential neighborhoods would decrease from 9.8 to 4.2 km (6.1 to 2.6 miles) for the minimum guideway and increase from 9.8 to 11.5 km (6.1 to 14.0 miles) for the maximum guideway. The comparable figures for the system B1 network are 32.0 to 23.3 km (19.9 to 14.5 miles) and 32.0 to 64.7 km (19.9 to 40.2 miles).

SENSITIVITY ANALYSES

A major part of the Milwaukee case study dealt with the parametric analysis of significant variables—supply, demand, cost, and community and environmental characteristics—associated with dual-mode systems. The emphasis was on the use of the UTPS sketch-planning, demand-analysis methodology, with its relatively low costs and quick turn-around time, to examine the consequences of designated changes in selected variables. The results of such analyses can, of course, be extremely useful in the more careful design of subsequent system alternatives, as more detailed levels of system planning are undertaken. After the most significant variables in each cluster—supply, demand, cost, environmental—were identified, a three-stage approach to the parametric analysis was followed. The three stages included single-variable analysis, within-cluster analysis (relations between variables within the same cluster), and between-cluster analysis (which is more demanding, and necessarily more selective, because the between-cluster combinations of variables that might affect one another can be large) (2).

The first two stages of the parametric analysis, for the five community and environmental factors considered here, were conducted by using a series of eight sample guideway stations, of which seven involved dual-mode modal-interchange stations, one involved a walk-in-only station, and four involved an adjacent guideway intersection. There was a balanced geographic distribution among these prototype stations: Three were located on arterial streets, at medium-density residential (with commercial frontage), low-density residential, and low-density commercial locations. The field reconnaissance indicated that, for most arterial-street guideways, there are commercial land uses of some kind at most of the major intersections identified as candidates for station areas. The sample also included four guideway-on-freeway stations, at medium-density residential and low-density residential locations, and one CBD station.

For each of the eight station locations, generalized site plans were sketched by using the results of the station-space analyses. A minimum land-consumption design was used and, as a part of the single-variable and within-cluster parametric analyses, a few design variations were explored. The only impact variable of the five considered here that varied significantly was that of household and business displacements.

Between-cluster parametric analyses were then conducted at the level of the overall system. Of all the between-cluster variations that were examined parametrically for system-wide sketch-planning analyses, only the minimum guideway and maximum guideway variations resulted in significant changes in all five of the neighborhood environmental-impact variables.

Station-area impacts, particularly household and business displacements, can also vary with other supply-and-demand variations of the system. These impacts can vary both with changes in the number of stations and in their average size. Station-area land requirements and household and business-displacement potentials can change in association with eight basic variations of system supply and demand; shorter station spacing, longer station spacing, lower station sizing (decrease in demand), higher station sizing (increase in demand), minimum guideway, maximum guideway, increased land-use density (in the vicinity of station areas), and decreased urban sprawl (increased concentrations of demand closer to the central city).

CONCLUSIONS

The parametric analysis of neighborhood and environmental impacts, set within a broader sketch-planning methodology, can help to enrich the amount of information on the consequences of AGT systems. For example, potential route alignments and station locations with significant negative impacts can be quickly identified, and a general picture of the extent of these impacts can be gained. Subsequent alternatives can be refined to reduce or mitigate such impacts. Other combinations of potential guideway links and stations—additional system alternatives—can be quickly tested by specifying those individual links and stations to be included in the new alternative. It may also be necessary to add more potential links and stations to the initial field inventory; this can be an important contribution to the thoroughness with which later system planning is conducted. Finally, the related between-cluster impacts on community and environmental factors that can be attributed to the many supply-and-demand variations of the system can be quickly examined.

The limitations of the indirect impact-analysis methodology suggested here should also be clearly understood; these are essentially the limitations attached to sketch-planning in general.

1. Sketch-planning results are generalized in nature. Specific impact estimates for individual links or station areas, such as areas of land to be acquired and numbers of dwelling units to be displaced, should not be expected, and procedures for their calculation are not included.
2. Care must consequently be exercised in using these generalized results in community and public-agency interactions. Because specific alignments, centerlines, and station locations are not investigated, it is possible that subsequent system and corridor planning will, for any individual link or station, significantly alter the initial assessment of consequences.
3. In the area of community and environmental factors, particularly at the corridor-planning level, considerable and major additional efforts are necessary to adequately specify the indirect effects that will actually be generated.

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Comparison of the Usefulness of Two Multiregional Economic Models in Evaluating Transportation Policies

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This report describes and compares two large-scale economic-forecasting models—the multiregional input-output model developed by Polenske and the multrieginal, multi-industry forecasting model developed by Harris—to examine their usefulness for transportation planning at national, state, and local levels. The models use fundamentally different methods of economic forecasting, and thus have different appropriate applications. Both the Polenske and the Harris models are currently used in analyzing regional economic activity by industrial sectors. A basic difference is that the Polenske model is used mainly for analyzing the effects of changes in interindustry trade flows between regions, whereas the Harris model is used mainly in forecasting regional growth and evaluating effects of alternative highway and other transportation systems. The Polenske model provides a framework for describing and analyzing the sales and purchases of all industries in every region of the economy and has been used to analyze the role of trade in the economic growth of particular regions, such as the California-Oregon-Washington region, as compared to the rest of the United States. The Harris model is designed to make both short-run and long-run forecasts of economic growth. Because it provides a framework for analyzing interindustry purchases, it has been used to evaluate the regional economic and environmental effects of alternative highway systems.

The assessment of regional effects is increasingly important in the development of transportation programs because of changing patterns of regional growth in the United States and because transportation investments and programs can significantly affect the economic growth of a region. To predict the regional economic effects of major capital investments, such as highways and other transportation facilities, a number of economic-forecasting models have been developed and are being used in transportation planning and policy evaluation at national, state, and local levels. These models have been developed as tools for transportation planning and policy evaluation and should be used with good judgment and other methods of social and economic analysis.

This paper describes and compares two large-scale economic-forecasting models—the multiregional multi-industry forecasting (MRMI) model developed by Harris at the University of Maryland and the multiregional input-output (MRIO) model developed by Polenske at the Massachusetts Institute of Technology and Harvard University—to examine their usefulness for transportation planning at national, state, and local levels. These models use fundamentally different methods of economic forecasting and thus have different appropriate applications.

Their similarities and differences are discussed under the headings of: (a) description, (b) uses, (c) major assumptions, (d) strengths and limitations, and (e) conclusions concerning their usefulness in transportation planning.

DESCRIPTION OF MODELS

Harris Model

The MRMI model is an econometric model composed of three major components, as shown in Table 1—a set of forecasting equations, a transportation-cost linear-programming algorithm, and a regional highway-congestion index—and uses national forecasts obtained from the interindustry forecasting model of the University of Maryland (INFORUM), developed by Almon (1). (INFORUM is not a component of the MRMI model, but rather is an independent model that has been used in a variety of applications, including the application described here.)

The basis of the Harris model is a set of forecasting equations that explain industrial location choices by the relative prices that industry faces at different locations. These prices include land, labor, and capital costs and the transportation costs that are incurred in shipping the raw and finished goods into and out of the region.

Through the use of a transportation-cost linear-programming algorithm for each of 71 commodity industries, transportation-rate data are converted to marginal transportation costs, which are the costs of transporting a marginal unit of a commodity either into or out of a region. These marginal transportation costs vary considerably by region.

Transportation-rate data include national and regional data on shipments by size, weight, type of goods, distance, and mode of transportation and use Interstate Commerce Commission formulas that consist of line-haul costs and terminal costs. The transportation rate of shipping a good between two regions is calculated according to the minimum cost by mode of transport, for each weight class, aggregated over all weight classifications.

The regional highway-congestion index, the third major component of the Harris model, is an index that measures the amount of traffic congestion on principal roads within each region. It was computed for each of the 173 Bureau of Economic Analysis (BEA) economic areas from Federal Highway Administration data for urbanized areas (aggregated or adjusted to the BEA areas) on vehicle distances traveled, lengths of freeways and arterials, and capacity of freeways and arterials.

INFORUM, which is a national input-output model, makes forecasts of the final-demand spending (consumer expenditures, investment, governmental expenditures, and exports minus imports) of the national economy for each year and generates a set of national output levels for each industry that is consistent with the final demand. Historical trends of technological changes and expected rates of adoption of new technologies are incorporated into its forecasts.

The Harris model makes regional economic forecasts under alternative transportation assumptions, such as changes in the transportation system, with the regional forecasts controlled to sum to the INFORUM national forecasts, which ensures consistent and reasonable regional forecasts. The Harris model forecasts regional shares and then applies the national values to obtain the regional values. In different applications, the regions used have been either individual counties or the BEA economic areas, which are multicounty areas considerably larger than metropolitan areas.

Improvements in highways or other transportation systems affect the cost of shipping goods between regions and thus have an effect on the marginal transportation costs or shadow prices. For example, if construction or the improvement of a highway results in a reduction in truck travel time between two regions, then the total transportation costs between the two regions will be reduced. These changes in marginal transportation costs have an important influence on industrial location decisions. In addition, highway improvements affect industrial location by reducing congestion within a region and by construction spending, which stimulates employment and income during the construction period.

For each of the 173 economic areas, the model makes year-by-year (from 1970 to 1990) forecasts of output, earnings, personal consumer expenditures, exports, and imports for each industrial sector; equipment purchases for each equipment-purchasing sector; construction expenditures for each construction sector; and government spending for each government sector. Figure 1 (2) shows how each year's forecasts are developed from the previous year's forecasts.

To test the accuracy of the model, forecasts for 1966 to 1970 were made, and the 1970 forecasts were compared with the actual 1970 regional data by using regression equations. Forecast accuracy was very high for total population, total employment, and total personal income. For employment, it was high in 83 of the 103 industrial and labor sectors, fair in 19, and poor in 1 (agriculture, which depends upon many noneconomic factors).

Polenske Model

The MRIO model requires three component sets of data for implementation as indicated in Table 1—base-year input-output tables for each state or region, interregional trade-flow tables for each commodity, and final demands for each state or region—and uses these data sets to make forecasts of interregional trade and interindustry outputs for future years. The model has three versions—column coefficient, row coefficient, and gravity coefficient. The column-coefficient version has been developed in the greatest depth and is used most often in implementation; thus it will be the only version described here. It can be implemented with differing degrees of aggregation. The most disaggregated version, which is discussed here, uses the 50 states plus the District of Columbia and 80 industries. For any level of aggregation, the process of implementation is similar.

The first component is a set of input-output tables for each state, which is prepared from base-year (1963) data by using state and national sources (3, 4). These tables show, for each state, all the interindustry purchases and final-demand purchases (by private and public consumers) made in that state in 1963. An example of such a table is given in Figure 2a [modified from Polenske's figure (5)], in which the entry in the motor-vehicles row under the machine-shop-products column shows the total purchases of motor vehicles by the machine-shop-products industry in Michigan in 1963. The sum of each industry column in that diagram shows the total production of that industry in Michigan, and the sum of each industry row shows the total consumption of the output of that industry in Michigan regardless of where that output was produced.

To show the interstate trade that accounts for where the output was produced, the second component of the model—interregional trade flows for each commodity—was developed. Interregional trade-flow tables for the base year 1963 were prepared for each industrial commodity. For example, in Figure 2b, the trade-flow table for motor vehicles shows the amount of motor vehicles shipped into and out of each state in 1963, which equals the column sum in the input-output table in Figure 2a. Trade-flow tables were prepared by using state and national data sources, with checking and adjustments to ensure a set of consistent data.

The third component for implementation—a set of final demands for each state—was prepared for the base year 1963 and projected for the forecast years 1970 and 1980 (3, 4). Final demand includes consumer expenditures, private investment, governmental expenditures, and net foreign exports. By using national and state data, each category of final demand was estimated for each state for the base year 1963 and for the forecast years 1970 and 1980.

Table 1. Basic characteristics of models.

Characteristic	MRMI (Harris) Model	MRIO (Polenske) Model
No. of regions	173 BEA economic areas; can also analyze counties and standard metropolitan statistical areas	51 (50 states plus District of Columbia); can also analyze census divisions
No. of sectors	216 (99 industrial, 28 construction, 8 governmental, 69 equipment-purchasing, 2 extra import, 6 population, and 4 extra labor)	86 (80 industrial and 6 final demand)
Years	1965-1966 and 1970 (base); 1970 to 1990 (forecast); to be updated to 1972 base	1963 (base); 1970 and 1980 (forecast); to be updated to 1972 base
Components	Set of forecasting equations; transportation-cost linear-programming algorithm; regional highway-congestion index; national forecasts from INFORUM	1963 base-year input-output tables for each state; interregional trade-flow tables for each commodity that is shipped; set of final demands, such as consumption, investment, and government expenditures for each state for each year to be forecast

Figure 1. Development of year-by-year forecasts in multiregional multiindustry forecasting model.

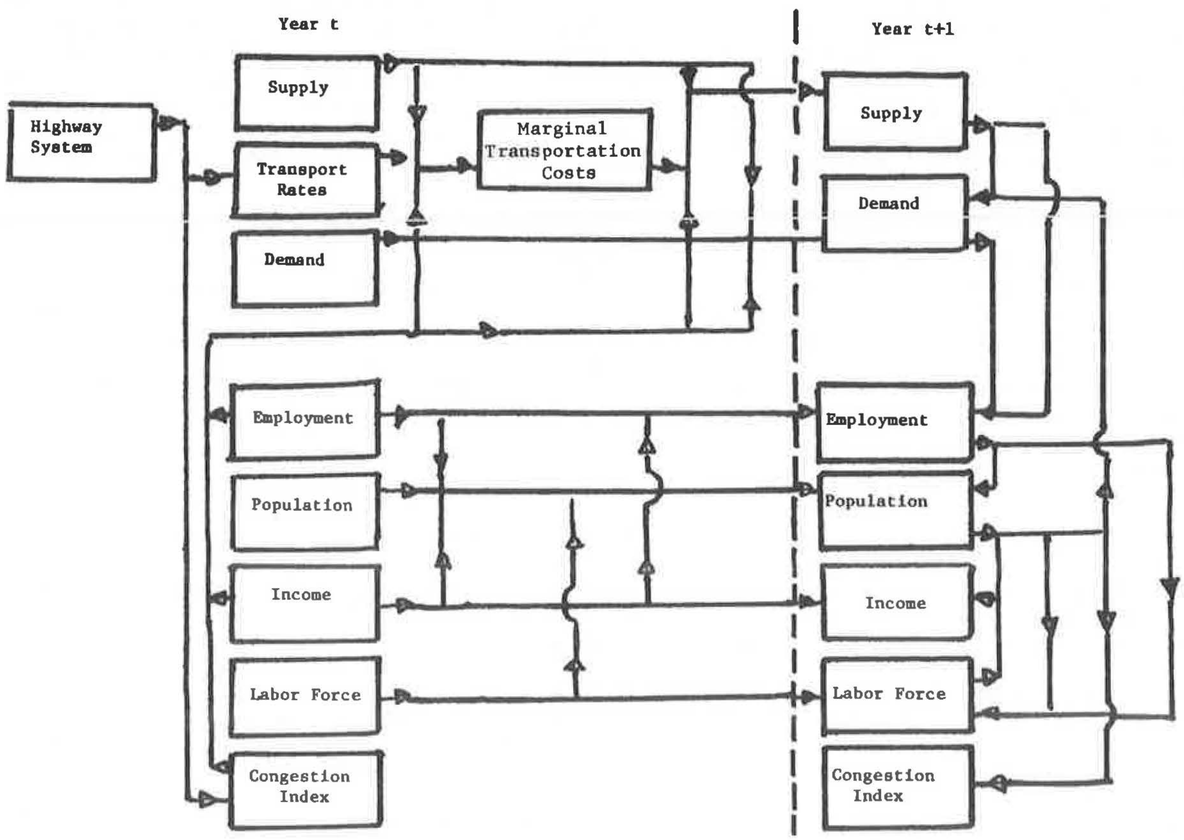
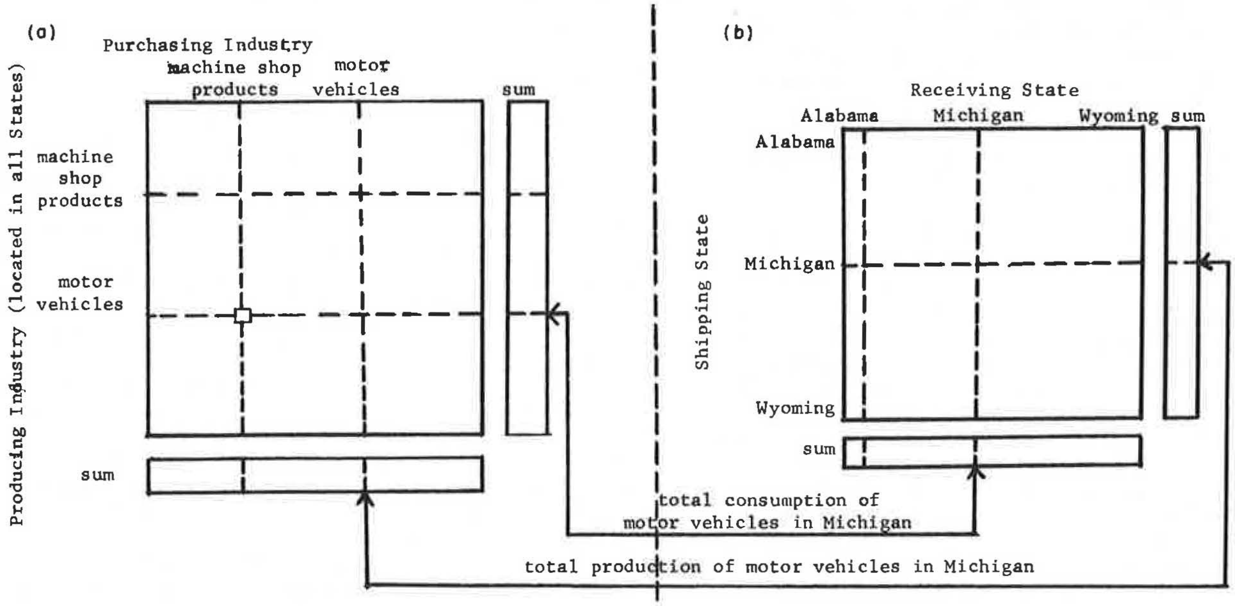


Figure 2. Relation between interregional trade flows and regional input-output table in the multiregional input-output model.



After assembly of the three components, the Polenske model uses computerized input-output techniques of matrix transformation and successive iterations to forecast interindustry purchases and interregional trade flows for the years 1970 and 1980. These forecasts show the levels of output of each industry in each state and the shipments of each commodity from state to state that would be generated by the levels of final demand that are projected for 1970 and 1980.

This information is useful to transportation planners and others because it can be used to analyze the changes in state outputs and trade between base and forecast years and provides an analytical framework for analyzing other changes. For example, in making decisions about highway and other transportation investments, it is important to predict the demands that will be placed on the proposed transportation system. Forecasts of industrial outputs and commodity shipments between states are an important element in predicting such demands and can also be used to analyze projected income and employment changes. However, because forecasts from the Polenske model are based on assumptions of unchanged technologies and structures of trade between states, it is more useful for short-run than for long-run analyses.

The accuracy of the model was tested by running it for 1947, 1958, and 1963 and comparing the resulting forecasts with actual data from those years. The results were very accurate for 1963 (the year on which it is based), moderately accurate for 1958, and less accurate for 1947. For example, forecast output for 1958 was within 10 percent of actual output in two-thirds of the sectors tested.

By modifying the model, for example, by updating or disaggregating the data in sectors that are of particular importance to transportation, planners can use the model to analyze the impacts of recent or projected changes in those sectors on other industries and commodity shipments.

USES

Both the MRMI and the MRIO models are currently being used to analyze regional economic activity by industrial sectors. A basic difference is that the major use of the Harris model is in forecasting regional economic and environmental impacts of alternative investments and programs, including highways and other transportation systems, whereas the Polenske model is used mainly for projecting the short-term effects of changes in interindustry purchases and trade between regions. The Harris model is designed for both short-run and long-run forecasting and for measuring the impacts of external changes in economic variables and can make economic forecasts at the county and functional-economic-area levels. The Polenske model provides a framework for describing and analyzing sales and purchases between industries in different regions and can be used to measure the short-run direct and indirect effects of changes in industrial purchases throughout the country.

Harris Model

Current Uses

1. The regional economic and environmental effects of hypothetical alternative U.S. highway systems were analyzed for the Federal Highway Administration (6). Six alternatives were studied—a base year system (if Interstate construction were stopped in 1970), a completed Interstate system (if construction were completed in 1976), an extended primary system, an economic-development system, an urban system, and a piggybacking (trailer-on-flatcar) system. These systems affect regional growth because improved highways lower transportation costs between regions and congestion within regions, and highway construction expenditures stimulate employment and income.

The model was also used to forecast 1990 regional resource and energy requirements for each alternative highway system. Data on national energy use, resource requirements, and pollutant emissions were converted to national coefficients for each industry (indicating the amount of energy used or pollutant emitted per unit of output), by using the INFORUM national input-output model (1). These coefficients were applied to the regional forecasts of industrial outputs to determine regional forecasts of energy use, resource use, and pollutant emissions for each alternative highway system.

The results of these applications showed that the benefits of a completed Interstate system by population size of the areas were mixed; i.e., some high-population areas would benefit, but others would not; and some low-population areas would benefit, but others would not. Both low-income and small BEA areas would benefit by extended primary or economic-development systems, with relatively more areas benefiting from the economic-development system. An urban system would stimulate growth in the largest urban areas, but the percentage gains are not large.

Energy, resource, and pollution forecasts generally reflect the impacts of the alternative highway systems. For example, if a large urban area gains in output by the construction of an urban highway system, its energy use, resource use, and pollution levels also increase.

2. A Canadian version of the Harris model was developed for the Ministry of State of Urban Affairs (7). This application involves the analysis of the interregional, multi-industry structure of the Canadian economy and the development of a model that uses Canadian national and regional data. The resulting Canadian version can be used to evaluate alternative transportation investments in Canada.

3. The model was applied at the county and metropolitan-area levels to forecast the economic and population impacts of proposed highway or other transportation investments (7). For example, the effects of a proposed 32-km (20-mile) segment of Interstate 190 were forecast for Worcester County, Massachusetts. Forecasts from the model have also been used to provide control totals for county and metropolitan-area transportation-planning models. The control totals can be used with national technical coefficients (inputs per unit of output for each industry) to generate county-level, input-output tables for use in transportation and other regional planning.

4. The effects of possible cutbacks in natural gas supplies in different areas of the United States were analyzed at the county level (7). In Maryland, the Harris model was used to evaluate two alternative allocation formulas for the distribution of the anticipated reduction of natural gas to users and the regional economic impacts of these formulas. In Texas, Arizona, New Mexico, and California, the model was used to evaluate the impacts of possible reduced agricultural production because of the decreased supply of natural gas, which is used as the source of power for irrigation.

Studies Under Way

1. The model is being used to analyze the regional economic effects of changes in personal travel costs and expenditures by modifying the national input-output model and the multiregional forecasting model to forecast the regional effects of personal travel-related expenditures (8).

2. The Harris model is being used for national and regional-level transportation-policy analysis and as an input in the urban transportation planning process (8). It is also being extended to analyze the economic and environmental effects of alternative transportation policies at all regional levels (national, state, metropolitan area, and county) for all major modes (highway, rail, air, and water). An important part of the study will be to modify the INFORUM model to predict the growth effects on the gross national product that would result from alternative investment levels in various transportation modes.

3. The model is being used in a project sponsored by the Federal Highway Administration to analyze the economic impacts of alternate levels of national highway performance, i.e., conditions of highways (taking into account operating characteristics such as average speeds and traffic levels and necessary maintenance), to obtain information for use in planning national highway policies.

Polenske Model

Current Uses

1. The economic interaction between electricity, coal, and freight transportation created by changes in regional technologies for generating electricity and in the interregional shipments of coal was analyzed (9). The 1963 base-year table of technical coefficients was updated to include 1970 data on coal and electricity production and the 1963 trade-flow table was updated to include 1970 coal-shipment data. The model was then rerun to forecast the effects of these changes on production and interregional trade.

For example, the eastern states were forecast to have decreased input requirements for nearly all industries (not just those directly related to coal) and the mountain and Pacific states were forecast to have increased industrial requirements, when compared to the nonupdated version of the model. The updated results are generally more reliable because they include more recent changes in technology and trade. Similar updating can be done for other industries and for years later than 1970.

2. Trade in the California-Oregon-Washington region and differences in economic growth between this region (a fast-growing region) and the rest of the United States were analyzed (10). The results showed that from 1963 to 1970 the California-Oregon-Washington region was growing fastest in those industries that were also growing fastest nationally. Also, growth in final demand in the California-Oregon-Washington region helped to generate increased production in other regions to supply those demands. This type of study can serve as a basis for analyzing the role of transportation in interregional trade and can be extended to other regions.

3. The impacts of expenditures for the proposed Consolidated Rail Corporation (Conrail) on employment and income in the Conrail region and in the remainder of the United States were analyzed (11). The Conrail region includes the northeastern and middle Atlantic states, Virginia, West Virginia, and some Great Lakes states. The Polenske model was used to calculate three major indirect effects of Conrail expenditures—increased industrial outputs, induced spending, and induced investment. The results showed that the greatest amount of jobs and income would be generated in 1985, the final year of investment expenditures.

Studies Under Way

1. Changes in technology and trade flows and investments are being incorporated into the Polenske model to extend it into a dynamic framework; i.e., regional technical coefficients and interregional trade coefficients would be predicted to change over time, according to past trends, and the dynamic model would be used to make more realistic long-run forecasts (9).

2. The regional and industrial interrelationships between the transportation and energy sectors are being analyzed. This has been done already for coal, electricity, and freight transportation and can be extended to other sectors and other years by modifying the model to include regional pollution and energy-use data by source industry, including transportation-related industries. This modification will enable the model to analyze alternative energy and transportation policies in general (9).

3. The economics of the automobile industry in Michigan are being analyzed by the Michigan Department of Commerce.

MAJOR ASSUMPTIONS

Harris Model

The equations for forecasting output, employment, income, consumer expenditures, and other variables were fitted by using 1965-1966 cross-section data and partial 1970 data. For example, 1965-1966 and 1970 regional data on income, industrial output, and other factors were used to fit equations for each industry to predict its output in each region. As 1972-1973 data become available, the equations will be reestimated, and this reestimation will be used to update the coefficients of the equations. The equations have been used to make year-by-year forecasts from 1970 to 1990.

Firms attempt to maximize profits and minimize costs. This is a standard assumption of most econometric forecasting models.

The 1965-1966 data on demand by industry used in fitting the equations include direct county data on personal consumer expenditures, federal defense expenditures, and gross foreign exports (aggregated to BEA areas). But, for all other industrial-demand data (interindustry purchases by each industry, other federal purchases, and state and local government purchases), direct county data were not available, and so national technical coefficients (inputs per unit of output calculated from national data) were applied to county totals (12).

Firms attempt to minimize transportation costs. Except for rate differentials, firms are indifferent to the mode of transportation used in shipping goods.

By using a linear-programming method of computation, national and regional transportation data (shipments by size, weight, type of goods, distance, and mode of transportation) are converted to marginal transportation costs for each industry in each region. Truck and rail are the only modes considered because it is assumed that industry location will be influenced primarily by the availability of those two modes.

Linear programming is the framework for the calculation of the marginal transportation costs associated with a given level of shipments out of and into a region, which are important factors influencing industrial location and thus are important in the Harris model.

Polenske Model

The trade-flow table, which indicates interregional shipments of goods, and the table of interindustry technology, which indicates amounts of inputs per unit of output of each industry, are constructed by using 1963 data. As 1972 data become available, these tables will be reestimated to reflect the 1972 structure of trade and technology. The 1963 structure of trade and technology has been used to make predictions (assuming different levels of final demand) of 1970 and 1980 levels of output in each industry in each region and of interindustry trade flows between regions. However, neither the structure of trade between regions nor the structure of technology is generally stable over time, and thus long-run forecosts of trade flows are generally not very reliable. More work on trade-flow forecasts is necessary, and as new data become available, the model can be modified to allow prediction of changes in technology and trade structures over time.

The column-coefficient version of the Polenske model, which is the version discussed here, assumes that, for each region, the fraction of total consumption of a good in that region that is important from another region is the same for each industry in the consuming region. For example, if 10 percent of the steel used in Michigan is imported from Indiana, then this percentage is assumed to be the same for every industry in Michigan that uses steel. This is equivalent to holding each supplier's share in each region's consumption constant over time. As a result, the net transfer (outflow minus inflow) out of a region may be progressively overestimated (or underestimated) in each time period following the base year, if production and outflow are growing (or declining), but the percentage of a region's consumption of a good coming from each remaining region is held constant (13).

The regional trade data used in constructing the interregional trade-flow table include the value of crosshauls (shipments of the same good in opposite directions, e.g., the value of oranges grown in California and shipped to Florida and the value of oranges grown in Florida and shipped to California). Crosshauls are somewhat important because aggregation of several commodities into a single commodity class can obscure the differences in the composition of traded commodities. For example, if crosshauls of oranges and other fruit between Florida and California were not counted in the trade-flow table, but rather only the net transfer of fruit from one state to the other were counted, then important data on trade patterns would be obscured (13).

STRENGTHS AND LIMITATIONS

Harris Model

Regional supply and demand are interrelated because of the use of forecasting equations, which allows changes in the location of output and resources to take place between regions. This avoids the problem of many input-output models in which the use of predetermined levels of final demand does not permit the production of goods in a region to influence demand (14).

The model is deliberately designed to predict industrial changes over time. Changes in technological relations are also included by using the INFORUM model to generate national totals, which incorporates estimates of technological changes into its technical coefficients.

Transportation information including costs and the effects of alternative systems (at present only highway systems are included, but the model can be generalized to other modes) is developed in considerable detail, and thus the model is capable of evaluating the regional effects of alternative highway (and later, other modal) systems.

Forecasts are generated from equations that were fitted by using 1965-1966 and partial 1970 data. Forecasts of the industrial output of regions that had unusually good or bad production in 1965-1966 will be over or underestimated relative to other regions. (However, updating of the model to a 1972 data base is planned.)

The model forecasts the distribution of highway benefits between regions, but has not been used to forecast total national net benefits of alternative highway systems.

Polenske Model

The data base of the model is comprehensive as a result of extensive data gathering and analysis. Interregional trade-flow data include trade between regions in both directions (crosshauls) rather than only net transfers (9).

The regional input-output and trade-flow data are internally consistent with each other and with the Department of Commerce national input-output model and the Bureau of Labor Statistics final-demand projections. Thus the results of the model can be linked to subregional and subindustry studies and to national input-output studies that use Department of Commerce or Bureau of Labor Statistics data.

Regional supply and demand are not interrelated; they are estimated in separate steps. First, future levels of final demand are estimated, and then fixed technical coefficients (inputs per unit of output, estimated from base-year data and assumed unchanged) are applied to obtain output levels (supply) for each industry.

The model, as currently developed, does not allow trade coefficients, which indicate flows of goods into and out of each region, or technical coefficients to change over time, and thus is not generally reliable in providing long-range forecasts.

There is no explicit development of transportation costs or the effects of alternative transportation systems; the only transportation data are the interregional trade flows, which do not include data by cost of transportation.

CONCLUSIONS

This report has described and compared two multiregional economic-forecasting models to examine their usefulness in transportation planning. The Harris model is an econometric model that is designed for short-run and long-run forecasting of regional economic and population impacts of alternative transportation and other investments. It has been used to make year-by-year forecasts to 1990. It uses a set of forecasting equations that explain industrial location on the basis of the costs (including transportation costs) that firms face at alternative locations. The Polenske model is an input-output model that is designed for projecting interindustry purchases and trade between regions for selected years by constructing and using multiregional input-output tables. It is useful in forecasting short-run impacts of changes in trade patterns and industrial production.

An important question for transportation planners and policymakers is whether these multiregional forecasting models can be used at the state level, or with state-level (15, 16) and metropolitan models that have been developed.

The Harris model has been applied at the county and metropolitan-area levels to develop forecasts that can be used as control totals for country and metropolitan planning models. In a study to be conducted for the Federal Highway Administration, outputs of the Harris model will be extended to the level of detail commonly used as transportation-planning inputs in land-use models and trip-generation analysis; e.g., employment by categories and population by households. Also, outputs at the regional and county levels from the Harris model can be used with national technical coefficients to generate county-level input-output tables for use in regional transportation planning.

The Polenske model can be used at the state level by using its state input-output tables in statewide economic planning and forecasting. Thus, a state could use the Polenske model either as its principal planning model or in conjunction with other state or substate models. For example, the state of Michigan is using the Polenske model to study the economics of the automobile industry, which is an important component of the Michigan economy.

Both the Harris and Polenske models have several uses in transportation and other related areas and thus are practical and important methods of economic analysis. Both models are examples of the growing usefulness of large-scale economic modeling in the transportation planning and policymaking process at the national, state, and regional levels.

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Predicting the Impacts of Transportation on the Spread of Urban Blight

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Large-scale, urban transportation developments can affect the spread of urban blight through residential areas both directly and indirectly. Sources of blight and their specifications in filtering models are reviewed. Relations between transportation developments and sources of blight are considered to determine whether filtering models can be used to predict the impacts of a development. While none of the models is adequate for this purpose, they provide the basis for a procedure to consider a proposed development's impacts.

Transportation has long had an important role in the spatial organization of cities (12). This role is most clearly specified and generally accepted as a constraint on suburbanization at the urban fringe (5). Within the city, however, it is less clear, particularly with respect to the spread of urban blight. This role has been investigated through two approaches.

The more theoretical approach is that of the latter-day disciples of von Thünen (3), who suggest that the poor are the most sensitive to transportation costs and consequently live near the job-rich central business district. A reduction in cost of transportation by new developments would encourage the poor and their attendant blight to expand outward. This theory assumes that transportation costs are significant determinants in the household-location process, an assumption that has been empirically challenged by Stegman (48). Moreover, the direct relation between the spatial diffusion of low-income groups and the spread of urban blight has not been rigorously specified and remains open to question.

The more intuitive approach to examining urban blight is based on the filtering concept. As housing stocks expand and contract relative to the number of households, the population of the location is said to filter between neighborhoods as it seeks better housing or is forced into less desirable sections. This movement and its rates have been empirically observed (30). It is hypothesized that the forces that drive the movement of households also stimulate the concurrent spread of blight. The intuitive logic of this approach has been accepted in transportation literature (9), although the filtering concept was developed in response to other issues and has been challenged elsewhere (10).

This paper examines the filtering approach and its possible application to the estimation of the potential impacts of transportation on urban blight. Postulated sources of blight and their specifications in filtering models are surveyed. The relations between transportation developments and blight are then considered to determine the applicability of existing models of filtering. Finally, a procedure is advanced for anticipating the potential impacts of a major transportation development on urban blight.

SOURCES OF BLIGHT

Postulated sources of blight are as numerous as its definitions. Terms such as economic retardation and social viability have been used for over 50 years (54), but each definition of blight essentially focuses on a state of environmental deterioration that sooner or later develops a physical expression. Consistent with its origin in biology, blight is defined as a transitional state, rather than an end condition.

Most simplistically, urban blight is related to the aging of the housing stock although, while age is an important variable, it can be offset by local investment in home maintenance, as shown by stable ethnic districts and the traditional center-city enclaves of the rich. Age also presents spurious effects in studies of urban transportation impacts because older residential neighborhoods are usually located along historical transportation corridors (26, 34, 38, 53). The tendency of radial freeways and rapid-rail lines to follow these corridors exaggerates the effect of age in subsequent transportation-impact studies (9).

If maintenance expenditures can offset the effects of time on housing stocks, then the sources of blight should be identifiable from residential disinvestment processes, which are rooted in the shifting demographic patterns of the city and the consequent redistribution of capital.

Urban demographic patterns are surprisingly stable considering the high degree of residential mobility in the United States. The majority of personal moves are attributed to changes in the life stage of individual households and usually include changes in family size (44). Intrametropolitan moves tend to follow stable paths, as a neighborhood's out-migrants are replaced by households having similar characteristics (1). Neighborhood change can be introduced by abnormally high out-migration, reduced numbers of replacement households, or the desire and ability of a different group to successfully compete with traditional replacement families for the available residences.

Capital shifts, which reflect moving concentrations of investment resources, can cause or follow demographic shifts. Declining personal incomes in a neighborhood can erode the ability of its residents to meet maintenance costs. When lending institutions perceive this declining as a risk factor, they generally reduce the availability of capital for major maintenance and thus guarantee the neighborhood's physical deterioration (11). This disinvestment process can be triggered by influxes or dislocations of specific income or racial groups (20), by short-term strategies of residential investors (10, 47), and by long-term, profit-maximizing strategies of lending institutions that direct their assets to new construction in the suburbs (24). Whether triggered by shifts of people or money, the change introduced by shifting intraurban migration patterns is reinforced by local reactions to the influx of a new socioeconomic group (45).

Filtering models generally describe the flow of people—categorized by their income—between given stocks of housing. The degree to which such flows can be related to the disinvestment process determines the ability of these models to describe the spread of urban blight (a problem that is shared with the other approach to investigating blight). Filtering models, however, have the advantage of specifying a greater variety of push and pull forces on the migration of households, and these forces more fully represent the disinvestment process and its impacts on future housing stocks.

DEVELOPMENT OF FILTERING MODELS

Most filtering models are developed to justify the provision of low-income housing through the construction of new housing for the rich. As the rich move into the new housing stock, their residences become available to the poor, who enjoy a subsequent increase in residential quality. The poor are thus pulled into better housing as the rich are pulled into new neighborhoods. More recent formulations, less interested in rationalizing laissez-faire housing policies, focus on the pressure exerted by the poor to push into adjacent neighborhoods.

Both push and pull forces were described in the first major exposition on filtering by Hoyt (25). In attempting to identify stable neighborhoods for Federal Housing Administration mortgage support, Hoyt related centrifugal population shifts along radial sectors to the spread of blight from the city's core. Expanding housing stock at the periphery pulls the rich outward and reduces their desire to resist invasion by the poor across the inner boundary of the sector. Resistance to the invasion of the poor and the subsequent blight is found mainly in districts with strong historical and ethnic traditions (14). Disinvestment originates in the desire for new residences expressed by the rich (8) and market imperfections that force sale to lower income groups who are closer at hand (41). Undermaintenance and the division of dwelling units during the transition period generates blight and encourages the remaining higher income residents to abandon the neighborhood.

In contrast to the negative aspects of instability suggested by Hoyt and his contemporaries, the models developed in the following decades present filtering as a positive process that expands housing opportunities for the poor. Grebler's (17) empirical studies in New York stimulated a variety of mechanistic formulations based on the pull effects of expanding housing opportunities at the suburbanizing fringe. Fisher and Winnick (15) used Grebler's data to show that expanding the aggregate supply causes a reduction of rent in the inner city, which brings more housing stock into the financial reach of the poor. By assuming differentiated but stable quality, the arguments of this period focused on the ability of filtering to open adequate housing opportunities to the poor. Calls for public housing (40), urban-renewal projects (21), quasi-public development corporations (13), and keeping hands off (46) have been based on variations of the Fisher and Winnick approach. All of these studies, including the attempt by Weathersby (56) to optimize the process with linear-programming techniques, ignored the possibility that blight will accompany the filtering process and offset its benefits.

Lowry (33) presented the major consideration of the relation between blight and filtering when he showed that the high depreciation inherent to older neighborhoods during periods of expansion of new housing stock may encourage short-range investment strategies and undermaintenance. The existence of such strategies has been reported by Chatterjee (10), Smith (47), and Stegman (49). Declining rents open the neighborhood to lower income groups, but only as the neighborhood deteriorates physically. Lowry suggests that first blight and then filtering follow the shifting opportunities, with questionable benefit to the poor.

Only recently have discussions of filtering considered the push effects inherent in Hoyt's formulation. Racial and economic constraints have trapped a growing population in the inner cities, and this group is now slowly pushing into older middle-class neighborhoods (2, 36, 39, 43). Grier (20) postulates that major dislocations of the poor by public works (specifically the Baltimore expressway system) will generate enough pressure to accelerate ghetto expansion and the exodus of higher income groups. The subsequent loss of property taxes from the demolition within the city and the retreat from it will decrease the resources available for public efforts to arrest blight. Harvey (23) suggests that the exodus applies only to the middle-income groups who lack the political and financial power of the rich. Unable to resist ghetto expansion or push the rich outward themselves, this group is forced into the suburbs.

Each of these formulations of the filtering process partially addresses the sources of urban blight. Models based on the pull of shifting opportunities describe the demographic shifts that result from excessive out-migration or a lack of similar replacement households. The ability of different groups to successfully compete with similar replacement households is suggested by the invasion models driven by push effects. These models remain descriptive and symptomatic and leave the link between demographic and capital shifts ambiguous. Lowry and Grier are exceptions, in their respective arguments that blight is triggered by the undermaintenance inherent in short-term investment strategies and the influx of low-income groups with their lesser ability to meet maintenance costs.

Can these filtering models capture the impact of transportation improvements on the spread of urban blight? The relations between transportation and the sources of blight are now examined to evaluate the use of filtering models as predictive, transportation-planning tools.

TRANSPORTATION, FILTERING, AND BLIGHT

Charles River Associates (9) have suggested several ways in which transportation decreases the productive value of property and thus affects the spread of urban blight. They argue that transportation developments cause:

1. Condemnation of existing housing stocks,
2. Proximity effects of a noxious facility, and
3. Shifts of housing opportunities to the suburbs.

It is hypothesized that these direct impacts generate the secondary impact of spreading urban blight through filtering. The first two direct impacts are most commonly the results of land-extensive freeways, although major joint-development projects undertaken with rapid-rail transit have the same effects. Both freeways and rail service are associated with the third impact.

The push forces from the removal of housing stock by condemnation for rights-of-way exert the greatest pressure on the inner city because many high-volume transportation facilities pass through this area of high population density en route to the central business district. Moreover, inner-city residents are the least able to move out of their current environment because of their income and race. Given a stable demand for inner-city housing, the decreasing supply of inner-city housing stock will stimulate increasing rents. Often, the poor can only meet rent increases by doubling up households in existing units. This is most easily done in unsubdivided houses at the fringe of the blighted area. Blockbusting (43), race riots (23), and other activities (29) all help to realize the push of blight following the dislocation of the inner-city poor.

The direct impacts of condemnation are not limited to the residents of blighted areas. Many low-income ethnic groups are held to the inner city by cultural bonds rather than by racial or related constraints (50). These cultural bonds are often dependent on the physical infrastructure, such as a local school, church, or park. Disruption of its critical infrastructure can destroy a neighborhood's cohesiveness and scatter its residents, as shown by some urban-renewal projects in the last decade (4, 18). The neighborhood-based financial institutions that support these ethnic neighborhoods disappear with their clientele (23), leaving the neighborhoods without capital for maintenance as the adjacent residents of blighted areas invade.

The proximity effects of a noxious facility are similar to the effects of condemnation for that facility with one major difference: proximity effects encourage, rather than force, dislocation. As a consequence, groups with stricter constraints on residential location will be less able to escape the added noise, air pollution, and safety problems created by increasing through-traffic. More affluent residential areas can offset proximity effects through larger setbacks and other physical buffers that are available in lower density areas (52), which have not shown significant sensitivity to these effects, at least with respect to property values (16, 27). The residential instability caused by proximity effects is potentially highest in the low-income, high-density, nonblighted neighborhoods that are harder to buffer and relatively easy to escape, as described by Harvey (23).

In contrast to the effects described above, transportation developments pull blight outwards according to the third hypothesis by Charles River Associates (9). This hypothesis must be considered in two stages: First, do transportation developments cause residential and employment opportunities to shift to the suburbs? If this can be established, does blight necessarily follow the centrifugal trend?

At least since Hurd (26), analysts have confidently attributed the city's spread to transportation developments. In earlier works, the role of transportation is considered as analogous to that of a skeleton, which provides a framework around which activities can be organized (38). Enlarging the skeleton increases the area available for new employment activities and housing stock. More recent works focus on transportation as a circulation system that provides the links between activities (53). Faster links allow greater distances between activities and thus expand the area for new housing stock. According to Barden and Thompson (5), both the skeletal and the circulatory roles of transportation determine the urban frontier and, by implication, the extent and spread of the housing stock within that frontier.

This view of transportation as a determinant of the limits of urban growth has intuitive appeal, but lacks validated evidence. Other forces have also acted on suburbanization, the dominant form of recent urban growth, during the period of urban freeway construction. Cheap loans backed by the Federal Housing Administration have been one of the many inducements for expanding new housing stock in suburbia. Of the many highway-impact studies summarized by the Federal Highway Administration (53), none have attempted to disaggregate the concurrent forces that can influence housing-stock expansion independent of freeway development. While few refute the constraint on a city's spread by the skeletal function of transportation, the degree to which its circulatory role stimulates or constrains housing development remains unspecified.

Advocates of a dominant role for transportation in urban expansion cite the suburbanization of truck-dependent industry as a major inducement to freeway-caused housing-stock expansion. Hammer, Siler, George Associates (22) offer some of the more convincing evidence that freeway developments have been a major force in decentralizing industry. For this to cause housing to follow, however, requires a greater employee sensitivity to the journey-to-work distance than has been found in recent studies (19, 48).

The view that better circulation will encourage residential expansion assumes that households tend to allot constant amounts of time to travel. However, the only attempt to verify this assumption (58) used cross-sectional data to confirm a temporal phenomenon with questionable curve-fitting techniques, and so the assumption remains inadequately tested.

Even if the impact of transportation on urban expansion could be specified, the use of filtering models to predict a subsequent pull on blight is questionable. Filtering models are particularly weakened by their deterministic nature. The flow of housing-stock ownership between categories of households must be free and continuous, yet many imperfections of the housing market are known to operate in opposition (10, 35). An attempt to capture these many imperfections would be susceptible to the problems associated with large-scale urban-development models enumerated by Lee (31). Indeed, forces such as Firey's historical prestige can be modeled only by superficial descriptions or probabilistic techniques, both of which tend to stress symptoms rather than causes (42).

These problems are compounded when the process of blight is added to filtering models. It has not been proven that the forces that drive filtering also generate blight or vice versa. For example, a factor such as differential property taxes may generate blight without stimulating a filtering process (32). Transportation impacts are entangled in the complex interplay of urban processes beyond our present ability to fully extract them.

PROCEDURE FOR PREDICTING TRANSPORTATION IMPACTS ON BLIGHT

Thus, the filtering concept appears to have limited application to predicting the impacts of transportation on urban blight. The relations between transportation and blight have not yet been rigorously identified, but the potential for transportation developments to influence the spread of blight remains and should be considered in the planning process. The simple tabulation of dislocated households and businesses by income, race, or area is inadequate to this task. An alternative procedure is now suggested.

The proposed method focuses on the low-income groups directly affected by the planned facility and their push effects on peripheral, middle-income areas. It is assumed that the inner-city population is most directly affected because the majority of urban transportation projects are located in their neighborhoods. It is also assumed that the wealthy will successfully resist the effects of noxious facilities and the invasion of lower income groups (23, 57). Pull effects exerted by expanding housing stock are considered unpredictable in view of the previously suggested complications.

The first phase of the suggested procedure identified blight-sensitive areas. Because blight tends to spread contiguously, existing blighted areas are identified first. The most common method for delineating such areas is based on social indicators, as discussed by Bixhorn (6). Once the boundary of existing blight is located, adjacent areas exhibiting current instability can be identified by high turnover rates and shifting socioeconomic characteristics, by using indicators similar to (but independent of) the blighted-area delineators. This areal classification will normally be limited in detail to census tracts. During this phase, the number of housing units available in each neighborhood (census tract) at a given time interval is tabulated by income and racial or ethnic constraints.

The second phase of the procedure identifies areas and populations that will be directly impacted by the planned facility. The special-area-analysis procedure for examining dislocation effects (51) outlines a method for delineating rights-of-way condemnation areas. These areas are then expanded to include all proposed joint-development projects that would dislocate the local population and their infrastructure through direct redevelopment or rehabilitation induced by property-tax increases (37). Thc dislocated population is categorized by the characteristics relevant to the housing-unit constraints used in the first phase. This population includes households suffering intense proximity impacts (primarily noise, vibration, and dirt). Proximity impacts from construction as well as the completed and in-use facility are considered (55). Public and quasi-public facilities destroyed or heavily impacted are also listed if they represent a critical infrastructure for the location population (28).

The third phase of the procedure compares the blight-sensitive areas delineated in the first phase with the directly impacted populations and infrastructure delineated in the second. The potential direct and indirect impacts of the planned transportation facility on the spread of urban blight can be traced through the following nine steps.

1. For nonblighted neighborhoods, the dislocation of households and the physical infrastructure critical to the neighborhoods's cohesion is tabulated. Dislocations caused by right-of-way acquisition and severe proximity effects are included. If an insignificant number of households and no infrastructure are effected, proceed to step 6.

2. Dislocated households are matched with available housing stock in areas that are not sensitive to blight. The matching is based on financial, distance, and racial constraints. The dislocated population thus accommodated is assumed to move without adversely affecting their new neighborhoods. Their old neighborhood is reclassified as sensitive to blight. Step 3 is now considered for the population thus accommodated, and step 4 is considered for households unable to find homes in nonblighted neighborhoods.

3. The ability of the local infrastructure to survive the departure of households in step 2 is evaluated. (For example, would local school enrollments drop below the minimum threshold for continued operation?) If some of the infrastructure fails, return to step 2 for households that would subsequently consider leaving. If the infrastructure does not fail, proceed to step 6.

4. If the housing stock available in blight-sensitive areas can accommodate the still-homeless population, proceed to step 5. If not, the local population will probably not leave their directly impacted neighborhoods, and the potential for local blight will increase. If housing opportunities open up at a later time, the population will probably move, and the neighborhood will become blighted. Proceed to step 6.

5. The ability of the infrastructure in blight-sensitive neighborhoods to accommodate in-migration is considered. [Chapter 8 in Boyce and others (7) is an example of this.] If the infrastructure becomes overburdened, the local population suffers dislocation. For this indirectly impacted group, return to step 2.

6. When all affected populations in existing areas of blight have been considered, the analysis is terminated and documented. Otherwise, proceed to step 7.

7. If the housing stock available in blighted areas can absorb the households dislocated by both the planned facility and ancillary projects without increased subdivision of housing units, the analysis is terminated and documented.

8. The ability of the dislocated population to push into blight-sensitive areas is evaluated in terms of the existing demographic and financial stability of those areas. If the push is unsuccessful, an increase in the population density of the blighted areas will probably occur, which also increases the potential for conflict and greater social pathologies (43).

9. The results of a successful push into blight-sensitive areas are evaluated by focusing on property values and rent adjustments. If values must drop to accommodate the invading population, the transition will have a large and immediate potential for blighting the neighborhood. If the invading population can pay existing values and rents, the transition should be relatively orderly and have a lower potential for inducing the spread of blight, provided there is appropriate public intervention and support with respect to capital availability. Proceed to step 5.

Once potential areas of transportation-induced blight are determined, the long-term impacts of a project can be more fully incorporated in its evaluation. If the project is approved and implemented, plans can then be laid for careful monitoring of neighborhood changes, and public intervention strategies can be prepared to arrest the potential blight before it spreads. Such strategies can include the provision of low-income housing, various financial-assistance programs, and direct replacement of the infrastructure.

CONCLUSIONS

This paper has examined several hypothesized impacts of transportation on the spread of urban blight. Models of filtering in the housing stock have been considered as a way to describe and predict those impacts, but have been found to be inadequate, and an alternative procedure has been proposed.

The precise impact of transportation on the spread of urban blight remains obscure, but the need to address the potential impact is important. The procedure outlined here is designed to consider the negative consequences of a proposed facility and provide adequate warning for the prevention of those consequences.

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Insights Into the Practice of Joint Development: Lessons From Experience

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Case studies of joint-development projects in six states and one Canadian metropolitan area were conducted for the Federal Highway Administration. Land acquisition associated with joint development, the extent to which highway agencies and other public bodies acquire more land than is actually needed for specific facility sitings, and the incidence of complementary public and private development projects on the surplus land were evaluated. Examination of the literature showed severe legal, financial, political, and institutional constraints that restrict this form of expanded acquisition and subsequent joint development. At the same time, however, numerous individual projects are being undertaken and somehow circumventing the constraints. The case studies examined over 35 specific projects completed or planned in Arizona, Florida, Kentucky, Maryland, New Jersey, and Nevada and a large number of developments on surplus land of the Toronto subway system. The studies showed situations where the highway or transportation agency was used as an arm of general-purpose local government in undertaking expanded acquisition. Many of the successful examples illustrated special administrative and financial arrangements between local government and the transportation agency for the acquisition and disposition of the land, unique institutional solutions for planning and implementing projects, significant support from public opinion, and a high quality of technical and political leadership.

Joint developments of public and private facilities associated with transportation systems have, for at least a decade, been a subject of some interest to federal and state transportation planners and professionals from a variety of disciplines. The term joint development has been defined in many ways. Essentially, it means projects related in space and time to the construction of a highway or a rapid rail line. The projects can range from public works (schools, fire stations, or parks) to commercial ventures (office buildings, hotels, or factories). The locations of these projects are related in space to the transportation facility (over, under, adjacent to, or within an immediate-impact corridor), and their construction is related in time (simultaneously, or relatively soon before or after) to the construction of the transportation facility.

Functionally, joint-development projects are in some way dependent on the transportation facility. A need for access to it is the most common form of dependency. Mitigating the impact of the facility on a neighborhood or community is—in the case of parks and social services—another functional tie.

The institutional context for joint development is invariably complex. The transportation agency plays a critical role in planning or in providing a site. Other public bodies are involved in financing or in processing approvals. Citizen groups and (in the case of commercial reuses) private entrepreneurs are also participants.

Much of the interest expressed in joint development has come from persons who view it as a way to balance, for public benefit, the land-use impacts of highways and rapid rail and to mitigate the adverse environmental, economic, or social impacts of transportation facilities on communities.

This interest has been discussed in numerous conferences and papers (1, 2). The Federal Highway Administration (FHWA) has provided some tangible support by

1. Making certain aspects of joint development eligible for administrative and financial participation (the highway act contains authorization for participation by highway agencies in various complementary facilities ranging from hiking and bicycling paths to replacement of public facilities acquired for highway use, the program manuals contain basic administrative provisions regarding highway agency participation in joint development, and the Mass Transportation Act of 1974 has certain provisions, which are as yet unfunded, enabling federal financial support to joint development in mass transit corridors) and
2. Funding several joint-development planning efforts involving Interstate highway corridors or impact areas, including the Baltimore concept team, and studies in Pensacola and St. Petersburg, Florida; and Reno and Sparks, Nevada.

Some states (e.g., Arizona, Nevada, Florida, and New York) have passed enabling legislation allowing their highway departments to participate in various aspects of joint development.

FHWA has published a catalog of joint developments (3), which identifies projects that have been planned or constructed across the country. This catalog is now in the process of being updated.

Although there has been extensive discussion of joint development as a concept, the results of actual efforts have not yet been formally evaluated. Have federal policies and programs to encourage joint development been consistent? Have they been effective? What factors bear on the success or failure of projects attempted under existing legislative authorizations? What can the experience of actual projects tell us about how well or how poorly existing mechanisms work? If joint development is to be an objective of national transportation programs, does experience suggest that changes are warranted at the federal or state level?

In 1976, a number of case studies of actual projects where joint development had been effected or planned were evaluated for FHWA. This was not the full-scale program review and evaluation suggested above. Rather, it focused primarily on one aspect of the process—land acquisition. Nevertheless, in view of the overall information gap that currently exists, some of the findings and conclusions from these case studies may be of particular interest because they can suggest certain factors that are required to establish effective joint-development projects and provide insights as to possible new policy and program approaches.

The evaluation dealt with joint development on surplus land adjacent to the transportation right-of-way. It was a part of a larger study and literature review on the subject of excess or expanded land acquisition by transportation agencies and other public bodies (4).

Four types of acquisition were examined—remnant and remainder purchases, land purchased to protect a facility or to protect an area from the impacts of a facility, land purchased expressly for recoupment of facility costs, and land purchased expressly for siting public or private projects complementary to a major facility.

Data from the larger study showed that there is little expanded acquisition, except by highway agencies, and that even highway-agency activity is seriously constrained.

Legal constraints arise from the strict interpretations of public use that are maintained in state enabling legislation and by the courts. Unless legislative mandates expressly include complementary facilities, clear transportation purposes must generally be demonstrated as the basis for acquisition. Moreover, the courts generally strike down attempts to purchase for recoupment of costs by resale.

On the fiscal side, the restricted budgets of most public agencies, including highway agencies, generally limit acquisitions to the land necessary for a specific facility site, even when broader mandates are available.

The public mood of increasing mistrust of governmental action and the public awareness that land acquisition has been and can be a source of corruption have also served to limit flexibility.

These constraints have been internalized by the executives of highway and other public-works agencies. Acquisition roles are seen as restricted to mandated responsibilities, not as part of a larger community-development framework.

The overview emphasized the constraints and limitations and concluded that surplus lands available for joint development would be accidental or the affect of particularly favorable local circumstances.

At the same time, numerous projects are apparently being attempted across the country despite the constraints. Here is the significance of the case investigations. FHWA wanted to know the legal, financial, political, and institutional dynamics of these projects. What kinds of uses were being developed? Were there any common lessons to be learned?

CASES

The cases selected for detailed field investigation came from six states and one Canadian jurisdiction, metropolitan Toronto. Joint development on surplus land of the Toronto subway system was included for comparative purposes.

All together, 13 separate jurisdictions were represented, and 35 individual acquisition-and-reuse projects were examined—exclusive of Toronto, where over 20 private developments have been built on surplus land. All of the U.S. cases involved acquisition associated with major Interstate, toll road, or Appalachian highways. All but one were situations where the highway agency was the primary or sole acquisition body. In many cases, new developments already exist on the land. The others are planned or programmed for construction. Although private commercial projects are represented, the largest number of joint developments already existing are for public and community facilities (except in Toronto). The public and community facilities are quite diverse, however, and illustrate the range of services suitable for land adjacent to a highway.

The U.S. projects examined are listed in Table 1.

LESSONS LEARNED

Legal Framework for Expanded Acquisition

The case studies reaffirmed that transportation agencies operate under several legal constraints in exercising expanded acquisition. Yet four cases demonstrate significant departures from these constraints. In each of these, the transportation agency was used as the administrative vehicle for acquisition, without necessarily holding title to the land, because the local elected government had determined that expanded acquisition to capture for the public the benefits of facility impact was a public purpose. In each, general-purpose government supervised the entire process of right-of-way acquisition for the transportation facility and the surplus land and entered into the process as a financial partner.

1. Pensacola: In Pensacola, the city council has signed a cooperative agreement with the Florida Department of Transportation (FlaDOT), which is acquiring land for the I-110 spur. In accordance with a joint-use corridor plan funded by FHWA and approved by the city, FlaDOT is acquiring impact parcels whose reuse for public and private facilities is established by the plan. Ownership of the land outside the highway right-of-way is vested in the city of Pensacola, however, and the city reimburses the state for the cost of the parcels over and above the appraised severance damages. Some joint uses will also occur on actual right-of-way land that remains in FlaDOT ownership. FlaDOT must justify these takings from the transportation standpoint.

2. St Petersburg: St Petersburg has signed a cooperative agreement similar to that signed by Pensacola.

3. Baltimore: In Baltimore, the cooperative process has been carried a step farther. All land acquired for Interstate highways must be approved by the city council and is owned in fee by the mayor and the city council. The Interstate Division of the Maryland Department of Transportation (MdDOT) for Baltimore is both a state

Table 1. U.S. projects.

Location	Route	Project
Maricopa County, Arizona	I-10	Flood control
Pensacola, Florida	I-110 spur	Public facilities (fire and police maintenance yards and community services); private facilities (shopping center, motel, and industry)
St. Petersburg, Florida	I-275	Maintenance facilities, parks, and flood control
Pikeville and Pike County, Kentucky	Appalachian Corridor B	Housing and industrial and commercial development
Baltimore	I-70N and I-95	Industrial and warehousing development
Montgomery County, Maryland	I-270 and I-370	Public facilities and transit
Prince Georges County, Maryland	I-495	Capital Centre Arena
Monmouth County, New Jersey	Garden State Parkway	Garden State Arts Center
Reno and Sparks, Nevada	I-80	Health center; Junior Achievement and Girl Scouts; parks; air rights for casinos
Las Vegas, Nevada	I-15	Recycling center; employment-security office; parks and playgrounds

and a city department. As a state agency, it receives state and federal transportation funds and is subject to all design and funding requirements of both governmental levels. As a city agency, it becomes an acquisition and development arm of the city government, and highway takings are owned in the same manner as any other municipal public land. This arrangement has enabled the mayor and the council to determine the condemnation lines for highway rights-of-way within the city. Joint-development planning often precedes the drafting of condemnation ordinances, which are adopted after public hearings.

In establishing condemnation lines, the city has generally considered the street nearest to the right-of-way as the maximum taking boundary. In so doing, some portions of the land within the boundaries do not meet state or federal financial criteria for right-of-way acquisition assistance. The city has legally justified its supplementary acquisitions through the broad set of public purposes available to it, including economic development, and has pooled its funds with those of the highway agency and used the Interstate division as the acquisition mechanism.

4. Toronto: The legal structure for subway right-of-way and surplus acquisition in Toronto is similar to the land-acquisition situation in Baltimore. The metropolitan council, the general-purpose government, establishes the alignment, which is approved by the province, and makes the acquisitions in its name by using the mechanism of a subway-property committee. This specially constituted agency includes representatives from both the metropolitan council (its planning and property departments) and the transit commission. Land surplus to the actual design requirements of the subway is included in the takings with the understanding that it may eventually be used for nonsubway development.

But even in Toronto, at least portions of all properties acquired must be justified as absorbed by the facility, its access, or support installations or because the facility eliminates their access or use. The taking of adjacent or nearby properties that are not directly impacted is disallowed. Even general-purpose government does not extend its legislative mandate very far.

5. Pikeville, Kentucky: The case of Pikeville demonstrates a broadened interpretation of taking authority, backed by a special form of legislative mandate. This is the Pikeville-Cut-Through where, under the umbrella of a model-cities program, the city acquired land for a complex multiagency project involving an Appalachian Development Highway and a Corps of Engineers river diversion. The Kentucky Bureau of Highways and a major railroad company will ultimately occupy portions of this land, which they will acquire from the city, and the excess land will be used for industrial development and other private and public uses. A major factor here is the Appalachian Regional Commission, which was specially chartered by Congress and the Appalachian states to assist in the economic development of this depressed area. The Appalachian Development Highway Program has economic-development purposes as well as transportation justification.

6. Monmouth County, New Jersey: Possibly the most striking example of legal constraints is that of the Garden State Arts Center. The New Jersey Highway Authority is a semi-autonomous builder of toll roads, financed by user charges, whose enabling legislation allowed it to build and operate park facilities related to the highways. The authority, with little interagency discussion or public participation, acquired land and built a large performing-arts facility to provide commercial as well as free entertainment. At first, the state legislature was unresponsive to public charges that the authority had exceeded its powers but in 1968, when the center opened and was found to have cost four times the originally announced estimates, acted and amended the authority's statute to forbid any future undertaking not directly related to highway purposes.

Financial Framework for Joint Development

Acquisition

The process of evaluating each potential land purchase by state and federal right-of-way officials and determining the portion that can be financed or assisted by the various levels of funding is complex and time-consuming. This is partly a function of the regulations and partly because of the general scarcity of funds. Marginal takings or takings more directly related to the joint-development objectives of the highway program, even when authorized by federal legislation (e.g., bikeways and miniparks), are carefully scrutinized and often dropped from consideration.

Several cases, however, demonstrated willingness by both federal and state officials to execute cooperative financial agreements or arrangements for land purchase with local authorities. These agreements allowed the executing transportation agency to expand its right-of-way acquisition into lands designated for nontransportation public purposes by the local community and then be reimbursed by the community. The variety of local funding sources merits comment.

1. In Pensacola, the city designated $1 000 000 of federal revenue-sharing money for joint-development land purchases. This was used to reimburse FlaDOT for total takings over and above what would have been paid for severance damages.

2. In St. Petersburg, the city council will make appropriations from its general fund, also totaling about $1 000 000, for similar arrangements with FlaDOT.

3. In Baltimore, the city has used the proceeds from an economic-development-agency bond issue and general-

fund revenues to enable the Interstate Division to purchase land beyond the minimum right-of-way.

4. In Kentucky, the city of Pikeville has used a variety of financial resources to pool with highway money: These include Appalachian Regional Commission grants and loans, money from the U.S. Department of Housing and Urban Development's Model Cities and Urban Renewal programs, and commercial bank loans and local tax revenues.

Disposition Financing Arrangements

The cases showed a wide variety of financial arrangements governing disposition.

Private Use

Three cases dealt with private-facility use of expanded acquisitions where project arrangements have already been made: Baltimore; the Capital Centre Arena in Prince Georges County, Maryland; and Toronto.

Baltimore is the one case where properties have been sold. These were negotiated purchases by private developers, from the city's economic development agency, at the market value for industry and warehousing. The city would have preferred to lease the properties, but legally cannot subordinate. The revenue from the sales and the taxes are returned to the general fund of the city. Several years ago the Maryland State Roads Commission sold a 0.52-km^2 (128.5-acre) remnant tract to the Maryland-National Capital Park and Planning Commission (MNCPPC) for about $300 000. This later became the site of the privately owned Capital Centre Arena. Now, MNCPPC has executed a 40-year lease with the builder and operator. In less than 10 years, the annual rent will have repaid MNCPPC the land purchase cost and, at the termination of the lease, the arena reverts to MNCPPC ownership. Beyond this, an admission tax, which thus far has amounted to about $1.5 million/year, goes to the local government, Prince Georges County. A real-estate tax payment will also be levied, but the precise amount and manner of payment are currently in litigation. Regardless of the final legal judgment, this payment is estimated to be at least $300 000/year.

In Toronto, the municipality can subordinate and has leased more than 22 parcels for private developments, most of which are high-value, commercial projects. The leases are executed for 33 to 50 years, with a right of one-time renewal. Market rents are charged. The improvements are taxed at full value, and the land is also taxed, with a reduction in the full value that is dependent on whether or not there is some subway use of the surface or the subsurface. All revenues are returned to the general fund and, at the expiration of a renewed lease, all improvements will revert to metropolitan council ownership. The Toronto projects have been profitable both to the municipality and the private entrepreneurs, who are not required to put capital into land. It is estimated that the full costs of right-of-way acquisition for the subway system will be repaid by lease revenues during the 1980s.

A lease arrangement is also planned for Pensacola. FlaDOT has executed a 55-year lease with the city for all of the land in its ownership where either public or private joint developments may take place. The omnibus lease is for $100. In turn, the city will sublease to private firms and public and community groups. The private leases will carry market rents that, under the cooperative agreement with FlaDOT and FHWA, will be contributions to the city's transportation system.

Public and Community Use

Some states have requirements of market rental or sales to public or community, as well as private, users. However, most of the cases illustrate sensitivity to the needs and limited budgets of nonprofit agencies. Indeed, many of the public-serving facilities could not be located in such accessible sites without some form of land subsidy. All of the several community and public facilities along the Nevada highways pay $1.00/year rentals to the state highway department. Toronto sold a parcel to a public-housing corporation for less than the land could bring on the open market. Pensacola plans to assess nominal rentals for facilities, such as community buildings and a school-board maintenance center, anticipating a market return from eventual private facilities on the joint-development sites.

Arizona has elected to grant permanent easements at no cost to the flood control agencies that have erected area-protection works on the excess acquisitions in Maricopa County. Land title remains with the highway department.

Institutional Framework for Joint Development

Despite the legal and financial restraints that severely limit the flexibility of the expanded-acquisition technique, the cases demonstrate several successful examples of joint-development projects. These are existing or programmed land uses on the acquired sites, compatible with both the transportation facility and the surrounding community. Many factors in the relative effectiveness are institutional.

Organizational Structure

One of the most significant factors is the organizational structure established to deal with the acquisition, planning, marketing, and disposition processes. Most successful cases have involved some formal interagency mechanism that coordinates or directs the process. This mechanism may or may not exist at the outset of acquisition but, if it does not, it will be created at some point in the situation when all parties realize that traditional liaison arrangements do not work. These are not traditional projects for either federal, state, or local agencies. Each entity has its statutory or administrative responsibility, which represents a piece of a puzzle that must mesh with the other pieces. The nature of the directing mechanism varies from case to case and reflects the peculiarities of local circumstances.

1. Toronto: In Toronto, the mechanism is the subway-property committee, which reports all acquisition, planning, and disposition decisions directly to the decision-making metropolitan council. The committee is composed of representatives from the planning and property departments of the council and of the Toronto Transit Commission. It is a one-stop shop and acquires land, recommends disposition, receives bids, reviews plans, and expedites development.

2. Baltimore: In Baltimore, the Interstate Division of MdDOT functions both as a state agency (subject to state and federal highway requirements and receiving funds from both) and as a city department. It reports to the mayor and council, handles acquisition and disposition, and contains the joint-development planning team, through which liaison to other key city agencies is effected.

3. Pensacola: From the very beginning of the I-110 spur planning process, an interagency coordinating com-

mittee was established, including state and federal representatives as well as city departments. The nature of the committee has changed and evolved over time, as has its name. But all parties are represented, and periodic conferences are held throughout the implementation stage of the highway and its joint uses.

4. Capital Centre: Although MNCPPC coordinated the project, a formal six-party memorandum of understanding was signed among the governmental agencies and private individuals most directly involved in building the arena to guide implementing actions. A special interagency task force implemented the agreement.

5. Pikeville: In Pikeville, the joint-use projects are not yet established. However, the special legislation that enabled the Corps of Engineers to participate in the program mandated that corps funds be used only if an interagency agreement was signed among the corps, the city, the State Bureau of Highways, and the Appalachian Regional Commission. An interagency coordinating committee, with technical support by a consulting firm, meets monthly.

6. Nevada and Arizona: There are two notable exceptions to the above conclusions. Projects both in Nevada and Arizona may be considered successful from a joint-use standpoint, although no special mechanism was established in either state. While these developments in each state required several years, they were nevertheless accomplished to the general satisfaction of all parties involved through normal governmental channels. The projects in both states were relatively simple and noncontroversial.

Continuity and Quality of Technical Leadership

Regardless of how well structured an organizational mechanism may be, without committed, knowledgeable staff leadership maintained over long periods of time, little will be accomplished. Such leadership is particularly important in joint development because of the time-consuming issues of intergovernmental, community, and developer relationships; the web of highway and other regulations; and the funding uncertainties involved. In each of the successful cases, such leadership and its continuity were demonstrated in the highway agencies at state and federal levels, in the local governments, and among the community leaders who were willing to follow through arduous project reviews until completion of facilities.

Role of General-Purpose Local Government

The more complex and controversial the projects, the more critical has been the role of general-purpose local government. This role is played out in diverse ways. Fundamentally, however, it is a political role. In matters as sensitive as these, dealing with the fabric of the community, it is the elected local officials who are the most responsible for that community. Authority and responsibility have been delegated to them, and they answer to the ballot box if these powers are abused. They have far more discretionary actions available than a transportation agency staff or a state or federal department.

From a structural standpoint, also, local government is critical. It can bring to bear a broader array of public purposes and uses (under the police power) than can a transportation agency. Local government has various forms of fiscal resources—taxing powers, borrowing powers, and revenue sharing—that can, if funds are available, supplement those of the transportation agency. Local government can make ordinances governing the use and control of land that can shape the market in respect to the location of transportation impact. It can readily assume a directing or coordinating role.

Public Support

A corollary to the commitment of local government is the commitment of public opinion. The more complex and potentially controversial the projects, the more essential it is for an articulate body of public opinion to approve the actions of the local government. This has occurred in Pensacola, where a broad spectrum of opinion from the chamber of commerce to the black community most directly impacted by I-110 has vocally supported the joint-development and expanded-acquisition efforts. It has also been true in Toronto, Baltimore, and the Capital Centre where local government actions that were or could be controversial were approved by important groups in the community.

Land Scarcity: Importance of the Market Mechanism and Public Regulation

No one will claim that joint development is an easy process. On the contrary, it is complex, costly, time-consuming, and fraught with red tape and uncertainty. From the standpoint of the private developer, whose financial equation is constrained by time as well as money, it can well be a process to be avoided if there is a viable alternative. If development sites are available and zoned within reach or view of a highway interchange, why bother with battling the bureaucracy? Why bother looking for land that, in both the Nevada and Florida contexts, carries with it the proviso that if the highway agency determines a necessary highway use within the time frame of a lease, the owner will be forced to vacate his facility (in Nevada, without compensation)? Private builders and developers have generally answered the question by clustering as closely as possible to the transportation facility, without occupying land owned by the public agencies. Other sites are easier, less costly, and preferable.

The cases suggest that certain factors are essential for successful private development. When the market for sites is strong, and sites are available only or primarily through joint development of publicly owned land, private enterprise will respond, negotiate, and build.

In the U.S. context, the air-rights developments of casinos at Reno and Sparks and the industrial projects in Baltimore bring this conclusion into sharp perspective. In Reno and Sparks, the demand for gambling casinos is high, and their profitability is great. The only sites zoned for such uses in the central areas are along the highway. No others are available without going further from the core. Most land in the core, however, is already built-up. This led private entrepreneurs in Reno to negotiate an air-rights lease to build a platform over the highway for a casino. In Sparks, the owners of an existing facility adjacent to the roadway were prepared to go through an arduous negotiating process to extend under the highway as the only expansion alternative. Neither of these operations has security of tenure: Leases are for a 5-year period, and the highway department can demand vacation on 90-d notice. But the profits are worth the risks.

Baltimore is a less extreme, but equally informative, example. Through a long and complicated process that involved the cooperation of an economic-development agency and the Interstate division, sites for industrial uses immediately adjacent to highway interchanges were recently made available. These are among the few such sites available in the built-up central city. Some have been sold, and one is already occupied. Desirable private uses have been established. But, despite longstanding efforts by the public agencies to market these sites in advance of their availability, these private commitments were not made until the availability was imminent. Here too, the private market responded, but to an immediately realizable time frame characteristic of the private development process.

At the Capital Centre, a regional demand for an arena combined with the extraordinary accessibility of the site to warrant the private effort.

In Pikeville, Kentucky, there is no physically and economically developable land available for major private commercial developments or housing, except that which the reconstruction efforts of the joint-use project will provide.

Of all the cases, Toronto best illustrates both the potentials and the problems. Since the early 1950s, rapid economic growth has produced a demand for central-city office, commercial, and hotel structures. But the central city was already built-up, and few land parcels could be assembled privately. Then the subway came and provided even more concentrated population and business demands in key locations within the core. However, the subway-development process resulted in the assembly of cleared land at or near the stations that, either as total parcels or in combination with nearby privately owned land, could become the sites of high-density commercial facilities. The market combined with the availability of these sites to make worthwhile private entrepreneurial dealings with the complexities of governmental ownership and review.

The Toronto experience is instructive also from the standpoint of local governmental development regulations as a factor in producing scarcity. The city of Toronto added to the attraction of the subway-oriented sites by providing bulk and density bonuses for those locations that were not generally available elsewhere. Indeed, this bonus system worked so well that, in the present climate of political backlash against intensive growth, it has been eliminated and replaced by height limits that make new subway-oriented development economically unfeasible.

Most of the uses examined in these cases have been public facilities or community services, which are not constrained by the market factors that govern private-enterprise decisions. All of those identified require land that is readily accessible to major transportation routes at prices that public and community-service budgets can bear. Without site subsidies, these agencies would probably not have such central locations, and some might not even exist.

Role of the Highway Agency

Because of legislative, financial, political, and institutional constraints, highway agencies have generally played reactive or cooperative roles in joint developments. They have generally not taken the lead of initiating projects. In most cases where complex or otherwise unusual projects took place, general-purpose local government normally took the lead and the burden of public opinion.

Over and above the constraints discussed, the federal highway program has itself acted as a check and balance on joint-development activity. The program provides the major source of funds for acquisition and for highway construction. It also sets standards and establishes procedures. Through divisional, regional, and national offices, it conducts reviews of state and local actions, that, depending on the issue or level, are often time-consuming. The reviews provide public safeguards. They can also seriously constrain joint development because of the time involved (it will be 10 years from the start of planning the I-110 project in Pensacola until the first joint development is constructed on expanded-acquisition lands), the design standards that protect the highway and its access, and the funding uncertainties.

Other criticisms of the federal process are that

1. The reviews conducted at the division level or above are often too remote from the projects and circumstances under review and thus insensitive to the factors involved and
2. Some officials at the division level or above are unsympathetic to joint development as a role for highway agencies or unfamiliar with those existing provisions of federal law of FHWA procedure that encourage participation.

(The only extensive examples of private joint development identified are those associated with the Toronto subway, where the subway-property committee is a one-stop shop in respect to disposition and design review. No higher levels of government are involved—a parallel that is clearly not possible in the United States because of present federal-state-local administrative and financing arrangements.)

CONCLUSIONS AND RECOMMENDATIONS

Despite the constraints, difficulties, and limitations, the cases illustrate that joint-development projects with positive public benefits can be created under the present system and that highway agencies can play a productive role in expediting their occurrence.

Individuals

At both the state and federal levels, there are individual highway officials who are community conscious, provide technical leadership, and are cognizant of the nuances of and the flexibility allowed in the regulatory structure. Few of the projects were initiated by highway agencies, but none could have been accomplished without the genuine interest and expediting actions of individual state and FHWA officials. Efforts should be made to provide appropriate tools for those already capable and to expand their numbers.

1. FHWA should prepare a manual on joint development that consolidates the applicable policies and procedures currently found in several sections of the Federal Highway Program Manual. This new document could contain examples of how projects can be initiated and approved and case studies of actual undertakings. It would help to alleviate confusion over existing regulations and could emphasize the present interest in the approach.
2. FHWA and the states should initiate seminars and special training programs on joint development. These would be vehicles for the exchange of experience. They should be opened to local government officials as well as transportation agency staffs and could provide both skills and confidence to individuals involved in initiating and developing projects.

Responsiveness to General-Purpose Government

In those complex projects in which general-purpose local government became the leader, the highway agencies performed responsive and important roles. They did so largely by providing skills unavailable to some of the communities (such as appraisers and in-house design staff) and by entering into cooperative financial arrangements that allowed communities and community organizations to use land at modest cost. These efforts should be encouraged and expanded.

1. Highway agencies, supported by FHWA, should make positive efforts to offer the services of their skilled personnel to communities interested in fostering joint development. This can be particularly important to small cities and rural areas that cannot afford to maintain staffs of appraisers and designers under normal operations and can be inhibited from undertaking joint development by the lack of personnel. Clearly, such staff assistance should not dilute the transportation mission of the highway agencies, but it can be applied in support of that mission.

2. Highway agencies, supported by FHWA, should make increasing efforts to enter into financial arrangements with communities and community groups for the use of surplus land associated with new transportation facilities. This would include establishing long and short-term leases for surplus land and initiating agree ments, as in Pensacola, to offer remnants at their residual value after damages. It would also include the use of agency personnel to acquire supplemental land beyond the right-of-way, in accordance with joint-development plans, with repayment by the municipality.

Inventory of Excess Land

In practice, highway agencies acquire more or less substantial amounts of excess land, although not for joint-development objectives. There are remnants and old borrow pits and waste sites in agency inventories throughout the country. There are also examples of land once acquired for right-of-way but no longer intended for highway use because of changes in alignment or governmental decisions to abandon the route. Some of the cases showed that astute highway officials, supported by state enabling legislation allowing community use of surplus lands, have helped establish beneficial, visible public or community projects on excess land. This practice should be encouraged.

State highway agencies, supported by FHWA, should make positive efforts to identify surplus land suitable for public or community use. They should initiate joint-use arrangements, especially through leasing, under which the highway agency maintains long-term ownership and control of the land.

Support of Joint Development Planning

Without highway agency and FHWA financial and administrative support, the joint-development planning in Pensacola, Baltimore, St. Petersburg, and Reno and Sparks could not have taken place. These planning studies may have far greater influence on how communities can capture public benefits of highway development and mitigate adverse impacts than can any direct role of the highway agency in acquisition and joint development. These plans, and the range of local regulatory and development actions that flow from them, are positive achievements. The practice should be increased.

Highway agencies, supported by FHWA, should broaden their financial and administrative support to highway-corridor planning by local authorities. This support should, moreover, extend to impact planning of facilities beyond the Interstate system; e.g., the federal-aid program and Appalachian systems where there may be many joint-development opportunities in the coming years. Through this planning assistance, local communities should be encouraged to adopt their own acquisition programs and regulatory techniques designed to capture for the public the widest range of benefits from highway development and mitigating negative impacts.

Demonstration Program

Each of the above suggestions is based on continuation of the present limited level of policy interest in joint development by the federal government and the states. Should that interest increase, one of the most important innovations would be a demonstration program in the use of the highway agency to acquire land for joint development.

The cases demonstrate numerous potential opportunities for public and community facilities and services in immediate impact areas of highways. Extraordinary difficulties exist, however, in mobilizing potential sites because of differing powers and budgets among governmental bodies. Even with advance planning for joint use, opportunities can be lost unless there is some form of coordinated acquisition mechanism to assemble and prepare sites in conjunction with right-of-way takings. Thus, the demonstration program should include the following principal features:

1. A joint-development plan would be prepared for the highway corridor. It would indicate a desirable pattern of land uses adjacent to and in the vicinity of the highway right-of-way. It would identify sites for public facilities and services and for private development on publicly held land. It would include proposals for regulatory procedures (e.g., zoning) and other measures to support implementation. The plan would be adopted, after public hearing, by the local governing body and would be approved by the state highway department and FHWA.

2. The plan would be accompanied by a capital acquisition-and-development budget, committed to by the local governing body and other relevant agencies. This would determine the amount of funds required for site acquisition and development of nonhighway elements and the approximate year when those funds would become available to the agencies involved.

3. The highway agency would proceed to acquire both the highway right-of-way and the sites specified for other public facilities in the plan. Money would be advanced for purchase of these sites and for site preparation by the highway agency through the state and federal highway programs.

4. Prior to purchase, the relevant public agencies would execute agreements with the highway agency for repayment (with or without interest) of the land costs and possession of the sites when funds became available under the capital program.

FHWA could initially establish such a program in a few cities on a demonstration basis and provide funds for both planning and acquisition as an incentive. Based on tests of performance, the approach could eventually become institutionalized as an integral part of the federal highway program, perhaps including a revolving fund for such purchases. Since the purpose of the purchases would be identified in advance, and since highway agencies can enter into agreements with other governmental bodies, special federal or state enabling legislation would not be essential, although legislative changes might be required in some states.

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Abridgment

Impact of Railroad Abandonment on Rural Highways

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Declining railroad patronage over the past 30 years has caused more and more people to question the need for much of the aging, little-used trackage that exists in this country today. One solution to the financial dilemma confronting many of the rail carriers is the elimination of railroad access to those rural areas that are served by lightly used branch lines. This paper addresses the problem of how a shift in transportation demand, which could result from the abandonment of a branch rail line, might affect the roads of a rural area.

The paper introduces an evaluative methodology that can be used to estimate the impact of rail-service discontinuance on rural highways and bridges. The methodology was developed from a research effort conducted at Purdue University and will itself be discussed only briefly in this paper. The major portion of the paper will describe the results of using the methodology for two areas in Indiana that have been confronted with the possible loss of direct rail service.

EVALUATIVE METHODOLOGY

The methodology that can be used for assessing the costs of upgrading the rural highway system to accommodate increased numbers of heavily loaded commercial vehicles is composed of several different procedures. The most important of these is the one developed for measuring the impact of railroad abandonment on highway pavements. This procedure is based on equations developed by the American Association of State Highway Officials and the U.S. Army Corps of Engineers. By using these design procedures as a foundation, formulas were developed that express the impact of railroad abandonment on a rural highway pavement in terms of the additional thicknesses of asphaltic concrete overlay that would be required to accommodate the increased traffic.

The procedure concerned with possible effects of railroad abandonment on rural highway bridges uses information that has been gathered by various agencies within a state. By analyzing data obtained from these secondary information sources, as well as personal inspection of bridges likely to be affected, it is possible to identify those structures whose physical deficiencies are a serious impediment to over-the-road transportation of the goods formerly moved by the railroad.

The methodology introduced in this paper also contains recommended techniques to be used to meet the data requirements of the evaluative system and a method for estimating the financial impact of a branch-line abandonment on affected rural highways. Detailed explanations of all of the procedures of the methodology are contained in a report that summarizes the results of this research effort for the Joint Highway Research Project at Purdue University (1).

TWO CASE STUDIES

Two areas in Indiana that were confronted with possible loss of direct rail service were investigated in regard to the impact that abandonment would have on local highways and bridges. The rail segments chosen for analysis were (a) the 44.2-km (27.5-mile) section of United States Railway Association (USRA) line 429 from Decatur to Portland and (b) the 41.5-km (25.8-mile) segment composed of USRA lines 589 and 590 between North Vernon and Madison. Both of these rail lines had been recommended by the Governor's Rail Task Force of Indiana for inclusion in the final system to be operated by the Consolidated Rail Corporation, but this was not done.

For the two case studies, a time span of 10 years was chosen as the length of the analysis period over which the impact was to be measured. Because both highway and railroad data were available for 1973, the 10-year analysis period was begun on January 1 of that year. Furthermore, because a normal increase in traffic volumes will probably occur on those highways, regardless of the final disposition of USRA lines 429 and 589-590, it was assumed that there would be a 4 percent annual increase in vehicle volumes throughout the analysis period. This supposition was based on traffic information obtained from the Indiana State Highway Commission.

Line-specific rail-traffic information for 1973 was obtained from the Penn Central Transportation Company traffic tapes at the Indiana University Center of Urban and Regional Analysis, The highways that would be most likely affected by rail-service discontinuance were identified by a survey of 33 rail patrons located in the case-study areas. In the first case-study area, which is composed of Adams and Jay counties and located in eastern Indiana, US-27, a facility that parallels line 429 for its entire 44.2-km (27.5-mile) length from Decatur to Portland, was identified as the highway that would acquire added truck traffic after abandonment of the rail line. For the second study area, which is in Jennings and Jefferson counties, Ind-7 and Ind-56 were identified as the highways that would receive the added truck traffic.

Because the sizes and configurations of the motor carriers to be used for transporting the diverted rail commodities were not precisely known, the procedure for converting rail carloads to an equivalent number of trucks was performed twice, assuming two separate truck configurations: (a) a five-axle tractor semitrailer carrier with a legal gross-weight limit of 27 333 kg (73 280 lb) and (b) a four-axle tractor semitrailer carrier with a legal gross-weight limit of 23 126 kg (62 000 lb). The directional distribution of the truck volumes was based primarily on information gathered from the shippers themselves during the railroad-user interviews.

The case studies led to the following conclusions:

1. The structural strength of the pavement of US-27 in the first case-study area is sufficient to accommodate the added truck traffic that will result from the rail-freight diversion. On the other hand, the impact on the pavements of Ind-7 and Ind-56 in the second study area ranged from almost zero for several sections to a high of 1.5 cm (0.6 in) of additional asphaltic concrete overlay for a 14.5-km (9.08-mile) segment of Ind-56 between Madison and Scottsburg. For all three highways, yearly maintenance costs will probably increase as a result of increased road wear.

2. None of the six bridges located on US-27 are currently classified as deficient, according to data compiled by the Indiana State Highway Commission. In the second study area, numerous bridges located on Ind-7 and Ind-56 are old, narrow, and possibly structurally deficient: Ten of the 19 structures should be either replaced or repaired. Thus, the abandonment of lines 589 and 590 could have a serious impact on these two highways.

3. The use of trucks for transporting commodities to firms located in the larger towns of the two case-study areas could cause added traffic congestion on major city streets. However, for the most part, increases in the numbers of trucks for both study areas were limited, on the average, to three or four more on a highway section each day. Increases of this magnitude are not likely to create congestion problems unless there are seasonal fluctuations that cause the number of additional trucks to greatly exceed the average.

4. Because the impact of abandonment was relatively significant in the second case study, the public costs that would be incurred from resurfacing the pavement sections that would be affected to the greatest extent were computed. These costs do not reflect annual highway and bridge maintenance expenditures; thus, they represent only a first approximation to the financial impact of abandoning lines 589 and 590. The costs were based on the 1973 average bid price of asphaltic concrete resurfacing for the state of Indiana and are \$82 600 for a 14.5-km (9.08-mile) segment of Ind-56 and \$62 600 for a 24.2-km (15.14-mile) segment of Ind-7.

SUMMARY

Some possible effects of railroad abandonment on rural highways and bridges have been discussed. Because the overall goal for either national, state, or local transportation policies should involve minimizing the total resource consumption of goods movement, the public costs associated with a highway providing equivalent service to a marginal railroad facility were investigated.

The results obtained from two case studies should not be construed as representing the impacts of railroad abandonment on highways in other rural areas. However, the results of these studies indicate that the abandonment of lightly used branch lines does not have as great an impact on rural highways as some highway and railroad interests would like to believe. Many of the rail facilities that have been proposed for abandonment in the Northeast and Midwest do not carry sufficient traffic volumes to cause significant impacts on nearby highways if service along these lines were to be discontinued. However, whether the impact of railroad abandonment on local roads and bridges is expected to be significant or is considered to be quite small, an area-specific investigation of its impact should be performed. This can be easily accomplished through the methodology introduced here.

ACKNOWLEDGMENTS

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