Impact of Transportation-Facility Deterioration and Abandonment

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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

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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	Impact 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

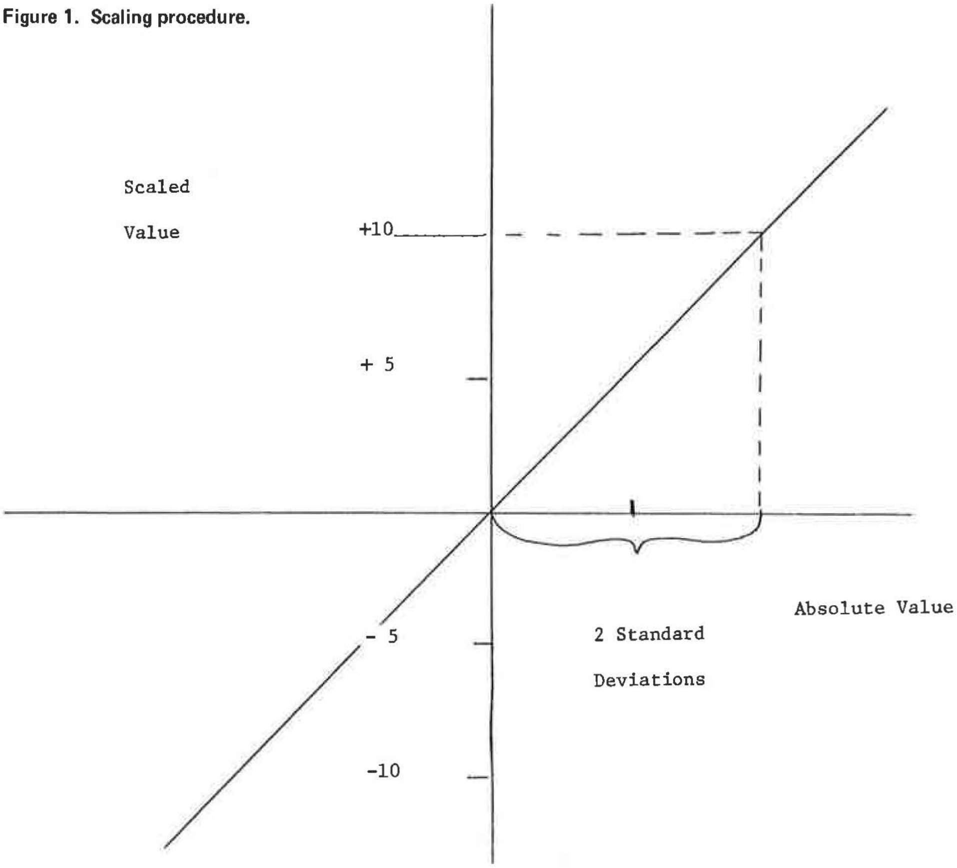
Twenty-five rail lines that were faced with possible service discontinuance as a result of the recent railroad reorganization provided the data for the sensitivity analysis. For each line, the composite social-impact index was calculated by each of the four importance sets. The results of these sensitivity 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.