ECONOMIC ANALYSIS OF ELEMENTS IN PAVEMENT DESIGN

R. K. Kher and W. A. Phang,
  Ontario Ministry of Transportation and Communications; and
R. C. G. Haas, Department of Civil Engineering, University of Waterloo

As competition for transportation investment dollars increases, all levels of management are being encouraged to become more cost conscious. This need for economy has resulted in haphazard implementation of cost reduction measures such as lowering pavement thickness standards or postponing construction. However, unless all implications of these measures are properly quantified in terms of trade-offs between present and future costs, these measures may, in fact, result in even higher overall pavement expenditures. A systems methodology to enable quantification of the trade-offs between various cost components of a pavement and selection of an optimum investment policy for any given situation is described. Through comprehensive analyses of alternative pavement strategies, the methodology provides individual cost components and the total cost of each alternative. Initial capital cost, resurfacing cost, maintenance cost, traffic delay cost during future resurfacings, salvage return at the end of the analysis period, and user costs are discussed, and it is demonstrated that certain elements, such as user costs, can be highly significant. An example is given to illustrate that trade-offs between various aspects of design as reflected by these costs can be efficiently studied by the methodology. Use of this methodology will enable agencies to develop uniform policies for cost reduction measures and alternative pavement standards.

•USE of economic analysis in highway engineering has received much attention over the years in an effort to provide highway authorities with better decision-making tools (1, 2, 3). The analysis has generally been applied to highway projects and even to highway networks, and the techniques are now being extended into pavement design (4, 5, 6, 7). In the course of seeking an improved decision-making tool for pavement management, it became apparent that direct agency costs of construction, rehabilitation, and annual maintenance did not provide a sufficient basis for determining the pavement structure design. The cost implications of lowered service to the public in terms of additional user operation costs, due to rougher pavements, and delay costs, due to traffic impedance during rehabilitation and maintenance, should also be included in the economic analysis. Management needs to find the middle ground to satisfy the objectives of providing an adequate service that satisfies the user but that keeps agency costs within imposed budget limitations.

A transportation agency that is responsible for providing and maintaining a system of roads that satisfies the present and future highway needs of a community is usually faced with budgetary constraints. The resulting situation for highway investment dollars generally leads the agency into haphazard implementation of cost reduction measures. The agency may be tempted to lower expenditures and accept the adverse implications of the additional user operation costs. However, this may not necessarily be in the best interests of the user; therefore, any such action must be preceded by an extensive economic evaluation that includes all the relevant agency and user cost implications. Such an evaluation methodology is presented in this paper. Its use in the

formulation of policies will enhance an agency's credibility and increase public acceptance of its decisions by enabling the agency to demonstrate reasonableness and objectivity in its decision-making processes.

In contrast to bridge and building structures, pavement structures do not fail catastrophically. Instead, pavements slowly deteriorate in riding quality, safety, structural capacity, and structural integrity with traffic and time. As an example, the pavement performance with respect to riding quality and safety is shown in Figure 1. In this paper only the economic consequences of riding quality performance are considered. The other aspects of performance may be considered in a similar manner.

The economic evaluation methodology and its elements are described below.

ELEMENTS OF PAVEMENT COST ANALYSIS

There are six major elements of cost that must be evaluated for each pavement strategy:

1. Initial capital cost,
2. Future resurfacing costs,
3. Maintenance cost,
4. Traffic delay cost during future resurfacings,
5. Salvage return at the end of analysis period, and
6. User costs of vehicle operation (i.e., time, accident, and discomfort).

These cost elements do not include all the costs involved in a highway project; however, a pavement design analysis should include only those costs that are related to the pavement. For example, right-of-way width is generally decided in the planning stage of a highway and is not a function of pavement strategy; therefore, it should not be included in the economic analysis of pavement design.

The six cost elements will be described in detail below, but, to facilitate understanding, the following example is presented for use in showing the various cost computations associated with the analysis: A four-lane divided rural highway is required for a total service life of 30 years including future resurfacings. The annual average daily traffic (AADT) in the first year after construction is expected to be 10,000 vehicles per day, and the annual average growth will be 5 percent, resulting in 25,000 vehicles per day by the end of 30 years.

Initial Capital Cost

Initial capital cost involves first the selection of possible initial designs to cover a spectrum of variety and experience. Designs with layer thicknesses slightly smaller and larger than those generally used for similar situations should be included. Alternatively, for agencies that base their selection on certain allowable deflections, additional designs that result in slightly lower and higher deflections should be included.

In the example described above, five initial roadway designs have been selected for analysis. A description of the designs is given in Table 1.

The next step is to compute the initial construction cost for each design selected. This involves the calculation of quantities of materials for each pavement structure. Material quantities are functions of their thicknesses in the structure as well as thicknesses of other layers and the width of pavement and shoulders. The cost of in-place material in a pavement structure depends on the quantity to be provided, the construction procedure used, the length of the project, and many other factors.

For the example described above, full-width granular sections are assumed for the five designs, and initial capital costs are computed based on assumed material prices. The initial capital cost for each design is given in Table 2. If an agency's decision is based on only initial capital cost, design C with the lowest initial cost of $198,600/mile ($124,125/km) would be the obvious choice. However, it will be shown later that, when future expenditures for the five designs are also considered, design C proves to be a poor choice.

Figure 1. Pavement performance measured by riding comfort index and skid safety index.
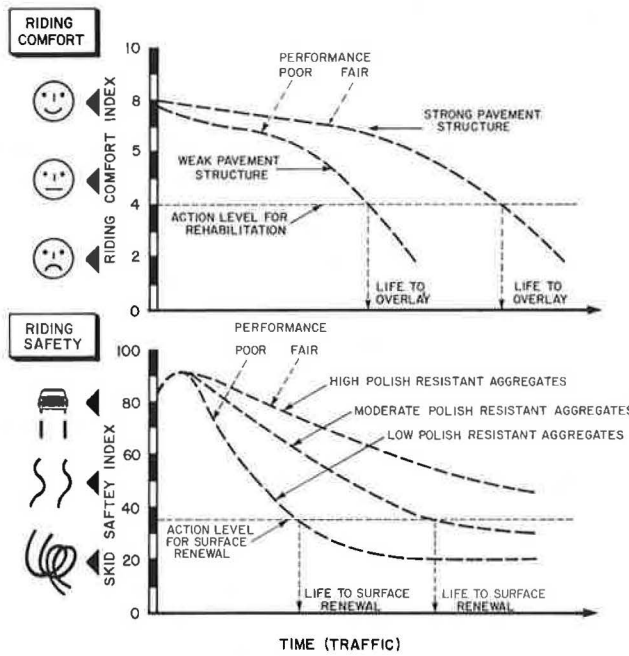
Table 1. Five initial roadway designs for example problem.

Design	Description	Actual Thickness (in.)			Equivalent Granular Base Thickness (in.)
		Surface	Base	Subbase	
A	Conventional	5	10	9	26
B	Conventional	4	6	15	24
C	Conventional	6	6	6	22
D	Deep strength	8	12	—	28
E	Full depth	12.5	—	—	25

Note: 1 in. = 25.4 mm. Layer equivalency factors = surface:base:subbase = 2:1:2/3.

Table 2. Various cost components for example designs.

Item	Design A	Design B	Design C	Design D	Design E
Initial capital cost, pavement plus shoulder	232,950	203,950	198,600	259,350	244,850
Resurfacing cost, overlay plus shoulder upgrading	49,300	70,450	81,300	27,300	52,750
Subtotal	282,250	274,400	279,900	286,650	297,600
Maintenance cost	35,100	31,400	27,500	41,400	34,300
Subtotal	317,350	305,800	307,400	328,050	331,900
Traffic delay cost	5,100	10,300	7,100	1,450	4,550
Subtotal	322,450	316,100	314,500	329,500	336,450
Salvage return values	13,550	15,100	16,300	13,100	17,200
Subtotal	308,900	301,000	298,200	316,400	319,250
Extra user cost	92,950	108,900	140,050	64,350	83,750
Total	401,850	409,900	438,250	380,750	403,000

Note: All costs are expressed as dollars per mile. 1 mile = 1.6 km.

Table 3. Various possible overlay thickness strategies for 2 to 4-in. (51 to 102-mm) thickness of one overlay.

No. of Strategy	Overlay Thickness (in.)	No. of Strategy	Overlay Thickness (in.)
1	2, 2, 2	.	.
2	3, 2, 2	.	.
3	4, 2, 2	.	.
4	2, 3, 2	18	4, 4, 3
5	3, 3, 2	19	2, 2, 4
6	4, 3, 2	20	3, 2, 4
7	2, 4, 2	.	.
8	3, 4, 2	.	.
9	4, 4, 2	.	.
10	2, 2, 3	17	4, 4, 4
11	3, 2, 3	.	.
		.	.
		.	.

Note: 1 in. = 25.4 mm.

Resurfacing Cost

Resurfacing cost includes future overlays or upgradings made necessary when the riding quality, or riding comfort index (RCI), of a pavement reaches a certain minimum level of acceptability. The riding quality of a pavement is described by the RCI in Canada and the present serviceability index (PSI) in the United States. The minimum acceptable level of riding quality generally depends on the function and classification of the highway. The maximum value of RCI and PSI is usually obtained immediately after initial construction and depends on construction quality, type of aggregate in the surface layer, material quality control, construction tolerances, and many other factors.

Essential to the determination of resurfacing costs are the algorithms that predict the number of years at which a pavement reaches the minimum specified level of roughness after initial or overlay construction. The models necessary to predict the performance histories of pavement structures are still under development by various agencies. Ontario has developed a performance prediction model based on principles of linear elastic theory combined with AASHTO and Brampton Road Test data and general experience (8). For those agencies where such prediction models are not available, objective information acquired to date regarding pavement lives, and subjective judgment based on local experience, can be used in the interim to estimate lives.

. Although a pavement designer may in some cases be able to recommend the type and thickness of a resurfacing based on past experience, accurate prediction of overall optimal strategy consisting of more than one overlay during a pavement's life is extremely difficult. For example, if 2 to 4-in.-thick (51 to 102-mm) are allowed and if algorithms are available to predict the lives of overlay thicknesses, there can be many combinations of one or more overlay thicknesses to obtain the desired total service life of a highway. An example of all possible overlay thickness strategies for this case is given in Table 3.

A review of the overlay strategies in Table 3 may cause one to question the reasons for analyzing so many strategies of overlay construction. For example, if three 2-in. (51-mm) overlays (strategy 1) successfully give a certain total service life for a pavement, why is it necessary to investigate strategy 2, which is similar to strategy 1 except for an extra inch (millimeter) of thickness in the first overlay? First, it is possible that an extra inch (millimeter) of the initial overlay may extend the life of the pavement so that only one additional 2-in. (51-mm) overlay may be needed to obtain the desired total life. Second, even if both strategies require three overlays, the extra 1-in. (25.4-mm) overlay in strategy 2 will increase the time until the next two overlays are needed in this design strategy and thus reduce the present values of these overlays. Such a reduction in the present values of these overlays might offset the additional cost (in terms of present value) of providing 1 in. (25.4 mm) of extra thickness of the first overlay. This might cause strategy 2 to be more economical than strategy 1.

For the five example designs (Table 1), approximate initial lives have been predicted, and example overlay policies have been selected. Costs of overlays, their discounted values, and subtotals of initial construction and overlay costs are given in Table 2 for each of these designs. Design C, an optimal design based on initial capital cost alone, is no longer the most economical design after overlay costs are added. Instead, design B becomes the most economical.

Maintenance Cost

A comprehensive economic analysis should include the estimation of all costs that are essential to maintain pavement investment at a desirable level of service or at a specified rate of deteriorating service. The level of maintenance, i.e., the type and extent of maintenance operations, affects the rate of loss of the RCI. Alternatively, if a certain performance history is desired, a specific level of maintenance will be necessary.

Performance as a function of maintenance level is shown in Figure 2. A maintenance level M_1 results in a performance history P_1 for a particular design. When the maintenance level is increased to M_2 the resulting performance history is P_2. The

additional maintenance expenditure of $M_2 - M_1$ has bought an additional life of $t_2 - t_1$ years. Note, in Figure 2a, however, that as time passes relatively larger increments of maintenance cost have to be expended to buy every increment of additional life.

As shown in Figure 2, a maintenance level can be represented by an annually increasing cost curve. The maintenance cost is minimal in the first year after initial construction, resurfacing, or reconstruction and gradually increases at a progressive rate.

Various maintenance operations such as pavement and shoulder maintenance, drainage and erosion, vegetation, structures, and snow and ice control are carried out for a highway. However, for pavement economic analysis, consideration should be given to only those items of maintenance that directly affect pavement performance, such as maintenance of pavement surface and shoulders. Of course, if any other item of maintenance affects pavement performance and if the trade-off between the cost of this maintenance item and the pavement performance can be quantified, this cost may also be included in the economic analysis. Maintenance costs of five example designs are given in Table 2.

Traffic Delay Cost

Overlay construction generally disrupts traffic flow and causes vehicle speed fluctuations, stops and starts, and time losses. The extra user cost thus incurred is often a significant proportion of the total overlay cost and may warrant its inclusion in the economic analysis. This indirect, nonagency cost has never in the past been given due consideration and has traditionally been considered only as a soft cost; however, the extra user cost is an expense to the road users and, therefore, should be included in the economic analysis.
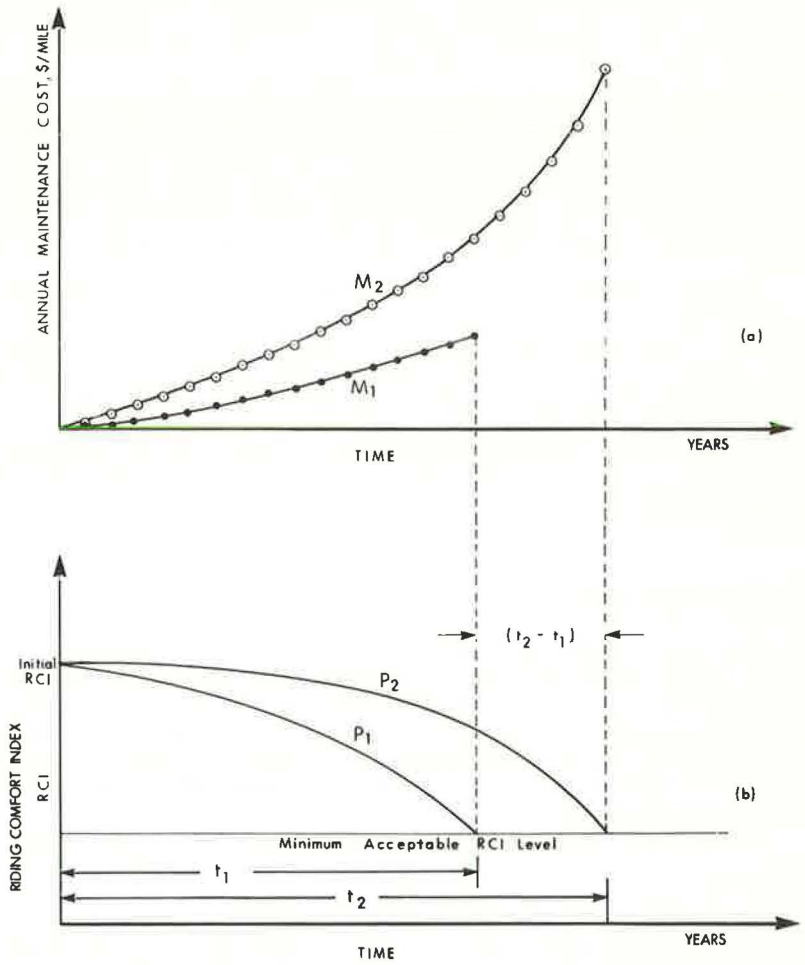
Traffic delay cost can be defined as a function of traffic volume, road geometrics, time and duration of overlay construction, road geometrics in the overlay zone, and traffic diversion method used. Cost is comprised of user time and vehicle operating values resulting from driving slowly, fluctuating speeds, stopping, accelerating, and idling. Based on traffic demand and available road capacity at the time of overlay construction, traffic delay costs can result from either of the following two situations:

1. Vehicle slows down to overlay zone speed, continues at this reduced speed through overlay zone, and accelerates back to the original speed; or
2. Vehicle stops, idles for a certain time, accelerates to overlay zone speed, continues at this speed through the overlay zone, and accelerates back to the original speed.
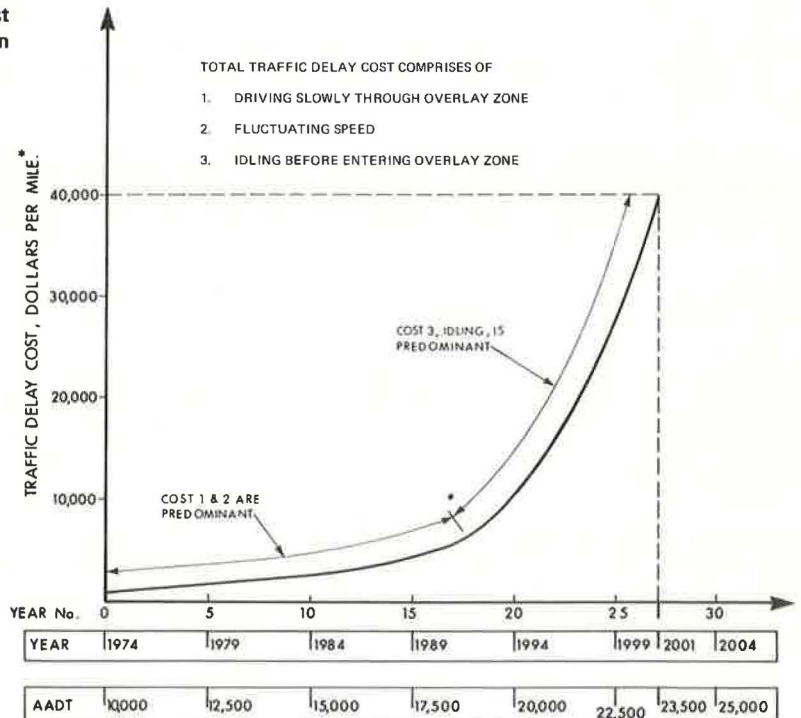
The latter situation develops when traffic volume at any time during overlay construction exceeds the available capacity; the former situation is more prevalent and generally occurs when traffic volumes are low and, as such, do not cause traffic stopping and idling. Traffic delay cost as a function of traffic volume is shown in Figure 3. The cost gradually increases as a function of AADT to a point where traffic volume in the peak hour is still smaller than available capacity through the overlay zone. AADT, which exceeds this value, results in vehicle stopping and idling and thus in a sharp increase in traffic delay cost. When traffic volumes are in this sharply increasing range, an overlay construction may cause such a significant traffic delay cost that the decision to provide an overlay may be changed. For example, if high traffic volumes are expected during the latter years of a pavement's life, optimum pavement design may favor stronger initial pavement or thicker overlay construction during the early years of a pavement's life.

Traffic delay costs for five example designs are given in Table 2. These are the discounted values of traffic delay costs during all overlays for each design strategy. When added to the sum of all previous costs, the subtotals show a shift of the optimal design among the five designs. Design C now becomes the optimal rather than design B, which had the least cost when only initial, overlay, and maintenance costs were considered.

Figure 2. Performance as function of maintenance level.

ANNUAL MAINTENANCE COST, $/MILE

M_2

M_1

TIME

YEARS

(a)

Initial RCI

P_2

P_1

RIDING COMFORT INDEX

RCI

$(t_2 - t_1)$

Minimum   Acceptable   RCI Level

t_1

t_2

TIME

YEARS

(b)

Figure 3. Traffic delay cost during overlay construction in various years in future.

TRAFFIC DELAY COST, DOLLARS PER MILE.*

TOTAL TRAFFIC DELAY COST COMPRISES OF

1.   DRIVING SLOWLY THROUGH OVERLAY ZONE

2.   FLUCTUATING SPEED

3.   IDLING BEFORE ENTERING OVERLAY ZONE

COST 3, IDLING, IS PREDOMINANT

COST 1 & 2 ARE PREDOMINANT

YEAR No.	0	5	10	15	20	25	30

YEAR	1974	1979	1984	1989	1994	1999	2001	2004
AADT	10,000	12,500	15,000	17,500	20,000	22,500	23,500	25,000

Salvage Return

Salvage return of a strategy is the value of a pavement at the end of its analysis period. Computation of this cost allows for a rational comparison of designs that have different material quantities and that are at different levels of roughness at the end analysis period. Although the economic comparison of various strategies is conducted over a fixed analysis period, actual useful service life of a design generally extends beyond this period. This extension, as shown in Figure 4, may be of different magnitude for every design and, therefore, should be taken into account in any economic comparison. For example, if designs B and C in Figure 4 are compared, the economic value of design B after 30 years will be higher than that of design C since the former is overlaid in the twenty-seventh year (longer residual life) and the latter is overlaid in the twenty-third year.

Salvage value of a material is a function of several variables. In addition to the volume of such material, it depends on when the material was provided, its durability, its position with respect to other pavement layers, and its anticipated use at the end of its service life. Salvage value of a material may be defined as a percentage of the original cost of the material. It should be emphasized, however, that percent salvage return can only be applied to that part of total material cost resulting from unit material price and not to the incremental unit price resulting from labor cost. Salvage percentage can be a negative value if it is anticipated that the material will have no use at the end of its service life and will have to be hauled away at extra cost.

Determination of the salvage value of the number of years that a strategy extends beyond the required service life is relatively difficult. However, a relationship between the salvage value of a strategy and its extended life can be developed.

Salvage return (a negative cost) should be discounted from the end of the analysis period (Table 2).

User Cost

Each alternative pavement design is associated with a number of indirect (soft) costs that accrue to the road user and must be included in a rational economic analysis. Similar to pavement costs, user costs are related to the performance history of the pavement. A pavement design that provides an overall high level of roughness over a longer time period will result in a higher user cost than a design that provides a relatively smooth surface for most of the time.

The four major types of user costs associated with a pavement's performance are as follows:

1. Vehicle operating cost consisting of fuel consumption, tire wear, vehicle maintenance, oil consumption, vehicle depreciation, and parts replacement;
2. User travel time cost;
3. Accident cost consisting of fatal accidents, nonfatal accidents, and property damage; and
4. Discomfort cost.

Each of the above costs is a function of roughness level and of the resulting vehicle speed.

As a pavement becomes rough, the operating speeds of vehicles are reduced. Lower speeds and rough pavements increase traveling time, level of discomfort, and other user costs. Since level of roughness for a pavement design depends on its initial construction thicknesses and materials, the extent of rehabilitation, and the extent of major and minor maintenance provided during its service life, user cost is interrelated with all of these factors.

There is a lack of extensive data on user costs as related to a pavement's riding quality. This is partly because of the inadequate attention given to this aspect of highway transportation costs. However, some data are available (3, 11) for use in determining the user cost component.

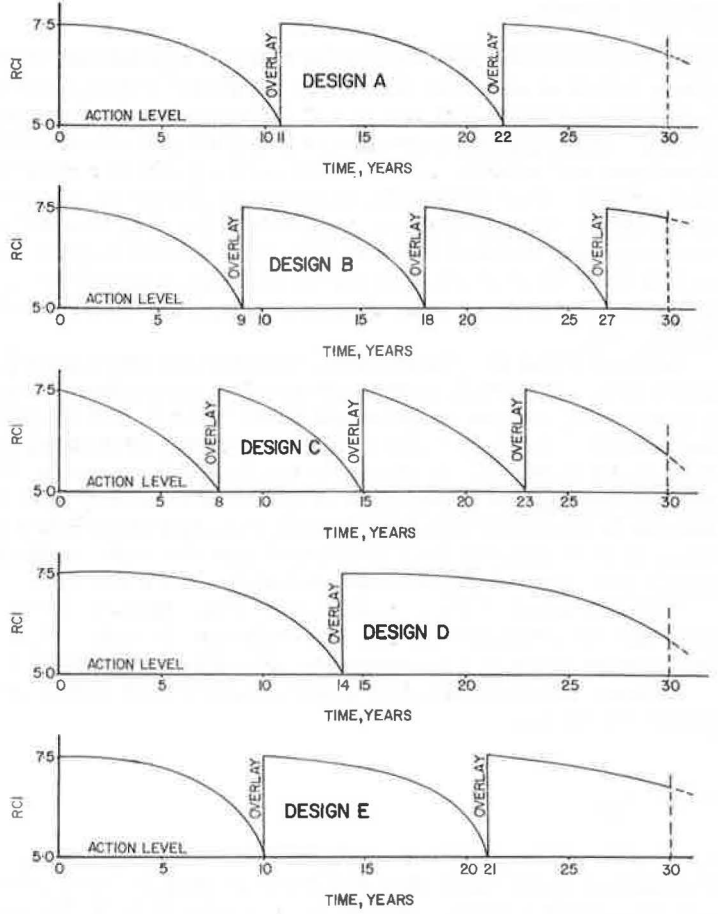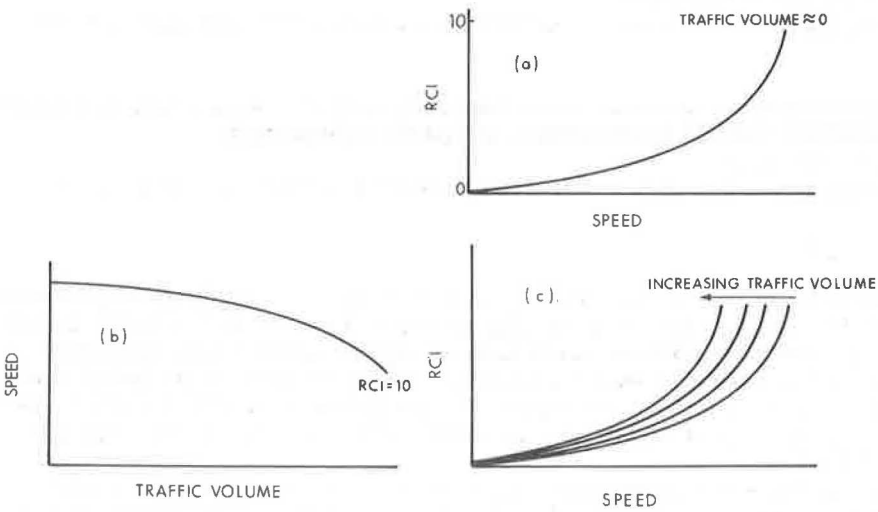Figure 4. Performance histories for example designs.

Figure 5. Speed as a function of roughness (RCI) and traffic volume.

Information necessary to determine total user cost on a pavement strategy falls into the following four major categories:

1. Determination of actual traffic expected on the facility and its anticipated growth during the service life;
2. Prediction of performance history of a pavement strategy in terms of its RCI versus age;
3. Determination of speed profiles adopted by motorists while driving on the particular pavement during its service life; and
4. Determination of user cost data for vehicle operation, travel time, and accident and discomfort, as functions of vehicle speed and the RCI.

Determination of speed profiles during the life of a pavement strategy is extremely important since it provides the means to relate user cost to the performance history. As the RCI of a pavement decreases with time, road users reduce vehicle speeds to adjust to the roughness of the highway. In addition to this adjustment, the driver may have to further reduce vehicle speed to adjust to the traffic volume. A typical roughness versus speed curve is shown in Figure 5a, in which the effect of traffic volume has been assumed to be negligible. Similarly, a typical traffic (congestion) versus speed curve is shown in Figure 5b, in which the effect of pavement roughness has been assumed to be negligible. Congestion is generally represented by a volume to highway capacity ratio (V/C), but in Figure 5b the term traffic volume has been used for simplification. Actual highway speed is a function of both roughness and traffic (congestion) as shown by curves in Figure 5c. The combined effect is not the simple addition of the two individual effects shown in Figures 5a and 5b, nor is it the minimum of the two. Although Figure 5c gives actual speed reduction on a highway, only a part of this reduction is attributable to pavement roughness and, therefore, to pavement design. The rest of the reduction results from capacity restrictions and, therefore, should be attributed to major reconstruction such as pavement widening, addition of lanes, and widening of shoulders.

Based on the simple roughness versus speed relationships shown in Figure 5c, Figure 6 shows speed profiles for two example designs. Speed is shown as a step function determined for the average RCI for each year. A lower overall average speed during the 30-year analysis period is observed on design T_1, which gives a relatively rougher surface when compared to design T_2.

A major data requirement for user cost computations is determination of unit costs [dollars per vehicle mile (kilometer) of operating, travel time, accidents and discomfort] as functions of speed and pavement roughness (RCI). These unit costs, along with anticipated future passenger and commercial traffic, lead to the calculation of total user cost on a pavement strategy.

Figure 7 shows typical unit cost curves as functions of operating speed and pavement roughness for each category.

For pavement economics, user cost should be represented by a difference between total user cost of traveling on a rough pavement and the total user cost of traveling on the smooth pavement had it stayed at the RCI level at which it was initially constructed. This difference is the extra user cost. Given the performance history of a pavement, its average RCI for each year determines the average operating speed for that year, and this in turn gives the extra user cost. Extra user cost per year, when discounted to its present value and summed over the service life of a pavement, gives the total extra operating cost for a strategy. The addition of extra operating costs to the subtotal of all previous costs (Table 2) shifts the optimal strategy from design C to design D.

SELECTION OF DESIGN

To achieve maximum economy for a pavement design, one should analyze a large array of alternatives. The alternatives should include all the available materials, various combinations of their thicknesses, and various policies of maintenance and resurfacings.

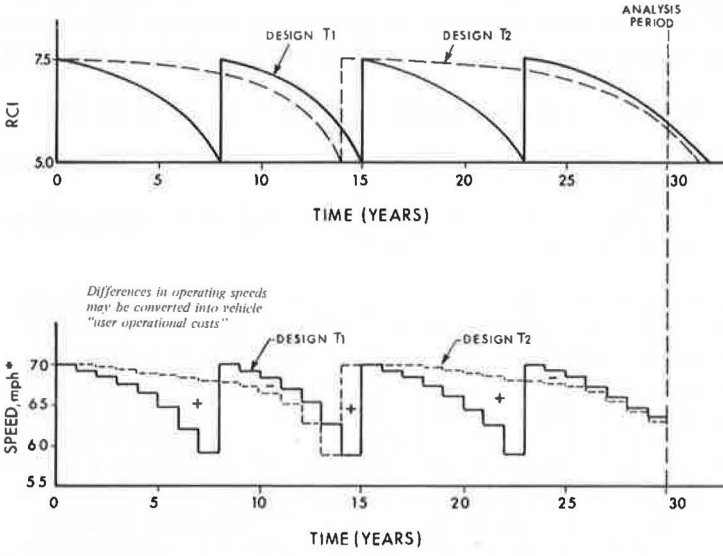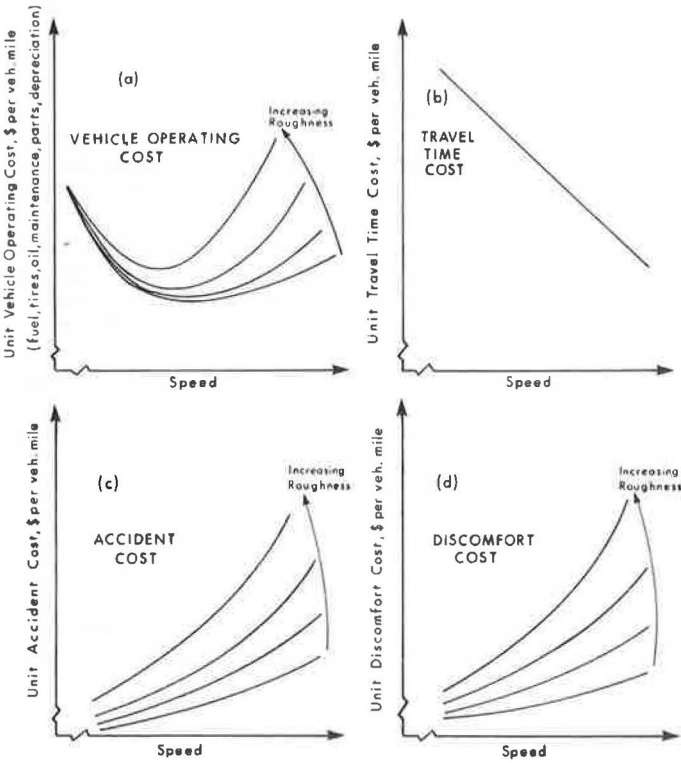**Figure 6. Speed profiles for example designs T₁ and T₂.**

Figure 7. Trends of user cost components as function of operating speed and pavement roughness.

Cost analyses like those in the previous sections should then be conducted, and the design with the least present worth of total overall cost should be selected.

Implications

It is difficult to quantify the relative importance that the decision maker would ascribe to various economic, social, and experience values based on current knowledge. The administrator, therefore, should be presented with design and cost details of optimal and several nearly optimal designs and should then select a design that is economically justified and in accordance with past experience. Cost analysis will provide information about the magnitudes of various cost components.

The role of cost analysis, using cost computations of the five example designs, in the selection of an optimal design strategy is shown in Figure 8. The effect of the addition of each cost component on the optimum solution and the least cost for the five example designs after each addition are also shown in Figure 8. Design C is the least costly design if only initial capital cost is considered; however, addition of resurfacing cost shifts the optimal to design B. Design C again results as a least costly design when maintenance and traffic delay costs are added; however, design D becomes the optimal when all the costs are included. This shift in the optimal design emphasizes why all significant cost components must be considered in pavement design. A design selected on the basis of initial capital cost alone or even with the addition of resurfacing cost may still not be the optimal design from the point of view of overall cost.

Additional Cost Components

Only six cost components have been discussed for use in the selection of a pavement design; however, there are other costs that may also be included to improve a rational pavement design decision.

A typical example is drainage and the associated maintenance. It is well known that improved drainage affects the performance of a pavement. However, it would not be rational to take into account the cost of drainage until the trade-off between this cost and pavement performance is defined in the form of an algorithm. When such an algorithm becomes available, alternate drainage designs can then be applied to each pavement design.

This leads to the definition of all costs that should be considered in an economic analysis of pavements. A simple definition is all costs that are functions of pavement layer thicknesses or that affect pavement performance and result in extra life or smoother pavement surface. As discussed above, algorithms to define trade-offs between cost and pavement performance must be established before such a cost is considered in economic analysis.

Cost components to be included in a pavement design decision also depend on the objectives and budget of the agency concerned. For some agencies, a design may be selected on the basis of only the costs that form their actual spending (agency costs). In such cases, traffic delay cost, extra user cost, and sometimes even salvage return of the pavement strategy may be ignored. For the example shown in Figure 8, design B would be considered optimal in such a case. However, even if cost components such as extra user and traffic delay cost are not included in the design selection process, these costs should still be computed and made available to the administrator as an aid in the decision-making process. Extra user and traffic delay costs will provide information about public acceptance of a design since these costs are good indicators of public reaction to an agency's design decision.

Significance of a cost component relative to total overall cost is another criterion that can be used to establish whether a cost component should be included in pavement economic analysis. Table 4 gives the relative significance of the six cost components that were analyzed for the five example designs (Table 1). Each cost is shown as a per-

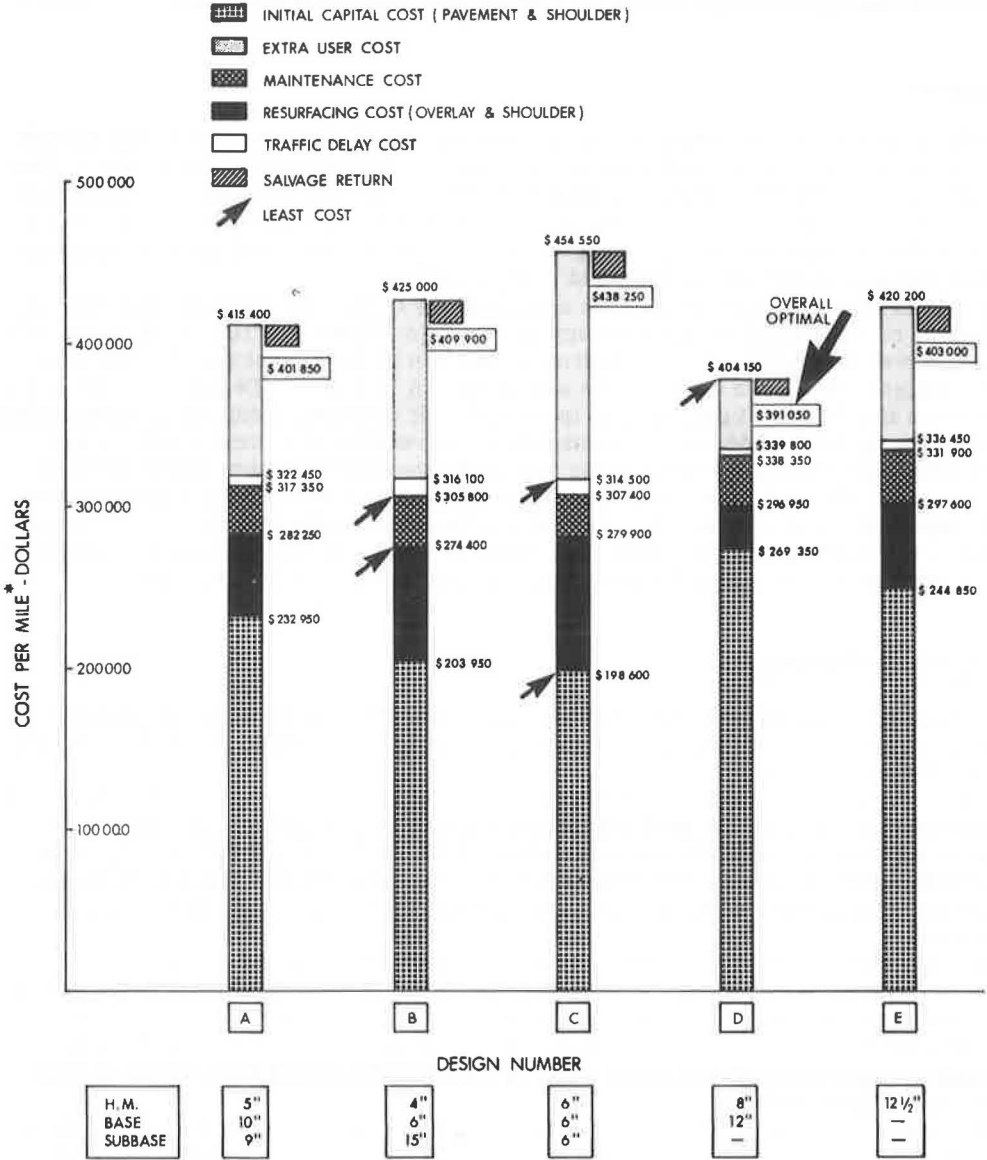**Figure 8. Cost components for five example designs.**

Table 4. Percentages of different cost components of five example designs.

Design	Initial Capital Cost	Resurfacing Cost	Maintenance Cost	Traffic Delay Cost	Salvage Return Value	Extra User Cost
A	58.0	12.3	8.7	1.3	3.4	23.1
B	49.8	17.2	7.7	2.5	3.7	26.6
C	45.3	18.6	6.3	1.6	3.7	32.0
D	66.3	7.0	10.6	0.4	3.3	16.5
E	60.8	13.1	8.5	1.1	4.3	20.8
Average	56.0	13.6	8.4	1.4	3.7	23.8

centage of total overall cost. A general review of Table 4 gives various cost components in their order of relative significance as follows:

1. Initial capital cost,
2. Extra user cost,
3. Resurfacing cost,
4. Maintenance cost,
5. Salvage return value, and
6. Traffic delay cost.

The relative significance of the various cost components is not constant and depends largely on the specific conditions of each design situation. For example, in the case of facilities carrying a high AADT, traffic delay cost may become a significant portion of total overall cost. Similarly, if the interest rate is lowered, the relative significance of all future costs may become greater as compared with the initial capital cost.

FUTURE RESEARCH

A comprehensive economic analysis approach for pavements has been described. A large number of algorithms to predict pavement and traffic behavior and to compute various cost components are required to conduct the analysis. Some of the available algorithms have been used for values in Table 2; others unavailable at present have been assumed. Research is required in the following major areas to develop new algorithms and data or to validate those presently available:

1. Prediction of performance histories for new as well as overlaid pavements,
2. Maintenance cost versus pavement performance prediction,
3. Traffic delay modeling and cost prediction,
4. Salvage value modeling,
5. Roughness versus speed relationships,
6. Future traffic predictions,
7. User cost modeling, and
8. Optimization modeling.

CONCLUSIONS

The economic analysis approach presented in this paper can be used to quantify trade-offs among various aspects of pavement design such as initial construction, resurfacing, maintenance, and user costs. A study of these trade-offs and optimization between various aspects of pavement investment will lead to economically sound decisions in pavement design.

The Ontario Ministry of Transportation and Communications has developed a computerized version of the economic analysis and optimization as discussed in this paper. The system, the Ontario pavement analysis of costs, is being used at present by the ministry to design pavements in the province.

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