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Use-Related Vehicle Depreciation

BERTELL C. BUTLER, JR.

ABSTRACT

An objective procedure to determine the depreciation component of vehicle operating costs requires the identification of the time- and use-related parts of depreciation. This division can be obtained from an analysis of vehicle survivor curves. Truck survey data on vehicle use by age are used to create vehicle survivor curves. These curves are based on an analysis of 86,615 vehicles and used to produce a procedure to differentiate between time and use. Vehicle depreciation due to use is shown to be based on predicting a vehicle's maximum potential life mileage, which provides the basis for determining the depreciation component of vehicle operating costs. This use-related depreciation is a function of road surface conditions based on relationships developed in the Brazil highway costs study.

Constructing and maintaining highways require money. Increasingly economic analyses have evolved to assess the costs and benefits of proposed investments in construction and maintenance. An important part of these analyses is the determination of the vehicle operating costs to be associated with alternative investments. These costs are related to fuel and oil consumption, tire wear, vehicle maintenance and repair, and depreciation. A procedure for determining the depreciation component of these vehicle operating costs is presented.

DEPRECIATION

There is general consensus that the costs of owning a vehicle can be divided into two categories. These vehicle cost categories are termed running costs and standing or fixed costs. Running costs involve using a vehicle (i.e., consuming fuel and oil, wearing out the tires) and deteriorating the vehicle. Some of the vehicle's deterioration is corrected by investing in maintenance and repair. Such repair only retards the deterioration process because the vehicle eventually wears out, or, at an extreme, the maintenance and repair burden becomes excessive and is equivalent to recapitalizing the vehicle.

Running costs for tire wear or fuel and oil consumption are directly related to vehicle use. Maintenance and repair are not as direct because vehicle repairs can be caused by such nonuse factors as the weather and vandalism. However, most repairs necessitated by nonuse factors can be isolated, and the maintenance and repair expenditures due to operating the vehicle can be identified.

A problem exists in attempting to identify the reduction in a vehicle's capital value that is related to its use on the road. At one extreme, a vehicle may be allowed to stand idle; deterioration is due to obsolescence and environmental factors. In this case, none of the vehicle's lost capital value should be treated as a running expense.

Winfrey (1) contends that only those costs altered by operating a vehicle on the road should affect decisions related to roadway design, construction, and maintenance. It seems clear that one could purchase a vehicle and never use it on the road. It might or might not deteriorate and become scrap. The point is that it has not been used on the road, and therefore its capital value cannot be depreciated against the road as a running cost. Conversely, one can picture a situation where a vehicle is purchased and operated on the road continuously, so that the maximum possible road use is obtained before the vehicle is scrapped.

Most vehicle use falls somewhere between these two extremes. Therefore, the reduction in a vehicle's capital value is due both to using the vehicle on the road and to time-related influences. If one accepts the premise that the loss in a vehicle's capital value should be divided into a use category and a time category, the problem is to determine how to proportion this division. The next problem is to determine how roadway characteristics affect the running cost portion.

TIME AND USE COMPONENTS OF DEPRECIATION

A method is needed for dividing depreciation into a time component and a use component. The method proposed assumes that vehicles decay or become obsolete over time and that they wear out when operated on a road. In the absence of information to the contrary, the rate at which a vehicle decays due to time has been assumed constant. This is shown as the intercept t in Figure 1. The rate at which a vehicle wears out due to use depends on the severity of use, and this determines slope b of the curve in Figure 1. If the percentage of total service life that is used up in 1 year is defined as W and the annual use as m, then

$$W = t + bm$$

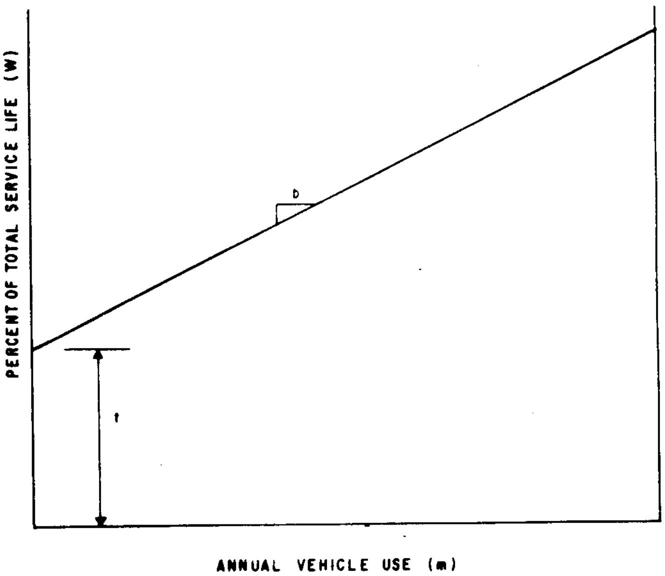

FIGURE 1 Percent of total service life related to annual use.

W is the portion of the vehicle's capital value that should be depreciated each year assuming constant annual mileage. The total capital value is unity, so the service life (SL) and the life mileage (LM) of a vehicle can be expressed as

$$SL = 1/W = 1/(t + bm)$$
$$LM = SL(m)$$
$$LM = m/(t + bm) \qquad (1)$$

An examination of U.S. Truck Survey survivor data suggests that a vehicle decays or becomes obsolete due to time in 40 years. This can be defined as the vehicle's maximum service life, and t would be

$$t = 1/\text{Maximum service life}$$
$$t = 1/40 = 0.025$$

The survey data also suggest that a vehicle has the potential to be driven approximately 800,000 miles. This defines a vehicle's maximum life mileage, and the rate of wear out due to use (b) would be

$$b = 1/\text{Maximum life mileage}$$
$$b = 1/800{,}000 = 0.125 \times 10^{-5}$$

If these values for t and b are substituted into Equation 1, one obtains the curve shown in Figure 2.

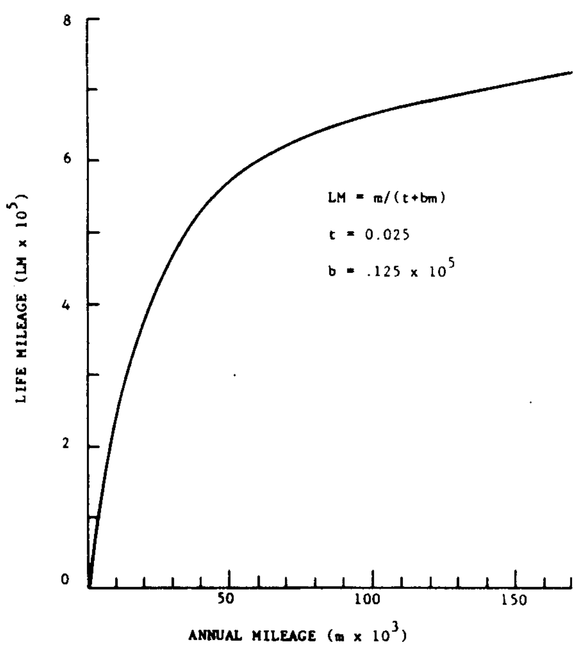

FIGURE 2 Life mileage as a function of annual mileage.

Daniels (2) has shown that the key to allocating depreciation to time and use is to determine the tangent to the curve as shown in Figure 3 and the tangent's intercept with the Y axis. Figure 3 shows how the slope and annual use define the portion of life mileage associated with time, and the intersection of the slope through the life mileage axis indicates the use-related portion of depreciation as shown in Figure 3. The derivative of Equation 1 with respect to annual mileage (m) gives the slope of the curve:

$$dLM/dm = (t + bm - bm)/(t + bm)^2 = t/(t + bm)^2$$

The slope is now multiplied by annual mileage (m) to produce T, which is divided by LM on the ordinate

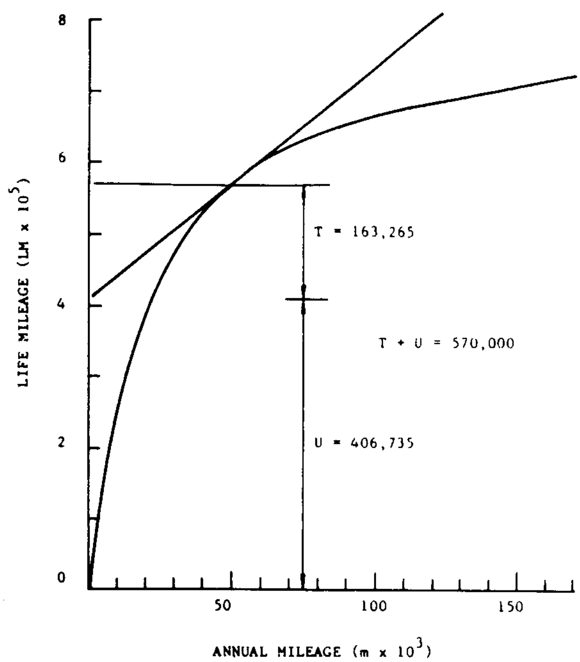

FIGURE 3 Variation of life mileage with annual mileage.

and shown to be equal to the portion of depreciation to be attributed to time:

$$T = tm/(t + bm)^2$$
$$T\ LM = [tm/(t + bm)^2]/[m/(t + bm)]$$
$$= t/(t + bm) = P_{time}$$

Because unity must be depreciated, the portion attributed to use must be P_{time} or

$$P_{use} = 1 - t/(t + bm)$$

The total capital value of a vehicle that is depreciated is normally considered to be the new vehicle's cost less scrap value and less the value of the original set of tires. This capital cost (C) needs to be divided into a use and a time component. The use portion of depreciation has been defined as P_{use}; therefore the depreciation cost per mile (D) of vehicle operation on the road is determined by dividing the portion of C assignable to road use (P_{use}) by the vehicle's life mileage (LM) or

$$D = C \times P_{use}/LM$$
$$D = C[1 - t(t + bm)]/[m/(t + bm)]$$

$$D = C[(t + bm - t)/(t + bm)][(t + bm)/m]$$
$$D = C(b)$$

This shows that only the coefficient b is needed to compute the part of a vehicle's capital value to be depreciated per mile of travel (i.e., the use component of depreciation).

DATA REQUIREMENTS

The key to determining an average b value for a class of vehicles on the road is to develop a life mileage-annual mileage curve for each class of vehicle. These curves can be constructed if vehicle fleet data are available on the distribution of vehicle age and mileage. The average service life of a fleet of given class and model year vehicles will be the average of the lives of the individual vehicles making up the fleet. However, the average service life for the fleet cannot be determined until all vehicles in the fleet have been retired from service. This occurs 30 or 40 years after the first registration of the vehicles in the fleet. Further, if a 1945 pickup truck is the model year and class being analyzed and the last 1945 pickup is retired in 1980, the average service life of a 1945 vehicle may not be a very accurate guide for predicting the service life of 1980 model pickup trucks.

Another approach is to examine the survivors in each age group of vehicles in use on a given date. By comparing the number of vehicles for each model year with the total number of vehicles of that vehicle model year that was put into service, the survival portion for the given date can be determined. This will produce a survival curve for the fleet being examined. It reflects the best available estimate of the future service life of the fleet in use at the date selected. If the pattern of vehicle service life is changing with time, there may be some inaccuracy in the prediction. A correction can be made if there are data available on the composition of the fleet for a number of recent years. The rate at which vehicles are being retired at each age can be determined, and, if this rate is not constant, a rate of change adjustment can be determined and used to improve the forecast of retirements for each age. This procedure would produce an improved and more up-to-date estimate of the expected service life for the current vehicle fleet.

TRUCK CENSUS DATA

Vehicle age and use information was obtained from the Census of Transportation, 1977 Truck Inventory and Use Survey Tape (3). The census tape was screened and vehicle records showing unacceptable life mileage or annual mileages were deleted. The unacceptable vehicles had either life mileages exceeding 4 million miles or annual mileages exceeding 300,000 miles. Only vehicles of designated model years later than 1945 and not classed as off-the-road vehicles were used.

The census tape provides a sample of the trucks on the road at a given time. The number of vehicles that enters the population each year is estimated and the number of trucks in each age category is used to establish the survival curves for the trucks on the road. From these survival curves and truck annual mileage, the average service life and average life mileage of trucks can be determined. Further, by grouping the census tape sample into different truck classifications, the average service life and average mileage for each truck class can be determined.

The vehicles were divided into five classes:

1. Light trucks [gross vehicle weight (GVW) less than 6,000 lb],
2. Light trucks (GVW 6,001 to 10,000 lb),
3. Medium trucks (GVW 10,001 to 19,500 lb),
4. Light-heavy trucks (GVW 19,501 to 26,000 lb),
5. Heavy-heavy trucks (GVW 26,000 lb or more).

Each class of truck was divided into 25 annual mileage categories. Two different summaries were created, one of annual vehicle mileage and a second of accumulated life mileage. The annual mileage was divided into 8,000-mile categories, and life miles were placed in 20,000-mile categories. Each vehicle class was summarized by age (based on model year). There were 86,615 vehicles in the sample and the number of vehicles in each class varied from 11,260 to 26,354.

LIFE MILEAGE-ANNUAL MILEAGE CURVES

Life mileage curves were created for each of the five vehicle classes identified. Average service life and life mileage can be established by constructing survivor curves based on the age distribution of vehicles currently in use, adjusted to reflect constant new registration in the relevant years. This was done in the following manner:

1. New vehicle registrations by year from 1946 through 1977 were obtained for each class of vehicle (4,5).
2. The census tape data were organized so that 25 annual mileage categories were established for each class of vehicle by age.
3. Each annual mileage category was analyzed separately and required that the distribution of vehicles be adjusted to reflect a standard level of registration before computing a survival portion. An example of the computations involved is given in Table 1.

TABLE 1 Computation Procedure for Developing Service Life Curves for Each Vehicle Class and Average Service Life and Average Life Mileage

Age (years)	Sample	Registered (in millions)	Survival Ratio/ 100	Survival Portion[a]	Annual Mileage	Weighted Annual Mileage[b]
1	800	3.1	2.6	1.00	15	15.0
2	700	3.0	2.3	0.88	14	12.3
3	600	2.9	2.1	0.81	13	10.5
4	500	2.8	1.8	0.69	12	8.3
5	400	2.7	1.5	0.58	11	6.4
6	300	2.6	1.2	0.46	10	4.6
7	200	2.5	0.8	0.31	11	3.4
8	100	2.4	0.4	0.15	9	1.3
9	50	2.3	0.2	0.08	8	0.6
10	20	2.2	0.1	0.04	7	0.3

[a] Average service life = 5.0.
[b] Average life mileage = 47.85.

4. The average annual mileage by age generated from the census tape was multiplied by the survival portion to get each year's contribution to the life mileage (see Table 1).
5. The sum of the survival portions for all vehicles gives the average vehicle service life for each annual mileage category.
6. The sum of the column reflecting annual mileage times the survival portion gives the average life mileage for each annual mileage category.

SERVICE LIFE-USE CURVES

The life mileage information developed from census tape data for the heavy-heavy (25,000 lb) class vehicles is shown in Figure 4. The points do not follow the curve form that was expected based on Figure 2. Actually, if the tangent is taken at the average annual mileage point for the entire population, the tangent passes through the origin, which would mean all depreciation should be attributed to time. An examination of other portions of the curve makes it clear that there are major use components of depreciation. Therefore, the tangent at the average annual mileage point for the population does not provide the desired time-use split as suggested by Daniels (2).

Service-life annual mileage data, developed from census tape data for heavy-heavy trucks, are plotted in Figure 5. This plot suggests that there may be two different curves, one for low annual use vehicles and a second for high annual use vehicles. A

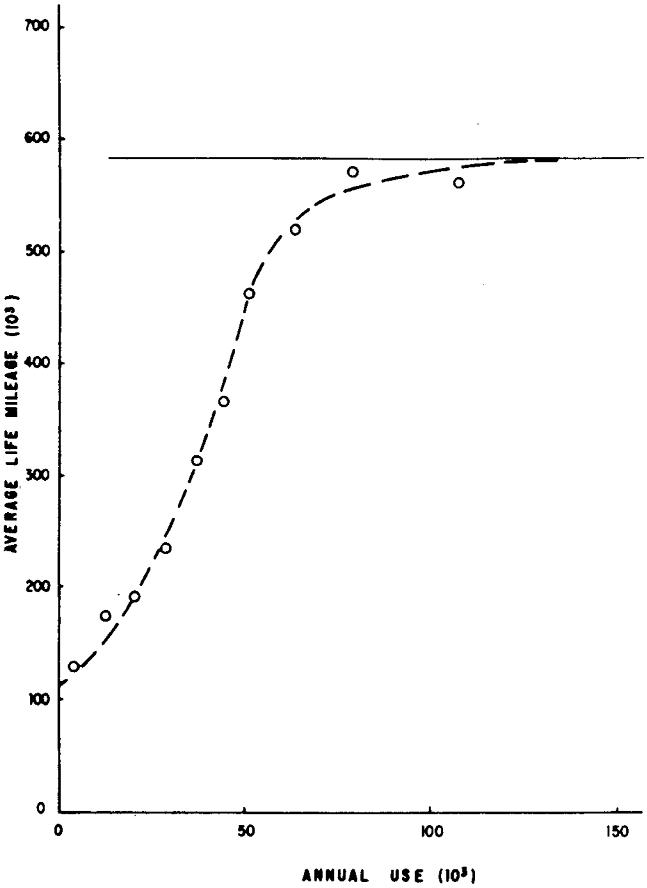

FIGURE 4 Life mileage-annual mileage data for heavy-heavy vehicles.

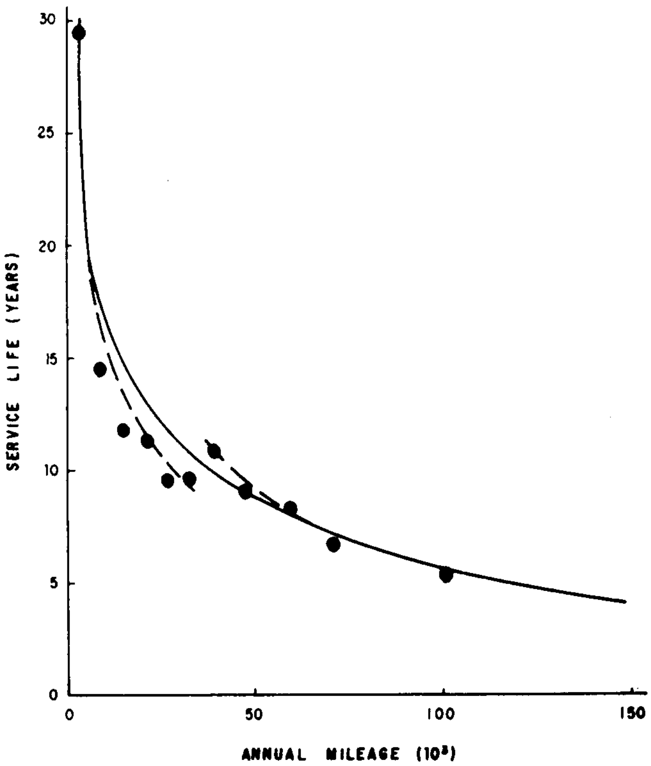

FIGURE 5 Service life-annual mileage data for heavy-heavy vehicles.

summary of the census tape data showed that the heavy-heavy vehicles could be divided into separate travel categories. Those vehicles in the local travel category had half the annual mileage of the others. Therefore, two sets of data were developed, one for local and a second for nonlocal heavy-heavy trucks. The service life data for the two travel categories are plotted in Figure 6. Although there are slight differences, the distinct separation of the local from the nonlocal, which was expected, did not materialize. Most probably, low annual use is more indicative of the factors affecting use and service life than is the designation of a travel category.

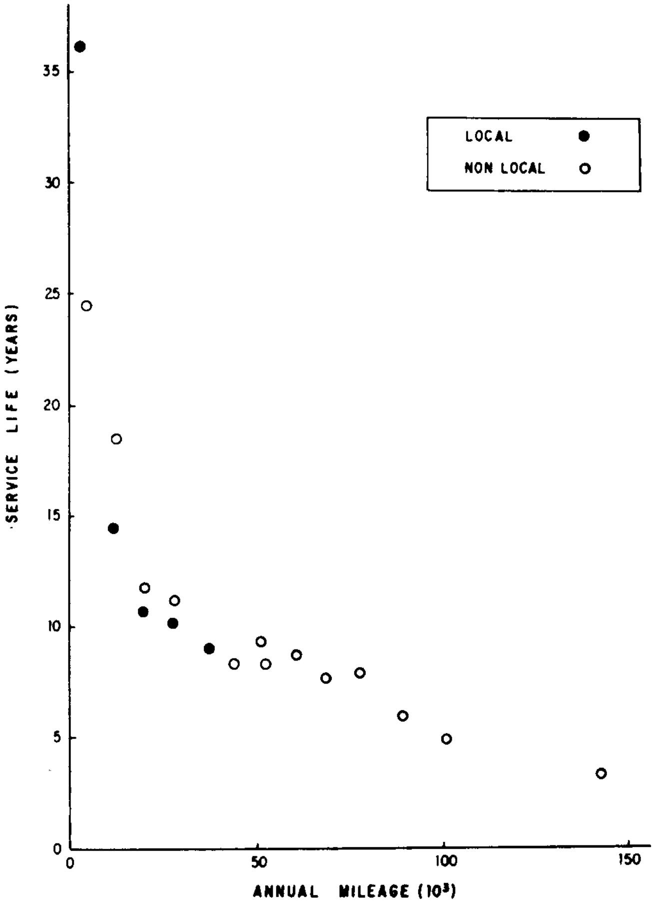

FIGURE 6 Service life-annual mileage data for local and nonlocal heavy-heavy truck operations.

A study of the plots suggested that there were different service life-annual mileage curves for low use and high use vehicles. Based on the plots, two theoretical curves were assumed. The equations presented earlier were

$$SL = 1/(t + bm)$$
$$LM = m/(t + bm)$$

where

- SL = service life (years)
- LM = life mileage
- m = annual mileage
- t = 1/maximum service life
- b = 1/maximum life mileage

Based on the data plots, it was estimated that the maximum service life will be about 40 years (i.e., the service life possible with almost no use). This is vehicle deterioration due to obsolescence and environmental factors. A 40-year service life makes t equal to 1/40 or 0.025. It was also estimated that two different maximum life mileage classes would bracket the data. These were estimated to be 600,000 (curve A) and 300,000 (curve B) miles. These are the maximum life mileages possible for a vehicle not subjected to time deterioration factors. Therefore, b in the life mileage equation would be expressed as

$LM = m/bm$
$LM = 1/b$
$b = 1/600{,}000 = 0.167 \times 10^{-5}$
$b = 1/300{,}000 = 0.333 \times 10^{-5}$

Figure 7 shows service life-annual mileage plots for heavy-heavy vehicles (>25,000 lb) (3) compared with theoretical curves for 40-year maximum service life and 600,000 and 300,000 maximum life mileages (curves A and B).

Plotted in Figure 8 are curves C and D, based on the same 600,000 and 300,000 maximum life mileage values but with no time-related deterioration factor. It seems clear that including a time deterioration factor improves that data fit.

The service life information for local travel heavy-heavy trucks (3) is plotted with curves A and B in Figure 9. The first three points follow curve B closely. Starting at 20,000 miles annually, the points transition over to curve A. This suggests that trucks do not wear out as quickly through use when they average a higher annual mileage. We believe that low use reflects short trips on local streets at slow speeds under congested conditions and that longer trips are involved in higher annual mileage. Long trips are at higher, constant speeds and are made under less severe operating conditions.

The service life data for nonlocal trucks (3) are plotted in Figure 10. In this case, the points start on curve B but start transitioning toward curve A almost immediately. Therefore, the low mileage use made of nonlocal vehicles is less severe than that made of local vehicles because the former have a greater service life for the same annual mileage.

It is proposed that vehicles wear out due to both time and use. The time factor, if a constant as assumed, can be determined by identifying the intercept on the service life axis of the service life-annual mileage curve. The data plots indicate that this occurs between 35 and 45 years. The rate at which vehicles wear out because of use varies with the severity of use. On an average, low annual mileage is hard use and associated with a rapid wear-out rate. High annual mileage is associated with easy use and a much lower wear-out rate.

In conclusion, the split between the use and time component of vehicle depreciation can be determined directly from a vehicle's service life mileage-annual mileage curve. This curve reflects the type of use made of vehicles at each annual use level. A maximum service life value (t) can be estimated from the service life plot and a value for the wear-out rate can be computed directly for each annual use level.

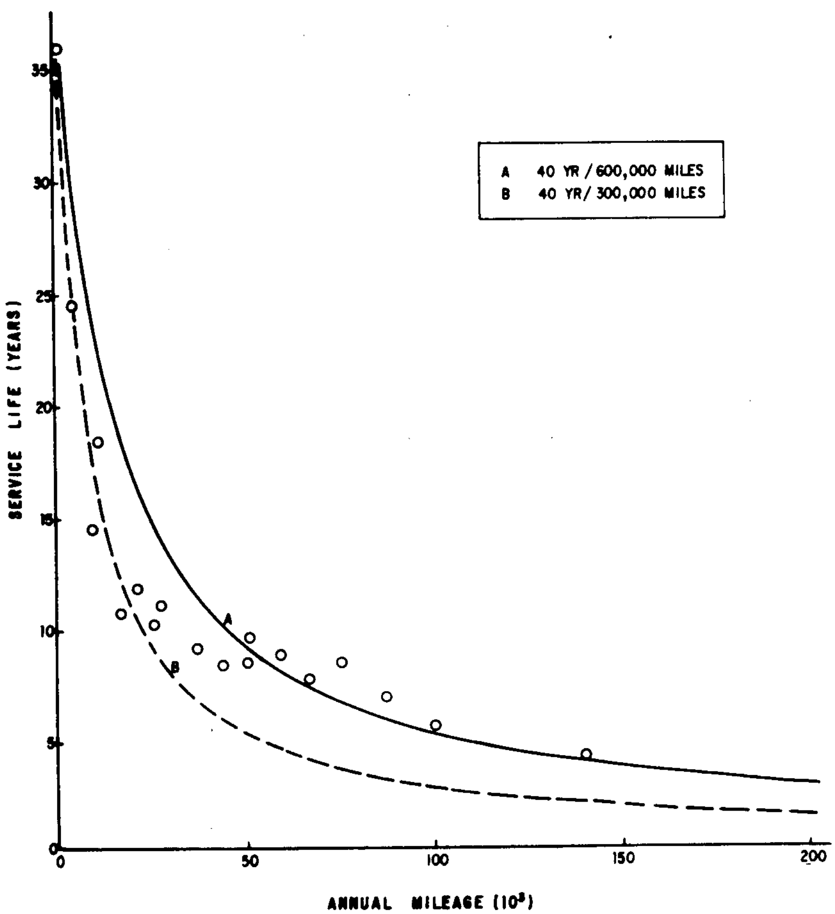

FIGURE 7 Heavy-heavy truck service life-annual mileage plots compared with theoretical curves.

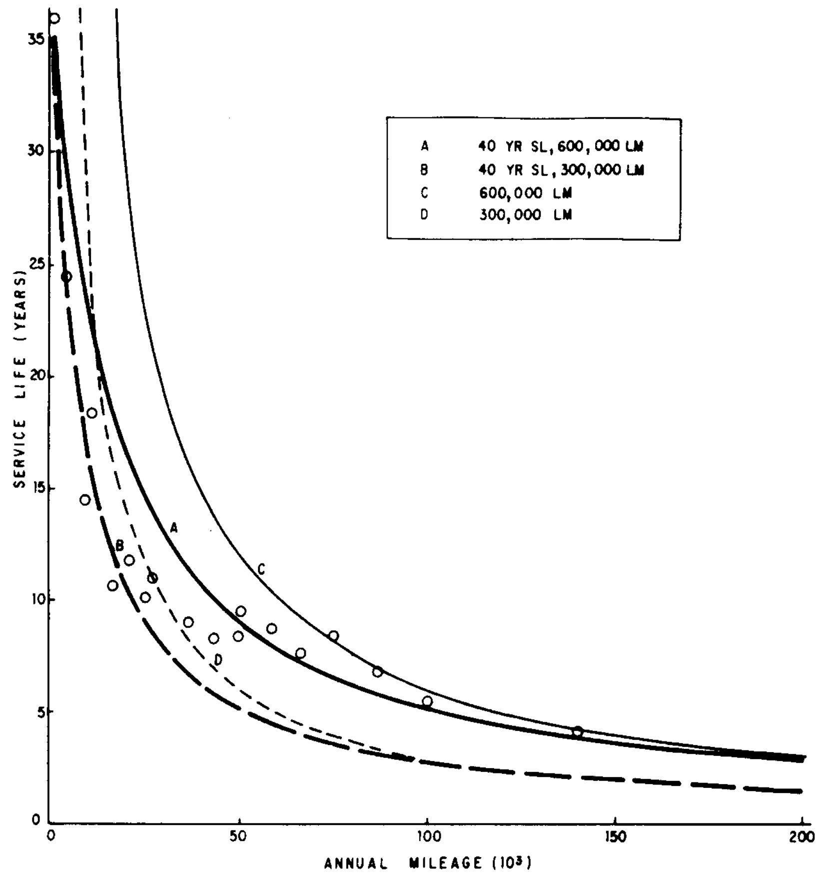

FIGURE 8 Theoretical curves relating service life to annual mileage.

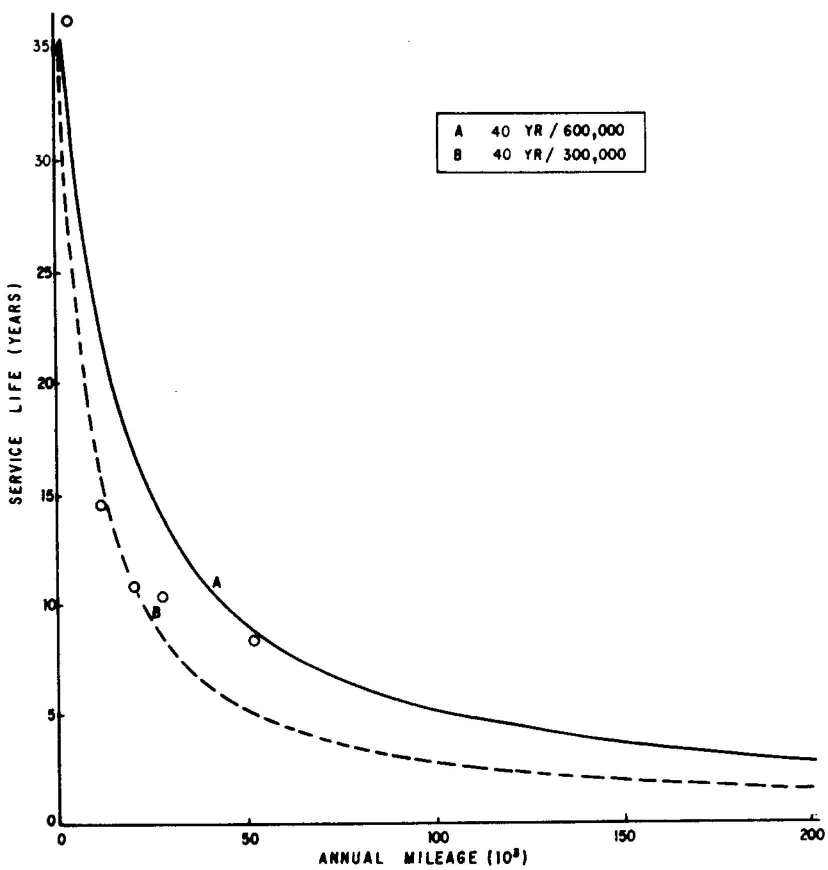

FIGURE 9 Heavy-heavy local truck service life-annual mileage plots compared with theoretical curves.

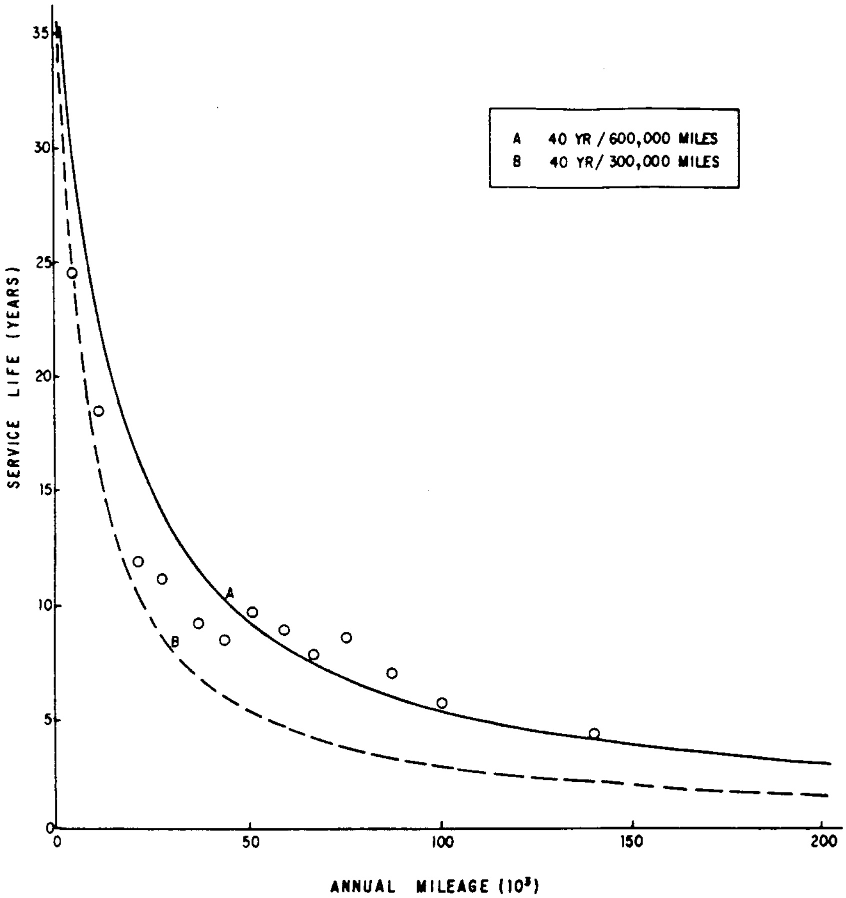

FIGURE 10 Heavy-heavy nonlocal truck service life-annual mileage plots compared with theoretical curves.

PREDICTING VEHICLE SERVICE LIFE CURVES

The service life curve for a vehicle depends on the conditions under which the vehicle is operating. Figure 11 illustrates five theoretical curves, each representing a maximum service life of 40 years and potential maximum life mileages ranging from 300 x 10^3 to 700 x 10^3. The maximum life mileage establishes the value for coefficient b in the general SL equation

SL = 1/(t + bm)

because b is the reciprocal of maximum life mileage.

The maximum service life for heavy-heavy vehicles estimated from the data falls between 35 and 45 years and was assumed to be 40 years. The reciprocal of maximum service life is t, which becomes 0.025. Therefore, the coefficient b associated with each heavy-heavy vehicle data point plotted in Figure 11 can be computed directly.

t/(t + bm)
SL = 1/(t + bm)
b = (1 - SLt)/SLm

The values of coefficient b computed for heavy-heavy trucks are shown plotted in Figure 12.

The curve drawn through the points falling between 0 and 60 x 10^3 annual mileage intercepts the ordinate at about 0.0037 x 10^{-3}. This is equivalent to a maximum life mileage of 270 x 10^3. Vehicles operating on this service life curve would be completely worn out after 270 x 10^3 miles if there were no time-related depreciation factors. This wear-out rate is the maximum indicated by the data. It is associated with heavy-heavy vehicles that operate very low average annual mileages. Such operation is thought to be under stop-go, congested conditions, which tend to wear a vehicle out more rapidly. The slope of the curve in Figure 10 is 0.37 x 10^{-4} and the average minimum b value seems to level off at about 0.0015. This value is associated with heavy-heavy trucks that achieve a high annual mileage, probably on long hauls and on good roads. No road is perfectly smooth, straight, flat, or uncongested. Therefore the data plots must reflect something less than ideal conditions. After a review of the available data, a b coefficient equal to 0.0012 was selected as the base value. This means that the maximum average life mileage for a heavy-heavy vehicle will be 833,000 miles.

The Brazil study (6) showed that annual vehicle use was a function of road roughness, geometry, and vehicle age. Increasing these factors reduced annual vehicle mileage. As annual mileage falls, so does life mileage, and reduced life mileage can mean that the vehicle is wearing out faster. Therefore, it seems reasonable to assume that vehicles operating on grades and rough roads wear out faster than those operating on smooth tangent sections of roads.

From Figure 12 it can be seen that local vehicles, which one might expect to be associated with factors that will wear them out faster than nonlocal vehicles, lie on the curve with slope -0.37 x 10^{-4}. This slope defines coefficient b as a function of annual mileage. Coefficient b for some of the nonlocal vehicles also lies on this constraining curve.

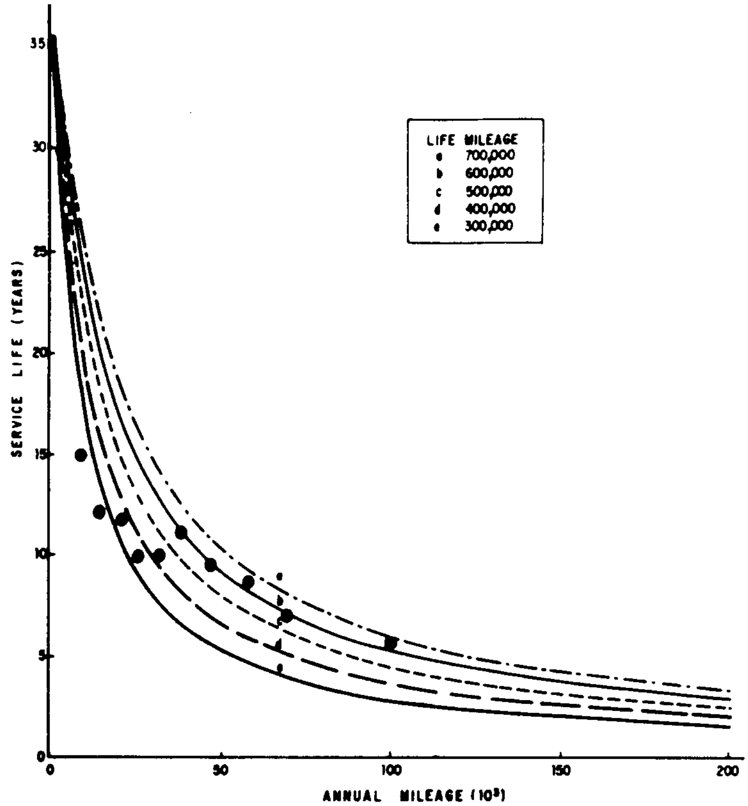

FIGURE 11 All heavy-heavy trucks compared with a series of theoretical curves relating service life to annual mileage.

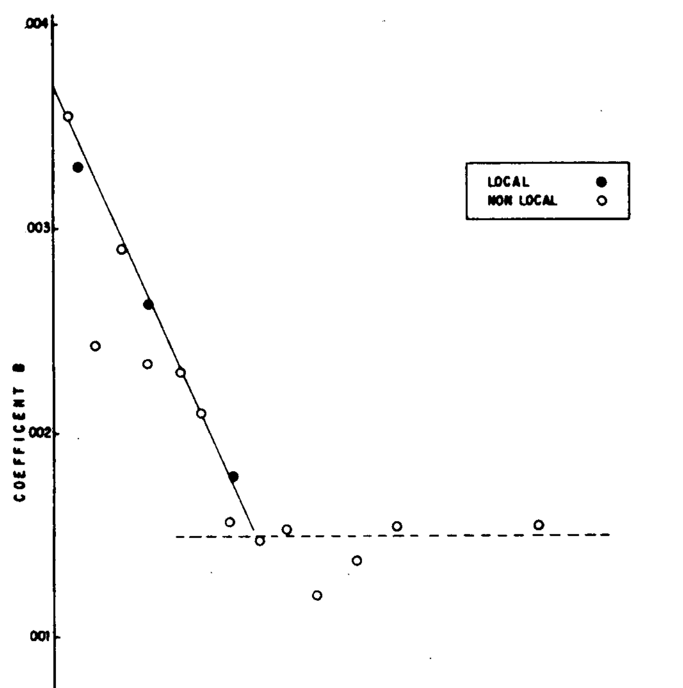

FIGURE 12 Coefficient b related to annual mileage for heavy-heavy trucks.

Other nonlocal annual mileage vehicles fall below the curve. These points may well reflect low annual mileage with no major change in life mileage, the type of mileage expected from a vehicle that is underused but not wearing out because of road factors such as roughness and geometry. Beyond an annual mileage of about 75,000 miles, coefficient b seems to level off. This suggests that there is a maximum (or optimum) average life mileage that can be pictured as slightly reduced because of overuse.

The usage equation developed during the Brazil study (6) for trucks is

$$U = e^{9.478 - 00267\,QI - 0.00193\,(R+F) - 0.0594\,AGE}$$

where

- U = monthly utilization in miles,
- QI = measure of road roughness based on Quarter car simulation over a defined profile,
- R+F = rise plus fall of vertical geometry in meters per kilometer, and
- AGE = average vehicle age in years.

If the Brazil equation is expanded for a road that is very smooth and flat for the average-age truck in Brazil, the annual mileage would be

$$U = e^{9.478 - 0.00267\,(15) - 0.00193\,(0) - 0.0594\,(4.30)}$$

$$U = e^{9.478 - 0.04 - 0.255} = e^{9.183} = 9730.30 \text{ km/month}$$

$$= 116\,764 \text{ km/yr}$$

$$= 72{,}569 \text{ miles/yr}$$

This annual mileage, if plotted on Figure 12, falls very close to the optimum coefficient b, (i.e., 0.0012×10^{-3}). Because it is believed that both roughness and geometry influence vehicle deterioration and therefore life mileage, the influence of both roughness and geometry on life mileage can be estimated by assuming that the reduction in annual mileage is due to an increase in coefficient b arrived at by projecting the reduction in annual mileage determined from the Brazil usage equation to a curve with slope -0.37×10^{6}. Therefore, we estimate coefficient b as

Assume QI = 100, R + F = 30, and AGE = 5

Then,

$$b = 0.37 \times 10^{-5} - 0.37 \times 10^{6}\,(e^{9.478 - 0.267 - 0.058 - 0.297})\,(12/1.609)$$

$$b = 0.37 \times 10^{-5} - 0.37 \times 10^{-7}\,(e^{8.856})\,(12/1609)$$

$$b = 0.37 \times 10^{-5} - 0.37 \times 10^{-7}\,(7016.36)\,(0.007458)$$

$$b = 0.0000037 - 0.000001936$$

$$b = 0.000001764$$

For these conditions the example shows that the maximum life mileage will be 566,893 miles (1/b).

SUMMARY

Vehicle depreciation was hypothesized to consist of time and use components. A service life model was proposed that contained a time component (t) and a use component (b). Data from the 1977 Truck Use Survey were used to develop service life curves that were compared with the proposed service life model. The data did not conform but indicated that the assumption of a time and a use component was correct. Further, a study of service life-annual mileage plots suggested that vehicle wear-out rates due to road use could be computed directly. This required that an estimate be made of maximum vehicle life mileage based on extrapolating the life mileage-annual mileage curve. Vehicle survival data could then be used directly in calculating vehicle wear-out rates (b) attributable to use.

Vehicle use related wear-out rates (b) were shown to be related to annual use under some conditions. By assuming that the major influence on the value of b was caused by adverse driving conditions, a procedure was proposed to predict b as a function of road geometry and road roughness.

Some of the assumptions made were tenuous but the procedure offers an approach to determining vehicle use related depreciation. Validation requires that vehicle survival and mileage information be developed for vehicle populations operating constantly on roads in various quality categories (i.e., good or poor surface conditions and low or high design characteristics).

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Self-Administered Mailback Household Travel Survey

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ABSTRACT

The development, application, and results of a low-cost self-administered mailback household travel survey used by the Capital District Transportation Committee (the metropolitan planning organization in the Albany-Schenectady-Troy Standard Metropolitan Statistical Area) are described. The objective of the survey was to update 1965 home interview survey data. Criteria employed in selecting the survey technique were that the technique minimize both cost and staff effort and that the technique produce usable personal and household travel information across a broad range of socioeconomic groups and geographic areas. Key features of the survey included the survey instrument design, the use of bus tokens and maps as incentives to increase response rates among lower income households, and the use of an interactive computer program for data entry. The selection of the survey technique and design of the survey instrument are described. Two pretests were employed to verify the effectiveness of the survey instrument and of the use of incentives. After review of pretest results, a full-scale (approximately 5 percent) sample of 12,500 households in the metropolitan area was drawn and the survey was undertaken in March 1983. Results of the pretests and the full-scale survey are discussed, as well as the procedures used to verify accuracy of responses and to enter data into computer files. Costs of each aspect of the survey effort are also described. The survey successfully elicited detailed socioeconomic and travel data with only a modest level of staff involvement and survey cost. Cost per usable survey response was approximately $14.00 for 2,610 responses.

In the spring of 1965 a comprehensive origin-destination survey was conducted in the metropolitan core of the Capital District (Albany-Schenectady-Troy, N.Y.) by the New York State (NYS) Department of Public Works (1). The study consisted of three parts: home interview, truck and taxi survey, and external survey. A vehicle-miles-of-travel survey was also conducted that attempted to measure the magnitude of vehicular travel in the survey area.

The Department of Public Works conducted the home interview portion of the survey to determine household, personal, and trip-making characteristics of residents and out-of-town visitors in the Capital District. The survey was taken in the urban (cordon) area and data were collected from one out of every fifty households (or 2 percent) in this area. A total of 3,697 samples were originally selected; however, 3,048 surveys were completed. The truck and taxi survey consisted of selecting a sample of 5 percent of commercial vehicles registered with the NYS Department of Motor Vehicles. The external survey was conducted by setting up roadside interview stations and portable traffic counters at the major and minor highway crossings of the cordon line.

The resulting origin-destination information and trip generation data, by mode and purpose, for various groups of urban households served as the data base for transportation planning in the Capital District through the 1970s. After the 1980 census, the Capital District Transportation Committee (CDTC), as metropolitan planning organization (MPO) for the area, programmed staff effort to investigate the feasibility of a small-scale household travel survey to supplement journey-to-work and demographic information available from the census.

Objectives of the CDTC survey were

1. To determine trip rates by mode, purpose, and occupancy for various classes of households grouped by automobile availability and employment status;
2. To determine median trip lengths by geographic area;
3. To allow for weighting of data according to 100 percent sample census results to provide regional means and medians for trip characteristics; and
4. To allow for detailed analysis of origins and destinations of all personal travel.

The resulting information would serve, with census information, as a data base for continuing transportation planning. Several survey techniques were investigated by the CDTC central staff to determine the anticipated cost and effectiveness of each.

SURVEY SIZE

Preliminary calculations indicated that 2,500 usable responses from a random sample of households would maintain adequate accuracy at all levels of desired disaggregation.

The 2,500 responses were expected to provide accuracy within ±7.9 percent at 95 percent confidence for regional means such as household trip rate (2). The 2,500 responses also would allow for acceptable levels of accuracy for rates calculated for subsets of the regional household population. Using up to nine subregional areas and four socioeconomic classifications to create 36 household "cells," for example, would still provide accuracy for means of household trip rates within approximately ±25 percent at the 95 percent confidence level (2). Calculations performed at the trip level (median trip length, for example), rather than at the household level, would have an even greater level of accuracy because they are based on a sample of more than 20,000 trips (at 8+ trips per household).

Adequate response by socioeconomic or geographic cell was deemed important because it was expected that responses would be adjusted to the true distribution (from the 1980 census) of households by cell to produce accurate regional means. A total of 2,500 responses were considered adequate to assure adequate response by cell.

SELECTION OF SURVEY TECHNIQUE

Several alternative techniques were examined, including traditional home interview of a sample of households, mailback survey distributed to nearly all households by means of an insert in daily newspapers, telephone interview of a sample of households, and mailback survey mailed to a sample of households. Examination focused on cost and effectiveness comparisons of the techniques as they would be applied to a detailed household and personal travel inventory. Minimizing staff administrative burden was also a consideration because it was desired to undertake the survey largely with existing staff during normal working hours.

Mailback

The major advantages of the mailback technique for the CDTC survey were its low cost and low administrative burden. It has been estimated that the cost of mail surveys is traditionally 20 percent of the cost of home interview surveys, per completed interview, and approximately 60 percent of the cost of telephone surveys, per completed interview (3).

The low administrative burden was reflected in the fact that the effort could be accomplished largely by existing staff during normal working hours. The survey could be expected to be largely self-administered, with availability to assist respondents by telephone during normal working hours the major obligation of staff members during the survey period. Postcard reminders would be used to increase response rates; evening work would therefore be limited to those callbacks necessary to complete or correct returned surveys for households that indicated that they were unavailable during the day. All other work could be accomplished as staff schedules permitted during normal working hours. As a result of this review of available techniques the Capital District Transportation Committee selected the mailback technique for testing in January 1982.

Some "rules of thumb" with respect to the mailback survey instrument design were followed to ensure usable results. These rules were

- Design the survey instrument so that the question answering sequence has no effect on the accuracy of the elicited responses;
- Design the survey instrument so that the questions asking for objective information can easily be checked or filled in;
- Ask a sponsor who is in good standing with and well known to the target population to sign the introductory letter or postcard and cover letter; and
- Stress the importance of the survey and the confidentiality of the responses in the cover letter, and if possible draw a comparison between the Census of Population and Housing and the travel survey.

A successful Kentucky Department of Transportation (KDOT) survey served as a starting point for the design of the instrument (3). The previously mentioned rules of thumb were used to adapt the KDOT instrument to the broader Capital District objectives of trip information on all trips, rather than information on just automobile driver trips as sought by KDOT. It was also determined that a pretest would be used to verify the feasibility of the technique for the Capital District survey before a commitment to undertake a full-scale survey would be made.

SURVEY DESIGN AND PRETESTS

Survey Design

The survey instrument was designed during the spring of 1982. The instrument was composed of an introductory letter signed by the Chairman of the Capital District Transportation Committee (a well-known local elected official), a household questionnaire, five travel tables, and a pre-addressed business reply envelope.

The layout was designed to elicit answers to straightforward questions about household size and composition, employment status, vehicle availability, and household income, before tedious travel tables were presented. The income question was asked as the final question in the household questionnaire sequence to maximize respondent cooperation in the survey.

Physically, the household questionnaire formed the outside of a folder containing the five loose, two-sided travel tables. The household questionnaire was designed to detach along perforations so that it could accompany completed travel tables in the return envelope. Instructions for the travel tables were printed on the inside of the front of the folder (the reverse side of the household questionnaire), and reminders and final instructions were printed on the inside of the back of the folder. Instructions were designed to be as brief and as simple as possible, to avoid discouraging potential respondents from completing the forms. Also, instructions included the name and telephone number of a staff member who could be contacted for assistance. Travel tables provided space for information on up to 11 trips per person. Respondents were instructed to use a separate sheet of paper for any additional trips.

Respondents were asked to assign a "person number" to each household member over the age of five and to provide sex, age, relationship to head of household, and employment status data for each member. Respondents were also asked to note whether each member traveled on the designated travel day. During the pretests, a specific midweek day was designated for the travel inventory; however, this required coordination of the printing and mailing of the surveys to ensure that the survey arrived at the household an appropriate time before the designated day. One result of the pretest was to change the designated day to "Next Tuesday," thus providing greater latitude with regard to timing. The household questionnaire also asked for data concerning vehicle availability, household location, and household income. The questionnaire provided a prominent space for respondents to provide a name, telephone number, and time of day for use by the staff in calling back to verify responses.

The layout of the travel tables was designed to minimize confusion on the part of the respondent. Arrows directed the respondent from question to question for each trip. "Checkoff" answers were used to the extent possible to minimize effort.

In addition, the form used a "Then I went to" method for linking trips in such a way as to eliminate the need to duplicate the destination of one trip as the origin of the next trip. The destination of the trip alone was requested. This also eliminated the extra work and confusion caused by asking "Purpose from" and "Purpose to" as was done in the KDOT survey and others.

One travel table was to be completed for each household member 5 years of age or older who traveled during the designated travel day. Respondents were asked to indicate the person number of the household member to whom the travel table applied.

To improve response rates, a follow-up postcard was sent to each household, timed to arrive within 1 week of receipt of the survey. The postcard requested that the householder complete and return the survey forms if he or she had not already done so.

First Pretest

On June 8, 1982, the first pretest was mailed to 288 Capital District Area residents randomly drawn from telephone directories. Of the 288 questionnaires that were mailed, 30 could not be delivered as addressed. No attempt was made to replace these 30 sample respondents for the pretest. By Friday, June 18, 31 completed surveys had been received, and on June 21, reminder postcards were mailed to the remaining 227 nonresponding households. Of the 258 surveys that were delivered, a total of 54, or 20.5 percent, were completed and returned (31 or 12.0 percent prepostcard, 22 or 8.5 percent postpostcard), and 43 (16.7 percent) of these were usable as returned or after brief verification telephone calls. Eleven unusable responses were from households that could not be reached during the 8 a.m. to 5 p.m. work day and were therefore not contacted.

The results of the first pretest verified that the survey instrument was effective in producing usable results. Mean trip rates, mode share, household size, and household income were very close to expected values. The overall usable response rate of 16.7 percent was nearly at the expected 20 percent level, even without repeated callbacks. No firm conclusions could be reached concerning the response rate by income group because of the size of the pretest sample, but although underrepresentation among lower income groups had been expected, responses from the $0 to $10,000 household income class represented 17.1 percent of all usable responses, compared with an expected value of 19.7 percent based on household distribution. The only significant deficiency in response rate was in the $0 to $4,999 group; this deficiency could be explained by the telephone directory sampling procedure.

Underrepresentation was found in response rates from two geographic areas: the city of Albany and the suburban area to the southwest of Albany (Delmar and the eastern parts of Rotterdam and Guilderland'. Usable response rates from these two areas were 3.7 percent and 3.4 percent, respectively, compared with 16.7 percent across all nine subregions. Although the variation among subregions could not be statistically verified, it was concluded that, if the overall response rate and the variances of the response rates between subregions could be corrected, a full-scale final survey would be warranted. Because most travel data reported by the responding households were sound, some form of respondent incentive, and to a lesser extent the survey instrument, was identified for further research.

Second Pretest

The second pretest was designed primarily to test the effect of incentives on response rate in areas from which response had been low in the first pretest. The introductory cover letter included an offer of two bus tokens for use on Capital District Transportation Authority (CDTA) buses or a free county map as a token of appreciation for completing the questionnaire. Reference to the incentive was included on the reminder section of the questionnaire folder, and boxes to check for token, map, or "nothing, thank you" were added to the return envelope.

Minor revisions to the survey forms were made to clarify the "How did you get there" column by rephrasing the mode choice options. (For example, "car/van/truck-driver" was changed to "driver-car/van/truck" to properly separate drivers from passengers.)

A clarification of the difference between CDTC and CDTA was made through an introductory postcard. The postcard was intended to improve the response rate among households that were not transit users; several respondents to the first pretest refused to cooperate because "they didn't have any bus service anyway."

During September 1982 a second household survey pretest incorporating the recommendations that resulted from the initial pretest (introductory postcard, offer of incentives, alteration of the "How did you get there" column on the travel table, and inclusion of a space to indicate the completion date of the survey) was conducted. One hundred households were chosen from the two subregions (superdistricts) that had low response rates in the first pretest. Of the 50 surveys mailed to households within each superdistrict, 47 were actually delivered in superdistrict 1 (Albany) and 49 were actually delivered in superdistrict 5 (Delmar and so on).

A total of 22 responses were received, 20 of which were useful. Ten responses were received from households located in superdistrict 1 (9 useful) and 12 responses were received from households located in superdistrict 5 (11 useful). Hence, the useful response rate for superdistricts 1 and 5, respectively, was 19.1 percent and 22.5 percent, which represents a total response rate of 20.8 percent for both districts. Of the 20 responding households, all but 4 requested a token of appreciation: nine respondents requested county maps and seven requested CDTA bus tokens.

The usable response rate for these two superdistricts was judged significantly higher than that obtained in the first pretest (20.8 percent versus 3.5 percent). It was concluded that the usable response rate from a full-scale survey would be at least 20 percent across all superdistricts and that a mailout of the survey to 12,500 households (4.7 percent of the four-county Capital District total of 267,000 households) would produce the desired 2,500 responses. The commitment to undertake the full-scale survey in the spring of 1983 was made by the CDTC Planning Committee in October 1982.

SAMPLING METHODOLOGY

The success of any sampling methodology depends on the completeness and accuracy of the sampling frame. Area telephone directories were used as the sampling frame for the two pretests but were found to be inadequate because the addresses did not include zip codes, and it was difficult if not impossible to match one of the 100 zip codes in the four-county area to a particular address. Zip code availability was of particular importance for two reasons: (a) accurate zip codes would ensure the best possible delivery and (b) addresses with zip codes would enable the survey and its component pieces (prepostcard and reminder postcard) to be mailed at third-class bulk rates for an estimated savings of $3,000 over the first-class mail rate. A search for more nearly perfect sampling frames resulted in the decision to use cross-reference directories as the major portion of the sampling frame. Three cross-reference directories (CRDs), the Hill-Donnelly Cross-Reference Directory covering Schenectady and vicinity, the City Publishing Company Cross-Reference Directory covering Greater Troy and vicinity, and the City Publishing Company Cross-Reference Directory covering Greater Albany and vicinity, were purchased (total cost $190). These three directories, published in April 1982, contain telephone directory listings rearranged by location (street/area) and by telephone number sequence. The listing of households by location was used as the sampling frame because zip codes were included in this listing. However, four inadequacies of this sampling frame were acknowledged:

- The CRDs are essentially rearrangements of telephone directories; therefore only those persons having listed telephone numbers are included.
- Addresses appear just as they do in the telephone directories, which means that some addresses in the CRDs do not contain specific box or street numbers.
- The CRDs cover only 92 percent of the sampling area, and the sample from the remaining portion of the sampling area had to be chosen from a different sampling frame.
- The CRD listings could not be easily separated into the nine superdistricts, and thus the sample could not be chosen by superdistrict.

These deficiencies in the sampling frame were analyzed before the CRDs were purchased and it was concluded that none would interfere with the choice of the sampling methodology. It was also determined that the representativeness of the sample chosen would not be undermined; samples for many other successful household travel surveys relied solely on telephone directories (4).

Because the sampling frame could not be divided into superdistricts, in accordance with the methodology suggested by David Hartgen, NYSDOT (5), it was decided that a systematic sample would best suit the available sampling frame. It was assumed that this sampling technique would ensure that all areas would be sampled and that areas more heavily populated with households would be more heavily sampled and result in a proportionately accurate sample (one that would reflect the true distribution of households by town, municipality, county, or when aggregated, by superdistrict). For example, if the city of Albany had twice as many households as the city of Schenectady, it was assumed that, by taking a proportionate systematic sample, the sample would contain twice as many Albany city households as Schenectady city households. It was assumed that, after data collection, comparison of results by superdistrict could be made as long as the population of each superdistrict was large enough to have produced a sufficient number of responses.

To ready the CRDs for this type of sampling, the overlap between books was partitioned off, and sections containing addresses of residences outside the sampling area were also blocked off. Similarly, pages containing only businesses were marked. The remaining pages were numbered 1 though 700. It was estimated that the three directories included 91.8 percent of the sampling area household listings and that the required sample size from the directories was 11,475 (12,500 x 0.918). It was calculated that if 17 samples were chosen per page, the total number of samples chosen from the CRDs would be close to 11,475. (Some pages that were not totally excluded contained many business listings. Therefore, to make the sampling fair, that is, so that one household would not have a higher probability of being chosen than another, only 5 to 10 samples were chosen from these pages.)

Based on the average number of household listings per page, it was determined that the choice of every 30th household (businesses were skipped) per page, after starting randomly, would require the sampler to go through each page at least once in order to end up with 17 choices.

Eleven towns in northern Saratoga County were not covered by the CRDs. Household population figures for each of these 11 areas were estimated and their percentage distribution calculated. To be consistent with a proportionate sampling methodology, these percentages were multiplied by the target number of samples, 1,025 (12,500 - 11,475), to estimate the number of samples needed from each town. Area telephone directories were then used to choose the 1,025 samples. Again, a systematic sampling technique was used. One additional step was required, however: each sample address was located on a map that showed zip codes, and each address was assigned a zip code. A total of 12,482 samples were chosen using the methodologies described; 11,447 household names and addresses were chosen from the CRDs and 1,035 from the northern Saratoga County telephone directories.

SURVEY PREPARATION FOR MAILOUT

As mentioned previously, low cost was a primary consideration in planning and developing the survey mechanism and associated tasks. To keep costs at a minimum, the persons hired to choose the sample were instructed to write each chosen household name and address on a sheet of paper that was overlaid on an address label template. Thirty names and addresses were contained on one sheet and were ready for copying directly onto self-adhesive address labels. The purpose of this was twofold: first, each sample name and address needed to be written only once and second, potentially high typing costs were not incurred. Hence, this process was both cost- and time-efficient. Three sets of address labels were created from each sheet of 30 names and addresses, so that the introductory postcard, the survey package, and the reminder postcard sent to each potential respondent would be addressed identically.

The survey material was sent directly from the printshop to the Workshop, a local organization that trains and employs physically and mentally handicapped persons. This organization charged $1,700 to stuff the envelopes with the survey package; affix address labels to each of the 12,482 introductory postcards, 12,482 survey packages, and 12,48? reminder postcards; and sort these three separate sets of 12,482 pieces into sacks according to the rules and regulations of bulk mailing--all very labor-intensive tasks. Workshop personnel were extremely efficient in performing these tasks; they finished ahead of schedule, stored the material until it was scheduled to be mailed, foresaw all potential problems with respect to post office requirements, and delivered each mailout to the post office on schedule.

SURVEY RESPONSE AND QUALITY CONTROL

The introductory postcard was mailed via bulk mail on March 14 and the survey package was mailed via bulk mail on March 22. The reminder postcard was mailed via bulk mail on March 29. Although precautions were taken to develop an accurate sampling frame, especially with respect to zip codes, a total of 1,825 survey packages were returned because they were undeliverable as addressed. Of these addresses, 1,606 (88 percent) were from the CRDs and 219 were from the telephone directories. The total number of survey packages that were actually delivered was 10,657.

The first incoming call about the survey was received on March 23, and between March 23 and April 22 a total of 89 calls were received. During this 18-day period, 43 calls were received during the first 6 days, 38 during the next 6 days, and 7 during the last 6 days. The 89 calls were categorized by reason. The categorizations and distribution of calls by category appear in Table 1. A total of 2,775 completed questionnaires were received between March 28 and June 8, a period of 73 days, 53 of which were work days. Four days elapsed between the survey package mailout and the receipt of the first

TABLE 1 Categorization of Incoming Calls by Purpose

Nature of Call	Number of Calls	Percent of Total Calls
Wrong person? (Are you sure you want me to fill this out?!)	16	18.0
Don't use transit	2	2.2
Need help	34	38.2
Complaint (about length of survey, income question, survey in general)	9	10.1
Refusal to complete survey	14	15.7
Other (need more travel tables, addressed to a deceased person)	14	15.7
	89	99.9[a]

[a]Does not equal 100.0 due to rounding.

completed surveys. Of the surveys returned, 36.8 percent were received during the first 5 work days that returns were received, and 43.8 percent were received during the second week that returns were received. A total of 80.6 percent were therefore received during the first 10 days that returns were received (see Table 2).

As the completed forms were received, a staff member opened each envelope and reviewed the responses for completeness, consistency, accuracy, and usefulness. Each returned survey was then put into one of three boxes--useful, useless, or callback (time specified). For example, some respondents simply mailed back the complete package or a letter stating the reason for their refusal to complete the form. A small number of respondents totally misunderstood the purpose or instructions and sent back totally unusable data. In these cases it was not expected that a callback would produce usable results, because it would require a detailed explanation of the survey purpose and instructions and would require respondent recall of all trip-making household members. Some survey forms were completed properly (the sequence of trips made sense, travel data for all persons above age 5 was included, and so forth), but one or all personal data questions were not answered or part of the trip information (e.g., minutes, miles) was omitted. These surveys were determined to be useful and it was thought that to call the respondent about the omissions in the information would be an invasion of privacy because the omissions were probably deliberate.

Other surveys that were received were completed properly but either were not 100 percent complete or were not consistent. For example, many completed travel tables were missing a return trip; other questionnaires received indicated that three persons in the household traveled but only two travel sheets were completed. In other responses it appeared that two people traveled together all day, but one person reported making more trips than the other person. Households returning these types of responses were called back so that the accuracy of the information they provided could be verified. A total of 254 households were telephoned, resulting in 250 useful responses (see Tables 3 and 4).

A total of 2,775 surveys were returned, which represents a response rate of 26 percent. Of these, 160 surveys were categorized as useless and 2,608 as useful. Hence, the useful response rate (out of the total number of survey packages that were actually delivered) was 24.5 percent. The useful responses came from approximately 1 percent of all households in the four-county area.

Survey response was considered satisfactory because usable responses exceeded the objective of 2,500. In addition, the effectiveness of the survey design was demonstrated by the low rate of complaint and refusal calls (23 out of 10,657 delivered packages) and calls for help (34). The fact that less than 10 percent of the responses received were not useful was an indication that the survey instrument was understandable by potential respondents.

TABLE 2 Household Travel Survey Response Time Distribution

	Elapsed Work Days[a]	No. Received	Cumulative No. Received	Percentage of Total Received	Cumulative Percentage of Total
Mailout	0				
First week of returns	4	103	103	3.7	3.7
	5[b]	23	126	0.8	4.5
	6	132	258	4.8	9.3
	7	368	626	13.3	22.9
	8	387	1,013	13.9[c]	36.8
Second week	9	493	1,506	17.8	54.6
	10	192	1,698	6.9	61.5
	11	206	1,904	7.4	68.9
	12	100	2,004	3.6	72.5
	13	226	2,230	8.1[c]	80.6
Third week	14	222	2,452	8.0	88.6
	15	73	2,525	2.6	91.2
	16	49	2,574	1.8	93.0
	17	33	2,607	1.2	94.2
	18	22	2,629	0.8[c]	95.0
Fourth week	23	82	2,711	2.9	97.9
Fifth week	28	37	2,748	1.3	99.2
Sixth week	33	13	2,761	0.4	99.7
Seventh week	38	6	2,767	0.2	99.9
Eighth week	43	3	2,770	0.1	100.0
Ninth week	48	2	2,772	0.1	100.1[d]
Ten weeks and more	53	3	2,775	0.1	100.2[d]

[a]Work days elapsed from the day of the survey package mailout.
[b]The reminder postcard was mailed 5 work days (1 week) after the survey package was mailed.
[c]Percentages of total received during the first, second, and third weeks were 36.8, 43.8, and 14.4, respectively.
[d]Does not equal 100.0 due to rounding.

TABLE 3 Timing of Callbacks

No. of Week-days After Mail-out Survey	No. of Households Called
6	23
7	9
8	29
9	16
10	11
11	19
12	44
13	23
14	21
15	35
16	7
17	12
18	4
	253

TABLE 4 Purpose of Callbacks

Purpose	No. of Callbacks	Percentage of Callbacks
Return trip(s) missing	213	83.9
One or more trips omitted	28	11.0
Miscellaneous	13	5.1
	254	100.0

The use of bulk rate mailings was also satisfactory; most respondents appeared to have received material well within the expected 10-day delivery schedule, as evidenced by the return of over 1,000 completed surveys within 8 working days of the mailout. If any problem was experienced with bulk mailing, it was with the coordination of the presurvey postcard, survey package, and reminder postcard. In some instances these items were delivered out of sequence, and on occasion the postcards were received but the package was never delivered. This prompted a few telephone calls requesting a package. These problems were minor, however, relative to the cost savings achieved by using bulk rate mailouts.

DATA ENTRY

Several alternative procedures for efficient data entry were investigated before the mailout of the full-scale survey. One option available was to have respondents self-code responses on survey forms designed to be readable by optical scanning equipment. This option was ruled out because of the difficulty of designing a survey form that would be both optically scanable and effective in eliciting usable responses.

The second option considered was to have staff code responses on a separate form that could then be optically scanned. However, certain responses such as household and trip destination addresses could not be easily entered on an optically scanable form without making the form unwieldy. Also, household data and trip data would require separate forms. The cost of designing and printing the forms needed and testing available optical scanning equipment was prohibitively high.

The option selected was to develop an interactive computer program that would allow clerical staff to enter survey data directly into a computer file by supplying answers to questions that appear on the computer terminal screen. The program was written in FORTRAN and tested and refined before the survey mailout. The program and data files were entered and maintained through an account at Rensselaer Polytechnic Institute (RPI) and accessed by remote terminal at CDTC central staff offices.

The procedure involved examination of the returned survey forms, callbacks, and corrections as necessary before data entry. Actual data entry involved logging in to RPI via telephone and entry of survey responses one household at a time. The program solicited data from the terminal operator by means of commands and questions such as "Enter the 4 digit household number" or "How many people live in the household?" The sequence of questions and commands led the operator through the entire survey response in the same order that items appear on the survey forms; responses to the household questionnaire were entered first, then responses to travel tables were entered.

When a negative response to "Did this person make any more trips?" was keyed in, the program moved on to the next person's trips; when all household members' trips were recorded, the program moved on the the next household. At the end of the terminal session, a paper printout of the data file created during the session was obtained and proofed. Corrections were made and the file added to the master file produced to date.

The results of the interactive data entry were quite satisfactory. Detailed household data and trip data including addresses, times of day, trip length, mode, purpose, and occupancy for 2,608 households and 22,308 trips were entered, proofed, and corrected in an average time of 14 minutes per household. A major reason for the efficiency was that no intermediate coding was required. Data were entered directly from the survey forms reducing the time required and minimizing the possibility of generating error in coding.

Costs to execute the program at RPI averaged $0.50 per household entered; however, the technique would be suitable for application on any microcomputer with at least 90K memory available for program storage. Resulting data files approached 2 megabytes in size and contained literal address records and coded values for all other responses.

A record format code was appended to each record in the data file to allow variable formats to be used. Variable formats were necessary because of the wide variety among households in the number of people per household and trips per person. The record format codes allowed data summary programs to access the varied record directly, using the codes as instruction about what information was contained in each record.

PRELIMINARY RESULTS

Socioeconomic and household person trip rate data from the 2,608 usable surveys were summarized and analyzed with respect to their compatibility with expected results. This process revealed that the reported mean household size (2.673), mean household income ($28,405), mean vehicle availability (1.68), and average employees per household (1.24) approached their expected values of 2.678, $25,843, 1.45, and 1.23, respectively (6). In addition, the household trip rate estimate of 8.5 person trips per household per day and the distribution of household trip rates by household size were close to their expected values (the expected average trip rate was between 7.5 and 9.0) (7).

However, further analysis of the data revealed that households of size one, low-income households, and households with zero vehicles available were underrepresented. Hence, the data file was adjusted or weighted by household size and vehicle availability in an attempt to smooth out the differences between the reported and expected socioeconomic distributions. Although the survey distributions for some socioeconomic variables were not identical to expected values, the trip rate data for each socioeconomic category are still representative of all households in the category because the minimum acceptable number of responses per category still exists. Therefore the data reported by households in each cell can be used in developing trip relationships by socioeconomic class and in producing regional means and medians.

The survey trip data must be further analyzed before final statistics can be made available and conclusions drawn. However, the results from the analyses of the socioeconomic data and household trip rates indicate that the expectations regarding the effectiveness of the survey instrument, sampling design, mailback technique, and accuracy of the survey data have been met.

COSTS OF SURVEY DEVELOPMENT AND APPLICATION

Certain inefficiencies were experienced in development of the survey approach that would not occur in repeat applications. Costs for administration and data entry of the full-scale survey were relatively low, however, indicating that the technique is suitable for repeat applications on limited budgets.

Survey Development

The inefficiencies experienced in the development of the procedure related to staff caution in making a financial commitment to the full-scale survey. As a result, considerable time was spent researching alternative techniques and circulating draft survey instruments to other agencies for review and comment. In addition to the two pretests discussed in this paper, a "pre-pretest" was performed with neighbors and relatives to gain advice and input to the survey design. Also, research was performed regarding alternative means of producing updates to Capital District travel behavior information without performing a survey. This effort was made to properly weigh the costs and benefits of undertaking a full-scale survey. Inefficiencies were also caused by staff turnover during the development phase. Overall, research, survey design, and all phases of pretests cost approximately $19,000 over a period of 18 months, including postage, printing, and indirect costs. The major portion of the cost was technical staff charges and indirect costs.

Survey Application

The actual administration of the full-scale survey was performed relatively efficiently as a result of an effective survey instrument that limited the number of unusable responses and callbacks. The interactive computer data entry saved considerable data coding time. Review of responses, including assistance to householders with questions and callbacks to households who returned incomplete responses cost only $3,700. Data entry by clerical staff and subsequent proofing of all entries by technical staff required an average of only 14 minutes per completed response and cost only $6,900 in staff time. Also, a local handicapped workshop was employed to stuff, attach labels, and sort the surveys for bulk mailing. The cost of this was only $1,700 or $0.14 per survey distributed.

These efficiencies resulted in a modest total cost for the full-scale survey. Overall cost was $36,600 including $4,500 for printing of survey materials and maps and purchase of bus tokens; $6,000 in postage for separate mailouts of presurvey postcard, survey package, reminder postcard and incentive, and for return postage for completed and nondeliverable packages; and $2,000 in computer time-sharing costs. The survey required 660 hours of technical staff time and 770 hours of clerical staff time. The average cost per completed, usable survey was approximately $14.00.

These costs do not include costs for further refinement and analysis of survey results. The Capital District Transportation Committee has a separate task scheduled for its 1983-1984 work program to undertake a detailed analysis of trip origins and destinations, for example.

Costs for repeat application of the survey could be expected to be somewhat lower; there would be no start-up costs associated with development of the computer coding technique, and CDTC's recent purchase of a large-capacity microcomputer with hard disk would eliminate most all or all of the computer time-sharing costs. The cost per completed survey for a repeat application could be expected to be approximately $10.00.

Costs of application of the survey procedure in other metropolitan areas would vary, depending primarily on agency indirect rates. For the CDTC survey, indirect rates of 120 to 160 percent were included in costs of technical staff time, and no indirect charges were associated with temporary, clerical staff time. Table 5 gives the costs associated with the survey application.

TABLE 5 Cost of Survey Application

	Person Hours		Cost ($)			
Task	Technical	Clerical	Staff	Printing	Postage	Other
Survey formulation and sample design	40	–	1,073	–	–	190[a]
Sampling	116	300	4,305	–	–	–
Mailout preparation	70	11	2,435	2,300	–	–
Mailout	–	–	–	–	5,300	1,700[b]
Research coding techniques, develop coding programs	148	–	3,707	–	–	–
Receive incoming calls, review responses, call back respondents	125	90	3,737	–	–	–
Data entry and proofing	162	443	6,914	–	–	2,000[c]
Incentive mailout	–	–	–	2,250	750	–
Total	661	844	22,175	4,550	6,050	3,980

Note: Dash = no cost.
[a]Directories purchased.
[b]Stuffing envelopes.
[c]Computer time.

OBSERVATIONS AND CONCLUSIONS

A self-administered household travel survey appears to be satisfactory in eliciting detailed household and personal travel information. Data collected by the Capital District survey will be used by the CDTC central staff and others for several years in updating 1965 travel relationships currently used in travel forecasting and other activities. Combinations of data obtained will also permit analysis of trip-making characteristics of various "life-cycle" groupings of households, and median trip length information by geographic area will be useful in updating traffic simulation models. The technique appears applicable to other metropolitan areas and repeatable in the Capital District for a modest investment of staff and financial resources.

ACKNOWLEDGMENTS

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Application of the Highway Condition Projection Model to Interstate 4-R Repair

DAVID T. HARTGEN

ABSTRACT

Procedures developed by the New York State Department of Transportation to evaluate repair strategies for the Interstate Resurfacing, Restoring, Rehabilitating and Reconstructing (I-4R) Program are described. Two procedures were used: (a) 5-year work programs for projected I-4R expenditures, developed by the department's 11 regional offices and based on a preliminary allocation of funds to substate areas, and (b) regional-level quantification of current and projected pavement repair needs using the highway condition projection model (HCPM). Both methods produced generally similar results. The HCPM was generally able to identify sections in need of repair and the work required. Overall, the HCPM placed pavement needs estimates at $164 million for 5 years; if implemented, these actions would substantially improve the condition of older New York State Interstates. Regional cost estimates for work needed were higher than HCPM estimates because of included nonpavement improvements. The analysis concludes that an overall network view of repairs is useful in balancing more specific project assessments, which are best prepared by experts closest both administratively and geographically to the project.

Numerous studies have documented the existence of significant deterioration in the extensive system of U.S. roads. At the national level estimates of the repair bill for highways and bridges run upward from $100 billion (1). Although evidence from the most recent Highway Performance Monitoring Study (2) suggests that the condition of local and state roads is worse than that of Interstates, most recent attention has focused on the overall condition and carrying capacity of the Interstate system. Failure of an Interstate bridge in Connecticut and associated traffic problems have further increased public and press attention to overall repair requirements. Although the proportion of Interstates in poor condition is lower than that of other systems (3), this proportion has increased rapidly in recent years. Many Interstates were constructed in the 1960s and early 1970s and are now beginning to require significant repair. The Surface Transportation Assistance Act of 1982 provides additional funds for resurfacing, restoring, rehabilitating, and reconstructing Interstates (I-4R), and these funds have been substantially increased over previous allocations. Nevertheless, considerable concern exists as to whether funding for I-4R repairs will be sufficient to maintain the high quality of the existing system, which carries more than 20 percent of the nation's traffic.

Some of the procedures being used by the New York State Department of Transportation (NYSDOT) to evaluate the condition of Interstates and to develop repair strategies that will allow the state to maintain its Interstates in good condition are described. The approach taken in New York is to combine a strongly decentralized project selection process (done largely through the department's 11 regional offices) with an overall assessment of repair needs based on idealized repair strategies developed by a pavement management task force. Estimates of the longer range impact of repair strategies (condition and cost) are then made with the department's highway condition projection model (HCPM). These estimates are then compared with similar estimates developed by the department's regional offices. A further purpose is to evaluate the capability of the HCPM to assist in the development of highway repair programs. Of particular interest is the ability of the model to identify candidate projects needing work, both in the short and long term; to identify what actions should be undertaken at these locations and when; and to estimate the cost of the work.

It is concluded that the use of broad methodologies for network assessment is particularly important in the allocation of funds for the Interstate system and that such methods can also be useful in identifying specific immediate and future repair needs. However, decisions concerning priorities of pavement improvement versus other actions, as well as the specifics of design for particular road repairs, are best left to engineering judgment and analysts closest to the site, both administratively and geographically.

OVERVIEW OF METHOD

Figure 1 shows an overview of the procedure. The process begins with an assessment of total funds

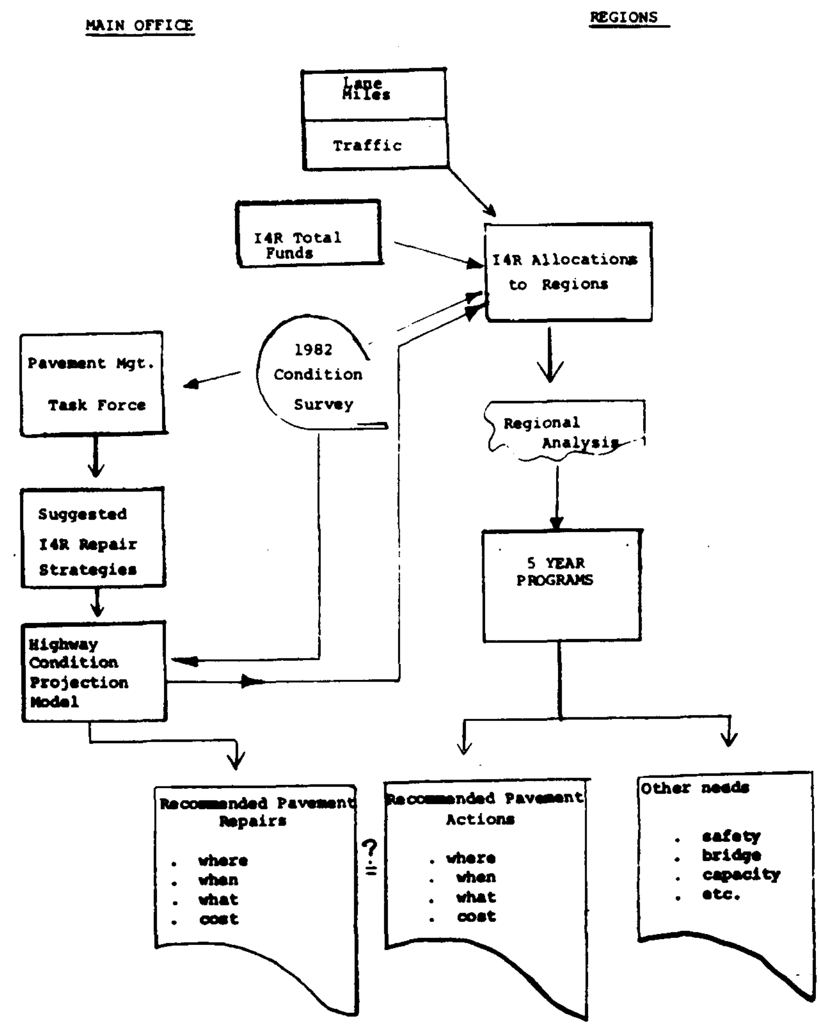

FIGURE 1 Analysis procedure for I-4R study.

available for the 5-year period (Table 1). Total I-4R funds available to New York ($530.5 million) are first reduced by the amount apportioned to the Thruway ($146.1 million). Remaining funds ($384.4 million) are then allocated to the department's 11 regions by the formula:

Allocations to regions = 75% (55% Int. lane-miles + 45% Int. VMT) + 25% (55% Int. bridge $ needs + 45% cost-weighted, pavement $ needs)

TABLE 1 NYS Regional I-4R ALLOCATIONS

Region	Prior Act[a]	Surface Transportation Act of 1982[a]
1 Albany	42.5	62.3
2 Utica-Rome	0.3	0.4
3 Syracuse	36.3	49.8
4 Rochester	18.0	26.5
5 Buffalo	8.9	14.4
6 Elmira	1.2	2.4
7 Watertown	10.9	17.7
8 Poughkeepsie	49.6	70.4
9 Binghamton	11.6	20.3
10 Long Island	–	–
11 New York City	83.3	120.2
NYS Thruway	100.2	146.1
Total	362.8	530.5

[a]In millions of dollars.

The first portion (75 percent) of the allocation is simply the federal formula based on lane-miles and VMT; the second portion (25 percent) adds factors for bridge and pavement needs. Pavement needs are developed from the 5-year estimates described herein weighted to account for different regional unit construction costs. Table 1 shows the allocation of funds to the department's 11 regional offices for the 5-year program.

On the basis of these allocations the regions analyze sections in need of repair and develop regional programs. The development of the program is undertaken largely by regional staffs with general guidance from the department's main office in Albany. Specific sections of highway to be repaired or otherwise improved are identified by the regions on the basis of their perception of various regional needs, including safety concerns, bridge repairs, capacity improvements, and pavement-related actions. Each regional office then submits a set of proposed repair actions for each of its funding categories including I-4R.

To provide a general state-level background to the regional assessments and to assist in the analysis of specific projects, the NYSDOT main office undertakes a separate assessment. This process begins with a current (1982) highway condition survey. This survey, which is an assessment of the condition of all sections of state touring routes (15,687 miles), is undertaken in the early summer of each year. This information, particularly the percentage of Interstates and other facilities in poor condition, was provided to the Department Pavement Management Task Force for analysis.

The goal of the task force was to develop recommended strategies for repair of the Interstate system. New York's Interstate system was largely constructed in the 1960s, although some sections are older. Three kinds of Interstate pavement are presently in place: rigid, flexible, and overlay (Figure 2). Analysis of the condition of these systems and of the recent history of deterioration of the systems showed that, for rigid Interstates, problems

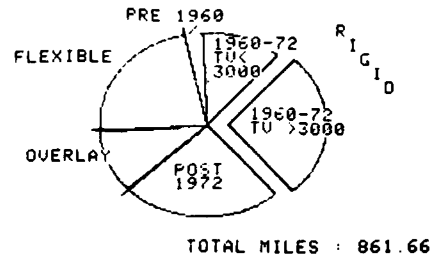

FIGURE 2 Miles of Interstate pavement groups.

with joint faulting are particularly severe for high-truck-volume roads that were built between 1960 and 1972. The reason for this is that load transfer devices between the concrete slabs have rusted through and failed, facilitating rocking movement. Some sections of Interstate, particularly I-84 north of New York City, are extensively faulted particularly in the driving (right-hand) lane where the highest percentage of trucking moves. Although other sections of highway exhibit various kinds of distress signals, the problems associated with faulting are believed to be the most severe on the current Interstate system.

Based on this analysis, the Pavement Management Task Force developed six groups of Interstates presented in Table 2 and Figure 2. For each group of Interstates, specific problems were carefully identified through detailed discussions with the task force and with regional and resident engineers.

TABLE 2 Pavement Groups

Pavement Group	Problems	Interstate Miles[a] (000s)
Rigid, pre-1960	Spalling, rutting Cracking Roughness	24.63
Rigid, 1960-1972, high truck volume (> 3,000)	Faulting > 1/4 in. Spalling Cracking	231.37
Rigid, 1960-1972, low truck volume	Faulting (less) Slight spalling	104.95
Rigid, post-1972	Slight spalling Surface and joints	209.12
Flexible	Cracking and rutting Some potholes	196.46
Overlay	Transverse joint reflection Edge spalling Rutting	95.13
Total		861.66

[a]Excludes Thruway.

Based on these analyses the task force then developed a set of recommended generalized repair strategies focusing on the maintenance of the rigid surface in as good shape as possible for as long as possible. Emphasis was on joint repair and protection of substructure, and the use of overlays for flexible and overlaid pavements as well as for rigid pavements with extensive surface deterioration but adequate base condition. The estimated costs of these repair actions and the resulting improvement in the overall condition of the pavement are given in Table 3.

These strategies, one for each pavement group, were then translated into input for the HCPM. This model, developed by the New York State Department of Transportation, projects the condition of each section of highway into the future using deterioration

TABLE 3 HCPM Input, I-4R Tests

HIGHWAY CONDITION PROJECTION MODEL

NYS DEPARTMENT OF TRANSPORTATION
TRANSPORTATION STATISTICS AND ANALYSIS SECTION

TEST DESCRIPTION: 1982 S-17 INTER BITUM; OVERLAY AT 12 YRS/COLD MILL AT 30% VOL = C

PARAMETER INPUT DESCRIPTION

NUMBER OF YEARS PROJECTED	25			
REPORT TYPE REQUESTED	ALL SUMMARIES REQUESTED			
CURRENT YEAR INPUT	1982			
INFLATION RATES	10.9%	8.7%	7.6%	7.4%
INTEREST RATES	12.9%	14.9%	13.7%	12.3%

DETERIORATION RATES

RIGID		OVERLAY		BITUMINOUS	
SURFACE	BASE	SURFACE	BASE	SURFACE	BASE
.21	.21	.40	.35	.32	.32

DESCRIPTION OF REPAIR ACTIONS ******************

ACTION NUMBER	DESCRIPTION	IMPROVEMENT IN: SURFACE	BASE	COST TO REPAIR MIL $/2LA MILE	PERCENT OF COST CAPITALIZED	ECONOMIC SERVICE LIFE	ENDING PVMT TYPE
3	MED. RECONST-PCC	7.0	7.0	1.000	100	25	RIGID
4	RECON RESURF PCC-OV	6.0	6.0	.500	80	20	OVERLAY
5	ML OVERLAY PCC -> OV	4.5	4.5	.200	80	15	OVERLAY
6	CM RESURFACE PCC-OV-OV	3.0	3.0	.120	80	07	OVERLAY
7	GRIND DR. LA/RESEAL PCC	0.4	2.5	.070	80	05	RIGID
8	PATCH SPL/RESEAL-PCC	0.5	1.0	.016	80	05	RIGID
13	MED. RECONST-BITUM	7.0	7.0	1.000	100	25	BITUM.
15	ML OVERLAY PCC-OV POST 72	4.5	3.0	.200	80	12	OVERLAY
16	CM RESURF-AC-AC-AC	2.0	2.0	.120	80	07	BITUM
17	GRIND DR. LA/PATCH SPL/RESEAL	0.8	2.5	.100	80	07	RIGID
25	ML OVERLAY AC-AC	4.5	3.5	.200	80	10	BITUM

STRATEGY MATRIX (ACTION X AT CONDITION X,X) ******************

rates supplied by the user. The model then applies a recommended repair strategy to the section and keeps track of information on necessary repair costs by year, pavement type, federal-aid class, and region. The model is extremely flexible and capable of analyzing a wide variety of repair strategies. It is further discussed elsewhere (4); Figure 3 shows its structure.

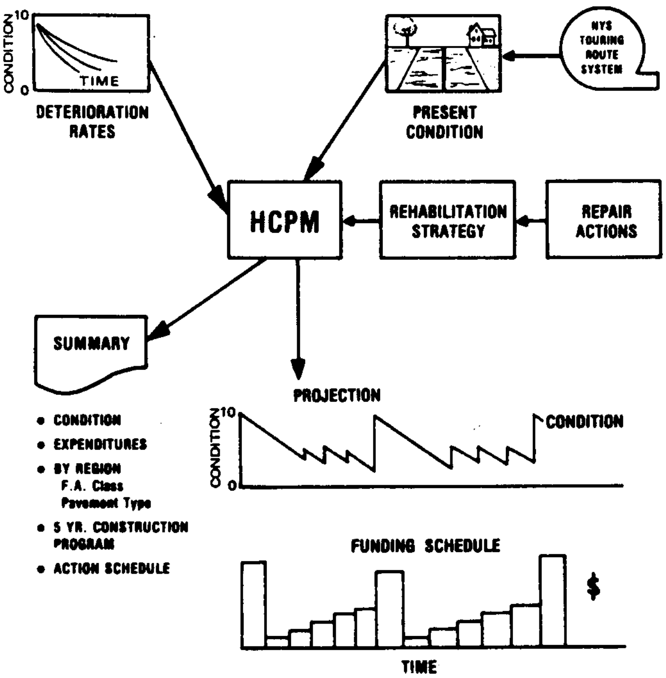

FIGURE 3 Highway condition projection model.

A sample strategy matrix for the actions listed in Table 3 is shown in Figure 4. The numbers within the matrix identify repair actions that would be undertaken when the section deteriorates to the condition shown. For example, a section of pavement in group 1 (rigid pre-1960) would be repaired using a multilayered overlay (action 5) when its condition

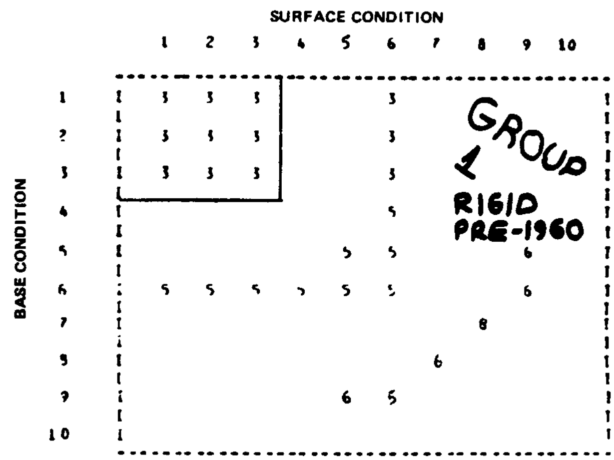

FIGURE 4 Sample study matrix.

had deteriorated to the 6-6 level. The condition scale used to assess highway condition here is one developed by the New York State Department of Transportation using photographs to score roads rapidly in the field. This scale is discussed thoroughly in other reports (5,6). The strategy matrix also shows a box in the upper left-hand corner; this is the minimum condition matrix; that is, the condition level below which roads will be not allowed to deteriorate. This matrix is used in combination with a lane-volume cut-off criterion identifying sections to which the strategy matrix should be applied. In the example discussed here the lane cut-off criterion was set at zero; thus the strategy matrix would be applied as shown to all highway sections in the group.

To account for different deterioration rates for various kinds of pavements and for the effect of traffic on deterioration, the model was supplied with deterioration rates given in Table 4. These deterioration rates were developed by analyzing the deterioration of existing sections of New York State highways.

The output of the HCPM is an estimate of overall condition of each group of pavements, necessary repair needs by region, federal-aid class, and type,

TABLE 4 Deterioration Rates[a]

Pavement Group	Rigid S	Rigid B	Flexible S	Flexible B	Overlay S	Overlay B
1	.21	.21	.35	.35	.32	.32
2	.30	.30	.45	.35	.32	.32
3	.20	.20	.35	.30	.32	.32
4	.21	.21	.40	.35	.32	.32
5	.21	.21	.40	.35	.32	.32
6	.21	.21	.40	.35	.32	.32

Note: S = surface and B = base.
[a]Points per year; ten-point scale.

for each year of the projection. Examples of these outputs are available elsewhere (4).

GENERAL RESULTS FROM HCPM

In the remainder of this paper the results of the HCPM forecast are summarized and compared with the proposed strategic actions developed by the regional offices. Table 5 gives the effect of the strategies on the overall condition of and necessary repair costs for the Interstate system. First-year costs are estimated at approximately $55.9 million, resulting in a significant improvement in the overall condition of all groups of Interstates except the newest rigid Interstates constructed after 1972 (group 4). Estimated 5-year pavement-only investment requirements, (that is, funding estimates corresponding to the 5-year program submitted by the regional offices) total $163.9 million and if implemented would result in an improvement in the average condition of the system. However, older sections of Interstates would be markedly improved under this strategy sequence, and newer sections of Interstates, not needing extensive repairs in the next 5 years, would continue to deteriorate and thus the total average would be only slightly higher than the 1982 condition. On balance, therefore, the model suggests that about $164 million over 5 years would be sufficient to maintain the overall condition of the Interstate system at its present level but that this funding would have to be concentrated, particularly on the rigid 1960 to 1972 high-truck-volume category and on flexible pavements (Figure 5). Over the 10-year horizon the distribution of financing would shift slightly away from group 1 (because these routes would be worked on the first 5 years) and increase for the rigid 1960 to 1972 heavy-truck-volume facilities (Figure 6).

The distribution of funds by action type is given in Table 6. The focus of the 5-year program (44 percent) is on multilayered overlays to be added on top of the existing poor concrete pavements. Coldmilling and resurfacing of asphalt concrete pavements account for another 22 percent of the work. Joint repair (actions 7, 8, and 17) account for approximately 5 percent of the work. Because the Interstate system is in relatively good condition, only 4 percent of funding is necessary for major reconstruction resurfacing.

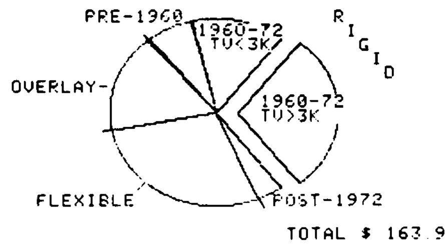

FIGURE 5 Five-year funding by pavement group.

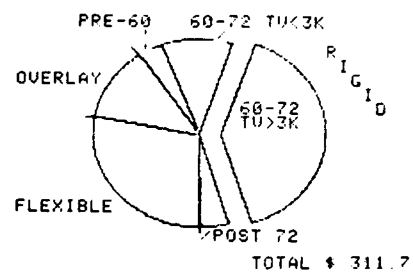

FIGURE 6 Ten-year funding by pavement group.

TABLE 6 Distribution of I-4R Repairs by Type: 5-Year Program

Action No.	Description	Percentage of Miles	Percentage of Funds
3	Med. reconst. PCC	–	–
4	Reconst./resurf. PCC-OV	1.0	4.0
13	Med. reconst.–bitum.	–	–
5	ML overlay PCC-OV	27.0	43.9
15	ML overlay PCC-OV post 1972	1.3	1.2
16	CM resurf. ACC-AC-AC	28.0	21.9
25	ML overlay AC AC	6.2	8.0
6	CM resurf. PCC-OV-OV	16.3	15.8
7	Grind DL/reseal PCC	7.2	3.4
8	Patch spl./reseal PCC	13.0	1.8
17	Grind DL/patch SP/reseal	–	–
Total		100.0	100.0

Note: Dashes = not applicable.

TABLE 5 Effect of Strategies on Condition and Repair Costs for Interstate System

Group No.	Description	1982 Condition Miles	1982 Condition S	1982 Condition B	1-Year Effect $	1-Year Effect S	1-Year Effect B	5-Year Effect $	5-Year Effect S	5-Year Effect B	10-Year Effect $	10-Year Effect S	10-Year Effect B
1	Rigid, pre-1960	24.63	6.1	6.2	5.1	[7.9]	[8.0]	11.6	[8.7]	[8.7]	11.6	[6.9]	[6.9]
2	Rigid, 1960-1972, HTV[a]	231.37	6.9	6.8	16.8	[7.1]	[7.2]	47.5	6.9	[7.2]	124.2	[7.9]	[8.6]
3	Rigid, 1960-1972, LTV[b]	104.95	7.0	6.4	9.1	[7.4]	[7.3]	23.7	[7.7]	[7.9]	34.0	[7.3]	[7.6]
4	Rigid, post-1972	209.12	8.6	8.4	2.1	8.5	8.3	6.8	7.9	7.9	13.9	7.3	7.6
5	Flexible	196.46	7.7	7.8	12.7	[7.9]	[8.1]	46.2	[8.3]	[8.3]	88.5	[8.7]	[8.7]
6	Overlay, 1982	95.13	7.4	7.3	10.1	[7.8]	[7.8]	28.1	[8.2]	[8.3]	39.5	7.5	[7.9]
Total (average)		861.66	(7.5)	(7.4)	55.9	[(7.8)]	[(7.9)]	163.9	[(7.7)]	[(7.8)]	311.7	[(8.0)]	[(8.1)]

Note: Tests based on strategies in 1/20/82 PMTF memorandum; S = surface; B = base. [ ] = improved condition.
[a]HTV = high truck value (>3000).
[b]LTV = low truck value (<3000).

REGIONAL ANALYSIS

The comparison of regional results was undertaken as follows. Careful reviews were made of the 5-year work programs submitted by each of the regional offices. From these work programs, all sections identified for Interstate 4R work were extracted and reviewed for work involving pavements. These sections were then compared with specific sections identified by the HCPM. Comparisons were made of

1. Specific locations,
2. Time frame of the period when work is necessary,
3. Nature of specified work, and
4. Estimated costs.

Table 7 provides a complete summary of each of the sections identified for repairs by HCPM and by regional analysis. The comparison by region is described next.

Overall, the best agreement between the analysis recommended by the model and that by the regions is for regions 7 (Northern Adirondack) and 8 (Poughkeepsie). In these cases both the regional analysis and the model identify largely the same sections of Interstate and in general estimate the same nature of work required by these sections. In these two regions estimated costs from the regional analyses tend to be slightly lower than the cost estimated by the HCPM (the reverse is usually the case). Sections not included in the regional analysis but included in the model tend to need work fairly late in the program. This may indicate that it is unreasonable to expect the regional analysis to identify sections that have not yet deteriorated extensively.

Less agreement is apparent in the comparisons for regions 1 (Albany), 3 (Syracuse), 5 (Buffalo), and 9 (Binghamton). In these cases the model identifies a larger number of sections requiring work, particularly toward the end of the 5-year program. In region 1, for example, both the regional analysis and the model identify similar sections, particularly rigid sections, for the short term. However, the regional analysis does not identify flexible and overlay pavements projected to deteriorate within the 5-year time frame. The patterning is similar for region 5 (although the results here are quite good) and for regions 3 and 9. In general, cost estimates from the regional analysis appear to be somewhat higher than those estimated by the model. This is because the regional estimates include additional work deemed to be necessary as part of the rehabilitation of the section, whereas the model makes cost estimates based only on the pavement work.

Greater disagreement is apparent in the comparisons of region 2 (Utica-Rome) and region 6 (the Southern Tier) although a very small number of sections are involved in each case. In both of these cases the model identifies work likely to be needed within the 5-year time frame, but the regional analysis does not include expenditures for this effort. In the case of region 2 the section of I-790 in Utica is presently in poor condition; in region 6, I-390 in the town of Avoca is presently in good shape and has not deteriorated.

For region 4 (Rochester) and region 11 (New York City), priorities for capacity, safety, and bridge funding account for the large discrepancies between the two analyses. In both cases the regional assessment focused on increases in capacity, safety work, and bridge repairs. In region 4 work is proposed for increases in capacity and a resurfacing effort associated with the Can-of-Worms (a large interchange southeast of the city) even though other sections of I-490 through the city of Rochester are identified by the model for needed repairs. In New York City the needs far outstrip the funding program. Although the model identifies a large number of sections of Interstate that are in need of repair and generally in poor condition, only a few of these are programmed; analysis of the region 11 program shows that the funds are going into bridge repair and safety work that is believed to be critical.

In general, the model seems to operate best in identifying pavements presently in poor shape and in specifying the nature of the work required. The mileage identified for action is generally larger from the model than from the regional analyses. This is because the model includes sections that are not yet in poor shape but are projected to deteriorate within the 5-year program. The regional analysis focuses on sections that are currently in poor shape, and less attention is paid to sections projected to be in that condition within the 5-year time horizon.

CONCLUSIONS AND DISCUSSION

This example suggests that a combination of decentralized decision making for specific projects and an overall network assessment is useful for program assessment. In NYSDOT experience, the highway condition projection model was found to generally be capable of identifying sections in need of repair both in the short term and over the horizon of the program. The model was found to be generally accurate in identifying the nature of the work required; however, it was less able to specify the precise costs of actions because regional costs vary and because elements of work in addition to pavement repair are often included in regional programs.

A particularly important conclusion is that the model looks ahead to the end of the time frame. Most of the regions focused on the current time and paid less attention to longer term efforts that may be needed. Regional accounts therefore often contain fewer, but more expensive, jobs.

The results also point to important concerns that should be kept in mind in using aggregate network tools for regional assessments. Perhaps the most important distinction is that the program is rightly based on a number of factors in addition to pavement condition. The regional assessments include such factors as safety, bridge work, capacity, and congestion needs as well as subregional geographic allocations. These factors, in practice, mean that there will be differences between the results of allocations based on any tool like the HCPM (even a complex one) and assessments based on regional views. The position of NYSDOT is that both assessments are valuable. The department is largely a decentralized operation in which the regional offices are responsible for the development of these programs; the availability of a highway condition projection model does not obviate the need for such assessment at the local level nor does it take away the responsibility for such assessment. It is unlikely that tools such as the HCPM will ever replace regional judgment because the development and operation of such tools in a centralized fashion presumes the existence of allocation rules that place a prespecified weighting on different factors. It is the view of NYSDOT that such weighting is best left to the judgment of those department experts who are closest administratively and geographically to the problems.

The model was found to be useful in structuring the overall size of the program and in placing local

TABLE 7 Comparison of I-4R Program, HCPM Versus Regional Analysis

Map Location		Pvt. Type	Description	Approx. Length	82 Cond.	HCPM ANALYSIS When	HCPM ANALYSIS What	HCPM ANALYSIS Cost	REGIONAL ANALYSIS When	REGIONAL ANALYSIS What	REGIONAL ANALYSIS Cost
REGION I											
A	I-87	R	From I-90 to 1/2 Mi. S of Mohawk	7.9	6/5	82	Overlay	4.7	-	-	-
B	I-87	R	1/2 M. N of Exit 9 to Exit 13	10.2	6/6	84	2.5" Overlay	6.5	84	4" Overlay	$11.0
C	I-87	R	Exit 16 to 1/2 Mi. S of 17	3.5	5/5	82	2.5" Overlay	2.6	84	4" Overlay	$ 5.0
D	I-890	R	3/4 Mi. from Sch. to Sch. city line	3.0	6/6	84	2.5" Overlay	.9	84	4" Overlay	$ 4.0
E	I-87	F	1/4 Mi. N of 14 to Exit 15	2.0	6/6	85	2.5" Overlay	.9	-	-	-
F	I-87	F	2 Mi. N of 17 to Hudson River	.5	6/6	85	"	.2	-	-	-
G	I-87	F	Hudson River to Exit 19	4.0	6/6	85	"	2.8	-	-	-
N	I-90	F	Exit 10 - 12, Rens. Co.	6.5	7/7	84	"	1.3	84	Overlay	$ 4.0
H	I-90	O	Fuller Rd. - 1/2 Mi. W of Exit 3	.25	8/8	85	Patch Reseal	.007	-	-	-
I	I-90	O	Albany City Line - Rt. 32	1.5	8/8	85	"	.070	-	-	-
J	I-87	O	Essex Co. (all)	25	7/8	85	Cold Mill resurface	$ 13	-	-	-
K	I-87	O	Alb. Co. 1/2 Mi S of Mok.	.5	7/8	85	"	.25	-	-	-
L	I-87	O	Mohawk River Exit 9	4.25	8/7	84	Cold Mill resurface	2.0	-	-	-
M	I-87	F	Exit 24 Essex Co. Line	14	8/7	84	"	3.6	-	-	-
REGION 2											
A	I-790	R	Utica, Rt. 5A - Thruway	1.0	5/5	82	Overlay	.3	-	-	-
REGION 3											
A	I 81-690	O	81-690 interchange	2.5	8/8	-	-	-		R&P	8.0
B	I 81	O	Tully (Exit 14) Exit 16	6.0	6/6	85	Overlay	1.8	84	R&P	7.5
C	I 81	R	Exit 12 - Tully (Exit 14)	12	6/6	85	Overlay	2.3	84	R&P	9.0
D	I 81	R	Thruway - Rt. 481	4	77	85	Overlay	2.0	85	R&P	1.6
E	I 81	R	Exit 32 - 33	7	87	85	Joint work reseal	.5	-	-	-
F	I 81	F	Exit 33 - 35	7	86	85	Cold Mill resurface	1.5	-	-	-
G	I 81	O	Exit 16A - Rt. 175	2	87	84	Cold Mill resurface	1.2	-	-	-
REGION 4											
A	I 490	R	Monroe Co. Line 1/2 M.W. of Rt. 36	4.4	67	84	Overlay	1.7	-	-	-
B	I 490	R	Rt. 259 - Rt. 204	4.9	65	82	Overlay	2.0	-	-	-
C	I 490	R	1/2 M. W. of Rt. 33 - I-390 Int.	3.1	67	84	Overlay	1.6	-	-	-
D	I 490	R/B	Clinton Ave. - Winton Rd.	2.8	66	82	Overlay	2.1	84	resurface	3.2
E	I 490	R	Can-of-worms - Rt. 96	7.3	77	85	Overlay	3.0	-	-	-
F	I 490	F	Rt. 96 - Thruway x 45	.4	76	84	Overlay	.1	-	-	-
G	I 390	O	various, Rochester, Gates	2.6	77	85	Overlay	.9	-	-	-
H	I 590	O	1 Mi. S of Rt. 31 - I 490	3.0	66	84	Overlay	.6	82	(add lane cow) Resurf.	6.7

TABLE 7 (continued)

Map Location	Pvt. Type	Description	Approx. Length	82 Cond.	HCPM ANALYSIS When	HCPM ANALYSIS What	HCPM ANALYSIS Cost	REGIONAL ANALYSIS When	REGIONAL ANALYSIS What	REGIONAL ANALYSIS Cost
REGION 5										
A I 190	R	I 90-N. Grand Isl. Bridge	21.5	32 to 66	83	Recont Overlay	19.7	83	Recon Repave	$22.0
B I 290	R	I 190 - I 90	9	65	83	Overlay	4.3	83	"	2.1
C I 190	R	N Grand Isl. Brdg.- Lewiston	7	66	84-85	Overlay	2.7	-	-	-
REGION 6										
I 390	R	Avoca T L - Steuben Co. Line	21	98	87	Joint Reseal	NA	-	-	-
REGION 7										
A I 87	F	Essex Co. Line - Salmon R. Rd.	10.3	67	85	Overlay	9.8	84	Overlay	2.9
I 87	F	Salmon River Rd. 3 M. N.of 456	14.3	77	85	Overlay		-	-	-
B I 87	F	Miner Farm Rd. - Canadian Border	7.6	67	85	Overlay	2.7	84	"	1.9
D I 81	F	Jefferson Co. Line- Adams/Hounsfeld Line	16.9	67	84	Overlay	6.7	84	"	4.6
E I 81	F	Exit 48- 5.72 Mi. N.	5.7	67	84	Overlay	2.3	84	"	1.3
F I 81	F	Rt. 411 - Rt. 12	9.3	77	84	Overlay	2.3	-	-	-
REGION 8										
A I 84	R	Penn. Line - Conn. Line	72	76	23 locations, 37 Mis	Grind DL, reseal	$6.1	138 lane miles	Joint Repair	$ 4.1
B I 287	R	Thruway - NE Thruway	11	66	13 locations, 7.1 Mi	Overlay	$3.3		Safety bridge reconditioning	NA
C I 587	R	Kingston	1.2	66	84	Overlay .6 Mi	.2	-	-	-
D I 684	R	I287 - I84	28	66 87	85	Grind DL, reseal 5.8 Mi.	2.1	84	Joint Repair	$ .6
E I 84	R	Rt. 311 - Ludingtonville	3.6	88	-	-	-	84	Joint Repair	$ .5
REGION 9										
A I 81	R	Rt. 17 - Rt. 7 Overcrossing	4.3	65	82	Overlay	2.2	84	R&P	$ 8.0
B I 81	R	Binghamton - Broome Co. Line	23	76	82	Overlay	4.2	82	Overlay (5 Mi. only)	$ 3.6
C I 88	R	Begn I 88 - Chenango Br.	4.2	65	82	Overlay	1.1	-	-	-
D I 88	F	Colesville	2.9	87	83	Cold Mill Resurface	.7	-	-	-
E I 88	F	Afton-Bainbridge	6.5	77	83	Overlay	2.4	-	-	-
F I 88	R	Sidney - Rt. 357	7.2	87	84	Repair Joints	.3	-	-	-
G I 88	R	Otsego-Del. Co. line CR-47	12.7	88	85	Reseal joints	.6	-	-	-
REGION 10 - Not analysed (no interstate)										
REGION 11										
A I 95	R	Cross Brox. Ex: Bronx R. Pk - I-295	3.5	66	84	Overlay	NA	-	-	-
B I 278	R	Staten Is. Ex: West Shore Ex - Richmond Rd.	4.6	56	84	Overlay				
C I 278	R	Brooklyn Qu Ex: 65th St. - Newton Creek	9.1	66 to 44	84	Overlay & Reconst.	NA			
I 278	R	BQE: Queens Bv - Grand Cent. Parkway	1.4	55	84	Overlay		84	Recon	15.7
D I 278	R	Buchner Exp. Randalls Isl - Hutchinson R. Pk.	4.1	66	84	Overlay				

TABLE 7 (continued)

E	I 295	R	Clearview Exp. 35th - 73rd	2.0	66	84	"
F	I 295	R	Cross Bronx Ex.: Bruckner Connection	.5	66	"	"
G	I 495	R	LIE: Kissena Blvd. NYC Line	5.7	55 76	84	Overlay, Grind reseal
H, J	I 678	R	Van Wyck: Nassau Ex. - Interboro Pkwy.	5.6	65 - 76	84	Overlay grind, reseal
K	I 895	R	Sheridan Ex: Bruckner Cross Bronx	1.1	66	84	Overlay
L	I 87	0	Maj. Deegan 3rd Ave. - NYC line	7.2	76	84	Cold Mill Resurface
M	I 95	0	Cross-Bronx: CWB - Bronx R. Pkwy.	4.4	77	85	Cold Mill Resurface
N	I 278	0	Bruckner:Bronx R.- White Pl. Rd.	1.3	66	83	"
P	I 278	0	BQE: Newton Crk. Queens Bvld	1.9	54 - 77	83	Cold Mill Resurface/Overlay

concerns in state perspective. The model was reasonably accurate in identifying major sections in need of repair and in forecasting future repairs. In this sense, therefore, it provides a balanced assessment of overall allocation strategies.

Given this role, what is the best strategy for using such a tool? In our judgment its best operation would be in the hands of regional analysts. Armed with such a procedure, regional analysts could themselves evaluate the long-term funding implications of locally developed repair strategies. This information could then be balanced with other needs for capacity, bridges, and so forth to develop a balanced program at the regional level. The department is presently working to decentralize the highway condition projection model so that it will be available in an on-line fashion to the regions in conjunction with their own highway condition files and other information. In this way strong pavement management principles tempered by sound local judgment and local concerns beyond the strict engineering of pavements can be combined in a successful management program.

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Method of Forecasting Payments on Construction Contracts

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ABSTRACT

The research on forecasting techniques for payments on current and proposed construction contracts reported in this paper was performed as part of a study to develop a system for generating a 1-to-2-year forecast of monthly cash flows for the Virginia Department of Highways and Transportation. The study revealed that presently used cash flow forecasting methods consistently underestimate ending cash balances. In addition, it showed that the behavior of individual contracts varies widely, with the percent paid out at the halfway point in the schedule ranging from zero to 93 percent. Furthermore, contractors' schedules, on which current forecasts are based, are not reliable indicators of contract duration, payout patterns, or final cost. By the end of the scheduled duration (contractual time limit not allowing for shutdowns) contracts are typically less than 70 percent complete. Cost overruns average 7.8 percent of the contract amount. Seasonality is a critical determinant of construction payout, as is exhibited by the fact that payouts can be six times as high in September as in January. A simple technique that emphasizes the effects of seasonality on payout and realistic estimates of contract duration explained more than 93 percent of the variation in a retrospective test of a sample data base. The accuracy of the forecasting method in actual use will depend on the variability of the weather and on the prompt entry of information on contracts let and scheduled advertisement dates into the forecasting data base.

During the past several years revenues for most highway departments have become volatile and unpredictable, and construction expenditures have been subjected to unprecedented rates of inflation. During such periods an agency runs a serious risk of encountering an inadequate cash balance in carrying out its construction and maintenance program. This risk can be minimized by (a) maintaining large cash balances that divert funds from current needs or (b) developing and using reliable management tools for short-term forecasting and monitoring of cash inflows and outflows. In Virginia the latter approach has been the chosen course of action, and in this paper one phase of improving the current forecasting technique--a more reliable construction payout model--is described.

Improved techniques for forecasting revenues, federal-aid reimbursements, and other cash flow components are beyond the scope of the paper, although research to improve these aspects of the forecasting techniques is being conducted. In this paper the data required to derive the construction contract monthly payout forecast are discussed, the techniques currently used in Virginia are critiqued, a new forecasting technique is explained, and, finally, a test of the technique is presented.

CASH FLOW FORECASTING IN OTHER STATES

States that have systematic cash forecasting methods, or are developing them, include Alabama, Arkansas, Pennsylvania, New York, Florida, Iowa, California, Utah, and Idaho. The project team reviewed in detail the methods that have been developed in Pennsylvania, New York, and Florida and concluded that the forecasting techniques in use in New York held the most potential as a basis for developing a forecasting method for use in Virginia. These techniques are described hereafter in the section on the monthly factors model.

In addition to details on forecasting techniques, the project team gained two significant insights from analyzing the forecasting systems in these states. The first is that a technically accurate forecasting technique, although vital to success, is not sufficient to generate good forecasts if the information system employed does not provide to the forecasting system a steady flow of up-to-date, accurate, and easily accessible data. The second insight is that an accurate cash flow forecasting system can be a useful management tool only if the forecasting function is closely integrated with the programming function, because programming changes must be promptly reflected in the forecasts and forecasted cash flow surpluses or shortfalls must be properly taken into account in programming decisions.

DATA COLLECTION AND PROFILE

Data were collected on 173 contracts that began after July 1, 1979, and were completed by August 1982. The payment data were plotted by computer against elapsed time for each contract, and these plots were compared to identify and exclude from the analysis contracts that exhibited unusual payout patterns. After exclusion of the outliers, the sample consisted of 162 contracts representing 19.5 percent of the construction activity during fiscal 1980, 27.4 percent during fiscal 1981, and 9 percent during fiscal 1982. The distribution of contracts by contract amount and duration given in Table 1 indicates that half of the sample consisted of contracts of $500,000 or less and 12 months or less in duration and that 9 percent were greater than $2,500,000 and longer than 1 year. Contracts from $500,000 to $2,500,000 and from 1 to 2 years in length made up 23 percent of the sample, or 37 contracts. This mix of large and small, short and long contracts is representative of the total work program of the Virginia Department of Highways and Transportation. The distribution of the dollar volume of construction activity by size of contract (Table 2) reveals that the 14 largest contracts accounted for over 50 percent of the dollar volume of construction activity for the sample and that the 92 smallest contracts

TABLE 1 Distribution of Sample by Duration and Contract Amount

Contract Amount ($)	Actual Duration from Contract to Completion (months) 0-3	4-6	7-12	13-17	18-24	25-36	Total
<250,000	11	18	15	1	0	0	45
250,001 to 500,000	1	3	33	9	1	0	47
500,001 to 1,000,000	0	1	15	15	2	0	33
1,000,001 to 2,500,000	0	1	1	12	8	1	23
2,500,001 to 6,000,000	0	0	0	2	1	5	8
>6,000,000	0	0	0	0	5	1	6
Total	12	23	64	39	17	7	162

TABLE 2 Distribution of Construction Dollar Volume by Size of Contract

Contract Amount ($)	No. of Contracts	Percentage of Dollar Volume	Cumulative Percentage
<250,000	45	3.3	3.3
250,001 to 500,000	47	9.9	13.2
500,001 to 1,000,000	33	13.2	26.5
1,000,001 to 2,500,000	23	23.4	49.8
2,500,001 to 6,000,000	8	18.6	68.5
>6,000,000	31.5	100.0	

made up about 13 percent of the volume. The average contract duration from contract date to completion, weighted by the dollar volume, is 18.4 months, and 80 percent of the contracts were for combination construction or combination plus bridge construction. The distribution of contracts by road system and project type given in Table 3 shows that 146 of the 162 contracts were on the primary and secondary

TABLE 3 Distribution of Sample by Road System and Project Type

Project Type	Road System Interstate	Primary	Secondary	Urban	Total
Combination or minimal plan	2	46	41	2	91
Combination with bridge	3	19	15	1	38
Bridge	4	5	14	0	23
Grading	0	2	0	0	2
Paving	1	3	0	0	4
Landscaping	1	1	0	0	2
Signals	2	0	0	0	2
Total	13	76	70	3	162

highway systems and, of these, all but 6 involved combination or bridge construction or both. Of the 13 Interstate contracts, 9 were for combination or bridge construction or both. The sample included only 3 urban projects.

The payout data show that the behavior of individual contracts was highly variable. For example, the ratio of actual duration to scheduled duration varied from less than one to six; the number of months between the contract date and the first payment can be anywhere from zero to 13; and the final amount paid the contractor can vary from 84 percent to 165 percent of the stated contract amount. This variability is illustrated in Figure 1, which shows the minimum, maximum, and mean payout by contract size group at 50 percent of time elapsed from contract date to completion date. Interestingly, the largest contracts, those greater than $6 million,

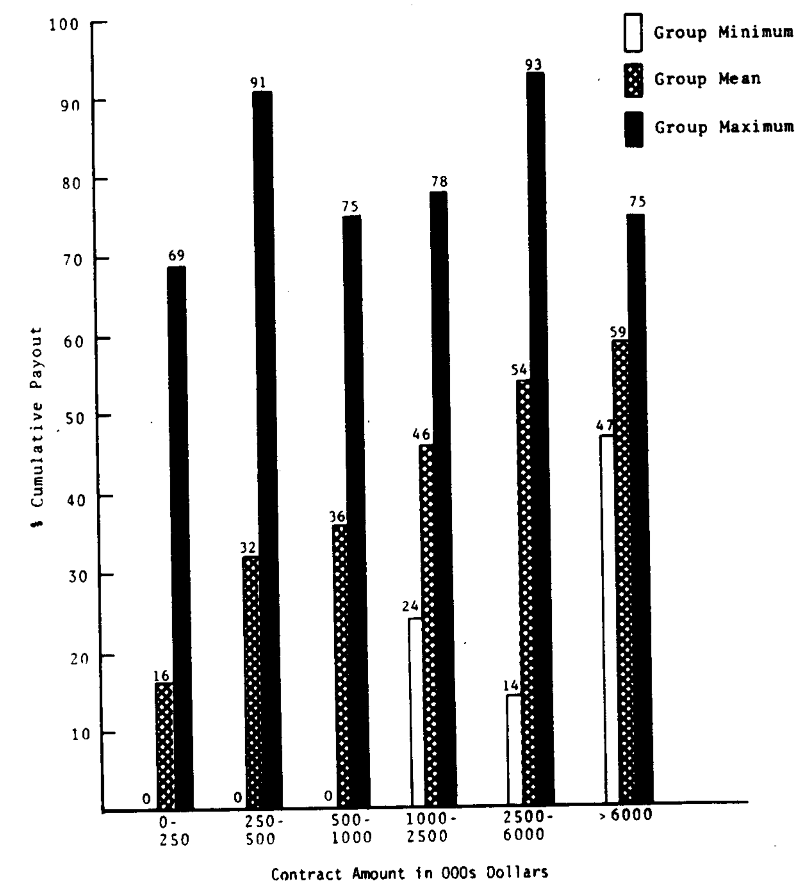

FIGURE 1 Percent paid out at 50 percent time elapsed, by contract size.

were the least variable, ranging from 47 to 75 percent payout at 50 percent elapsed time. However, the next to largest category of contracts, $2.5 to $6 million, was among the most variable, ranging from 14 to 93 percent, and for the three smallest contract size groups, the minimum payout at 50 percent elapsed time was zero and the maximum 91 percent.

Despite the variability of individual contracts, predictable patterns were found. The pattern shown in Figure 2 is that longer duration contracts paid out more rapidly at any point in the life of the contract than did shorter duration contracts. For example, at 50 percent time elapsed, a 7-to-12-month contract was 29 percent paid out, on the average, but a 25-to-36-month contract was 60 percent paid out. In general, the percent paid out was likely to be closer to the percent time elapsed on long duration contracts than on short contracts. The data also show that large contracts had smaller cost overruns, in percentage terms, than smaller contracts. Large contracts also tended to stay closer to schedule than smaller contracts.

CURRENT FORECASTING TECHNIQUES

Current Contracts

The techniques currently used by the department to forecast construction contract payout have certain identifiable limitations. In the case of current contracts, the forecast is based on the contractor's progress schedule estimate. If the cumulative payout is not equal to the scheduled payout, the difference is distributed equally over the months remaining on the progress schedule. If the project is not completed on time, the balance remaining in the contract, if less than $100,000, is paid out in the following month and, if greater than $100,000, over the following 6 months.

The difficulty with this forecasting technique is that the data show that contractors' progress schedules were not reliable indicators of the actual duration of contracts, final cost, or payout patterns. Contractors' schedules typically did not allow for any delays in construction, particularly seasonal slowdowns and shutdowns. This finding is illustrated by Figure 3, which shows the ratio of actual to scheduled payout throughout the scheduled time period for contracts of various sizes. As a general rule, contracts fell further and further behind as they approached the end of the scheduled time limit. For example, contracts in amounts from $1 million to $2.5 million were nearly on schedule at the 25 percent time elapsed point, but by the 75 percent time elapsed point they had fallen to 72 percent of the scheduled estimate. By the time the projects were scheduled for completion only 64 percent of the work had been done and paid for. The largest projects, those over $6 million, generally stayed closer to schedule than smaller projects, but they also fell behind as time elapsed, until they were only 87 percent completed when the scheduled time limit was reached.

Table 4 gives the extent to which schedules were exceeded on contracts of various sizes. The number of additional months needed ranged from 5 to 25, with a dollar-volume-weighted average of 14.5 months, or 82 percent of scheduled duration. The final cost of a project was generally much closer to the original contract than was duration. The cost

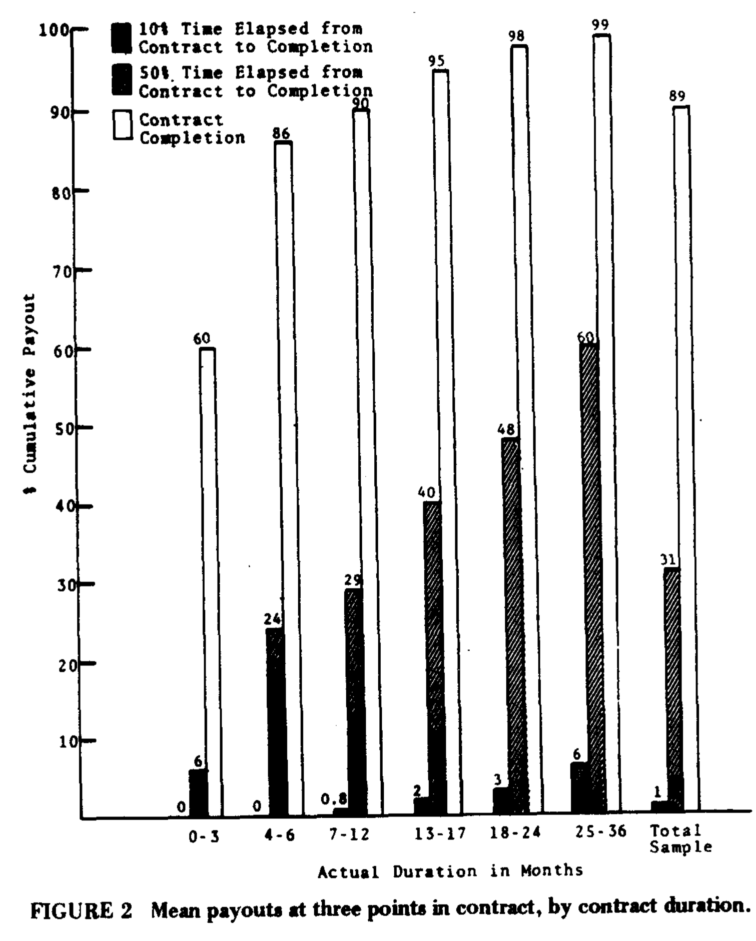

FIGURE 2 Mean payouts at three points in contract, by contract duration.

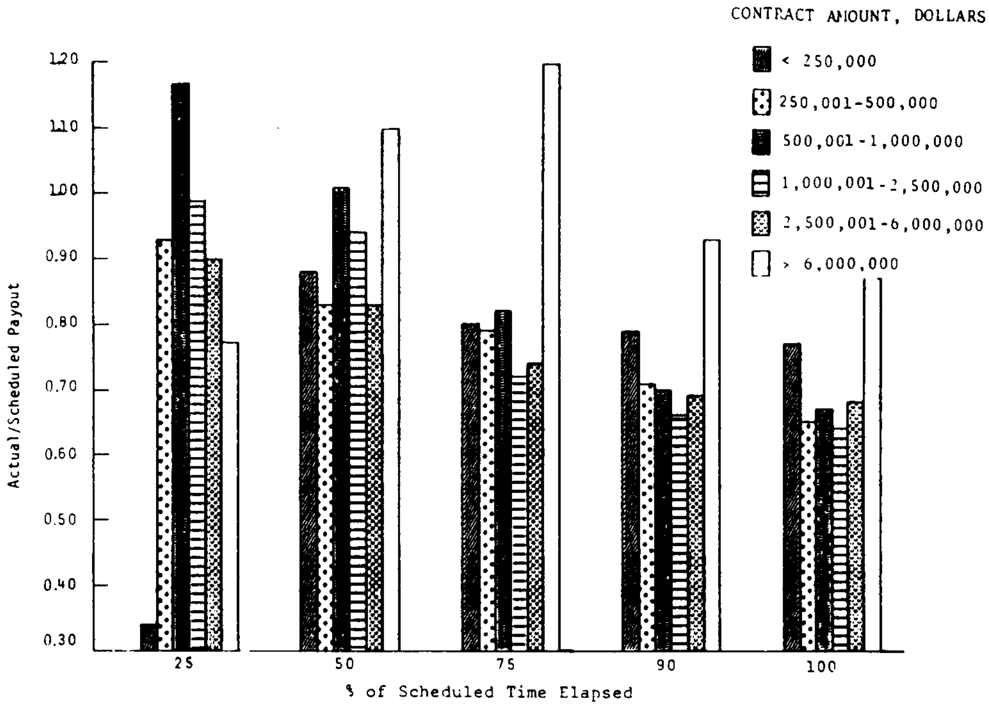

FIGURE 3 Actual/scheduled payout versus time elapsed on contractors' schedules.

TABLE 4 Schedule Overruns by Contract Size

Contract Size ($)	Actual Duration/ Scheduled Duration	Additional Months Needed
<250,000	1.83	5.0
250,001 to 500,000	1.88	8.8
500,001 to 1,000,000	1.88	10.9
1,000,001 to 2,500,000	2.10	18.0
2,500,001 to 6,000,000	2.08	25.0
>6,000,000	1.44	10.0
Weighted average	1.82	14.5

overruns ranged from 2.7 to 11.6 percent, with contracts exceeding $6 million having the smallest percentage overruns. The weighted average for the sample was 7.8 percent. The current forecasting technique takes into account only a small portion of these overruns. Work orders received on a contract through the date of the forecast are added to the original contract amount for a revised contract total. Future payments are projected until the sum of payments is equal to the revised contract total. When this point is reached in the forecast, no further payments are projected. This method makes no attempt to forecast work orders not received at the time the forecast is made. Furthermore, work orders account for only 28 percent, on the average, of cost overruns; the remaining 72 percent consists of quantity overruns, which do not require work orders.

For example, on one contract, work orders received by July 1980 amounted to $29,000, for a revised contract total of $5,090,000. A forecast made in that month, therefore, would have projected payments totaling $5,090,000. However, work orders totaling another $70,000 were subsequently received for a revised contract total of $5,160,000. In addition, the final sum of payments actually made came to $5,303,000. The total cost overrun was actually $242,000, of which only $99,000 was accounted for by work orders.

The following is a summary of the limitations of the current forecasting techniques for ongoing contracts.

1. Over-reliance on contractors' progress schedule estimates, which are not good indicators of actual payments made and which tend to ignore the seasonality of construction;
2. Failure to make reasonable estimates of the actual duration of contracts; and
3. Failure to anticipate probable cost overruns, which range from 2.7 to 11.6 percent of the contract amount.

Proposed Contracts

The forecasting technique used for payouts on proposed contracts also has shortcomings. The 23-month-payout forecasting schedule assumed for all proposed contracts is given in Table 5. When this schedule is plotted, it becomes a smooth curve as shown in Figure 4.

TABLE 5 Twenty-Three-Month Payout Schedule for Proposed Contracts

Month	Monthly Payout (%)	Cumulative Payout (%)	Month	Monthly Payout (%)	Cumulative Payout (%)
1	0.6	0.6	13	4.0	79.6
2	3.7	4.3	14	4.2	83.8
3	7.0	11.3	15	3.7	87.5
4	9.2	20.5	16	1.6	89.1
5	6.9	27.4	17	2.8	91.9
6	6.9	34.3	18	1.6	93.5
7	7.0	41.3	19	2.2	95.7
8	6.7	48.0	20	1.0	96.7
9	7.2	55.2	21	1.1	97.8
10	7.8	63.0	22	1.5	99.3
11	5.6	68.6	23	0.7	100.0
12	7.0	75.6			

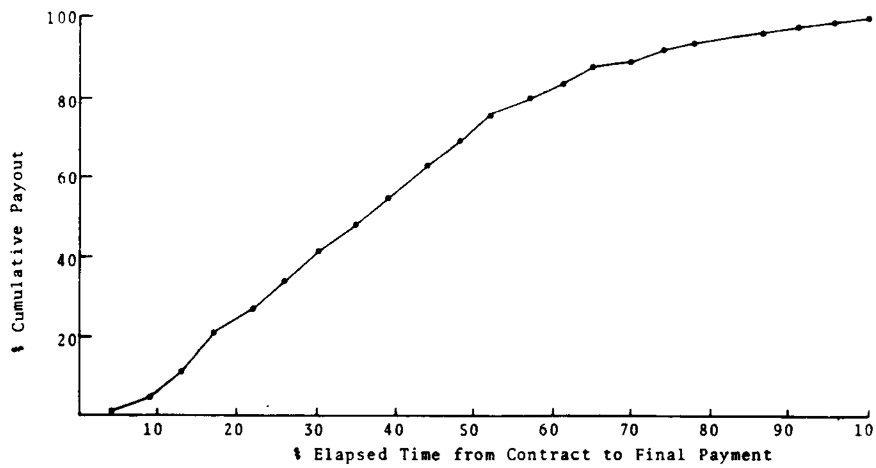

FIGURE 4 Twenty-three-month payout curve used for proposed contracts.

The principal weakness of this 23-month forecasting technique, aside from the failure to anticipate cost overruns, is that it does not allow for the seasonality of construction work. The importance of seasonality is shown in Figure 5, which shows monthly construction payout during fiscal year 1982 as a percentage of the total for the year. As may be expected, the peak period for construction activity was summer and autumn, and the slow season was the middle of winter (January and February). The monthly percentage for the peak month of September was more than six times the percentage for the slowest month of January, and the effect of seasonality naturally varied from year to year. This variability, as well as the role of seasonality in forecasting, will be discussed in greater detail later.

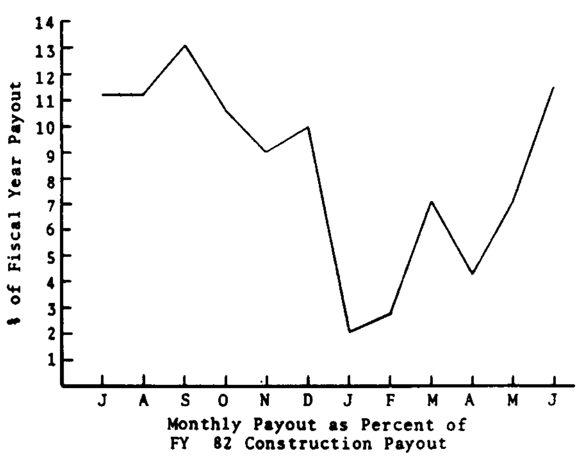

FIGURE 5 Seasonality of construction payout.

Forecasting Results

The final result of these forecasting limitations is an unsatisfactory forecast. This is illustrated by a comparison of actual construction payouts from April 1982 to March 1983 with a forecast made by the budget division in April 1982 using the techniques described previously. The most striking feature of this comparison is that the forecast seriously underestimated the summer and autumn construction peak and underestimated payout more than three times as often as it overestimated payout, because the technique fails to consider seasonality. The difficulty of predicting the advertisement dates of proposed projects may also have affected the forecast. Until recently, these advertisement dates were quite uncertain and neither the information in the computerized project development monitoring system (PDMS) nor the 2-year advertising schedule was reliable as a forecasting input.

The programming and scheduling division recently completed an analysis of the advertising schedule released in October 1982, and the reliability of the schedule was found to have greatly improved--of the 179 projects scheduled for advertisement from October 1982 through March 1983, 159 were advertised. Of these, 127 were advertised in the month scheduled and another 28 were advertised within the same quarter. In addition, 14 projects were advertised that had been advanced or added to the schedule, and 6 projects were dropped from the schedule. Variability in advertisement dates is normal in department operations and will limit the accuracy of any forecasting technique. Nevertheless, this limitation can be significantly offset by timely updates of the forecasting data base whenever the advertisement schedule is changed.

DEVELOPMENT OF NEW FORECASTING TECHNIQUES

The problem of forecasting payouts on construction contracts relates to the following factors, each of which will be discussed separately: (a) contract duration, (b) the final amount paid the contractor (known as the final estimate), (c) payout patterns, and (d) advertisement dates for proposed contracts.

Contract Duration

Contract duration is defined, for the purposes of this paper, as actual elapsed time in months from the month in which the first payment is made to the month in which work is completed. Intuitively, contract size would be expected to be the single most powerful determinant of duration, and an analysis of the data has shown this to be correct although the relationship is not strictly proportional. Other factors that may influence contract duration are project type, road system, and the month in which the contract is signed.

A regression analysis was performed on these factors. The results of the analysis showed that 69 percent of the variation in duration was explained by contract size but that the increases in duration were less than proportional to the increases in size, especially for the largest contracts. The results also showed that contracts took less time to complete on the secondary system than on the other systems, and less time to complete if the contract was signed in January, February, March, April, July, or December. Contracts took longer to complete if they were combination construction projects involving bridges or if they were signal projects. An equation that includes all of these variables can explain 76 percent of the variation in contract duration. This equation is

$$\text{ACTDUR} = -38.78 + 3.84 \ln \text{NETAMT} - 3.28\ \text{MNCN} - 0.49\ \text{RDSYS} + 1.53\ \text{PRTYPE}$$

where

- ACTDUR = duration in months from month of first payment to month of completion;
- NETAMT = original contract amount;
- MNCN = month in which contract is signed (1 if January, February, March, April, July, or December, otherwise 0);
- RDSYS = road system (1 if secondary, otherwise 0); and
- PRTYPE = project type (1 if project is a combination contract with a bridge involved or a signal project, otherwise 0).

Table 6 gives the durations calculated for contracts of various sizes and categories using this regression equation. For a given contract size, the contracts with the longest estimated durations were combination construction plus bridge or signal contracts on the Interstate, primary, or urban systems and were signed in May, June, or August through November. Contracts with the shortest estimated durations were those other than combination plus bridge or signal projects on the secondary system signed in January through April, July, or December. The difference between the shortest and longest duration estimated for contracts of a given size was 5.5 months.

Amount of the Final Estimate

As discussed in a previous section, final estimates (the amount paid the contractor) ranged from 102.7 to 111.6 percent of the original contract amount. For forecasting purposes, the mean percentage cost overrun for each contract size group was used to predict the size of the final estimate for each contract:

Final estimate = Cost overrun factor x contract amount where cost overrun factors are

Cost Overrun Factor	Contract Size ($)
1.090	<250,000
1.078	250,001 to 500,000
1.116	500,001 to 1,000,000
1.094	1,000,001 to 2,500,000
1.115	2,500,001 to 6,000,000
1.027	>6,000,000

Payout Patterns

The timing, number, and size of the monthly payments on a construction contract constitute the payout pattern. The payout patterns of the sample contracts were analyzed by two methods. The first was multiple regression analysis and the second a method of monthly factors analysis that emphasizes seasonality and is a modification of the method used by the New York State Department of Transportation (NYSDOT).

Regression Analysis

A regression analysis was performed for each contract size group in Table 2. The cumulative percent paid out in each month in the life of each contract was analyzed as a function of the percentage of time elapsed from the first payment to the completion date, the month in which the payment was made, and the cumulative percent already paid out. The regression equation includes the square and the cube of the percentage of time elapsed (PCTT), and in this polynomial form allows for changes in the slope of the payout curve. The variable PMTMON accounts for the fact that construction activity is much lower in winter and early spring than in the rest of the year.

$$\text{PCTP}_t = a + b(\text{PCTT}) + c(\text{PCTT}^2) + d(\text{PCTT}^3) + e(\text{PCTP}_{t-1}) + f(\text{PMTMON})$$

where

- PCTP_t = cumulative percentage of final estimate that is paid out by the end of month t;
- PCTT = percentage of time elapsed over the period from the first payment through the month of completion;
- PCTP_{t-1} = cumulative percentage that was paid out by the end of month t-1; and
- PMTMON = dummy variable representing the month in which the payment is made; the

TABLE 6 Contract Durations (months) Calculated by Regression Equation

	Secondary Highways				Interstate, Primary, and Urban Highways			
	Contract Month[a]				Contract Month[a]			
	1-4, 7, 12		5, 6, 8-11		1-4, 7, 12		5, 6, 8-11	
	Project Type[b]		Project Type[b]		Project Type[b]		Project Type[b]	
Contract Amount ($)	C+B or Signal	Other	C+B or Signal	Other	C+B or Signal	Other	C+B or Signal	Other
125,000	5.5	4.1	8.8	7.4	6.3	4.9	9.6	8.2
375,000	9.5	8.1	12.8	11.4	10.3	8.9	13.6	12.2
750,000	12.1	10.7	15.4	14.0	12.9	11.5	16.2	14.8
1,500,000	14.6	13.2	17.9	16.5	15.4	14.0	18.7	17.3
3,000,000	17.1	15.7	20.4	19.0	17.9	16.5	21.2	19.8
6,000,000	19.6	18.2	22.9	21.5	20.4	19.0	23.7	22.3
12,000,000	23.1	21.7	26.4	25.0	23.9	22.5	27.2	25.8

[a]Contract months are keyed consecutively; month 1 is January.
[b]C = combination contract; B = bridge contract.

dummy variable is 1 if the month is January, February, March, or April and 0 if the month is May, June, July, August, September, October, November, or December.

The results of the regression analysis were quite encouraging and the R^2s are given in Table 7 for each contract size group. Significance tests on the explanatory variables were acceptable at the 95 percent level of confidence. The results of a forecasting test of these equations will be presented in a later section.

TABLE 7 R-Squares for Payout Regressions

Contract Size ($)	R^2
<250,000	0.87
250,001 to 500,000	0.94
500,001 to 1,000,000	0.96
1,000,001 to 2,500,000	0.98
2,500,001 to 6,000,000	0.99
>6,000,000	0.99

Monthly Factors Analysis

A forecasting technique based on the duration of individual contracts and the seasonality of the total work program has been in use by the NYSDOT for several years. The basic equation is

$$ESTPMT_t = AMTREM_{t-1} \times (MONFACT_t/\Sigma_t^n MONFACT)$$

where

- $ESTPMT_t$ = estimated monthly payment for month t;
- AMTREM = amount remaining in the contract after the payment made in month t-1;
- $MONFACT_t$ = monthly seasonality factor for month t; and
- Σ^nMONFACT = sum of monthly seasonality factors for the months remaining in the contract's duration from month t to month of final payment.

The monthly seasonality factors are computed from historical data by dividing the total construction contract payout for each month (for all contracts) by the total payout for the year. The result gives an estimate of the percentage of annual payout that typically occurs in each month. Then the monthly seasonality factors used for forecasting may be averaged over several years to smooth out year-to-year variations. The first step in adapting the monthly factors method to Virginia was to calculate the monthly seasonality factors for the Virginia Department of Highways and Transportation construction program. In order to determine the variability of these factors, they were calculated using four data bases: (a) monthly payouts for the total construction program for FY 1981, (b) monthly payouts for the total construction program for FY 1982, (c) FY 1981 payout for the sample data base described previously, and (d) total payout for the combined 3-year sample data base. The results are shown in Figure 6.

The fiscal 1981 sample showed the greatest difference between the peak month and the lowest month of the year: The July factor of 0.16 was more than eight times the March factor of 0.019. On the other hand, the seasonality was less extreme for the combined 3-year sample. The proportion of the total annual payout for the peak month of July was 0.12, about three times the proportion paid out for the lowest month, March, which was 0.036. The totals for fiscal years 1981 and 1982 exhibited intermediate levels of seasonality, with the most highly variable months being January, which ranged from 0.021 to 0.069, and March, which ranged from 0.019 to 0.071. The peak months of July and August were moderately variable. In contrast, the months of September and October were quite stable. This means that year-to-year variations in monthly seasonality could produce forecasting errors of several millions of dollars, particularly in January and March and in the peak months. Forecasting tests were conducted on the sample using monthly factors from the combined 3-year sample and from the fiscal 1981 sample. The results of these tests will be presented in the next section.

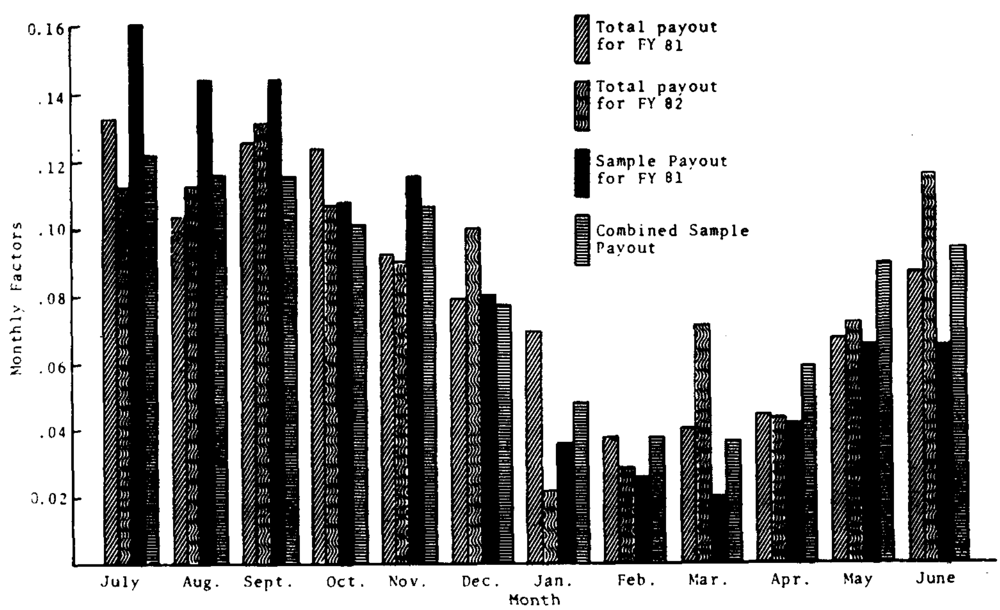

FIGURE 6 Variations in monthly factors from sample and aggregate payouts.

A number of trial calculations with the monthly factors equation indicated that it performs better empirically if certain assumptions are made about the timing and size of the first two payments as well as the final payment. Based on the data in the sample, the first payment is assumed to occur 1 month after the contract month if the estimated duration is less than 3 months, and 2 months after the contract month if the estimated duration is 3 months or longer. Using the sample data base, the sizes of the first, second, an final payment are specified as a percentage of the final estimate, depending on the contract size group. These percentages are given in Table 8. Next, the percentage of the contract that is paid out by the completion month was calculated from the sample by size of contract (Table 9). In addition, the payout pattern was constrained such that the payment percentage made in the month following completion equals [1 - (% paid by completion month + % last payment)], the next payment always equals zero, and the last payment is made 3 months after completion.

TABLE 8 First, Second, and Final Payments as Percentage of Final Estimate

Contract Size ($)	First Payment	Second Payment	Final Payment
<250,000	14.5	23.8	6.5
250,001 to 500,000	8.2	12.0	3.7
500,001 to 1,000,000	5.5	10.4	2.6
1,000,001 to 2,500,000	5.0	6.1	1.0
2,500,001 to 6,000,000	4.7	5.6	0.5
>6,000,000	2.6	3.1	0.001

TABLE 9 Percentage Paid Out by Completion Month

Contract Size ($)	Percentage Paid Out
<250,000	86.9
250,001 to 500,000	88.6
500,001 to 1,000,000	93.9
1,000,001 to 2,500,000	96.5
2,500,001 to 6,000,000	97.3
>6,000,000	100.0

The following example illustrates how duration, final estimate, and monthly payments are calculated using the methods described. In this example

Project no. = 0641-016-150,
Project type = combination construction,
Road system = secondary,
Contract amount = $79,771,
Contract month = June,
Estimated duration = -38.37 + 3.84 (ln NETAMT) - 3.28 (MNCN) - 0.49 (RDSYS) + 1.53 (PRTYPE),
NETAMT = $79,771,
MNCN = 0 for June,
RDSYS = 1 for secondary,
PRTYPE = 0 for combination construction,
Duration = -38.37 + 3.84 (ln 79771) - 3.28 (0.0) - 0.49 + 1.53 (0.0) = 4.07 rounded to 4 months from first payment to the month of completion,
Final estimate = $79,771 x 1.090 = $86,950 (this adjusts for cost overruns), and

Monthly factor = JAN .048, FEB .037, MAR .035, APR .060, MAY .094, JUN .091, JULY .114, AUG .118, SEP .117, OCT .104, NOV .106, DEC .076.

Using the monthly factors shown, the following estimates of payout can be made (note that November is the estimated completion month).

Month	Payment ($)	Calculation
June	0	The model is constrained so that no payments are made in first two months after contract date
July	0	
Aug.	12,655	86950 x .145 (total payment times 1st payment proportion for contracts less than $250,000)
Sept.	20,721	86950 x .238 (total payment times 2nd payment proportion for contracts less than $250,000)
Oct.	20,891	[.104/(.104 + .106)] [(86950 x .869) - (12655 + 20721)]
Nov.	21,293	[.106/.106] [(86950 x .869) - 12655 + 20721 + 20891)]
Dec.	5,749	[86950 - (12655 + 20721 + 20891 + 21293)] - [86950 x .0649]
Jan.	0	Next-to-last payment always = 0
Feb.	5,643	86950 x .0649 (total payout times last payment %)

The calculation for the month of October, in greater detail, is

October monthly payment = (October monthly factor/Sum of factors for months remaining from October to completion month) x Amount remaining to be paid out by completion month.

In the foregoing calculation, the monthly factor is .104 for October, the sum of remaining factors to completion month is .104 for October + .106 for November, which equals .210. The total amount to be paid out by completion is $86,940 x .869 = $75,560, the amount already paid out = $12,655 + $20,721 = $33,376, the amount remaining to be paid out by completion = $75,560 - $33,376 = $42,184, and the monthly payment = (.104/.210) x $42,184 = $20,891.

The payout forecasts generated by the monthly factors method can be plotted as payout curves comparable to the standard curve shown in Figure 4. In general, the payout in the monthly factors curve is less accelerated than in the standard curve until near the end of the curve, and it is also less smooth than the standard curve, with dips and bulges that show the effects of seasonality. For example, from November to March the slope of the curve is less than it is from June to October, indicating a slower rate of payout. Of course, no forecasting technique or payout curve can possibly duplicate the highly variable behavior of individual contracts. Nevertheless, the forecasting tests described in the next section indicate that the monthly factors method can do a better job of duplicating the behavior of all contracts taken together than does the standard payout curve.

RETROSPECTIVE TESTS OF FORECASTING TECHNIQUES

The forecasting techniques described in the previous section were tested retrospectively to determine if they could duplicate the payout patterns of the sample. This was not a true forecasting test, however, for the following reasons: (a) a true forecasting test should be on contracts that were not in the sample used to develop the forecasting technique; (b) the retrospective tests did not involve predicting the advertisement dates for proposed contracts; and (c) the retrospective tests utilized monthly seasonality factors based on the actual sample data, whereas in actual forecasting one will always be trying to predict the next year's payout using monthly factors from the previous year or years. Such monitoring is under way.

Tests of Monthly Factors Method

A simplified version of the monthly factors method was tested using two sets of monthly factors. The simplified version of this method is designed to be simple to implement because it does not require updating each month based on the payments that have been made. When a contract has been added to the data base, no further information will be required, unless the contract is a proposed contract the estimated cost or advertisement date of which is changed.

The retrospective test using monthly factors from the combined 3-year sample was extremely successful. As Figure 7 shows, the forecast tracked the highs and lows of construction activity very closely. Statistically, the monthly factors method explained more than 93 percent of the variation in construction payout in this test. On the other hand, the method underestimated the construction peak in June through September of 1980 by several million dollars. This indicates the possibility that weather conditions were exceptionally good that summer, allowing the summer peak to be even higher than usual.

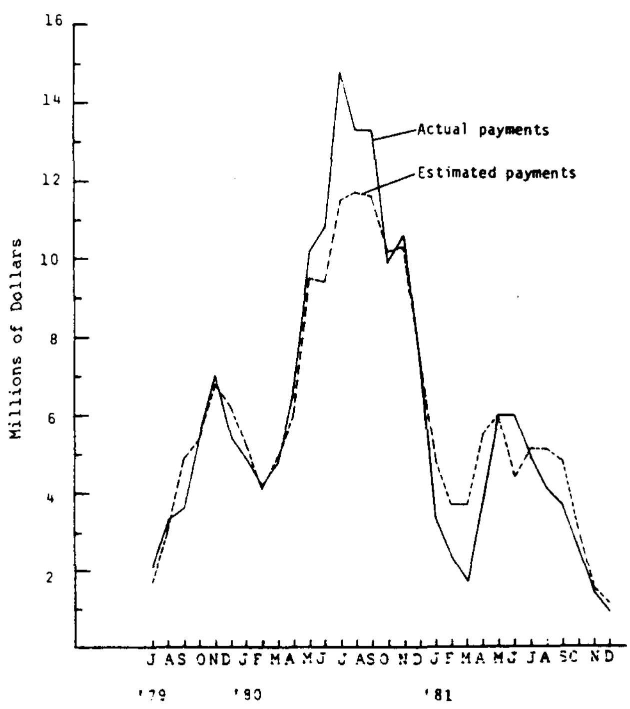

FIGURE 7 Test of simplified monthly factors method using factors from combined sample.

Another retrospective test was performed using monthly factors from only the fiscal 1981 portion of the sample to see if more specific monthly factors would improve the forecast. The estimates of the summer peak were much closer, but the rest of the forecast was not as good. Overall, the percentage of variation explained in this test was about 85. This result indicates that it is very difficult to improve one segment of the forecast by tailoring the monthly factors to it without adversely affecting the rest.

A more elaborate version of the monthly factors method was also tested. In this version, the data base was continually updated so that the amount remaining in each contract each month was calculated using the actual payments made up to that point. Surprisingly, the results of this test were not as good as those of the streamlined version.

Tests of Regression Method

The regression method described previously was also tested in both a simplified and an elaborate version. Both of these tests were significantly worse than the monthly factors method. The reason may be that the regression method does not capture the effects of seasonality as well as the monthly factors method. Furthermore, even though the R^2s were high, small percentage errors on large contracts resulted in relatively large absolute errors in terms of dollars per month.

IMPLEMENTATION REQUIREMENTS

The information and procedures required for implementation of the simplified version of the monthly factors method are relatively simple and the department is currently implementing the method as a comparison with the current forecasts. This forecasting method requires less new information each month than does the method now used for current contracts. For each contract, whether existing or proposed, six items of data are needed:

1. Project number,
2. Project type,
3. Road system,
4. Federal share (optional),
5. Contract amount or construction cost estimate, and
6. Contract date or advertisement date.

Implementation of the forecasting method will initially require a data base consisting of all projects that have been awarded, advertised, or scheduled for advertisement. After that, monthly updates will be required on (a) new contracts that have been awarded and (b) any changes in advertisement dates or construction estimates for projects on the advertising schedule.

The sample data base of completed contracts used to develop the forecasting method will be expanded to include all additional projects that have been completed since August 1982. These data will be reanalyzed to ensure that the equations for duration and final estimate and the monthly factors are representative of recent construction activity. This process of data collection and reanalysis will be repeated periodically.

CONCLUSION

Analysis has shown that aggregate payout on construction contracts can be adequately predicted given improved forecasting techniques and information management. The forecasting technique described in this paper requires information only on the type of construction, the road system, the size of the project, and its actual or prospective start date to make estimates of payout that are up to 93 percent accurate. This degree of accuracy can be attained by frequent and timely updates of the information in the forecasting data base on contracts let and on contracts on the advertisement schedule. Because payments to construction contractors are a major cash flow item for the Virginia Department of Highways and Transportation, as they are in many states, it is anticipated that better forecasts of construction payout will be a valuable aid in the budgetary process.

Setting Priorities of Highway Projects by Successive Subsetting Technique

MARK D. HARNESS and KUMARES C. SINHA

ABSTRACT

The development of a technique that can be used to set priorities within a given work category of highway improvement projects is described. After impact categories have been developed, respective priority evaluation measures assess the importance of specific projects within each impact category. The proposed technique of successive subsetting combines the impacts of each candidate project in a work category to determine which projects should be implemented for a given budget. A sample problem consisting of a group of bridge replacement projects is presented to illustrate the application of the technique.

Traditional approaches--weighting factors and developing combined scores of sufficiency ratings--to setting priorities among highway projects have the serious drawback of masking the importance of individual factors. The use of such approaches does not always produce an optimal set of projects, nor can specific reasons be given for selection choices. In the face of increasing highway construction costs and an increasing backlog of improvement projects, greater efficiency in selecting projects for implementation, as well as provision for the defense of the set of projects selected for implementation, must be established.

In this study it is assumed that projects have already been established for given needs. It is also assumed that the best alternative within each project proposal for a particular location has already been chosen. Under these assumptions, a priority-setting technique has been developed that can aid in the choice of the set of projects for implementation within a given work category. This study was sponsored by the Indiana Department of Highways (IDOH) and has been developed for use within its planning division.

HIGHWAY IMPROVEMENT IMPACT CATEGORIES AND PRIORITY EVALUATION MEASURES

When priorities are determined for individual projects within a work category or functional classification, significant types of impacts must be determined. After this, methods for measuring the extent of these impacts must be developed to describe the importance of each project. An impact category is defined as the general impact type that has a specific importance level within a work category. A priority evaluation measure is the value that represents the importance of a project with respect to a given impact type.

SUCCESSIVE SUBSETTING

The major problem in using a priority-setting technique is that available data are mostly subjective and have a low degree of accuracy. Consequently, in the proposed technique, it is assumed that impacts of highway improvements cannot be measured precisely and that, if they can be, the limits of accuracy are quite large. It is assumed that all projects in each impact category can be lumped only approximately into a small number of groups. The members of each group will then have about the same impact value or priority evaluation measure.

The key to this technique is that each smaller group or subset may also be divided into additional smaller groups using different evaluation criteria. A representation of the successive subsetting operations is shown in Figure 1. As a result, although the first separation of projects may produce only, for example, five groups, the second round of subsetting may produce 25 groups (or five groups of five). This procedure may be used as many times as there are impact categories. Consequently, a group of projects separated into three subgroups five times will produce 243 subsets. Five groups divided five times will produce 3,125 subsets.

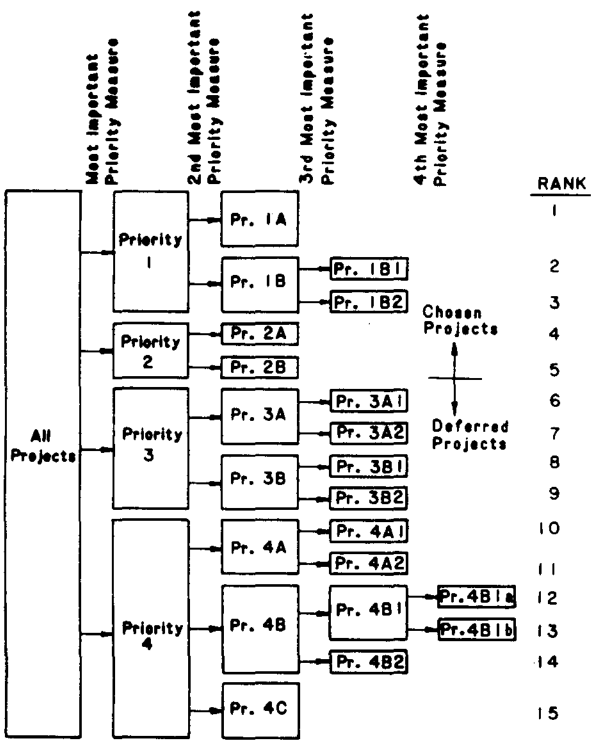

FIGURE 1 Flow chart of successive subsetting technique.

Use of this technique allows a large number of projects to be ranked in a small number of steps using data that need not be highly accurate. In addition, only a few impact measurements are necessary for each project proposed. This means data requirements can be substantially reduced.

REQUIREMENTS OF SUCCESSIVE SUBSETTING TECHNIQUE

Instead of determining the numerical priorities for each type of impact, the relative importance of different types of impact needs to be ranked. Then, for each budgeting or work category, the projects must be split into several subgroups according to the most important priority measure. Each subgroup must again be separated into more subsets using the second most important priority evaluation measure. This continues until all projects belong in a separate subset.

For a single subsetting step, the decision maker must have an understanding of the degree of accuracy of the priority evaluation measures to be used. Subgrouping should be done only if there is a smaller degree of difference between values. However, rather than using precise statistical methods to determine which values are statistically different, the user can visually observe the distribution of the values and make approximations between different values. Then, by repeating this step using other priority evaluation measures for each of the smaller subgroups, each category may be subdivided a number of times to produce a finely separated distribution of all projects by rank.

Before the impact categories can be ranked, the decision maker must clearly understand the relative importance of the impact categories and their respective priority evaluation measures. The first subsetting step has the greatest influence on what priority a given project will have. This is because, in the second subsetting step, in the absence of the use of any trade-off curves, the second most important priority evaluation measure will affect only the ranking of projects within the original subgroups. For example, a project located in the second most important subgroup in the first subsetting step cannot move up to the most important subgroup.

If the relative importance of impact categories is clearly distinguished, that is, if each priority evaluation measure clearly has a greater significance than the next most important measure, the priority evaluation measures may be ranked and applied successively to produce individual subsets for all the projects.

However, if some priority evaluation measures have similar importance levels, either within or between different impact categories, trade-off curves must be developed to combine these measures. Figure 2 shows how two priority evaluation measures may be combined to subgroup projects. The relative importance of the two priority evaluation measures is reflected in the slope of the lines separating the subgroups.

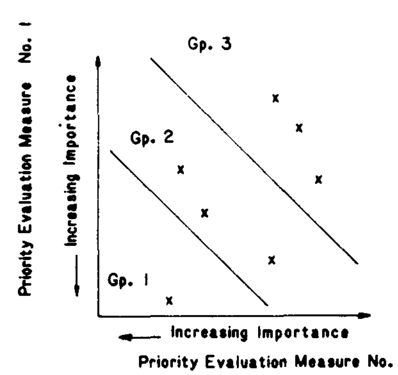

FIGURE 2 Single subgrouping of projects using two priority evaluation measures.

If more than two priority evaluation measures have about the same level of significance, they may be combined as shown in Figure 3. Here the resulting subgroupings for the first two measures are traded off against a third measure. The result of this sub-

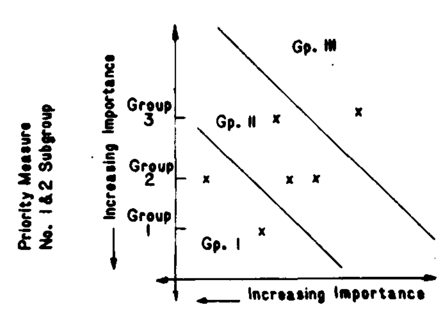

FIGURE 3 Single subgrouping of projects using three priority evaluation measures.

grouping step may then be traded off with further priority evaluation measures.

However, when two or more measures are traded off, they combine to produce only one subgrouping step. Consequently, if a large number of projects must have their priorities determined, this may be a disadvantage. It is possible, however, to offset this small number of subsetting steps by increasing the number of groups made in each subsetting step. Again, however, the accuracy of the data must not be overestimated.

One advantage of this priority-setting method is that sets that have no subsets with more than one project do not have to be further subdivided. Only those groups having projects with very similar priority evaluation measure values must be subdivided using the increasingly less significant impact categories.

In addition, if the overall budget level is known, subsetting of projects need be applied only in the groups where the cutoff point lies between programmed and deferred projects. A group does not need to be subdivided if all of the projects in it will be selected. However, for the purposes of this study, all of the projects will be ranked in case changes in budget level are made.

SUMMARY OF STEPS

The general steps involved in the application of the proposed technique are

1. List priority measures in order of decreasing significance combining those of nearly equal importance.
2. Plot projects by their most important priority evaluation measure or measures.
3. Separate projects into subgroups.
4. For each subgroup, repeat steps 2 and 3 using the next least important priority evaluation measures until each project is in its own subgroup.
5. Rank projects in decreasing order of priority.
6. Select projects for implementation in order of rank until the budget for the given period has been met.

APPLICATION OF THE PROPOSED TECHNIQUE

This section describes the application of the successive subsetting technique to the bridge replacement work category using a set of 22 proposed bridge replacement projects.

Bridge inventory ratings for each of the 22 bridges were collected. These were rated in accordance with the FHWA Bridge Inventory and Appraisal Manual (1). The key for the subjective condition ratings required by this manual is given in Table 1.

TABLE 1 Key for Subjective Condition Ratings *(1)*

Numerical Rating	Bridge Condition
9	New
8	Good
7	Good with minor maintenance needed
6	Fair with major maintenance needed
5	Fair with minor rehabilitation needed
4	Marginal with major rehabilitation needed
3	Poor with rehabilitation or repair needed
2	Critical with need to close and rehabilitation or repair needed
1	Critical, is closed and may not be repairable
0	Critical, is closed and beyond repair

Bridge replacement projects may be evaluated using four major impact categories: the cost to the highway department to replace the bridge, the physical condition of the present bridge, the traffic volume using the bridge, and the safety of persons driving over the bridge (see Table 2).

TABLE 2 Relative Importance of Bridge Replacement Priority Evaluation Measures

Rank	Impact Category	Priority Evaluation Measure
1	Physical condition	Minimum of superstructure condition and substructure condition
2	Physical condition	Remaining life
3	Traffic safety	Deck width
4	Traffic safety	Road narrowing on bridge
5	Service and highway department cost	ADT ÷ state share of construction cost
6	Traffic safety	Approach alignment
7	Traffic safety	Deck pavement condition
8	Location	Road classification

Physical Condition

The most important factor in bridge replacements is the physical condition of the existing bridge. This measures the ability of a bridge to avoid a catastrophic failure.

Because IDOH bridge data are gathered according to federal guidelines (1), priority evaluation measures available for this impact category are the subjective measures of substructure condition, superstructure condition, and remaining life.

Theoretically, the life of a bridge will end when either the substructure or the superstructrue becomes so poor that the bridge must be closed to prevent its collapse while someone is using the structure. Therefore, ideally the remaining life value will be proportional to the minimum of the substructure and superstructure condition values. However, this is not always true because of the subjective nature of the measurement of these values.

Instead of using remaining life as the sole measure of physical condition, both the minimum of the two condition ratings and the remaining life may be used. These may be combined by plotting the minimum of the superstructure and the substructure ratings against the remaining life value.

The 22 projects were subdivided into eight groups according to physical condition, as shown in Figure 4. The numbers in the figure indicate project numbers in the 1982-1984 IDOH work program (2). It can be seen that a remaining life of 5 years is approximately equivalent to a minimum superstructure or substructure condition rating of 3. Likewise, 20 years of remaining life correspond to a minimum condition of 7. Therefore, projects that lie perpendicular to the values of the linear relationship should be placed in the same subgroup. This should best reconcile the discrepancy for projects having remaining life and minimum condition values that do not fall on the line. Therefore, projects having condition ratings of 3 and a remaining life of 5 years were placed in the most important category (group A). The next most important group consisted of the projects having conditions of 4 and lives of 5 years and the project having a condition of 3 and a life of 10 years. The five projects in this category (group B) were deemed to be in approximately the same physical condition. The remaining 13 projects were combined into six groups in the same manner. Of the eight groups, groups F and H needed no further subdivision.

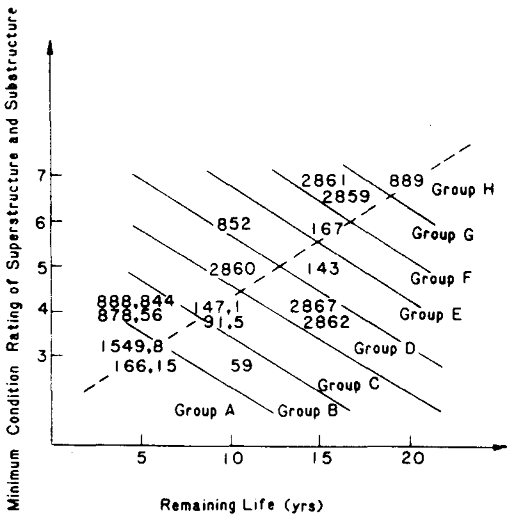

FIGURE 4 First subgrouping step for sample bridge replacement problem.

Traffic Safety

The second most important aspect in determining bridge replacement priorities is traffic safety. The best measurement of this is the accident rate on the bridge. However, because this was not available, values of approach alignment condition, deck width, road narrowing on the bridge, and deck pavement condition from the bridge sufficiency rating data were used (see Table 2). Road narrowing was defined as the bridge deck pavement width minus the roadway pavement width.

Assuming deck width is the most significant priority evaluation measure and road narrowing is the next most significant, each subgroup from the physical condition subsetting step may be subdivided into several subsets.

The remaining six groups were subdivided according to safety as shown in Figure 5. In this subsetting step, deck width and road narrowing represent two different types of safety hazards, but deck width was determined to have greater influence on priority than does road narrowing. An example of this is that even though project 8 had a pavement width 5 feet narrower on the bridge than on the approach and project 1549 was 5 feet wider on the bridge, both projects were placed in the same safety subgroup because both had deck widths of about 35 feet.

In drawing the lines separating the subgroups, the decision maker must decide in each case how much need, according to the narrowing evaluation measure, is required before a project may be advanced to a group having greater need according to the deck width evaluation measure. In all six classes (see Figure 5) it may be seen that the slope of the lines separating the subgroups could have been vertical without changing the membership of each subgroup. However, if project 56 of class B had had the same deck width but a very low road narrowing value, the line separating the groups could have been drawn further to the right to include this project in group B.a. Of these subgroups, only six needed further subdividing.

Service and Highway Department Cost

The next most important impact group for bridge replacements is the cost to replace the bridge. The level of service provided by the bridge is also important (see Table 2). Because these two groups have approximately the same level of importance, they may be combined into a single subsetting step. The highway department cost may be measured by either the total right-of-way and capital cost of the bridge or the share of this cost that the state highway department must pay. The latter method will give higher priority to bridges having greater amounts of federal funding. The level of service provided by

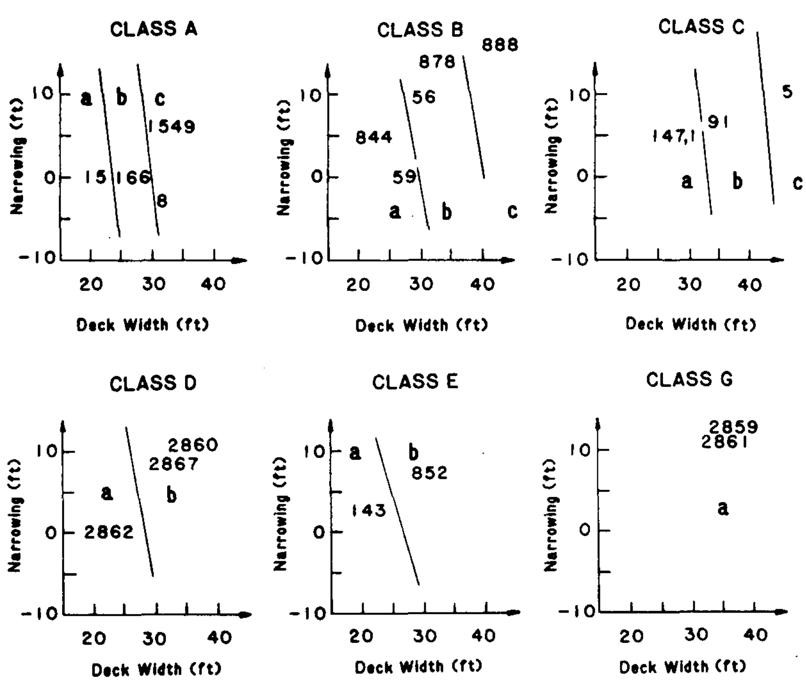

FIGURE 5 Subgrouping by safety priority evaluation measures within each condition category.

the bridge may be easily measured by the ADT on the roadway that the bridge serves.

Instead of using a trade-off curve to combine the service and cost measures, a logical measure combining these two measures would be the service-to-cost ratio:

Service/cost ratio = ADT/construction cost

This value shows the relative number of vehicles that would be served per dollar of construction cost. A larger value would represent a more cost-effective project. These values may be used to subdivide the subgroups that result from the previous traffic safety subsetting step.

Subdivision according to the service-to-cost ratio is given in Table 3. Here groups A.c., B.a., B.b., C.a., D.b., and G.a. had their remaining projects ranked. Because each of these groups had only two projects in them, the project with the greater service-to-cost ratio was given the higher priority.

TABLE 3 Subgrouping by Service-to-Cost Ratio for Remaining Safety Categories

Class	Project No.	Service ÷ Cost	Rank
A.c.	1549	163	i
	8	22	ii
B.a.	844	21	i
	59	21	i
B.b.	878	10	ii
	56	40	i
C.a.	147	81	i
	1	37	ii
D.b.	2860	52	ii
	2867	162	i
G.a.	2861	99	i
	2859	45	ii

However, in group B.a., both projects had the same service-to-cost ratio. Therefore, only one subgroup (group B.a.i.) needed further subdividing. This was done according to the next important priority measure, approach alignment, which is another safety measure.

Project No.	Approach Alignment	Rank
844	8	2
59	4	1

Project Ranking

Now each project must be ranked against each other project. This may be done by listing the total set of projects in descending order of importance. For example, if only the first three impact categories were used, the most important project would be in the most important condition group, the most important safety subgroup, and the most important service-to-cost subgroup. Finally, after each project has been ranked, projects may be chosen for implementation during the budget period until the total budget level has been met.

The projects were ranked, and the appropriate projects chosen for implementation are given in Table 4. The total budget considered for the sample bridge replacement problem was $1,025,000.

RESULTS OF THE SAMPLE PROBLEM

The technique used for the bridge replacement problem has resulted in a ranking of the 22 candidate projects, seven of which were chosen for implementation within a 2-year budgeting period. Because of the nature of the subsetting technique, these seven projects were in the worst physical condition of the projects considered.

For the 2-year budgeting period, the bridges in the worst physical condition subgroup and three of the five bridges in the second worst condition subgroup were selected. All three of the projects in the second worst condition subgroup had low safety ratings. From the position of these bridges in Figure 4 it can be seen that all seven projects chosen had a minimum superstructure or substructure condition of 4 or less and a remaining life of 10 years or less. In addition, all seven projects had a road narrowing value of 10 ft or less, and six had a deck width of 30 ft or less. The distribution of the priority evaluation measures for all the proposed projects is shown in Figure 6.

Obviously, the categories with the greatest need are substructure condition, superstructure condition, and remaining life. The distribution of chosen projects is also concentrated on the right side in the deck width and road narrowing categories. The categories of state share of construction cost, deck pavement condition, approach alignment condition, and ADT are relatively uniform for the chosen projects. This is because of the relatively lower degree of importance placed on these priority evaluation measures.

TABLE 4 Final Rankings and Project Choices for Implementation

Rank	Project No.	Project Cost[a]	Available Budget[a]	Overall Condition Estimate
Chosen				
A.a.	15	136	1,025	–
A.b.	166	166	889	Very poor
A.c.i.	1549	19	723	Poor
A.c.ii.	8	45	704	Poor
B.a.i.1	59	302	659	Poor
B.a.i.2	844	57	357	Poor
B.b.i.	56	237	300	Poor
Deferred				
B.b.ii	878	122	63	Poor
B.c.	888			Poor
C.a.i.	147			Fair
C.a.ii.	1			Fair
C.b.	91			Fair
C.c.	5			Fair
D.a.	2862			–
D.b.i.	2867			–
D.b.ii.	2860			Poor[b]
E.a.	143			Fair
E.b.	852			Fair
F.	167			Good
G.a.i.	2861			Good
G.a.ii.	2859			Good
H.	889			Very good

Note: Dashes = not done.
[a]In thousands of dollars.
[b]Subjective rating error.

CONCLUSIONS

The successive subsetting technique has been developed to set priorities for highway improvement projects within work categories. This can be done using fairly inaccurate and subjective data. In addition, the technique is very flexible and simple to use. A computer is not necessary. Exact measures of importance of different impact types do not need to be known in advance. The specific grouping of projects

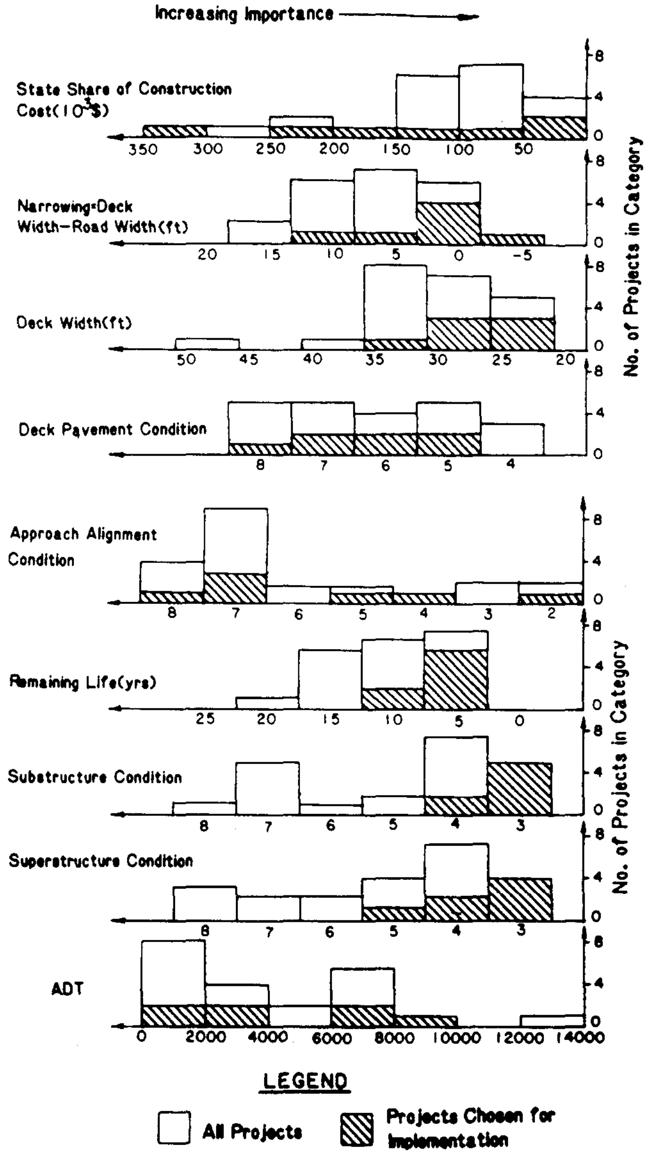

FIGURE 6 Distribution of priority evaluation measures for all sample bridge replacement projects and for those chosen for implementation.

is determined after individual values for priority evaluation measures are plotted and their distribution over all projects is known. Then the projects must be separated into groups having similar priority evaluation measures. The decision maker needs only a general understanding of how the data were gathered and of the limits of accuracy of the individual measurements.

One problem that may develop using this technique is that for work categories that have a large number of projects it may be difficult to separate each project into its own group. This problem may be resolved in several ways. Either more priority evaluation measures may be applied to produce a greater number of subsetting steps or a greater number of subgroups may be made in each subsetting step.

Because the relative priorities of each project are ranked using the subsetting technique, it is easy to determine which projects should be added or deleted if there are adjustments to the overall budget level after the program has been developed.

An important aspect of the subsetting technique is that it may also reveal which projects may not be in the appropriate work category. For instance, several projects in the bridge replacement sample problem were determined to be in relatively good condition. It would be better if these projects could be placed in a less costly work category. For example, bridges in relatively good condition could be moved from the bridge replacement category to the bridge maintenance category. This recategorizing of projects could reduce overall highway improvement costs as well as the number of backlogged projects in some categories. Less important projects could also be placed in job categories requiring less extensive work. A bridge that might have a relatively low priority in a bridge replacement category might receive a relatively high priority in a bridge rehabilitation or bridge maintenance category.

This technique can isolate projects that have data discrepancies. Projects that have both high and low ratings within the same impact category should be re-examined to determine the true condition of the existing structure or roadway section.

The simplicity and straightforwardness of this procedure should make it appropriate for use by both more and less technically trained personnel. As a result, it could be used at both state and local levels of jurisdiction as well as at central and district levels of state highway offices. The graphic format should make it easily understandable by the layman.

In addition, the flexibility of this technique should make it usable as both a manual and a computerized procedure. If computerized, it would be most useful to input trade-off curves after the distributions of individual project priority evaluation measures have been plotted.

ACKNOWLEDGMENTS

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The contents of this paper reflect the view of the authors who are responsible for the facts and the accuracy of the data presented herein.

Transportation Improvement Program for Northeastern Illinois

ELIZABETH A. HARPER

ABSTRACT

This is the first of a two-part analysis of the effectiveness of programming federal highway funds in northeastern Illinois. The analysis is an attempt to determine if amendments to the transportation improvement program (TIP) and awards against the TIP alter the originally approved investment profile enough to diminish its consistency with regional priorities. The investment profile refers to the mix of projects and investments with respect to investment categories (e.g., maintenance, improvement, expansion), facility types (e.g., structure, roadway), fund sources, and geopolitical areas. The profile was compared three times: at approval time, after amendments, and after awards. Attempts are made to explain differences that were found, and implications for the region's programming policies are discussed.

The following paper is the first part of a two-part analysis of the effectiveness of programming federal highway funds in northeastern Illinois. The second part is to be accomplished in the fall of 1983, the end of the 1983 fiscal year.

The analysis resulted from questions raised about the effect of awards and amendments on the achievement of the goals and objectives implicit in the approved transportation improvement program (TIP). As stated in the TIP preface: "The project contained in the MYP and AE detail the next steps the region intends to take in achieving its transportation priorities." The process involved in developing this particular goal-oriented list of projects is extensive and involves "hundreds of meetings and thousands of person hours." And "when the Policy Committee, as the region's MPO, ultimately endorses the TIP...all projects within it have been screened on technical and fiscal bases, and have been reviewed to ensure their consistency with regional priorities (1, p. v). In addition, analyses, to indicate the extent to which the investment priorities are being addressed, are performed on the originally approved TIP. It is therefore desirable to determine if (a) the amendments and awards in any given year alter the originally approved investment profile so that its consistency with regional priorities is diminished, and (b) the investment profile from year to year is synergistically maintaining progress toward the region's goals and objectives. The second question will require a comparison of the impacts of consecutive TIPs. The first, the subject of this paper, requires an examination of changes that occur during a given year.

INTRODUCTION

After approval of the TIP, and within any 1 year, there are two ways that the final mix of projects actually implemented can be altered: (a) amendments to the program via the work program committee (WPC) or the policy committee (PC) and (b) awarding of limited portions of the approved program. Trends in these activities should maintain consistency with goals assumed by the WPC and PC at TIP approval time. In an attempt to determine what trends, if any, exist in the changes that occur throughout the year the TIP investment profile is examined at approval time, after amendments, and after awards. Profile means the mix of projects and investments viewed in terms of investment categories, facility types, fund sources, and regional councils.

IMPACT OF AWARDS ON TIP

The FY 82 FHWA awards include 266 projects and $262.3 million dollars. This accounts for 70 percent of the $377.5 million programmed in the amended FY 82 FHWA A list. Award rates for previous years have also been approximately 70 percent.

The major emphasis of the awarded program is maintenance and improvement with 86.7 percent ($227.3 million) awarded in these categories (Table 1). Almost half the awarded investment was for roadway projects and almost one-third was used for work on structures (Table 2).

The major funding sources of awarded projects were Interstate Transfer (nearly 60.0 percent) and Federal Aid Urban (29.7 percent) (Table 3). Forty-nine percent of the awards were for projects in Chicago. In addition to Chicago, regional councils with a high proportion of the total awards include South (9.3 percent), Northwest (6.6 percent), and Southwest (6.5 percent) (Table 4).

The foregoing provides a summary of the awarded program, and it also raises a question as to how this awarded program changes the emphasis of the policy committee's approved program. To determine this, a profile of the final amended annual element was compared with a profile of the awarded program. The profile includes four variables: investment category, facility, fund source, and regional council. Overall, these comparisons showed that the awards did not substantially change the makeup of the final amended TIP. There are, however, slight variations.

The most notable shift seen in investment categories (Figure 1) is away from expansion, addition, safety, and other investments to maintenance and improvement investments. According to the data in Table 1, maintenance and improvement categories together made up 81.7 percent of the amended program and 86.7 percent of the awarded program.

The data in Table 2 indicate that structure investments were increased from 17.1 percent of the amended program to 23.8 percent of the awarded program. Roadway investments also increased as a proportion of the total program. These shifts are shown in Figure 2.

The awards process had its most dramatic impact on the mix of fund sources. A major shift from Interstate Transfer Transit (ITT) to Federal Aid Urban (FAU) is shown in Figure 3. Table 3 indicates that

TABLE 1 Changes in Investment Category

Investment Category	Original Dollars (000s)	Original Percentage of Total	Amended Dollars (000s)	Amended Percentage of Total	Awarded Dollars (000s)	Awarded Percentage of Total
Signalization and intersection	39,659	10.9	32,253	8.6	25,190	9.6
Widen and W/RS	37,462	10.3	37,051	9.8	19,852	7.6
Reconstruct, etc.	49,766	11.2	60,023	15.9	55,198	21.0
Other improvements	63,327	17.4	71,820	19.0	41,187	15.7
Total improvements	181,214	49.9	201,147	53.3	141,427	53.9
Resurface	60,258	16.6	53,341	14.1	44,726	17.0
Structure rehabilitation	18,810	5.2	15,098	4.0	11,686	4.5
Other maintenance	25,313	7.0	39,447	10.4	29,604	11.3
Total maintenance	104,381	28.7	107,886	28.6	86,016	32.8
Add lanes	19,188	5.3	14,345	3.8	10,179	3.9
Other expansions	22,944	6.3	25,611	6.8	8,021	3.1
Total expansion	42,132	11.6	39,956	10.6	18,200	6.9
Addition	14,456	4.0	9,654	2.6	9,075	3.5
Safety	7,807	2.1	4,501	1.2	2,829	1.1
Other	13,514	3.7	14,389	3.8	4,786	1.8
Total	363,504		377,533		262,333	

TABLE 2 Changes in Facility Type

Fund Source	Original Dollars (000s)	Original Percentage of Total	Amended Dollars (000s)	Amended Percentage of Total	Awarded Dollars (000s)	Awarded Percentage of Total
Roadway	173,255	47.7	168,819	44.7	126,829	48.3
Intersection and signalization	43,943	12.1	36,150	9.6	27,848	10.6
Structure	47,485	13.1	64,625	17.1	62,472	23.8
Railroad crossing	4,584	1.3	7,559	2.0	1,274	0.5
Miscellaneous[a]	86,161	23.7	88,526	23.4	38,487	14.7
Other[b]	8,076	2.2	11,854	3.1	5,423	2.1
Total	363,504		377,533		262,333	

[a]Includes non-facility-specific projects like regionwide engineering.
[b]Includes shoulders, weigh stations, sidewalks, and so forth.

TABLE 3 Changes in Fund Source

Facility Type	Original Dollars (000s)	Original Percentage of Total	Amended Dollars (000s)	Amended Percentage of Total	Awarded Dollars (000s)	Awarded Percentage of Total
ITH	208,819	57.4	208,250	55.2	151,466	57.7
FAU	72,544	20.0	86,036	22.8	78,084	29.8
IDOT	42,788	11.8	44,278	11.7	26,864	10.2
ITT	39,353	10.8	38,969	10.3	5,919	2.2
Total	363,504		377,533		262,333	

TABLE 4 Changes in Regional Council Investments

Regional Council	Original Dollars (000s)	Original Percentage of Total	Amended Dollars (000s)	Amended Percentage of Total	Awarded Dollars (000s)	Awarded Percentage of Total
Chicago	169,517	46.6	170,883	45.3	128,629	49.0
North Shore	11,765	3.2	11,974	3.2	10,740	4.1
Northwest	16,442	4.5	19,472	5.2	17,218	6.6
North Central	7,261	2.0	9,118	2.4	9,588	3.7
Central	17,816	4.9	17,435	4.6	6,050	2.3
Southwest	32,374	8.9	36,924	9.8	17,202	6.5
South	29,706	8.2	28,762	7.6	24,313	9.3
Lake	16,920	4.7	17,348	4.6	13,456	5.1
McHenry	3,575	1.0	3,910	1.0	2,102	0.8
Kane	10,410	2.9	10,948	2.9	4,740	1.8
DuPage	29,210	8.0	27,063	7.2	15,165	5.8
Will	10,791	3.0	9,212	2.4	5,106	1.9
Regionwide	7,717	2.1	14,484	3.8	8,024	3.1
Total	363,504		377,533		262,333	

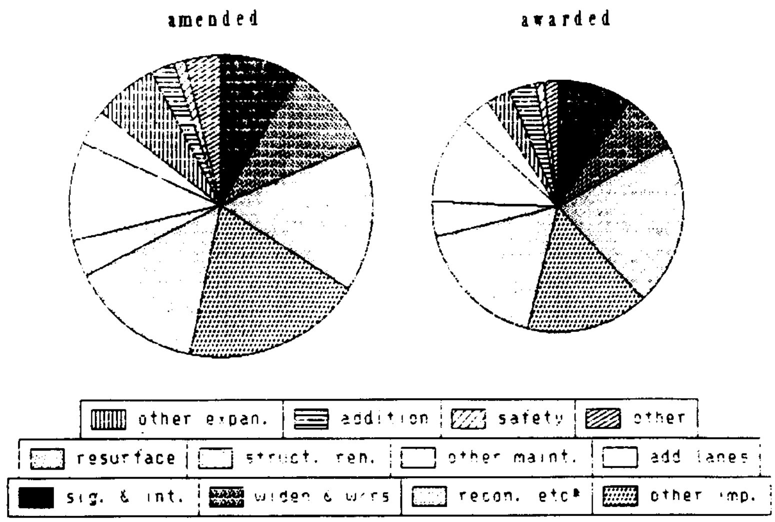


FIGURE 1 Investment categories: amended and awarded.

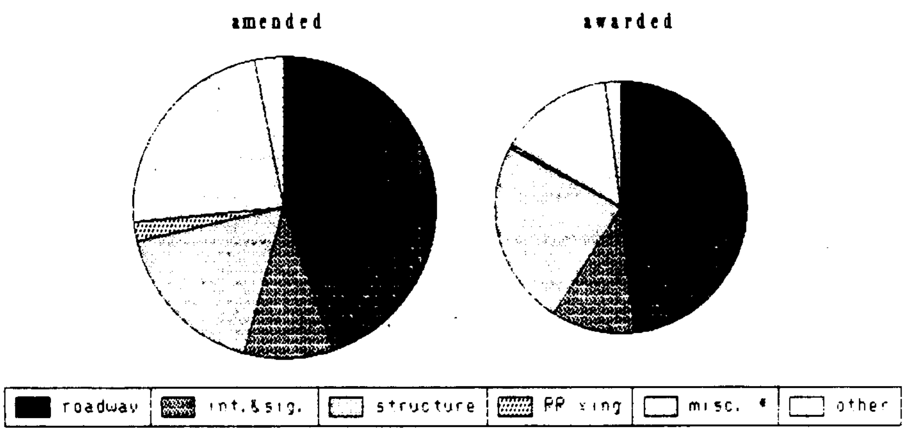


FIGURE 2 Facility types: amended and awarded.

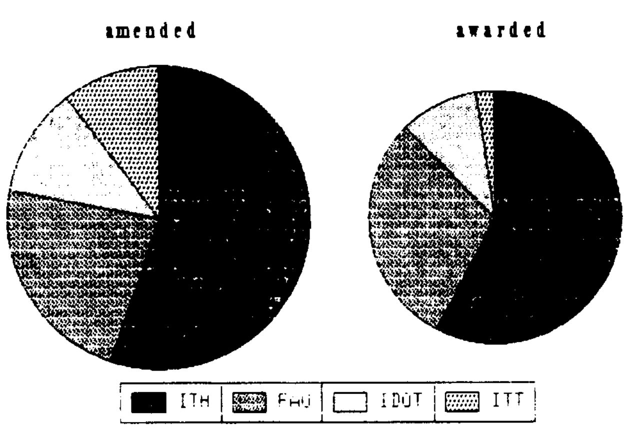


FIGURE 3 Fund sources: amended and awarded.

15.2 percent of the ITT funds were awarded whereas 72.7 percent of the FAU funds were awarded. Figure 4 shows that the high award rate for Chicago (Table 4) has a relatively small impact on the remaining councils, although some minor shifts occur.

DISPOSITION OF UNAWARDED PROJECTS

In the previous section it was shown that the awards process slightly changes the profile of the program. However, awards are historically only 70 percent of the amended program. This raises a question as to what happens to the extra $110 million that is programmed in the annual element but unawarded. Specifically, are there any patterns to be found in the investments that are not awarded?

Figure 5 traces the unawarded investments. Only 81 percent ($88.9 million) of the unawarded FY 82 annual element was in the original unamended version of the FY 82 annual element. Eleven percent ($12.3 million) of the FY 82 unawarded investment was amended into the final annual element from the multiyear element and 8 percent ($8.9 million) was added to the annual element through amendments as new projects. Presumably these projects were added to the annual element in anticipation of their being awarded, but $10.9 million of them were dropped. A total $66.6 million in unawarded projects were dropped and therefore not carried over into FY 83.

In addition to the $110.1 million in unawarded projects in the final amended FY 82 annual element, $90.1 million ($179.0 minus $88.9 million) of the original unamended FY 82 annual element projects were unawarded. These investments were either moved to the multiyear element (68.7 million) or deleted ($21.4 million) via amendments. Therefore, $200.2 million ($110.1 + $90.1 million) in projects were in the FY 82 annual element sometime during the programming year but were unawarded.

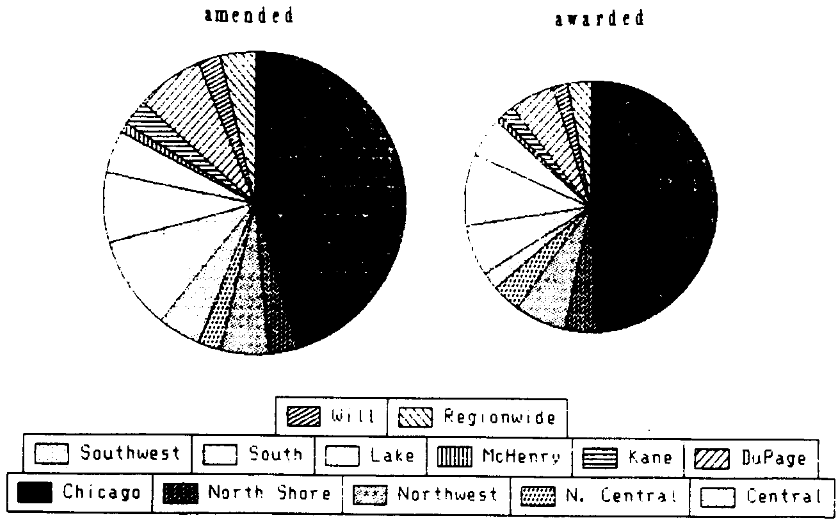


FIGURE 4 Regional councils: amended and awarded.

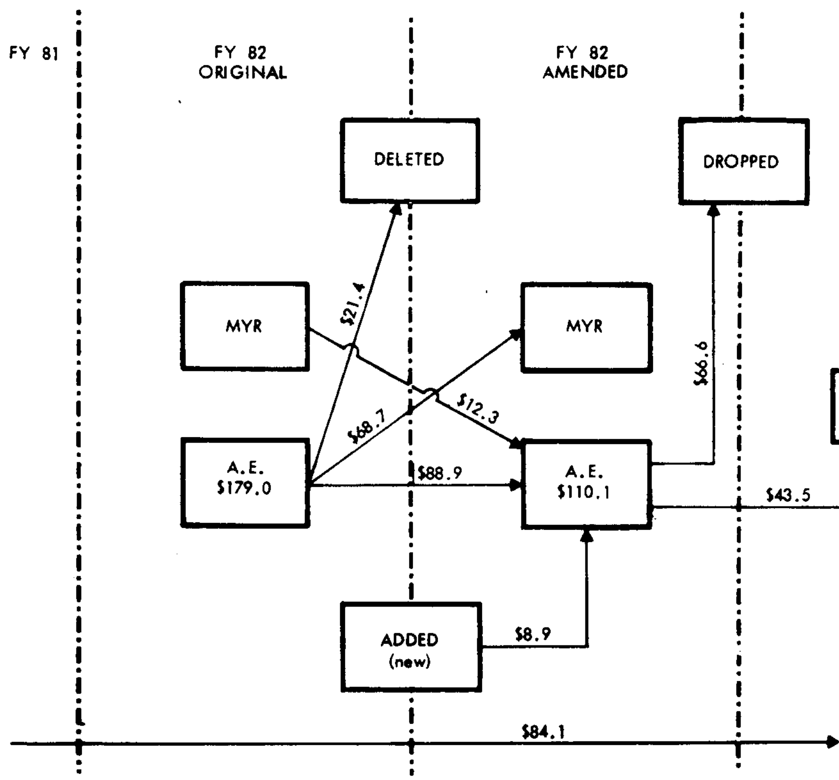


FIGURE 5 Unawarded FY 82 annual element investments (000,000s).

The $200.2 million is a substantial investment--three-quarters the size of the total awarded program. These unawarded projects apparently make up a set of marginal projects that float in and out of the annual element and between programming years. Only $43.5 million was carried over into FY 83. Eighty-four million of the unawarded FY 82 investment was originally programmed in the FY 81 annual element or multiyear element and carried over to the FY 82-86 program, unawarded, and either dropped or carried over into FY 83-87.

The maintenance of this large unawarded investment (in the current as well as the previous and pursuant programs) allows (a) a flexible programming strategy that takes best advantage of a changing funding environment, (b) changes in the program profile and size without the obvious notice or intent of the WPC as a whole, and (c) the awards decisions of the funding entities to have a major impact on the profile of the region's annual element.

IMPACT OF AMENDMENTS

The amendment process is designed to allow implementors to change the TIP to reflect changes in availability of funds and project readiness. This flexible amendments procedure recognizes the rapidly changing political and economic forces affecting funding and project preparation and attempts to take advantage of this dynamic environment for the region's transportation interests.

However, without monitoring, the amendment process could allow for gradual yet radical changes in the TIP investment profile. The discussion in the first section of this paper indicated that the awarded program changes the profile of the final amended program to a slight degree. That part of the analysis was based on the difference between the final amended program and the awarded program. However, the magnitude of amendments may change the content of the TIP significantly before awards. The discussion in the second section indicated that the unawarded investments that are amended out of the annual element are substantial. Amendments in FY 82 added 60 projects to the annual element and deleted 23 projects for a net increase of 37 projects and $26.7 million. That is an increase (attributable to projects moved in or out of the annual element) in dollars of 7.3 percent and in projects of 10.2 percent. Amendments to costs that did not move a project in or out of the program account for a decrease of $12.7 million in the annual element. Altogether the dollar amount of the amended annual element is 3.8 percent larger than that of the originally approved annual element.

To determine if the content was changed significantly via the numerous amendments, the annual element investment in the original (unamended, approved) and final (amended) versions was compared by investment category, facility, fund source, and regional council. The data in Table 1 show that amendments increased improvements slightly from 49.9 percent of the original program to 53.3 percent of the amended program (Figure 6). Addition and safety investments were decreased. Some shifts for facility types are seen in Table 2. Shown in Figure 7 are increases in structure and railroad crossing investments and decreases in roadways, intersections, and signals. Changes in fund sources between the original and final programs appear to be nonexistent in Figure 8. The data in Table 3 indicate a slight increase in FAU funds and a comparable decrease in ITH funds as proportions of the total programs. Figure 9 and Table 4 show slight changes in the profile of the TIP with respect to regional councils.

COMBINED IMPACTS

The discussion in the first section indicated that

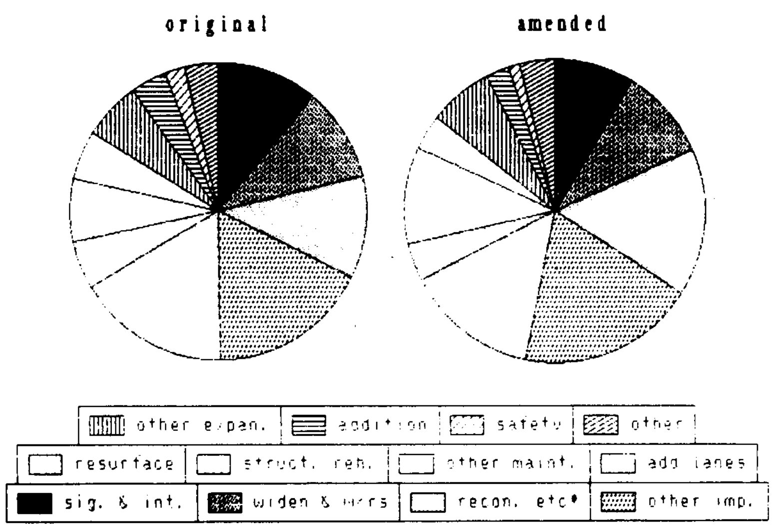


FIGURE 6 Investment categories: original and amended.

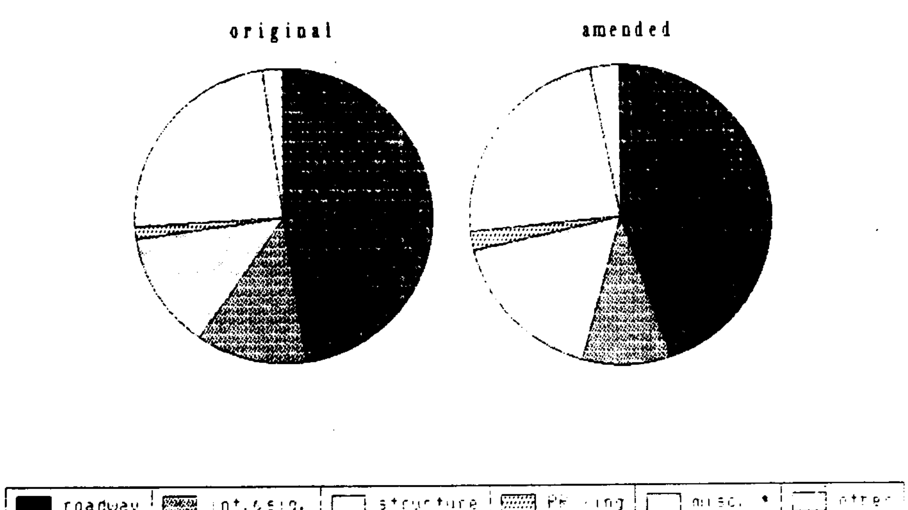


FIGURE 7 Facility types: original and amended.

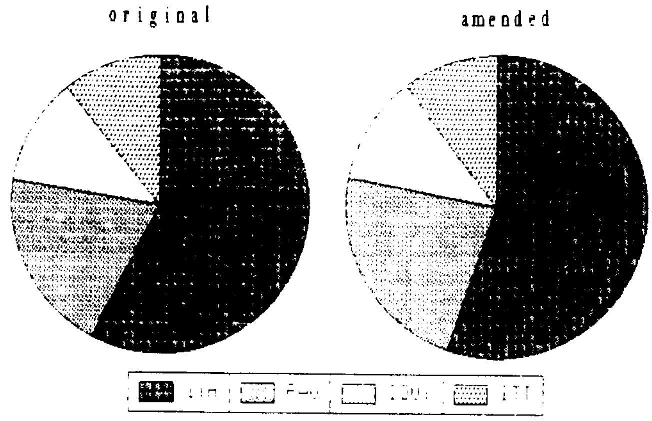


FIGURE 8 Fund sources: original and amended.

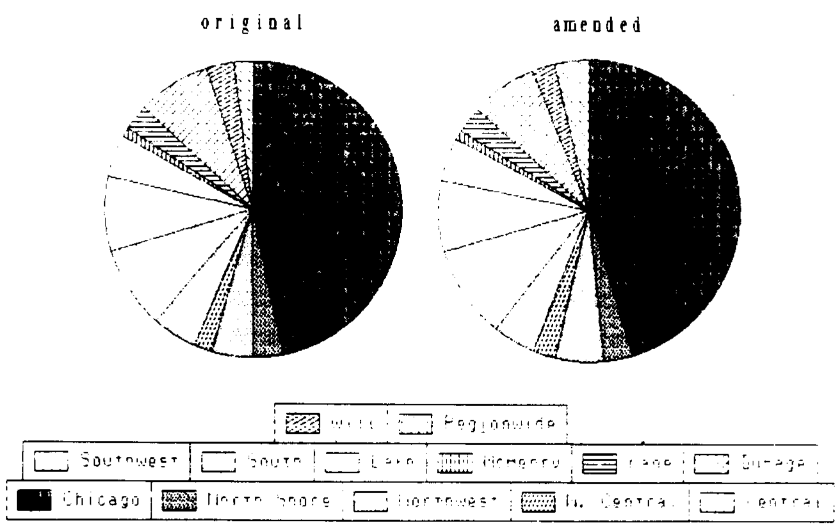


FIGURE 9 Regional councils: original and amended.

the 70 percent award rate was slightly changing the profile of the amended program. Subsequent sections indicated that amendments are substantial and, in a few cases, causing notable changes in program profile. Figure 10 shows the original and final pro-

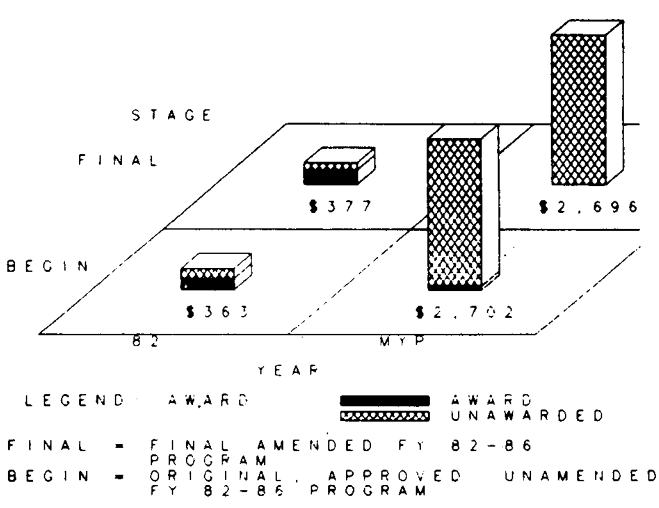


FIGURE 10 Original versus final program by year and award status (000,000s).

grammed investments by year and award status. It illustrates that only 62.3 percent of the awarded investment was in the original annual element. Thirteen percent was added through amendments as new projects, and 25 percent was brought forward from the multiyear element. In the following paragraphs the combined impacts of these amendments and awards on the program profile are examined.

The combined impacts show a notable increase in maintenance and improvement investments at the expense of all other investment categories (Figure 11). Within improvements, reconstruction investments increased considerably from 11.2 percent of the original program to 21.0 percent of the awarded program (Table 1). Other maintenance also increased substantially.

Another major shift occurs within facility type (Figure 12). Investments in miscellaneous facilities made up 23.7 percent of the original program but only 14.7 percent of the awarded program. Investment in structures increased from 13.1 percent to 23.8 percent (Table 2).

The combined impacts also show significant changes in fund sources. Figure 13 shows that the original program was 10.8 percent ITT and 20.0 percent FAU, whereas the awarded program was 2.2 percent ITT and 29.8 percent FAU (Table 3).

The most notable change in the regional councils (Figure 14) is an increase in the investment in Chicago from 46.6 percent of the original program to

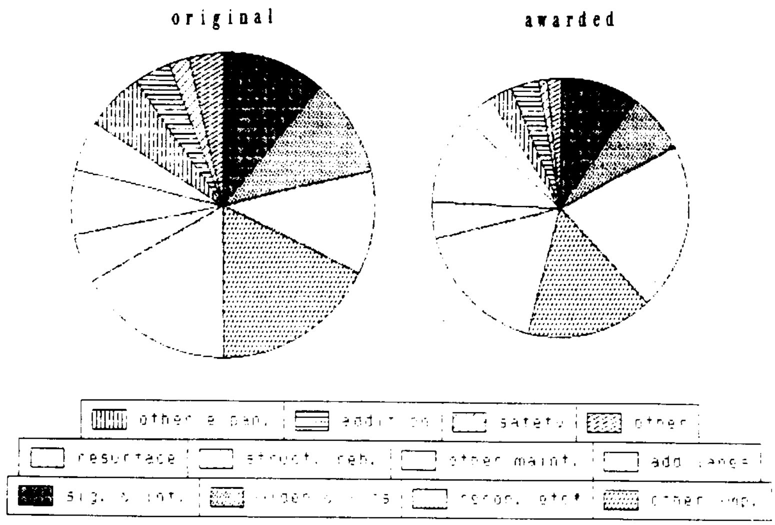


FIGURE 11 Investment categories: original and awarded.

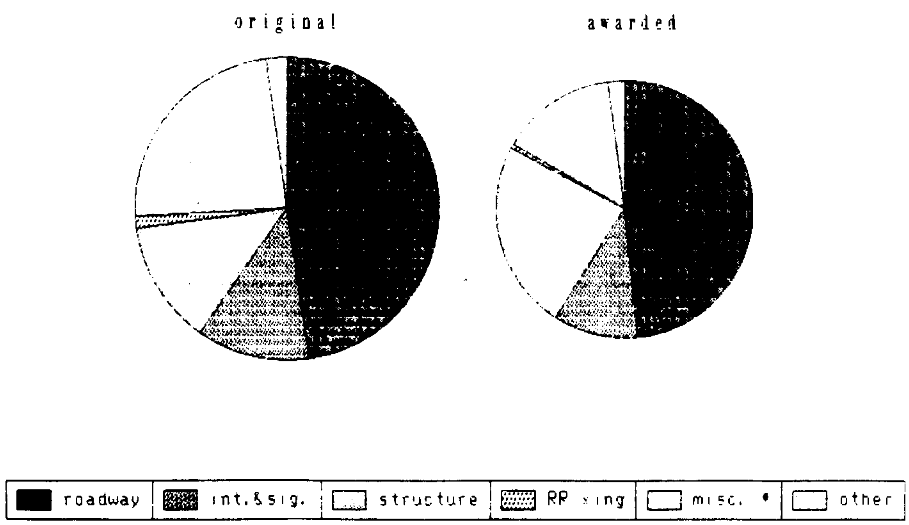


FIGURE 12 Facility types: original and awarded.

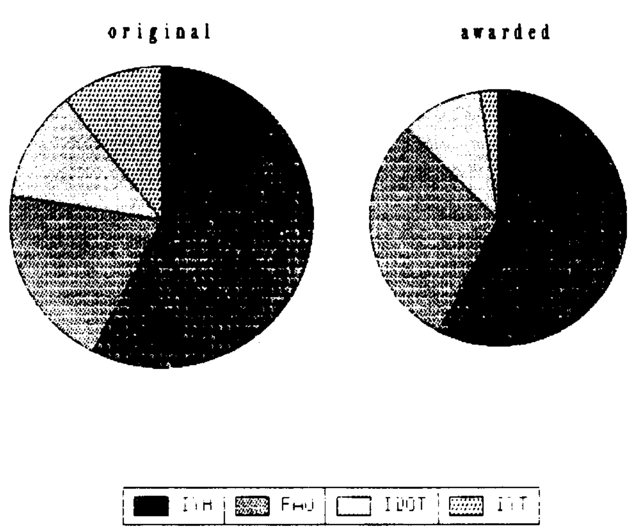


FIGURE 13 Fund sources: original and awarded.

49.0 percent of the awarded program. Because there are so many councils, other shifts are not obvious in Figure 14; however, the data in Table 4 indicate that significant changes did occur.

All of the preceding has been based on shifts of investment dollars among categories and types of investments--not on numbers of projects. This is because the amount programmed is a better indicator of program emphasis than are numbers of projects. However, changes in costs of projects caused by inflation, deflation, or improved estimates could change the magnitude of investments in categories or types of investments without really changing the original profile or intent of the program.

Therefore, the changes in costs caused by both amendments and awards were examined. The differences in awarded costs vary considerably, both above and below the programmed cost. Twenty-six projects were awarded at costs more than 50 percent higher or lower than the programmed costs. However, average costs were raised slightly by amendments from $934 thousand to $953 thousand. The awards process raised the average cost of projects from $953 thousand to $993 thousand.

Program	Average Cost ($000s)	Maximum Cost ($000s)	Minimum Cost ($000s)
Original annual element	934.5	15,175	4
Final amended annual element	953.4	40,000	0
Awarded	933.7	45,780	0

In spite of the implications of this table, more projects are awarded at costs lower than their programmed costs than are not. In addition, the percentage difference between awarded and programmed costs is approximately the same for both high-cost and low-cost projects. However, the fewer higher cost projects are more often awarded at costs higher than those for which they were programmed, and lower cost projects were more likely to be awarded at costs lower than those for which they were programmed. This explains the higher average awarded cost. These cost differentials effected by the awards may parallel the shifts in investment profiles seen in previous sections. It is likely that major differences in awarded and programmed costs reflect a change in project scope or description and would therefore be reflected in the previous pages.

CONCLUSIONS

In general, the unawarded and amended portions of the TIP were of a magnitude great enough to create significant potential for changing the intent of the original program. However, except in a few cases, the amendments and awards did not appear to significantly alter the profile of the program. Some important observations can be made about the shifts seen in the TIP profile caused by amendments and awards.

The most obvious of these shifts was toward increasing investments in structure improvements. The major cause of these shifts is the advancement of a new structure (Lake Shore Drive at the Chicago River) from the annual element "B" list to the annual element "A" list, and its subsequent award. Although it can be said that this is insignificant because it is only one project, it still represents a large portion of the awarded program ($40 million) and greatly limits capital funds available for other investments.

A shift, primarily due to awards, was seen in fund sources. Local programmers have less power over the availability of the funds by source than over the actual use of these funds. However, major differences exist in the restrictions and uses of the various funds such that major shifts in the kinds of funds that make up the total program could dramatically affect other aspects of the profile of the program. That some shifts are occurring in fund sources without major shifts in other aspects (such as investment categories, regional councils, and work types) could indicate that programmers have in most cases carefully planned and adjusted the program to most effectively use available funds regardless of their source. The flexible amendments procedure helps make this possible. For example, addition projects were decreased by about 34 percent through amendments, but almost all of the remaining addition projects were subsequently awarded. It is probable that programmers correctly anticipated which of the addition projects were likely to be awarded and diverted the remaining funds to other eligible projects.

In addition to the $262 million awarded program, $200 million was programmed in the FY 82 annual ele-

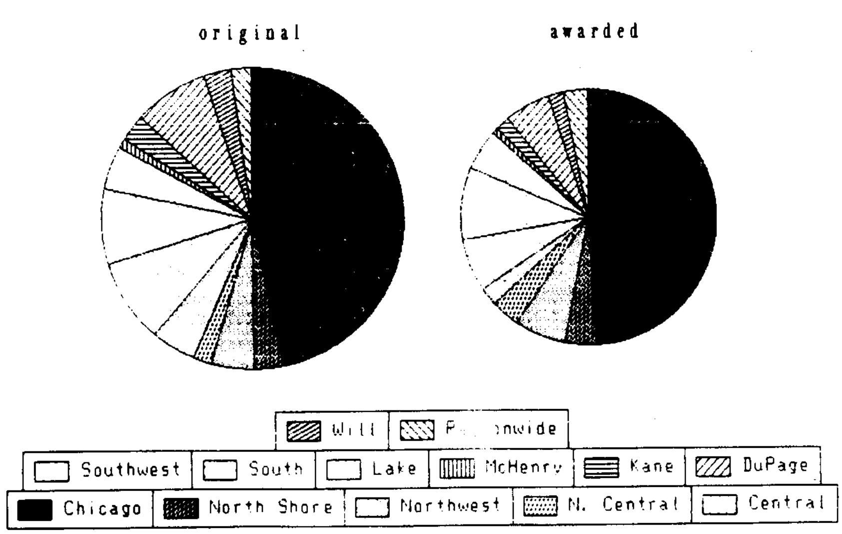


FIGURE 14 Regional councils: original and awarded.

ment sometime during the programming year but not awarded. Many of these projects were brought forward from previous years and many were carried over into FY 83. However, many were added to the annual element through amendments and many awarded projects were added to the annual element through amendments. The implication is that staging of projects for eventual award is not occurring. Rather, programmers are maintaining a large set of annual element projects from which to select for potential award. This appears to be an effective means of programming for maximum advantage in a dynamic and unpredictable funding environment.

However, cost differentials are great between the original and final annual elements as well as between the final and awarded program. On average, projects are awarded at lower than programmed costs, but the percentage differences between programmed and awarded costs are high. This suggests that significant changes in scope are occurring but that changes in any individual project are counterbalanced by changes elsewhere in the program.

REFERENCE

1. FY 83-87 Transportation Improvement Program for Northeastern Illinois. Chicago Area Transportation Study, Chicago, Ill., 1982.

Pennsylvania Priority Commercial Network: Development and Applications

THOMAS E. TENEYCK, DENNIS E. LEBO and LINDA M. PROCTOR

ABSTRACT

The development and application of Pennsylvania's Priority Commercial Network are documented. The Priority Commercial Network encompasses approximately 12,000 miles of roadway of the greatest importance to commerce in Pennsylvania. The roadways identified carry traffic of more than 500 trucks per day or are connector roads for specific regional industries such as coal. The methodology used in network development, coordination efforts, and the physical aspects of the system are described. Major findings with respect to weight-restricted bridges, long steep grades, and truck incident locations are analyzed as they pertain to commercial restrictions. The Priority Commercial Network has served its intended purpose as an effective decision-making tool in highway and bridge program development as well as in several other key departmental initiatives: (a) innovative bridge funding legislation, (b) identification of an agricultural access roadway system, (c) pavement management, (d) measuring agency performance, and (e) setting department objectives.

The Pennsylvania Department of Transportation (PennDOT) has undertaken a new initiative to facilitate a program development process consistent with the goal of promoting commerce and economic development by focusing decision making on goods movement by truck. Highlighting the network of highways that is frequently used by commercial truck traffic enables the department to efficiently identify deficiencies that deter commercial truck travel.

The Priority Commercial Network (PCN), which consists of all major truck routes throughout Pennsylvania, was identified as the base system within which to specify major areas where restrictions to commerce occur or are about to occur. Analysis of this network provides a view of the performance of the highway system and a framework within which to measure the performance of the highway and bridge programs. It is a basis for evaluating district and agency performance in delivering products that effectively address the key objective area of highway commercial transportation. Deficiencies identified on the PCN are prime candidates for projects to be input to the PennDOT twelve-year program. The information obtained from monitoring the status of projects or potential projects located on the PCN can be used as input to evaluation of the performance of the highway and bridge programs.

The PCN has had direct influence on key department initiatives in pavement management, setting objectives, and evaluating farm-to-market roadways.

METHODOLOGY

The initial task in this study was to develop a statewide system of highways and bridges that are of the greatest importance to truck travel. Information on the volumes of truck travel in Pennsylvania was obtained from the PennDOT truck monitoring program and from the most recent information contained in traffic information files.

The basic system was identified as the set of road segments across the state with average daily truck traffic (ADTT) of 500 or more. This basic system was stratified into four levels of ADTT (500 to 1,000, 1,001 to 3,000, 3,001 to 5,000, and > 5,001) and one level designated Interstate. An additional level of roads (priority connectors) with ADTTs less than 500 was added in areas where available information showed volumes fluctuating above and below the 500 ADTT level or where a highway was considered to be of regional importance to commerce even though its level of truck traffic was below established parameters.

Major coal-haul routes were also added as a supplement to the basic PCN. The 2,900-mile system of coal-haul routes identified in the 1981 Core Coal Haul Study was the basis for these additions. The initial Priority Commercial Network identified totaled 9,500 miles.

The constraints to commercial travel that were identified on the network included deficient bridges, high truck incident locations, and long steep grades. Deficient bridges on the network (sufficiency rating < 80.0) were extracted from the Structure Inventory Records System (SIRS) data base and include bridges that are either structurally deficient or functionally obsolete. High truck incident locations were defined as locations with 10 or more truck-related accidents during the most recent 3-year period. These locations were derived from the PennDOT accident record system. Finally, the long steep grades on the network were identified according to a department study that incorporates grade, daily truck volume, and truck accident data in classifying long steep grades.

COORDINATION

The objective of the coordination phase of the study was to draw on local and regional perspectives to refine the initial state-level definition of the Priority Commercial Network and its associated constraints. This phase was also intended to use local and regional input to identify key access points to the priority network.

Metropolitan planning organizations, district offices, regional planning agencies, and other local and regional organizations were consulted during this phase. In addition, as the study progressed, other advisory and local interest organizations became involved in the review process. The suggestions and comments that ensued from these coordinative efforts were incorporated, where appropriate, as revisions to the initial network. As a result of these coordination efforts, the Priority Commercial Network of state-owned roads increased by 17 percent to a total of 11,457 miles. Because of constant highway improvements and changes, the PCN definition and constraints are reviewed and revised at timely intervals.

PHYSICAL ASPECTS

Through the use of special data base indicators, the PCN was integrated into the PennDOT roadway information system of all state-owned highways. Pennsylvania owns approximately 45,000 miles of highways; thus the PCN comprises approximately 25 percent of state-owned mileage. Simple computer programming techniques allow PennDOT to view physical aspects of the network from a statewide or regional perspective at any time.

Various characteristics of the PCN are presented in Table 1:

- More than one-half of the PCN has truck volumes of between 500 and 3,000 trucks per day,
- The Interstate system comprises approximately 10 percent of the mileage, and
- The PCN is made up of 26 percent rigid base roadways, 32 percent flexible base roadways, and 42 percent composite roadways.

According to pavement serviceability ratings (Table 2):

- Thirty-six percent of the network is in good condition, 60 percent is in fair condition, and only 4 percent is in deteriorated condition.
- Over 7,000 miles of the PCN have been resurfaced since construction.
- As shown in Figure 1 and Table 3, 98.8 percent of the PCN is on a federal-aid system.
- Seventy-four percent of the system is rural, and 26 percent is located in urban areas.
- Two-thirds of the network is on the federal-aid primary system.

FINDINGS

The analysis of Pennsylvania's Priority Commercial Network proved extremely valuable in the development of the PennDOT highway and bridge program. Network findings indicate that a new level of information and understanding, heretofore unavailable to decision makers throughout PennDOT, can be provided by the commercial network analysis. The framework provided by this information is viewed as both defensible and objective.

TABLE 1 Statewide Highway Mileage on the PCN

Miles	<500 ADTT	500-1,000 ADTT	1,001-3,000 ADTT	3,001-5,000 ADTT	>5,001 ADTT	Coal Haul	Total
Highway	3,945	3,234	2,570	113	21	439	10,322
Interstate	0	34	327	484	290	0	1,135
Total	3,945	3,268	2,897	597	311	439	11,457

TABLE 2 Pavement Serviceability Ratings

	Deteriorated			Fair			Good			
	0.9	1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-3.9	4.0-4.5	4.5+	Total
Miles	16	31	434	1,243	2,546	3,064	2,349	1,385	389	11,457
Percent	–	–	4	11	22	27	21	12	3	100

Note: Dash = less than 1 percent.

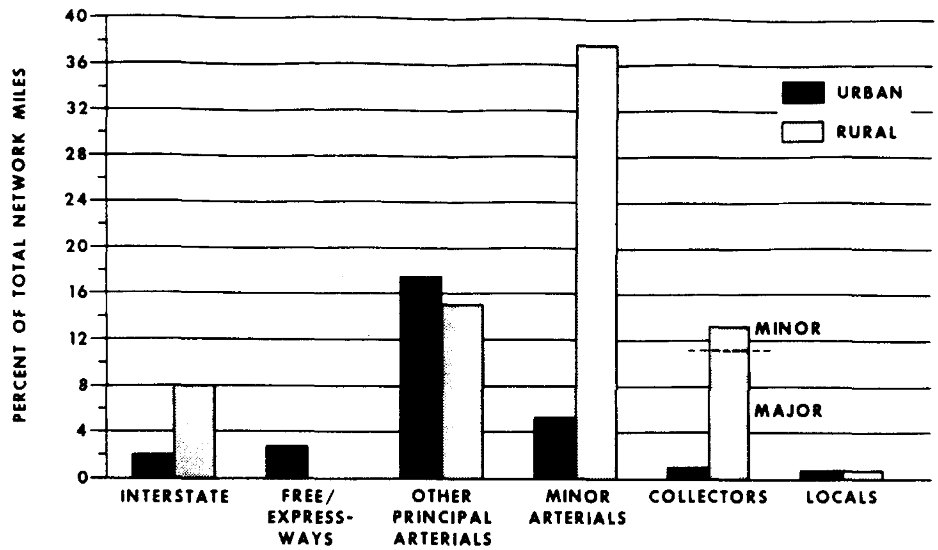


FIGURE 1 Priority Commercial Network mileage by functional class.

TABLE 3 Mileage by Federal-Aid Systems

System	Description	Mileage	Percent
Federal-aid interstate	Urban	225.3	
	Rural	905.1	
Total		1,130.4	9.9
Federal-aid primary			
Freeways and expressways	Urban	263.5	
Principal arterials	Urban	1,320.3	
Principal arterials	Rural	1,704.6	
Minor arterials	Rural	4,344.9	
Total		7,633.3	66.6
Federal-aid secondary			
Major collectors	Rural	1,357.7	
Total		1,357.7	11.8
Federal-aid urban			
Principal arterials		598.2	
Minor arterial		550.0	
Collectors		54.3	
Total		1,202.5	10.5
Non-federal-aid			
Local	Urban	7.4	
Minor collector	Rural	103.8	
Local	Rural	22.2	
Total		133.4	1.2

The constraints to commercial travel that were identified on the network included deficient bridges, high truck incident locations, and long steep grades.

Bridges

Analysis of all bridges on the 11,457-mile Priority Commercial Network shows that 1,095 of the bridges are currently deficient [sufficiency rating (SR) <80.0 and structurally deficient or functionally obsolete]. The estimated cost to repair or replace these bridges is $1.2 billion. A further effort was made to identify the most critical needs. The deficient bridges were separated into six categories and compared with all bridge deficiencies statewide:

1. Category A--All bridges statewide with SR < 80.0,
2. Category B--Priority commercial bridges with SR < 80.0,
3. Category C--Priority commercial bridges with SR < 50.0,
4. Category D--Priority commercial bridges posted or closed or with SR < 25.0,
5. Category E--Priority commercial bridges with SR < 25.0,
6. Category F--Priority commercial bridges posted or closed, and
7. Category G--Priority commercial bridges posted or closed and with SR < 25.0.

Category D (posted and closed bridges, or bridges with sufficiency ratings less than 25.0) represents a a population of deficient bridge structures that de- mand immediate attention for programming purposes.

Updated information obtained from Pennsylvania's Structure Inventory Records System including the number of bridges 20 feet and longer, the square footage of deck area, and cost to repair or replace these bridges is recorded by district for each of the six categories in Table 4.

Long Steep Grades

Of 93 long steep grades identified statewide before this study effort, 85 are located on the PCN. During the coordination phase the districts and planning commissions identified 38 additional grades that they considered problems for truck travel. The 38 grades identified needed to be evaluated using the methodology and criteria that resulted in the 93 initial grades, and progressive levels of improvements needed to be identified.

Of the initial 85 grades, 68 were found to be adequately signed; the signing of the remaining 17 grades is being upgraded. Ten PCN grades have been signed to the maximum extent and have been targeted for physical improvements (such as mandatory pull-off areas or truck-escape facilities). PennDOT has reviewed these grades and determined a progressive set of improvements to be considered by the districts in future betterment programs.

High Truck Incident Locations

Of the 278 incident locations identified on the network, 242 (87 percent) are on highways that carry

TABLE 4 Bridge Deficiencies on the Priority Commercial Network

DIST NUMBER	STATEWIDE NETWORK A S.R. < 80.0 #	SQUARE FT. DECK AREA	% DA	COST	PRIORITY COMMERCIAL NETWORK B S.R. < 80.0 #	SQUARE FT. DECK AREA	% DA	COST	C S.R. < 50.0 #	SQUARE FT. DECK AREA	% DA	COST
1-0	774	2,269,550	9.28	191,767	171	1,137,420	8.95	56,660	92	604,802	9.60	46,007
2-0	459	1,112,222	4.55	168,148	72	538,008	4.23	52,930	39	212,058	3.37	46,408
3-0	840	1,618,328	6.62	328,602	118	685,443	5.39	165,158	81	487,344	7.74	155,355
4-0	386	1,241,567	5.08	84,904	45	488,395	3.84	17,321	10	147,039	2.33	10,279
5-0	463	2,100,091	8.59	106,666	114	1,364,040	10.73	47,870	32	343,178	5.45	31,784
6-0	600	4,071,610	16.65	301,491	108	2,596,428	20.43	144,515	46	1,603,410	25.46	80,805
8-0	819	1,965,526	8.04	77,495	92	634,097	4.99	9,553	33	264,614	4.20	7,723
9-0	391	1,030,231	4.21	77,823	37	362,254	2.85	7,979	10	71,570	1.14	3,831
10-0	632	1,834,688	7.50	236,140	116	1,037,986	8.16	86,565	27	172,615	2.74	42,910
11-0	400	5,314,845	21.73	631,731	112	2,695,639	21.21	360,901	64	1,965,316	31.20	307,352
12-0	646	1,896,007	7.75	275,702	110	1,171,686	9.22	212,673	32	426,353	6.77	40,952
TOTAL	6,410	4,454,665	100.00	2,480,469	1,095	12,711,396	100.00	1,162,125	466	6,298,299	100.00	773,406

DIST NUMBER	STATEWIDE NETWORK A S.R. < 80.0 #	SQUARE FT. DECK AREA	% DA	COST	PRIORITY COMMERCIAL NETWORK D POSTED & CLOSED OR S.R. < 25.0 #	SQUARE FT. DECK AREA	% DA	COST	E S.R. < 80.0 #	SQUARE FT. DECK AREA	% DA	COST
1-0	774	2,269,550	9.28	191,767	31	277,824	8.45	34,856	30	260,674	8.57	33,388
2-0	459	1,112,222	4.55	168,148	13	36,316	1.10	9,633	11	32,245	1.06	8,155
3-0	840	1,618,328	6.62	328,602	28	247,266	7.52	98,166	24	193,469	6.36	70,660
4-0	386	1,241,567	5.08	84,904	1	32,220	.98	762	1	32,220	1.06	762
5-0	463	2,100,091	8.59	106,666	6	117,265	3.57	23,864	6	117,265	3.86	23,864
6-0	600	4,071,610	16.65	301,491	21	712,166	21.65	50,547	12	660,668	21.73	44,468
8-0	819	1,965,526	8.04	77,495	12	45,130	1.37	3,745	10	41,475	1.36	3,317
9-0	391	1,030,231	4.21	77,823	1	2,408	.07	1,025	1	2,408	.08	1,025
10-0	632	1,834,688	7.50	236,140	9	62,115	1.89	28,284	8	54,135	1.78	25,707
11-0	400	5,314,845	21.73	631,731	29	1,446,245	43.98	235,307	25	1,399,793	46.04	226,817
12-0	646	1,896,007	7.75	275,702	12	309,823	9.42	32,495	7	246,314	8.10	17,249
TOTAL	6,410	4,454,665	100.00	2,480,469	163	3,288,788	100.00	518,684	135	3,040,666	100.00	455,412

TABLE 4 (continued)

DIST NUMBER	STATEWIDE NETWORK A S.R. < 80.0 #	 SQUARE FT. DECK AREA	 % DA	 COST	PRIORITY COMMERCIAL NETWORK F S.R. < 50.0 #	 SQUARE FT. DECK AREA	 % DA	 COST	 G POSTED & CLOSED OR S.R. < 25.0 #	 SQUARE FT. DECK AREA	 % DA	 COST
1-0	774	2,269,550	9.28	191,767	5	67,325	4.72	17,328	4	50,175	4.25	15,860
2-0	459	1,112,222	4.55	168,148	6	11,696	.82	3,442	4	7,625	.65	1,964
3-0	840	1,618,328	6.62	328,602	13	168,813	11.81	77,690	9	115,017	9.74	50,184
4-0	386	1,241,567	5.08	84,904	1	32,220	2.25	762	1	32,220	2.73	762
5-0	463	2,100,091	8.59	106,666	5	114,260	8.00	23,864	5	114,260	9.67	23,864
6-0	600	4,071,610	16.65	301,491	17	181,533	12.70	32,697	8	130,034	11.01	26,618
8-0	819	1,965,526	8.04	77,495	10	28,917	2.02	3,340	8	25,263	2.14	2,912
9-0	391	1,030,231	4.21	77,823	1	2,408	.17	1,025	1	2,408	.20	1,205
10-0	632	1,834,688	7.50	236,140	7	59,795	4.18	27,792	6	51,815	4.39	25,215
11-0	400	5,314,845	21.73	631,731	18	647,765	45.33	150,948	14	601,312	50.92	142,458
12-0	646	1,896,007	7.75	275,702	11	114,271	8.00	29,123	6	50,762	4.30	13,877
TOTAL	6,410	4,454,665	100.00	2,480,469	94	1,429,003	100.00	368,011	66	1,180,891	100.00	304,739

1,000 or more trucks per day; of these 242, 74 (30 percent) are on Interstates.

Sixty-eight of the 278 incident locations have had 101 separate projects programmed. Of the 101 projects, 24 have been completed within the last 2 years, 38 are included in the 4-year priority program, 34 are included in either the fiscal year 1982-1983 or fiscal year 1983-1984 betterment programs, and 5 are programmed beyond the first 4 years. Examples of projects include resurfacing, shoulder, guardrail, median barrier construction, signalization, channelization, and turning lane construction. The remaining 210 locations (75 percent) identified during this study have not had projects identified or developed.

APPLICATIONS

In addition to the obvious development benefits, the PCN has served Pennsylvania in five additional key initiatives:

1. Bridge funding legislation,
2. Development of an agricultural access network pilot study and statewide implementation,
3. Delineation of a pavement management system,
4. Measuring agency performance, and
5. Setting department objectives.

Bridge Funding Legislation

An important initial use of the PCN resulted in state legislation to address the bridge problem in Pennsylvania. Legislators recognized the seriousness of the problem by passing a $1.4 billion bridge bill to rehabilitate or replace 979 structures during 6 years. This bill addresses various categories of bridges, and the PCN was instrumental both in the development of the bill and in the public and legislative acceptance of the bill as well as of the associated funding requirements.

Through this legislation, Pennsylvania has placed high priority on bridge repair. Bridges are the key stepping stones across Pennsylvania's entire 117,000-mile road, street, and highway network. The closing of a single bridge can make miles of good roadway useless until the bridge is replaced. In a similar manner, a weight restriction can force commercial traffic into lengthy and costly detours, sometimes on roads not designed to carry heavy traffic, contributing to the further deterioration of the highway network. This is especially true of restrictions on the PCN.

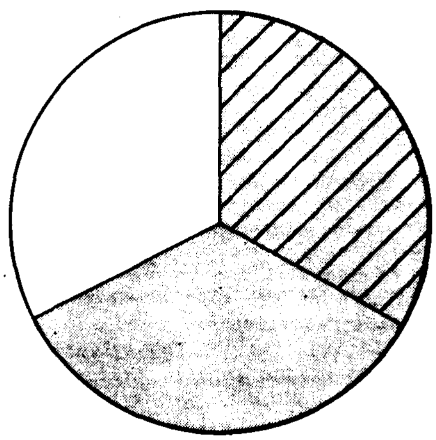
Pennsylvania has approximately 56,000 bridges; 21,600 are 20 feet or more in length. There are numerous deficiencies on this vast system of bridges: 7,500 bridges are structurally deficient or functionally obsolete; 3,800 bridges are restricted to 20 tons or less; and 200 are closed to all traffic (three-quarters of these are off the state system). The total repair bill for this backlog of deficiencies is estimated at $3 billion.

Funding to meet this bridge crisis has been far from adequate. Under the Federal Surface Transportation Assistance Act of 1978, Pennsylvania received $180 million in federal critical bridge funds over a 4-year period. Through the Surface Transportation Assistance Act of 1982, the need for additional bridge funding was recognized. Pennsylvania will receive approximately $363 million over 4 years. However, this is only a meager beginning compared with the $3 billion backlog of requirements.

In addressing these funding shortfalls, the PCN provided a new base of information on which to make decisions concerning the numerous bridge replacement and rehabilitation projects. The PCN was a method of assigning priorities to bridge deficiencies, placing importance on those problems most critical to commercial movements and the state's economic well-being.

In the analysis of PCN bridge deficiencies, the needs far exceeded the revenues anticipated under the Twelve Year Capital Improvement Program. Bridge deficiencies on the PCN were categorized (see Table 4). A balance had to be struck depending on funding assumptions and the level of deficiency to be addressed. The Pennsylvania Department of Transportation Program Management Committee decided to concentrate programming priorities on category D, those bridges posted or closed or having very low sufficiency ratings.

Figure 2 shows the September 1982 program status of the category D bridges. Of 148 bridges in this category, 101 (68 percent) were programmed. Of the 101 programmed bridges, 48 were included in the first 4 years. The remaining 47 structures that were not programmed had to be addressed.



PROGRAMMED (101)
PROGRAMMED FOR FIRST FOUR YEARS (48)
NO PROGRAM STATUS (47)

FIGURE 2 Priority Commercial Network programmed bridges. Bridges posted or closed, or with sufficiency ratings less than 25.0 (148 structures).

With other state and local priorities to consider, there still remained a serious lack of funding for these important commercial bridges. During late 1982 legislation was proposed to address the orphan bridge problem (orphan bridges carry highways over railroads and ownership of these bridges is in question). Planners worked with lawmakers to expand this legislation to provide a complete and comprehensive bridge program. With expanded funding, the inclusion of a greater number of PCN bridges was possible while still addressing other state priorities.

The entire 6-year program covers 979 structures and addresses the following categories of bridges.

Bridge	No.	Approximate Cost ($)
Big PCN bridges	25	381 million
Other PCN bridges	211	347 million
Other priority state bridges	208	248 million
Local and agricultural bridges	329	178 million
Orphan bridges	206	196 million

The PCN bridges comprise only 24 percent of the bridges in this program but constitute 54 percent of the cost.

To fund this program, an additional fee per axle was imposed on all trucks using Pennsylvania highways. To gain legislative and public acceptance of the measure, the economic benefits to be derived from improvement of the PCN bridges were promoted. Based on the number of trucks detouring around the 104 restricted PCN bridges and an average operating cost per mile, the total annual cost to the trucking industry is $228 million. Because the trucking industry must pay an additional $69 million in annual taxes, the cost-benefit ratio to that industry is better than 3 to 1.

The PCN provides an overall picture of bridges inhibiting commercial traffic--the traffic most affected by bridge restrictions. The PCN provides the information to best select, at present and in the future, those projects that promise the greatest return to Pennsylvania's economy.

AGRICULTURAL ACCESS NETWORK PILOT STUDY

The Priority Commercial Network is serving as a basis for development of further information on highway and bridge problems affecting specific sections of the economy. Pennsylvania is currently developing an Agri-Access Network to complement the Priority Commercial Network. This is an extension of the PCN focused on information on rural roads and bridges essential to the agricultural industry and rural communities of the state.

Pennsylvania's agriculture is a vital industry. Cash receipts from marketing of farm products total $3 billion annually. Agriculture and agribusiness form the largest single industry in the state. One out of five jobs, including those of supermarket clerks and trucking, processing, and production personnel, is in agribusiness. Farming operations also contribute heavily to the economy through their large purchases of petroleum products, machinery, equipment, and materials.

The transportation system has significant impacts on agriculture and rural communities. Obstructions, such as weight-restricted bridges, cause trip diversions of service vehicles that translate into higher operating costs. Continuing rail line abandonments also place an additional burden on rural roads and bridges.

This current project is a cooperative effort between officials of the transportation and agricultural sectors. Coordination with local government and farm organizations has been established and is continuing throughout the effort. Local input and assistance in identifying the network are essential elements of the project.

The planning effort is identifying a network of roadways most important to agriculture for the transport of commodities to market and supplies to the farm. This effort is identifying critical bridges in need of rehabilitation or replacement to improve the efficiency of movement of products to and from farm-related businesses as well as to increase the safety of travel by the rural population. Problems associated with the movement of emergency vehicles and loaded school buses are also being identified.

The already identified Priority Commercial Network is serving to focus the identification of these routes. Information gathered throughout this project has also supported the importance of the PCN. The entire PCN has proven to be essential to the state agribusiness economy. The majority of major operations serving the farm community such as processing plants, fertilizer plants, and feed mills have been found to be located along or directly adjacent to the PCN.

The PCN is almost entirely comprised of higher functionally classed highways such as Interstates, expressways, and arterials. Whereas these highways link major urban centers and serve statewide and interstate travel, the agri-access highways are mainly collector routes linking agricultural areas and rural communities with the PCN.

Identification of these essential roadways that provide access between rural agricultural areas and the PCN is key to reducing transportation costs to the agricultural community and to obtaining the greatest benefits from the expenditure of limited roadway and bridge improvement funds.

DELINEATION OF A PAVEMENT MANAGEMENT SYSTEM

The Priority Commercial Network is presently being viewed as an integral part of the Department of Transportation's initial pavement managment system.

Pennsylvania has more than 45,000 miles of state-owned roadways. To implement a working pavement management system, the roadways are being stratified with various levels of condition surveys proposed for each system. The Interstate system and the PCN are being used as the core system in pavement management. One hundred percent roadway distress surveys and rideability surveys will be performed on the system of highways in a uniform manner throughout each of the 11 engineering districts. Individual district surveys will be performed on the remaining roadways throughout Pennsylvania.

This stratification of systems will allow Pennsylvania to manage the roadways with a unique importance to commerce in a manner to best support economic development. The methodology also affords an opportunity for district offices to recognize the interregional importance of the PCN and to manage this roadway system accordingly. There is a need to manage a vast roadway system at various administrative levels, and a PCN allows for innovative decision making at both the network and project levels.

MEASURING AGENCY PERFORMANCE

The Priority Commercial Network provides a system of highways from which to measure how well the agency has addressed commercial and economic needs and interests. This was accomplished by evaluating all construction awards on and off this network.

Construction work initiated on the PCN from January 1, 1979, to October 1, 1982, is given in Table 5. More than $1.3 billion was spent for 1,470 projects on this network. This compares with $1.7 billion for all awards during the same period. Approximately two-thirds of the $1.3 billion was spent on the replacement and rehabilitation of bridges and on the restoration of the commonwealth's highway and Interstate system. Three hundred ninety-six million dollars, or less than 30 percent, was spent on major construction and highway completion projects.

A comparison was made between awards on the PCN and all awards for the same period. This is illustrated in Figure 3. The PCN comprises nearly 25 percent of all state highways; however, nearly 80 percent of all improvement dollars were spent on this vital network.

TABLE 5 Priority Commercial Network Construction Awards Versus All Awards

Program	PCN Awards ($000)	All Awards ($000)	PCN as Percentage of All Awards
Bridge replacement	99,862	139,326	71.7
Bridge rehabilitation	137,252	178,013	77.1
Major construction	1,216	3,013	40.4
Highway completion	395,524	395,524	100.0
Highway restoration	324,000	506,182	64.0
Interstate restoration	316,351	317,272[a]	99.7
Local restoration	142	44,162	0.3
Energy conservation	6,383	9,224	69.2
TSM improvements	252	427	59.0
Safety	56,734	81,874	69.3
Total	1,337,716	1,675,017	79.9

[a]Interstate funding used for Wood Street Bridge in Pittsburgh.

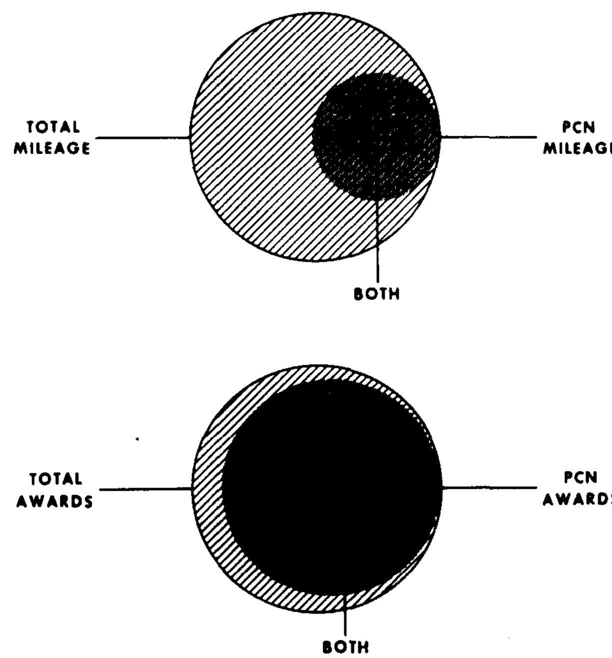


FIGURE 3 Comparison of total state highway mileage and PCN mileage with total state awards and PCN awards.

SETTING DEPARTMENT OBJECTIVES

The Priority Commercial Network forms one of the four major highway systems in Pennsylvania. In assessing the various requirements of these systems, the PCN is treated as a separate system for planning analysis. For example, in the determination of the backlog routine maintenance requirements of the various state highway systems, the requirements of the PCN were estimated. The dollars needed to overcome backlog maintenance needs related to pavement, shoulders, drainage, and appurtenances were estimated in terms of three levels of maintenance effort: dollars needed for that share of the system in good condition (i.e., requiring the least expenditures), dollars needed to repair mileage requiring a moderate level of maintenance effort, and dollars required for that share of the network requiring extensive maintenance efforts. An examination was also made of 1981-1982 winter services expenditures (snow and ice removal) to determine the distribution of costs for the network among the 11 engineering districts of PennDOT. Similarly, major construction and bridge improvement requirements for the PCN have been estimated.

In setting directions for the future efforts of

PennDOT, the number of roadway surface improvements to be accomplished over the next several years on the PCN is being examined. This includes the amount of restoration to be accomplished on the Interstate portion of the network. It also includes determining the magnitude of resurfacing, surface treatment, and seal coating to be accomplished on the non-Interstate portions. Resurfacing is applicable to those sections with higher traffic volumes; surface treatment and seal coating are preventive maintenance techniques used to protect those parts of the network with lower volumes of traffic.

In conclusion, the Priority Commercial Network has been an essential tool in departmental decision making and is now becoming a recognized highway system in Pennsylvania.

Development of Pennsylvania's Agricultural Access Network

DENNIS E. LEBO

ABSTRACT

A two-county pilot study was conducted to develop an Agricultural Access Network in Pennsylvania. The study identified the essential roadways that provide access to the rural agricultural areas for the transport of agricultural commodities to market and supplies to the farm. It further identified key transportation obstructions inhibiting movement of products and supplies. The pilot study used direct input from local representatives in the identification and refinement of the network. The process used in developing the network is described and the results of the study are summarized. The identification of the Agricultural Access Network provides important information concerning which projects will yield the greatest economic benefits to the agricultural and rural communities of Pennsylvania.

The efficient movement of agricultural products and farm inputs in Pennsylvania is highly dependent on rural roads and bridges. Restrictions on Pennsylvania's vast rural transportation system can result in substantial economic impacts on the agricultural and rural communities.

The Pennsylvania Department of Transportation (PennDOT) conducted a pilot study to develop an Agricultural Access (Agri-Access) Network. The purpose of the study was to provide information for responsible decision making and improve roadway service and access for rural communities and related agricultural commercial activities. This concept was an extension of another important initiative that involved the development of a Priority Commercial Network (PCN) composed of the major commercial routes in the state.

The objectives of the pilot study were to

- Identify the essential roadways that provide access between rural agricultural areas and the PCN,
- Identify key transportation obstructions that inhibit movement of farm and forestry products to market and supplies to the farm, and
- Evaluate the effectiveness of the process used in the pilot study before applying the concept statewide.

In this paper the approach used in the development of the Agri-Access Network is described and the results of the analysis conducted in the two demonstration counties are summarized.

BACKGROUND

Agriculture is an extremely important segment of Pennsylvania's overall economy. There are 61,000 farms that market nearly $3 billion worth of crops and livestock annually. There are also numerous related activities comprising the agribusiness industry that employ supermarket clerks and trucking, processing, and production personnel. One of five jobs in Pennsylvania is in agriculture or agribusiness. Farming operations also indirectly contribute to the economy through large purchases of petroleum products, machinery, equipment, materials, and services.

The transportation system has significant impacts on agriculture and rural communities. An adequate system of rural roads and bridges is important for farming and forestry operations and for overall rural economic development. The many agribusinesses and rural communities of Pennsylvania are geographically dispersed, have varying transportation requirements, and often have fewer transportation alternatives than do sectors located in the urban and suburban areas.

Providing an effective system of rural roads and bridges that meet the various needs of residents and businesses has become a difficult challenge for state and local governments. Many of Pennsylvania's rural roads and bridges were first constructed when farm and forestry products moved to nearby markets in small quantities on small lightweight vehicles. Today both commodities and farm supplies travel greater distances in larger trucks that carry loads at or near the maximum legal limit of 80,000 lb. Pennsylvania, with approximately 56,000 bridges, has more than 4,000 structures that are restricted to loads of 20 tons or less and many other bridges that are obsolete for modern travel. These obstructions cause trip diversions that translate into higher operating costs and eventually higher costs paid by consumers.

The identification of an Agri-Access Network is a follow-up to another recent planning initiative of PennDOT involving the improvement of commercial transportation and the promotion of economic development. In 1982 planning personnel worked with local and regional planning agencies to identify a Priority Commercial Network (PCN). This network is mainly composed of Interstate routes, primary traffic routes, and key coal-haul routes that handle heavy volumes of truck traffic and serve as the economic backbone of the state. The PCN has been important for setting priorities of projects that will yield the greatest returns to Pennsylvania's economy. It has been particularly instrumental in the passage of a $1.4 billion bridge bill to address the state's serious bridge problem. This program will address a variety of bridge deficiencies and, in particular, will eliminate all bridge obstructions to commercial traffic on the PCN, ultimately saving millions of dollars annually in trucking costs associated with detours.

Although the PCN provided valuable information on the heaviest truck routes, many roads serving the rural areas and the agricultural industry were not included. For this reason, a pilot study was conducted to identify those highways providing access between the PCN and the rural agricultural areas. This study provided information on which roads are most important to rural farming areas and on which obstructions are creating the greatest hardships for the movement of agricultural products and supplies.

APPROACH

The approach used in the pilot study had two principal characteristics:

- The study used existing data bases and information sources and thereby eliminated the need for extensive new data collection.
- The study relied on input from representatives at the local level for the identification and refinement of the network.

Data Base and Information Sources

Several PennDOT computer data bases facilitated network evaluation and data retrieval:

- The Pennsylvania Roadway Information System (PARIS) provided information on roadway characteristics and use that was helpful in analyzing and evaluating initial network findings. Data extracted from PARIS included average daily traffic (ADT), truck percentages, functional class, and federal-aid classifications.
- The Structure Inventory and Record System (SIRS), an inventory of state and local bridges, was used to identify structurally deficient, functionally obsolete, and weight-restricted bridges on the Agri-Access Network.
- The Project Management System (PMS) was accessed to categorize deficiencies according to their program status.

Other sources of agricultural and economic information were used in the analysis of the pilot counties and in the development of criteria to assist in future statewide application of the study process. These included

- Pennsylvania Crop and Livestock Summary,
- 1977 Economic Census, and
- The Structure and Characteristics of Bulk Milk Pickup Routes in Pennsylvania, 1982.

Coordination and Local Participation

The pilot study was guided at the state level by the Agricultural Transportation Task Force consisting of representatives of federal, state, and local government and farm organizations. The task force was structured as a steering committee and a work group. The steering committee provided direction and advice throughout the study. The work group assured the timely performance of scheduled tasks. Work group participants provided the link between state officials and local leaders of their respective organizations.

Local participation was very prominent at several points of the study. In the initial meetings at the county level, county extension agents provided valuable knowledge of the agricultural economy and the location of generators of heavy agricultural loads. Meetings with key representatives of farm organizations yielded the preliminary network identification and information on how the transportation system affects particular operations. During the refinement task, all involved groups reviewed the initial findings and made recommendations for revisions and priorities.

Methodology

The work program for the pilot study was composed of several tasks, each yielding specific products. Although most tasks were related to the identification of an Agri-Access Network and obstructions on that network, certain tasks were directed to the development of information to aid in the formation and application of a statewide study. A description of the methodology is divided into three general phases:

- Preliminary identification,
- Data analysis and evaluation, and
- Refinement and review.

Preliminary Identification

The first phase of the study was accomplished through field visits and interviews with county extension agents and key representatives of farm organizations. The main objectives were to identify where the major agricultural activities are taking place and to identify a preliminary Agri-Access Network. Maps, showing the previously identified PCN, provided the basis for identification. This eliminated the need for duplicate identification of these major commercial routes.

Within each county the major areas of farming activity, the main points for delivery of agricultural products, and the main sources of agricultural supplies were identified. Information concerning the major agricultural products and lumber, and the locations of various activities related to these products, was included. Locations included, but were not limited to, generators of heavy loads such as lumber, milk and poultry processing plants, feed mills, and fertilizer plants. This information was plotted on maps including an indication of where commodities move from one county or state to another. The local participants' knowledge of the agribusiness functions was extensive and provided the sound base needed for further development of the Agri-Access Network.

The next step was the development of a preliminary system of highways deemed most important to carry heavy agricultural loads. These highways provided a network complementary to the PCN. They consisted of those routes providing access to groups of farms and essential agricultural and rural functions. Local representatives readily identified this preliminary Agri-Access Network from their experience. They also noted specific transportation problems related to this network.

Data Analysis and Evaluation

The preliminary network and bridges on the network were identified on PennDOT data bases. This facilitated data retrieval and analysis during the pilot study. It will also provide for future periodic review and development of information for setting program priorities.

Analysis was conducted to identify those agri-access roads most critical to hauling of 40-ton loads. Available average daily traffic (ADT) information and truck classification counts were analyzed to determine which highways carry larger 4- and 5-axle trucks. Information, gathered from local farm representatives in earlier tasks, about the benefits of lower-than-maximum load limits to particular county activities was also important. Bridge engineers were consulted to determine the feasibility and cost-effectiveness of upgrading bridges to less than maximum load limits.

A most important portion of the work program involved the identification of highway obstructions. Weight-restricted bridges, posted and bonded roads, and other obstructions to agricultural truck traffic on the identified agri-access highways were identified and located on maps. The bridge information was extracted from the Structure Inventory and Record System (SIRS). Throughout the study, other data were compiled to be used in assigning priority to the obstructions and deficiencies that were identified. This included such items as (a) county production figures and economic information, (b) approximate number of farmers dependent on a particular deficient bridge or route, and (c) increase in distance or time or both due to detour.

The evaluation of the preliminary Agri-Access Network involved examining the characteristics of the highways, especially those characteristics related to function and use. This facilitated the establishment of criteria to provide a basis for the evaluation of agri-access roads in other counties of the state. Several sources of information were examined:

- Sample truck classification counts were taken to determine the existing level of truck traffic on the identified roads in the pilot counties. These counts separated traffic by vehicle type and number of axles. This information was combined with existing traffic count information from PennDOT files and data bases to determine truck traffic levels on the preliminary network.
- The functional classification of the identified network roads was examined to determine the type of use made of these highways. Comparisons were made between the two demonstration counties. These were also compared to similar findings for the PCN to determine similarities and differences.
- County economic information was examined to develop comparisons according to agricultural dependence. The total economic activity sales for each county were extracted from census information. This total was compared with the total agricultural activity sales to determine each county's economic dependence on agriculture.

Refinement and Review

The objective of this task was to refine initial findings from local knowledge. Farm organizations, the county extension service, regional agricultural representatives, township representatives, local transportation officials, and county planning agencies participated in this task. Participating organizations were provided maps of the preliminary network and associated listings of the identified obstructions. Project descriptions and the status of projects programmed to eliminate the obstruction were included.

Each organization was asked to verify information, make suggestions for revisions, and note additional problems related to the movements of agricultural products and supplies. Local officials were also requested to include problems related to the movement of emergency vehicles and loaded school buses. The collection and compilation of the refinement products were facilitated by the county extension offices. Throughout this task, all organizations had ample opportunity for equal review.

At the conclusion of this local review period, recommendations were incorporated into the network and listings of obstructions. The final products were presented to and approved by the Agricultural Transportation Task Force. This final product was agreeable to all participating organizations.

DEMONSTRATION COUNTIES

Lancaster and Tioga were the two Pennsylvania counties chosen for this pilot study. Both areas are highly agricultural, but they also have other differing characteristics that were thought to be representative of conditions in other sections of the state. A comparison of several county facts is presented in Table 1. There are significant variations between these counties in the levels of population, road mileage, and agricultural production. The land use patterns are also quite different, which is primarily a result of the topography of the land.

Lancaster County

Lancaster County is unique because it is the leading agricultural producing county in the state and also contains one of the major urban areas. The county is located along the southern border of Pennsylvania east of the Susquehanna River. Many of the commodities produced in Lancaster County are transported to the city of Philadelphia located only 60 miles to the east.

Fertile soil and gentle terrain have made Lancaster County one of the richest farming areas of the nation. This county is the leading producer of

TABLE 1 Data on Demonstration Counties

	Lancaster	Tioga
Total population	362,346; 7th in state	40,973; 50th in state
Rural population	164,580 or 45% of total county population	33,846 or 83% of total county population
Total land area (miles^2)	946.1	1,146.0
Forest land	153.3 (16.2%)	728.9 (63.6%)
Crop land	584.7 (61.8%)	187.9 (16.4%)
Pasture land	32.2 (3.4%)	116.9 (10.2%)
Other	175.9 (18.6%)	112.3 (9.8%)
Largest cities and boroughs	Lancaster (city, pop. 54,725)	Wellsboro (boro., pop. 3,805)
	Columbia (boro., pop. 10,466)	Mansfield (boro., pop. 3,322)
	Elizabethtown (boro., pop. 8,223)	Elkland (boro., pop. 1,974)
	3,588.1	1,763.4
Total roadway (miles)	1,318.7	769.0
State system	2,269.4	994.4
Local system	1,008	601
Bridges (total)	754	488
State system	254	113
Local system	5,330 (1st in state)	1,060 (12th in state)
No. of farms		
Agricultural production		
Primary activity/Rank	Cattle, calves, milk, and crops (wheat, corn, alfalfa, hay, tobacco)/1st	Milk, sheep, lambs/6th, hay/4th
Value/Rank in value of agricultural products	$435,580,000/1st	$47,937,000/12th

agricultural products in Pennsylvania. Lancaster County's agricultural products are valued at over $400 million annually. Much of this value reflects extensive livestock activities involving dairy, poultry, and meat animals. The county is a leading producer of several crops including wheat, corn, alfalfa, hay, and tobacco. Despite its high production levels, the county's output is unable to meet the feed requirement of all livestock. Tobacco is grown primarily in the eastern portion of the county. Poultry operations are generally located in the northern half of the county, and dairy farming is prominent in the southern half.

Heavy truck tonnages are customarily associated with the hauling of such commodities as milk, feed, the products of poultry processors (broilers and eggs), and fertilizer. Although there are some dairies located in the county, most of the milk produced there is trucked from the farm to the Philadelphia region. Most of the milk is transported in large tractor-trailer tank trucks. Milk pickups and feed deliveries are the activities most associated with the heavy daily truck trips. The trucking of fertilizer from plant to farm is a seasonal activity, mainly occurring in the spring and fall.

The city of Lancaster, located in the center of the county, is the hub of economic activity. Many of the industries located in and around the city are related to agribusiness. The majority of generators of heavy tonnages to and from the farm are located along main arterial routes included in the PCN.

Tioga County

Tioga County is typical of many of the rural northern counties of Pennsylvania. This region is mountainous and sparsely populated. Tioga is located along the border of New York State and has the second largest land area of any county in Pennsylvania.

Because the county has no major urban centers, much of the economic activity is related to farming. Largely because of the county's mountainous terrain, dairy farming is the principal agricultural activity. Milk production ranks sixth in the state. Of $53 million in total 1981 agricultural cash receipts in Tioga, $49 million resulted from livestock products--primarily milk.

The majority of the milk produced in Tioga County is trucked to New York State. Heavy truck tonnages of milk hauling are in the form of 10-wheel tankers holding approximately 30,000 pounds of milk. The use of larger milk tankers could provide cheaper and more efficient service to the dairy farmer. The terrain and the current posted bridge situation prevent the use of these larger vehicles in this county. This is a concern in Tioga County because the dairy farmer is responsible for transportation costs.

More than 63 percent of Tioga's land area is forested. There is little access to the southwestern quadrant of the county, which is primarily mountainous. The lumber industry produces heavy loads in excess of 75,000 pounds. The timbering activities are scattered and constantly changing locations. Sawmills are located near US-6 and other main PCN routes.

A major problem associated with Tioga County is lack of alternate routes. Tioga has 21 percent more land area than Lancaster County but only one-half the mileage of highways. This is because of the differences in terrain and population. For this reason, detours associated with posted bridges are generally longer.

RESULTS

Network

The Agri-Access Network was identified in both Lancaster and Tioga counties. The mileage totals are

	Lancaster	Tioga
Preliminary network		
State owned	227.7	245.6
Locally owned	37.0	
Refinement additions		
State owned	11.6	16.3
Locally owned	13.5	
Final network	289.8	261.9
PCN	376.9	155.1

The network mileage comparisons between the two counties indicate both similarities and differences. The Agri-Access Network in Lancaster includes 50.5 highway miles that are owned by townships; the network in Tioga includes only state-owned mileage. The Agri-Access Network consists of similar mileage totals in the two counties. Although the PCN mileage in Lancaster is more than twice that in Tioga, a summation of both networks indicates that these networks comprise 51 percent of all state-owned roads in Lancaster and 54 percent in Tioga.

The Agri-Access Network, as defined during this pilot study, will not necessarily remain constant. As is done with the PCN, the Agri-Access Network definition and constraints will be reviewed and revised at timely intervals. Revisions in the network may result from changes in the size and number of farms or in the type and size of farm equipment. The establishment or relocation of agricultural truck generators may affect the importance of adjacent highways. Continuing rail line abandonments may also place an additional burden on other rural roads and bridges not previously identified.

Obstructions

Bridge restrictions were found to be the most significant restrictions to the movement of agricultural products. The following table gives the status of the bridges on the Agri-Access Network.

	Lancaster	Tioga
Total bridges	124	189
Structurally deficient	31	52
Functionally obsolete	26	24
Posted	18	16
Programmed for repair		
Bridge bill	6	8
Twelve-year program	4	1
Maintenance program	5	5

There are 133 agri-access bridges that are classified as structurally deficient or functionally obsolete. A total of 52 of these deficient bridges were identified during this study. These bridges are currently weight restricted, critically need repair to avoid posting, or were identified by reviewing agencies as obsolete for current travel demands.

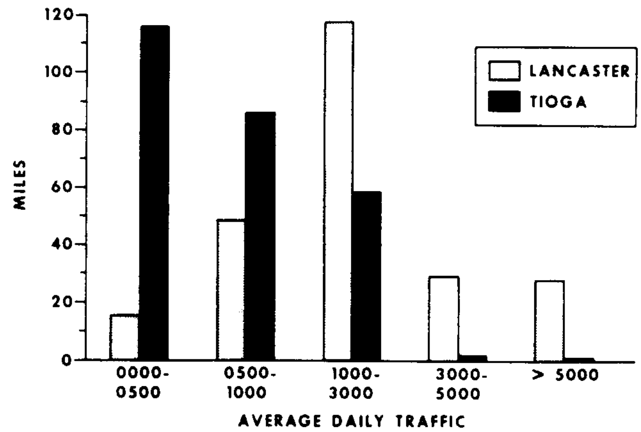
A total of 29 bridges on the Agri-Access Network are programmed for replacement or rehabilitation. Improvements are identified under one of three programs: bridge bill, twelve-year program, or maintenance program. The bridge bill projects are capital improvement projects contained in the $1.4 billion bridge bill and will be under way within the next 6 years. The twelve-year program projects are capital improvements recommended for the 6 years beyond the bridge bill. Maintenance projects are smaller cost improvements that are completed with county maintenance appropriations.

There were other obstructions noted during the refinement stage of the pilot study. These generally involved maintenance level problems related to roadway conditions or problems inhibiting the use of large farm equipment. A particular problem noted in Tioga County involved coal hauling on several routes in the northeastern quadrant of the county. Each year after surface treatment is applied to the routes, heavy coal trucks use the roads, which results in rapid deterioration of the roadways. These routes provide better access for marketing of products than the alternate route, Traffic Route 549. Using this alternate route involves traversing a long steep grade that is difficult for truck travel.

Network Evaluation

The Agri-Access Network for the two counties was evaluated and compared. The findings can be used to generalize the type of highways that were identified during the study and to provide criteria for eventual application of the pilot study principle to other counties of the state. The travel levels and functional classification of the network highways were the main characteristics examined.

A comparison of travel levels indicates considerable variance between the two counties. Figure 1 shows a summary of mileage by average daily traffic (ADT) range. The majority of network highways in



ADT RANGE		LANCASTER	TIOGA
0000-0500	=	15.403 MILES	115.740 MILES
0500-1000	=	49.605 MILES	86.434 MILES
1000-3000	=	118.838 MILES	58.526 MILES
3000-5000	=	28.062 MILES	.737 MILES
5000 & GREATER	=	27.367 MILES	.485 MILES
TOTAL	=	239.275 STATE-OWNED MILES	261.922 STATE-OWNED MILES

FIGURE 1 Mileage by ADT range.

Lancaster has traffic levels above 1,000 ADT. In Tioga, 77 percent of the network roads carry less than 1,000 ADT, and 44 percent carry under 500 vehicles per day. An analysis of truck traffic levels on the network produces similar results. From sample truck classification counts, an estimate was developed of mileage by average daily truck traffic (ADTT) range. The figures indicate that it is difficult to define equal truck traffic criteria for dissimilar counties such as Lancaster and Tioga. A level of 50 trucks per day is reasonable in Lancaster, but 50 percent of the identified network in Tioga has ADTT below this level. The following is an estimate of mileage by ADTT range.

	Miles	
ADTT	Lancaster	Tioga
25 to 50	22	130
50 to 100	126	78
100 to 300	101	51
Above 300	41	3

A comparison of other highway characteristics of the Agri-Access Network yields greater similarities. The functional classification status of the network is shown in Figure 2. An important finding is that a large majority of roads in both counties are either major or minor collectors. The network in both counties is composed of 76 percent collector roads. The separation of mileage by federal-aid classification

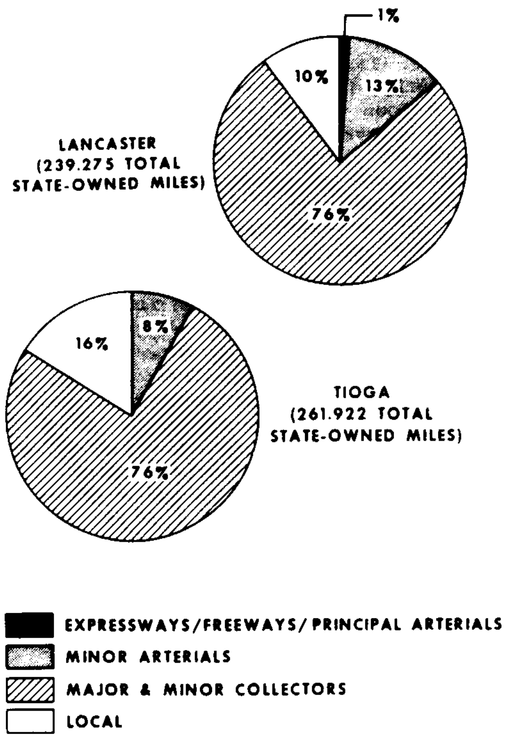


FIGURE 2 Mileage by functional class.

is given in Table 2. The majority of mileage (56.7 percent) in Tioga is not on a federal-aid system. If locally owned mileage is included for Lancaster, 57.1 percent is non-federal-aid.

Figure 3 and Table 3 present the same comparisons for the PCN in the two counties. A large majority of highways on the PCN are arterials. Approximately 98 percent of the PCN is on the federal-aid-system. The PCN serves statewide and regional travel and links cities and boroughs. The Agri-Access Network provides connections between the higher and lower systems, serves smaller communities and intracounty travel, and links local traffic generators.

Network Criteria

After examining alternative methods of determining

TABLE 2 Agri-Access Network Mileage by Federal-Aid System

System	Lancaster	Tioga
Federal-aid primary		
Principal arterials (urban)	2.840	0
Minor arterials (rural)	14,342	21.420
Subtotal	17.182 (7.2%)	21.420 (8.2%)
Federal-aid secondary		
Major collectors (rural)	85.537	92.080
Subtotal	85.537 (35.7%)	92.080 (35.1%)
Federal-aid urban		
Minor arterials	17.946	0
Collectors	3.293	0
Subtotal	21.239 (8.9%)	0
Non-federal-aid		
Minor collectors (rural)	91.827	107.069
Locals (rural)	23.490	41.353
Subtotal	115.317 (48.2%)	148.422 (56.7%)
Total state-owned miles	239.275	261.922

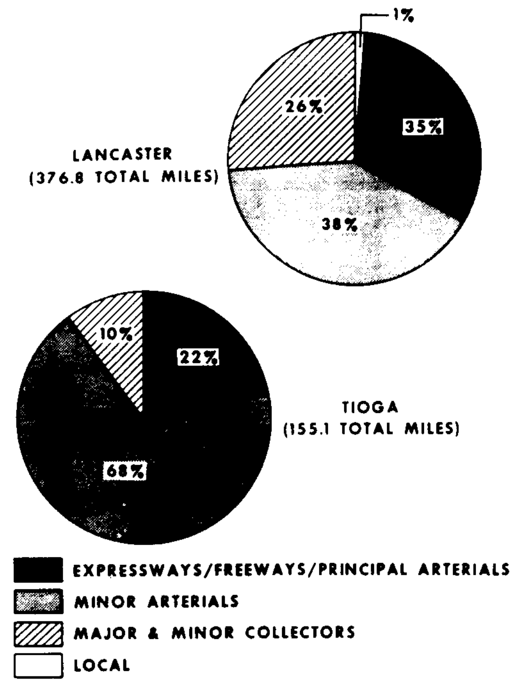


FIGURE 3 PCN mileage by functional class.

TABLE 3 Priority Commercial Network Mileage by Federal-Aid System

System	Lancaster	Tioga
Federal-aid primary		
Freeways and expressways	10.826	0
Principal arterials (urban)	52.328	0
Principal arterials (rural)	66.332	34.414
Minor arterials (rural)	122.424	105.784
Subtotal	251.910 (66.9%)	140.198 (90.4%)
Federal-aid secondary		
Major collectors (rural)	90.620	12.223
Subtotal	90.620 (24.0%)	12.223 (7.9%)
Federal-aid urban		
Principal arterials	3.706	0
Minor arterials	20.873	0
Collectors	0.673	0
Subtotal	25.252 (6.7%)	0
Non-federal-aid		
Minor collectors (rural)	8.246	2.693
Local (rural)	0.864	0
Subtotal	9.110 (2.4%)	2.693 (1.7%)
Total	376.892 (100.0%)	115.114 (100.0%)

truck criteria, three guideline criteria for evaluating agri-access roads were established:

- Functional class of selected roads,
- A 25 to 50 sliding scale of trucks per day, and
- Agricultural activity by county.

The network analysis in Lancaster and Tioga showed a large portion (76 percent) of the network was composed of collector roads. These findings substantiated the basis on which functional criteria could apply statewide.

A sliding scale of 25 to 50 trucks per day was established after analysis of truck traffic levels on the Agri-Access Network. Table 4 gives guidelines for the determination of levels of truck traffic to be expected on the Agri-Access Network in different

TABLE 4 Guidelines for Truck Criteria: County Scale of 25 to 50 Trucks per Day, County Ranking by Agricultural Importance

County	Agricultural Activity (%)	County	Agricultural Activity (%)
25 Trucks/Day			
Fulton	40.0	Wyoming	15.9
Sullivan	32.2	Tioga	15.5
Susquehanna	26.9	Adams	13.0
Juniata	25.6	Wayne	12.6
Potter	22.0	Bradford	11.9
Perry	21.5	Snyder	10.8
50 Trucks/Day			
Union	9.2	Schuylkill	1.8
Bedford	8.4	Jefferson	1.6
Franklin	7.7	Erie	1.6
Huntingdon	7.4	Lycoming	1.4
Lancaster	7.3	Venango	1.3
Mifflin	6.3	Warren	1.2
Armstrong	5.7	Northampton	1.2
Somerset	5.1	Fayette	1.1
Chester	4.8	Dauphin	1.0
Crawford	4.7	Washington	0.9
Lebanon	4.1	Cambria	0.9
Columbia	3.6	Monroe	0.8
Montour	3.5	McKean	0.8
Centre	3.2	Elk	0.8
Clarion	3.0	Westmoreland	0.7
Northumberland	2.8	Carbon	0.7
Indiana	2.8	Bucks	0.7
Berks	2.6	Clearfield	0.6
Mercer	2.5	Lehigh	0.5
Clinton	2.5	Cameron	0.5
Forest	2.2	Lackawanna	0.4
Pike	2.0	Luzerne	0.3
Greene	2.0	Beaver	0.3
Cumberland	2.0	Montgomery	0.2
Butler	2.0	Delaware	0.2
York	1.9	Philadelphia	0.0
Lawrence	1.9	Allegheny	0.0
Blair	1.9		

counties. The criteria for county ranking of agricultural importance were developed based on the percentage of agricultural activity compared to total economic activity sales. The greater a county's dependence on agricultural activities, the lower the level of truck traffic required on identified highways. This concept proved acceptable as long as there remained a degree of flexibility and consideration for the seasonal dimensions of farming activities.

The third criterion to consider is the level of agricultural activity in each county. Future network development in the remainder of the state should take into account relative levels of agricultural activity in counties. The total mileage identified in each county should be in general proportion to that county's agricultural level of agricultural activity.

Critical Heavy-Load Roads

Because of the larger and heavier vehicles used in Lancaster County, preliminary analysis did not identify any bridges beneficial at less than maximum load limits. However, because of conditions peculiar to Tioga County's agricultural community, such as rugged mountain terrain, isolated rural areas, and long detours, six bridges in this county were identified by farm representatives as beneficial if posting limits were raised to 20 tons. Such upgrading would mean the difference between survival and ruin to approximately 15 farms in Tioga.

The feasibility of building or upgrading bridges to less than maximum load limits was investigated with transportation bridge engineers. Their analysis showed that it would not be cost-effective to build or replace bridges for less than 40-ton limits. However, it was determined that, in certain cases, bridges could benefit users if strengthened to raise load limits above very low levels. These repairs will be temporary and future replacement of the bridge will be necessary as funding becomes available.

After conferring with PennDOT bridge engineers, it was decided that future recommendations for less than 40-ton load limits would be determined on a project-by-project basis.

CONCLUSIONS

This pilot study has identified an Agri-Access Network and provided valuable information for decision making in the Pennsylvania Department of Transportation. It has provided vital knowledge of the relative importance of rural roads and bridges to rural economic activities in two counties. The results can be useful in the determination of which improvement projects will provide the greatest economic benefits to rural areas.

Involvement of local representatives at various stages was important to the success of the study. These individuals, who are most affected by obstructions on the highway system, provided direct input concerning the relative importance of particular roads and bridges. The exchange of information between state and local representatives supported the process and resulted in a better local appreciation of state government.

Statewide application of the approach used in the pilot study is expected to require certain flexibility. Travel levels on the Agri-Access Network are expected to vary considerably between different parts of the state. In rural, sparsely populated counties such as Tioga, the relative importance of agricultural activities must guide the development of the network. Certain criteria have been established as a basis for future network identification. Application of these principles in a responsible manner can yield reliable and defensible information.