The Investment Analysis Approach to Estimating Highway Needs

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● TIME and effort spent by highway departments on highway needs studies over the past few years have paid dividends. The magnitude of the highway problem, locally and nationally, has been brought into proper perspective. The engineer's knowledge of geometric and structural needs has been translated into understandable dollars and cents terms that have become accepted by the general public.

The so-called "engineering approach" is the usual means of estimating costs to improve road systems to a state of adequacy. In this approach, data on traffic, condition, deficiencies, and service characteristics are compiled for each individual road section. Engineering field checks and inspections are then made, needs determined, and costs of improvement estimated and identified either as an immediate need or as a future need within the next 5, 10, 15, or 20 years.

Under such an approach most of the needed improvements on existing roads fall in the category of "needed now." Successively lesser amounts show up as being needed each year thereafter. Since any actual improvement program to meet such a needs schedule would not be practical, it is the usual practice to take the results of the engineering approach and rework them in the office so as to produce a realistic program, say for 10 years. This 10-year "catch-up" program would then include all the measured needs within the first 10 years *plus* an allowance for stop gaps and replacements. Stop gaps represent construction necessary to keep roads in operation until the final improvement can be made. Replacements represent work (principally resurfacing) necessary in the last part of the 10-year period on roads built in the first part of the 10-year period. Some allowance must also be made for those improvements which are "needed now" but which are deferred to the fifth or sixth year of the 10-year catch-up program. When eventually built, the volume of traffic for which they will be designed will be somewhat higher. This could result in an increase in the original cost estimate.

The 10-year catch-up program represents only one condition. For purposes of financial planning, costs of 12-year, 15-year, 20-year, and other catch-up programs must also be repared and studied. Additionally, it is desirable to develop future costs for the years following the catch-up period so as to enable long-range credit financing proposals to be worked out. In these particular cases money is borrowed during the catch-up period and repaid afterwards. Obviously a sound financing plan must take into account not only the debt repayment but also the construction and replacement needs in the years following the catch-up period.

In summary, the outstanding advantage of the engineering approach, especially for the principal road systems, is that it produces a clear-cut, supportable cost estimate based upon study of the physical needs of individual road sections. Substantial amounts of time and effort are, however, required in making these estimates in the first instance. And although progress is being made in streamlining the engineering approach, there is, at present, no quick and easy means of rearranging, recasting, and spreading out basic needs study data so as to provide long range, year-by-year, cost estimates for the many program alternatives that crop up in planning a financial program.

The so-called "investment analysis approach" offers considerable promise in this respect. This approach can be used in those states and on those road systems where the road-life study is up to date. It is based upon the premise that under a condition of sustained traffic increase over a period of several years, there should be a corresponding increase in the investment (cost-new less depreciation) in the highway plant. In other words, if traffic were to increase 40 percent over the next 10 years there would need to be a corresponding increase of about 40 percent in the investment in highways over these same 10 years. Of course, today's highways are not adequate. Hence, unless this backlog of existing deficiencies is also overcome, the 40 percent increase in investment over a 10-year period would not result in adequate highways. It would simply continue to keep the highways at the same relative position with respect to meeting traffic needs at the end of 10 years as they are today.

An illustration may clarify this point. Three years ago the results of a nationwide study of capital investment in highways were reported at the Annual Meeting of the Highway Research Board (*1*). Figure 1 is taken from this report. It shows three lines, all based on January 1, 1953 price levels. The top line shows the accumulated capital outlays made for all highways, roads, and streets in the United States up to January 1, 1953. The middle line shows the amounts remaining in service after making deductions for construction work that has been retired and is no longer in existence. It represents the original cost-new of all highways, roads, and streets still remaining in service. But all of these highways, roads, and streets are not brand new. They have aged and a portion of their original service life has been used up. In other words they have depreciated. The depreciated amounts are represented by the bottom line.

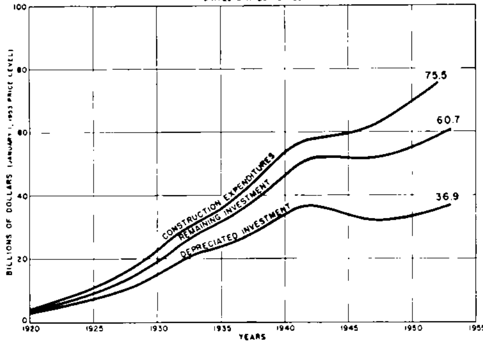

Figure 1. Accumulated construction expenditures, remaining investment and depreciated investment.

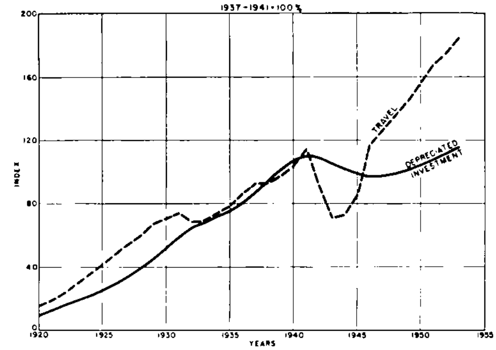

Figure 2. Trend in travel and depreciated investment: United States totals.

It may be well at this point to note that the basis for computing this chart was the yearly outlays for construction. The accumulation of these construction amounts is the top line. With this top line as a starting point the road life study data and analysis procedures make it possible to compute the bottom line—depreciated investment. Conversely, if the starting point had been the bottom line—if all that was known was the trend in depreciated investment—it would be possible to reverse the computations to find out what the construction amounts are. This will be called the "reverse computation" when this process is mentioned later.

In summary, Figure 1 shows that up to January 1, 1953, (1) $75.5 billion had been spent for construction of all highways, roads and streets in the United States; (2) $60.7 billion was the amount, cost-new, still in service; and (3) this total, when depreciated for service already consumed, amounted to $36.9 billion. It is the bottom line, depreciated investment, that is primarily involved in the investment analysis approach. It is this trend that should correspond to the traffic trend.

The solid line on Figure 2 shows the trend in depreciated investment referenced to the years 1937 to 1941 as a base of 100 percent. This trend corresponds to the one for depreciated investment (bottom line of Figure 1) except that it includes certain minor adjustments due to price index revisions that were later considered desirable.

The years 1937 to 1941 have been selected as a base of reference because they represent one of the most favorable periods in the development of highways. True, there were many highway needs during this period. But on the average it is a period during which highways reached their highest level of development in relation to the traffic demands imposed upon them. Prior to this period there was a sustained increase in the level of development. Subsequent to this period and after the war years, the traffic growth far outstripped growth of the highway plant.

This can be readily seen by inspection of the traffic trend which is plotted as a dashed line on Figure 2. There is a similarity in the two trends up to 1941. The traffic then fell off until 1944, made a rapid recovery, and since 1946 has been increasing steadily. The trend in depreciated investment likewise dipped during the war. This was due to the fact that highways continued to depreciate during a period when capital outlay was drastically curtailed. After the war a slow recovery began—much slower than the traffic trend. Inspection of Figure 2 shows just how slow it was. In fact it took seven years of postwar construction for the depreciated investment to overcome the wartime dip and recover to the level it was back in 1941.

The similarity of the two trends in the prewar years is sufficient to raise a question as to whether such similarity might not have continued in the postwar years under an adequate highway program. Certain rough computations made during 1953 seemed to support this hypothesis. Assuming that the hypothesis is correct, it would follow that if traffic could be predicted into the future, then the level of needed highway investment could likewise be predicted. Then, by knowing (1) the existing level of investment and (2) the future level of needed investment, it would be a simple matter to compute the annual capital outlays necessary to raise the depreciated investment from one level to the next. This would be done by the "reverse computation" process previously mentioned. It would give the construction needs.

An opportunity presented itself to test this theory early in 1954. At that time a highway needs study using the engineering approach was being made in West Virginia, the results of which would not be available until midyear. In the meantime, studies have been made in West Virginia of probable future travel trends. Also available were the results of the salvage value and investment analysis made as part of the road life study on the primary rural State highway system of West Virginia and covering all construction and retirements up to 1954.

With this as a starting point, an analysis of the investment in the system was made which produced a series of values for the depreciated investment in terms of constant 1953 dollars for each year up to January 1, 1954. The resulting trend was then referenced to a base of 1937 to 1941 (= 100 percent) and compared with the travel trend and its future extension. These two trend lines are shown on Figure 3. There is a wide gap between the two trends in 1954. The next step was to test the theory that the trend in needed investment should basically be the same as the travel trend. To do this simply involved the assumption that for a 10-year program, for example, the trend in depreciated investment would catch up to the travel trend in 10 years (to point *A* by 1964). If a 20-year program was assumed, it would catch up in 20 years (to point *B* by 1974); and so on for any selected catch-up period. Once the trend in depreciated investment catches up to the travel trend, it is assumed that adequacy will be sustained thereafter. This means the investment trend then becomes identical to the travel trend.

Next, computations were made of the construction amounts necessary to raise the level of investment up to the travel trend to points *A*, *B*, and other selected catch-up program periods. This was done by the "reverse computation" process. To do this required certain assumptions as to the investment lives of recent and future construction of various roadway elements—grading; low, intermediate, and high type surfacing; and structures. The decision as to the proper service lives to use in these cases is the most critical part of the analysis. However, it is probably no more

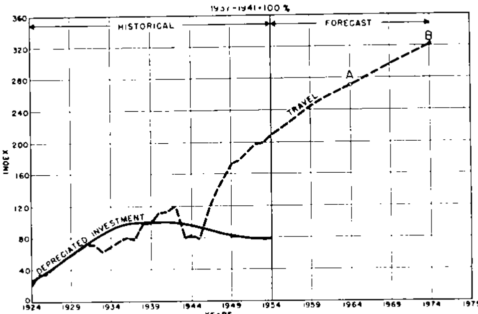

Figure 3. Trend in travel and depreciated investment: West Virginia.

critical than certain decisions that must be made when evaluating needs on a project by project basis in the engineering approach. Such estimates of service lives, of course, can be reasonably approximated from a study of the past trends. Allowances must also be made for the increases in service lives that will result when roads are rebuilt to the structural and geometric design standards called for in the needs studies. It is quite possible for example, that the service life of future surfacing would be increased by as much as 25 percent over the present average. For grading on the highest type roads, future service lives may be as much as 75 to 100 percent greater.

The cost estimates developed from the engineering approach in West Virginia became available in mid-1954. These were then compared with the earlier estimates of the construction needs computed in reverse by the investment analysis approach previously described. The agreement between the two estimates seemed to bear out the reasonableness of the latter approach. The following is quoted from the 1954 report "A Factual Study of Highway Needs in West Virginia":

> "A completely separate statistical analysis of capital investment, excluding right-of-way, in the rural State primary system was prepared as part of this study . . .
>
> Adjusted to 1953 price levels and reduced 10 percent to represent the proposed rural State Trunkline System, the analysis shows that:
>
> —$38 million annually would be required for construction alone to meet traffic needs in 20 years. That compares with $35 million per year derived from the field studies . . .
>
> —A 15-year program, for construction only, would require $47 million annually, compared to $45 million determined by field studies . . .
>
> ". . . The field study results are less than, but similar to, the investment analysis, although developed on a wholly different basis. The similarity gives assurance that both methods are adequate . . ."

Subsequently, similar analyses were made for the rural primary highway systems of Missouri and Washington. In each case reasonable approximations of total needs were obtained. Additional studies are now being made for other States where road life studies are sufficiently far advanced.

Research on the investment analysis approach is still in its initial stages. There is, however, one general finding that warrants mention. It has been found that over a 30-year period, the total capital outlay needed to build an adequate highway system and thereafter keep it adequate is about the same regardless of the time taken for the initial catch-up program.

This is shown on Figure 4 for 10, 20, and 30-year catch-up programs. Data used are averages for the rural primary systems of Missouri, Washington, and West Virginia. The height of the bars represents the total construction costs over a 30-year period. The total costs are about the same in all three cases, the principal differences being in the relative amounts needed in the first and second decades of each catch-up program. In other words, the first bar shows that for a 10-year catch-up program, there would be a heavy expenditure in the first decade while catching up to adequacy. Thereafter, in the second and third decades the cost to sustain adequacy would be somewhat less. For the 30-year catch-up program, on the other hand, the costs would be the least in the first 10 years and successively greater in the next two decades. Total costs over 30 years would be about the same in each instance. But in one case the road system would become adequate in 10 years and thereafter be kept adequate. In the other case the road system would not become adequate until 30 years have passed.

Perhaps the most attractive feature of the investment analysis approach to estimating highway needs is the ability to process the data in various ways. For example, in the study of alternative financing plans, it is desirable to have a year-by-year array of construction needs during various catch-up periods, say 10, 12, 15, and 20 years. It is also desirable to have a year-by-year array of future needs for 10, 20, or even 30 years after the shorter catch-up periods. Similarly, it may be desirable to know at what rate the highway needs will be overcome under various financing proposals.

The investment analysis approach can provide such data readily. Its outstanding advantages are the speed with which needs estimates can be prepared, the small amount of man-power required, and its extreme flexibility in arraying needs data in various ways. But there are also disadvantages in that it treats road systems as lump sums rather than by individual road sections.

Possibly the best circumstances exist in

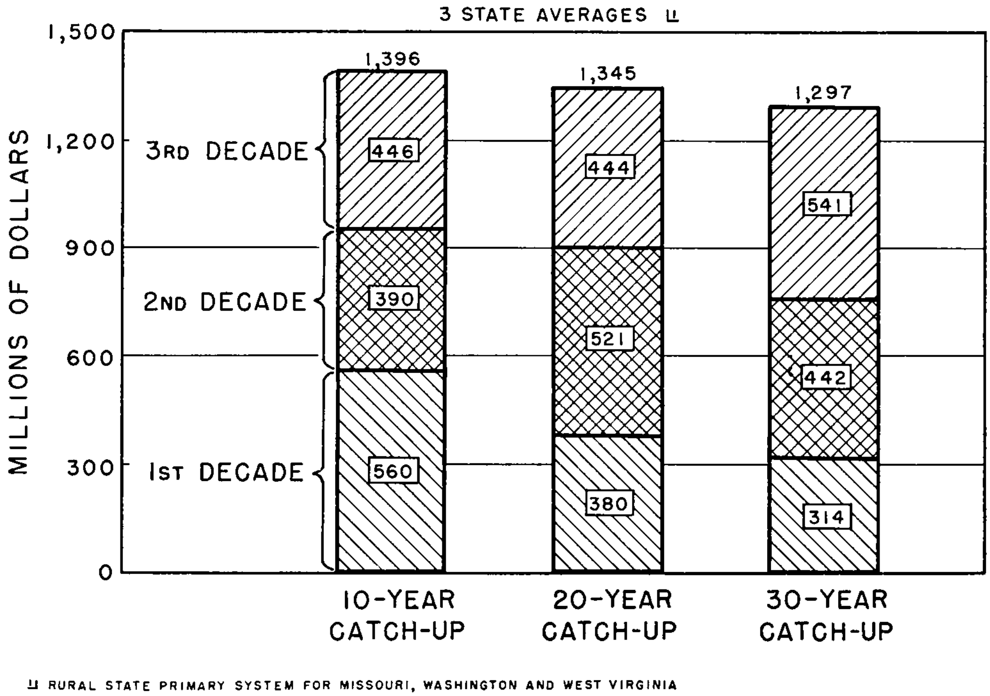

Figure 4. Construction needs for 10, 20, and 30-year catch-up programs.

those cases where a State has *both* the results of an engineering study of needs and an up-to-date road life study. In such instances, the investment study can be used as a means of introducing flexibility into the engineering results. As a case in point, a given state may have a well developed engineering study which provides an estimate of the cost of bringing each road section up to adequacy within 10 years. With such information as a base, the investment analysis approach can then be used to adjust the needs study findings to show costs of 12-year, 15-year, 20-year, or any other catch-up period and to extend the needs into future years beyond the catch-up period.

Further, there are cases where a needs estimate has been prepared upon certain assumptions as to future traffic growth. If these assumptions were to be changed for one reason or another, it would obviously affect the needs estimate. The making of such revisions could pose considerable difficulties in the engineering approach. Under the investment analysis approach a revised estimate could be prepared quickly.

Additional investment studies and further refinement of the analysis processes are desirable before specific relationships and findings can be presented which will adequately reflect the widely varying conditions encountered in the various States. The concept and technique of analysis are, however, quite simple. Preliminary results attest to the reasonableness of the investment analysis approach. They give indication that this product of the road life study can be effectively used in estimating highway needs for various conditions of future traffic and in arraying such needs on a year-by-year basis for financial planning purposes. The attractiveness of the investment analysis approach becomes doubly apparent in States where the road life study is up to date. In such cases, the staff and time requirements for the analysis are only a fraction of those needed for the engineering approach.

REFERENCE

1. Farrell, F. B., and Paterick, H. R., "The Capital Investment in Highways, 1914 to 1952," Proceedings of the 32nd Annual Meeting of the Highway Research Board, January, 1953.

Financial Planning for an Expanded Highway Program

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Of the nationwide estimate of $101 billion in immediate highway needs, $45 billion were found on the federal-aid systems below the level of the interstate; and $33 billion on roads and streets not eligible for federal aid. Engineering plans to meet these needs must be matched by equally adequate financial plans. A successful financial plan should (1) provide for completion of the accelerated highway improvement program within the desired number of years; (2) take care of maintenance, administration, and other regular commitments of the highway department; (3) meet interest and principal charges on the debt, if any, incurred in financing the program; and (4) provide sufficient additional revenues to meet the gradually increasing needs for the replacement and expansion in the years following completion of the program.

A technique for the examination of alternate financial plans, familiarly known as the "cut-and-fill" method, was applied to the needs of the federal-aid systems (other than interstate) as they might be found to exist in an average state. The indications are that substantial increases in the rates of state taxes for highways must be brought about if these systems are to be improved to adequacy within a reasonable number of years. Financing with current revenues only would require drastic tax increases during the period of the accelerated program, with the prospect of a considerable reduction after its close. By resort to bond issues such a program may be financed by a relatively moderate increase of tax rates extending over the entire period of the bond issue. Although the problem will be found different in each state and the decisions made will be governed by prevailing fiscal policy, the procedures for critical study of different financing proposals are applicable in all cases.

● RECENT studies of highway needs have supplied us with the figure of $101 billion as the investment necessary for an adequate road and street plant. Not unnaturally the spotlight has been thrown upon the federal aspects of the problem, and especially upon the financial requirements of the National System of Interstate Highways. It is the purpose of this paper to examine the needs of the highway systems below the interstate level, in an effort to gauge the nature and magnitude of the financing problem as it would confront the average state.

NEEDS OF THE SEVERAL ROAD AND STREET SYSTEMS

In Figure 1 we have a perspective on the nationwide highway problem as the estimates were worked out in the study of 1954. Highway systems are grouped into three classes—the interstate system, other highways eligible for federal aid, and non-federal-aid highways, chiefly county and local roads and streets. Of the $101 billion ($100 billion in the continental United States) in estimated 10-year needs, the interstate system, as it was constituted in 1954, claims slightly less than a quarter. The recent addition of 2,300 miles in urban areas will probably raise the $23 billion estimate by $4 or $5 billion, part of which will be a net addition to the grand total. The needs of other federal-aid highways total nearly $45 billion—not far from half; and those of non-federal-aid roads and streets, $33 billion, or about one-third.

A facet of the problem that has perhaps re-

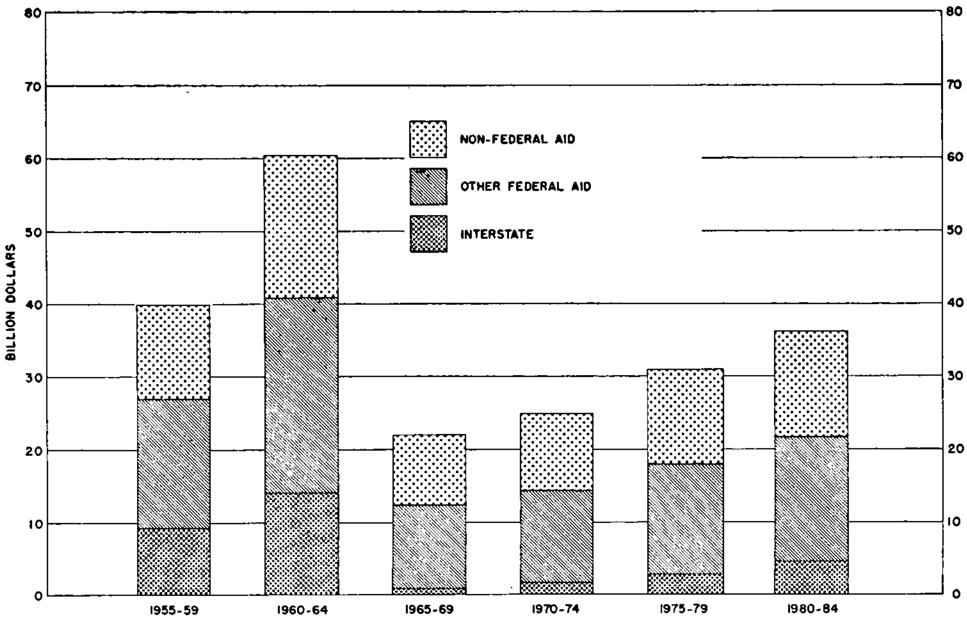

Figure 1. A summary of highway needs, 1955–1984.

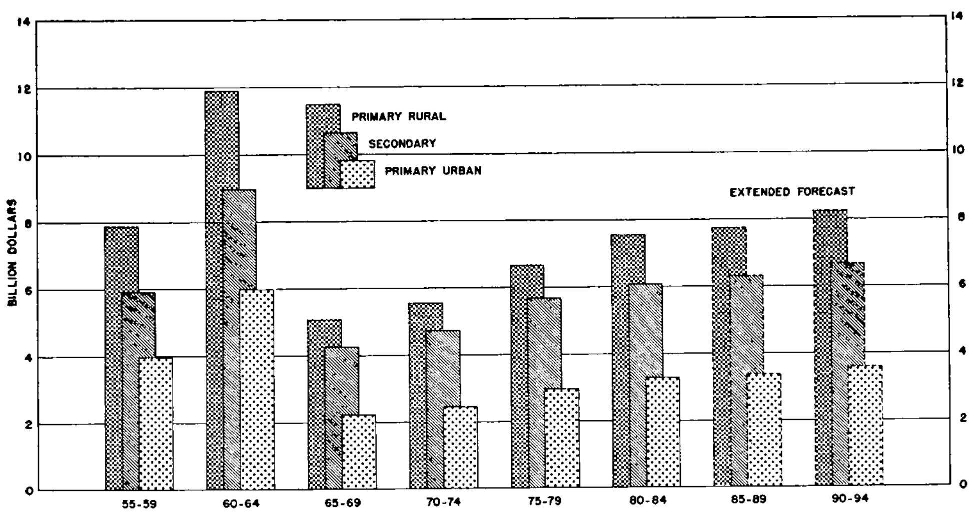

Figure 2. Needs of the federal-aid systems other than interstate, 1955–1984, with extended forecast to 1994.

ceived too little attention is that of the requirements for replacement and for increased highway capacity after the completion of the catch-up program of accelerated highway construction. Roads—even the best of them—neither endure nor remain adequate forever. Figure 1 shows by 5-year intervals the accrual of construction needs during the 20 years following the close of the projected 10-year improvement effort. Summation of the 5-year totals reveals that $114 billion in replacement and expansion needs will come due during this 20-year period—a total somewhat greater than the needed investment during the initial 10-year effort.

In Figure 2 the needs of federal-aid highways, below the interstate level, are set forth for the primary rural system, for the secondary system and for the federal-aid highways in urban areas. For the 10-year catch-up period the needs of the primary rural system are estimated at slightly less than $20 billion; those of the federal-aid secondary system at about $15 billion; and the claims of the federal-aid urban group are set at nearly $10 billion.

Here, even more than in Figure 1, the accruing needs after the close of the initial investment period compel attention. During the period 1965–84 federal-aid primary rural roads (other than interstate) will require expenditures of $25 billion for replacements and expansion, an amount exceeding the needs of the 10-year accelerated program by 25 percent. The urban routes, requiring as they do relatively large expenditures for the long-lived elements, right-of-way and structures, makes relatively modest demands during the 20-year period; but the secondary system requires $21 billion, nearly 40 percent in excess of the outlay during the 10-year catch-up period.

The two sets of bars at the right of the graph give an indication of the accrual of highway needs in the two 5-year periods between 1985 and 1994. Although the values given do not have high standing as a forecast, it can be said that if normal expectancies with respect to needed replacement and needed additions to capacity come to pass, the highway needs during the fourth decade will be something like those shown in the chart. Long-term predictions such as this are useful in financial planning.

Figure 3 shows the needs-accrual profiles for roads and streets not eligible for federal aid, with a similar projection of the forecast to 1994. Here the ratios of replacement and expansion needs to those of the initial program are relatively rather high. It is clear that on these lower highway systems the demand for a short-term catch-up program is less urgent than on the systems of greater traffic importance; but the need for a sustained effort over the long pull is plainly evident. This is especially true of the rural group, which includes some state highways, but mostly county and local roads. Replacement and expansion needs are very substantial even in the decade following the 10-year accelerated program. The extended forecast hints that needs in the fourth decade will be even greater than those of the first decade, or catch-up period.[1]

[1] A more thorough discussion of the estimated needs of the several road and street systems, as found in the study made pursuant to Section 13 of the Federal-Aid Highway Act of 1954, is given in the report, "Needs of the Highway Systems, 1955–84," House Document No. 120, 84th Congress, 1st Session.

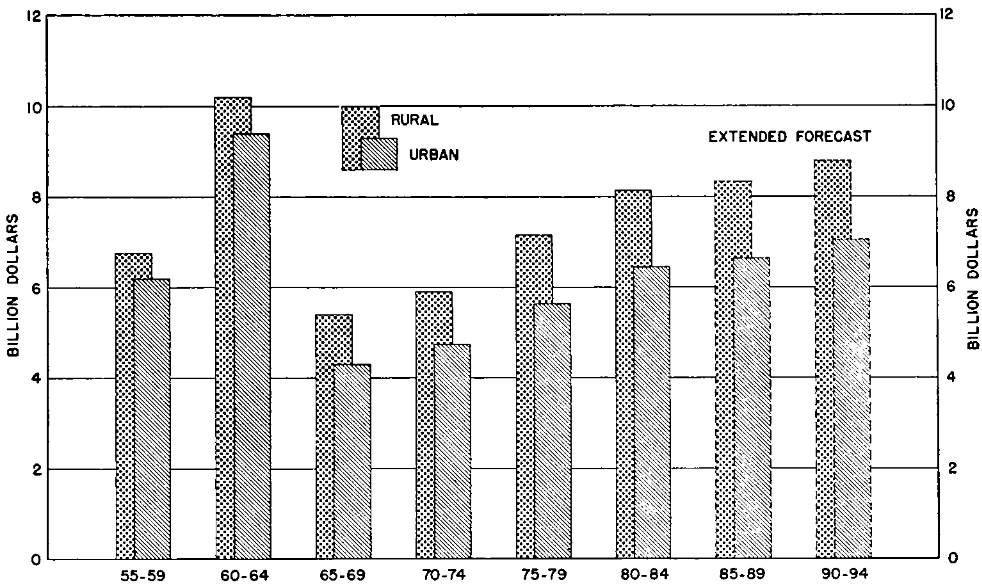

Figure 3. Needs of road and street systems not subject to federal aid, 1955–1984, with extended forecast to 1994.

TABLE 1
ESTIMATED HIGHWAY NEEDS[1], IN $ BILLION OF ALL ROAD AND STREET SYSTEMS IN CONTINENTAL UNITED STATES, BY 5-YEAR INTERVALS, 1955–1994

System	Needs of 10-Year Catch-Up Period			Replacement and Expansion Needs Following 10-Year Catch-Up Period						Grand Total
	1955–1959	1960–1964	10-Year total	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	
Interstate system:										
Rural	5.0	7.5	12.5	0.4	0.9	1.4	2.4	3.4	3.8	24.8
Urban	4.2	6.5	10.7	0.3	0.7	1.3	2.2	2.9	3.1	21.2
Total	9.2	14.0	23.2	0.7	1.6	2.7	4.6	6.3	6.9	46.0
Other federal-aid highways:										
Primary										
Rural	7.9	11.8	19.7	5.1	5.5	6.7	7.6	7.7	8.2	60.5
Urban	3.9	6.0	9.9	2.2	2.5	2.9	3.3	3.4	3.6	27.8
Total	11.8	17.8	29.6	7.3	8.0	9.6	10.9	11.1	11.8	88.3
Secondary:										
On state highway systems	3.9	6.1	10.0	2.5	2.9	3.5	3.7	3.8	4.1	30.5
Not on state highway systems	2.0	2.9	4.9	1.7	1.8	2.2	2.4	2.5	2.6	18.1
Total	5.9	9.0	14.9	4.2	4.7	5.7	6.1	6.3	6.7	48.6
Total other federal-aid	17.7	26.8	44.5	11.5	12.7	15.3	17.0	17.4	18.5	136.9
Total, all federal-aid highways	26.9	40.8	67.7	12.2	14.3	18.0	21.6	23.7	25.4	182.9
Non-federal-aid roads and streets:										
Other state:										
Rural	1.5	2.2	3.7	1.1	1.1	1.4	1.6	1.7	1.7	12.3
Urban	0.7	1.1	1.8	0.4	0.4	0.4	0.5	0.5	0.6	4.6
Total	2.2	3.3	5.5	1.5	1.5	1.8	2.1	2.2	2.3	16.9
County and local rural roads	5.3	7.9	13.2	4.3	4.8	5.8	6.5	6.7	7.1	48.4
Local urban streets	5.5	8.4	13.9	3.9	4.3	5.2	6.0	6.1	6.4	45.8
All non-federal aid:										
Rural	6.8	10.1	16.9	5.4	5.9	7.2	8.1	8.4	8.8	60.7
Urban	6.2	9.5	15.7	4.3	4.7	5.6	6.5	6.6	7.0	50.4
Total	13.0	19.6	32.6	9.7	10.6	12.8	14.6	15.0	15.8	111.1
Grand total, all roads and streets	39.9	60.4	100.3	21.9	24.9	30.8	36.2	38.7	41.2	294.0

[1] The estimates of highway needs presented in this table are also given, in more abbreviated form, in the report "Need of the Highway Systems, 1955–84," House Document No. 120, 89th Congress, 1st Session, with the exception that the forecast of future needs is here extended through the year 1994.

The data shown graphically in Figures 1, 2 and 3 are presented numerically in Table 1.

REQUIREMENTS OF FINANCIAL PLANNING

These several needs profiles have been exhibited in order to underline the long-term character of the highway finance problem. In devising an accelerated program to satisfy immediate needs, no state can afford to neglect the accrual of further capital requirements in the years that follow. The task of financial planning, thus complicated by the necessity to peer into the future, is of equal difficulty and stature with that of engineering planning. An unusual combination of technical proficiencies, combining engineering, economics, and statistics, is needed for this work, both in the research and planning staffs of the highway departments and in the experts who may be called in as investigators or consultants.

A successful financial plan must meet four requisites: *First,* to provide for completion of the accelerated highway improvement program within the desired number of years; *second,* to take care of the expenses of maintenance, operation, administration, service of pre-existing debt, and other regular commitments of the highway department; *third,* to meet interest and principal charges on the debt, if any, incurred in financing the new program; and *fourth,* to provide sufficient additional revenues to meet the gradually increasing needs for replacement and expansion in the years following completion of the program. The character of the plan best suited to a given situation is largely dependent on the relative magnitudes of the immediate highway needs and those that will accrue in later years. The alternatives range from current-revenue financing to a long-term bond-issue program.

THE CUT-AND-FILL CONCEPT

A method of analysis designed to produce a plan meeting these requirements has become familiarly known as the cut-and-fill method. In schematic form the concept is illustrated by Figure 4. The heavy curved line traces the profile of highway needs: First, those of the initial accelerated or catch-up period, 1956–65; and second, those of the ensuing three decades, during which the needs for replacement and upgrading or expansion of the system develop only gradually. It is evident that a needs profile of this shape lends itself readily to a system of financing whereby a large bond issue sold during the initial construction period can be retired during the ensuing period when replacement and expansion needs are at a minimum.

By inspection the year 1994 was taken as the limit of the bonding term, since the rate of increase of needs accruals begins to fall off at about that time. The straight heavy line represents the rate of revenue supply that will exactly balance needs at the year 1994—it subtends the same area as the profile of highway needs. The area above this line, lying between the years 1956 and 1965, represents *bonds issued.* The area—equal in size—lying below it and above the needs curve and spanning the years 1966 to 1994, represents *bonds retired.* The representation is completed by computing interest—at 2 percent in this example. The total revenue requirements of the program are traced by the broken black line.

Although the solution is greatly oversimplified in Figure 4, it will be observed that, granted the validity of the needs-accrual profile, the financing illustrated on the chart is entirely prudent, since the rate of increase of revenue supply is greater than the rate of increase of accruing needs at the year 1994.[2]

[2] For somewhat similar treatments of bond-issue financing in relation to the accrual of highway needs see Bertram H. Lindman, "Supplemental bond financing for acceleration of the Ohio highway program," Ohio Department of Highways, 1951; and J. P. Buckley, Automotive Safety Foundation, "Economics of alternative highway programs," presented before the American Society for Engineering Education, at Pennsylvania State University, June 1955.

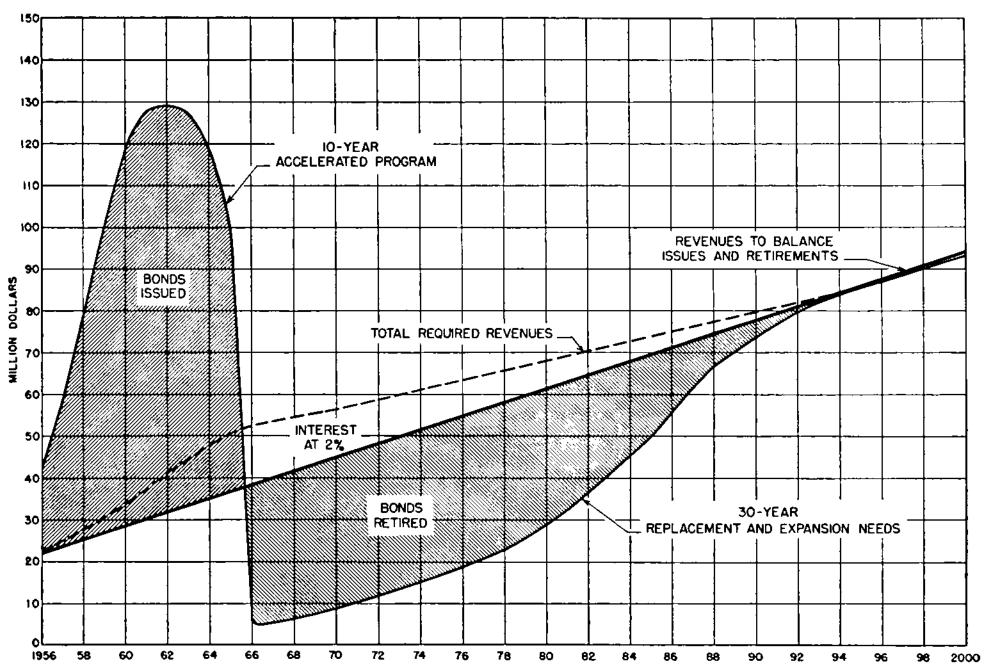

Figure 4. Illustration of the cut-and-fill concept in financial planning for highways.

APPLICATION OF THE PRINCIPLE TO FEDERAL-AID SYSTEM NEEDS

Application of the cut-and-fill principle to an actual situation requires a method of successive approximations whereby the existing highway needs, the bond issue, and the required revenues are brought into a consistent relationship. The major ingredients are a long-term profile of highway needs and a forecast of available highway revenues, at existing rates, over the same period of years, both dependent for their validity upon an adequate forecast of travel volumes. The result is not a decision of policy, but, in effect, the determination of the maximum prudent bond issue and the minimum prudent increase in the level of highway taxes that will finance the needed improvement program.

To illustrate this method of analysis, the needs of the federal-aid systems (exclusive of the interstate) in an average state have been taken. The dimensions of the problem are not dissimilar to those of the state highway system in such a state, since there are state highways not on the federal-aid systems and, conversely, federal-aid secondary highways not on the state systems. For reduction to the scale of an average state, nationwide figures, in general, have been divided by 50.

Figure 5 gives three alternate needs-accrual profile curves for the combined federal-aid systems (primary rural, primary urban, and secondary) in an average state. Corresponding data are given in Table 2. Since the year 1955 is behind us, the time period is taken as 1956–1995. The original nationwide highway needs study was based on the assumption of a 10-year catch-up program. In this chart, however, the alternates of a 12-year and a 15-year program are also contemplated. In making the choice between them, a state would have to weigh the advantages of achieving adequacy at an early date against the difficulties, in financing, in manpower, and in industrial and organizational capacity, of a rapidly stepped-up program.

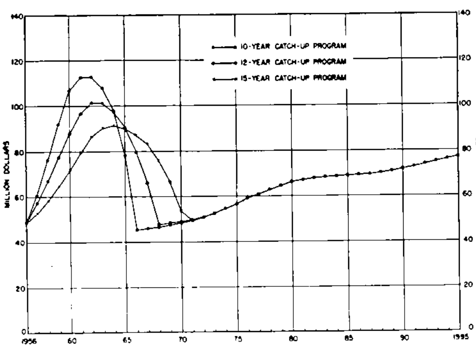

Figure 5. Needs of the federal-aid systems (exclusive of interstate) in an average state.

Because of the probability that a program to be legislated and put into motion in 1956 would have only a minor effect on construction expenditures in that year, the value $48.5 million, predicted on the basis of recent trends, was taken as the 1956 total for all three programs. In each case the expenditures of the catch-up program period have been scheduled so as to rise to a maximum and then recede toward the relatively low level of annual replacement and expansion requirements during the years immediately following the conclusion of the accelerated program.

The differences among the three initial programs are apparent: Average annual expenditures for the 10-, 12-, and 15-year catch-up programs are, respectively, $89, $81, and $73 million. Their cumulative totals, $893, $970, and $1,098 million, respectively, differ because of the accrual of further needs during the longer program periods. Beyond the year 1973 the differences in the accrual of needs are not great. For that reason, and to avoid confusion in the plotting, only the profile of needs for the period following the 12-year program is shown.

REVENUES PREDICTED AT EXISTING RATES

In Table 3 and Figure 6 we have the second major ingredient of the recipe—highway revenues available to the federal-aid systems (exclusive of interstate), as predicted at current tax rates. The left-hand panel shows them classified by source; the right-hand panel by object of expenditure. The predicted revenues rise from $51 million in 1956 to $76 million in 1975 and $100 million in 1995.

By far the largest proportion comes from state revenues—69 percent in 1956, rising to 78 percent in 1975 and 83 percent in 1995. In the year 1954, state-government revenues for highways were derived 93 percent from road-user taxes, 4 percent from highway tolls, and 3 percent from general-fund appropriations and miscellaneous sources. For these calculations user-tax revenues were predicted on the

TABLE 2

ESTIMATED 10-, 12-, AND 15-YEAR CATCH-UP PROGRAMS FOR THE COMBINED FEDERAL-AID SYSTEMS (EXCLUSIVE OF INTERSTATE) IN AN AVERAGE STATE, TOGETHER WITH FORECASTS OF REPLACEMENT AND EXPANSION NEEDS THROUGH 1995

10-Year Program

Time period	Estimated system needs
	$ million
1956	48.5
1957	60.4
1958	76.1
1959	91.9
1960	106.7
1961	112.7
1962	112.8
1963	107.9
1964	97.6
1965	78.2
10-year total	892.8
Average, 1956–65	89.3
10-year total, 1966–75	496.0
Average, 1966–75	49.6
Amount in 1975	56.6
Cumulative total, 1956–75	1,388.8
10-year total, 1976–85	656.2
Average, 1976–85	65.6
Amount in 1985	68.9
Cumulative total, 1956–85	2,045.0
10-year total, 1986–95	727.7
Average, 1986–95	72.8
Amount in 1985	77.4
Grand total, 1956–95	2,772.7

12-Year Program

Time period	Estimated system needs
	$ million
1956	48.5
1957	57.2
1958	66.8
1959	77.4
1960	87.9
1961	96.6
1962	101.4
1963	101.3
1964	97.3
1965	90.4
1966	79.7
1967	66.0
12-year total	970.5
Average, 1956–67	80.9
8-year total, 1968–75	407.5
Average, 1968–75	50.9
Amount in 1975	56.2
Cumulative total, 1956–75	1,378.0
10-year total, 1976–85	653.4
Average, 1976–85	65.3
Amount in 1985	68.9
Cumulative total, 1956–85	2,031.4
10-year total, 1986–95	726.8
Average, 1986–95	72.7
Amount in 1995	77.1
Grand total, 1956–95	2,758.2

15-Year Program

Time period	Estimated system needs
	$ million
1956	48.5
1957	52.8
1958	58.2
1959	64.7
1960	71.7
1961	79.3
1962	86.3
1963	90.1
1964	91.0
1965	89.8
1966	87.0
1967	83.0
1968	75.8
1969	66.3
1970	53.6
15-year total	1,098.1
Average, 1956–70	73.2
5-year total, 1971–75	261.8
Average, 1971–75	52.4
Amount in 1975	55.8
Cumulative total, 1956–75	1,359.9
10-year total, 1976–85	652.6
Average, 1976–85	65.3
Amount in 1985	69.9
Cumulative total, 1956–85	2,012.5
10-year total, 1986–95	725.0
Average, 1986–95	72.5
Amount in 1995	76.6
Grand total, 1956–95	2,737.5

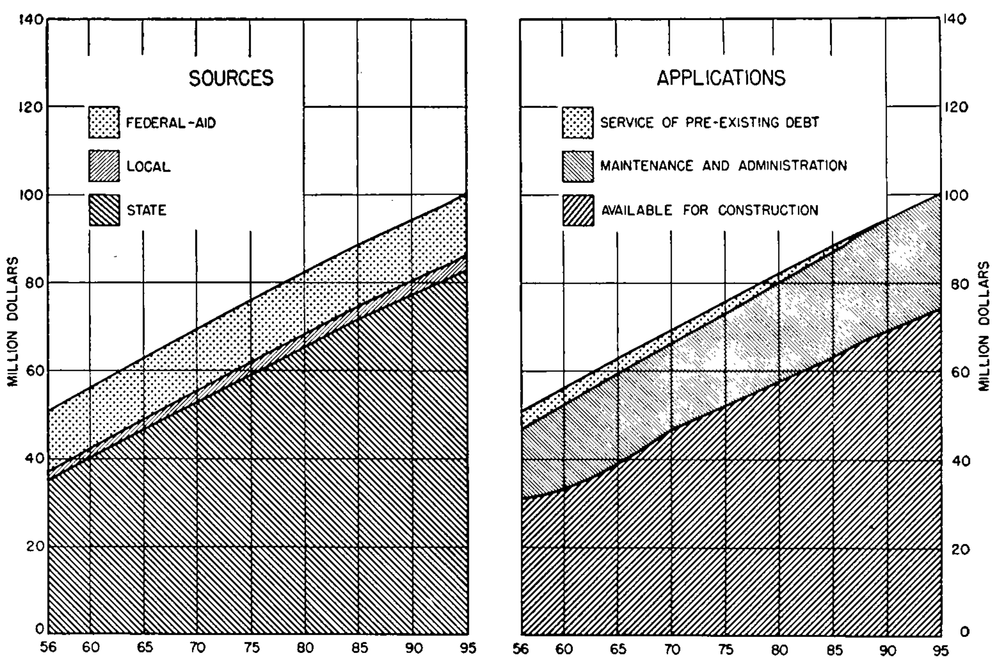

Figure 6. Predicted revenues of an average state, available for the federal-aid systems, exclusive of interstate.

TABLE 3
PREDICTED REVENUES (IN $ MILLION) OF AN AVERAGE STATE, AVAILABLE FOR THE COMBINED FEDERAL-AID SYSTEMS (EXCLUSIVE OF INTERSTATE) FOR THE YEARS 1956–95, ASSUMING THE CONTINUATION OF CURRENT RATES OF TAXATION

Time period	Grand Total Revenue	By Source			By Application (12-Year Program)		
		Federal-aid	State	Local	Service of Pre-existing debt	Maintenance and administration	Revenue available for capital outlay
1956	51.0	14.0	35.4	1.6	3.7	15.9	31.4
1957	52.3	14.0	36.7	1.6	4.0	16.6	31.7
1958	53.7	14.0	38.0	1.7	3.9	17.4	32.4
1959	55.0	14.0	39.3	1.7	3.8	18.3	32.9
1960	56.4	14.0	40.6	1.8	3.7	19.2	33.5
1961	57.7	14.0	41.9	1.8	3.7	19.9	34.1
1962	59.0	14.0	43.2	1.8	3.5	20.4	35.1
1963	60.3	14.0	44.4	1.9	3.4	20.7	36.2
1964	61.6	14.0	45.7	1.9	3.3	20.8	37.5
1965	62.9	14.0	46.9	2.0	3.3	20.6	39.0
1966	64.2	14.0	48.1	2.1	3.1	20.4	40.7
1967	65.4	14.0	49.3	2.1	3.0	19.9	42.5
Subtotal	699.5	168.0	509.5	22.0	42.4	230.1	427.0
Average, 1956–67	58.3	14.0	42.5	1.8	3.5	19.2	35.6
8-year total, 1968–75	569.3	112.0	439.0	18.3	20.9	161.8	386.6
Average, 1968–75	71.2	14.0	54.9	2.3	2.6	20.2	48.4
Amount in 1975	75.7	14.0	59.2	2.5	2.3	21.3	52.1
Cumulative total, 1956–75	1,268.8	280.0	948.5	40.3	63.3	391.9	813.6
10-year total, 1976–85	830.0	140.0	663.1	26.9	19.1	228.7	582.2
Average, 1976–85	83.0	14.0	66.3	2.7	1.9	22.9	58.2
Amount in 1985	89.0	14.0	72.1	2.9	1.6	23.9	63.5
Cumulative total, 1956–85	2,098.8	420.0	1,611.6	67.2	82.4	620.6	1,395.8
10-year total, 1986–95	950.6	140.0	779.7	30.9	3.0	250.5	697.1
Average, 1986–95	95.1	14.0	78.0	3.1	0.3	25.1	69.7
Amount in 1995	100.3	14.0	83.0	3.3		26.0	74.3
Grand total, 1956–95	3,049.4	560.0	2,391.3	98.1	85.4	871.1	2,092.9

basis of the forecasts of travel volume furnished by all states in the 1954 study, with adjustments for increases in user-tax rates since that time. To avoid a separate prediction of the future course of toll revenues—available to the lower federal-aid systems chiefly from toll bridges—funds from this source, as well as miscellaneous receipts, were assumed to increase proportionately with user-tax revenues.

Increases in local road and street revenues were estimated by reference to recent trends and the predicted trends of general economic indexes.

In order to have an entirely neutral estimate of future federal-aid receipts it was assumed that the current annual authorizations of $315 million for the federal-aid primary system, $210 million for the federal-aid secondary system, and $175 million for federal-aid highways in urban areas would be available in the future for the federal-aid systems outside the interstate. The annual total is $700 million, or $14 million for the average state.

In the righthand panel of Figure 6 exactly the same revenues are subdivided by object of expenditure. The area shown at the top of the chart and diminishing with the years represents the service of highway debt contracted prior to the inception of the new program. Beneath this, the predicted expenses of maintenance, operation and administration are shown, and the net revenues available for capital outlay are given at the base of the chart.

The apparent dip in the trend of funds available for construction during the first few years results from an allowance for special administrative expenses, roughly proportional to capital outlays, during the period of accelerated construction activity. Ignoring this minor variation, we find that funds available for construction increase from $31 million out of a total of $51 million, or 61 percent, in 1956, to $52 million out of $76 million, or 69 percent, in 1975; and to $74 million (and percent) out of $100 million in 1995. Involved in this trend is the assumption, not unreasonable but of course not inevitable, that the expenses of maintenance, operation and administration

TABLE 4

COMPARISON OF AVAILABLE REVENUES (IN $ MILLION) WITH NEEDS, IN TOTAL AND ON A UNIT BASIS, FOR THE COMBINED FEDERAL-AID SYSTEMS (OTHER THAN INTERSTATE) IN AN AVERAGE STATE

10-Year Catch-Up Program

Years	Construction needs	Predicted revenues: State and local	Predicted revenues: Federal-aid	Predicted revenues: Subtotal	Additional required revenues
1956–65	892.8	203.8	140.0	343.8	549.0
1966–75	496.0	329.8	140.0	469.8	26.2
1976–85	656.2	442.2	140.0	582.2	74.0
1986–95	727.7	557.1	140.0	697.1	30.6
Total, 1966–95	1,879.9	1,329.1	420.0	1,749.1	130.8
Grand total, 1956–95	2,772.7	1,532.9	560.0	2,092.9	679.8
Cents per gallon of equivalent State motor-fuel tax					
1956–65	8.035	1.834	1.260	3.094	4.941
1966–75	3.438	2.286	.971	3.257	.181
1976–85	3.687	2.485	.787	3.272	.415
1986–95	3.488	2.670	.671	3.341	.147
Average, 1966–95	3.541	2.504	.791	3.295	.246
Average, 1956–95	4.319	2.388	.872	3.260	1.059

12-Year Catch-Up Program

Years	Construction needs	Predicted revenue: State and local	Predicted revenue: Federal-aid	Predicted revenue: Subtotal	Additional required revenues
1956–67	970.5	259.0	168.0	427.0	543.5
1968–75	407.5	274.6	112.0	386.6	20.9
1976–85	653.4	442.2	140.0	582.2	71.2
1986–95	726.8	557.1	140.0	697.1	29.7
Total, 1968–95	1,787.7	1,273.9	392.0	1,665.9	121.8
Grand total, 1956–95	2,758.2	1,532.9	560.0	2,092.9	665.3
Cents per gallon of equivalent State motor-fuel tax					
1956–67	7.066	1.885	1,223	3.108	3.958
1968–75	3.452	2.326	.949	3.275	.177
1976–85	3.672	2.485	.787	3.272	.400
1986–95	3.483	2.670	.671	3.341	.142
Average, 1968–95	3.367	2.400	.738	3.138	.229
Average, 1956–95	4.296	2.388	.872	3.260	1.036

15-Year Catch-Up Program

Years	Construction needs	Predicted revenues: State and local	Predicted revenues: Federal-aid	Predicted revenues: Subtotal	Additional required revenues
1956–70	1,098.1	354.0	210.0	564.0	534.1
1971–75	261.8	179.6	70.0	249.6	12.2
1976–85	652.6	442.2	140.0	582.2	70.4
1986–95	725.0	557.1	140.0	697.1	27.9
Total, 1971–95	1,639.4	1,178.9	350.0	1,528.9	110.5
Grand total, 1956–95	2,737.5	1,532.9	560.0	2,092.9	644.6
Cents per gallon of equivalent State motor-fuel tax					
1956–70	6.129	1.976	1.172	3.148	2.981
1971–75	3.435	2.357	.918	3.275	.160
1976–85	3.667	2.485	.787	3.272	.395
1986–95	3.474	2.670	.671	3.341	.133
Average, 1971–95	3.088	2.221	.659	2.880	.208
Average, 1956–95	4.264	2.388	.872	3.260	1.004

will increase somewhat less rapidly than travel volumes and the revenues derived therefrom, thus gradually releasing a larger proportion for capital outlay.

NEEDS AND REVENUES COMPARED

A comparison of predicted capital needs with predicted revenues available for construction is given in Table 4 and Figure 7 for each of the three alternate catch-up periods, 10, 12, and 15 years, and for the ensuing decades. In the three upper panels of Figure 7 values are expressed in millions of dollars. In the lower panels they are converted to equivalent amounts in cents per gallon of state motor-fuel tax. This procedure takes some liberties with the data, since motor-fuel taxes are only one (although the largest) of the sources from which the revenues of the federal-aid systems are and will be derived. Equivalent cents per gallon have been found, however, to be the most convenient and most easily visualized unit by means of which predicted revenues may be compared with those required to finance a highway program. In actual practice the required increase in revenues may be distributed among various revenue sources, including increased motor-vehicle imposts, state general funds, highway tolls, local taxes, and federal funds, as well as the state motor-fuel tax.

The conversion to equivalent cents per gallon was made by the use of a rate of motor-fuel consumption, applicable to all motor vehicles as a group, of 12.73 miles per gallon. On this basis the revenue produced by a tax of 1 cent per gallon is equivalent to about 0.79 mills per mile of travel. Estimates of total vehicle-miles in each year were based on the forecasts made in connection with the 1954 nationwide study of highway needs. No adjustment was made for increased travel volumes (and consequent increased revenues) resulting from earlier completion of the needed construction under the 10- and 12-year catch-up programs.

The range in values of annual travel volume in an average state, and that of the corresponding yield of state motor-fuel tax are illustrated as follows:

Year	Annual Vehicle Miles of Travel in an Average State	Annual Yield of a State Motor Fuel Tax of $0.01 per Gal.
	(millions)	*($1,000)*
1956	12,153	9,547
1965	16,071	12,624
1975	20,258	15,913
1985	24,609	19,332
1995	28,243	22,186

The comparison of revenues with needs is presented in pairs of contiguous bars. Heavy dimension arrows indicate the excess of needs

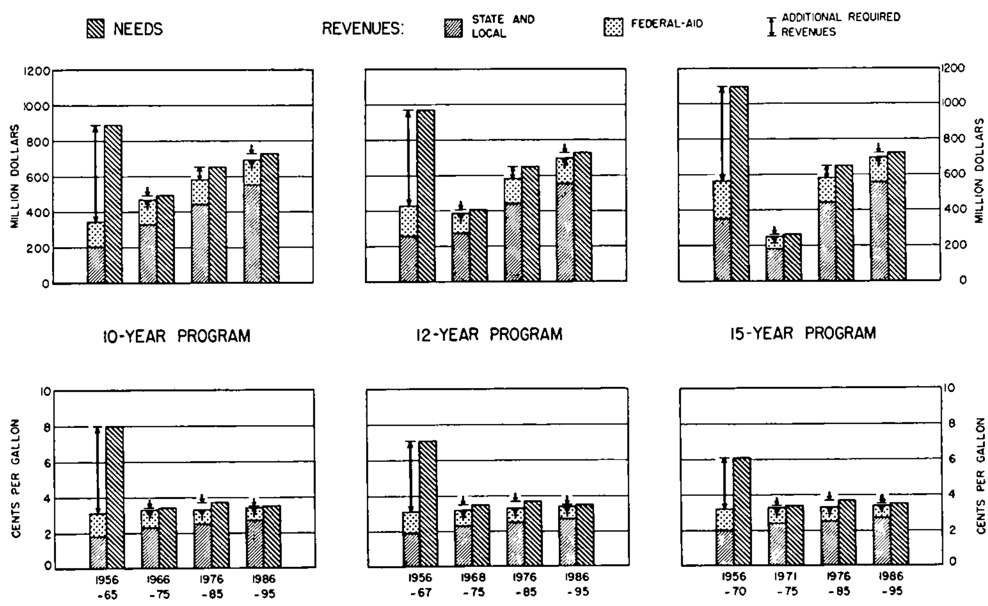

Figure 7. Federal-aid systems, other than interstate, comparison of available revenues, with needs on unit basis.

over revenues—the additional revenue required under the condition of current-revenue financing. In the left-hand panels, it would take $893 million or the equivalent of $0.08 per gallon of motor-fuel tax, to pay the cost of the 10-year catch-up program in this average state. Revenues predicted at current tax rates amount to $344 million, the equivalent of 3.1 cents per gallon. It would take a raise in revenues equivalent to 4.9 cents per gallon to finance this program out of current income. After the close of the 10-year catch-up period, predicted revenues would be very nearly sufficient to meet the accrual of replacement and expansion needs.

A similar story is told in the center and right-hand panels. To meet the needs of the 12-year accelerated program in the years 1956 to 1967 would require additional revenues equivalent to a motor-fuel tax of $0.04 per gallon. The 15-year program would require an increase equivalent to 3.0 cents per gallon, making the total requirement nearly double the amount of revenues predicted to be available for capital outlay during the period 1956–1970.

This is the picture of current-revenue financing, if the goal of producing an adequate highway plant in a reasonable time is to be achieved. It requires a formidable, although perhaps not unthinkable, increase in highway tax rates during the period of accelerated investment. There is a temptation, when confronted with a situation like this, to lower one's sights and decide to "make do" with something less than adequacy in highway provision and service. Credit financing, however, offers an alternative by which the desired goal may be achieved without putting quite so much strain upon the pocket nerve of the user-taxpayer.

40-YEAR BOND-ISSUE PLAN

Figure 8 portrays the results of a calculation designed to finance the 12-year catch-up program, plus accruing needs over the following 28 years, by means of a bond issue the total term of which would cover the entire 40-year period. For illustrative purposes the needs-accrual profile has been extended another five years. Only capital items relating to the 40-year period are shown, the costs of maintenance, administration, and service of pre-existing debt having been deducted at the outset.

Bonds issued, indicated by the mountainous

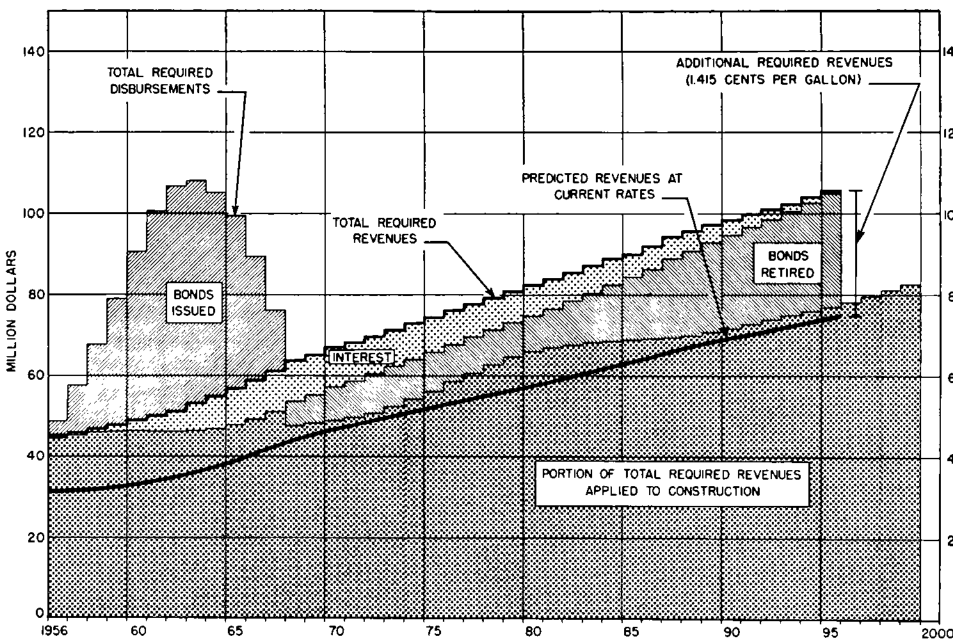

Figure 8. Calculation of 40-year bonding plan for combined federal-aid systems, exclusive of interstate.

cross-hatched area at the left of the chart, amount to $408 million out of a total 12-year investment of $970 million. The equal amount of bonds retired over the ensuing 28 years is shown in similar hatching with reversed slope. The light stippled area represents interest, computed at 2½ percent per year—a rate perhaps somewhere near a median for state issues that may include revenue and limited-obligation bonds as well as those backed by the faith and credit of the state. Total interest payments amount to $243 million over the 40-year period, an average of $6.8 million per year. Interest accounts for only 6.1 percent of the total revenues required for the entire period, or 8.1 percent of the money put into new capital outlay and interest.

The massive area of heavy stipple at the base of the chart represents current revenues applied directly to construction. During the initial 12-year period direct capital outlays of $562 million account for 58 percent of the total capital investment in highways; bond issues account for the remaining 42 percent. Since all capital outlays in the ensuing 28 years are made out of current revenues, it is clear that the bond issue, although large, plays only a fractional part in the total financial plan.

Predicted revenues at current tax rates are shown by the heavy continuous line. The total revenues required to finance the program are traced by the heavy stepped line above the stippled area denoting interest. The area between these two revenue lines, denoted by the dimension lines at the right of the chart, represents the revenues required in excess of those predicted. Expressed in equivalent state motor-fuel tax, these additional required revenues amount to $.01415 per gallon in each year. Similar calculations made for the 10- and 15-year programs indicate additional revenue requirements equivalent to $0.0141 and $0.0134 per gallon, respectively. If, as seems not unlikely at the time of writing, new federal-aid legislation should materially increase the authorizations for federal-aid highways below the inter-state level, the necessity for increased state taxation to finance federal-aid needs will be correspondingly reduced.

The calculation illustrated in Figure 8 serves to demonstrate the manner in which a continuous and gradually increasing flow of revenues may be used to finance a construction program greatly accelerated in a short period of years, to be followed by a relatively moderate build-up of replacement and expansion needs over a long period. The term of the bond-issue plan (40 years in total, although no bonds would be issued for more than 30) may arouse some objections. The two facts—(a) that the financing takes care of all needs for initial construction, replacement, and upgrading during the 40-year period and (b) that at the close of the period the rate of revenue supply is considerably in excess of the rate of accrual of needs—should be sufficient to quiet such fears. The excess of predicted revenues over predicted requirements may be regarded as a safeguard against unforeseen contingencies.

In a calculation of this sort the length of the bonding term is contingent upon the composite life span of the highway investment in right-of-way, grading, surfacing, and structures. The results, therefore, tend to set bounds of prudence to (1) term of bond issue, (2) amount of bond issue, and (3) amount or rate of increase in supporting revenues, the limit in the latter case being minimum rather than maximum. In working out the financial plan for an individual state, consideration must be given to other factors, including the general financial situation in the state government, established public policy, and popular attitudes toward credit financing. Alternative plans, with varying terms of bond issue and varying levels of increased revenues, must necessarily be developed before a decision is reached.

METHOD OF CALCULATION

The procedure in the so-called cut-and-fill method of bond-issue calculation is one of successive approximations. Since the profile of needs and the schedule of predicted revenues are known, it is only necessary to determine the rate of additional revenue supply that will accomplish the desired financing in the chosen period of years. The estimated additional revenues can be expressed in terms of cents per vehicle-mile of travel or, as in Figure 8, in equivalent cents per gallon of state motor-fuel tax. The first estimate, and the calculation based on it, may be wide of the mark; however, repeated estimates will rapidly converge toward a rate of increased revenues that will just pay off the bond issue in the year selected as the final date of retirement.

The process of calculation is illustrated by Table 5, which gives values for each year of

TABLE 5

CALCULATION OF A 40-YEAR BOND FINANCING PLAN FOR COMBINED FEDERAL-AID SYSTEMS (EXCLUSIVE OF INTERSTATE) IN AN AVERAGE STATE (IN $1,000)

Year	Required Expenditures						Required Revenues							Credit Financing		
	Program Needs and Commitments				Interest on new financing at 2½%	Total	Amounts predicted at current tax rates				Additional required revenues[1]	Total	Bonds issued (Jan. 1)	Bonds retired (Dec. 31)	Bonds outstanding on Dec. 31
	Capital outlay	Maintenance and administration	Service of debt outstanding at end of 1955	Total			Federal-aid	State revenues	Local rural and urban revenues	Total					
1956	48,520	15,849	3,700	68,069	92	68,161	14,000	35,380	1,580	50,960	13,509	64,469	3,692	—	3,692
1957	57,160	16,627	3,980	77,767	389	78,156	14,000	36,660	1,620	52,280	14,003	66,283	11,873	—	15,565
1958	66,770	17,455	3,880	88,105	909	89,014	14,000	38,020	1,660	53,680	14,525	68,205	20,809	—	36,374
1959	77,350	18,353	3,840	99,543	1,688	101,231	14,000	39,340	1,720	55,060	15,022	70,082	31,149	—	67,523
1960	87,920	19,166	3,740	110,826	2,728	113,554	14,000	40,660	1,760	56,420	15,515	71,935	41,619	—	109,142
1961	96,560	19,902	3,720	120,182	3,991	124,173	14,000	41,900	1,800	57,700	15,980	73,680	50,493	—	159,635
1962	101,410	20,423	3,500	125,333	5,371	130,704	14,000	43,160	1,860	59,020	16,462	75,482	55,222	—	214,857
1963	101,320	20,692	3,400	125,412	6,743	132,155	14,000	44,440	1,900	60,340	16,943	77,283	54,872	—	269,729
1964	97,340	20,761	3,340	121,441	8,004	129,445	14,000	45,660	1,960	61,620	17,404	79,024	50,421	—	320,150
1965	90,450	20,620	3,240	114,310	9,070	123,380	14,000	46,880	1,980	62,860	17,863	80,723	42,657	—	362,807
1966	79,670	20,342	3,120	103,132	9,833	112,965	14,000	48,100	2,040	64,140	18,327	82,467	30,498	—	393,305
1967	65,990	19,916	2,980	88,886	10,204	99,090	14,000	49,340	2,080	65,420	18,793	84,213	14,877	—	408,182
Subtotal, 1956–67	970,460	230,106	42,440	1,243,006	59,022	1,302,028	168,000	509,540	21,960	699,500	194,346	893,846	408,182	—	—
1968	47,600	19,229	2,920	69,749	10,204	79,953	14,000	50,560	2,140	66,700	19,257	85,957	—	6,004	402,178
1969	48,200	19,512	2,860	70,572	10,054	80,626	14,000	51,800	2,180	67,980	19,724	87,704	—	7,078	395,100
1970	48,900	19,779	2,620	71,299	9,877	81,176	14,000	53,040	2,220	69,260	20,189	89,449	—	8,273	386,827
1971	49,700	20,051	2,620	72,371	9,671	82,042	14,000	54,200	2,260	70,460	20,626	91,086	—	9,044	377,783
1972	50,600	20,307	2,700	73,607	9,445	83,052	14,000	55,460	2,300	71,760	21,088	92,848	—	9,796	367,987
1973	52,200	20,620	2,480	75,300	9,200	84,500	14,000	56,700	2,360	73,060	21,569	94,629	—	10,129	357,858
1974	54,100	20,949	2,400	77,449	8,946	86,395	14,000	57,980	2,400	74,380	22,054	96,434	—	10,039	347,819
1975	56,200	21,287	2,280	79,767	8,695	88,462	14,000	59,220	2,440	75,660	22,517	98,177	—	9,715	338,104
Subtotal, 1968–75	407,500	161,734	20,880	590,114	76,092	666,206	112,000	438,960	18,300	569,260	167,024	736,284	—	70,078	—
Cumulative, 1956–75	1,377,960	391,840	63,320	1,833,120	135,114	1,968,234	280,000	948,500	40,260	1,268,760	361,370	1,630,130	—	70,078	—

1976	58,500	21,615	2,080	82,195	8,453	90,648	14,000	60,500	2,500	77,000	23,002	100,002	—	9,354	328,750
1977	60,700	21,938	2,000	84,638	8,219	92,857	14,000	61,800	2,540	78,340	23,488	101,828	—	8,971	319,779
1978	62,900	22,239	1,980	87,119	7,994	95,113	14,000	63,100	2,580	79,680	23,977	103,657	—	8,544	311,235
1979	64,700	22,541	1,940	89,181	7,781	96,962	14,000	64,420	2,620	81,040	24,464	105,504	—	8,542	302,693
1980	66,100	22,844	2,000	90,944	7,567	98,511	14,000	65,700	2,660	82,360	24,951	107,311	—	8,800	293,893
1981	67,000	23,079	2,040	92,119	7,347	99,466	14,000	66,960	2,720	83,680	25,428	109,108	—	9,642	284,251
1982	67,700	23,304	1,860	92,864	7,106	99,970	14,000	68,240	2,760	85,000	25,902	110,902	—	10,932	273,319
1983	68,300	23,524	1,840	93,664	6,833	100,497	14,000	69,500	2,800	86,300	26,377	112,677	—	12,180	261,139
1984	68,600	23,708	1,760	94,068	6,528	100,596	14,000	70,780	2,840	87,620	26,858	114,478	—	13,882	247,257
1985	68,900	23,870	1,640	94,410	6,181	100,591	14,000	72,100	2,860	88,960	27,355	116,315	—	15,724	231,533
Subtotal, 1976–85	653,400	228,662	19,140	901,202	74,009	975,211	140,000	663,100	26,880	829,980	251,802	1,081,782	—	106,571	—
Cumulative, 1956–85	2,031,360	620,502	82,460	2,734,322	209,123	2,943,445	420,000	1,611,600	67,140	2,098,740	613,172	2,711,912	—	176,649	—
1986	69,200	24,054	1,340	94,594	5,788	100,382	14,000	72,940	2,940	89,880	27,660	117,540	—	17,158	214,375
1987	69,600	24,305	500	94,405	5,359	99,764	14,000	74,140	2,960	91,100	28,100	119,200	—	19,436	194,939
1988	70,100	24,541	440	95,081	4,873	99,954	14,000	75,300	3,000	92,300	28,539	120,839	—	20,885	174,054
1989	70,900	24,750	200	95,850	4,351	100,201	14,000	76,360	3,040	93,400	28,934	122,334	—	22,133	151,921
1990	71,800	24,964	180	96,944	3,798	100,742	14,000	77,440	3,060	94,500	29,330	123,830	—	23,088	128,833
1991	72,900	25,168	160	98,228	3,221	101,449	14,000	78,500	3,120	95,620	29,725	125,345	—	23,896	104,937
1992	74,000	25,371	100	99,471	2,624	102,095	14,000	79,560	3,140	96,700	30,120	126,820	—	24,725	80,212
1993	75,100	25,595	—	100,695	2,005	102,700	14,000	80,620	3,180	97,800	30,514	128,314	—	25,614	54,598
1994	76,100	25,794	—	101,894	1,365	103,259	14,000	81,800	3,240	99,040	30,954	129,994	—	26,735	27,863
1995	77,100	26,013	—	103,113	697	103,810	14,000	82,980	3,300	100,280	31,393	131,673	—	27,863	—
Subtotal, 1986–95	726,800	250,555	2,920	980,275	34,081	1,014,356	140,000	779,640	30,980	950,620	295,269	1,245,889	—	231,533	
Grand total	2,758,160	871,057	85,380	3,714,597	243,204	3,957,801	560,000	2,391,240	98,120	3,049,360	908,441	3,957,801	—	408,182	—

[1] Equivalent to $0.01415 per gallon of state motor-fuel tax.

the entire 40-year period. In order that the variation of the smaller items may be readily traced, values are given to the nearest thousand dollars. Essentially the computation consists of a year-by-year determination of the following quantities: (1) Bonds to be issued or retired in the year; (2) the amount of revenues directly applicable to construction; and (3) the required interest payments.

The following formulas have been found useful in the calculations for the initial program period, or period of bond issuance. They are based on the assumptions that no bonds will be retired during the issuing period and that the bonds for each year are issued at the beginning of the year.

Let

N = Highway needs of a given year;
D = Debt outstanding at end of preceding year;
B = Bonds issued in given year;
I = Total interest paid in year;
R = Total revenues available in year; and
i = Annual rate of interest

Then, if receipts and expenditures balance,

$$R + B = N + I \qquad (1a)$$

$$B = N - R + I \qquad (1b)$$

But

$$I = i(D + B)$$
$$= i(D + N - R + I) \qquad (2)$$

Transposing,

$$I(1 - i) = i(D + N - R) \qquad (3a)$$

$$I = \frac{i}{1 - i}(D + N - R) \qquad (3b)$$

Substituting Eq. 3*b* in Eq. 1*b*,

$$B = N - R + \frac{i}{1 - i}(D + N - R)$$

$$= \frac{N - R + iD}{1 - i} \qquad (4)$$

These formulas may be readily adapted to varying circumstances of bond issuance and retirement.

CONCLUSION

We have pictured some of the alternatives that may be explored in the analysis leading to a financial plan. Under conditions such as those depicted, current-revenue financing requires drastic tax increases during the initial catch-up period, with only moderate rates in the ensuing decades. A long-term bonding plan may be financed with a relatively small increase in highway tax rates, sustained throughout the period. Intermediate choices are offered by bond issues of shorter term, requiring greater revenue increases at the outset, but less total cost. The suitability of different solutions depends in large part upon the contour of the needs-accrual profile. If the immediate needs are large in comparison with those of the next two or three decades, a long-term bond issue such as that portrayed in Figure 8 is a valid solution. If the immediate needs are only moderate in comparison with those of subsequent years, either current-revenue or short-term bond-issue financing is indicated.

The necessity to pay interest makes all bond-issue financing of greater total cost to the state than financing with current funds. That the cost to the taxpayers may be less, rather than more, is sometimes overlooked. Those who contribute to the support of the highways have alternate uses for their money, yielding either profits or tangible satisfactions, which they must forego in part if increased taxes are paid. The extent of the sacrifice is best measured by the interest-earning power of the money if invested privately, which would generally be more than it would cost the State to borrow the same funds. Thus a bond issue may give highway users and other taxpayers a better bargain than a drastic raise in taxes to finance a current-revenue plan.