Session Three

Monday, September 19, 1960, at 7:30 p.m.

PRIORITY ANALYSES—PROJECT SELECTION

HARRY C. SCHWENDER, Presiding

Physical and Economic Rating Methods for Priority Considerations

M. EARL CAMPBELL

Road rating procedure will have but little meaning unless it becomes one of a series of constituted steps in the total process of planning for highway improvement. Order is the foundation stone of science, and the goal of scientific programing. Rating procedure makes little sense unless placed in proper perspective and sequence in the assembly-line flow that unites all of the component parts into an approved annual program or so-called "capital budget,"—unless it helps to translate highway needs into a construction program.

To provide perspective for this discussion on rating methods for priority considerations a recapitulation of antecedent procedures is in order. It is assumed that now the purpose, goals and standards of achievement have been established. When the ends are set the means are polarized. In other words, we may now assume that (1) certain highways have been "justified", (2) these highways have been classified into systems, and (3) reasonable standards have been established in accordance with the economy.

As a prelude to rating it would also be helpful if certain related determinations have been accomplished in addition to the above three: (4) needs, (5) fiscal capability, and (6) resource allocation and fund apportionment formulas (Fig. 1).

Preliminary to rating, then, it would be desirable to have already created a long-range program with time periods set for the completion of its various increments.

As to needs, first there are the maintenance needs which should have first priority, after administrative needs and debt service have been satisfied. And maintenance needs are growing with increasing age of highway systems, with increasing traffic volumes and loads, with expansion and improvement of the systems, and with increasing demands for higher quality service; for example, in the increasing demands for snow and ice control.

Next, there is the contingency fund for emergencies and for flexibility. Whether spent by State forces or under contract, the contingency fund for work that results from crises and Acts of God, can hardly become a part of deliberate priority planning.

Then comes the construction needs. These can be broken down into (1) the current backlog of needs, (2) the future accruals from continuing functional and structural obsolescence, (3) the future accruals resulting from growth and shifts in economic activity, and (4) accruals from inflation.

It is the highway construction needs that this present conference is primarily concerned with as it considers the process of formulating highway construction programs (Fig. 2).

As usual in the planning process the first concern is to establish the goal in light of needs and fiscal capabilities and then to determine the norm and means of achievement, and finally to learn how to achieve the summum bonum by putting first things first.

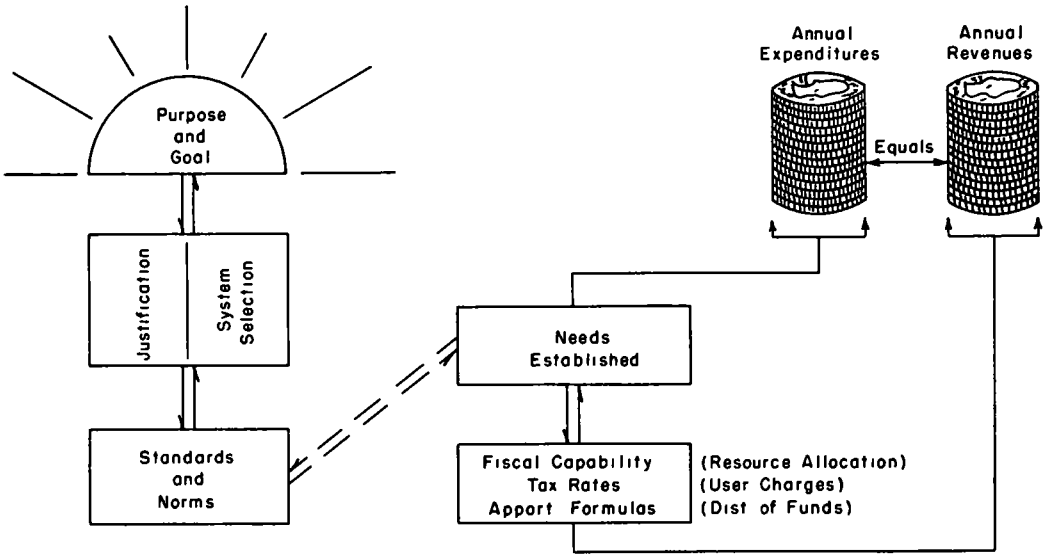


Figure 1. Desirable prelude to adequacy ratings.

To reiterate, it would be helpful if these preceding steps have been taken: the long-range plan created, its rate of achievement set by a satisfactory fiscal arrangement, the total plan divided into increments by time periods, by class of work, by systems, by funds and by other necessary categories (Fig. 3). Now, comes the initial planning pointed toward the ranking of sections of highway (or projects) for improvement with the objective of carrying out the master plan in intent and on time: to develop a dynamic, growing, unified, balanced, economic transportation system.

SCOPE

The challenge of a master plan is that of keeping the eyes upon the goal and of moving steadfastly toward the goal, in recognition that activities are aimless without a target.

This paper deals with a single step in this forward movement toward the objective. It deals with the subject of road rating and its role as one step toward priority ranking. This step follows after that of determining and categorizing needs and of securing means to fulfill the needs. While elementary in character the paper deals in fundamentals.

Physical and economic rating goes hand-in-hand with social and political and other evaluations. This paper treats only the physical and economic ratings—the assessment of the road, itself, and its environment for its relative adequacy in design and structural condition. The ratings are an expression of degree of adequacy in the existing circumstances and do not pretend to rank for priority.

A companion paper, by Arthur C. England will deal with social, political, administrative and other evaluations that must be weighed with the road adequacy ratings in listing and ranking priorities. The companion paper treats the difficult subject of merging values whose measurements are on a different scale. This is a vital part of the process of formulating the highway construction program.

Speaking in defense of this blending or merging action, it might be said that if the resulting decisions are within the framework of the master plan and provide an orderly and practicable succession of activities all oriented toward the goal, and which do not impede the progress of attainment, then the summum bonum can be achieved through this marriage: priorities composed of the best both in the economic and social order.

This paper deals only with the rating procedure. It starts after the creation of a general master plan and it is followed by a merging of economic and socio-political evaluations into a priority listing. The priority listing evolves into a program (or an

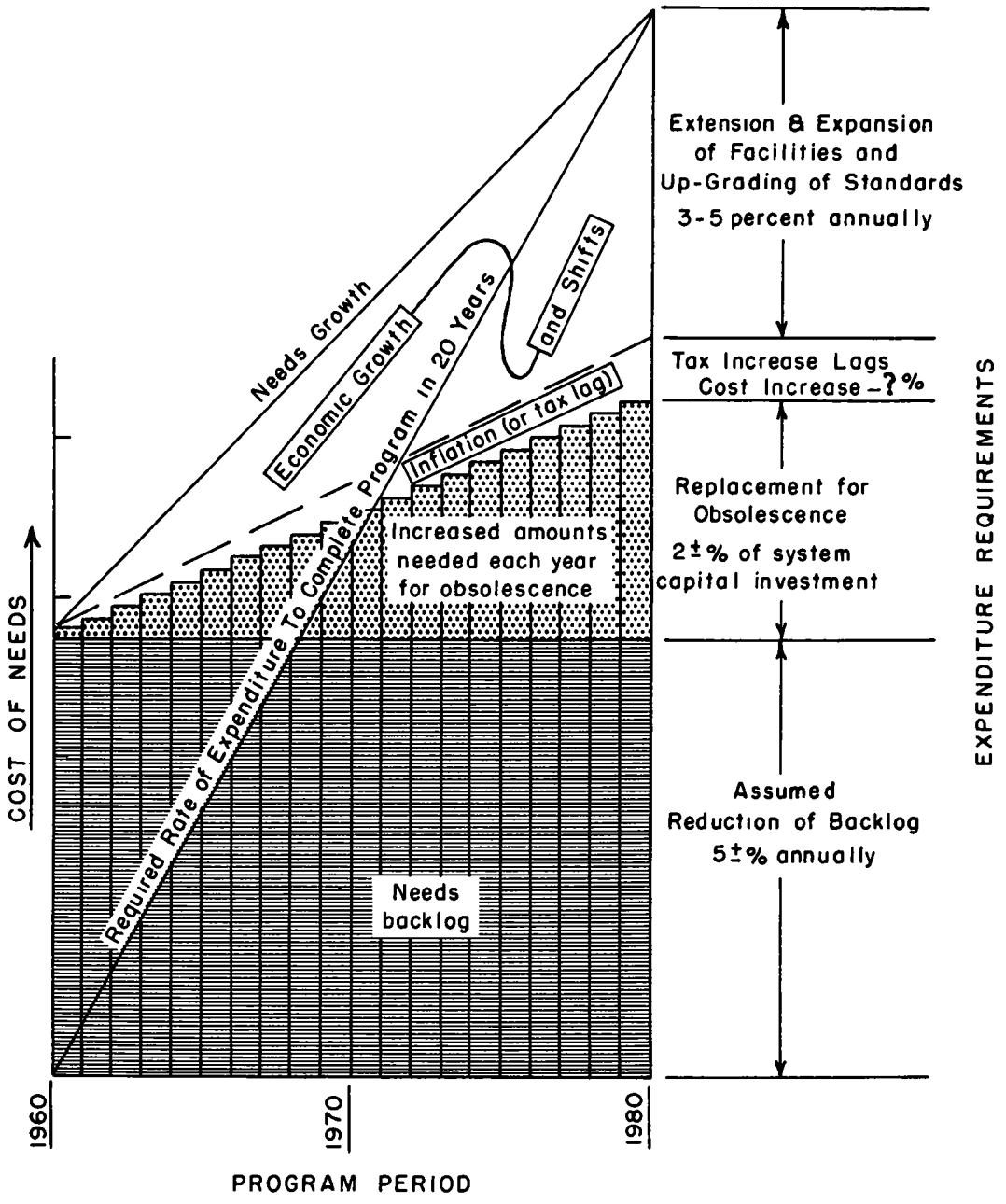


Figure 2. Schematic diagram of highway needs.

annual or biannial budget) as revenues are in sight, and thence into the scheduling of contracts in the fullness of time. This puts the steps into a broad perspective and spots the place of adequacy ratings.

It should be remembered that this paper deals with ratings for priority considerations and not with priority ratings, themselves. The distinction is significant. The several methods to be discussed rate adequacy, economy, solvency and related matters. The discussion will indicate the potentialities of ratings. It is not within the

province of this paper to detail all of the methods and techniques but rather to discuss their place, popularity, and plausibility in planning and in programing.

PURPOSE OF RATINGS

Discussing first the purpose of so-called "sufficiency", "deficiency", "adequacy" and other methods for rating the physical facility in terms of obsolescence or deterioration it is found that their intended purpose is as shown in Figure 4.

In connection with the first two items in Figure 4 it should be observed that the critical deficiency might be in safety, service, or structural condition of the highway, and in each of these possibilities the specific deficiency is isolated, thus suggesting the appropriate remedy.

Ratings are pointed toward the ultimate formulation of a short-term program, for example, five years, and finally to an annual or biennial capital budget, but it should

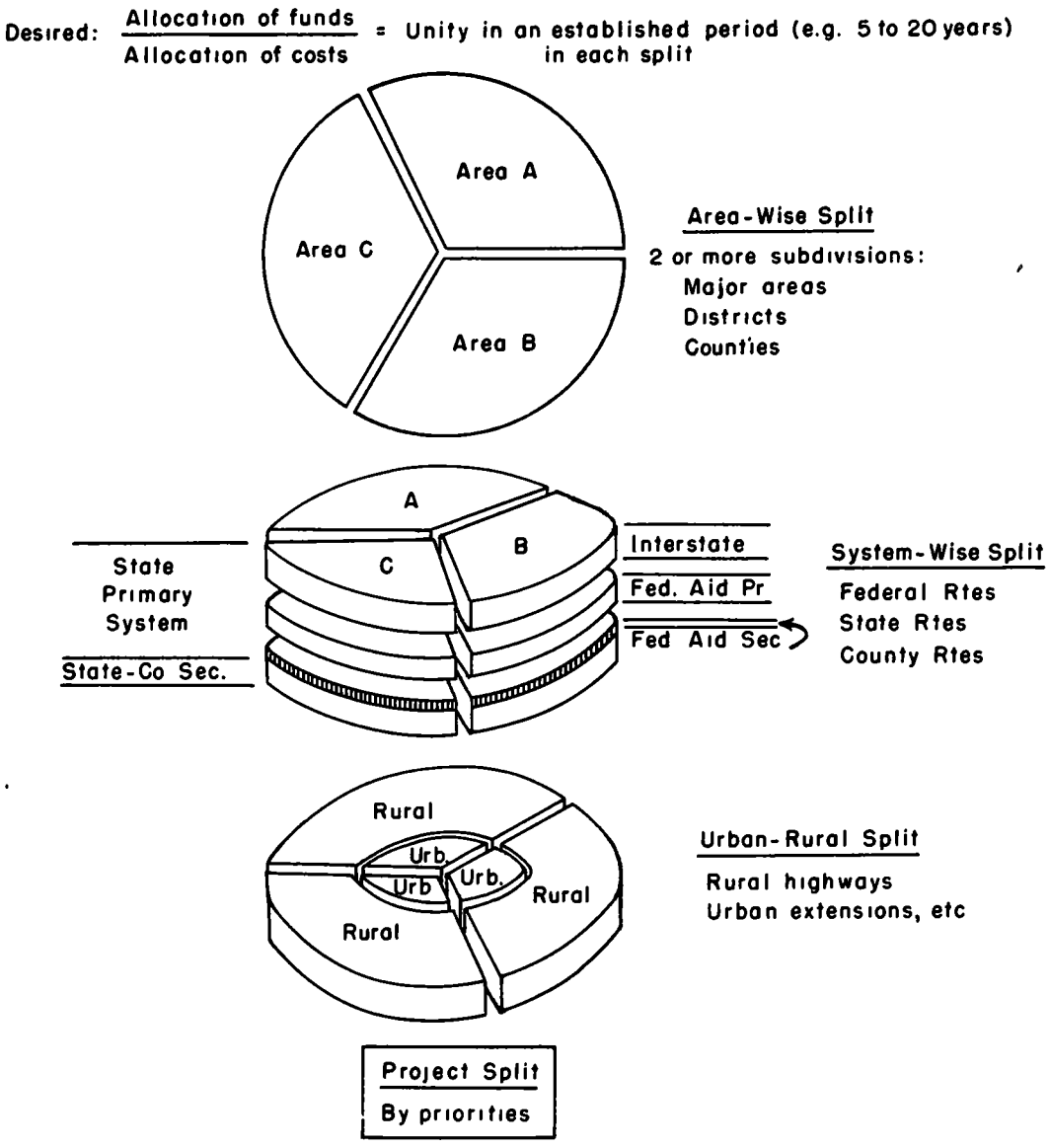


Figure 3. System and apportionment split for importance and spread.

be emphasized that they can serve importantly in long-range needs and fiscal studies for each of the several systems.

Other ratings, such as the benefit-cost ratio, rate of return on investment, and minimal transportation cost indicate how good an investment the project is from the user standpoint, while the solvency quotient indicates whether the project is self-liquidating from the user "earnings" produced within the limits of the project, or prorated thereto.

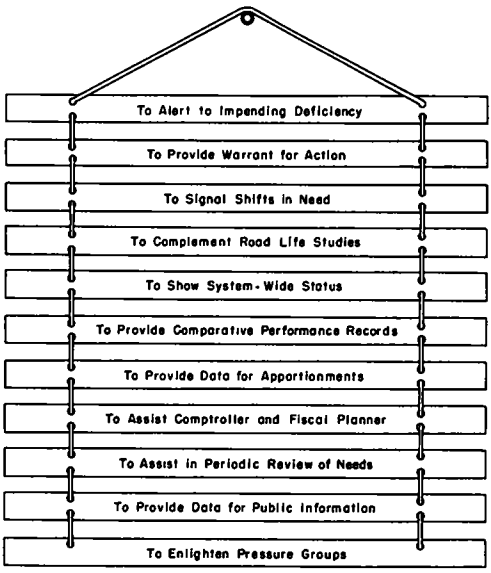


Figure 4. Intent of adequacy ratings.

PHILOSOPHY AND CONCEPT OF RATING

Imagination and practicality should conjoin in setting the goal and in creating the master plan. The evolution of a step-by-step method of reaching the goal requires the best thinking that administration, engineering, economics and other disciplines can give.

The critical job in programing is the ranking of needs. During the rest of this paper the implication will be economic need—not that other needs are not of equal importance, but because they are discussed in the companion paper. Specifically, the desired end in ranking is to make an unequivocal and valid determination, for example, that a certain bridge in one area is more needful now than a highway, or bypass, or expressway, or resource road in that same area, or in some other area.

This brings one face to face with ends, norms, means and performance standards in order to proceed in a systematic and straightforward manner. For continuity of purpose and plan, for a diminution of crash and crisis programing, for a means of holding the line against pressures when revenues are scarce, it would be desirable to develop a consistent, or reproducible adequacy rating—a rating that would measure a section in terms of a norm, or an established standard.

Such a rating to be reproducible by the same rater or different raters should have a minimum of subjective determinations; it should be a numerical rating with a convenient scale and the component parts to be scored should so far as possible be evaluated by a common yardstick.

Further, in order that the aims of the rating device be identical with and implement the aims of the needs study the same criteria used in determining standards for the needs study should, as far as possible, be carried over into the rating plan to determine the degree of a section's adequacy or deficiency, and serve as a measuring stick for determining its deviation from the standard or norm. And if the standards in the needs study are money based then we might say that the standards in adequacy ratings (the cut-off point for critical deficiency in an element, for example) are likewise dollar based. If the needs study has been realistic in allowance for growth then ratings can evaluate all but a minor part of roads required in the next two decades or so, for the existing system is the now dominant problem (Fig. 5).

In the final analysis the cut-off point for critical deficiency should bear the same reasonable relation to fiscal capability as the intolerable sections in the needs study do if the intent of the needs study is fulfilled in the warrants of the rating study. This does not imply that exigencies from local growths and shifts will not occur in a dynamic economy which will demand a modification in resource allocation, apportionment and standards. Continual review is part of a continuous "rolling" program.

Should we try to approach the ethical through an attempt to promote—in an economic

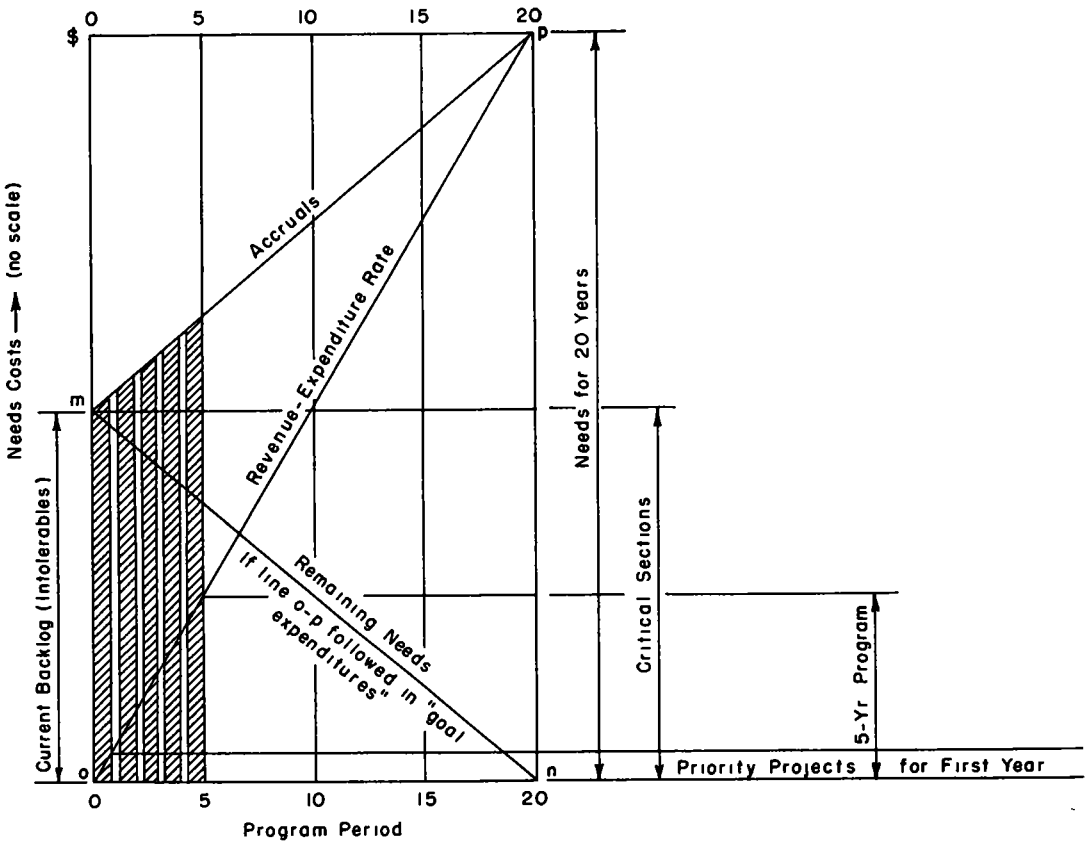


Figure 5. Mathematics of term program.

sequence—the economy of every part? If we follow this philosophy are we blind to the findings of sufficiency ratings? It is a hard fact that the sections with most critical deficiences do not always promise the greatest return on the investment for improvement—but it is a harder fact that if we do not abide by the critical deficiency ratings we can easily deviate from the path to the goal. However, there is usually such a big back log of critically deficient projects that we can for the time being select from them the emergency projects and then add the most economic from among the rest.

With the concept that critical deficiency is the major determinant we approach the development of rating method—a score card, so to speak. It was recognized from the start that rating methods would have a minimum of peripheral vision: they would see the need for more capacity, higher speed, fewer accidents and roadway betterment on a particular system, but they would not translate these findings automatically into a finding for a new system, nor an extension of the existing system. Such needs as an interstate system, or resource roads, or bypasses are by-products rather than end products of ratings. Informed judgment and complementary studies will find the by-products.

Any adequacy scoring is difficult to make whether for a section of highway 1,000 ft long or for a section 10 miles long. A recent analysis of elements rated by 36 State highway departments using some form of sufficiency rating showed some 30 elements scored among all these States, the average State scoring about 10 separate elements and no 2 States using identical score sheets, with the number of items ranging from 4 to 15. In addition to these 30 elements, if the items considered in other types of road ratings are added the total number of items to evaluate approaches 50. Naturally, some of these items overlap and it would be difficult to say without thorough empirical testing

how many of the 50 items are statistically significant. Nevertheless, the array of items to be judged and composed into an index value on any one project is formidable. We might inquire what human mind unaided by a check list or scoring sheet can scan so many component parts and assess its individual adequacy, and if done, can retain and compare these abstract values for several thousand control sections or projects? What measure of reproducibility would be obtained on a repetition? What commonness in agreement among districts or States?

Even with the most objective score cards covering all significant elements there is required an experiential knowledge of defects, their cause, prognosis, remedy and cost of correction. The team of highway diagnosticians must have a rich background in the recognition and rating of structural defects and geometric deficiencies. It has been stated that a clever planner can manipulate the weights of the several rated and thus "gerrymander" the program. Of course he can. But of all places to violate ethics this is the least likely.

Field checks of structural defects should be made periodically, and likewise a check made of those elements (such as traffic and land use) which change with time and season. Of course, only the geometric elements which have been changed need be rechecked. In field checks it appears that there is no consistent pattern among State highway departments in regard to who does this work. In some States the district engineer and/or a selected staff makes the check. The planning engineer and/or assistants may be responsible and the work done on a statewide basis. Sometimes the construction and maintenance engineers do the scoring. Although there is not conformity in method the States report high reproducibility in results within the State.

Eventually the whole office procedure may be handled by linear programing when we understand better the interrelations among the multiple components and how a change in value in any component affects the composite score. Then predesigned punched cards will rule out any vagaries of the mind in repetitive interpretations or reiterations.

Inasmuch as standards are economy based and vary among the several States (and even within the State) the rating methods also vary. A common method might be devised for each system, however, so that all States used the identical score cards but set different cut-off points for critical deficiency and for the norm. Such a method would allow a comparison of the adequacy of a particular system for capacity, safety, and structural condition, and would be a useful guide for determining status, trends, and needs.

Another argument that can be made for a uniform scoring is that suggestions and recommendations for road improvement come from many sources; such as, district engineers, State construction and maintenance engineers, State planning and traffic engineers, delegations, other State agencies, other governmental jurisdictions, and interested individuals. Each group can give reasons for its recommendation but few will have a thorough and comprehensive objective analysis.

> If all the people of the state and all areas are to be treated fairly, then there must be some long-term continuing plan for road renewal based on priorities determined in as objective a way as possible.
>
> Even an engineer may be influenced in his judgment of needs by his greater knowledge of certain routes than others within a system, unless he has an over-all, consistent, and impartial scaling of all sections of the system for comparison and guidance.
>
> There has never been, nor will there ever be, the utopian situation in which a state has sufficient funds, time, personnel, and equipment to attack simultaneously all the projects required to bring its roads up to standard. Choices must be made."—Hope Wiley.

DEGREES OF NEED AND URGENCY

If we could measure the relative urgency of needs a ranking of projects could be made. Need and urgency are relative in degree and a qualifying adjective is often used to attempt to show the relative need and urgency.

With respect to need we use such qualifying adjectives as vital, great, fair, casual, and very limited; with respect to urgency we use such words as immediate, critical, serious, moderate, and little.

None of these quantify, however, and we could as well rate need from A to E and urgency 1 to 5. Thence, A-1 would be of highest importance and greatest urgency, E-5 would be of no present concern. But how would A-5 or E-1 be interpreted? So a numerical scale to indicate the relative urgency of need was sought.

It was accepted that if a project was included in a justified system, then its own importance was "justified" and established. On the other hand, the measure of relative urgency has often been debated. In the needs studies it has been customary to set up a dividing line between the "tolerable" and "intolerable," the "intolerable" sections forming the current backlog of needs. The tolerable would gradually become intolerable with the passage of time, the State primary roads needing replacement or relocation at a rate of (roughly speaking) about 2 percent annually.

Considering the current backlog which might represent a substantial part of the existing system the total need may be so great that the projects included therein may have to be spread through several years of construction, and thence the individual projects rated for priority on a year-to-year basis. Thus, a still finer scale of values must be drawn within the intolerable or critical range.

Adequacy ratings measured on a scale from zero percent to 100 percent provide for a graduated numerical scoring for a distinction among the critically deficient sections as well as defining the cut-off or demarcation between the critical and non-critical. These ratings indicate the degree of urgency. These ratings may show that an area of a State with a greater need than another may have less urgency. Importance, we might say, relates to type and amount of service. An economic analysis furnishes a means of measuring importance, and that this importance can be determined in the measurement of relative loss in user benefits and also in the relative lack in fulfillment of economic (as well as social) activity in the area of influence, that is, the potential loss. The number of people served, together with the benefits and costs per person, are desirable bits of information.

By setting the sufficiency rating alongside of the importance rating a guide to ranking is provided in these measurements of remaining life and quality of service.

STANDARDS FOR RATING

As far as possible the same division point should be made between tolerable and intolerable in the needs studies as made between the noncritical and critical deficiencies in sufficiency ratings. Going on from there, of course, the measuring scale of adequacy ratings usually rates by point values all the degrees of adequacy to 100 in one direction and to zero in the other.

Structural Condition

As to structural condition, some States measure the deficiency in terms of maintenance costs as related to the norm and make no field inspection for rating purposes. If an acceptable adequate standard for maintenance could be established, and then an agreed point established for an indication of critical deficiency we might have a practicable standard which would obviate field rating. But caution is necessary because some roads receive little repair when reconstruction is anticipated, thus the maintenance cost records would belie the true condition. Much research needs to be done yet on maintenance standards, both to determine the proper round-the-year standard, and to determine the point of diminishing return as maintenance costs become excessive and hence indicative of more than routine maintenance. If not based on an optimum standard, allocations made for maintenance can perpetuate an uneconomic sub-standard

and a wasteful deluxe standard. At present, maintenance standards and expenditures vary not only among the States, but among the highway districts and counties within a State. Therefore, cost accounting is generally inadequate.

Safety

In regard to safety, the figures to be presented are nationwide averages. Each State can translate these figures into terms of its own local experience. The nationwide fatality rate for 1959 was 5.4 per 100 million vehicle miles (ranging from 2.5 to 9.6 among the 48 states), the injury rate about 200 per 100 million vehicle miles, and property damage accidents 1,500 per 100 million vehicle miles; and at a cost of about 1 cent per vehicle mile, and more than $2,000 per road mile (6.2 billion dollars for about 675 billion vehicle miles). It has some intolerable components. If the Interstate System had been completed before 1959 the rate for that year might have been 4.8. Beyond that what hope do we have in the immediate future? Of course, as congestion increases, fatalities decrease but total involvements swell. What ideal can be set in rural areas (with a 1958 fatality rate of 7.3) and in urban areas (with a 1958 fatality rate of 3.3)? What can we regard as intolerable? We have suggested that we must keep our standards money based. But here we have one cent per vehicle mile that we can nibble on, and by spending a fraction of a cent per vehicle mile for improvement of hazardous sections, who knows but what we might not reduce the accident bill more than we spend for betterment.

More research should be done with respect to geometry and speed-volume-accident relations and costs. Safety is one of the great historical challenges in highway research. The goal in aviation is to cut its accident record toll in half. Is such a goal feasible in the highway industry where we pay about twice as much accident tax per gallon (14 cents) as we pay in State road tax per gallon of gasoline?

Service

In the service function, or speed-volume relations in terms of capacity, where is the point of diminishing return in capacity and speed-volume relations? Certainly each road section has its own critical limits which can be determined by economic analysis. We know also that there are maximum possible capacities at speeds usually below the desirable.

Programing is a translation of needs into action. Needs studies can provide the basis for this translation and not serve simply as a means of convincing the legislature and the electorate that more money is needed.

Needs studies may use actuarial or road life tables to predict the future because these studies must serve for fiscal planning before the fact. Needs studies can well become a part of the programing process which "translates needs into action by way of the annual budget and in accordance with the flow of available revenue balanced with the flow of urgent projects." Needs studies can be projected into programing, serving as an effective guide all the way through. Actuarial tables from road life studies, used in a complementing trend analysis, will provide an illuminating beam to beacon the shallows and the safe channels. Actuarial tables show average life expectancies, whereas performance ratings pinpoint the remaining life expectancy in a specific project.

Needs, adequacy rating, and actuarial tables change with population growth and shifts, with changes in economic activity, and with changes in use of the motor vehicle. The goal of a needs study is a moving target. Ratings furnish guidance for required shifts in direction to keep focused on the moving target.

If standards are economy based, then priorities should also be rooted in economy, but in the over-all economy, not just in dollars for the user. And a growing economy brings pressure not only for an expansion of facilities but for an attendant upgrading of standards. These observations show that the hand of the comptroller and the hand of the engineer must always know what each is doing.

METHODS AND TECHNIQUES OF RATING

A canvass by the Highway Research Board in June 1960 showed that 38 States make adequacy ratings which are used in varying degrees and for a variety of purposes as previously discussed. Four States are now studying adequacy ratings for technique and feasibility.

Seven of these 38 States are required by law to rate their highways for adequacy. (I do not personally advocate the prescription of an inflexible rating technique nor its precise role in programing, for this would fetter the administrator in his more discriminating judgment and might inadvertently move the program off target. Nevertheless, it might help to have a declaration of intent by the legislature that adequacy ratings be used as a supplementary guide in long-range planning and programing.) In addition to the 7 States which have statutory enactments providing for the rating of highways, 11 states have administrative orders requiring such rating.

Principal rating methods reported in the canvass were:

Sufficiency rating (in various modifications)	32
Deficiency rating (in various modifications)	2
Service	1
Congestion warrant	1
Priority analysis	1
Adequacy rating	1

Methods now being studied include:

Sufficiency rating	2
Deficiency rating	1
Continuous programing	1

Complementing analyses of some type were made by nearly all of the 38 States making adequacy ratings. Among the types of correlative studies reported were capacity, maintenance cost, rate of return on investment, accidents, speed, structural performance, benefit-cost ratio, operating cost, integration, area growth, remaining life, economy, solvency quotient, objective and subjective factors, minimum transportation costs, and serviceability-performance.

Most of the techniques are a matter of record and are familiar to the analyst. The adequacy ratings are detailed in the manuals of the States which make these ratings. With the many types and techniques now in use it is seen that there is no tidy ranking formula.

Some discussion of the type of rating, and its potential role may provide perspective. The methods can be categorized into three groups:

1. Adequacy ratings, which rate safety, service and structural adequacy (included are design-performance ratings, condition ratings, serviceability-performance ratings, capacity and accident indexes);
2. Service indexes alone, which rate adequacy for traffic operations: the quality of traffic flow (included are congestion and capacity indexes, and travel time); and
3. Economic analyses, which rates economic consequences of improvement or non-improvement to user or non-user and reflects the consequences in solvency, insolvency and in the general economy (included are benefit-cost ratio, rate of return, minimum cost of transportation, solvency quotient).

Among the several methods listed some directly measure the characteristics of traffic flow and maintenance operations, while others measure the geometrical and physical attributes. Both types of analyses should be made translatable to the other, but much empirical data on interrelation of the various components are needed to make an accurate translation. More data on performance are needed, for example, to interpret the reading of the Benkelman beam, the profilometer and the roughometer in terms of critical deficiency.

Each index can furnish valuable information. Each index can play a significant part

in the making of decisions. But when comparisons are made by ranking projects in terms of sufficiency ratings, benefit-cost ratio, rate of return, minimum transportation cost, solvency quotient and by other ratings, the rankings do not correspond. It is questionable whether any individual rating method can serve as the sole criterion in decision making.

Why the difference? The answer is that adequacy ratings measure the urgency for action whereas the economic analyses measure the importance of the action. The adequacy rating is blind to absolute costs, it does not prescribe the solution, it simply says that the project is or is not adequate for the existing conditions, pointing out the deficiency. The economic analysis, while highlighting daily economic loss, might not score the adequacy nor show criticalness of condition, nor give an answer for the "poor earner" but critically deficient link. But each has its own purpose which it can serve well. It is suggested that only the critically deficient sections having a warrant for action need a supplementing economic analysis, since all sections have the assumption of justification.

ELEMENTAL AND COMPOSITE RATINGS

There has been considerable debate regarding the wisdom and unwisdom of combining the elemental ratings into composite ratings. There is in each a distinctive purpose and therefore a need for both the elemental and the composite.

The composite can be helpful in a long range appraisal of needs and accomplishments. Yet, in determining an individual project's needs, our Lord's perceptiveness can be applied. He said: "....broad is the way that leadeth to destruction and many there be which go in thereat..." (Matt. 7:13). In other words the road has adequate capacity, and the structural condition must be sound to attract so many, yet its fatality rate is 100 percent. How would you rate it? It just might score a passing mark in our composite index.

The retention of the identity of the individual element and its separate scoring assures notice of any critical deficiency warranting action. It also provides a separate comparability of the systems, counties and States for relative adequacy of safety, of service and of structural conditions.

ALERTING TO IMPENDING NEED

The inevitable critical deficiency of a project is approached with a telling sureness. The period of time from critical deficiency to emergency can be read in the declining periodic adequacy rating for the project. Life curves of the individual project may be platted from periodic ratings, even as the service-life curve of a particular type of pavement in a certain system can be plotted from annual retirement data.

By projecting the historical ratings, a date for an "alert" can be foretold. A study of trend in deviation from standard toward critical might be made for each component, and then an appropriate curvilinear projection would suggest the time for action. With a long lead time (5 or 6 years) required from preliminary survey to contract letting such an alert will allow the requisite time for reconnaissance, location and design before the critical date arrives.

The engineering department can be helped immeasurably in its planning if alerted to the approaching critical index rating when projects must be programed for surveys and plans.

After the alert is sounded it is almost a matter of calculated time until the date of critical deficiency arrives.

Periodic ratings will also bring to light any accelerating or retarding deviations that might eventuate in some switch in rank as time comes for budgeting. All of these procedures, including the calculated date for the alert and critical deficiency can be programed for the electronic computer.

The whole process of programing is ideally suited to Operations Research, to the teamwork of many disciplines moving toward a common objective. The result of rating is the measuring and projecting of trends, the alerting and the ranking, all at the same time. If the rating of any project indicates a marked deviation from the expected rate

of change normal for that kind of project, an alert is sounded for investigation to discover why it is so much better or so much worse than expected.

WARRANTS FOR ACTION

Warrants are determined by balancing the flow of available revenue with the flow of needs. Even as the orbital path of a satellite is determined by a balancing of the centripetal and centrifugal forces likewise the measure of critical deficiency is defined by the two flows of cash and needs, and though the orbit may be erratic, the warrants reflect the equilibrium—a balance determined by many component forces on each side.

I used the traffic signal warrant for several years, calling it an "engineering warrant" but wondering how it was determined. Then one day, the late Dr. Miller McClintock explained the basis for this warrant. He had made a survey of the intersection movements over a large area of Chicago in preparation for the installation of signals. He ranked the intersections in terms of traffic movement, then knowing that the city had allocated a certain sum of money for signalization which was not sufficient to purchase signals for all of the intersections surveyed, he setupon the fixing of a warrant for signalization. Matching signal with intersection volume by rankorder, he determined the traffic movement for the lowest ranking intersection for which a signal could be afforded. This pattern was adopted as the minimum warrant for traffic signal and became a national standard—a standard based on Chicago's economy rather than upon scientific measures of over-all economy of such a regulated traffic flow. Signal warrants have changed since that time, of course.

Warrants are based on standards and standards are based on the "hoped for" rate of meeting needs under the appraised fiscal capability of the taxed beneficiaries. The critical point might not be the same in different States.

The measure of a critical deficiency is a warrant for action. The rating does not specify the action. A "Remarks Column" records and quantifies the deficiency. It names the category and cause of deficiency. The engineer must weigh and choose appropriate action (betterment, reconstruction, relocation, etc.).

A listing of warrants is not a priority listing. A warrant shows only the need for action. If money based, the possibility of eventual action is assured. If not economy based the critical sections may proceed to a state which can only be tagged "emergency." Just how long a project can or should remain on the critical list is a moot question. Available funds over a five- or six-year period should fairly match the warrants for that period. Pyramiding the warrants is both futile and frustrating.

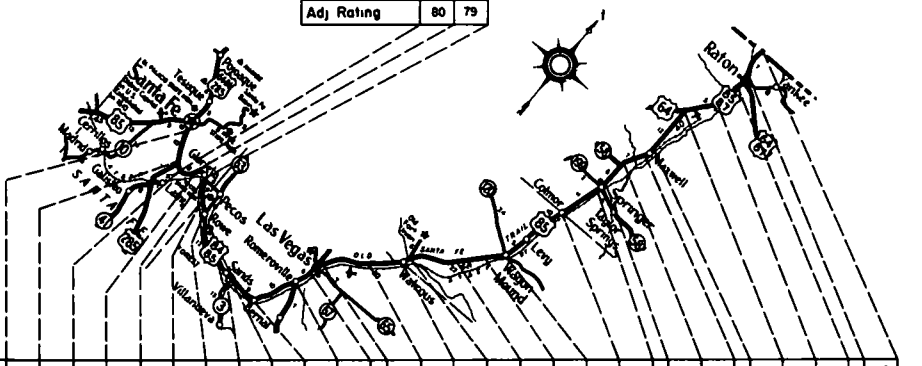
A modification of the classical sufficiency rating procedure was made recently in New Mexico. It provides an excellent means of isolating the critically deficient section—the one with a warrant for action. It also provides a composite index which aids in choosing among the many projects with warrants for action, and to provide trend studies for projects and for systems. The following excerpt is taken from the 1959 New Mexico Sufficiency Rating Report:

> It was decided, in setting out on a fresh approach to sufficiency ratings, that the method should provide as precisely as possible the information needed to determine which sections of highway were critically deficient, the reason or reasons for the deficiency, and indications of the corrective measure needed. (see Fig. 6.)
>
> Before selecting items for evaluation, the conditions obtaining for a highway of complete adequacy were determined. It was agreed that a highway section meriting a rating of 100 should have a thoroughly sound structure, be free from those hazards which can be obviated by road design, and have the capacity to handle satisfactorily the traffic generated by user demand.

N. M. STATE HIGHWAY DEPARTMENT
PLANNING DIVISION

SUFFICIENCY RATINGS ON PRIMARY SYSTEM 1959

Length	3.9	3.2
Surface & Shoulder Width	24 36	24 36
ADT 1958	1945	1910
Foundation & Suface	10 13	10 21
Safety	16	6
Capacity	30	30
Adj Rating	80	79



Length	7.4	2.0	3.9	3.2	3.2	5.1	12.9	2.4	9.0	7.8	4.3		10.0	6.8	2.1	9.0	7.2	5.8	14.6	10.4		6.1	6.0		11.8	6.9	4.9		6.5
Surface & Shoulder Width	22 40	22 36	24 36	24 36	24 36	22 30	24 36	24 28	24 28	24 28	24 32			24 32	24 28	24 26	24 32	24 32	24 32	24 32		24 36	24 36		24 36	24 36	24 36		36 38
ADT 1958	3200	1945	1945	1910	1577	1430	1477	1461	1488	1518	2600		2400	1210	1239	1109	1140	1153	1841	1042		1505	1152		1151	1672	1940		2573
Foundation & Suface	10 12	10 13	10 13	10 23	10 [illegible]	10 [illegible]	10 21	10 20	10 20	10 20	10 12	Urban	Under Constr	[illegible] [illegible]	10 11	10 23	[illegible] [illegible]	10 17	10 17	10 17	Urban	10 14	10 13	Urban	10 13	10 18	10 16	Urban	10 11
Safety	4	[illegible]	16	6	3	10	6	[illegible]	[illegible]	[illegible]	3			7	[illegible]	[illegible]	3	5	4	4		12	3		12	9	5		7
Capacity	?	22	30	30	30	30	29	27	23	23	25			30	30	30	30	30	30	30		30	30		30	30	30		27
Adj Rating	42	59	80	80	67	74	79	73	69	69	60			53	66	79	49	77	76	76		79	71		79	79	73		65

LEGEND
CRITICALLY DEFICIENT
* ADT REPRESENTS TRAFFIC IN BOTH DIRECTIONS ON DIVIDED HIGHWAY

FAP ROUTE 1
(INTERSTATE 25)

Figure 6.

It was concluded, furthermore, that the single figure of the adjusted rating fell far short of revealing all the information desired from the sufficiency rating of a section, and that the adjusted rating was an unreliable criterion in designating a critically deficient section. A plan was adopted whereby each section would be classified as critically deficient when a critical deficiency existed in any one of its major characteristics— structure, safety, or capacity. This approach to critical deficiency is one of the chief differences between the New Mexico method and that of other sufficiency-rating systems.

In many other systems a numerical dividing line such as 60, 65, or 70 is selected as the demarcation between adequate sections and those which are critically deficient. The adjusted rating automatically places a section in the adequate or critically deficient category. However, when priorities are assigned on the basis of adjusted ratings, it is found that certain sections rating below 60 or 70, or whatever the level, are actually adequate for the present because they have no critically deficient factors, while a section with an over-all rating above the required level in reality merits a high priority because of one decidedly critical factor. A re-evaluation is then necessary to identify these exceptions among all of the sections rates.

SYSTEM ADEQUACY REFLECTED IN RATINGS

"Are we making progress toward the goal for adequate highways and is our fiscal program adequate and economical?"

Trends in adequacy ratings provide a method of measuring and comparing the rate of actual progress with the rate of planned progress. The analysis can be made in terms of any of the major components or in terms of the composite. Comparisons can be made between systems, counties, regions or States to determine relative adequacy of any function, the relative need, and relative urgency for improvement, and thus aid in more equitable apportionments.

An economic analysis can also be made to compare the profitability of alternate investments, and the economic consequences of historic actions and of projected action. Although rate of return is not the sole criterion of highway improvement, an analysis of a whole system by rate of return device could provide fiscal illumination.

System solvency should also be analyzed periodically because if a system continues insolvent standards must eventually be lowered, work delayed, or revenue increased. (Here solvency is defined as the revenue "earned" or produced by or for a system.)

PRESENTING THE FINDINGS

If it is difficult to rate a project without a score card, and to sort ranking projects without a rating method, it is also difficult to visualize the findings without a pictorial presentation.

The 1959 New Mexico report observes: "In addition to being one of the useful tools in highway administration, the graphic presentation of sufficiency ratings gives interested citizens an opportunity to view the road conditions of an entire system at a glance, to identify the sections of greatest concern to them, and to compare the condition of these sections with that of others."

Many techniques are available and here the artist and the engineer can use imagination to achieve the most efficacious presentation. The following list of methods by no means exhausts the possibilities:

1. Pictorial, perspective, three dimensional
   (a) Relief, or isoline maps (a series of overlays: topographic, economic, etc.)
   (b) Colors and symbols
2. Functional maps
   (a) Capacity maps
   (b) Accident maps
   (c) Speed, and travel time maps
   (d) Volume, showing purposes, dollar value, etc.
3. Diagrams, charts, graphs (time series, comparisons, cause and effect)
   (a) Straightline logs
   (b) Costs (operating, maintenance, accident, etc.)
   (c) Flow diagrams of funds, programing procedures, etc.
   (d) Historical trends and projections, progress, adequacy, etc.

A colored motion picture with sound is of much more value than black and white still pictures. Psychologists tell us of the value of motion, color and sound to bring to life and attract and hold attention. The whole programing method can be an entertaining story by this method, and can be used for delegations, for training of employees and before legislative committees.

Mapped ratings helps the administrator to more easily select a well-balanced capital budget.

FISCAL PLANNING AND ROAD RATINGS

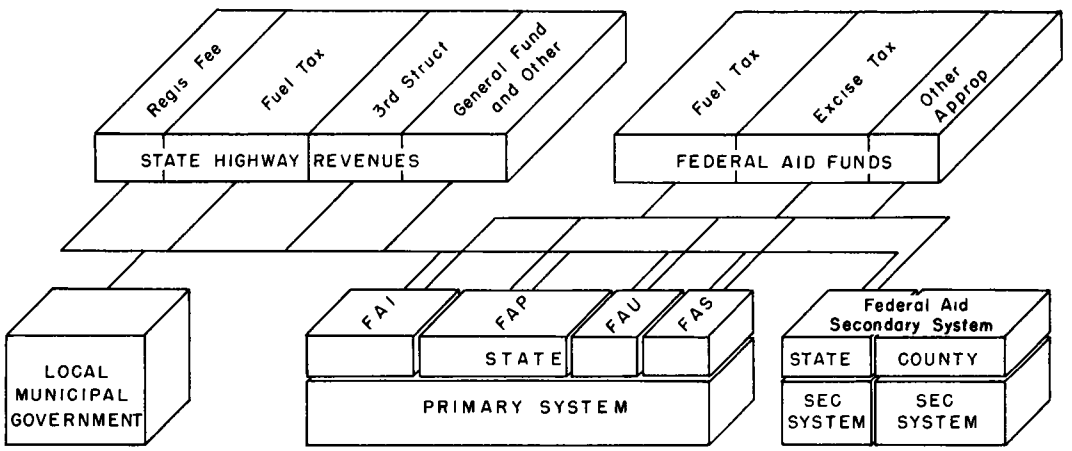
Road ratings focus the attention on the "rolling" 5-, 6- or 7-year advance programing plan rather than upon a 20- or 30-year plan. At this point the fiscal and priority planning must lock step. This re-emphasizes the need to use comparable score cards in rating intolerable sections in needs studies and critical deficiencies

in road ratings. For if the needs are to be translated into fulfillment in a stated period of time then the warrants must be compatible with the criteria for intolerability.

If the needs study projected investment depreciation along with desired upgrading, then there should be no imcompatibility between projected needs and year-by-year warrants. Some years will have more warrants than others and a backlog of unrequited warrants will at times be listed. Inasmuch as some previous years saw fluctuations in amount and kind of construction, so current years will show a fluctuation in amount of critical deficiencies. The differential traffic volumes among the routes, the changes in construction specifications and other changes will also result in fluctuations in annual warrants.

A good needs study supported by a road life analysis can forecast the fluctuations within a reasonable degree and show when backlogs of warrants beyond normal may be expected. But if a backlog of warrants increases consistently and continuously year after year without recession it shows that the needs study, the fiscal arrangements and possibly the criteria or warrants are not in harmony.

An analysis of the questionnaire returns regarding road ratings showed that six States apportioned money among two or three major regions of the State, that 23 States apportioned funds by districts, and 11 States apportioned funds to lesser jurisdictions. Of course, funds are also split among the several systems. This all adds up to the fact that apportionments provide for a spread of projects. This spread has not necessarily been made in accordance with relative need, or equity. Ratings and corollary economic analyses will help determine the relative importance and urgency. Systematic progress toward the goal and a balanced development is often hampered by apportionment formulas unrelated to need. Matched funds would be more realistic if they were allocated in accordance with relative highway need and urgency and fiscal capability of the matching political subdivision (Fig. 7).



Note This shows major revenue sources and major allocations of funds to systems Further distributions are made by: (a) major areas, (b) districts, (c) counties, (d) rural-urban; and (e) cities.

Figure 7. Flow diagram of revenues and expenditures for state highways.

ADEQUATE REVENUES FOR ADEQUATE ROADS

If any gain is to be made the revenues must be sufficient to provide for (a) an extinction of current deficiencies over the planned period, (b) meet continuing deficiencies, (c) plus an increase in need arising from increasing economic activity, and (d) plus anticipated inflation. The target is moving upward in some States faster than revenues.

ROLE OF RATINGS

One administrator said, "There is so much work of top priority to be done, and so little money to do it with that it doesn't make much difference where the work is done—it is worthwhile anywhere if it has a critical deficiency rating." If ethics are not violated in carrying out this philosophy, it might be practical. But the greater the dilemma, the more need there is for the best choice.

What is the role of ratings? As noted previously, they can reveal need for upgrading service function and structural betterment. They cannot reveal need for extension of service because they only rate an existing system. Origin and destination with land-use studies are needed for that determination. But the dominant problem is with the existing roads, and ratings of adequacy, supplemented with economic analyses, afford facts needed for these decisions. And all who are entrusted with responsibility of programing decisions are entitled to have all of the pertinent facts spread before them.

Even in "period programing" where the "Five Year Plan" is lifted out of needs study and budgeted, road ratings can be helpful in making a more precise selection of projects for the annual budget, because ratings will assist in the choice of projects of greatest urgency. In particular, ratings will signal the shifting and changing needs in a dynamic economy. A rating tells what is wrong. An economic analysis tells how to correct the deficiency. Priority ratings say when.

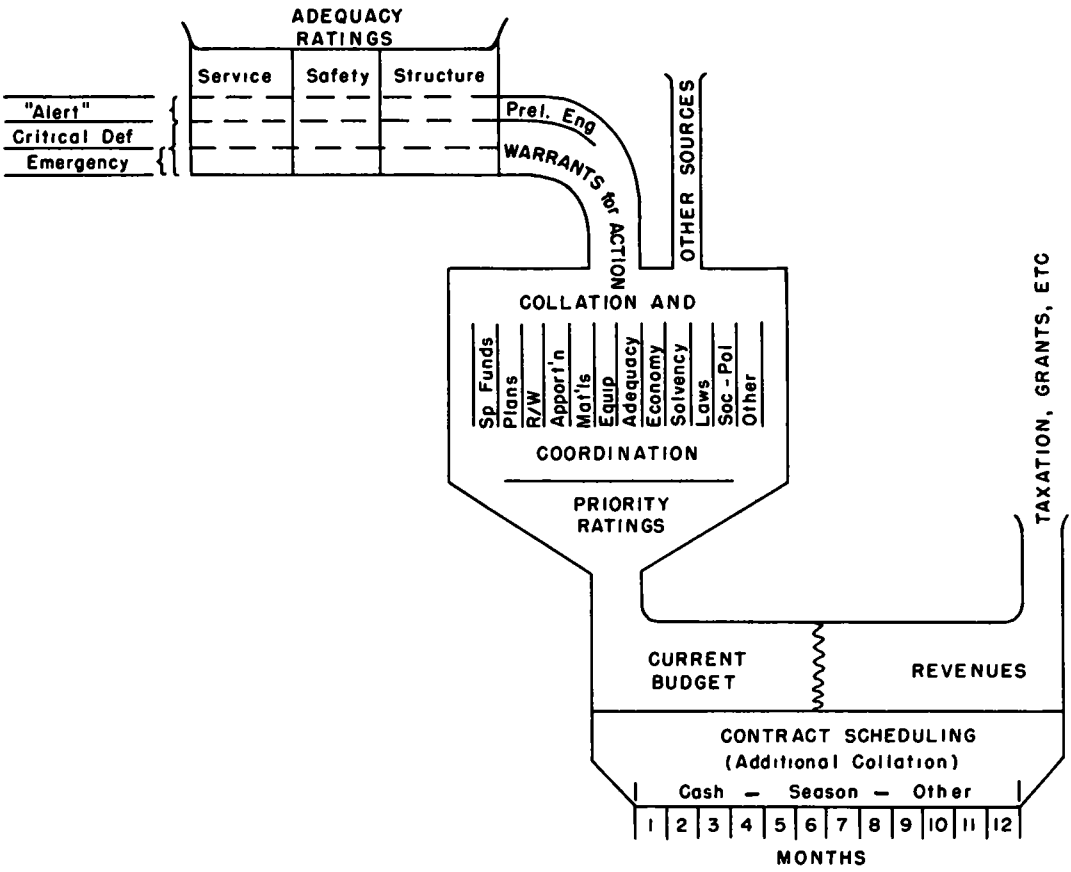


Figure 8. Adequacy ratings to priority ratings.

PRIORITY RANKING

If social consequences paralleled economic consequences, and if skilled men, highway revenue, and road material and equipment were in abundant supply, there might be less need for England's companion paper. But we come now to that point where ratings must be weighed with many practical considerations before priorities come to the top. This paper stops short of priority rating discussion because adequacy ratings are not priority ratings. They furnish one worthy procedure but only one in the total process. Now the ratings must be sorted in piles in light of area needs, availability of funds, plans, right-of-way, contractors and many other factors (Fig. 8). The companion paper tells how this is done.

RELATED RESEARCH NEEDED

Many problems need solution before linear programing methods can serve in highway construction programing. Many research problems will need a solution before the one step of rating is perfected. Needed rating research includes:

1. A polishing of the several methods of economic analysis.
2. Empirical values for weighting items in sufficiency ratings.
3. Comparative analysis of needs studies, road life and sufficiency rating for correlation.
4. Break-even or break-over point, or point of diminishing returns in costs of:
   (a) Maintenance vs betterment, reconstruction, etc.
   (b) Accident vs measures for reduction.
   (c) Volume-speed vs capacity.
   (d) Traffic control and highway improvement.
5. Type of accident by type of exposure.
6. Relation of accident involvement to exposure, by type.

ACKNOWLEDGMENTS

The ideas and material for this paper have come from discussions with highway engineers throughout the United States, and from special canvass. I have acknowledged sources in a few instances, but a listing of all the people to whom I am indebted would include one or more persons from nearly every state. I have drawn freely from these sources and now acknowledge my gratitude for the assistance.

REFERENCES

Highway Programing

Adams, R.W., "Economic Growth and the Highway Program." Proc. Amer. Assoc. of State Highway Officials, pp. 60-66 (1958).

American Telephone and Telegraph Co., Dept. of Operation and Engineering. "Engineering Economy." 195 Broadway, New York, N.Y.

Anderson, J.A., "Simple System of Determining Priorities of Improvement for Low-Type Roads." Proc., Northwest Conf. on Road Building, pp. 98-104 (1959).

Bhagat, D.G., "Adequacy Assessment of Highways." Jour. of Indian Roads Congress, 23:1, Paper No. 207, pp. 117-157 (Nov. 1958). Highway Research Abstracts, 29:3, pp. 6-7 (March 1959).

Carey, W.N., Jr. and Irick, P.E., "The Pavement Serviceability-Performance Concept." HRB Bull. 250, pp. 40-58 (1960).

Charlesworth, George and Paisley, J.L., "The Economic Assessment of Returns from Road Work." Proc., Inst. of Civil Engineers (London), Vol. 14, pp. 229-254, (November 1959.) Highway Research Abstracts, 30:2, pp. 16-17 (Feb. 1960).

Charlesworth, George, Reynolds, D.J. and Wardrop, J.G., "Road Improvements: Choosing Priorities by a New Formula." Engineering (London), 188:4873, pp. 185-188 (Sept. 11, 1959).

Clees, Elmer., "Factual Programming." Proc., Western Assoc. of State Highway Officials, pp. 23-27 (1958).

Donnell, P.M., "Tennessee's Programing Study: First Year's Experience and Techniques for Updating." HRB Bull. 194, pp. 49-60 (1958).

Donnell, P.M., and Tuttle, L.S., "Priorities Determination and Programming in Tennessee." HRB Bull. 158, pp. 63-77 (1957).

Grant, E.L. and Oglesby, C.H., "A Critique of Some Recent Economic Studies Comparing Alternate Highway Locations." HRB Proc. Vol. 39 (1960).

Granum, James O., "Highway Program Evaluations." HRB Bull. 158, pp. 126-131 (1957).

Highway Research Board., "Highway Needs and Programming Priorities." Bull. 249, 1960. 75 pp. Contains: Gardner, E.H., "The Congestion Approach to Rational Programming." Granum, J.O., and Burnes, C.H., "Advance Programming Methods for State Highway Systems."
Hummel, C.M., "A Criterion Designed to Aid Highway Expenditure Programming."
Covault, D.O. and Michael, H.L., "Estimation of County Primary Road Systems Needs by Sample Survey Methods."

Johnston, J.E., "Economic Costs of Traffic Accidents in Relation to Highway Planning." HRB Bull. 263 (1960).

Jorgensen, R.E., "Annual Inventories and Priorities for the Highway Program." Proc., Purdue Univ., 39th Annual Road School, pp. 52-63 (1953).

Jorgensen, R.E., "How Are We Doing? - Where Are We Going?" Paper presented at the Highway Engineering Conference, Univ. of Arizona, Tucson, Ariz., November 20, 1959. 13 pp. mimeo.

Kanwit, E.L., Steele, C.A., and Todd, T.R., "Need We Fail in Forecasting?" HRB Bull. 257 (1960).

Martin, James W., "Programming Highway Construction." Proc., Kentucky Highway Conference, pp. 11-15 (1958).

McMonagle, J. Carl., "A Comprehensive Method of Scientific Programming." HRB Proc., Vol. 35, pp. 33-37 (1956).

Nash, W.W., and Voss, J.R., "Analyzing the Socio-Economic Impacts of Urban Highways." HRB Bull. 268 (1960).

Newcomb, Robinson, "Financing a Highway Program." Traffic Quarterly, 13:4, pp. 504-525 (Oct. 1959).

Newcomb, Robinson, "Highway Planning for a Growing Economy." HRB Proc. Vol. 39 (1960).

Powills, M.A., Jr., "County Highways vs. County Highway Planning." Based on a study "Highway Planning for Hennepin County, Minnesota," published by George W. Barton and Assoc., Evanston, Ill. County Officer, 25:4, p. 115 (April 1960). Highway Research Abstracts, 30:6, pp. 18-19 (June 1960).

Renshaw, R.W., "Treatment of Deferred Costs in Economic Analysis." HRB Proc. Vol. 39 (1960).

Sargent, J.R., "Transportation Programming." Proc., Northwest Conf. on Traffic Engineering, pp. 15-18 (1951).

Steiner, P.O., "Choosing among Alternative Public Investments in the Water Resource Field." American Economic Review, 49:5, pp. 893-916 (Dec. 1959).

U.S. Dept. of Agriculture, Agricultural Research Service., "The Economic Impact of Highway Improvement." (3 parts). Washington 25, D.C.

U.S. Interagency River Basin Committee, Subcommittee on Benefits and Costs. "Proposed Practices for Economic Analysis of River Basin Projects." Revised by Subcommittee on Evaluation Standards. Washington, D.C., U.S. Gov. Print. Office, 1958. 56 pp.

U.S. Bureau of Public Roads. Circular Memorandum to Regional and Division Engineers; from G.M. Williams, Asst. Comm. Subject: Sufficiency Rating Plans in Use by 33 State Highway Departments and the Bur. of Public Roads.

U. S. Bureau of Public Roads. Circular Memorandum to Regional and Division Engineers; from M. B. Christiansen, Chief, Construction and Maintenance Division. Subject: Use of Numerical Ratings by State Highway Departments for Determining the Adequacy of Highway Sections.

Land Use as Related to Highway Development in Rural Areas

Johnson, A. E., "Impact of the Interstate Highway Program on Rural Areas," Proc., Southeastern Association of State Highway Officials, pp. 55-60 (1956).

Keller, W. J., "Land Use Planning in Relation to Highways," Public Roads, 23:1, pp. 5-13 (March 1942). (Delta County, Colorado study.)

Lambert, W. H., "County Road Planning in Relation to the Use Made of the Land." Proc., 23rd Annual Highway Conference, University of Colorado; University of Colorado, Engineering Experimental Station, Circular No. 23, pp. 90-96 (1950). (Discussion of Delta County study.)

Marschner, F. J., "Land Use and Its Patterns in the United States," U. S. Department of Agriculture, Agriculture Handbook Series No. 153, 1959. 277 pp.

Minnesota, University of, Department of Agricultural Economics, "Workshop on Rural Land Use Development," November 20, 1958, Summary of Discussion, 1 p. mimeo.

National Planning Association, "Rural Low-Income and Rural Development Programs in the South," 1959, 22 pp. mimeo.

North Carolina, University of, Institute for Research in Social Science, "In the Shadow of a Defense Plant: A Study of Urbanization in Rural South Carolina; A Final Report of the Savannah River Urbanization Study," (June 1954). 259 pp.

Stout, Samuel E., "The Influence of Current Mode of Transportation on a County," Proceedings, 42nd Annual Road School, Purdue University; Engineering Bulletin Series No. 90, pp. 134-139 (April 1956).

Thompson, Lorin A., and Madden, Carl H., "Socio-Economic Relationships of Highway Travel of Residents of a Rural Area," HRB Bull. 67, pp. 15-21 (1953).

Discussion

Hall.—Referring to Figure 6 from the New Mexico manual, I was interested in the absence of a rating on the urban areas. I wonder, particularly in view of what appears to be generally the high points in the profile, if there will be any comment as to the ratings given to the urban sections on this particular route.

Wiley.—I should answer that, since this chart came out of New Mexico. We do not rate the urban sections any more. We did a few years ago. We did not use quite the same system then, because we ran into different problems there. But the fact is that often we ran into other difficulties, such as routes that were incapable of improvement, right-of-way difficulties, and difficulties of agreement on location and timing, so we found that the ratings did not seem to serve the same purpose in urban areas as in rural ones. For this reason, we have not concentrated much on that since.

Hall.—How are the urban sections placed in competition for the funds with the rural sections?

Wiley.—To the extent that we have urban funds, those are earmarked. But we do spend a certain amount of primary money on primary extensions in urban areas, as well. This is simply done by a determination of the commission itself, depending on when the projects are ready. There is no formula for anything of this kind.

England.—Campbell mentioned the research in connection with geometry relative to accident frequency and the cost of the betterment. Has any research been undertaken in this country with respect to accident experience before and after improvements? I have heard there are some studies being conducted in England.

Campbell.—There has been a number of studies on route improvements and a great deal on spot improvements.

Granum.—You did a lot of work in Connecticut, years ago.

England.—It does not seem to work into this result though.

Morf.—This work is going on in Illinois, and in many other states there have been made before and after studies with freeway construction, and also detail studies of causes of accidents on freeways.

England.—How about on other sections, where there may be a betterment in alignment or a cross-section on a two-lane rural section?

Granum.—There has been quite a bit of work done in Oregon, New York, Texas, Vermont, and Louisiana, but not nearly enough.

Campbell.—Some of the investigations have shown that when you improve a road, you get more accidents. I would not say that that is the usual answer.

Livingston.—I would like to comment that it is not altogether a matter of before and after. It is the accident rate of a road with certain kinds of geometric characteristics, because the accident rate appertains to a certain type of facility, and you are not concerned with whether it was before or after, but just as it affects the road as it exists.

In other words, we take a freeway, compare it with an expressway and with a noncontrolled access highway having certain geometric characteristics. This is where the differences are really critical.

McWane.—There have been quite a few studies by a great many States on accidents occurring before and after improvements, which have provided rather differing results in different cases. In some cases the accident rate has actually gone up after improvement.

But I would like to comment on a study that has recently been initiated by the Automotive Safety Foundation and the Bureau of Public Roads, of searching the literature for investigations that have been made to determine the relationship between geometric features of the highway and accidents. If any of you know of such studies, it would be much appreciated if you would advise Cris of the Bureau of Public Roads, or Shoper of the Automotive Safety Foundation, or me. They are anxious to find all of these scattered studies they can, and by bringing them together think they may be able to get conclusions out of combinations that the individuals have not been able to get from isolated studies.

They also want to know of any extensive studies that have been documented, either published or unpublished.