"HIGHWAY RESEARCH AND USER BENEFIT ANALYSIS"

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We are most appreciative of the invitation to participate in this Eleventh Annual Kentucky Highway Conference which has become an inspiring Kentucky institution. We have come to learn and to unlearn as we share in your program and as we discuss some of the many vital problems of mutual interest.

The content of this paper could be directed solely to highway research as related to highway user benefit analysis but we were advised that the paper is to serve a dual role: First, to acquaint you with the Highway Research Board, itself, and second, to provide a synthesis of present thinking in regard to the Road User Benefit Analysis as a rational and useful analytical device in making highway investment decisions.

At the outset, we desire to make it clear that this paper simply attempts a creative synthesis, and we want to extend credit to the many helpful discussions we have had with members of the staff of the Highway Research Board on both of the subjects presented and especially to Elmer M. Ward, Assistant Director, who prepared in large part the material relating to the Board, and to Robley Winfrey, D. W. Loutzenheiser, Clarence Steele and others of the Bureau of Public Roads, and to Claude Rothrock of the Ohio Department of Highways for their personal assistance, and also to Richard Zettel of the University of California who, along with others, furnished ideas through their writings in regard to the Benefit-Cost Ratio Analysis.

1. Highway Research Board

In acquainting you with the Highway Research Board, since it is an agency of the National Academy of Sciences-National Research Council, a brief picture of the parent organization is presented to provide helpful historical background.

National Academy of Sciences

The Academy itself was established on March 3, 1863 under a congressional charter signed by President Lincoln, as a private, non-profit organization of scientists, dedicated to the furtherance of science and its use for the general welfare. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an advisor to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

National Research Council

In April 1916 when the entry of the United States in World War I was foreseen, the National Academy of Sciences offered its services to the President of the United States. President Wilson at once requested that steps be taken to organize the research agencies of the country, not solely with respect to the necessities of possible war, but also because of the importance of developing and utilizing them more effectively under peace conditions. This led to the establishment, in September 1916, of the National Research Council, a federation of governmental, educational, privately-endowed, and industrial research agencies, resting upon the charter of the National Academy, and extending the scope of its activities into every branch of the mathematical, physical and biological sciences, and their applications to engineering, medicine, agriculture and other useful arts.
For two years the Research Council acted as an emergency or a temporary organization to assist the Government in coordinating the scientific resources of the country in prosecution of the war effort. On May 11, 1918, by Executive Order the President requested the Academy in view of the new and important possibilities of science and research in time of peace as well as war, to establish the Council on a permanent basis. Subsequently, the Council has devoted its energies to promotion and support of scientific research in general, although continuing to maintain cooperative relationships with government scientific bureaus and their activities. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government designated by the President of the United States and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership in various boards and committees. The Council itself is composed of eight major divisions.

Establishment of the Highway Research Board

Included in the eight divisions of the Council is one which concerns itself with Engineering and Industrial Research. On October 8, 1919, representatives of organizations in this Division met in Chicago with representatives from the Bureau of Public Roads and the Mississippi Valley Conference of State Highway Departments to discuss the importance and necessity for the immediate inauguration of a national program of highway research. A report from this group recommended that the Division of Engineering and Industrial Research appoint a subcommittee to cooperate with the Chairman of the Division in coordinating the activities of highway research committees, six such committees being recommended for establishment.

On October 26, 1920, the Chairman of the Engineering Division addressed a communication to the governing boards of certain national organizations, federal and state highway departments and educational institutions stating the need for highway research, indicating the projected committee organization and inviting representatives to a conference for the purpose of completing the organization.

On Armistice Day, 1920, this meeting was held and the organization accomplished. From the time of its organization in 1920 until 1924, it was known as the Advisory Board on Highway Research of the National Research Council.

As constituted, the Board is a cooperative organization of highway technologists of America operating under the auspices of the Academy-Research Council and with the support of the several State highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway technology and transportation.

purposes of the Board

The purposes of the Board are to encourage research and to provide a national clearing house and correlation service for research activities and information on highway administration and technology by means of: (1) a forum for presentation and discussion of research papers and reports; (2) committees to suggest and plan research work and to correlate and evaluate results; (3) dissemination of useful information and (4) liaison and cooperative services.

The Board does not maintain scientific laboratories, or generally conduct original research in its own name, but seeks to correlate and integrate the work of individuals and organizations for a directed and coordinated attack upon the many unsolved problems in the highway field and to publish and disseminate the information thus obtained.

Highway Research Board Organization

The Board is composed of 48 member organizations and approximately 1700 individual associate members. The administration is carried on by an Executive Committee of twenty members, five of whom are ex officio. These are the Execu-
The technical work of the Board is done by committees composed of specialists which are organized under six major departments: Economics, Finance and Administration; Design; Materials and Construction; Maintenance; Traffic and Operations; Soils, Geology and Foundations. The Chairmen of these departments serve at the discretion of the Executive Committee and with the members of the department are responsible for planning the over-all research program, suggesting projects for research, providing counsel on research methods, sponsoring and screening papers which are not referable to committees, reviewing activities of the several committees of the department, and providing an annual report to the Board on department and committee accomplishments.

Committees
During the past year the Board's six departments and 85 technical committees were active in conducting highway research and in analyzing and correlating the results of completed work. The Board's committee roster now includes 799 men who fill 1,308 committee assignments. The members are selected on the basis of their eminence in the fields or subjects under consideration and are appointed from State highway departments, federal agencies, colleges and universities, counties, cities, industry and other relevant agencies. Technical assistance to the committees is provided by the permanent staff of the Board. Appointments to the committees are made upon recommendation from the respective chairmen to the Department Chairman. The Department Chairman then forwards his recommendations to the Board and the official letters of appointment on behalf of the Chairman of the Board and Executive Committee are sent from the Director's office.

Research Correlation Service
Fourteen years ago, in response to an expressed need and with the support of the State highway departments, the Board expanded its service of stimulating research and of disseminating information through the institution of the Highway Research Correlation Service. An initial and continuing objective of the Service is to find out what highway problems exist that might be solved by research, to assist in the establishment of research project committees or in arranging some other appropriate means to solve the problem, and to convey the findings to all interested persons.

In accordance with the adopted plan for correlation service, the Board has five professional engineers, each of whom is specializing in one or more of the branches of highway technology represented by the six departments under which the technical committees operate. As members of the technical staff, these engineers serve their respective departments and committees with technical assistance. A considerable part of their time is spent in making periodic visits to the State highway departments and other agencies engaged in highway research, where they sit down with the administrator and researcher and discuss their problems of operations and research activities, thus acquiring and disseminating first-hand information on developments of a nation-wide highway research program amounting to an annual expenditure approaching ten million dollars. Hence, through the field contacts of the technical staff the correlation service links each State highway department with the other State highway departments, federal agencies, universities and colleges, and industrial organizations engaging in highway research.
In addition to the liaison provided by the staff engineers, other special services are provided, such as: help in formulating research projects, preparation of special bibliographies, search for specific library information, compilation of regional practices or procedures relating to special problems, preparation of lectures for conferences or schools, and other related services.

Annual Meeting

One of the most valuable functions of the Board has been that of providing a distinctive meeting place for highway engineers and technologists where they may present the results of their research work and have them discussed by others interested in the same matters. During the first week of January the 38th Annual Meeting was held in Washington, D. C. and was attended by more than 2100 interested persons from all sections of the United States, Canada and several foreign countries. 180 technical papers covering every phase of highway work were presented and discussed at 41 sessions during the week. In addition to the technical sessions, the six departments and 78 of the project committees held business meetings.

The papers and reports presented at this meeting as well as reports of findings from special projects administered by the Board will be published in proceeding, Bulletins, Special Reports, Research Reports, Abstracts and Circulars throughout the year. This will amount to approximately 75 publications involving over 4,000 pages of printed material. These publications are disseminated to the State highway departments, the Bureau of Public Roads, engineering colleges, Member Organizations, Associate Members, library subscribers and by sale on order.

Special Projects

This provides a cursory resume of the organization and functions of the Board. In addition the Board is occasionally requested to administer large-scale field research projects. In 1950-51 a group of twelve northeastern and North Central States, including Kentucky, sponsored what was known as Road Test One-MD. Conducted on an existing Portland cement concrete pavement near La Plata, Maryland, this project had four test sections and cost about one quarter million dollars. From 1952 to 1954 a group of eleven Western States and Alaska sponsored the WASHO Road Test at Malad, Idaho. Conducted on two specially-built loops of asphaltic concrete, this project had 40 test sections and cost about a million dollars. We are now engaged in conducting a third test known as the AASHO Road Test at Ottawa, Illinois, the largest and most comprehensive highway research project in history. The American Association of State Highway Officials (which includes Kentucky) is sponsoring this test. This project has 836 test sections and will cost about 22 million dollars. These funds come from all 48 States, the District of Columbia, Hawaii, Puerto Rico, the Bureau of Public Roads, the Automobile Manufacturers Association, and the American Petroleum Institute. The Department of Defense is cooperating and assisting in the test by providing the drivers for the 70 test vehicles which operate about 19 1/2 hours a day six days a week. Inasmuch as a speaker is appearing on this program to discuss the AASHO Road Test, no further details regarding it will be given in this paper.

Summation

It is hoped that from this resume you have gained a better conception of the organization and functions of the Highway Research Board. In short, the functions of the Highway Research Board may be summed up in the words of welcome to those attending its Second Annual Meeting (November 23, 1922) by Dr. Venet Kellog, who at the time was Permanent Secretary of the National Research Council. Dr. Kellog said: "... the Council has an extremely wide and catholic interest in science, an interest that extends from the science of the structure of the atom to that of the laws of the stars; from that of the nature and behavior of a single living cell to that of the nature and behavior of man. It has an interest in the purest of so-called pure sciences, and in the most practical of applied sciences."
Organizationwise, in bringing together as it does a variety of disciplines, and
drawing upon highway research personnel from all parts of the free world in
volunteer efforts, the activity of the Highway Research Board has been called one
of the greatest and most remarkable cooperative efforts in the advancement of
science. Those who conceived of the possibilities of an Advisory Board of Highway
Research never dreamed of the potential of the organization as evidenced by such
devotions as comprehended in the cooperative work of 85 project committees and
in the more dramatic 22 million dollar cooperative endeavor known as the AASHO
Road Test.

II. Highway User Benefit Analysis

The Problem

In 1922 a report of the Director of the Highway Research Board noted the
expenditure of six-hundred million dollars during the previous year for highways
in the United States. In this report, in pointing out economic problems issuing
from the expanding highway effort, he stated that the cost of operating vehicles
was much greater than providing improved facilities for their operation. By way
of illustration, he said that a reduction in grade reduced operating costs, and then
be raised a question—quite similar in substance to questions engineers are raising
today—"how much can an engineer afford to spend in capital costs of construction
in reducing grades?"

If engineering economy was a vital factor in 1922 to a determination of how
to get the greatest benefits at least cost in the annual investment of six-hundred
million dollars, it is no less important in 1959 to a determination of the most
judicious annual investment of ten and one-half billion dollars.\(^1\) In the first in-
stance there was pressure to extend surfaced mileage at the sacrifice of adequate
standards. This sacrifice led to early obsolescence. Today there is some sacrifice
of deliberate action to the pressure of urgency. This sacrifice could lead to un-
 economical use of resources.

Purpose of Highway Construction

Digressing, or rather backing up for a moment, we might inquire: "Why are
highways improved, or new ones built?" The usual answers are: (1) to correct
or provide a substitute for obsolete roads (inadequate geometric standards for
current traffic requirements resulting in congestion, accidents, inconvenience, dis-
comfort, etc.); (2) to provide facilities more nearly coincident with major traffic
desire lines which may have shifted; (3) to correct or provide a substitute for
deteriorated pavements and other structures (structural depreciation which results
in higher maintenance costs and vehicle operating costs, time losses, accidents and
discomfort); (4) to provide new access for resource and land development (this
purpose has not been considered an obligation of highway departments with the
same priority as the first three purposes, and policies vary somewhat among States
regarding the building of access roads.

Need for Expansion of Highway Facilities

The rate of annual increase of the gross national product and the rate of over-
all increase in vehicular miles have closely paralleled each other for quite a few
years, but with vehicular miles rising faster. It seems logical to assume that the
rate of increase of highway traffic would exceed that of the GNP, if there is suf-
ficient highway capacity to allow the increase, for these reasons:

1. The number of families owning two or more cars continues to increase
with consequent increase in travel;
2. As population increases, urban areas expand spatially and more driving
per capita ensues;

\(^1\) The 10½ billion dollar over-all (Federal, State and local) expenditures for 1958 was
3. Rate of personal consumption expenditures (including transportation) is increasing slightly faster than the GNP is increasing thus creating more traffic;
4. Shifting of transportation from rail to highways is increasing highway traffic;
5. Shifting of travel from mass transit to automobile increases highway traffic;
6. Shorter work week encourages more travel;
7. Increasing number of older people driving as longevity increases adds to highway traffic;
8. Delivery trucks giving way to shopping and delivery in private auto on "cash and carry" basis increases highway traffic.

It has been estimated that the GNP will increase at the rate of about 3/4% per year, compounded annually, and that traffic in order to "stay even" with GNP increase must increase at the rate of 5% per year, compounded annually. What this would mean in highway facility increase in terms of additional lane mileage and cost is hard to say. To some extent there may be a current excess in system capacity, and to some extent there may be elasticity in system capacity; therefore, there might not be a straight-line relationship between the increase in traffic and the increase in lane-mileage requirements in order to preserve the status quo in service.

We know that when a new expressway is built through a congested traffic corridor, there is an increase of traffic through the corridor which may exceed the assumed normal rate of growth by as much or more than 25%. This new increment of so-called "generated" or "induced" traffic may be that component of normal traffic growth which was denied because of inadequate highway facilities. I am not prepared to say how to quantify the benefits from this increment of traffic, but it seems reasonable to assume that there are benefits from the release of this traffic which was previously bottled up.

When one considers the somewhat parallel growth of the GNP and traffic—noting that they "go hand-in-hand", so to speak, it is impossible to separate one from the other and say "this is cause and this is effect." They are mutually dependent and within limits a change in rate of growth in either one might be reflected in a change of rate of growth in the other.

**Development of Benefit-Cost Ratio Concept**

This preamble it is hoped, evinces the need not only to continue to invest in highways but to obtain the greatest possible returns in proportion to the amount invested. This philosophy is not new, and was put into succinct words by Professor W. M. Gillespie more than 100 years ago. More recently, in 1937, Technical Bulletin No. 7 entitled "The Economics of Highway Planning" published by the Oregon State Highway Department—still recommended for reference—suggests a method of evaluation called the "Benefit Quotient". The principle embodied is based on the concept that the best investment for the user is the one which returns the greatest benefits per dollar of cost.

Still more recently, in 1952 (with reprints in 1955 and 1957), "Road User Benefit Analysis for Highway Improvements", an informational Report by the Committee on Planning and Design Policies of the American Association of State Highway Officials was published. This 137-page report provides in detail the concept, method of analysis, measures of benefits, and the relevant data need in "Road User Benefit Analyses" which is also referred to as the "Benefit-Cost Ratio Method of Analysis."

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1 Robinson Newcomb, Economist, in an address on January 22, 1958, also in the June 19, 1958 issue of Engineering News-Record in an article entitled: "Highway Program is Big—But It's Not Big Enough!

Quite a few eminent engineers and economists have treated this subject as will be seen by reference to the appended bibliographies. This paper, therefore, will not attempt to detail again what has been done so well in these other treatises. Rather, this paper will attempt to define, place the method in perspective as an economic tool, note its intended function and limitations, note the differences of opinions regarding components of formula and measurements of benefits, and finally report some research underway and research needed.

Let me reiterate that my contribution is one of synthesis rather than formulation of concepts.

**Definition of Benefit-Cost Ratio**

A method to guide in selecting the most profitable among possible alternate highway locations (between common points) from the standpoint of engineering economics, by comparing annual user benefits of subject facilities with the added annual costs. Some analysts hold that each alternate must be compared with an affected existing facility, while other analysts hold that the B/C ratio may apply also to compare two or more new locations, one with another, regardless of whether there be an affected existing facility.

**Cost Computation**

Annual costs as herein used consists of amortization of capital investment plus interest, plus maintenance and operation.

If the improvement consists of *modernizing an existing road* through additions, betterments, or reconstruction, the added cost is computed (1) by determining the projected annual cost of this improved highway (annual costs of the existing road, whether retained in whole or in part or not at all, plus the projected annual costs of the new capital investments). (2) by determining the projected annual costs of the existing highway, and (3) by deducting the projected annual cost of the existing highway from the projected annual costs of the improved highway.

If the improvement consists of *relocation* (either a generally parallel facility, cut-off, or bypass) with or without improvement to the affected existing highway(s), the added cost is computed (1) by determining the projected annual cost of the relocation plus the annual cost of the affected existing highways, (2) by determining the projected annual cost of the affected existing highway(s) assuming no additional facility to be built, and (3) by deducting the cost computed in (2) from the costs computed in (1). (In broadening the concept of the B/C ratio to compare new alternates with each other the same general method outlined above would apply.)

It will be readily seen in following this procedure, that that part of the projected annual costs of the existing highway which consist of amortization and interest might be nearly identical in step 1 and 2, while the projected maintenance and operations costs might change.

In explanation of the identical amount for amortization regardless of whether the existing highway is retained in whole or in part or not at all is this fact: the amortization period and resultant annual costs (or "payments") are based on the estimated service life of the several component parts of the composite highway and annual costs, or "hypothetical payments" would continue until the end of the assumed amortization period regardless of what happens to the physical highway, itself. Even though it were razed as soon as built, the annual capital costs and interest would continue until the end of the assumed amortization period. (Note that the amortization period, or pay-off period, of the existing road and the improved road will not end at the same time, nor do the time periods need to be coterminous for this analysis). This concept is made clearer when one thinks of the existing highway as being financed by bonds, and perhaps even clearer when one considers self-liquidating bonds used to finance a toll road.

Incidentally, it might be mentioned at this point that benefit-cost ratios, revenue-cost ratios, and rates of return which depend upon an amortization period...
longer than the estimated composite life period to show a favorable ratio are not
good investments, generally speaking. The paving of earth roads furnished sub-
stantial benefits in the 'twenties but we have seen certain roads relocated and
reconstructed twice within a bond amortization period, because of early obsolescence
resulting from "mileage stretching" specifications designed to get the road user
out of the mud. Thus the highway department was servicing a second bond
issue on the most recently relocated highway while still servicing bonds on two
other abandoned locations. The benefits of getting out of the mud were high and
if the revenue were sufficient to redeem the bonds during the service life of the
road, the amortization period should have been made shorter. Service lives are
uncertain on the individual project, to be sure, but the knowing employment of
sub-standard design is certain to shorten the service life.

To get back to the main line again, it is seen that added costs consist of the
annual cost of the improvement plus any increase, or minus any decrease in pro-
jected maintenance or operations cost on the existing highway.

**Benefit Computation**

Annual Road User Benefits consist specifically of savings to the traffic traveling
between common beginning and ending points which is directly involved or
affected by the improvement. It should be noted that the benefits herein com-
puted stem from difference in "costs of service", rather than from difference in
"value of service".

The savings are computed by (1) calculating the projected annual costs of
incidental user-cost items (vehicle ownership, operating, and time costs for vehicle
occupants, goods, etc.) for a selected time period\(^4\) for the traffic using the
"affected" existing highways assuming no improvements to be made, either by
relocation or modernization of existing highway(s). [However, in making the
computations beginning and end points should be selected which will be common
for a considered relocation]; (2) by calculating the projected annual costs of in-
cidental user-cost items (vehicle ownership and operating and time costs for
vehicle occupants, goods, etc.) for the same selected time period as in (1) for the
diverted traffic over the improved facility and residual traffic over the existing fac-
tilities between the common points noted in (1) above;\(^5\) (3) by deducting the costs
computed in (2) from those computed in (1).

Note: Common beginning and ending points need not be a single pair of zones or
points but may be any number of pairs so long as the improved section is
included in the circuit and the total benefits and the total added costs as
computed separately for each pair of zones or points and then summed for
the calculation of the total cost-benefit ratio.

**Concept Translated to Formula**

In developing the concept for translation into a formula, we see that benefits
are related to added costs, or

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\(^4\) This may be the same as the "amortization period" or estimated service life but is often
less because of the uncertainties involved in traffic forecasting as well as uncertainties in
predicting service life of the "composite" highway. However, the two periods need not be on
incident, so long as the same "amortization period" and same traffic forecast period are used
on the several alternates because the B/C ratio will retain the same rank or relative position
in the array of these ratios. An extended traffic forecast period—coincident with the amorti-
zation period—would serve to make a more favorable B/C ratio, but this would apply in the same
measure to each alternate and would be the same as multiplying each B/C ratio by the same
factor—it would enhance the value of each without changing its relative position.

**Benefit-Cost Ratio** is not used as the sole criterion for justification of a project, it can be required
that the traffic forecast period and the amortization period need not be co-extensive, although
the traffic forecast period should not be longer than the amortization period, and it would be
ideal if the same period could be used for each. If costs are computed separately for the esti-
ated service life of each component of the highway, it follows that the traffic forecast period
could not be the same as the several amortization periods.

\(^5\) Normal growth is projected for the diverted and residual traffic volumes. Generated or
induced traffic is not included in the computations by some analysts.
The Benefit-Cost Ratio as herein described does not purport to appraise a project for economic justification nor to establish priority rating among isolated construction projects on a system-wide basis. Although the method has been used as an auxiliary guide for both of these purposes, strictly speaking, its purpose is to provide help in choosing among alternate highway locations serving common beginning and ending points—a closed circuit or circuits over the improved highway is held to be necessary to the computation by some analysts. Parenthetically, it might be stated that the ratio, as such, is not an indicator of tax responsibility of the benefited users of the appraised projects, nor is it intended for use in fund apportionment.

In order to establish economic justification for a highway project, the solvency (Revenue-Cost Ratio) of the project should be appraised. Solvency appraisals are involved with detail and questions such that the subject cannot be included in this paper. However, it is pointed out that in computing revenue derived from a project, some consideration should be given to project length in relation to user trip length, and to the improved highway’s effect on general taxation as well as user taxation. Another facet of the subject is that the rate of return on the investment should be at least equal to the going interest rate, and some economists suggest the use of the method known as rate-of-return as a corollary tool for appraising alternate projects for priority selection.6

6 Principles of Engineering Economy (1950) by Eugene Grant.
The failure of an individual project to measure up favorably either in B/C Ratio Analysis or Revenue-Cost Ratio Analysis does not automatically eliminate the project from consideration. Such elimination would serve to perpetuate bottle-necks on what otherwise would be a free-flowing system. The maintenance of system integrity is more essential than that each project show up favorably in revenue and costs. Nevertheless, an analysis should be made of each proposed project to determine how its affects the system economy lest blind selection of projects lead to an insolvent system. Too many financially unsound projects could lead ultimately to a financial collapse of the entire system.

Another area that should be examined—although at present not includable as an item in the B/C Ratio—is that of the economic benefit to abutting land and to the community as the result of highway improvement. Some 43 studies of the economic impact of highway improvement (impact on land use, land value, etc.) are now in progress in 23 states. The findings from these studies will need synthesis before they can generally be utilized in a justification or priority formula.

In connection with making the selection from the top-ranking B/C Ratio the question has been raised: “Suppose that some other alternate whose ratio is not as favorable numerically provides much greater benefits and that by spending a little more money these greater benefits can be realized, which then of the alternates should be chosen? If one holds strictly to the concept of maximum benefits per dollar of investment, the top-ranking alternate would be chosen. But it might be demonstrated by the “Second Benefit Ratio” (See p. 136 of the AASHO “Road User Benefit Analysis for Highway Improvements”) that by comparing the added benefits of the second choice over the first choice to the added costs of the second choice over the first choice a favorable B/C Ratio obtains and the second choice might be moved into first place if the revenue side of the picture justifies it.

We have heard the comment regarding a proposed location: “That’s where it ought to be but we don’t have the money to build it there”. In many cases this is a commentary on the need for increased highway revenue. In nearly every such case there comes the day when the computing of a Benefit-Cost Ratio becomes necessary the second time and the road again relocated.

Some analysts prefer to compare the alternates on the basis of total transportation costs of each, i.e., the sum of road-user costs and highway costs. This provides another valuable method of comparing alternates, where, of course, the route with the lowest total cost would merit favorable consideration.

Comments on Formula Components

While there is general acceptance of the component parts of the numerators R—R, there are some analysts that consider it an unnecessary refinement to employ the denominators, H—I but instead would compute and use a denominator consisting of simply the cost of the improvement, which is usually not far from H—I.

Includable Items in Benefits

Items relating to user benefits which can be measured and translated into monetary value are usually acceptable. Items which are not reducible to acceptable monetary equivalents, items which might be of substantial proportions but are non-compatible in terms of monetary equivalents, are excluded by some analysts. Hence, such items as suffering and death as result of accidents would be excluded—but not the actual monetary costs resulting therefrom—, also such items as comfort, convenience, time spent in pleasure driving. Nevertheless, both in justification and priority determination all of these non-compatible items should be given consideration, but assigning unreal values to items such as comfort and convenience can easily tip the scale to a desired end. Assumed values can swing the scale either way.

Caution should be exercised that each item included as a benefit bedefensible or we may gain nothing—we are just transferring money from one pocket to another without any actual economic gain.
APPENDIX A

Relevant Research Underway

The following items of research now being conducted will be useful to the B/C Ratio Analysis:

1. Research into truck operating costs is being conducted under the sponsorship of the HRB Committee on Economics of Motor Vehicle size and weight and may be reported during 1959.
2. Research into cost of traffic accidents is continuing in several States in cooperation with the Bureau of Public Roads and additional reports will be published as studies are completed.
3. The Highway Safety Study being conducted by the Bureau of Public Roads, which should provide information with respect to analysis of accident costs and which will be useful to the B/C Analysis, is to be reported to Congress on March 1, 1959.
4. The AASHO Road Test now being conducted at Ottawa, Illinois, by the HRB when completed and analyzed should provide useful data on road costs and also vehicle operating costs.
5. The so-called “210 Study” or Highway Cost Allocation Study being conducted by the Bureau of Public Roads is progressing with another report due to Congress March 1, 1959, and a final report due January 3, 1961.
6. The HRB Committee on Highway Capacity is accumulating and analyzing new data with the objective of revising the Highway Capacity Manual, useful in B/C Ratio Analysis.
7. The study of principles of engineering economy as applied to highway improvements is underway at Stanford University, Palo Alto, California, under the leadership of Professor Eugene Grant. Analytical methods of solving two questions are sought: “Should the project be built at all?” if so, “what are the relative economics of various features of the project?” Some progress is expected in a year or so.
8. Some 43 or 44 studies of the economic impact of highway improvement are underway in 28 states. Some of these are short-term studies, and some long-term (5 to 10 years, or more). When completed and synthesized, the findings from these studies should yield information relative to economic gain and shift.

Questions and Problems to Be Resolved Through Research

1. How to handle extra costs to users and abutters during period of construction.
2. How to handle traffic operating costs to State during construction.
3. What consideration should be given to stranded business establishments.
4. What costs result from control of access.
5. How to adjust for disbenefits to abutting property owners on account of noise, fumes, and traffic-related dis-economics.
6. How include generated traffic in B/C Ratio.
7. Should B/C Ratio be based on whole trip lengths between O and D, or on traffic within control sections. It is readily seen that an expensive
bridge, tunnel, railroad separation structure, etc. might not qualify in terms of benefit or solvency ratios, yet they may be a small link in a chain that would qualify in both. How long should a project be?

8. Up-dating of values given in AASHO Manual is need ed periodically and for geographic regions.

9. Should benefits per user or benefits per vehicle mile be criterion for selection?

10. What is the relation of B/C Ratio to revenue driven from general fund?

11. To what extent is the equal and opposite reaction principle of physics applicable in economic analysis, e.g., in analysis of gains—are there offsetting losses? Are user benefits from increased safety regarded as disbenefits to lawyers, doctors, etc.?

12. Is it too much to anticipate a rational economic concept—such as the mass-energy concept—embracing the whole economy and a way to fit into it the field of highway need and finance which can be subdivided for application of the various component problems, instead of so many isolated entities in analytical methods?

13. How much can one afford to pay in taxes and other costs for time, comfort and convenience on highways. What is the best that can be provided in the different systems to obtain the greatest economy. If “benefits” do not reduce out-of-pocket costs, to what extent can we afford them.

14. How compare the economy of stage construction against initial completion.

15. The economic impact of highway improvement spreads like waves from a pebble dropped in a pond. One does not measure the kinetic energy of the pebble by measuring and adding the transmitted energy in all the waves, yet in highway economics we have found no other way to analyze the transmitted economic change.

16. How can the Siamese Twins of shift in economic wealth and net gain be separated. In some cases what is thought to be net gain is the realization of a potential for any likely area—“what might have been “waiting to be” in any area and “happened to take place at this time and place.”

17. How can the estimated increase in vehicular miles be translated into lane mileage figures.

18. How can reliable traffic forecasting methods for individual projects be devised?

19. Objective determination of monetary value placed on time by various classes of road users, and whether value increases linearly with increase in time saved per individual trip—should a sliding scale be employed for value of time—if so, how determined?

20. Determination of monetary values of non-user benefits and whether or how to include in B/C Ratio Analysis.

21. Objective determination of monetary value placed on comfort, convenience, freedom of movement, and other intangible values.

22. Determination of service and dollar life of the several components of a highway as related to design, traffic, weather, and other factors.

23. Determination of vehicle depreciation factor as affected by highway type and condition, and method of separating mileage and time factor.

24. What items and what value should be used in traffic control and operations (e.g. police patrol)?

25. What administrative costs, if any, should be assigned to highway costs.

26. How determine value of highway to National Defense and general welfare and whether such value be included in B/C Ratio Analysis.

27. Is taxation included in B/C Ratio? Should any part of general fund taxation be included.

28. Should motor vehicle insurance be included—if so, what coverage?
APPENDIX B

BENEFIT-COST RATIO ANALYSIS

Highway Research Board
Library
Selected References


APPENDIX C

ANALYSIS OF ROAD USER-BENEFITS

Selected References


APPENDIX D

SELECTIVE BIBLIOGRAPHY ON VALUE OF TIME, COMFORT AND CONVENIENCE

Compiled in Bureau of Public Roads Library, September '58


Los Angeles, City Engineer. The Economy of Freeways. Los Angeles, 1953, 14 pp.


APPENDIX E

SELECTIVE BIBLIOGRAPHY ON VALUE OF TIME, COMFORT AND CONVENIENCE

Compiled in Bureau of Public Roads Library September 1958


APPENDIX F

Economics of Highway Planning
Selected References

Bacon, Edmund N. Urban Redevelopment and Highway Planning. HRB Bulletin No. 64, pp. 9-12, 1952.


