

CURRENT ASPECTS OF RESEARCH ON ECONOMIC LIFE OF HIGHWAYS

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SYNOPSIS

Radical changes in our national economy have resulted in corresponding changes in the nature of current highway research. Large amounts of work connected with research on economic life of highways have been suspended for the duration. However, the opportunity is here now to observe performance of highways under conditions of severest stress in their brief history, and the data now being made a matter of record in connection with each highway improvement embody the kind of evidence required for evaluating performance characteristics of the highway plant. Such data can be readily assembled and analyzed at a future date as the occasion may demand.

Past research on economic life of highways has been directed toward a determination of the annual cost of highways. Eventually depletion and replacement of the highway plant will become stabilized and equal in amount. The trend to that ultimate stage of development can be checked temporarily and actually reversed for a short time by major improvement programs, but it cannot be stopped indefinitely. Once this stage of development is reached, all revenue available for highway purposes must be used for maintenance and replacement of worn-out sections to the exclusion of further extensions or substantial increases in standards of service being rendered, wherein the attainment of such extensions or improvements in standards results in further increase in capital outlay for the highway plant.

The achievement of post-war improvement programs will have a tremendous effect upon the economic development of the country during the interim period that highways built under such programs are rendering service. Related to the costs of obtaining this service are such detailed problems as local rehabilitation work, size of construction contracts, preparation of adequate plans, alternate bids, standardization of construction types, establishment of maintenance sections correlated with construction programs, etc. All of the foregoing must be given consideration in the efficient and effective management of the post-war program at the end of the present emergency, and each has its individual effect on the economic life and annual cost of the highway system.

Since the beginning of the present war emergency many remarkable transformations have been achieved in various phases of our national economy. It has been in the national interest to generate tremendous activity in new war-time enterprises, and to expand, curtail, and suspend certain other activities of our normal peace-time enterprises; and because of the intricacies of our economic system, such vast changes and adjustments affect every individual.

As the result of a national program to prolong the usefulness and service expectancy of existing assets, and to conserve national wealth to the utmost, many far-reaching incursions upon the American way of life have been made. There was no precedent to aid in effecting

these organic changes. Decisions, nevertheless, had to be made expeditiously and efficiently, new and untried policies were formulated rapidly and were synchronized with other nationwide changes in our national economy.

Prime examples may be observed in the fundamental changes accomplished in the motor vehicle manufacturing industry, and in the adjustments made in the operation of our vast system of highways. In December, 1941, it became necessary immediately to gear highway service fully with the all-out war effort. Long range planning was temporarily sacrificed in the interests of an energetically prosecuted highway program to provide immediate and satisfactory service in response to demands created by the establishment of new war in-

dustries, by the change in the traffic pattern, and by the increased frequency of heavy axle and gross loads. Labor restrictions and a priorities procedure governing production and sale of equipment and materials developed rapidly. Programs for construction and maintenance of highways were scrutinized in detail and approved solely on the basis of merit and importance to the war effort. In retrospect it may be observed that the success of the undertakings has been the result of proper appreciation, interpretation, and evaluation of the numerous elements involved in the programs which produced such radical and rapid adjustments.

A major contribution in the accomplishment of these changes in highway administrative policies and procedures in an orderly manner under the most adverse conditions has been made through use of factual data amassed by the State-wide highway planning surveys. Although it is true that many functions of the surveys have since been curtailed or suspended, it should not be hastily inferred that these operations were unnecessary, but rather that their value lies primarily in usefulness of application to conditions existing in peace time. When these conditions change, a similar change logically eventuates in the nature of research bearing upon such problems.

Since the inception of the planning surveys in 1935, the Public Roads Administration has sponsored extensive research in the field of economic life of highways. The first comprehensive presentation of findings of this phase of the surveys, termed the road life studies, was made at the twenty-first annual meeting of the Highway Research Board in December, 1940.¹ Throughout the succeeding year research continued with the ultimate objective of arriving at the annual cost of the national system of highways, but with the advent of the present war emergency, these long range investigations were deferred in favor of solving more immediate and pressing problems.

Procedures developed in the first six years of detailed research conducted by the road life studies in 46 states were closely integrated with and became a part of routine records cur-

rently maintained in most State highway departments. The value and utility of these uniform and basic records pertaining to each construction and reconstruction project undertaken since the beginning of each State highway department's operations have been proven on innumerable occasions. The work which has been largely curtailed during the present emergency is that portion pertaining to the summarization and analysis of basic information involving preparation of numerous tabulations of salient data considered essential for evaluation of average service lives, methods of and reasons for retirement, salvage values, etc.

Results of initial analyses pertaining to the economic life of highways made prior to the present emergency were of considerable value from the standpoint of reducing to actual figures certain data upon which previous estimates varied as much as 100 per cent, according to the judgment of the individual and the uses to which the data were placed.

A considerable gap too frequently exists between the viewpoints of those who are engaged in research and those who are in administrative capacities. The former are responsible for segregation, analysis, and evaluation of those detailed factors which have an important bearing upon their findings; the latter are primarily concerned with the uses to which the general findings can be placed.

As is often the case, research reports embody numerous tabulations and discussions of the involved statistical procedures and methods of control and analysis, and it is left to the judgment of those concerned in the ultimate use of the data to piece together all the variables to arrive at certain conclusions. To be of greatest benefit, such detailed data must be digested, summarized, reduced to a minimum number of practical significant items, brought up to date, and then correlated with other findings pertaining to the same problem.

Thus, in the field of economic life of highways the factors that must be considered and the statistical procedures that must be followed in actuarial analyses of the life of each type of highway construction, and the volume of work required in the evaluation of effect of traffic, location, design standards, maintenance policies, etc., are so numerous that the average highway administrator would have little time for other work if he were to concern himself with detailed findings of this field of research.

¹ Robley Winfrey and Fred B. Farrell, "Life Characteristics of Surfaces Constructed on Primary Rural Highways", *Proceedings, Highway Research Board*, Vol. 20, 1940, also *Public Roads*, Vol. 22 No. 1, March, 1941.

It is essential, therefore, that the highway administrator be aware of the general significance of data pertaining to life characteristics under peace time conditions of a property such as the highway system.

An industrial property is normally considered as reaching stability of growth and performance when periodic plant replacements become and remain equal to periodic plant depletions. At this ultimate stage of development the average age of the plant, in years, reaches a fixed value of approximately 50 per cent on the probable life, in years, or in other words, the age, in years, and the expectancy, in years, become approximately equal. When this point is reached with respect to surfacing on primary rural highways, the nation-wide surfacing program will then be predominantly one of reconstruction and replacement of worn-out surfaces to the same general standards, and extensions to the system and programs for general improvements in surfacing standards will have been largely accomplished. It is to be noted, however, that programs for the latter can still be accomplished in those cases where further increases in capital outlay for the highway plant are not involved or are offset either by transfers of certain roads to local authorities or by the lowering in standard of surfacing required on formerly higher type roads occasioned by decreased traffic or other economic changes.

For those engaged in scientific research, it is necessary to segregate and appraise all factors which may have an effect upon the findings. All conditions must be carefully analyzed with respect to component parts, conditions, normal and peak loads, etc. Road life study was started and carried on after the initial period of rapid expansion and modernization of the highway systems; but in spite of its extensive and detailed scope in recording the history of every mile of primary rural highway, some very significant elements were found impracticable or impossible to isolate and evaluate.

For example, one phase of past research conducted under the road life study included the cataloguing of the various reasons for retirement of road surface types. It was a most difficult task to analyze past records to determine the reason for retirement, whether (1) structural deterioration, (2) functional obsolescence, (3) construction of related highway

improvements, (4) change in administrative policy, etc.; any or all of which may have accounted for the retirement. Frequently a road which was functionally obsolete may have been afforded little or no maintenance in the period immediately prior to its retirement. However, past records reported no such circumstances and the individual who attempted to assign a specific reason for retirement found only vague and incomplete information of little value.

This attempt to evaluate one of the conditions affecting service life of highways was not successful for past work. However, the procedure was not abandoned, on the contrary, it was applied to current work. Thus it would only have been a question of time until sufficient data were obtained to enable accurate appraisal of various factors involved. After proper evaluation, administrative policies and construction practices could then be modified to the extent necessary to obtain greater service yield from the public investment in the highway plant.

The analysis of data collected with respect to reasons for retirement is merely one example of various phases of the long range research program in connection with economic life of highways which have been curtailed or suspended for the duration. Other examples involve gauging the effect of character and volume of traffic, degree of maintenance, stage construction practices, etc., upon the service life of highways. It is erroneous to conclude that the present temporary moratorium on research on economic life of highways will have any lasting effect upon progress being made toward ultimate findings of the investigation. On the other hand, records now being maintained are in excellent order for later analysis and the opportunity is here to observe the performance of the highway plant under conditions of the severest stress in its brief history.

Construction and maintenance work on the highways is now being prosecuted under controlled conditions which could not be achieved during normal peace times. Under present war-time restrictions, highway improvements and replacements can not be undertaken without thorough and complete justification, and authority for work will be granted only in most meritorious cases. Thus, the numerous factors which enter into the selection of such im-

provements and replacements are currently being made a matter of record, and it is realized by those engaged in investigation of economic life of highways that evaluation and analysis of the performance of the highway system under known conditions can be readily accomplished from such records after the present emergency. Hence, research on the service life of highways will eventually be advanced by several years.

A few statements are in order concerning service life characteristics and performance of surfacing on primary rural highways since the entry of the United States into the war. At that time the composite average age of all types of surfacing existing on the primary rural highways was approximately 8 years, with an apparent future service life expectancy of about 12 years. Net salvage value at the end of the expectancy period has been estimated at approximately 30 per cent, which roughly has the effect of extending service life expectancy by 6 years (30% of 8 plus 12). Probable life (age plus expectancy) would then be 26 years (8 plus 12 plus 6).

Because of its relatively young age and because of continued public demand for higher standards of service, a theoretical state of stability of development probably would not be reached by surfacing on primary rural highways for many years under peace time conditions. During such an emergency period as the present, the curtailment of normal construction and improvement programs temporarily accelerates the trend toward the point where the age of the highway system becomes 50 per cent of the probable life. However, it may be readily determined that several years will elapse before average age and expectancy become equal, and it is most doubtful that this condition will ever be reached during the present emergency.

The temporary acceleration to a statistically computed point of stability during an abnormal period such as that experienced in the past two years is purely an artificial one created by an accumulation of large amounts of deferred reconstruction work which would not occur under normal circumstances. Eventual liquidation of deferred reconstruction work programs will largely offset the abnormal trends in the interim period. It is important that these conditions and trends be evaluated, by one means or another, to assist highway admini-

strators in determining the extent of deferred reconstruction work and in recognizing the significance of current economic changes insofar as the future of the highway transport facility is affected.

Regardless of the character of the highway system when stability is reached, whether real or artificial, it must be realized that, even under most favorable conditions, the trend to that point where age and expectancy are equal in amount can be checked temporarily, and actually reversed for a short time by major improvement programs, but it cannot be stopped indefinitely.

The heterogeneous character of the surfaces on primary rural highways is such that the potential reserve of service as measured by the expectancy can not be used uninterruptedly over any extended period of time. When routine maintenance will no longer suffice to keep weaker sections of highway in usable condition, these worn-out portions must be replaced as they become unserviceable, otherwise full service expectancy value of contiguous portions or segments will not be obtained. Furthermore, it is necessary to reinforce various sections of the system in conformity with readjustment of stresses applied to it during the present emergency. Similarly, many new links in the system are continually being forged to bridge gaps constantly being opened up through establishment of additional war facilities and enterprises.

Post-war improvement of the network of highways to standards which are capable of rendering service for over 30 years will obviously have a tremendous effect upon economic development of the country throughout this interim 30 year period. Each proposed improvement must, therefore, be geared into a well planned national system in which maximum benefit accruing to all users will be realized.

A patchwork improvement or rehabilitation of an existing obsolete system of primary roads in a particular State or area is not likely to redound to the credit of the individuals responsible or to the area in which such work is performed. In the past it has been unhappily a common occurrence that certain long through-routes were scrupulously avoided in their entirety by large volumes of traffic merely because of intermittent stretches which were substandard or poorly maintained or which

were resplendent with numerous unintegrated traffic control devices and similar restrictions upon those very people whom the highway was supposed to serve and attract

The establishment of policies and practices with respect to contract procedure is likewise an important part of post-war planning, and will have its place among the various factors which must be evaluated in analyses pertaining to performance and economic life of highways

Lengths of contracts warrant careful study and investigation. Construction costs per mile on a single 10 mile contract are considerably lower than on twenty individual $\frac{1}{2}$ mile contracts awarded to separate contractors, each of whom must incur certain fixed moving-in, set-up, and moving-out costs, at the same time increasing engineering costs and curtailing efficient use of large amounts of construction equipment, all of which have the effect of pyramiding the annual cost of operation of highway facility.

Incomplete preparation of plans, as for example on excavation work, frequently forces bidders to "pad" their estimates. Actual field investigations have proved that an accurately prepared mass diagram accompanying plans for excavation work consistently enables an efficient contractor to underbid his competitors and to conduct field operations with a minimum of cross-haul and other wasteful and non-productive operations

The practice of permitting alternate bids on presumably comparable types of construction, generally for the purpose of admitting use of certain restricted or patented processes, is short-sighted if award is made on the basis of lowest initial construction cost. It is generally the case that little or no planning enters the picture from the standpoint of determining maintenance requirements of these "orphan" types of construction for the remainder of their service life. As an alternate procedure, test sections of limited length should be built at points where performance of various types can be observed under comparable conditions, but not at such points where specialized equipment is required for the sole purpose of their maintenance at haphazard or random locations.

Related to the above is the generally ill-defined situation with respect to those portions of the highway system adaptable to portland

cement concrete, bituminous, and other types of construction. Evidence of alternating influence brought to bear by organizations promoting their special interests is apparent in many localities. Many roads exist today on which the construction varies from one type to another throughout a given short maintenance section. It becomes obvious, therefore, that a significant consideration in the post-war plan of operation of the highway facility is the establishment of uniform road construction standards and surface types within each maintenance section. The realization of this plan of operation will greatly reduce annual road costs through increased efficiency in maintenance.

The foregoing are merely a few of the problems not generally brought to mind in considering post-war planning. They are, however, vitally important and occupy a predominating position not only with respect to their significance as factors which have a direct bearing upon economic life of various types of highway construction, but from the immediate and pressing requirements for efficient and effective management of the post-war program at the end of the present emergency.

Further, it should be recognized that when the so-called state of stability of development of the primary highway system is reached the average ultimate life of surfacing may be approximately 33 years. At that time average age becomes approximately equal to remaining expectancy and the rate of actual depletion or wearing out of surfacing on the highway system will be 3 per cent per year. This is a factor that can be readily determined and one which long range planners must take into account in making their forecasts of income and revenue required for upkeep of the highway facility. Too often it has been the tendency to cast a dim-sighted glance into the future under a roseate assumption that so-called "permanent" roads will henceforth require no further care than a minimum of routine maintenance.

There is no permanent type of highway construction and the evidence irrefutably reveals that the day is not too far distant when every iota of revenue available for highway use will be required for upkeep of the system to the exclusion of any further additions or improvements to a higher standard involving con-

tinued increases in capital outlays. It is obvious, then, that when that day is reached the credit will accrue to those farsighted individ-

uals who are now formulating post-war plans to insure that a maximum service system of highways will be in operation at that time.

APPLICATIONS OF HIGHWAY ECONOMICS

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SYNOPSIS

There are at least two points of view as to certain relationships involved in highway economics. One is that the state, or other government unit, is merely an agency which collects highway funds and uses them for the benefit of the taxpayers, these benefits constituting the "earnings" of the highways. The other is that the state is engaged in the business of selling highway service and that the "earnings" of the highway system are the tax payments, computed on a vehicle-mile basis. The author supports the former conception.

The question of whether the "return on the investment" is the excess of benefits over costs, or the excess of tax payments over costs, is also discussed, with the author adhering to the former definition.

The rest of the discussion is based upon the acceptance of the author's conclusions noted above and includes a statement of ten fundamental economic principles, together with examples of their application in making economic comparisons of highway projects.

It is concluded that regardless of theories as to what constitutes earnings, there is no question as to the fact that the same persons, in general, pay for the highways and pay the cost of operating vehicles over them, so that maximum economy is attained only when the sum of these two costs is a minimum; also that in applying the principles of highway economics all theoretical computations should be based upon sound common sense.

In his monumental work "The Economic Theory of Railway Location", A. M. Wellington, one of the outstanding engineers of the nineteenth century, wrote, "It would be well if engineering were less generally thought of, and even defined, as the art of constructing . . . The [engineer's] true function and excuse for being, as an engineer, as distinguished from a skilled workman, begins and ends in comprehending and striking a just balance between topographical possibilities, first cost, and future revenue and operating expenses". For the highway engineer the key to the application of this principle may be found in the 1929 statement of the Highway Research Board Committee on Highway Transportation Costs to the effect that annual highway transportation cost equals the annual road costs plus the annual operating costs of the vehicles. This

Committee statement could well be considered the cornerstone of highway economics.

There are at least two fundamental points of view relating to certain financial relationships involved in highway work, particularly the primary function, or status, of the highway departments.

One viewpoint is the result of historical development. When rudimentary highway construction was first begun in our colonial period, it was merely an individual or cooperative undertaking by settlers who improved the roads for their own benefit. Later the management of the roads was turned over to the smallest local government units so that the work could be better organized, and still later, because of increased traffic, the townships or similar units became inadequate to handle the more important highway projects and the tax-