and of course it is necessary for the contractors to maintain their plants in order to continue in business Repairs are needed from time to time, as well as preventive maintenance to replace parts before they cause breakdowns or cut down production. In addition, machines are completely rebuilt or replaced when certain stages of deterioration are reached, and machines are also replaced because of obsolescence. A good measure of these expenditures is given in a study made by the Bureau of Public Roads, An Economic and Statistical Analysis of Highway-Construction Expenditures, to which reference has already been made. This showed that 55 percent of the contractors' margin for overhead and profit was required for repairs and depreciation of equipment. Depreciation charges are converted into employment through the purchase of replacement equipment. While the purchases take place somewhat irregularly, on a large program carried out by many contractors, total purchases are likely to be very close to total depreciation. Accordingly purchases of equipment and of repair parts and the resulting wage employment have been estimated as shown in Tables 4 and 5.

Total wage employment resulting from contract expenditures of $1,000,000 as given in Table 6 is 847,100 hours Of this total, there are approximately 1.14 off-site manhours for each hour worked at the site. The range between the different types of work is not great; the maximum figure of 877,800 which is for bituminous paving is only 9 per cent greater than the minimum figure of 804,100 for concrete paving The differences between types in the individual subdivisions of employment tend to compensate when these subdivisions are added. The cost per manhour ranges from approximately $1 14 in grading and drainage to approximately $1 24 in concrete paving. Average cost per manyear ranged from $2,094 for grading and drainage to $2,307 for concrete paving, with an average of $2,181. These figures are not cheap, but they measure the cost of employment resulting from permanent and valuable improvements, and the wage payments are distributed among workers in heavy industries, basic materials industries and complicated manufacturing, as well as among the workers at the construction site.

CURRENT AND POST-WAR APPLICATION OF ROAD LIFE DATA

By R. C. Faltinson, *Manager*

Financial Survey, Texas State-wide Highway Planning Survey

SYNOPSIS

The problem of determining which roads and how much mileage should comprise our state highway systems is the essence of efficient administrative planning. One of the basic items involved in arriving at the size of a state road system is the amount of revenue available. Next, the annual expenditure requirements upon existing roads of each surface type must be estimated closely The relationship between expenditure requirements and anticipated revenue will then enable the administrator to determine the maximum number of miles which can be constructed and efficiently operated. This involves the use of a system of priorities in the selection of new highway designations, and in the selection of projects for the improvement and maintenance of the existing highway system.

Road life data are of material assistance to the highway administrator in making new designations and in selecting projects for new construction. When a mile of new road is completed, there is likely to be a strong temptation to regard it as a permanent improvement and to move on to the next mile to be built Actually that mile begins to be a definite expense from the moment of its completion, and this expense continues and normally increases each year until finally

together with changes required by traffic and other economic factors, it reaches such a point that replacement becomes necessary

The future value of road life studies is contingent upon the results which may be obtained from application of the data It is the function of the road life study to analyze the data and present the findings in a usable and understandable form to assist highway administrators in the careful planning necessary for providing adequate facilities for highway transport

Eight years ago, in 1935, the Public Roads Administration, in cooperation with the States, inaugurated the planning surveys to gather the minimum amount of factual information deemed essential to efficient highway management The road life study, as a unit of the planning survey, was organized for the purpose of assembling and analyzing certain data pertaining to the replacement and reconstruction of various elements of the highway plant.

The beginning of the road life studies in the several states was inconspicuous. The functions of such a division followed a new thought trend and thus the men who were to perform the work were of necessity, inexperienced in their specific duties. A manual of instructions was issued by the Public Roads Administration which was later supplemented and clarified in numerous instances, so that now it may be taken for granted that the mechanics of conducting a road life study are fairly well understood by road life personnel in the several States In a like manner, it appears that the initial objectives of the Public Roads Administration have with reference to the original mileage tables and the analysis of the retirement and replacement characteristics of the highway plant been attained.

The data recorded by the road life studies have applications to many factors of highway administration. The procedure in developing these applications is new and more or less uncharted. Recognition of the principles which govern the use of these data is at least of equal importance with the standardization of the mechanics of recording the information.

During the present war emergency, it appears that there are innumerable needs for information which could be supplied by the road life studies They may often be called upon to supplement the findings resulting from an analysis of traffic or road inventory data, to coordinate maintenance with construction data, or in many other ways to assume the position of the middle man in bringing information from other highway divisions to a common ground

Data assembled and prepared by the road life studies can be of material assistance in several phases of highway administration if properly prepared in accordance with sound engineering principles It is not intended to give the impression that the basic information compiled by a road life division with respect to replacement and reconstruction of the highway plant is sufficient within itself to permit handling any subject that may be discussed, but that application of the data plus additional information can throw light on many of these subjects

One of the major issues on which more adequate planning is needed is the selection of additional highway mileage and the improvement of the existing system. This involves a system of priorities, in connection with which a central office will require information from several sources in determining the priority rating. It is believed that practically every highway department is committed or obligated to construct and maintain a larger highway system than presently available funds will support. Highway administrators do not desire to operate in a haphazard manner when establishing a construction program. Whether in war time or in peace time, they have need for some kind of a priority system. Much of the information upon which a system of priorities should be formulated probably can be collected and compiled by the planning survey to which the data furnished by the road life studies will form a valuable adjunct

The usual reaction to data of this nature is that they provide only a general picture of the average life of various roadway surface types, because economic conditions, improvements in design and construction methods, administrative policy, all are constantly changing. In addition, priorities in the use of road materials will at this time make any study from past practices of small value. The personnel engaged on the road life studies realize more

than anyone these limitations on the application of the data, but recognition of these limitations permits their inclusion within any analysis that may be undertaken, and compensations may be made accordingly.

The retirement and replacement data developed by the road life studies give a graphical picture of the trends of past and anticipated future retirement of roadway surfaces By a little persuasion and character study, they can be made to reveal their story. There is an old saying, "Just as a twig is bent, so will the tree grow". Thus, past trends must be taken into account to enable intelligent appraisal of the influences which are going to determine the course of future roadway improvements.

By utilizing the mass of data that have been brought to bear upon the retirement and replacement characteristics of the highway plant, forecasts of future replacements can be made with considerable accuracy. If present maintenance standards are reduced, and resurfacing and reconstruction are curtailed, the difference between actual future retirements and predicted future retirements will indicate the effect of such practices and the approximate amount of deferred construction will be reflected.

The purpose of this paper is to invite a discussion on the subjects incorporated herein. To what extent can the data compiled by the road life studies be applied to assist in establishing priority of projects? We all know there are a number of factors which must be considered, some of which are (1) traffic density, (2) condition of riding surface, etc , (3) local development; (4) related improvements, such as connecting routes and gaps in through routes.

Another important factor in highway administration which has been mentioned is that of *expansion of a road system.* This involves some knowledge of the ultimate size the road system should attain. What should the road life division know about the size of the road system?

In order to determine the cost requirements of the Texas highway system, the road life personnel made an analysis of every highway construction job built by the State Highway Department since its beginning in 1918. This analysis presents the following information for each type of surface· (1) the cost per mile of original construction, (2) the average life-period, (3) the average cost per mile for reconstruction, and (4) the annual cost per mile for maintenance This information furnishes the basis for an estimate of the total annual expense for every mile of each type of road construction. Such an estimate of anticipated expenditure per mile is essential in determining the size and nature of the State highway system which can be financed adequately with the available revenue.

As of January 1, 1938, Texas had a maintained system of 21,800 miles plus 4,200 miles on the designated system, or a total of 26,000 miles The maximum limit which can be financed adequately on estimated revenue that will be available is about 24,500 miles. This maximum of 24,500 miles is derived by applying the average annual roadway cost per mile of $1,579 to the estimate of revenue to become available annually The average annual expense incurred for roadway and bridges consists of annual maintenance $360 per mile, annual betterment construction $302 per mile, annual replacement $917 per mile.

Although several subjects may be outlined for discussion concerning which the application of road life data would serve a useful purpose, it is believed this particular one is one of major importance. In other words, the problem of determining which roads and how much mileage can and should comprise our state highways probably is the essence of efficient highway administration. Other subjects to be discussed are no less important but have restricted application in their bearing on this subject.

One of the first steps in determining the size of a road system is to determine the amount of revenue available or how much money can be spent. The next step is to determine the annual expenditure requirements upon the roads now in existence. The relationship of expenditure requirements to revenue will enable a determination of the approximate number of miles which can be operated from anticipated revenue.

The character of roads and road system classifications requires a diagnosis in determining expansions or reductions necessary in the state systems It is desired to quote an excerpt from a paper by Carl E Fritts, Traffic Engineer, Washington Department of High-

ways, which outlines the manner in which the road systems in Washington were analyzed.[1] This paper also appeared in the January, 1941 issue of American Highways

"It is our belief that if the primary system were chosen to achieve certain clear-cut purposes it might be possible to add the secondary system to provide a second degree of service However, we find in Washington that the two groups of services overlap and that it is easier to combine their functions and then to leave as a land service system, a tertiary system. Accordingly we have attempted to choose a system of secondary roads which, when added to the primary system, leaves little doubt as to the end of the secondary and the beginning of the tertiary system.

"It is our thought that the greatest service may be rendered by establishing a complete system of roads which may be compared to a tree We believe it is necessary to grow the trunk and limbs to provide the means of carrying fruit-producing elements to the foliage After all, we are principally concerned with a wholly planned system which will serve adequately to produce the greatest social and economic benefits.

"If we find that the designation of the primary system has been deficient or in error, and if now we attempt to add a secondary system, we think we can throw the two systems together and formulate a combined system which takes into account all of the trunk and limbs on a tree and not include any twigs or leaves. The leaves and twigs would then comprise the tertiary system. The inclusion of any of the tertiary system would be difficult because they are all routes of equal importance and most certainly on a tree we can tell the difference between limbs, and the leaves and twigs Perhaps the determination of the distinction between secondary and tertiary roads is not so easy, but in the following analysis I think we can show a point of separation which indicates the end of the limbs and beginning of the foliage "

This excerpt states that is is necessary to determine the road system requirements before estimating the ultimate size of each road system. For instance, Texas has 21,800 miles on the primary and secondary systems, which includes the federal aid system, but it is entirely possible that part of this mileage really belongs on the tertiary system. If this is true, we are not providing, under our present cost estimates, 21,800 miles of state highway service, and we should not be within 2,700 miles of our present maximum limit of 24,500 miles, since a portion of the 21,800 miles should be transferred to other authorities

When a mile of road is built through a surfacing stage there is a strong temptation to regard it as a permanent fixture and move on to the next mile to be built Actually there is a definite expense connected with each mile of improved roadway. What should be the relationship between expenditures on existing surfaced mileage and on mileage not yet improved through a surfacing stage? A road system also has some maximum to which it can attain in size What are the factors in determining the ultimate size of the road system in each classification? Some roads on any system are necessary even though they cannot by any revenue producing formula be considered self-supporting. To what extent can roads within a system be subsidized from the total revenue available for the system?

Some road surface types will last longer and possibly have a lower annual cost than others What are the factors in comparing annual roadway costs with the allocation of annual revenue produced? What salvage may be anticipated from construction when further improvements are to be made? What effects have bridges upon an estimate of expenditures? Are bridge retirements caused by their own deficiencies or are most losses of investments in structures caused independently of the structures themselves? Knowing the answers to the latter questions, we should be able to determine whether our bridges are giving the most for the money and whether the same service could be obtained by cheaper construction.

Are expenditures for additional mileage each year justified in view of the conditions of existing facilities? If so, an inventory and economic study is necessary in connection with the route or routes to be added to the existing system

Most of the above questions have some bearing on the conduct of road life work. Possibly none of the subjects can be dealt with entirely from road life data, but most road life data is of interest to designers, ad-

[1] Carl E Fritts, "A Method of Selection and Designation of a Federal Aid Secondary or Feeder Road System," *Proceedings*, Highway Research Board, Vol 20, p 93 (1940).

ministrators, accountants, or statisticians. The extent of usefulness of the road life or other division of a highway department depends upon the adequacy and accuracy of its information and upon the adaptability of that information to the subject in question. The road life study in particular should have the answer to adequacy, because it is concerned with the construction and maintenance of highways, and, with allowance for the human element of error, it should answer also to the accuracy requirement in that the information constantly presents a check on itself by current work or comparison with other records

Another factor which has equal significance in determining the worth of road life information concerns the methods of analysis employed after the basic data have been collected. The preparation of any estimate requires a source of information and application of that information The usefulness and dependability of an estimate depend equally on the source of information and the manner of applying that information The application necessarily involves some personal opinion but the minimum of bias probably will insure the maximum in value. Thus, the usefulness of estimates in supplying any departmental need is commensurate with the extent to which recognized principles or common factors affecting highway administration are followed in preparing the estimates.

Estimates are compounded on known behavior, and predicated on the probable future behavior of similar units. Road life estimates are based upon data covering a relatively short period during which there is about one generation or cycle in the life of the highway system. As policies and programs mature, there is a gradual change from one general type of construction to another. This change may result in variable characteristics which may or may not have been in evidence when previous estimates were prepared Thus, it can be seen that road life estimates are subject to modification or refinement as additional construction and retirement experience becomes available for analysis.

Since priorities affect the availability of essential road materials, and since tire and motor fuel rationing will probably reduce revenue, the question will arise as to how much this will affect the basic retirement and replacement characteristics of various road types as well as estimates of future replacement mileages and funds for such construction The trends previously developed are based on past history of roadway construction and retirements During the past 20 odd years, the highway departments have experienced many changes which affected the average lives developed for various roadway surface types and by their very character reflect the effects of *all* factors that have influenced construction and retirements, including those of changes of administrative policy and economic conditions

During the present and future, because of a shortage of critical road materials, labor and equipment, roadway surface types will, in all probability, not receive adequate maintenance, nor will normal reconstruction and resurfacing programs be accomplished. Such a condition will lead to higher reconstruction and resurfacing costs by loss of the opportunity of deriving the maximum salvage from the original facilities. Additional costs accrue in the form of excessive depreciation of the original investment. Lack of adequate maintenance and failure to resurface or reconstruct roadway types at the proper time does not evade an expense, but merely postpones it, and will probably result in a much higher total expense by failing to protect the investment at the proper time It is probably impossible to estimate accurately or forecast the net effect of the war on the State system of roads. These effects will be dependent upon the duration of the emergency, its severity, the extent to which our highways are used for military transportation, and other factors which can be measured only from day to day.

The present curtailment of construction and the probable future reduction in maintenance, occasioned primarily by priorities on essential road materials and equipment, have had their counterpart in the past During the construction and retirement period 1918 to 1941 there were many factors which influenced the average life of the various roadway surface types During certain periods in the past, adequate maintenance, resurfacing and reconstruction of existing facilities could not be provided because of lack of funds There have been improvements in design, methods of construction, changes in economic conditions which cause fluctuation in unit cost, and also changes in administrative policies. All of these factors affect the retirement and replace-

ment trends and result in different average life expectancies for different construction periods.

During the past years, the State system of highways suffered from lack of materials and labor occasioned by insufficient funds to provide improvements as they were needed. For the present, and a period in the future, the State system of roads may again suffer from a lack of materials and labor as a result of priorities. In both of these instances, identical results will be produced although the causes are different. Retirement and replacement experience during past years reflects the lack of materials and labor which was then caused by insufficient funds. Deferred construction led to higher maintenance, resurfacing and reconstruction costs, as a result of postponing reconstruction beyond the time that maximum salvage of existing facilities could be obtained

The estimates of annual roadway costs made from road life survivor curves probably will not depart very far from actual experiences in the future, since it appears that we shall continue to suffer from the same old disease although produced in a different way. In the future, we may suffer from a lack of critical road material and equipment caused by the war. The effect of this lack of material will then be the same as was predicted by the curves which cover earlier construction periods.

It is also highly probable, should the contingencies of war require that a considerable portion of our State system of highways be used for military transportation, that funds for maintenance and construction will be increased to normal needs.

All of the typical trends of replacement and retirement can be reliably projected into the future and thus furnish a basis for quantity estimates of future replacements expressed in miles of each of the surface types. Since the estimates of unit costs include the same factors as do mileage replacements, it is believed that estimates of mileage replacements and costs, to a certain extent, provide for various factors which may affect our construction in the future.

In any event, the deviation of predicted retirements from actual retirements will enable definite determination of the net effect of the war period upon the highway system and the extent to which post-war programs of mileage replacements and annual roadway costs will require modification or refinement.

The road life study follows a process similar to a perpetual inventory system, and modifications of estimates are maintained abreast with changing conditions This circumstance enchances both the adequacy and accuracy of the estimates, but effective use of the basic data is obtained by giving proper consideration to current circumstances.

The future value of the road life studies is contingent upon the results which may be obtained from application of the data. Unquestionably, the art of constructing and maintaining a highway system on a sound economic basis and of formulating future highway programs that will furnish adequate highway facilities for transportation at reasonable cost advances in efficiency as knowledge is obtained from properly controlled practical and economic research projects fully recorded. It is the function of the road life studies to furnish data in a usable and understandable form so that highway administrators can more intelligently provide adequate highway facilities for transportation It is the duty of highway administrators to utilize these data effectively.