

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-

payers obtained greater benefits by turning over the management of certain roads to the counties. Finally, about fifty years ago, it began to be realized that still greater benefits would accrue to highway users if they assigned the management of the most important roads to the States. A new State agency was needed to handle this new service, and therefore the state highway departments were established to do for the taxpayers what they were no longer able to do for themselves as individuals, or through small local government units. There seems to be no evidence that anyone considered any governmental highway authority as anything but a service agency. The only measure of their effectiveness was the amount of benefit they were able to give the highway users.

In recent years, however, a different point of view has been developing among highway engineers. Apparently a few at least have begun to think of the highway departments, or the States, not as service agencies but as entrepreneurs engaged in the business of selling highway use to customers. They begin to speak of highway "earnings", not in terms of benefits to the users who furnish the capital, but in terms of receipts of these capital and maintenance funds from the users in the form of taxes. They consider the justification for any proposed road improvement not entirely from the standpoint of the benefits which would result to the citizens who would pay for the improvement, but largely from the standpoint of the taxes which would be credited to that road, after all user taxes have been figured on a vehicle-mile basis.

From this point of view every mile of unnecessary distance added to a road would increase its earnings, also the rougher the roads and the steeper the grades, the greater would be the gasoline consumption and hence the earnings—as long as the public could be forced to use these roads. In other words, the worse the roads the higher the earnings! Of course, no one advocates bad roads to increase earnings, but that would be the effect if money provided by users is to be classed as earnings.

Let it be assumed that under this earnings theory the improvement of a certain road is barely justified. Now assume that the legislature reduces motor vehicle taxes substantially but collects the difference from some

other tax source. Then the earnings are no longer sufficient to justify the improvement although the returns to the users would be as great as ever. If it can be imagined that motor vehicle fees could be abolished entirely, then no further highway improvements of any kind would be justified under this "Earnings" theory, even though the same amount of funds were available from other sources.

Of course, the idea of any such change in the source of highway funds is probably fantastic, but at least the abolition of taxes on the use of highways would be possible and any theory which would collapse with a change in the source of funds hardly seems to be a sound basis for the application of highway economics. It is completely unworkable now when applied to certain local roads and surely highway economics is not a science which applies only to heavily traveled state systems financed by motor vehicle taxes.

There are then these two conflicting theories as to earnings.

One is that the earnings on invested capital are returns in cash or other benefits, which accrue to the taxpayers as investors. In the case of highways, under this theory, the cash returns are in the form of decreased operating costs, savings of time, which has a cash value, and the reduction of accidents, which cost money. There are other less direct and obvious financial returns in many cases, and other benefits which cannot be measured in terms of money. Also under this theory, the state, county, or other government unit, acting through its highway department, is the agent appointed to receive the highway users' contributed funds and spend these so as to give the greatest returns, or "earnings" to the taxpayers. The highway departments are purely service organizations for these taxpayers and have no earnings whatever of their own.

The other theory is that the state is engaged in the business of selling highway use, with charges so high that they not only cover the operating cost of the system as it exists at any given time, but also furnish annually the capital for extending and improving the system. Although it is probably not done in any other business, the funds collected for operating the system and those for capital expenditures are lumped together and called earnings. Then

the justification for any given improvement is determined upon the basis of the amount of these "earnings", which will accrue when they are assigned to the project on a vehicle-mile basis. If the annual earnings thus computed are larger than the annual cost of the project, it is called economically justified, otherwise it is not. Maximum service to the taxpayers is of course desirable, but the controlling factor in economic evaluation is "earnings" not service.

In some cases the tax payments, reduced to a vehicle-mile basis, are referred to as "income" which would seem to be a rather more logical term than "earnings", but has the same meaning in this case.

A combination of the two theories, outlined above is sometimes used in evaluating projects. McCullough and Beakey¹ first determine a "solvency" quotient which is the ratio of the annual income to that part of the annual cost chargeable to the users, then they determine a "benefit quotient" which is the ratio of the annual benefits to the same costs used in the solvency quotient. Finally these two quotients are combined to determine the desirability of the projects. It may be desirable to know the degree of "solvency" of each project, as thus determined, but if the solvency of the total of all department operations is maintained by seeing that total expenditures do not exceed total revenue, and if each project results in annual benefits to the taxpayers greater than its annual cost, it is difficult to see why any further solvency tests are needed.

Involved in the two theories of economic evaluation is the matter of "return on the investment", as meaning a net profit above costs. Under the service theory, an item of interest is usually included in computing the annual cost of a project, so that if the benefits equal the cost, the net return to the taxpayers who furnish the capital is an amount equal to this interest. Any additional benefits constitute a return on the investment greater than interest at the rate used. It is these excess benefits, if any, which form the definite justification for the expenditure.

Under the earnings theory the state, as distinct from the taxpayers, is considered as being the investor and entitled to collect from the

taxpayers an excess amount to give the state a net profit on the capital which these same taxpayers have furnished.

As previously indicated, my personal belief is that the state is not an investor, entitled to collect a profit from the taxpayers, but is an agent appointed to collect and disburse highway funds solely for the benefit of the taxpayers. It seems to me that any theory which awards the earnings of capital to agents, instead of to the people who furnish the capital on which the earnings are made, is fundamentally unsound, also that any highway engineer who thinks of his department as being in the business of selling highway service to its employers (the taxpayers) has forgotten the purpose for which it was established. My opinion is stated with the most humble realization that it may be entirely wrong, but in this discussion of certain applications of highway economics, it will be assumed that the government units and highway departments are merely the servants of the citizens and that the "earnings" of highways are the benefits which they return to the taxpayers, not the payments made by these taxpayers for investment in new roads and maintenance of existing roads.

I believe that the term "highway earnings", as it is now used by some highway engineers, is merely a method of expressing traffic counts in terms of dollars instead of numbers of vehicles. If we find that all the annual vehicle receipts of the state divided by all the annual vehicle-miles amounts to 0.5 cent per vehicle-mile, and then compute the "earnings" of any given road by multiplying its vehicle-miles by 0.5 cent, the result appears to have little meaning. Referring to vehicle-miles in terms of such an allotment of the investment and maintenance funds supplied by the motorists, may be useful for some purposes, but it seems unfortunate that the only possible justification for highway improvements has been somewhat obscured by this use of the word "earnings". I believe that the sole objective of all highway work should be benefit to the taxpayers, and that such benefit constitutes the only earnings involved.

HIGHWAY BENEFITS

What are the economic benefits which the taxpayer receives from highway improvements or stated another way, the "earnings" which he obtains from his investment in these high-

¹"The Economics of Highway Planning," Technical Bulletin No. 7, Oregon State Highway Department, 1938.

way improvements? Why is he willing to make these investments and thus permit highway departments to exist?

Some of the economic benefits are very obvious and definite, others are more general and indirect, while still others are so nebulous that it is difficult to determine with certainty whether they are really economic or belong to some other category. A reduction in vehicle operating expense constitutes a definite financial return to the taxpayers on the money they have invested in highway improvement. There is no question about that. Beautiful landscaping may so inspire motorists that they will make more money when they get back on the job, or it may increase the value of adjacent property, but whatever economic benefit there may be is usually so hard to measure that it is easier and safer to call it a general benefit without trying to put any money value on it. There is a sufficiently large field for the exercise of economic judgment in matters that are fairly definite, without trying to make evaluations which require more imagination than judgment. It is important to know where to draw the line, if for no other reason than to maintain the engineers' reputation for sound thinking. The temptation to stray off into space has sometimes been too great to resist, leading to rather unsound conclusions, such as the computation of great savings due to a pavement on the assumption that all the thousands of vehicles using the improved highway would be plowing through the mud and dust of an earth road if the pavement had not been built.

ECONOMIC PRINCIPLES

There are certain fundamental principles and relationships which every highway engineer should keep constantly in mind. These might be listed as follows:

1. The total cost of highway transportation includes both road costs and vehicle operating costs
2. The same persons pay for the roads and for the operation of the vehicles
3. The annual cost of vehicle operation may be many times as great as the annual cost of the roads.
4. The main purpose of highway improvements is to reduce operating costs and facilitate traffic movement
5. Maximum economy is attained only

when the sum of the road costs and operating costs is a minimum, consistent with other benefits

6. Any saving in road costs which results in an increase in operating costs greater than the saving in road costs is really not a saving at all but is a waste of the taxpayers' money.
7. In evaluating proposed improvements the only proper standard of comparison is the benefit which each will return to the taxpayers (in most cases the users) who pay the bills
8. The fact that the road costs come from definite highway appropriations, or funds, while operating costs and savings are not subtracted from, or added to, these funds, should not distort the engineer's vision of the whole financial problem. The latter costs and savings are just as real as if they appeared in the account books.
9. The allotment of tax receipts upon a vehicle-mile basis to any particular road is not necessarily a measure of the benefits which the taxpayers will receive from its improvement, or of the justification of such improvement.
10. 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 [proper] balance between . . . first cost and operating cost."

If the engineer agrees that the maximum economic benefit to the taxpayer should be the primary objective of all highway planning, location, design, construction, and maintenance, then he is confronted with the problem of methods to be used in attaining this objective. The subject is so broad that its latest discussion in book form required 450 pages², and it is hardly probable that the authors felt that they had covered the whole field even in that excellent volume. All that one can hope to do in a single paper is to call attention to a few general principles and methods of applying them.

The best starting point is a highway planning survey, which should furnish the answers to the following questions

1. Just what highway facilities do we now have?

² Highway Economics by Tucker and Laeger, International Textbook Co. (1942).

2. What highway improvements will produce benefits to the taxpayers amounting to more than the cost of improvements?
3. In what order should the various economically justified improvements be made?

The first question is answered by a road inventory. The second and third are answered by a traffic survey and the computation of annual costs of proposed improvements, plus the annual cost of vehicle operation in each case. The third question must be answered because there are probably no highway systems anywhere without justifiable projects which must be programmed over a period of years. Any realist knows that economics can not be the sole guide in making such a program, but economics should be kept constantly in mind.

ECONOMIC COMPARISONS

So much has been written on the subject of economic comparisons that those engineers who have been very much interested in the matter are already familiar with the principles and methods involved while those to whom it is a new field will wish to refer to more extended discussions than can possibly be included here. All I shall try to add to this paper are a few points which seem to be frequently ignored or wrongly applied.

One common economic mistake in the general location of highways is ignoring or underestimating the cost of unnecessary distance. I have in mind a lake which lies in the natural path of a long state trunk line. The state road goes around on the east side of the lake while a rather poor and crooked country road goes around on the west side. If properly located on the west side, a state road would probably be at least 5 miles shorter than the present road. Under normal conditions the traffic is something less than 1,000 vehicles per day, or say 300,000 per year. If it is assumed that the average variable operating costs for all types of vehicles amount to 4 cents a mile, then the extra cost of traveling the 5 miles is about \$60,000 a year.

If the possible saving due to a new location on the west side is capitalized at 4 per cent, it would indicate a justifiable expenditure of \$1,500,000 for the new road, which would probably be more than twice the actual cost. That, however, is misleading, as it does not provide for depreciation or maintenance of the

new road, or deduct maintenance on the present road, if turned over to the county. The maintenance would still have to be paid by the county but would be offset by ending the maintenance on the present west-side county road. Interest and depreciation on the new road would probably be about \$35,000 a year, thus giving a net saving to the taxpayers of about \$25,000 a year. If the traffic were twice as heavy, the gross savings would be \$120,000 a year, instead of \$60,000, and the net savings would be \$85,000 instead of \$25,000. This does not include the value of the time saved.

Of course under the "earnings" theory, previously discussed, such a relocation would be unprofitable, and so, presumably, undesirable, because the state, after paying for the new construction, would lose the tax payments, or "earnings", allotted to 5 miles of road, regardless of any benefit to the taxpayers.

While it is probable that savings due to elimination of distance are often underestimated, it has sometimes happened that they were grossly overestimated by including all vehicle costs in the savings. Obviously there will be no savings in such items as interest, insurance, license fees and garage.

In setting grade lines such considerations as balancing cuts and fills, and avoiding heavy excavation, sometimes loom larger in the mind of the engineer than maximum economy for road users. Money saved in construction may possibly cause the waste of a larger amount in operating cost each year, as long as the road lasts, than the total amount saved by failure to reduce steep grades. It is only the sum of construction plus operating costs that is important to the people furnishing the money for road building.

Perhaps the most frequent violence done to this principle is in balancing increasing annual maintenance costs on an old road against the annual costs of a new one without giving enough thought to large wastes in higher operating costs on the old road. Every engineer knows of instances of saving a few dollars while throwing away many dollars in this manner, whether he recognizes them or not.

One more point in connection with the applications of highway economics may be worth noting here, and that is in connection with the valuation of time. Some engineers feel that any attempt to set a money value on lost time

is foolish while others give it an exaggerated value, or manipulate a reasonable value until it runs into fantastic figures

It does not seem unreasonable to place an average value of 60 cents an hour on the time of an individual. However, because 60 minutes are worth 60 cents, it does not follow that one minute, by itself, is worth one cent, or anything at all. If an individual, or a vehicle, is delayed just one minute in a day, the loss is probably nothing, but let us see what we can do with statistics.

Granted that a person's time is worth 60 cents an hour, which is one cent a minute or $\frac{1}{2}$ cent for 15 sec. Assume that the average vehicle carries 2 people, then that is $\frac{1}{2}$ cent for 15 sec. of vehicle time. An unnecessary traffic signal delays each vehicle 15 sec and the traffic volume is 20,000 vehicles per day. Twenty thousand times $\frac{1}{2}$ cent amounts to \$100 per day or \$36,500 per year. Also 20,000 times $\frac{1}{2}$ minute times 365 equals 3,650,000 man-minutes or about 61,000 man hours a year. This is probably enough time to build 15 fighter planes, the lack of which might lose an important battle, prolong the war and cost a million lives—all because of a bad traffic signal back in New York, Detroit or Chicago!

This is truly appalling, but there is one thing the statistician forgot—that is, that a delay of 15 seconds just by itself means nothing, and that 0 times 2 times 20,000 times 365 is still 0. I have seen computations purporting to show that on a heavily traveled highway an expenditure of nearly \$50,000 would be justified to save two seconds per vehicle on a two-mile section, although it would be almost a miracle if any one vehicle could travel twice over any two-mile road without varying its

own elapsed time more than two seconds. In this case, it would seem that the computed time saving was not only worthless, regardless of the number of vehicles involved, but that it was also largely imaginary.

While a few seconds loss of time to one vehicle, when multiplied by a large number of vehicles, would seem to have no significance if it happened only once, such a loss repeated frequently during one day will have a real meaning to as many persons as are affected. A 15 second delay every 5 minutes for 10 hours amounts to half an hour, and that is certainly a real loss with a real money value.

I see no way of making rules which will fit all cases, but it is important not to permit the possibilities of mathematical manipulation to run away with common sense.

CONCLUSION

It is to be hoped that there will be sufficient discussion of the question as to what constitutes highway "earnings" so that everyone can at least have a clear basis for forming his own opinion as to whether they are the funds furnished by the taxpayers for highway construction and maintenance or the benefits received by the taxpayers as a result of their highway investments.

Regardless of theories as to earnings, there is certainly no question about the same persons paying for the highways and for the vehicle operation, so that the maximum economy results only when the sum of these two items is a minimum.

Finally engineers should keep in mind at all times the idea that in applying the principles of highway economics all theoretical computations should be based upon sound common sense.