Professor Breed: We have a state highway system of 1800 miles and our density of traffic on roads in Massachusetts, I believe, is the greatest in the United States It is over 3000 vehicles per day per mile on the average There are 61 per cent of our highways in the State system which carry upwards of 3000 vehicles per day Such roads as the Newburyport turnpike running north from Boston toward New Hampshire carries an average of 8000 vehicles per day and about 25,000 on Sundays and holidays, and that 25,000 per day is quite comparable with the New Jersey viaduct That road is a three and four lane road Massachusetts has such dense traffic on so many miles that we get quite a lot of money

Dean Marston You do not have to use general State sources?

Professor Breed Not at all

Dean Marston. Has any study been made into this distribution of a certain percentage to State roads and a certain percentage to something else from the point of view of the source of money?

Mr Breed I cannot answer that Some of the State highway department officials have been quite interested in these studies we are making, and there is some hope that the State may make a State-wide analysis of highway costs I feel personally that this is the type of study that could be made in cooperation with the Bureau of Public Roads because it would likely be of national value I believe the problem would be simpler in Massachusetts than in most states because of the very complete record this State has of cost and of traffic

THE ECONOMY OF HIGHWAY IMPROVEMENTS

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SYNOPSIS

In estimating the economy of contemplated road improvements, the question, "how much can we afford to invest now to save a determined amount of annual expense?" can be answered by comparing the additional investment with the saving in cost which it effects

This method of computing economy is illustrated in detail by a project for improving a gravel road by surfacing it with concrete For the cost data assumed it is shown that the improvement is justified for an annual traffic of 200,000 vehicles or more, but that for 100,000 vehicles it does not appear to be economical The computation shows that the saving in annual road cost is relatively small in comparison with the saving in vehicle operating cost when the annual traffic is large Indeed an approximate economy determination can be made by considering the vehicle cost only.

In the light of the old Roman saying that "the welfare of the people is the supreme law," the wonderful development of our highways shines as an outstanding example of public service for the benefit of the people. Viewed in that light, optimum service with economy should continue to be the guide

Economy determinations are valuable aids not only to business ventures, the main incentive for which is profit, but also for public activities such as the building of the nation's highways Economy for individual enterprises has not always lead to general prosperity or even to continued prosperity for the enterprises themselves

Likewise, economy studies are essential to highway development, but may not have predominating influence in the getting and expending of funds

It is apparent that stressing economy to the limit would defeat its own aims, for the roads carrying the most traffic would absorb the available funds and leave none for the subsidiary roads upon which much of the traffic must originate

The economy of an additional investment in a business enterprise can be determined from known data concerning amounts invested and yields before and after the investment and may be predicted with reasonable certainty, except for rapidly changing conditions

The yield is the annual operating revenue less the annual service cost, and the latter is the total of expenditures for operation, maintenance, insurance, and the annual provision for depreciation, which latter for highways is called the annual provision for "periodic maintenance"

The method generally used was stated by Arthur M Wellington nearly fifty years ago in his "Economic Theory of Railway Location" When the revenues are known the yields may be computed by subtracting the costs, and then the difference in yields may be compared with the difference in investments, or with the additional investment in an enterprise The percentage which the additional yield bears to the additional investment is a precise measure of the economy of the additional investment The economy may be determined by Wellington's method even when the revenues are unknown provided they are known to be equal, but when we attempt to use Wellington's method to arrive at the economy of highway improvements one of the first things that becomes apparent is that the operating revenue from highway transportation is not only unknown but by its very nature can never be known as an amount of money, because it is so largely in the form of service Also we know very little about the equality of the operating revenues before and after a highway improvement

The nearest measure we have of the operating revenue of a highway transportation system, consisting of public roads and private vehicles, is the annual traffic, the changes in which become intricate and uncertain in response to social and economic stimuli. Hence, we are forced to predicate the economy of highway improvement upon the annual traffic being the same after as before the improvement and base the computations on the reduction in cost, whereas increased revenue usually is the main incentive for investment in a business enterprise

With the revenue eliminated from consideration there are two ways in which we may proceed to compute the economy, which are designated as the "Total Annual Cost Method," and the "Saving in Annual Expense Method"

The Total Annual Cost Method The interest upon the total investment is computed and added to the annual service cost to arrive at total annual cost, and then total annual costs may be compared. This is the method used by the Committee on Highway Transportation Economics in its 1929 and 1930 reports It took much time and effort to determine the "cost to construct" for short sections of roads, so the suggestion has been made that an approximation of the amount invested by a State in its highway system could be arrived at in other ways

Saving in Annual Expense Method We may compare the investment to be added in making an improvement with the difference in annual service costs before and after the improvement, that is, compare the additional investment with the saving in cost which it effects This second method is the one used in this report in an attempt to answer the question "how much can we afford to invest now to save a determined amount of annual expense?" An answer to this question may be stated as follows. "The economy will be shown by computing the percentage of saving to the cost of the improvement," because the saving is the only return upon the investment which we can compute.

To illustrate this method of computing economy, consider an improvement by surfacing a gravel road with concrete Data are assumed approximately as given by Mr A C Benkleman for the State of Michigan, in his paper, "Demonstrating the Economy of Good Roads," in Civil Engineering for July, 1933

The cost of surfacing a mile of gravel road with concrete is estimated to be $15,000 The average annual maintenance for the gravel road is estimated to cover periodic maintenance The annual cost for "periodic maintenance" of the concrete road is computed as the 4½ per cent annuity for replacement of the concrete surface every 25 years at a cost of $15,000 per mile

The cost of operating an automobile for a mile is estimated to be 8 mills less on a concrete surface than on a gravel road This estimate of saving per vehicle mile is taken from Figure 1, page 87 of the 1932 Proceedings of the Highway Research Board, "A Study of Costs on Various Types of Highway," by Raymond G. Paustian.

Table I sets out these data and the computations:

From Table I it is easy to see that the improvement is justified for an annual traffic of 200,000 automobiles, and in increasing measure up to 750,000, for which the annual saving is over 40 per cent of the cost of the improvement For an annual traffic of 100,000 automobiles the improvement appears to be non-economic, and an annual traffic of 150,000 automobiles is on the border line and does not so amply justify the improvement as a larger annual traffic It is assumed that the percentage of saving to investment should be at least twice the current rate of interest, say 10 per cent, in order to promise real economy

TABLE I

COMPUTATION OF ECONOMY FOR CHANGE FROM GRAVEL ROAD TO CONCRETE SURFACE PER MILE OF ROAD

(The annual traffic is estimated to be the same after as before the improvement)

	Annual Road Costs				Annual Saving			
	Gravel Road	Surfaced with Concrete						
Number of automobiles per year	Annual Service cost, i e, average annual cost of maintenance	Average annual maintenance	Annual cost for periodic maintenance 4½% annuity for replacement every 25 years at cost of $15,000	Annual Service Cost	Road Cost	Vehicle Cost	Total	Percentage of $15,000
100,000	$880	$328	$336	$664	$216	$800	$1,016	6 77
150,000	954	347	336	683	271	1,200	1,471	9 8
200,000	1,020	360	336	696	324	1,600	1,924	12 8
400,000	1,130	440	336	776	384	3,200	3,554	23 7
750,000	1,485	575	336	911	574	6,000	6,574	43 8

In order to have accuracy in computations by this method it is necessary to have accurate data as follows

(a) The average annual maintenance cost for each type of surface This may be compiled from records of costs of similar maintenance

(b) A reasonably good estimate of the life of each type of surface and the cost of replacing it

(c) The present annual traffic, rather closely estimated and classified as to type of vehicle

(d) An estimate of the difference in vehicle-mile cost on the two types of road surface, determined as accurately as possible

More dependence is to be placed on the difference than on the vehicle-mile costs themselves The difference should be accurate to less than a mill, because a variation of one mill with an annual traffic of 750,000 automobiles means a variation in annual saving of $750 per mile, which overshadows the saving in road costs

The computations also show that the saving in annual road cost is relatively small in comparison with the saving in vehicle cost, when the annual traffic is large, for an annual traffic of 750,000 automobiles the saving in vehicle cost is computed to be $6,000 out of a total saving of $6,574 Consequently, the economy of changing to a higher type of road surface is mainly dependent upon the amount of traffic and the difference in vehicle costs on the different surfaces

In fact, the saving in road cost on changing to a higher type of pavement is relatively so small that we may get an approximate economy determination by considering the saving in vehicle cost only Thus, if the vehicle cost per mile is 8 mills less on the next higher type of pavement, an annual traffic of 400,000 vehicles per year will mean a saving in annual vehicle cost of $3,200 per mile of road due to the change, and this capitalized at 10 per cent gives a permissible expenditure of $32,000 per mile, whereas the change can probably be made for $15,000 per mile

The larger the annual traffic, the greater is the justification for changing to the next higher type of road surface irrespective of the investment, or the "cost to construct" the existing road, and to a considerable extent irrespective of the annual road cost

This balancing of the saving in annual expense against the cost of making the improvement appears to be applicable particularly to the computation of economy for individual projects for the improvement of existing highways without taking into account the additional service which may result from an increase in annual traffic on a section of road which is improved or on the highway system of the State Such increased service might well prove to be more compelling than the saving in vehicle cost only

No attempt is made to apply this second method to the study of state highway systems, for which the first method appears to be applicable with some modifications

A modification of the committee's formula for annual road cost suggests itself, and that is to compute the interest upon the investment rather than on the "cost to construct," because the investment probably can be found from the records of expenditures, and then make deductions for assets retired or no longer useful, very much in the same way that "fixed investment" is kept for a public utility.