In the four roads given in Table X, part of the gas tax did not go to the state roads but was used on county or city roads, which of course serve the motor vehicle owner It is therefore equitable in these analyses of state roads to treat as contributions only that portion of the gas tax that was actually expended by the state on roads, but in those states where some of the gas tax receipts are expended for purposes other than roads the motor vehicle owner should be given credit for his full contribution

A cent or two added to the gas tax (if applied wholly to state roads) would considerably change the amounts in the last column of the table It is also evident from this table that a gas tax of four to six cents in states having many miles of highways with light traffic may be consistent with a three cent tax in Massachusetts, Connecticut or New York

The Committee gratefully appreciates the assistance given by the officials of the Highway Division of the Department of Public Works of Massachusetts

The figures used in this report have not been verified by the Department of Public Works nor have they had an opportunity to criticize them, and therefore the responsibility for their use lies wholly with the Committee

The correlation and assembly of data and computations of road costs were done by Mr Alexander J Bone, under the general direction of the author

A STUDY OF COSTS ON VARIOUS TYPES OF HIGHWAYS

By Raymond G Paustian

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SYNOPSIS

A discussion of the various items that go to make up the cost of highway transportation including roadway costs, vehicle operating costs and contributions to road funds through gasoline taxes and license fees On the basis of average values for the different items a table is presented showing the relations between operating costs, tax contributions, and annual roadway costs for various traffic volumes on the three types of roads Based on the assumptions necessarily made an annual traffic of 675,000 vehicles apparently contributes enough through taxes, on the average to pay the annual cost of a high type road

"A knowledge of all of the factors entering into total cost of transportation is needed to furnish a basis for the equitable taxation of vehicles, for the proper layout of highway improvement programs, and for the economic design of roads In other words, *highway transportation cost* is a dominant factor in the solution of all highway problems

In planning an improvement program, the type of improvement should be used for which the annual transportation cost will be the lowest at which the expected traffic can be adequately served "[1]

There can be little doubt as to the necessity for the proper determination and interpretation of highway transportation cost, especially in these times when every expenditure, every improvement, every plan, whether proposed or executed, is so carefully scrutinized, its justifiability so rigorously attacked The problem is almost limitless, but it is hoped that the following cost studies of various types of highways will indicate how useful a rather general conception of the entire subject may be

HIGHWAY TRANSPORTATION COST

The Committee on Highway Transportation Costs in 1929, presented a method of determining the cost of transportation over a given highway, and, in 1930, offered a set of detailed computations, which illustrated the use of its method

"The annual cost of transportation over any length of highway," as defined by the Committee, "consists of the yearly cost of providing the roadway ready for service plus the cost of operation of all vehicles while using that particular road during the year " It is further stated that "the cost of highway transportation per vehicle mile is equal to the annual road cost per mile plus the annual operating cost per mile of annual traffic, less the contributions to road funds, all divided by the annual traffic per mile "

Continuing with the Committee's report,—"The annual cost of a road may be expressed as the total average yearly expenditure that will construct, replace, and maintain in perpetuity in standard serviceable condition any existing road under existing traffic and climatic conditions This amount may be calculated by determining the amount of money which, if set aside today, will return, in perpetuity, as interest, sums sufficient to pay annual interest charges on construction cost, to provide a sufficient annual maintenance charge, and to accumulate periodically necessary replacement costs, and by multiplying that amount by the rate of interest prevailing in current state financing "

In brief, then, to determine the cost of transportation over a given highway, it becomes necessary to know or be able to estimate (1) the annual cost of that highway, (2) the annual traffic using the road, (3) the operating costs of this traffic, and (4) the contributions of this traffic to road funds

COSTS ON VARIOUS TYPES OF HIGHWAYS

It seems advisable to confine this analysis to three broad types of highway surfaces, rather than to try to make a comparative study of

[1] From Report of Committee on Coordination and Program, Ninth Annual Proceedings, Highway Research Board

costs on each of the dozens of types of highways in use today Inasmuch as there are so many variables entering into the problem, this seems, at least for the present, to be the best course to follow

Classification of Surfaces The prevailing types of highway construction have been classified in various ways by different individuals, but the following classification seems logical·

Low Type	Natural earth Sand-clay Untreated gravel Traffic-bound macadam
Intermediate Type	Water-bound macadam Surface treated macadam Surface treated gravel Penetration bituminous macadam
High Type	Bituminous concrete Sheet asphalt Portland cement concrete All block pavements

Construction Costs Within any one of the above groups, the cost of figures for the different surfaces included in the group will probably show considerable variation In order to arrive at some sort of a solution without entailing an endless and needless amount of work, it becomes necessary to rely upon average values The average values given in Table I have been arrived at after rather careful study and appear to be logical Their probable correctness has been checked by careful comparison with records of construction cost, brought down, of course, to the present date It should be noted that the roads used in this study are assumed to be parts of a state highway system

It is interesting to note that the construction cost of the intermediate-type road is roughly twice that of the low-type road, while the cost of the high-type is approximately double that of the intermediate-type road

Annual Costs Having determined a reasonable value for the construction cost of each of the foregoing surface types, it becomes necessary to make a further estimate of the probable expenditures for annual and periodic maintenance on each of these surfaces Furthermore, such estimates must be made for all practical volumes of traffic

Of the items making up the annual cost, the first is interest on the construction cost Four per cent has been chosen as a more or less average figure and when applied to the total construction costs gives the values in Table II It is very evident that the interest cost is constant, regardless of the volume of traffic

Of all the items entering into the annual cost calculations, that of annual maintenance is probably the most difficult to obtain This is especially true when it is necessary to know the variation of these costs with traffic Undoubtedly, annual maintenance costs do increase with traffic, but no one seems to know just how this variation takes place Several writers have made estimates, but all agree that there is available only a meager amount of data For the present, the values given by T R Agg on page 406 in his text on the "Construction of Roads and Pavements" will be used These values are given in Table II, in the formulae, M is the annual charge for maintenance of the pavement surface and T is the annual traffic in tons Table II also shows a definite sum allotted to maintenance of shoulders, which, of course, must be added to the cost of surface maintenance to get the annual maintenance cost per mile for a given volume of annual traffic

TABLE I

ELEMENTS OF CONSTRUCTION COST FOR VARIOUS TYPES OF ROADS

Item	Type of road surface		
	Low	Intermediate	High
Right-of-Way	$1,000	$1,000	$1,500
Drainage Structures	2,000	2,500	3,000
Earthwork	3,000	4,500	6,000
Surface	2,000	9,000	20,000
Appurtenances	100	200	200
Engineering and Administration at 4%	325	690	1,225
Total	$8,425	$17,890	$31,925

TABLE II

ELEMENTS OF ANNUAL ROAD COSTS FOR VARIOUS TYPES OF ROAD SURFACES

Item of road cost	Type of road surface		
	Low	Intermediate	High
Interest on Investment at 4%	$337	$716	$1,277
Annual Maintenance of Road Surface	$150 + \frac{T}{550}$	$250 + \frac{T}{900}$	$100 + \frac{T}{3000}$
Maintenance of Shoulders	$25	$35	$50
Salvage Value	0	$2,250	$10,000

In predicating a charge for periodic maintenance or replacement of the pavement surface at the end of its life, it again becomes necessary to rely upon estimates That the volume of traffic does affect the life of a pavement surface is very evident; a pavement carrying a very light traffic would surely last longer than one carrying a large volume of traffic On the basis of this fact, certain assumptions have been made and the periodic maintenance charges calculated therefrom The life of high-type pavement has been assumed to vary from 90 years for very light traffic (10,000 tons annually) to 15 years for heavy traffic (4,000,000 tons annually). For the intermediate-type surface, this figure has been assumed to vary from 25 years to 3 years, and for the low-type surface, from 10 years to 1 year.

In the present analysis, each surface has been assumed to have a certain salvage value at the end of its life. The difference between the initial cost and the salvage value represents the sum that must be accumulated during the life of the pavement surface. The salvage value may be expressed as a percentage of the initial value, or as a condition per cent. For a high-type surface, a condition per cent of 50 has been chosen, for intermediate-type surfaces 25, and for low-type surfaces 0.

TABLE III

COST OF OPERATION FOR COMPOSITE CAR

(Annual Travel 7000 miles)

Cost items	Cents per mile
Gasoline at 20¢ per gal.	1.27
Oil at 25¢ per quart	0.25
Tires and tubes	0.43
Maintenance	1.22
Depreciation	1.63
License	0.14
Garage, $4 a month	0.69
Interest at 6 per cent	0.47
Insurance	0.33
Total Cost	6.43

Note. License cost based on the national average fee of $10.10.

Table IV shows the annual road costs that have been calculated for each type of surface for an annual traffic varying from 10,000 to 4,000,000 tons.

Traffic Costs. For any given volume of annual traffic, it will be necessary to determine the composition of the total traffic, the operating cost of this traffic, and its contributions to the road funds through the gas taxes and the license fees.

The vehicles which make up the traffic using our roads today are of two classes, passenger vehicles and commercial vehicles. From the more recent of the transportation surveys completed by the U. S. Bureau of Public Roads, it is very evident that commercial vehicle traffic comprises approximately ten per cent of the total traffic on our state highways. The Iowa Engineering Experiment Station[2] in a recent publica-

[2] "Automobile Operating Cost and Mileage Studies," Robley Winfrey, Iowa Engineering Experiment Station Bulletin 106, 1931.

tion has found that the average passenger vehicle weighs approximately 1¼ tons The average truck (1¼ tons) weighs 3000 pounds empty and approximately 5000 pounds with an average load On the tonnage basis it is quite evident that commercial vehicle traffic comprises about 20 per cent of the total These values apply to Iowa conditions, but for the purpose of this analysis, they are highly satisfactory

The authority just mentioned has also shown the operating cost per mile for the average passenger vehicle to be as shown in Table III

As the values given in Table III are probably for vehicles that have operated over low, intermediate and high-type surfaces, it is possible to say that they may be taken as average figures for intermediate-type surfaces There are sufficient data available to enable one to estimate,

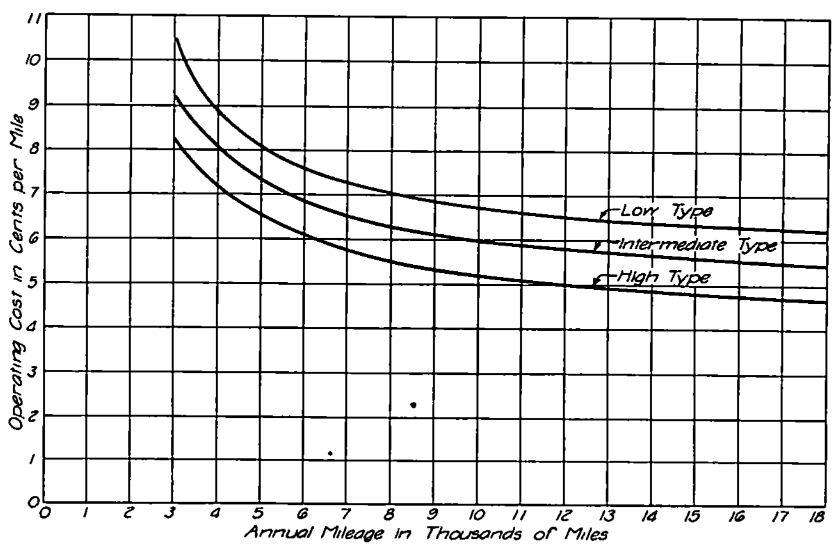

Figure 1. Operating Cost of Composite Car on Various Types of Surfaces

from this, the relative operating costs on both high and low-type surfaces The variation of operating cost with annual mileage for the composite passenger car is shown in Figure 1 Commercial vehicle operating costs have been estimated at 7 38 cents per mile on high-type roads, 8 40 cents per mile on intermediate-type surfaces, and 9 62 cents per mile on low-type roads These values for commercial vehicles are based on an annual mileage of 8000 miles and an average license fee of $20 20, and do not include the cost of drivers' wages or other overhead expenses

Contributions of traffic to road funds are obtained from two sources the gasoline tax and the registration or license fee Inasmuch as the road types being studied have been assumed to be parts of a state system, it is necessary to determine the proportion of the total contributions that goes to this system of roads This proportion varies widely in individual states and it seems advisable to use an approximate average value This average has been obtained by a careful study of the tabulations of gasoline taxes, motor vehicle registration fees, licenses, etc , for the year 1931, as compiled by the U S Bureau of Public Roads These tabulations show that of the total gas tax collections, 68 6 per cent is apportioned to use on the state roads while 23 7 per cent is used on local roads The registration fee collections are likewise disposed of in the proportion of 68 1 per cent to state roads and 22 8 per cent to local roads The average gasoline tax collected in 1931 was 3 48 cents per gallon

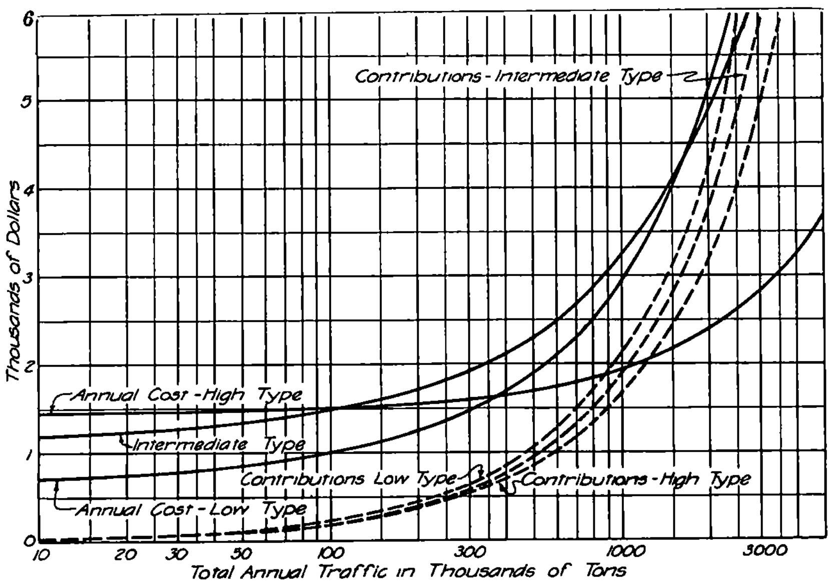

Figure 2. Relative Annual Costs of Different Types of Highway Surfaces as Related to Traffic

It is rather evident that each vehicle using a highway contributes a certain sum, per mile of travel, to the road funds through the gas tax and the license fee For instance, with the cost per mile for the composite car on intermediate type roads at 1 27 cents if it is known that gasoline costs 20 cents per gallon, and that 68 6 per cent of the gasoline tax of 3 48 cents is used on state roads, the amount that each passenger vehicle contributes to the road funds through the gasoline tax is $686 \times 3\ 48 \times \frac{1\ 27}{20} = 0\ 152$ cent per mile of travel The average commercial vehicle pays 0 25 cent per mile for the license fee If 68 1 per cent of this amount reverts to state road funds, each commercial vehicle contributes 681 × 0 25 or 0 17 cent per mile These factors have been worked out for both types of vehicles using each type of surface and will be found in Table IV

TABLE IV

OPERATING COSTS, TAX CONTRIBUTIONS AND ANNUAL ROAD COSTS FOR VARIOUS TRAFFIC VOLUMES ON DIFFERENT TYPES OF HIGHWAY SURFACES

Type of surface	Annual traffic					Annual road cost						Cost of operation		Contributions to road funds					
	Annual tonnage			No of vehicles						Proportion to				Gasoline tax		Registration fee		Total	
	Comm vehicles	Pass vehicles	Total	Comm vehicles	Pass vehicles	Int	Annual maint	Periodic maint	Total	Comm vehicles	Pass vehicles	Comm vehicles @ 7 38¢/mi	Pass vehicles @ 5 64¢/mi	Comm vehicles @ 0 169¢/mi	Pass vehicles @ 0 120¢/mi	Comm vehicles @ 0 17¢/mi	Pass vehicles @ 0 098¢/mi	Comm vehicles	Pass vehicles
High	2,000	8,000	10,000	800	6,400	$1,277	$153	$12	$1,442	$288	$1,154	$59	$361	$1	$8	$1	$6	$2	$14
	4,000	16,000	20,000	1,600	12,800		157	18	1,452	290	1,162	118	722	2	15	3	12	5	27
	10,000	40,000	50,000	4,000	32,000		167	27	1,471	294	1,177	295	1,805	7	38	7	31	14	69
	20,000	80,000	100,000	8,000	64,000		183	42	1,502	300	1,202	590	3,610	13	77	13	62	26	139
	40,000	160,000	200,000	16,000	128,000		217	66	1,550	310	1,240	1,180	7,219	27	153	27	123	54	276
	100,000	400,000	500,000	40,000	320,000		317	105	1,699	340	1,359	2,952	18,048	68	384	68	314	136	698
	200,000	800,000	1,000,000	80,000	640,000		483	178	1,938	388	1,550	5,904	36,096	135	768	136	627	271	1,395
	400,000	1,600,000	2,000,000	160,000	1,280,000		817	336	2,420	484	1,936	11,808	72,192	270	1,536	272	1,234	542	2,770
	800,000	3,200,000	4,000,000	320,000	2,560,000	↓	1,483	499	3,259	652	2,607	23,616	144,384	541	3,072	544	2,469	1,085	3,541
												@ 8 40¢/mi	@ 6 43¢/mi	@ 0 204¢/mi	@ 0 152¢/mi	@ 0 17¢/mi	@ 0 098¢/mi		
Inter-mediate	2,000	8,000	10,000	800	6,400	716	296	162	1,174	235	939	67	412	1	9	1	6	2	15
	4,000	16,000	20,000	1,600	12,800		307	226	1,249	249	1,000	134	823	3	19	3	12	6	31
	10,000	40,000	50,000	4,000	32,000		340	285	1,341	268	1,073	336	2,058	8	48	7	31	15	79
	20,000	80,000	100,000	8,000	64,000		396	362	1,474	295	1,179	672	4,115	16	97	13	62	29	159
	40,000	160,000	200,000	16,000	128,000		507	562	1,785	357	1,428	1,344	8,230	32	195	27	123	59	318
	100,000	400,000	500,000	40,000	320,000		840	733	2,289	457	1,832	3,360	20,576	82	486	68	314	150	800
	200,000	800,000	1,000,000	80,000	640,000		1,396	1,245	3,357	671	2,686	6,720	41,152	163	973	136	627	299	1,600
	400,000	1,600,000	2,000,000	160,000	1,280,000		2,507	1,590	4,813	963	3,850	13,440	82,304	326	1,946	272	1,234	598	3,180
	800,000	3,200,000	4,000,000	320,000	2,560,000	↓	4,729	2,160	7,605	1,521	6,084	26,880	164,608	653	3,892	544	2,469	1,197	6,361

												@ 9 62¢/mi	@ 7 37¢/mi	@ 0 250¢/mi	@ 0 186¢/mi	@ 0 17¢/mi	@ 0 098¢/mi		
Low	2,000	8,000	10,000	800	6,400	337	193	166	696	139	557	77	472	2	12	1	6	3	18
	4,000	16,000	20,000	1,600	12,800	│	211	217	765	153	612	154	943	4	24	3	12	7	36
	10,000	40,000	50,000	4,000	32,000	│	266	253	856	171	685	385	2,358	10	60	7	31	17	91
	20,000	80,000	100,000	8,000	64,000	│	357	301	995	199	796	770	4,717	20	119	13	62	33	181
	40,000	160,000	200,000	16,000	128,000	│	539	399	1,275	255	1,020	1,539	9,434	40	238	27	123	67	361
	100,000	400,000	500,000	40,000	320,000	│	1,084	471	1,892	378	1,514	3,848	23,584	100	595	68	314	168	909
	200,000	800,000	1,000,000	80,000	640,000	│	1,993	641	2,971	594	2,377	7,696	47,168	200	1,190	136	627	336	1,817
	400,000	1,600,000	2,000,000	160,000	1,280,000	│	3,811	980	5,128	1,025	4,103	15,392	94,336	400	2,381	272	1,234	672	3,615
	800,000	3,200,000	4,000,000	320,000	2,560,000	↓	7,447	2,000	9,784	1,957	7,827	30,784	188,672	800	4,762	544	2,469	1,344	7,231

Effect of Traffic Volume on Costs The terms that have just been discussed and evaluated can now be applied to definite volumes of traffic, operating costs, tax contributions and annual road costs for various traffic volumes may thus be determined A tabulation of these values for an annual traffic varying from 10,000 to 4,000,000 tons is given in Table IV These data have been presented in graphical form in Figure 2

In discussing this analysis, it should be remembered that the basis for the entire study lies in assumed values for many items, assumed because it is impossible, as yet, to know their true values The assumptions made, however, are within the bounds of reason and any conclusions that may be drawn from this study should have some significance

The annual cost curves shown in Figure 2 indicate clearly how the annual cost for each type of road varies as traffic increases It is quite apparent that the points of intersection of these curves mark the place where, for any increase in traffic, the annual cost of the higher type is less than that of the lower type surface It is very interesting to note that the annual costs of the low-type and high-type surface are equal when the annual traffic is less than 500,000 tons, while the low-type and intermediate-type surfaces have equal annual costs when the volume of annual traffic is over 1,500,000 tons

The curves shown as dotted lines in Figure 2 indicate how the tax contributions vary with annual traffic on each of the three types of surfaces being studied Considering any single type of surface, it is at once apparent that the intersection of the "contribution" curve and the "annual cost" curve represents the point where annual road costs and tax contributions are equal From the figure, annual road costs and tax contributions are equal when the volume of annual traffic is 900,000 tons for high-type roads, 2,650,000 tons for intermediate-type roads, and about 10,000,000 tons for low-type roads These values represent respectively, annual traffics of about 675,000, 1,800,000 and 6,000,000 vehicles

CONCLUSIONS

The foregoing discussion is intended as an additional step in the development of the analysis of highway transportation costs Definite conclusions from so general an analysis are made with difficulty, especially when one considers the numerous assumptions it was found necessary to make One or two points are significant and are worthy of mention

An annual traffic of 675,000 vehicles apparently contributes enough, through taxes, to pay the annual cost of a high-type road This annual traffic represents an average hourly traffic of 75 vehicles—a figure that is probably exceeded on the majority of our high-type surfaced roads The vehicles using high-type surfaces are evidently contributing more than enough money to pay the annual cost of the road The excess contributions, of course, are being used, and justly so, to pay the annual costs of light traffic roads

DISCUSSION

ON

HIGHWAY TRANSPORTATION COSTS

PROFESSOR N W DOUGHERTY, *University of Tennessee* I have read a number of magazine and text book discussions which undertake to evaluate the saving made when distance is reduced Most of them assume that since the average cost of operating a mile of distance is about eight to ten cents per vehicle this amount will be saved if distance is reduced Notice that the fixed charges, with small operating mileage, run the operating cost up to eighteen cents per mile When you have a large operating mileage per year you bring the cost down to five cents per vehicle mile Of the five cents only a part may be saved because the fixed charges still enter in to the cost

MR F LAVIS, *Consulting Engineer, New York* In regard to values of savings in distance, I hardly think we should concern ourselves here unduly with what magazines say I doubt very much if discussions in responsible technical journals make the mistake of assuming that savings of distance affect all operating costs

It is evidently, however, necessary to place further emphasis on the statement of the Committee that there is the greatest danger in applying any of these figures indiscriminately and unintelligently

PROFESSOR MORRISON One thing which is apt to be overlooked is that even the vehicle operating costs which vary with mileage are not entirely chargeable to the distance operated and should not be entirely credited to distance saved

For instance, gasoline is used in starting and idling as well as in traveling With my own car I get an average of less than 10 miles per gallon, but on a long trip I get more than 12 miles per gallon Therefore, by the elimination of one mile of distance I save $\frac{1}{12}$ gallon of gasoline, not $\frac{1}{10}$ gallon That means that only 80 or 85 per cent of my average cost per mile for gasoline is saved by eliminating the mile of travel

Tires deteriorate with age, abuse, and accidents as well as with mileage so that the cost probably varies even less directly with distance than does the cost of gasoline Maintenance costs increase with mileage but there are many items such as new batteries, brake adjustments, and body repairs which depend more upon frequency of use than upon distance traveled Depreciation is apt to be due more to obsolescence than to use

After the average total cost per mile for gasoline, oil, grease, tires, maintenance, and possibly depreciation, has been computed then something less than 100 per cent of this cost is saved for every mile of distance which is eliminated Attempts have been made to determine just what this per cent should be but it is very difficult, if not impossible, to determine it accurately and the engineer can only use a figure which, in his best judgment, is conservative

The main point is that not all of the sum of these variable costs is saved by eliminating distance, and none of the fixed costs such as license fees, garage, insurance and interest

PROFESSOR DOUGHERTY I did not make my point clear I say that in many magazine and text book discussions you will find that the authors are not trying to evaluate the saving made by a reduction in distance but are putting down all the operating costs of the motor vehicle Many of the items are not proportional to the operating cost of a mile in distance If the average operating cost of a mile is ten cents and you multiply this sum by the amount of traffic per year, times the miles of distance saved, the result is not the saving that may be obtained by cutting down distance

There are many items in the cost that are not proportional to distance at all When you travel a few miles per year, your operating cost per mile is high

If you examine the discussions previously referred to you will find that the authors are trying to prove that to save a mile of distance you can afford to spend much, even millions of dollars This, for the ordinary rural highway is purely fallacious You cannot afford to spend the amounts thus obtained

MR LAVIS I do not agree with the previous speaker that it is fallacious or fantastic to say that the saving of a mile in distance may justify the spending of a million dollars On the contrary, the amount which justifiably may be spent may be many times that amount

Without going into detail I would refer particularly to the studies which were made in connection with the design of Route 1 Extension of the New Jersey State Highways (now Route 25) The main section of this highway cost $25,000,000 for eight miles and it was considered imperatively necessary to check very carefully the economic factors, that is to say, the effect on the operating costs of vehicles, of the location and design

I think this was the first case where an attempt was made to apply fully to highway construction the economic theory of location which was developed for railways by the late Arthur M Wellington Several individual factors had been studied and applied elsewhere, but not, so far as the speaker is aware, the application of the theory as a whole

These studies are described in a paper entitled "Highways as Elements of Transportation" published in Vol 95 of the Transactions of the American Society of Civil Engineers 1931, and at some greater length in Mr S S Johannesson's book on Highway Economics

DR L I HEWES, *U S Bureau of Public Roads* I am a little puzzled to decide whether the gentleman means for us to infer that if we made the roads longer the operating costs would be cheaper, or whether he is pointing out a fallacy in the reasoning of the preceding paper If his position is sound I feel a large part of my life has been misspent because it has been one of my objectives to reduce mileage although I think it is quite true that we have seen some rather extravagant claims made

I suppose you are all familiar with the studies made in New Jersey prior to the construction of the superhighway between Jersey City and Trenton They introduced there a new element to me, and that was the time losses, rating the value of trucks at a certain number of cents per minute and similarly with the other vehicles That question of the value of time of course is one that might be debated extensively It leads us to the question of why operate an automobile anyway I think these studies are extremely valuable and possibly are of some danger It is obvious, however, that the heavily traveled roads are the money making ones and that fact has made extreme bearing on some of the questions that are now being agitated, in particular the attempts to take revenue away from the main trunks and peddle it around to the roads that cannot earn their keep

I have not seen any magazine articles that claim ten cents saving per mile for reduced distance Twenty years ago when the Bureau published my bulletin on Highway Bonds I had the temerity to make some comparisons on a basis of five cents However, I think a rating of the economy of improvement could best be handled by setting up a table of what could be saved at one cent, two cents and so on, allowing the engineer to select from the data which he has at his command the proper saving figure

MR L E PEABODY, *Bureau of Public Roads* It seems to me that the difference between Dr Hewes and Professor Dougherty might be this point: Professor Dougherty contends that not all of the saving is at an operating rate of ten cents a mile The individual user whose mileage is sufficiently large, operates at about five cents per mile He does not want ten cents applied to all the traffic

Dr Hewes is thinking of the aggregate of traffic carried by a road and he is urging that the roads carrying the most traffic and the largest volume be considered the greatest earners, as they are, and that saving in distance on those highways is most valuable, although not every vehicle upon them operates at the ten cent per mile rate

MR E W JAMES, *U S Bureau of Public Roads* The material presented by this Committee at the meeting last year and at the present session appears sound up to the point where it becomes necessary to determine some method of applying generally to the highway net the element of vehicle costs as a part of total transportation costs The discussion last year pointed out the unsoundness of general conclusions based on the study of specific sections of road or based on applications of the data to separate road sections

The application actually made in last year's report of the factual data then in hand indicated, however, the direction in which a wide general application of the data should be sought

Assuming that we have all the facts necessary regarding vehicle operation, it appears that adequate and sufficient additional data may be found: (a) in the density of traffic on the road system, and (b) in a complete condition chart or map of the same system

The density figures collected exactly as if for a flow chart will furnish the amount of traffic on every section of all routes of the system The condition chart will locate every section and indicate its length, type, width and other physical details Such a condition chart predicates the knowledge of original costs and the date of construction and maintenance charges These enable us to determine present cost and total annual cost, section by section

With these data in hand, it then becomes possible to answer a large variety of questions progressively in greater detail according to the way the facts are applied

If the question, is "Does the highway system as a whole pay for itself?" we may determine an average density of traffic, disregard types, determine the sum of the maintenance and carrying charges, and answer the question definitely If the question is put in another form, such as "Does a particular type of pavement in the system pay for itself as a whole?" again we have data for answering the question The density figure for all roads of the specified type can be determined together with the fixed charges and an answer given to the question Again, if the query takes the form "Is a specific section of road paying for itself?" the material already presented and the report of the Committee last year and this year indicate the method of arriving at a definite answer

Finally, we are in a position further to analyze the application of the data relative to vehicle operation to answer the question within what limits of traffic does a pavement of specific type pay for itself

From the density figures and our condition chart, with the data implied as accompanying that chart, we can make an array of sections based on frequency intervals of traffic, giving those intervals such value by trial as will best suit conditions The application of this method will enable us to determine, for instance, whether on roads of a specified type traffic from 0 to 499 will carry the total transportation charges, whether in the next frequency interval 500 to 999 the traffic will or will not carry the total transportation charges, and so on, through each frequency interval for which cases can be found on the specified types of pavement in the entire system By this method, for instance, we might find that a bituminous macadam with a very heavy base, and therefore of relatively high original cost for this type, may not pay for itself in the frequency group 500 to 999, or in a lower group, that it will pay for itself in the frequency group 1000 to 1499, and then again in the next frequency group 1500 to 1999, it will not pay for itself because of high maintenance charges

For the designer and the administrative official responsible for laying out a highway system and fixing a program of construction with the implied selection of types and determination of all design features, this last method of analysis seems to be the most suggestive and valuable

The data required additional to that relative to vehicle operation are only such as can be obtained in the ordinary traffic survey of the State to determine density figures, together with the state records of construction and maintenance