RURAL MAIL CARRIER MOTOR VEHICLE OPERATING COSTS ON VARIOUS TYPES OF ROAD SURFACES

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SYNOPSIS

Operating cost records for 160 cars operated by rural mail carriers in Iowa and in Indiana have been assembled, summarized, and analyzed for the purpose of determining the operating cost differentials for various types of road surfaces The data show that the average unit operating cost differentials are from 5 to 10 times greater than the average unit motor vehicle tax contribution for the construction and maintenance of roads, and therefore should be considered as the most important factor in selecting the type of surface to be used for given traffic conditions

From the detailed daily record of these cars covering every phase of operation such as miles of travel on each surface, rate of travel, weather, number of stops, load, gasoline and oil consumption, tire expense, maintenance costs, garage rental, license fees, taxes, insurance, depreciation, interest, and extra help The unit operating costs were determined for each type of surface

From the plotted data the average cost of operation for the year-round condition was found to be about 8 cents per mile for earth or natural soil roads, 5 cents per mile for untreated gravel surface, and 3½ cents per mile for portland cement concrete or bituminous macadam surfaces The operating cost was 2¼ cents per mile less in summer than in winter for earth roads, 1¾ cents per mile for untreated gravel, and 1 cent per mile for pavement The average annual travel for all cars was 10,919 miles, for cars operating entirely on earth roads, it was 1,500 miles, for cars operating on gravel roads, 11,000 miles per year, and on paved roads it was 14,000 miles per year The average miles of route covered per hour, including stops, was about 14 on gravel and pavement and 8 per hour on earth roads for the year-round condition During the summer it was 16 miles per hour on paving and gravel as compared to 10 miles per hour on earth roads In the winter it was 12 miles per hour on paving and gravel as compared to 6½ miles per hour on earth roads If it is assumed that the value of the mail carriers' time is 50 cents per hour, the paved or gravel road would then provide a time saving 2⅔ cents per mile over the earth road for the year round condition

In the statistical analysis, the average cost of gasoline, oil, tires and maintenance for the year-round condition was 3.17 cents per mile for earth roads, 2.46 cents per mile for gravel roads, and 1.73 cents per mile for paving The cost of gasoline, oil and maintenance for the winter months was 3.44 cents per mile for earth, 2.56 cents per mile for gravel, and 2.06 cents per mile for paving For the summer months these costs were 1.97 cents per mile for earth, 1.71 cents per mile for gravel and 1.49 cents per mile for paving

Applying these data to determine the traffic volume necessary to justify changing from an unimproved earth road to an improved gravel surfaced road for a surfaced road for a typical Iowa county, it was found that 20 vehicles a day are required if operating costs only are considered and 3 vehicles a day if a time value of 2⅔ cents per mile is added

Cost records for 160 cars operated by rural mail carriers in Iowa and in Indiana have been assembled, summarized, and analyzed for the purpose of determining the operating cost differentials for various types of road surfaces This study, which is being conducted by the Iowa Engineering Experiment Station, will serve as a pilot study for a more comprehensive program now being planned as a cooperative project with the Bureau of Public Roads to determine as nearly as possible the true operating cost differentials for various types of road surfaces

Although the Iowa Engineering Experiment Station has conducted studies along these lines over a period of more than fifteen years under the direction of Dean T. R Agg, these studies have provided only partial information in regard to operation costs, generally covering only such items as tractive resistance, fuel consumption, and tire wear, for various surfaces, or covering all items related to operating costs for cars and trucks but without reference to surface types In many cases road tests were conducted only under favorable weather conditions and over short test courses Or in the case of projects where studies were made of cost records turned over to the Station by car or truck owners, practically no information was available to indicate the mileage traveled on various types of surfaces Accordingly, this study is the first comprehensive car cost study which has come to the writer's attention in which the mileage traveled on each type of surface is known and in which the cars operated practically every day of the year in all kinds of weather

While it is true that the operation of a car on a rural mail route is a highly specialized operation and should not be considered as typical of the operation of cars on all rural highways, certainly not on main state highways, it seems fair to state that this type of operation is quite common on a large mileage of local county roads, land service roads, or farm-to-market roads which are in great need of improvement Rural mail service, school bus service, the collection and delivery of farm products such as milk, eggs, butter, poultry, meat, etc, and the country nurse or doctor service, all have much in common as far as the nature of their motor vehicle operation is concerned and furthermore, they constitute a large portion of the traffic on these roads Stops in all of these services are frequent, and speeds are generally low, rarely exceeding 30 or 40 miles per hour The nature of the service in practically all cases requires operation every day of the year in all kinds of weather Therefore, a study of operating costs for cars operated by mail carriers may be considered as fairly representative of operation on the purely local or farm-to-market roads That such a study is important becomes apparent when one realizes that approximately two million of the three million miles of road in this country may be included in this class

During the past 20 years of intensive road building the highway engineer has been concerned mainly with the improvement of the important state and county routes which carry the large bulk of traffic Now that the main highways are practically all improved with all-weather surfacing, considerable attention is being given to extending the surfacing program to farm-to-market roads In certain eastern states, notably in Pennsylvania, this work has gone forward at a rapid pace However, in many of the midwest, far west, and southern states, much remains to be done Funds for road improvement in these more sparsely populated areas are not as easily obtained as in the eastern states The value of road improvement and improved road surface construction is still not fully realized in these states Renewed emphasis might profitably be given to that well known roadbuilder's slogan "car owners pay for good roads whether they have them or not" This implies that the car costs on unimproved roads are considerably higher than on improved roads due to additional fuel required, extra tire wear, maintenance expense and other costs which in many cases far exceed the cost to the car owner in the form of extra taxes for improving the road

In the case of main highways where the traffic volume was large, even 10 or 15 years ago, it was easy to show that the savings in operating cost justified the improvement Refined and carefully controlled studies of operating costs were not necessary. Today the highway engineer is called on to make decisions in regard to the selection of surfacing improvements for secondary roads on which the traffic is much lighter and for which a more careful analysis of all the cost factors is necessary than on the main state highways, if a wise economic selection of the type of surface improvement is to be made.

The differences in operation cost on stabilized surfaces, such as soil, cement, or oil stabilized roads, and on the higher types of surfaces, such as the various bituminous surfaces, portland cement concrete, brick, etc., are small and are difficult to measure. No attempt was made in this study to measure these differences. The cars in this study operated largely on portland cement concrete, untreated gravel and on unimproved earth or natural soil surfaces. The differences in operating costs on these surfaces were very marked. In fact, the differences in the operation costs for the year round conditon on earth as compared to gravel or paved surfacing far exceed previous estimates. If the low annual mileage of cars traveling on earth roads is taken into account and if the time factor is evaluated those particular data indicate that a traffic volume as low as three vehicles per day justifies an investment of $1,000 per mile for road surfacing improvements for road conditions similar to those in Iowa on its local farm-to-market roads.

"THE MAILS MUST GO THROUGH!"

Road improvements on our main highways are so general that many road users and, indeed, many highway engineers too, have forgotten what mud roads are like. They are not aware of the many inconveniences, of the extra equipment required, and extra costs incurred on mud roads such as are shown in Figures 1 to 4. Uncle Sam says, "The mails must go through!" and the rural mail carrier must take the roads as he finds them. The reports from a large number of carriers showed that special equipment was being used by these carriers to operate on mud roads and snow-covered roads which are practically impassable if standard equipment is used.

In Figure 1 a special mud car is shown using large diameter rear wheels to permit operating in the deep ruts formed on mud roads. The extra clearance between the wheels and the fenders prevents the mud from accumulating under the fender to the point where it will interfere with the free action of the wheel. This open type fender makes it easy to clean out the mud on a gumbo road where the mud has a tendency to stick to the tires and roll up in thick layers which must be removed with a spade at frequent intervals. The mud condition and deep ruts shown in Figure 2 are quite common on unimproved local roads throughout the middlewest today. One ingenious mail carrier recognized that there should be a close relation between mud roads and corrugated metal pipe. He decided that if the county engineer failed to use it effectively, then he would use it to prevent being bogged down in the mud by clamping about a 12-inch section of the pipe to each rear wheel forming an extension to the wheel which would provide the necessary support after the tire pene-

Figure 1. Special "Mud" Car Used in Jefferson County

trated the mud to the depth of the corrugated metal pipe as shown in Figure 3. Several mail carriers reported the use of the special Snowmobile equipment shown in Figure 4. The Snowmobile equipment is effective both on snow-covered and muddy roads. But it is quite

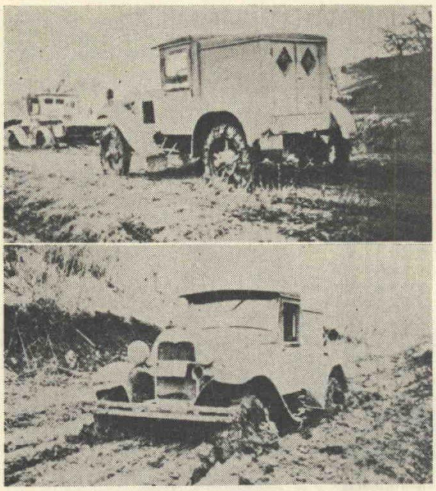

Figure 2. High Clearance Axles in Use on Jackson County Roads

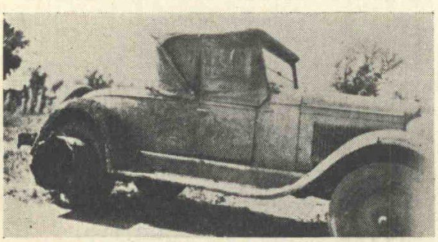

Figure 3. Corrugated Metal Culvert Pipe Used as Wheel Extension for Deep Mud on Buchanan County Roads.

evident that the operating costs for equipment of this type or under these conditions are appreciably higher than on improved roads with all-weather surfaces. Also the average speeds are very much lower for this equipment and on these roads than for standard car equipment on hard road surfaces. How much greater these costs and the accompanying delays are on earth roads than on all-weather surfaces is a question which has not been fully answered up to this time. The analysis of complete daily records of operating costs extending over a full year, as were obtained in the mail carrier reports, provides some valuable factual evidence in regard to those costs and delays.

CAR COST STUDY REPORT FORMS

Route and Car Descriptions

The first step was to send out Form 1 which was filled out by the carrier who agreed to furnish us with a daily record of all car operation items and costs both on and off the route for at least 12

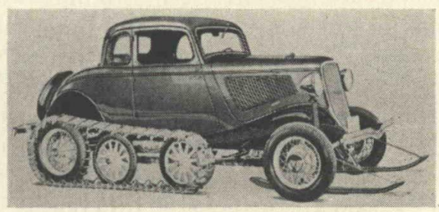

Figure 4. Snowmobile with Ski Runners in Front and Traction Belt Drive on Rear, Used to Combat Mud and Snow.

months. This Form provides a complete description of the route and of the car.

Separate forms were made for each car used or for a new car if a change was made during the year.

Daily Record Book

A daily record book was sent out to each carrier. This book provided a daily record of the type shown in Form 2 for one full month. On the front cover of each book the month and the year were filled out by the owner, together with his name and address, the make, year model, number of cylinders and the license number of the car. A new book was started the first day of each month and the book for the previous month was sent in to the Experiment Station at Ames.

It should be noted that the daily record was fairly easy to keep yet it provided all the necessary information to conduct the study Thus for each day the speedometer reading was given, followed by the temperature and weather conditions which were checked, the pounds of mail carried, the travel time including stops, the miles driven on route, the itemized expenditures such as gasoline, oil, tires, repairs, chains, greasing and other items of expense The hours of personal labor on the car each day were listed Remarks covering such items as road condition, delays, detours, accidents, extra help, chains used, etc , were also noted At the bottom of the page the miles of road driven off the route were classified according to the four road surface types previously defined

On the inside of the back cover Form 3 was provided to keep a record of tire mileage, the make, cost and a record of tire changes during the month

Monthly Summary Sheets

After the daily record book was sent in, a preliminary monthly summary was made and entered upon Form 4 On this form a careful record of the route and off route mileage was entered and classified as to surface type for the total mileage operated each month A monthly summary of all operation items was listed on Form 5 This provides for a summary of route and off route mileage, the amount of cost of gasoline used, oil, tire cost, maintenance costs which included tire chains, anti freeze, washing, greasing, repairs, and personal labor at 40 cents per hour, the cost of extra help, the miles of travel per hour (including stops) and miscellaneous items which were listed under remarks

Final Quarterly and Annual Summary Sheet

After a full year's record was completed, a final quarterly and yearly summary was made for each car and entered upon Form 6 The quarterly summary covered the same items listed on the monthly summary *Extra Help* A distinction was made between extra help with and without the car Extra help with the car may generally be interpreted to mean that the roads were passable but travel was so slow and so difficult that the carrier needed assistance to cover the route in a reasonable length of time Extra help without the car may be interpreted to mean that the roads were impassable either because of snow or mud and that the car had to be replaced with some other form of transportation as the use of a horse or a team and wagon, or of several men on foot from points on the route which were accessible

Recorded Costs In the summary for the year both recorded and adjusted costs are tabulated The recorded costs are merely the sum of the costs set down in the daily record books Since the record was kept for only one year, the recorded cost did not provide a complete and accurate record from which a true unit cost of operation could be computed In many cases no records were entered covering such items as tire replacement, garage rental, insurance, depreciation, and interest or if such items were entered they were not representative of the actual cost for the 12 months during which this study was made In many cases considerable tire data were given which were helpful in determining the average tire life for operation on various surface types, but this information rarely, if ever, was given in such a way that the recorded cost indicated accurately the cost for the year for the definite mileage over which the car was operated The records also provide information in regard to depreciation since the trade-in value for a number of cars was given Unfortunately the depreciation based on these trade-in values generally covered periods greater than that over which the cost records were kept In order to arrive at a uniform basis for comparing unit operating costs, adjusted costs were computed for such items as tires, garage, insurance, depreciation and interest The explanation of how these adjusted costs were computed is given below

Adjusted Costs The adjusted costs for gasoline, oil, and maintenance were the same as the recorded costs This was also true for the license fee except where penalties were paid, no penalties being included in the adjusted cost

Tire costs were computed on the basis of the miles of travel on the types of surface over which the tires were used The percentage of total miles traveled on hard surfaced roads was calculated and the average life of the tires taken from Table 1 The average tire life shown in this table was determined from a study of the tire mileage data reported on Form 3 and from tire wear tests conducted by the Station as reported at the last annual meeting [1]

The tire cost in cents per mile was computed on the basis of the average mileage per tire given in the table and an average tire replacement cost of $15 per tire To obtain the adjusted tire cost it was only necessary to select the correct value for unit cost in Table 1, multiply it by the total miles driven, and add to this the tire repairs as recorded in the Final Monthly Summary on Form 5

Many carriers made no charge for garage rental To arrive at a uniform adjusted cost, the rental values which were recorded were averaged It was found that $2 50 per month was close to the average and this figure was selected as a fair rental charge for rural mail carrier cars

[1] "Gasoline, tire wear, and coefficients of friction on various road surfaces" by R A Moyer and H W Tillapaugh Proc Highway Research Board, Vol 16 (1936)

Insurance charges were figured on the basis of rates at Ames, Iowa, during 1936 The coverage included $5,000 property damage, and $10,000 and $20,000 public liability The standard rates for fire, theft, and tornado were applied for cars less than 7 years old For cars older than 7 years, the depreciated value of the cars is so low that the cost of insurance for fire, theft, and tornado is not justified

To arrive at a fair method of determining depreciation a study was made of used car values for various standard makes of cars As a result of this study, Table 2 was made up showing depreciated values of Iowa and Indiana cars for various ages from a new car to a car 7½ years old It should be noted in this table that the depreciated value is given in percent of the value new for each half year up to 7½ years Beyond this age the depreciated value was assumed to be equal to the salvage value and, therefore, the depreciation was zero for all such cases When no delivered price was given, it was obtained by multiplying the list price by 1 24 for Iowa and 1 22 for Indiana To compute the depreciation over any period, it was necessary to know the age of the car at the beginning and end of the period Thus if the car in question was 1 5 years old at the beginning of the year and, of course, 2 5 years at the end of the year, it can be seen from the table that the depreciated value for such a car in Iowa would be 51 9 percent at the beginning of the year and 40 5 percent at the end of the year The depreciation for the year is the difference between the two or 11 4 percent of the value new If the delivered price was $700, the depreciation for the year would be 11 4 percent of $700 or $79 80

The interest charges for all cars were computed using a rate of 6 percent per annum on the depreciated value of the car at the beginning of the year or fraction of the year over which the summary was made

In the summary for the year the total cost for each item was obtained and this was then reduced to a unit cost, that is to the cost in cents per mile, by dividing the total cost by the total miles traveled during the year The total cost of operation for the car was then obtained by adding all of the individual costs A separate total was obtained for operation of the car not including extra help and also including extra help A third item reported was the cost of extra help without the car This covers the cost of extra help using a separate form of transportation required when the roads were impassable, and is referred to as car transportation replacement cost in this report

ANALYSIS OF COST RECORDS AND DISCUSSION OF RESULTS

Since only a small percentage of cars were reported as operating exclusively on one type of surface, it was necessary to devise methods of analyzing the cost records which would permit isolating the unit costs of operation on each surface as accurately as possible To accomplish this purpose two methods of analysis were used, one involved plotting the cost data on graph paper indicating the variations or trends in costs as the percentage of travel on earth, gravel, or on paved roads varied, the other involved the use of the statistical method of least squares to determine the unit costs on each type of surface There was substantial agreement in the results obtained by both of these methods in all cases in which the same basic data were used The graphical method, although lacking in accuracy, has the advantage of bringing to the reader a fairly complete picture of all of the facts related to cost and this is the method most frequently referred to in the following discussion

Comparison of Unit Costs for 160 Cars Using the Graphical Method

In Figure 5 the unit cost of operation for each of the 160 cars is shown for varying percentages of total mileage traveled on earth roads as compared to the mileage on pavement and untreated gravel for the year 1936 These costs represent the adjusted total operating costs and do not include the cost of extra help or a charge for the driver's time

TABLE 1

AVERAGE TIRE LIFE AND UNIT TIRE COSTS FOR VARYING AMOUNTS OF TRAVEL ON HARD SURFACED ROADS

Per cent hard surfaced roads	Average life per tire, miles	¢ per mi for four tires
0– 40	18,000	0 333333
40– 60	20,000	0 300000
60–100	22,000	0 272727

TABLE 2

DEPRECIATED VALUES OF IOWA AND INDIANA CARS

Age, years	Percent of value new*		Age, years	Percent of value new*	
	Iowa	Indiana		Iowa	Indiana
0 0	100 0	100 0	4 0	27 3	27 8
0 5	73 2	74 0	4 5	23 6	24 0
1 0	59 8	60 7	5 0	20 0	20 3
1 5	51 9	52 7	5 5	17 0	17 3
2 0	45 8	46 5	6 0	14 0	14 2
2 5	40 5	41 2	6 5	11 3	11 5
3 0	35 7	36 3	7 0	8 9	9 0
3 5	31 5	32 0	7 5	7 0	7 1

* Value new is the total delivered price paid by owner — 100%

It should be noted that the average cost for cars traveling exclusively on gravel and paving is about 4 cents per mile as compared to 8 cents per mile when the travel is exclusively on earth roads The minimum cost on gravel and paving is about 2½ cents per mile as compared to 6 cents per mile on earth and the

FORM 1

RURAL MAIL ROUTE CAR COST STUDY

ROUTE AND CAR DESCRIPTIONS

Nov 1, 1935

(1) Carrier David R Allred RR 5 Town Des Moines

(2) Street 1705 12 County Polk State Iowa

(3) Number of boxes on route 400.

(4) Miles traveled each day that route is carried 39.25

Road surface type	Route miles	Miles between home and P O (both ways)	Total daily miles
1 (Rigid pavements) Concrete, brick, sheet asphalt, wood block, granite block, etc	17	3	20
2 (Semi-rigid treated) Bituminous macadam, oil treated gravel, tarvia, etc			
3 (Surfaced but untreated) Gravel, crushed rock, sand-clay, shale, cinders, etc	17		17
4 (Natural earth) Clay, loam, gumbo, sandy soil, etc	2 25		2 25
Total	36 25	3	39 25

(5) Make of car Studebaker Year model 1935 Body style Sedan

No of cylinders 6 Date purchased 12 20-34 New or used New

List weight 2960 List price $785 (see license receipt)

Delivered price, new including equipment $986 50

Actual weight with driver and average mail load 3175

Monthly rental value of garage $3 00

(6) If you operate 2 cars, note similar information for the second car on the reverse side

Return to

Engineering Experiment Station
Iowa State College
Ames, Iowa

FORM 2

PAGE FROM DAILY RECORD BOOK

RECORD FOR Feb 17 (Month and Day), 19 36

Speedometer reading, morning 18835

Approx air, temperature, morning 27°

Dry, wet, rainy, quiet, windy, icy, snowy
(check ones applicable)

Approx pounds of mail carried 75

Hours required to cover route 6

Miles driven on route 45

Itemized expenditures on this day

		Total Cost
Gasoline, gallons	8	$ 1 46
Oil, quarts	1	$ 0 26
Tire repair		$ 0 35
Chains		$ 5 90
Extra help		$ 1 00
		$

Hours personal labor on car 1

Remarks, road condition (impassable, slippery, √ soft, etc), delays, detours, accidents, extra help, √ chains used, √ etc

Road icy, one mile detour on earth

Miles driven off route by road surface types

Concrete, brick, asphalt, etc	Oiled gravel, asphalt or tarmacadam, etc	Plain gravel, shale, crushed rock, etc	Natural earth	Total
10		3	1	14

FORM 3

TIRE MILEAGE AND COST RECORD

Serial No	Mfr or Make	Plies	Cost	Wheel	Put on		Taken off		Total mileage
					Date	Speedometer	Date	Speedometer	
730-K	Atlas	4	13 25	R F	8-14	29102			
960-K	"	"	"	L F	"	"			

FORM 4

Name David R Allred No 5
R R 5 No boxes 400 Town Des Moines County Polk State Iowa
Make Studebaker Year model 35 Body Sedan No cyls 6
Date purchased 12-20-34 New or used New List weight 2960
Road weight 3175 List price 785 Del cost 986 50 Garage rental $3 00

Surface type	Route	Home P O	Total daily
1 Pavement	17 00	3 00	20 00
2 Treated			
3 Gravel	17 00		17 00
4 Earth	2 25		2 25
Total	36 25	3 00	39 25

Cost Summary For Year

Item	Cost, $	¢ per mi
1 Gasoline		
2 Oil		
3 Tires		
4 Maintenance		
5 Depreciation		
6 License	20 00	
7 Garage		
8 Interest		
9 Insurance	30 00	
Total		
10 Extra help		
Total		

Miles per gallon, gas ______

Miles per quart, oil ______

Average speed on route ______

Month	Speedometer reading			Correct mileage	Surface mileage (Upper fig off route)			
	Beginning	End	Difference		1	2	3	4
Nov '35	16230	17627	1397	350 1047	342 534		450	8 63
Dec '35	17627	18833	1206	153 1053	153 537		453	63
Jan '36	18835	20004	1169	114 1055	114 538		454	63
Feb	20004	21203	1199	141 1058	141 540		455	63
Mar '36	21203	22664	1461	374 1087	374 554		467	66
Apr '36	22664	24097	1433	393 1040	393 530		447	63
May	24097	25580	1483	523 960	523 490		413	57
June	25580	26886	1306	423 883	423 450		380	53
July	26886	28396	1510	470 1040	470 530		447	63
Aug	28396	29850	1454	534 920	534 469		396	55
Sept	29850	31299	1449	449 1000	449 510		430	60
Oct	31299	32658	1359	285 1074	285 548		463	63
Nov	32658	34466	1808	1054 754	1054 385		324	45
Total								

FORM 5

Final Monthly Summary of All Operation Items

Name David R Allred No 5

Month	Total correct mileage route mi above	Gasoline			Oil			Tire $	Maintenance, $						Total		Extra help $	Av route speed	Remarks
		Gal	$	Mi per gal	Qts		Mi per qt		Chain an-fr	Wash Gr's	Rep	Lab 40¢	Total $	Total ¢ per mi	$	¢ per mi			
Nov '35	1047 1397	110	20 12	12 7	10	3 26	140		4 05	0 75	0 87	2 80	8 47	0 606	31 85	2 280		12 9	Defroster— $1 53
Dec '35	1053 1206	99	17 12	12 2	10	3 28	121		0 35	1 50	1 00	1 60	4 45	0 369	24 85	2 061		11 2	
Jan '36	1055 1169	108	19 44	10 8	5	1 63	234		0 82 1 40	0 75	7 92	1 60	12 49	1 068	33 56	2 871	0 15	9 7	Storage— $0 75
Feb '36	1058 1199	113	20 79	8 9	10	3 25	120	0 50	0 31 1 35	0 75	3 80	2 40	8 61	0 718	33 15	2 765	2 00	9 2	Tow-chain— $2 39
Mar '36	1054 1440	123	21 92	11 7	5	1 63	288			2 40	2 72	2 80	7 92	0 550	31 47	2 185	1 50	10 0	
Apr	1040 1433	110	19 57	13 0	10	2 66	143			2 25	3 43	0 80	6 48	0 452	28 71	2 003		13 0	
May	960 1483	113	20 15	13 1	5	1 65	297			0 75	7 18	2 40	10 33	0 697	32 13	2 167		12 0	
June	883 1306	97	17 26	13 5	5	1 63	261			0 75	16 95	5 20	22 90	1 753	41 79	3 200		12 3	
July	1040 1510	100	17 78	15 1	10	3 26	151	0 50		2 50	1 00	1 60	5 10	0 338	26 64	1 764		12 9	Insurance 1 yr $30 00
Aug	920 1454	108	19 26	13 4	5	1 63	291	0 40 22 44		0 75	1 50	1 60	3 85	0 265	47 58	3 272		12 4	
Sept	1000 1449	111	19 71	13 1	10	3 26	145	0 85		0 75	1 52	2 00	4 27	0 295	28 09	1 939		12 2	
Oct	1074 1359	115	20 48	11 8	5	1 63	272	33 00	5 40	0 60 1 50	21 88	4 40	33 78	2 486	88 89	6 541		11 3	
Nov	754 1808	142	24 30	12 7	18	5 34	100			2 01	16 40	0 80	19 21	1 063	48 85	2 702		11 2	
Dec																			
Total																			

FORM 6

FINAL QUARTERLY AND ANNUAL SUMMARY FOR ALL CAR OPERATION ITEMS

Name David R Allred R R 5 Town Des Moines County Polk State Iowa No boxes 400

Make Studebaker Director Year 1935 Body Sedan Road weight 3175 Date purchased 12-20-34 Delivered cost $986 50

Summary by Seasons

Period	Mileage			Mileage by surface types								Av * route speed	Gasoline		Oil		Maintenance		Extra help			
				Pavement		Treated		Gravel		Earth									With car		Without car	
	Total	Route	Off route	Route	Off route	Route	Off route	Route	Off route	Route	Off route	Mi per hr	Mi per gal	¢ per mi	Mi per qt	¢ per mi	$	¢ per mi	$	¢ per mi	$	¢ per mi
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
Dec -Feb 1935-1936	3574	3166	408	1615	408			1362		189		10 0	11 2	1 605	143	0 228	25 55	0 715	2 15	0 068		
Mar -May 1936	4377	3087	1290	1574	1290			1327		186		11 6	12 6	1 408	219	0 136	24 73	0 565	1 50	0 049		
June-Aug 1936	4270	2843	1427	1449	1427			1223		171		12 6	14 0	1 272	214	0 153	31 85	0 746				
Sept -Nov 1936	4616	2828	1788	1443	1788			1217		168		11 6	12 6	1 397	140	0 222	57 26	1 240				
Year	16837	11924	4913	6081	4913			5129		714		11 3	12 6	1 412	172	0 183	139 39	0 828	3 65	0 031		

Summary for Year

		Gasoline	Oil	Tires	Maintenance	Garage	License and taces	Insurance	Depreciation	Interest	Total	Extra help†		Total‡
												With car	Without car	
		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Recorded cost	$	237 78	30 85	57 69	139 39	36 00	20 00	30 00			551 71	3 65		555 36
	¢ per mi	1 412	0 183	0 343	0 828	0 214	0 119	0 178			3 277	0 031		3 308
Adjusted cost	$	237 78	30 85	48 17	139 39	30 00	20 00	27 82	145 02	36 40	715 43	3 65		719 08
	¢ per mi	1 412	0 183	0 286	0 828	0 178	0 119	0 165	0 861	0 216	4 249	0 031		4 280

* Average route speed equals total route miles divided by the total time spent on the route

† Extra help is divided, where possible, into help used with the regular route car (recorded under "with car"), and help which is hired to cover the route or a portion of the route (recorded under "without car") Costs under "without car" are usually not true transportation costs as the salary of the operator is often included

‡ Column (14) is the sum of columns (11) and (12)

maximum is about $6\frac{1}{4}$ cents per mile on gravel and paving as compared to $11\frac{1}{4}$ cents per mile on earth One reason for this large spread in costs between the minimum and maximum values is due to the wide variations in annual mileage and the age or depreciation charges against the car To reduce the effect of the wide variations in mileage and age, the unit costs of 98 cars operated more than 5,000 miles per year and with ages of 3 years or less (1933 to 1936 year models) were plotted (Figure 6) and it is interesting to note that the average curve is almost identical to that obtained in Figure 5 It is to be expected that the differences between the maximum and minimum costs are less under these conditions than when the cost data for all cars are used This is borne out by the data in Figure 6

The item of extra help is shown in Figure 7 to have a marked effect on the cost for all cars for the year round condition although the effect is greater on earth roads than on gravel and paving On the former it raised the average cost only $\frac{1}{2}$ cent per mile as compared to a $1\frac{1}{2}$ cents per mile increase on the latter. The minimum cost remained the same but the maximum cost was raised about 1 to $1\frac{1}{2}$ cents per mile The cost of extra help on gravel and paving is no doubt due almost entirely to blizzards and the presence of snow on these roads while on earth roads the cost of extra help was due not only to snow but also to the mud condition which interfered seriously with travel on these roads

The unit transportation replacement costs given in Figure 8 are quite variable as might be expected The data are scattered so widely that an average curve probably should not be shown for these data Of course, since travel by horse or on foot is much slower than by car, the costs should normally be higher as indicated on the graph than under conditions when a car can be used Also, the small change in the average cost on gravel and paving as compared to earth indicated here should be expected because with roads impassible in either case the type and cost of transportation replacement would be very nearly the same on the average for both types of surface

The extreme seasonal effect is shown in Figure 9 in which the unit costs for

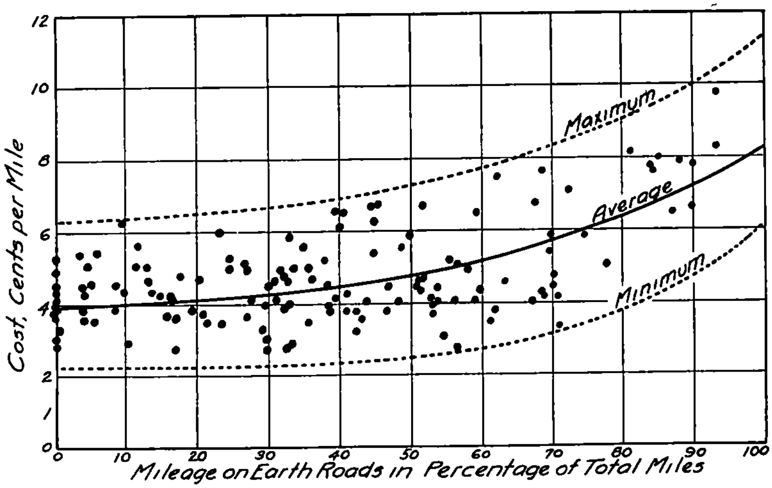

Figure 5 Unit Cost of Operation (Excluding Extra Help) for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel for the Year 1936

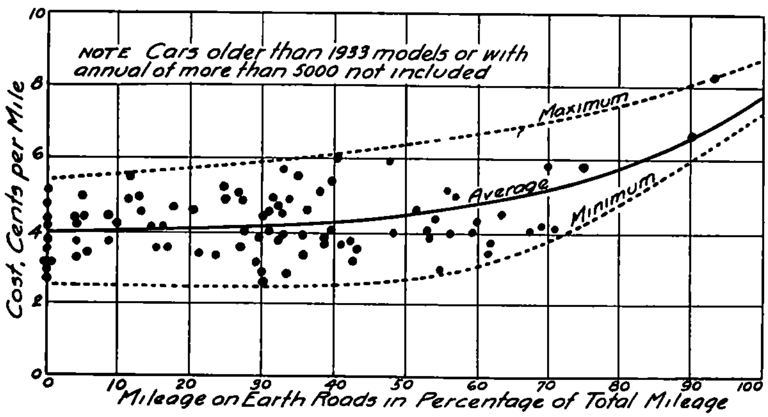

Figure 6 Unit Cost of Operation (Excluding Extra Help) for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel for the Year 1936.

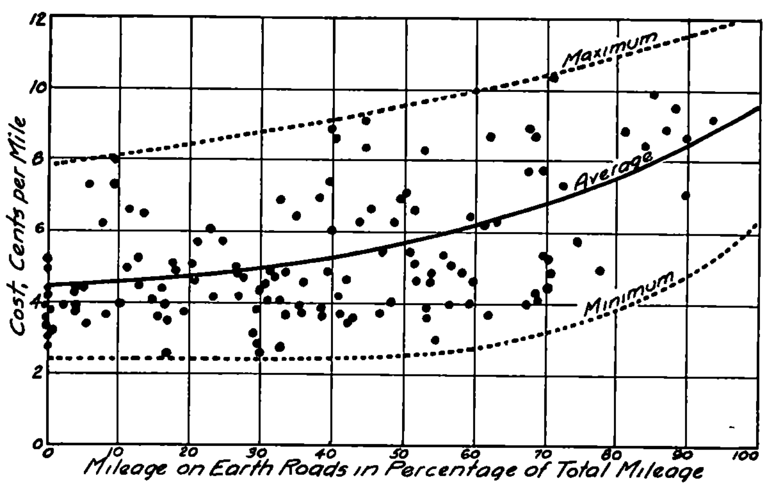

Figure 7 Unit Cost of Operation (Including Extra Help) for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel for the Year 1936

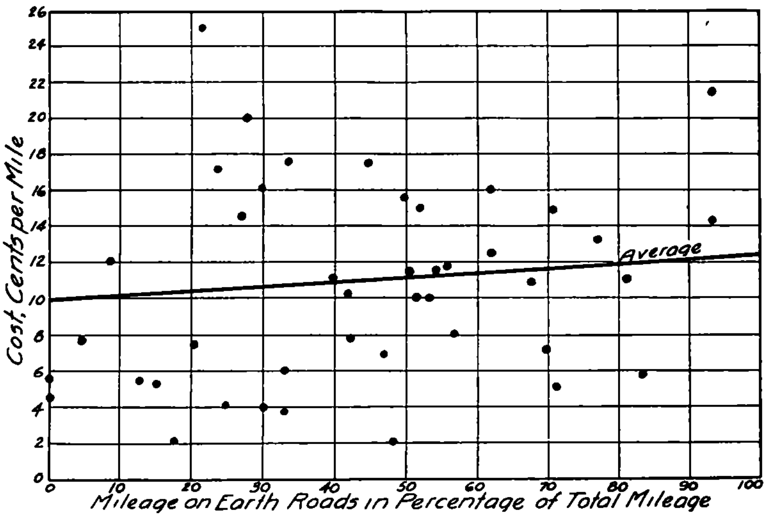

Figure 8 Unit Transportation Replacement Cost for Varying Percentages of Total Mileage Traveled by Regular Car on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel

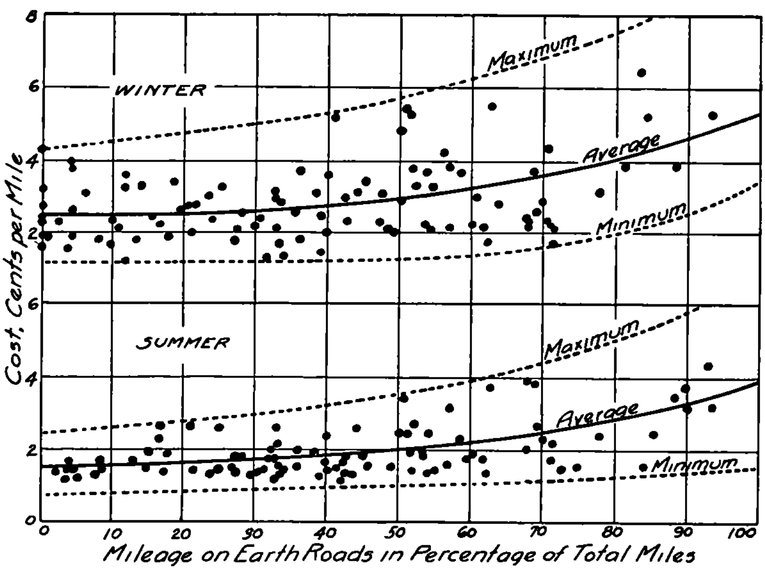

Figure 9 Unit Cost of Gas, Oil, and Maintenance for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel for (a) Winter of 1935-36, (b) Summer of 1936

gasoline, oil, and maintenance are given for all of the cars for the winter and summer seasons These curves show that the spread in unit costs is much greater in winter than in the summer season and on earth roads than on gravel and concrete In fact, on paved roads during the summer months the difference in the unit costs for these items of operation is roads The cost of gasoline, oil, maintenance and extra help on earth roads is just about double that on gravel or paved roads The curves in Figure 11 show that extra help is a factor only in winter and spring months on paved roads, whereas there is a definite extra cost indicated due to extra help during all seasons for cars operating on earth roads

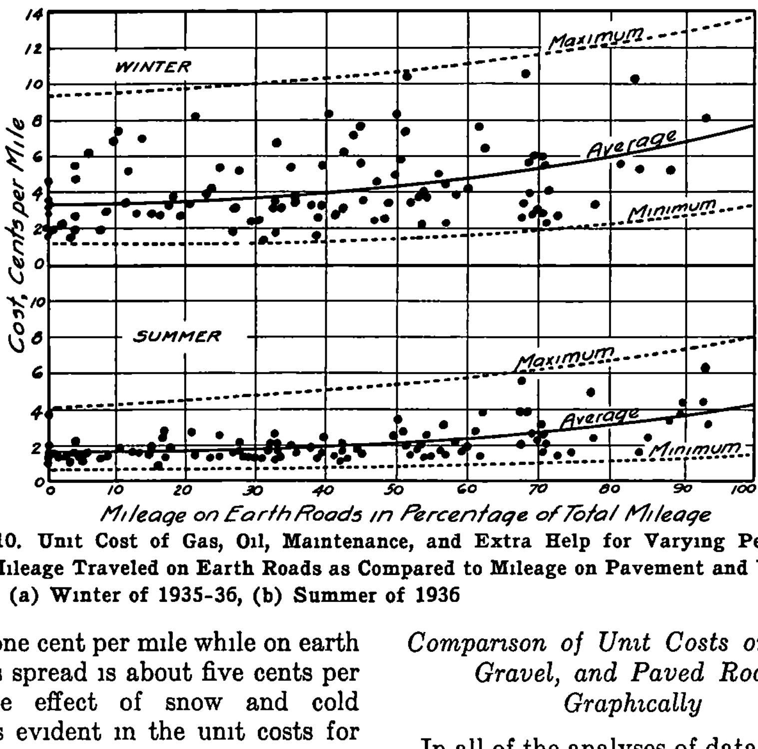

Figure 10. Unit Cost of Gas, Oil, Maintenance, and Extra Help for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel for (a) Winter of 1935-36, (b) Summer of 1936

less than one cent per mile while on earth roads, this spread is about five cents per mile The effect of snow and cold weather is evident in the unit costs for the winter months, the average cost on paving being about one cent higher in winter than in summer This represents an increase of about 70 percent due to the extreme seasonal effect These figures give some indication of the extent to which traffic profits by snow removal

When extra help is included in the items of cost to bring out the seasonal effect as shown in Figure 10, there is practically no change noted in the costs for the summer months but there is an average increase of about one cent per mile on gravel and paving and slightly more than three cents per mile on earth

Comparison of Unit Costs on Earth, Gravel, and Paved Roads Graphically

In all of the analyses of data discussed up to this point, the comparisons were made between the costs on earth roads as compared with the costs on gravel and concrete combined This comparison seemed fair because the data indicated that the greatest differences in cost were those due to travel on mud roads, the differences between gravel and paved roads being very much smaller The number of samples available to make a study of the direct comparison between the costs on earth and gravel, earth and paving, and gravel and paving seem rather small to establish definite trends,

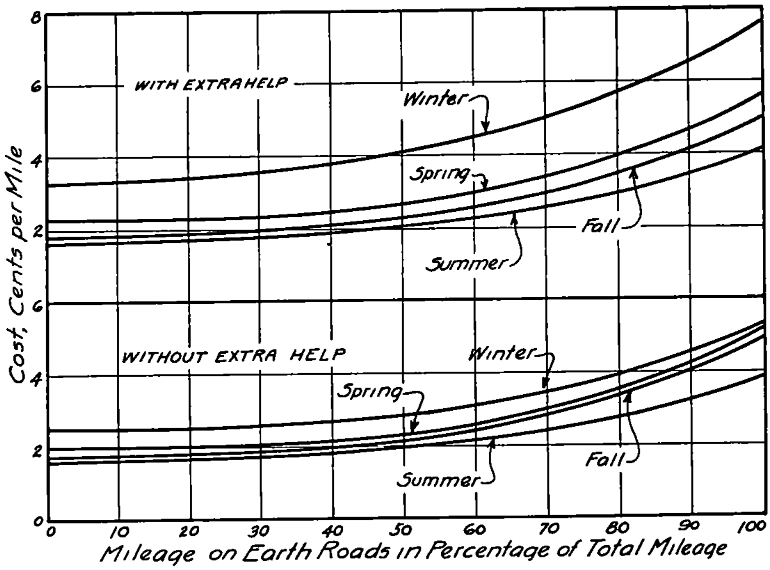

Figure 11 Unit Cost of Gas, Oil, and Maintenance for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel for Seasons of 1936 (a) With Extra Help, and (b) Without Extra Help

nevertheless, these data are shown in Figure 12 and seem to be fairly consistent with the data previously discussed The greatest difference in the unit cost of operation, according to these data, is that between gravel and earth which amounts to about 4¾ cents per mile In the comparison between earth and paving this difference is reduced to 3½ cents per mile But if the unit cost on earth of 8¾ cents per mile, shown in the comparison between earth and gravel, is used as the correct cost, the difference between the cost on paving and earth is about five cents per mile The average difference in cost on gravel and paving is shown to be about 1¼ cents per mile, the average cost on paving being about 3½ cents per mile as compared to 4¾ cents per mile on gravel for the year round condition and not including extra help

Using the data for these same cars to study the seasonal effect, it is interesting to note that the greatest spread in unit costs for gas, oil, and maintenance

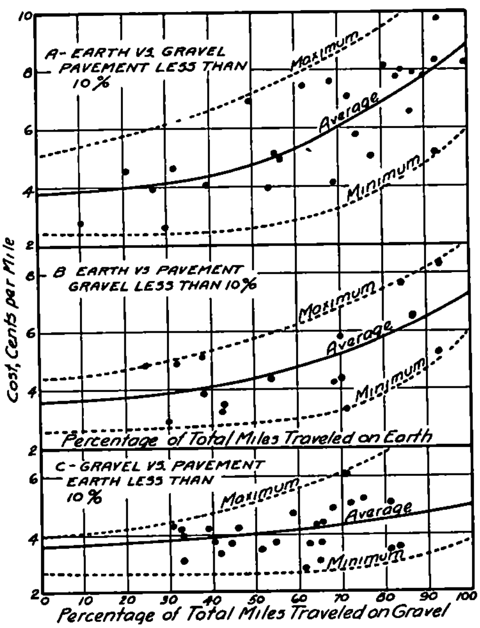

Figure 12 Unit Cost of Operation (Excluding Extra Help) on (a) earth as compared to Gravel, (b) on Earth as Compared to Pavement, and (c) on Gravel as Compared to Pavement

is obtained in the comparison between earth and gravel and the smallest difference is shown in the comparison between gravel and paving It is significant that the cost of gasoline, oil, and maintenance is the same for all the percentages of gravel during the summer months when comparing costs on gravel versus costs on paving In other words these data indicate that the difference in cost on gravel and on paving is very slight during the summer months

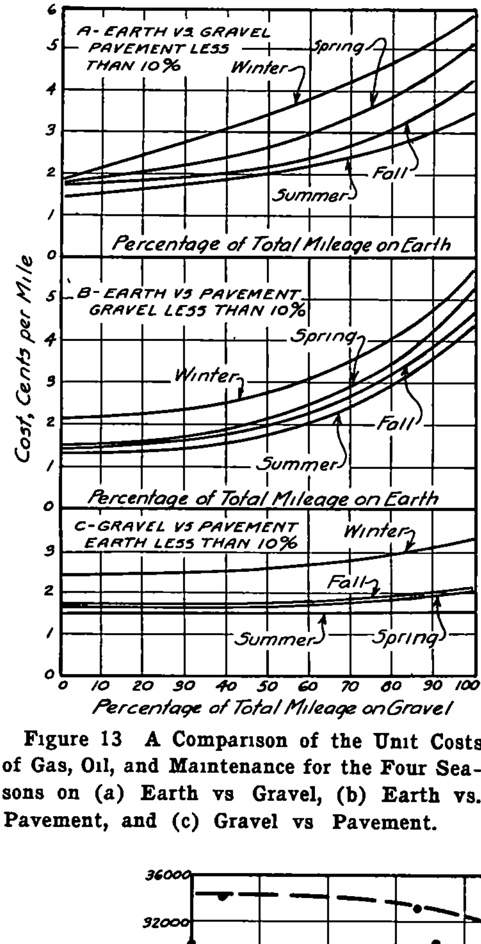

Figure 13 A Comparison of the Unit Costs of Gas, Oil, and Maintenance for the Four Seasons on (a) Earth vs Gravel, (b) Earth vs. Pavement, and (c) Gravel vs Pavement.

Annual Mileage of Cars

In the operation of any car, there are certain total annual charges such as garage rental, license fee, taxes, insurance, interest and depreciation which are the same or very nearly so, no matter what mileage the car is driven during the year Variations in annual mileage will, therefore, bring about corresponding variations in the total unit costs of operation of the car A car which is driven a relatively low mileage during the year will show a correspondingly large increase in the unit cost of operation, whereas for a large annual mileage the unit costs will show a corresponding decrease The data in Figure 14 indicate a wide variation in the annual mileage The greatest annual mileage is shown to

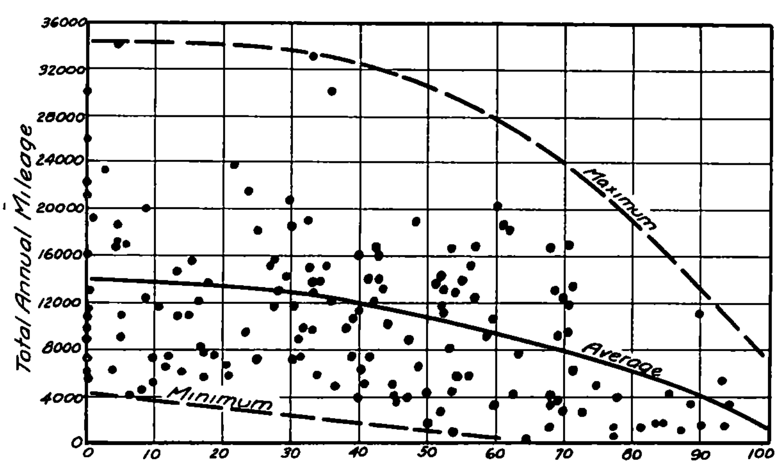

Figure 14 Annual Mileages for 160 Cars for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel

be driven on gravel and paving and the lowest when the operation is exclusively on earth roads. By taking the actual mileage records it was found that the total mileage driven by the 160 cars was 1,747,040 miles or an average of 10,919 miles per car. Of this average 3,516 miles were on paving, 3,789 on gravel, and 3,614 on earth roads. However, taking the trends as indicated by the average curve in Figure 14, the average annual mileage of a car operated exclusively on earth roads was only about 1,500 miles, on paving 14,000 miles, and on gravel a separate study indicated the mileage to be about 11,000 miles annually.

The differences in the annual mileages on earth, paving, and gravel account in part for the large differences in the unit cost of operation. The graphical data show that the difference in the total unit cost on gravel or paving and on earth is about $4\frac{1}{4}$ cents per mile whereas the difference in the cost of fuel, oil, and maintenance is only about $2\frac{1}{2}$ cents per mile. This $1\frac{3}{4}$-cent increase shown by the average curve is due to the low annual mileage on earth as compared to the mileage on gravel or paving, and to the higher average age of cars traveling on earth as compared to gravel and paving.

Age of Cars

The ages of the cars driven over the various types of roads had a variable effect on the unit cost of transportation because a higher rate of depreciation is charged against new cars than against older cars. From the records in Form 1, the average age of all cars was found to be 2 years and 3 months. The average age of cars operated on paving and gravel was found to be 1 year and 1 month and for cars operated on earth roads 4 years and 3 months. Since the rate of depreciation is much lower for cars operated on earth, it will be seen that the higher unit cost on earth road due to the low annual mileage on earth will be offset in part by the lower unit cost for the item of depreciation. While it is quite logical to expect that older cars should be driven on earth roads and that the annual mileages on earth should be lower than on gravel or paving, it seems fair to state that in comparing unit costs greater weight should probably be given to the fact that the annual mileage may be low on earth roads than that the average age may be high because under certain weather conditions it is very difficult to travel large mileages whereas the age of the car is not so affected.

Average Rate of Travel on the Route

While the rate of travel did not enter directly into the unit cost computations, it is an important factor which should not be overlooked. The rate of travel on the route is shown in Figure 15. The average rate of travel should not be confused with the average speed because the former is based on the entire time required to cover the route including stops and does not give a direct indication of the average road speed. The average curve for the rate of travel shows a definite rate of decrease as the mileage on earth is increased. The average rate is about 4 miles an hour slower in winter than during the summer months. The average rate of travel on earth is about 8 miles per hour as compared to 14 miles per hour on gravel and paving.

The most significant use which can be made of these data is that these differences in the rates of travel represent a real time saving value to the mail carriers. Thus, if the low value of 50 cents per hour were to be used to represent the value of the average mail carrier's time, then for these particular data the carriers operating on gravel or paving would have a time saving advantage equal to 2⅝ cents per mile A 60 mile route on earth would require 7½ hours on an average day as compared to about 4¼ hours to cover the same distance on gravel or paving For differences as large as this there can be little doubt but that the time saving factor provides a real economic advantage for the gravel or paved road over the earth road for operations of the mail carrier type which were used in obtaining adjusted costs in the graphical solution

Using the average annual mileage of 10,919 miles and the standard fixed charges or overhead costs previously established, the total unit cost of operation for the year round condition will then be 4 82 cents per mile on earth, 4 11 cents per mile on gravel, and 3 38 cents per mile on paving If the average age of the cars on earth is increased to 4 years and 3 months and the annual mileage reduced to 1,500 miles per year, the total unit costs on earth will then be 9 23 cents per mile, which is slightly higher than the cost obtained in the graphical solution The unit cost of operation on earth might quite properly be further increased by about ¾ cents per mile for extra help and 2⅝ cents per mile as a time factor representing the money value of time saved on gravel or paving over travel on earth for this particular group of drivers The extreme average difference in the cost of operation on earth as compared to paving is therefore about 9½ cents per mile for the year round conditions, while a conservative difference

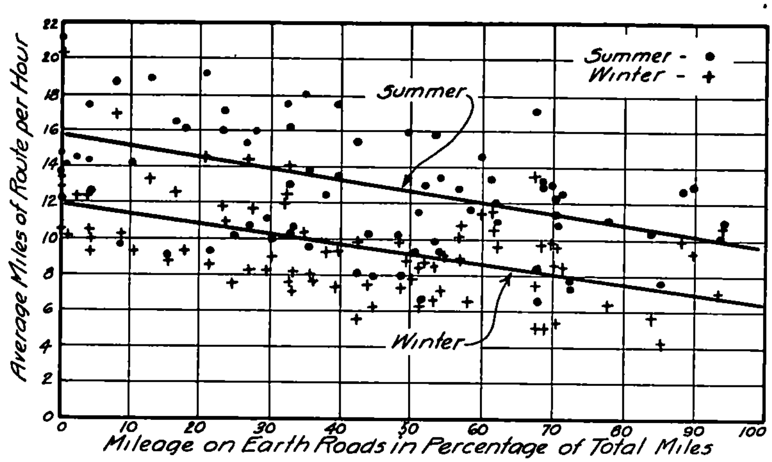

Figure 15 Average Miles of Route Covered Per Hour, Including Stops, for Varying Percentages of Total Mileage Traveled on Earth Roads as Compared to Mileage on Pavement and Untreated Gravel Surfaces

Statistical Analysis by Method of Least Squares

The comparative costs of gasoline, oil, and maintenance for earth, gravel, and concrete were computed by the statistical method of least squares to be 3 17 cents per mile, 2 46 cents per mile, and 1 73 cents respectively for the entire year, 3 44 cents per mile, 2 56 cents per mile, and 2 06 cents per mile for the winter months, and 1 97 cents per mile, 1 71 cents per mile, and 1 49 cents per mile respectively, for the summer months These results are based on the actual recorded costs and are not adjusted for mileage, age, or any of the other factors is 1½ cents per mile if only the savings in gasoline, oil, tires and maintenance are considered

APPLICATION OF UNIT OPERATING COST DATA TO A STUDY OF ECONOMIC COMPARISONS OF EARTH AND GRAVEL ROAD SURFACES

The purpose of determining the unit operating costs for various road surfaces is mainly to make it possible for the engineer to select the types of surface construction which will furnish transportation at the lowest cost The amount of money which the engineer is justified in spending for road surface construction depends quite largely on the volume and type of traffic operating on the road If the traffic is light, the road will of necessity be a low cost type but if the traffic exceeds 100 or 200 vehicles a day a more costly or higher type of construction will generally be necessary to provide the most satisfactory transportation service at the lowest cost The solution of the problem of determining the traffic volumes required before the change from one surface type to a higher surface type is justified is not an easy one because reliable and accurate cost data have not been available Since the data in this report have provided for the first time some definite information concerning the detailed costs of operation on unimproved earth roads as compared to gravel roads, a general solution of this problem to indicate when the engineer is justified to improve an earth road with a gravel surface seems to be an appropriate part of this report The following solution applies particularly to roads in the middlewest on which the rural mail, the school bus, and similar types of service requiring daily operation in all kinds of weather, constitute the bulk of the traffic

In making the economic comparison of earth and gravel roads, the total annual transportation cost per mile of road for varying volumes of traffic was computed using the following formula

Total annual transportation cost per mile of road = Annual maintenance cost per mile + annual depreciation per mile + annual interest per mile + annual motor vehicle operating cost per mile

Although the maintenance and depreciation costs for various surface types vary depending on the volume of traffic, the traffic in this case will be assumed to be so light (from 0 to 50 vehicles a day) that the differences in maintenance and depreciation can be neglected Recent annual reports of county engineers in Iowa have indicated that $75 00 per mile is a fair average maintenance cost for local county earth roads and $100 00 per mile for gravel roads This latter charge may be assumed to include an allowance for gravel replacement to keep the surface perpetually as good as or better than new In Iowa it is generally true that county gravel roads require less blading or similar maintenance than do earth roads to keep them in a smooth serviceable condition

For the natural earth surface no charge for depreciation or interest is necessary In the case of the gravel road the depreciation charge is included in the maintenance charge An interest rate of 4 percent was charged on the investment which for this solution was assumed to be $1,000 00 per mile Many Iowa local county roads have been gravel surfaced for considerably less than $1,000 00 per mile, but this seems to be a fair and convenient figure to use in solving this problem While a lower interest charge, or in fact no interest charge, might be recommended by some engineers, the result would be changed only slightly The higher interest charge for the larger investment requires more traffic to justify the investment and thus is on the conservative side in reaching a decision

In making the economic comparisons shown in Figure 16, three different values of unit operating cost were used In Figure 16a the same average annual mileage and the same average age was used for cars operating on gravel as for

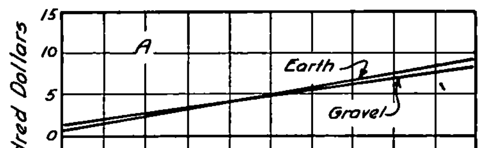

Figure 16 Economic Comparison of Cost of Transportation on Earth and Untreated Gravel Surfaces for Traffic Volume up to 50 Vehicles Per Day when (A) Cost Is Based on the Average Annual Mileage and Car Depreciation for Cars Operating on All Surfaces, (B) Cost Is Based on Actual Annual Mileage and Car Depreciation Determined from Car Data on Each Surface, and (C) Cost Is Based on Actual Annual Mileage and Car Depreciation and Including also a Time Factor for Slower Rates of Travel on Earth

the cars operating on earth The unit cost on earth in this case was 4 82 cents per mile and on gravel 4 11 cents per mile, the higher cost being due to increased gasoline, oil, tire and maintenance costs on earth than on gravel In Figure 16b the cost on earth was increased to 9 23 cents per mile which represents an adjusted cost based on the lower annual mileage, the greater average age, and the higher cost of extra help on earth than on gravel as determined from the mail carrier cost records In Figure 16c the cost on earth was further increased to 11 90 cents per mile, the additional increase being the 2⅔ cents per mile time factor which it was shown is the value of time saved by traveling on gravel instead of earth if the driver's time is assumed to be worth 50 cents per hour

The curves in Figure 16c show that a traffic volume of 25 cars per day will provide sufficient savings in gasoline, oil, tires, and maintenance when operating on gravel instead of earth roads, to justify the $1,000 investment and the $25 00 per year extra maintenance required to build and maintain the gravel road It should be noted that the small difference of 0 7 cents per mile in operating costs on gravel and earth is sufficient to justify this improvement with only 25 vehicles per day If the total costs of operation on earth and gravel as determined in this study are used, the curves in Figure 16b indicate that a traffic volume of 4 vehicles per day justify the change from earth to gravel And if the value of time saving is added, a traffic volume of 3 vehicles per day will justify the change

Now, of course, anyone familiar with studies in economic comparisons will know that while savings of one cent per mile and of 5½ or 8 cents a mile will justify the changes indicated above, there is no actual saving unless the traffic volumes are greater than those indicated or unless additional benefits, which cannot be evaluated, result from the changes That the latter is generally accepted to be true is conceded by persons familiar with this situation

There is another very real and very practical question which must be met, if the findings of such studies as this are to be put into effect That is, although the engineer can show that savings in operation cost of 1 cent per mile or 5½ or 8 cents per mile are possible, he still is confronted with the problem of collecting the 1 cent per mile or the 5½ or 8 cents per mile tax to pay for the improvements which make these savings possible The uninformed car owner in the rural areas in many cases will prefer to pay a "mud tax" in small amounts daily or weekly than to pay the large road tax, gas tax, or license fee needed for road improvements which will bring returns far exceeding the tax charged against the car owner The average motor vehicle tax in Iowa and in the United States as a whole is easily less than ½ cent per mile and yet the savings or benefits derived from this tax, or service charge as it more properly should be called, far exceeds the ½ cent tax per mile It is doubtful if a satisfactory tax plan can be devised which will make it possible to collect a use tax or vehicle tax as large as 1 cent per mile and certainly not as large as 5½ cents or 8 cents per mile The fact still remains that unless a satisfactory plan can be found for financing road improvements of this type, car owners will continue to pay a "mud tax" on earth roads They will pay for road improvements which were never built Nor will car owners living along side of earth roads enjoy the fire protection, the health protection, and the social, educational, marketing and other advantages which follow in the train of road improvements in which the rural home is made accessible in all kinds of weather

In the mid west states, the secondary road improvement situation has not yet reached the stage where the engineer is concerned with improvements justified by a traffic of 5 vehicles per day, but there are thousands of miles of roads in Iowa alone on which the traffic ranges from 20 to 50 or more vehicles per day for which basic information of the type sought in this kind of study will be very useful in selecting surface improvements and maintenance methods providing satisfactory transportation service at the lowest cost

SUMMARY AND CONCLUSIONS

While this report is intended as a progress report and the work is to be continued, it has progressed far enough to warrant the presentation of the following summary and conclusions

1 The average annual mileage for the 160 mail carrier cars was 10,919 miles, thereby providing 1,747,040 miles of travel for which complete cost records were available for study

2 From the plotted data, the average cost of operation for the year round condition was 8 cents per mile on earth, 5 cents per mile on gravel, and 3½ cents per mile on paving

3 The average operating cost was 2¼ cents per mile less in summer than in winter for earth roads, 1¾ cents per mile less for gravel, and 1 cent per mile less for paving

4 Expenditures for mud elimination and snow removal are amply justified if the traffic volume exceeds 25 vehicles per day

5 The plotted data indicated an average annual mileage of 14,000 miles per year on paving, 11,000 miles per year on gravel, and 1,500 miles per year on earth

6 The average miles of route covered per hour, including stops, was 14 on gravel and paving and 8 on earth roads for the year round condition During the summer it was 16 miles per hour on paving and gravel and 10 miles per hour on earth During the winter months, it was 12 miles per hour on paving and gravel as compared to 6½ miles per hour on earth

7 The time value of paved or gravel roads over earth roads for these data is

2⅔ cents per mile if the carrier's time is worth 50 cents per hour

8 Extra help increased the average cost of operation on gravel and paving ½ cent per mile and on earth 1¼ cents per mile

9 The average transportation replacement cost (for horses, teams, or men on foot) was from 50 to 100 percent higher when the roads were impassable than the average car operating cost when the roads were passable

10 The average age of the 160 cars was 2 years and 3 months The average age of cars operated predominantly on earth was 4 years and 3 months and on gravel and paving 1 year and 1 month.

11 In the statistical analysis using the method of least squares, the average cost of gasoline, oil, tires, and maintenance for the year was 3 17 cents per mile on earth, 2 46 cents per mile on gravel, and 1 73 cents per mile on paving

12 The cost of gasoline, oil, and maintenance for the winter months was 3 44 cents per mile on earth, 2 56 cents per mile on gravel and 2 06 cents per mile on paving, while for the summer months it was 1 97 cents per mile, 1 71 cents per mile, and 1 49 cents per mile, respectively

13 A traffic volume of 25 vehicles per day will justify an investment of $1,000 00 per mile and an extra annual maintenance expenditure of $25 00 per mile in improving an earth road with a gravel surface based on the saving of 0 7 cents per mile in operating cost on gravel as compared to earth indicated in the cost records of the 160 cars studied in this report

14 A traffic volume of 3 vehicles per day will justify the improvement from a natural earth to a gravel surface if the annual mileage factor, the average age of car, extra help and the time factor are evaluated according to the cost data of these particular cars

15 The cost data indicate that a radical change in our highway taxation and financial policies for secondary road improvement is needed if it is desired to eliminate the "mud tax" which persists on our local county and farm-to-market roads

ACKNOWLEDGMENTS

The preliminary work on this project was carried on largely under the direction of Robley Winfrey, Research Engineer, for the Iowa Engineering Experiment Station By the time the project was actually under way and cost records were being sent in, Mr Winfrey was on leave with the Bureau of Public Roads, and the supervision of the project was turned over to the writer

Much of the detailed work in connection with the assembling and summarizing of the cost data has been under the supervision of Edwin R Davis, Louis W Heichenroeder, and Clarence W Rice, research assistants of the Experiment Station A large portion of the detailed office work was done by a staff of N Y A student workers

Special thanks are due the rural mail carriers who cooperated in every way possible to provide us with the information and cost data which have made this report possible

DISCUSSION ON OPERATING COSTS

Prof R L Morrison, *University of Michigan* I believe that the widest possible publicity should be given to direct savings to motorists because of highway improvement The motor vehicle owner is continually being told what large taxes he is paying but very little is said of the savings resulting from the road improvements which the taxes make possible If it costs 1½ cents per mile more to travel on gravel than on a pavement, then the gravel road collects a tax equivalent to about 22 cents per gallon of gasoline, or more than three times as much as any state collects In other words, assuming that he gets 15 miles per gallon of gas, for every 15 miles he travels on a pavement the motorist pays from 2 to 7 cents gas tax to the state, depending upon what state he is in, but for 15 miles on a gravel road he also pays an additional 22 cents, or more, for added gasoline consumption, tire wear, etc

MR FRED LAVIS, *Consulting Engineer:* I can only emphasize what Professor Morrison has said about the difficulties of getting people generally, and even some so-called experts, to appreciate the importance of these cost studies It is probably not necessary to preach this doctrine to this audience as I expect you all appreciate it I do think, however, that it is desirable not only that we ourselves realize the economic importance of this matter but that we should also disseminate the knowledge and preach its importance to laymen in such a way that it will be appreciated by them also

One of the first studies of this kind was made in connection with the layout and design of what is now Route 25 New Jersey, between the Holland Tunnel and Elizabeth—one of the earlier so-called super-highways There we attempted to evaluate the effect of the location, of rise and fall, rates of gradient, curvature, loss of time, etc, on the operating costs of vehicles The general public, however, was not interested in this The talk about saving a cent a vehicle mile, or that the loss of a minute in time was valued at a tenth of a cent, or what ever the values may have been, did not appeal to them Even when multiplied by 10,000,000 or 15,000,000 vehicles a year it was thought to be a purely theoretical engineering calculation which did not affect any individual They could not visualize the losses of these small sums of money

In speaking at various public meetings, however, I recall two illustrations which seemed to be appreciated This was before the construction of the Holland Tunnel and the ferries between New Jersey and New York were always congested at week-ends and holidays There were often long queues of vehicles waiting to get on the ferries and I suggested that if a man in a car were waiting at the rear end of one of these long lines, and someone offered for, say, half a dollar, to let him go forward to the front of the line, he would gladly have paid the amount His time or his convenience, or his pleasure was, therefore, worth something—it had some money value

At another meeting in the City of Newark we were explaining that the construction of this by-pass highway would relieve the congestion in the streets of that city and, among other things, permit easier access to the stores for shopping, etc The meeting had been addressed by representatives of various social societies, the Elks, Lions Clubs, etc, when a farmer from out of town arose and said, while I don't belong to none of these yere animal clubs, I want to say it would be a fine thing if some of us could get here in town without its taking a whole day to buy a shirt

Not long ago a Professor in one of our universities, who has a good deal to do with teaching transportation, expressed some skepticism over these "fine spun theories" but if they are applied with reason, they may be a very valuable guide in the economic design of some of our more important highways, costing $500,000 a mile and more, which affects for many years the operating costs of many millions of vehicles.

MR T W NORCROSS· *U S Forest Service* The importance of reductions in the cost of vehicle operation should not be minimized But there are other values and savings which are infrequently mentioned and which are of real importance For instance the value of the savings in travel time resulting from traveling over a better and higher standard road This saving, especially on a business road, frequently greatly exceeds the savings in operation cost of vehicles In fact for many classes of road use, the travel time is a good measure of the service value of the road But there are other savings resulting from better transportation and these cannot be adequately evaluated by the amount or speed of traffic These arise through the service rendered to the protection, development and utilization of resources—agriculture, mining, power, timber, etc I will give one illustration Up until the past few years the regular established practice of stockmen at the end of the grazing period was to drive the sheep over a road or stock driveway to the market or railway shipping point Not only were the services of several herders required but the time required was great, the sheep lost much weight during their arduous and slow journey of several days, feed along the route was seriously reduced, road banks were broken down, ditches and culverts clogged and finally when the journey was finished, it frequently developed that the market price was not as favorable as a few days earlier Now, to a greater and greater extent, trucks are being used The stockman determines the market price by radio, phone or newspaper When he is satisfied that it is the right time for him to sell, the sheep are loaded into trucks and within a few hours are delivered in prime condition at the market or shipping point Measured by volume of traffic, the service value of the road is of little consequence But measured by the money savings of each truck load, the road is of high value