A STUDY OF SAVINGS MADE BY RESURFACING PORTIONS OF STATE TRUNK LINE SIXTEEN

Thesis for the Degree of B. S.

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"A STUDY OF SAVINGS MADE AT RESURFACING PORTIONS OF STATE TRUNK LINE SIXTEEN"

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THESIS

FOREWORD

The sources of information from which the material for this thesis were obtained are; Professor Hitchcock of the Michigan State College faculty, Professor Agg of the Iowa State College Experiment Station , and the various departments of the Michigan State Highway Department. Professor Hitchcock has aided materially through his information on weights of motor vehicles and has aided considerably in a ranging the material. Professor Agg is at the present time the only reliable authority on transportation costs and his bulletin on costs issued by the Iowa State Experiment Station is the basis for costs used in this thesis. Mr. Purton, head of the statistics department of the State Highway Department aided with all the facilities of his department in the compilation of data.

A study of savings made by resurfacing portions of State trunk line sixteen. (M 16)

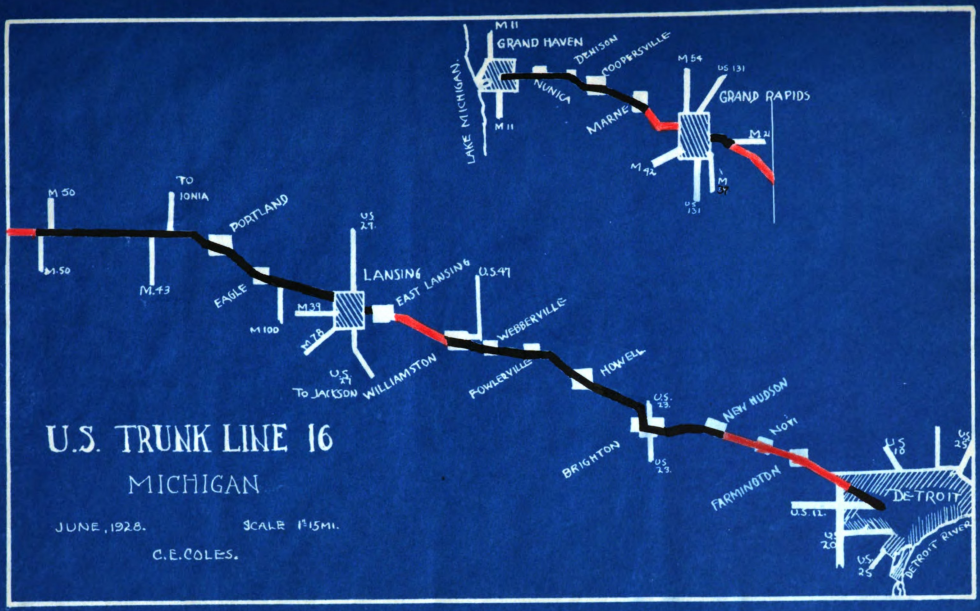
It will be the purpose of this thesis to show the savings which can be made through changing from one highway surface to another, both through the lowered vehicle costs and through lowered maintenance and reconstruction costs of the highways. This will be shown by applications of known savings to one of the more familiar highways of the state, trunk line sixteen, known as M 16.

There are several reasons for selection of M 16 for this study. First, this is one of the longest highways of the state and possibly carries more tons of traffic per year than any other in this state. Second, this highway is now completely resurfaced from Detroit to the western terminus at Grand Haven. Third, the records for this highway, both for costs and maintenance are more complete than any of the others. Fourth, being situated approximately half way between the points of heavy snow and light snow, the maintenance figures will contain an average figure for snow removal. Last, this highway carries a large proportion of through traffic, that is traffic from Detroit to Muskegon or, Grand Rapids to Detroit, which tends to give greater accuracy to the traffic censuses and make better figures for computations, than where there is a heavy traffic between points fairly close to each other and absence of traffic between other points.

The figures for maintenance and construction and for traffic censuses are furnished by the State Highway Department for the period from 1908 to 1917. Figures for construction beginning in 1901 and those for maintenance and traffic census in 1913. Figures, though obtainable for 1918, are incomplete and no use. In the year of 1918 the counties, such of them as were has for various to changed over to the system recommended by the state and the larger part of them discarded all records previous to this date, making it impossible to compile maintenance costs prior to 1919 and inadvisable to try to do it for that year. Therefore all figures used herein shall be from 1920 on.

The stretches of highway taken for examples in this discussion are located in representative sections of the road and are those points for which the most accurate and complete traffic census is obtainable. The lengths of these sections will vary from year to year due to the policy of the highway department to make all maintenance patrol sections begin and end at some convenient point and at the places where surfaces change. Due to this unevenness of length computations will be made pro rating costs over these lengths for each mile.

The accompanying map will show the sections of highway used for computations in red and the remainder of the route in black.



U.S. TRUNK LINE 16

MICHIGAN

JUNE, 1928. SCALE 1" 15 MI.

C.E. COLES.

The material used for the computation of costs will be found in Bulletin 89 of the Iowa State College Experiment Station, " Highway Transportation Costs" by Prof. T.F.Agg. Prof. Agg has found that the cost of transportation per mile for a composite passenger car is as follows:

Surface	Cost per vehicle mile
Average Portland Cement concrete and asphalt filled brick roads	$.10
Best Portland Cement And Asphalt filled brick.	.93
Best Gravel	.109
Ordinary Gravel	.118
Waterbound macadam (well maintained)	..111
Bituminous macadam (well maintained)	.108
Average sheet Asphalt.	.10
Average Asphaltic concrete .	.10
Best earth (well packed)	.12
Ordinary earth (lightly packed)	.128

Professor Hitchcock gives the average weight of passenger vehicles in this State to be 1.2 tons, so dividing the above values by 1.2 will give the costs in ton miles, which is a more convenient form for computation and will reduce the passenger vehicle costs to a figure based on the same units as the truck costs.

Prof. Agg finds the following figures for costs per ton mile for trucks with pneumatic and solid tires, assuming a speed of ten miles per hour for trucks with solid tires and fifteen miles per hour with pneumatic tires.

Surface type	Solid tires	Pneu. Tires.
Average cement concrete and asphalt filled brick	$ .08	$ .081
Best cement concrete and asphalt filled brick	.0775	.077
Best gravel	.085	.088
Ordinary gravel	.09	.094
Waterbound macadam (well maintained)	.087	.0885
Bituminous macadam (" ")	.088	.088
Sheet asphalt (average)	.081	.082
Asphaltic Concrete (average)	.08	.081
Best Earth (well packed)	.090	.085
Ordinary earth (lightly packed)	.095	.0895

The following items are considered in computing the costs permile of transportation; gasoline, oil, tires, maintenance, depreciation, interest, insurance, garage, and license fee. In figuring costs for a truck or buss and additional item is included, the cost of the driver's time for each mile traveled also being a cost item. As there are no figures available on costs of motor busses over various types of surfaces there will be no effort made to compute savings made by these vehicles.

Prof. Agg has evolved the following formulae for the computation of annual cost per unit of highway surface:

For the cost per annum where the economic life of the pavement is not exceeded,

(1) $C = M + (I - S) f + IR$

Where C is the annual cost per unit of surface.

M is the equated annual cost of maintenance per unit of roadway surface.

I is the initial cost per unit of roadway surface, including administrative and engineering overhead.

S is the salvage value of the unit roadway surface at the end of its economic life.

f is the annual deposit that will accumulate $1.00 in a period equal to the economic life of the roadway, with interest at 4% compounded annually.

R is the rate of interest applicable to highway costs, and usually taken as 4%.

The annual cost after the economic life of the pavement is exceeded is figured by means of the following formula:

(2) $C_1 = M_1 + RI$

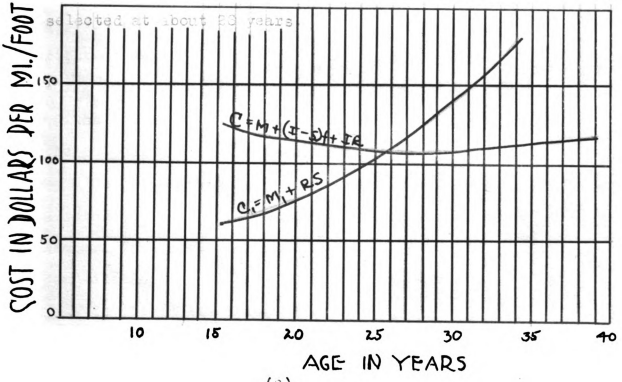
where the terms are as above,

C_1 being the annual cost per unit of roadway surface,

M_1 the annual equated costs over the period.

and R and I being as in equation (1)

It may be seen that since there are no figures for depreciation in formula (2), that the economic life of a highway may be computed by finding the costs by means of formula (1) and by formula (2) for several different years and that when C_1 becomes greater than C then the economic life of the highway has been exceeded. By finding values for both formulae for several points a graph may be drawn which will greatly simplify the computation of the economic life. A curve with age in years plotted as abscissae and the costs per unit of highway surface as ordinates will give two distinct curves which will cross at some point where C and C_1 are equal and then separate as one grows larger than the other. [illegible] drawn will give the economic life of the portion of pavement selected at about 20 years.



(3)

Costs will now be computed for the section from the village of Williamston to East Lansing , a distance of about 10.74 miles, now entirely paved with 18 foot concrete. This roadway was constructed as follows:

1908	1 mile	9' gravel
1910	1.18 mi.	9' gravel
1917	4.180 mi.	18' gravel
1913	1.31 mi.	18' gravel
1915	1.027 mi.	18' gravel
1916	1.019 mi.	18' gravel

In 1924 the entire stretch was reconstructed with 18' concrete pavement, with a total mileage of 10.311, some of the original gravel being left out by straightening some curves in the right of way. It is very evident that most of this gravel surface had reached its economic life by the year of 1914 both by the costs of maintenance and the impossibility of keeping the pot holes and ruts leveled off.

The mileage above reduced to units of foot miles gives a total of 151.33 foot miles of roadway in the section. The original cost of this road was $ 68,415.11 or $4,039.33 per mile foot.

To obtain the annual cost per unit, C_1 is used in the formula $C_1 + R_1 + T$.

The value R_1 is found by getting an average for this value over the whole period considered in the computation. Therefore:

1909 ------3½ miles of gravel were maintained at a cost

of $12,815.07, all of the road being 16' wide, or the annual maintenance was $\frac{12,815.07}{16 \times 9.5}$ = $ 83.89 per mile foot.

1931----9.5 miles of 16' gravel road maintained at a cost of $15,998.74 or

$$\frac{15,998.74}{9.5 \times 16} = \$105.00 \text{ per mile foot.}$$

1932 ---- 9.5 miles of 16' roadway were maintained for $9,812.00 of

$$\frac{9,812.00}{9.5 \times 16} = \$80.85 \text{ per mile foot.}$$

1933-----In 1933 10.71 miles of gravel and 3 miles of concrete pavement were maintained at a total cost of $21,388.07 or

$$\frac{21,388.07}{10.71 \times 16} = \$11.81 \text{ per mile foot.}$$

1934---- During 1934 this route was detoured throughout and traffic was routed over 17.91 miles of 16' gravel roads and as these were the existing county roads and in rather poor state of repair to begin with the maintenance for this detour was large. The 17.91 miles were kept up for an outlay of $ 38,131.89 for the year or a cost of

$$\frac{38,131.89}{17.91 \times 16} = \$ 134.15 \text{ per mile foot.}$$

1935 In 1935 the new pavement was opened to travel and the maintenance for the whole length of 10.99 miles due to $ 3,993.59 or

$$\frac{3,993.59}{10.99 \times 16} = \$ 18.81 \text{ per mile foot}$$

1933---- Through some mistake there are no maintenance costs kept in the records of the State Highway Department for the year of 1933.

From the above data we can compute the cost per unit surface of the gravel road and using the formula for the cost after economic life the cost will be the average cost of maintenance since the factor SS becomes zero since there was no salvage value in the old gravel highway. Therefore the cost per unit of surface was. $ 100.0% per unit.

Now we can compute the cost of each unit of the concrete highway annually, and are restricted to the figures for one year only since this data for 1933 is missing.

The cost of this pavement was $414,834.70 and was 10.311 miles in length and was 18' wide making a unit cost of

$$\frac{41,834.70}{10.311 \times 18} = \$ 3,333.00 \text{ per mile foot.}$$

The economic life of this pavement cannot be determined by means of graphs or computations but may be assumed to be 20 years which is a conservative figure for pavement of this quality.

The salvage value of a concrete pavement is not more than 30% according to several contractors and State Highway Department, since it only serves as a base for a new surface and actually forms the sub grade of the new pavement, which of course can be made of less thickness and affords a good surface for hauling supplies used in construction.

The factor f in formula (1) is that amount which legislatures annually are willing to appropriate, compounded annually will reach the value of $1.00 in the period constituting the economic life of the pavement. This value is found to be $.0247 for an economic life of 20 years.

F, the rate of interest, is assumed at 4% since this value is considered to be nearly correct by Professor Agg.

Substituting these values in the formula (1) we get C to equal

$$\$100.00 + (3,885.00 - 741.33)f + 3,885.00F.04$$

or $C = \$140.42$ per mile foot of concrete

Thus it is apparent that in this case the annual cost of the concrete pavement per unit is more than double the cost of the gravel replaced.

The traffic census for this particular pavement for the years concerned are as follows:

Year	Passenger cars	trucks	total
1930	170,880	19,810	191,690
1931	297,470	35,530	333,000
1932	333,100	34,981	368,100
1933	no figures available		
1934	" " "		
1935	618,480	140,320	758,780
1936	944,732	166,733	1,111,465

Now considering the transportation costs for the vehicles using the highway on the basis of costs per ton mile of traffic we find that in 1930 the volume of traffic was 205,068 ton miles per mile of passenger car traffic and 61,724 ton miles per mile of truck traffic. This traffic cost to transport over the existing gravel

Considering the average weight of passenger cars at 1.2 tons and the average weight of trucks at 3.1 tons the volume of traffic is easily found by computation from the traffic census. The costs for vehicles over the different types of pavement being for passenger cars, $.10 per car mile over average concrete and $.118 per car mile over the ordinary gravel road. The truck ton mile is $.098 for average pavement of concrete and $ .088 for the ordinary gravel. The cost per ton mile for passenger cars is found by dividing 10 by 1.2 giving a figure of $.083. The following table will show the volume of traffic and the costs per mile foot of surface for gravel and concrete. Volume being shown as a ton mile figure.

Year	Volume Pass. Cars	Volume truck	Cost Over Gravel	Concrete
1830	305,910 ton miles	21,781 T/	$ 33,877.77	$ 33,1[illegible]
1831	344,248 " "	116,143 " "	70,838.90	37,[illegible].7[illegible]
1832	369,721 " "	[illegible],[illegible] " "	80,0[illegible]7.33	37,1[illegible]
1833	no figures available			
1834	" "	"		
1835	930,[illegible] " "	1[illegible],1[illegible]	1[illegible],[illegible]70.47	1[illegible],1[illegible].1[illegible]
1836	1,[illegible],714 " "	[illegible],[illegible]1	1[illegible],[illegible]7.81	1[illegible],[illegible]1[illegible].[illegible]

From these figures we can figure the cost of transportation over each type of road per mile for the same volume of traffic and compute the saving per unit of surface from the combined highway and vehicle costs over each surface. The saving for the first year of the resurfaced road is the difference between the cost of traffic for the gravel and concrete surfaces divided by the width of the concrete which is 18', less the difference between the annual cost

per unit surface which amounts to

$$\frac{\$47,170.17}{19} - (\$140.19 - 100.02) = \$\,2,477.50$$

per mile foot of surface.

For the next year, 1923, for which no maintenance figures can be found, assuming the same cost of maintenance, the saving is found to be

$ 2,340.53 per mile foot of surface.

Following the same methods of procedure the costs and savings for the section between Detroit and New Hudson will be computed. The highway here was built as follows;

1910	1.3358	Mi.	9' gravel		$3408.83
1911	.708	"	"	"	1507.00
1911	.300	"	"	"	900.00
1914	1.030	"	16'	"	4,574.00
1917	2.030	"	"	"	8,808.5[illegible]
1915	1.800	"	"	"	4,894.79
1916	4,104	"	"	"	10,[illegible].[illegible]

all in Oakland County.

In Wayne County the earliest records give the cost of 3.178 miles of 17' concrete pavement as $71,181.72

The replacement of this highway surface with concrete was in the following manner:

1920	1.771	Mi.	20' concrete		$ 75,737.02
1920	3.784	"	"	"	38,100.17
1920	.700	"	"	"	[illegible],570.89
1925	11.75	"	20'	"	330,[illegible].[illegible]

a total mileage of 18.030 and a total cost of $1,0[illegible],7[illegible].47

or a cost per mile foot of $ 3132230

The cost of the gravel surface was $43,000.00 for 178.818 miles of 18 foot wide surface or a unit cost of $270.40.

Now, assuming that the average life of this gravel was exceeded it is necessary to find the equated annual cost of maintenance per unit for the two types of surface.

Year	Length	type	cost	unit cost
1920	7.38	18' Gav.	$11,191.45	$ 93.40
1921	11.841	" "	17,733.44	94.80
1922	11.741	" "	19,776.38	108.10
1923	11.841	" "	17,111.47	81.10

Average annual maintenance for the gravel was $ 98.70 per mile foot.

The following table gives the maintenance for the concrete which replaced the gravel

1920	4.17	18'	$ 1,071.87	$ 15.78
1921	4.835	"	1,073.35	37.44
1922	4.735	"	3,733.17	43.10
1923	4.735	"	1755.42	61.44
1924	31.385	"	18,333.14	16.20

Average annual maintenance for Oakland county $ 39.47 per mile foot.

In Wayne county the county board of Highway Commissioners took over the roads at the time when it was mostly macadam and soon had the road paved with concrete. Maintenance over this piece of road from Farmington to Redford is originally heavy, this highway at present being the second heaviest traveled section of road in the state.

The maintenance for this section follows:

year	cost per mile foot.
1920	$ [illegible]
1921	1[illegible].80
1922	136.80
1923	80.45
1924	109.99
1925	75.74
1926	121.80

The average annual maintenance for this road was $[illegible].44 per mile foot.

Applying the formulae for annual cost of highways we find that for the gravel road the formula $C_1 = N_1 + F$ $C_1 = N_1$ since the salvage value is to be considered as zero so the annual cost is $86.735 per mile foot.

For the concrete highway

$$C = N + (I - S) f + IS$$

$$C = 11.44 + (6,330 - 110) .0247 + 3.50 \times .04$$

C = $[illegible] per mile foot per year in Wayne County.

For Dallas County C = $ 87.03 per mile foot per year.

Traffic over this section was as indicated by the following table

Year	Pass. cars	trucks	ton miles	cost per mile gravel	cost per mile concrete
1920	[illegible]	110,710	307,041	$ [illegible],783.35	$ 74,[illegible]
1921	[illegible]	116,100	310,[illegible]	88,547.54	78,[illegible]
1922	[illegible]	[illegible]	1,[illegible]	143,881.03	110,[illegible]
1923	[illegible]	[illegible]	1,[illegible]	130,[illegible].51	97,[illegible].14
1924	2,191,[illegible]	119,[illegible]	2,[illegible]	350,[illegible].01	254,[illegible]
1925	3,[illegible]	318,[illegible]	[illegible],[illegible]	511,[illegible].37	421,[illegible]

The falling off in truck traffic over the period of [illegible]

1921 can be explained by the fact that parts of the road were under reconstruction and not favorable to the use of heavy trucks while easily negotiated by passenger cars at small loss in time and distance.

To, knowing the average cost of traffic per mile foot over the gravel and over the concrete, we can calculate the saving per mile foot per year for this section. This saving is (cost of traffic over gravel plus the annual cost of gravel) less (the annual cost of the pavement plus the cost of traffic over the pavement) This amount is, for this case, $ 4,105.18 per mile foot in Wayne County and $ 4397.43 in Oakland County where annual cost is much less.

The next section of this highway to be considered will be that section extending from the western city limits of Grand Rapids to the village of Byron, formerly Berlin. This section was already paved with concrete in 1917 with the exception of .330 miles of gravel built in 1917 at a cost of $ 4,180.43, or a cost of $ 857.83 per mile foot. In 1924 this gravel and some of the concrete were replaced with an 18' concrete pavement costing $ 102,535.72 for 3.187 miles or a cost of $1,778 per mile foot. The remaining original pavement 1933 miles of 18' concrete cost $ 60,431.84 or $ 2,233.00 per mile foot.

Maintenance figures are rather incomplete for this patrol section and there was a change of patrol section numbers from year to year and no number has been found for the year 1922 and the mileage for the year of 1930 is omitted making results for those years rather unstable.

~~Year~~ ~~length~~ ~~type~~ ~~cost per mile foot.~~

year	length	type	total cost	cost mile foot
1931	4.8 Mi.	Con.	$ 1857.91	$ 814.10
1932	4.0 "	"	1033.31	971.00
1933	4.5 "	"	2757.04	613 .34
1934	4.814	"	3125.00	1273.30
1935	13.9	"	7281.00	345.83
1936	4.8	"	3701.38	757,00

The average figure for maintenance for the concrete was $804.01 per mile foot, an exceptionally high figure, but perhaps justified by the aging of the pavement and the fact that the pavement was constructed of rather poor materials and shows considerable wear, cracks and general disintegration in many spots and is being patched continually.

A study of the traffic census for this district for the six years covered gives the following facts:

year	pass.cars	trucks	trailers	total cost per mile	cost per mile
1930	333,533	9,684	371,035	$84,903.87	$47,459.40
1931	371,330	37,330	546,008	81,846.34	45, 791.74
1932	414,000	43,100	649,730	74,489.85	39,81[illegible]
1933	645,660	71,710	989,198	69,387.96	62,7[illegible]
1934	785,400	93,600	1,180,340	161,703.78	105,[illegible]
1935	433,170	65,370	857,351	75,510.87	64,[illegible]
1936	745,537	88,[illegible]13	1,017,[illegible]84	[illegible]8,[illegible]78.71	84,[illegible]0.06

Since we have no reliable data to use in figuring the annual cost per unit per foot the best that can be done is to compute the average annual saving due to the installation of concrete in savings in vehicle costs. This data gives an annual saving of $ 893.48 per mile foot per year .

The next section studied is the highway from Pratt Lake near the Kent-Ionia County line and the intersection of M-46 with M-21 a few miles east of Grand Rapids. This highway is an entirely new section over part of the route since the line was relocated so as to avoid the towns of Lowell and Ionia and to straighten out the road so that the new route instead of connecting with M-46 connected with M-37 which was reached from the point on to M-18 and old M-21 from Ionia to Grand Rapids now called M-21.

The route which carried the traffic was constructed of macadam and gravel and cost $ 6,540 per mile and $645.00 per mile foot. As in the case of the Grand Rapids - Ionia road we have no accurate means of computing the annual cost per unit of highway and will be limited to computing the saving per unit present value in vehicle costs through operation over concrete pavement as opposed to gravel highways.

The available traffic data is as follows:

Year	Pass. Veh.	Truck's	Tonnages	Cost gravel	Cost of Conc.
1920	303,300	47,800	607,480	$38,182.00	$ [illegible]
1921	330,300	53,300	665,650	84,087.40	[illegible]
1922	405,300	54,300	693,700	73,810.30	[illegible]
1923	343,300	71,740	807,168	111,335.09	[illegible]
1924	317,340	41,300	876,084	102,274.00	[illegible]
1925	431,170	57,370	873,051	77,329.19	[illegible]
1926	737,391	72,791	971,074	102,380.00	104,947.31

The annual average saving in vehicle cost per mile foot is $273.30 for this particular case.

From the foregoing information it is evident that the savings in vehicle costs are the larger of the items entering into the economics of highway costs. While the cost per unit per year for concrete is greatly in excess of the cost

per unit for other types of surface, the maintenance for concrete is much less and the savings in vehicle costs are another factor which far overbalance this initial cost and yearly cost figure. Since the vehicle cost plays such a large part in determining savings over a highway it is readily seen that there is a relation between the savings and the volume of traffic using the road, and that as the volume increases the savings will increase in some ratio with the increase in volume.

ROOM USE ONLY