Time and Fuel Consumption for Highway User Benefit Studies

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Time savings and fuel savings are two of the more important benefits that accrue to users through highway improvement.

User time savings result whenever highway improvements reduce travel distance, permit higher speeds, or reduce the frequency of stop-and-go and slowdown maneuvers. User fuel savings accrue when improvements reduce travel distance, mitigate any of the resistances encountered by moving vehicles, or reduce the frequency of stop-and-go and slowdown operations.

The reduction of travel distance, frequency of stop-and-go and slowdown events, and resistance to movement, as well as increase in speed, resulting from highway improvements can be estimated from data available in published reports and by making traffic studies at locations where improvements are planned. However, information on current savings in time and fuel use associated with these effects of highway improvements have been insufficient for benefit analyses.

During the summer of 1959 the Bureau of Public Roads conducted a study of passenger cars and single-unit trucks to determine the effect of variation of pavement surface type and operating speeds on fuel consumption, and the effect of the elimination of both a stop-and-go and a slowdown operation on fuel and time consumption at various operating speeds. This study also included the determination of the fuel consumed while vehicles are stopped with engine idling. The results of this investigation are presented in this report in graphical and tabular form.

● **THE OBJECTIVE** of highway user benefit studies is the evaluation of the advantages or gains accruing to users as a result of highway improvements. Two of the more important of these advantages are reduced fuel consumption and reduced travel time. The relationship between highway vehicles and the roadway over which they travel is so clos that even small changes in the characteristics of the road will be reflected in the amount of time and fuel needed for highway trips. Minimum values of time and fuel consumption are possible only when the roadway is ideally suited to the vehicle and to the traffic volumes with which it must operate. The ideal highway from the fuel saving point of view would be straight and level, have a smooth surface, and be so designed that the movements of each vehicle would be completely unaffected by the presence of other vehicles. Although in practice no highway can be built to such standards, all improvements are directed towards this ideal. When properly engineered, the improvement of a highway makes it possible for users of that highway to complete trips in less time and frequently with less fuel consumption. Highway user benefit analyses, if they are to be complete and accurate, must include consideration of these savings.

IMPROVEMENTS RESULTING IN TIME AND FUEL SAVINGS

Time savings are brought about through changes in highway facilities which reduce travel distance, the number of stop-and-go and slowdown operations, the amount of time vehicles are stopped at traffic signals, stop signs, etc., as well as through improvements which permit vehicles to be operated safely at higher speeds. Every mile of travel distance eliminated from the trips saves the time needed to cover that distance. Elimination of stop-and-go and slowdown operations saves the time consumed while decelerating and accelerating, that would not be consumed if constant speed could be maintained, as well as the time spent delayed at stops in the case of stop-and-go operations.

Highway changes which improve sight distance or add to highway capacity will generally result in increased nominal highway speeds where nominal highway speed is defined as the modal operating speed of all vehicles of a given class while moving on sections of a highway where they are not slowed or stopped by highway impedances such as traffic signals and sharp curves. On two-lane roads carrying traffic volumes less than practical capacity, the nominal highway speeds of vehicles with low weight horsepower ratios will be increased if sight distances are improved through reduction of rise and fall and curvature, since this will permit a greater number of the drivers wishing to travel at the higher speeds to pass the slower drivers. On any road carrying a traffic volume equal to or greater than practical capacity, the nominal highway speeds of these vehicles will be increased by providing greater capacity through lane widening or construction of additional lanes.

The nominal highway speed for vehicles having high weight horsepower ratios will be increased mainly through reduction of grades.

All improvements which lessen travel distance and the resistances to movement at constant speed plus those which reduce the frequency of stop-and-go and slowdown operations result in fuel savings. Improvements which decrease resistance to vehicular movement reduce the energy requirements needed for operation; this results in fuel savings since the energy output of an engine is provided by the fuel it uses. Reducing the frequency of stop-and-go and slowdown operations reduces fuel consumption by reduring the number of times vehicles must overcome the inertia resistance encountered during accelerations. Furthermore, the elimination of stop-and-go operations saves the fuel that would be used when vehicles are stopped with engine idling.

A reduction in fuel use at any given speed will result from each of the following types of improvement: reduction of surface roughness, reduction of rate of rise and fall, and reduction of curvature. These improvements will frequently permit higher operating speeds which, because of greater air and rolling resistances at higher speeds, will result in an increased rate of fuel consumption; but for the same speed before and after improvement, fuel consumption will be reduced.

The frequencies of stop-and-go and slowdown operations are reduced through the construction of grade separation structures to eliminate intersections at grade, through provision for access control to reduce the number of access points, and through construction of additional lanes where they are necessary to provide capacity to relieve congestion. In addition, the frequency of slowdown operations is reduced when curves sharp enough to require vehicles to reduce speed are removed through alignment changes. Reduction of standing delays is brought about through elimination of intersections at grade or, where conflicting traffic flows at an intersection are not separated, by improving signal or signing arrangements.

TIME AND FUEL SAVINGS IN BENEFIT STUDIES

The saving in either fuel or time consumption due to any one type of highway improvement is the difference between what the amount consumed would be if the improvement were made, and what the amount would be if the improvement were not made. Where two or more types of improvement are made at the same location at the same time, the savings for each can be computed by assuming that the other improvement is completed since, in general, the saving resulting from one improvement is independent of the effect of other improvements. For example, if a highway reconstruction project involving the upgrading of surface and reduction of rise and fall is considered, the savin or difference in fuel consumption for operation on the improved surface rather than on the gravel surface for the new rate of rise and fall will be the same regardless of the fact that the rate of rise and fall had been changed; and the saving due to reduction of rise and fall of the improved surface is unchanged by the fact that the surface had been upgraded.

The difference in fuel saving for the conditions before and after an improvement is a true measure of fuel benefit even when the particular improvement makes possible higher operating speeds which usually increase fuel consumption. An example of this is surface improvement. When a gravel surfaced road is improved with a bituminous or concrete surface, the nominal highway speed will increase due to the smoother running surface. The fuel saving that users will realize through surface improvement is the difference between the fuel consumption on the gravel surface at the nominal highway speed for the gravel road before improvement, and what the fuel consumption would be at the same speed but on the improved surface. The fact that users elect to travel at a higher speed on the improved road with the corresponding increase in the rate of fuel use does not nullify the saving in fuel use at the lower speed made possible by the improvement. Any increase in fuel consumption due to the higher operating speeds should be considered separately and included in benefit studies as a negative fuel benefit.

The analysis of user benefits for any highway improvement project can be made most satisfactorily by computing separately the savings for each type of improvement involved and then summing these savings to obtain total savings. For example, a proposed highway reconstruction project may include three types of improvement: reduction of curvature, lane widening, and a reduction of the average rate of rise and fall. The amount of fuel and time saving obtainable through each may be determined separately, then added together to give the total savings. Care must be exercised when summing these savings that the same saving is not counted twice. An illustration of this danger is where a two-lane gravel road is reconstructed as a four-lane divided highway with a concrete pavement. Both upgrading the surface and increasing the number of lanes permit higher operating speeds with the consequent reduction of time consumption but the time saving for the higher speed can be included only once. The danger of double counting savings is not great, however, when savings are determined directly since the effects responsible for each saving are clearly evident.

The data needed for the computation of annual time and fuel savings are the following

1. The average gross operating weight of each class of highway vehicle that will use the route being studied.
2. The number of vehicles of each class expected to use the road per year.
3. Complete and accurate information on the planned improvement.
4. The effect each type of improvement will have on speeds, frequency of stops and slowdowns, and length of stopped delays.
5. The saving in time and fuel consumption for each class and weight of vehicle due to reduction in distance, reduction of the rate of rise and fall, changes in speed, elimination of stop-and-go and slowdown maneuvers, and the saving in fuel consumption which will result from surface upgrading and reduction of standing time with engine idling.

Items 1 and 2 concern data which are peculiar to each project and should be secured by traffic volume and loadometer studies on the routes where improvements are planne The information on the physical changes to result from construction (Item 3) should be obtained from an investigation of the site and a study of improvement plans. Much information on the effect of improvements on highway operations (Item 4) is available in the literature. Schwender, Normann, and Granum (1) present curves that make it possible to estimate how vehicle speeds will change with variations in traffic volume, lane width, number of lanes, and sight distance. It will, however, frequently be necessary to investigate traffic operations at the site. For example, when a grade intersection is to be eliminated, the best way to obtain data on percentage of drivers delayed and the average length of delay is by measuring these factors at the intersection which is to be eliminated.

In connection with the magnitude of savings of time and fuel due to change in route length, reduction of resistances to movement at constant speeds, and change in traffic operations (Item 5), satisfactory data are incomplete for current vehicle classes and weights. In 1950, Saal reported on a comprehensive study (2) made in 1948 on the time and fuel consumption of trucks as affected by rate of rise and fall. This report contains graphs showing how the time and fuel consumption of vehicles of 10,000 lb and more gross weight varies for changes in rate of rise and fall. Particularly important to benefit studies is a graph published in a subsequent report (3) which demonstrates how the fuel consumption of passenger cars varies with rate of rise and fall.

Useful data are also available in the literature on the fuel consumption of a few vehicle classes for stop-and-go and slowdown operations. These data, however, are limited in scope to only certain vehicle classes and gross operating weights and do not include all ranges of operating speeds; therefore, they are not sufficiently comprehensive for a general benefit analysis.

The lack of complete data on the variation in time and fuel consumption as affected by changes in traffic operations and surface conditions for all vehicle types and weights led to an extensive investigation of the use of time and fuel by highway vehicles during the summer of 1959. The Bureau of Public Roads conducted such a study in the Washington, D.C., area using passenger cars and single unit trucks while the University of Washington made a similar study using buses and tractor-trailer combinations. The objective of both these studies was to measure under controlled conditions the savings in time and fuel consumption by highway vehicles, whether positive or negative, resulting from changes in vehicle speeds, surface upgrading, elimination of stops and slowdowns, and reductions in grades. Sawhill has prepared a report on the results obtained for the tractor-trailer combinations and buses (4).

TIME AND FUEL CONSUMPTION OF PASSENGER CARS AND SINGLE-UNIT TRUCKS

The time and fuel consumption of three vehicles was investigated in the Bureau of Public Road study: a passenger car, a pickup truck, and a two-axle, six-tire, dump truck. These three classes of vehicles accounted for over 92 percent of the total vehicle miles of travel in 1956 and over 98 percent of the vehicle miles of travel accumulated in that year by all highway vehicles other than buses and tractor-semitrailer, or truck full-trailer combinations (5). Data for the passenger car were obtained for one loading condition only. Data for the trucks were taken for enough different loads to cover the lower range of gross vehicle weights for single-unit trucks. The loading for the passenger car tests was two persons, the driver and one observer. The pickup truck was operated with no load except for the driver and one observer, and with a load approximately equal to full load capacity. The dump truck was operated with no load and with one-half full load only. There was not enough time in the test period to include runs with the dump truck at full load.

A popular make of passenger car was selected as being typical. It was a six-cylinder 1957 standard 4-door sedan with a 3-speed automatic transmission. It had been in service for two years and had traveled 30,000 miles. Data on this vehicle are given in Table 1.

A new six-cylinder 1959 popular make 4,900 lb G.V.W. truck with a manual shift was used for the pickup tests, and a six-cylinder 1950 medium-type dump truck which had been in service for 50,000 mi was used for the dump truck tests. Both trucks were checked on a dynamometer previous to the tests and the efficiency of combustion measured with an exhaust analyzer at a wide range of loads. Necessary mechanical repairs

TABLE 1

VEHICLE DATA

	Gross Weight (lb)						
Type of Vehicle	No Load	Half-Full Load	Full Load	No. of Axles	Net Horsepower	No. of Cylinders	Transmission
Passenger car	3,850	-	-	2	123 at 4,200 rpm	6	Automatic
Pickup truck	3,860	-	5,340	2	120 at 4,000 rpm	6	Manual
Dump truck	10,200	15,300	-	2	89 at 2,800 rpm	6	Manual

were made so that at the time of the tests the vehicles were operating at near optimum efficiency. Data on these trucks are also given in Table 1.

Data on the time and fuel consumption of these vehicles were obtained from a series of test runs made over a nearly straight section of Va. 350 (Shirley Highway) between the Edsall and Fort Belvoir interchanges. This is a divided highway of four 12-ft lanes of portland cement concrete with well built shoulders of firmly compacted gravel 10 ft wide. The test runs were made between two fixed end points set 8,000 ft apart. These points were at nearly the same elevation and the rate of rise and fall between them was less than 0.2 ft per 100 ft.

The following types of test runs were made between end points of the test section:

1. Constant speed runs on the paved surface at indicated speeds of 15, 25, 35, 45, and 55 mph.
2. Constant speed runs on the gravel shoulders at indicated speeds of 15, 25, 35, and 45 mph.
3. Stop-and-go runs on the paved surface at indicated operating speeds of 15, 25, 35, 45, and 55 mph.
4. Slowdown runs (10-mph speed reduction only) on the paved surface at indicated operating speeds of 15, 25, 35, 45, and 55 mph.

Three runs of each type were made for each vehicle and load in each direction at each of the given speeds. The idling fuel consumption was obtained for each vehicle at engine speeds of 450, 550, 650, and 750 revolutions per minute.

The runs were conducted by driving the vehicle over the test section and recording the amount of time and fuel consumed between end points, the direction of travel, time of day, fuel temperature, and run speed as indicated on the vehicle speedometer. For the constant speed runs no other data were taken. On the stop-and-go and slowdown runs the vehicle was brought to a stop or the speed reduced by 10 mph and immediately accelerated back to speed as many times as possible between the end markers, passing each end marker at a constant speed equal to the given run speed. Additional data recorded for these runs were the time during which acceleration took place after each stop or slowdown, the number of stops and slowdowns, and the number of gear changes for each acceleration. The rates of speed change used for both the stop-and-go and slowdown operations during deceleration and acceleration were those of the typical driver under ordinary conditions (6).

Recording the time of day made it possible to determine wind direction and velocity at the time of each run by reference to wind data collected by the Weather Bureau at the nearby Washington National Airport.

The first step in the analysis of the field data was to compute the true speed of each test vehicle for each indicated run speed. The indicated run speeds recorded in the field were as read on the speedometer and generally were in error. They were used during the test because it was easier for the driver to maintain a given speed consistently if he had a definite reading on the speedometer rather than to attempt to hold the speedometer needle at a point where the run speed would be the true speed. The true speed was computed from the known run distance and the run time recorded for the constant speed runs. Since the fuel consumption was measured directly by noting the amount of fuel drawn out of the reservoir of a burette type fuelmeter, no correction was required for errors in the fuel measuring equipment. However, since the volume of fuel measured varied with the temperature of the fuel, a necessary step in the analysis was correction of all fuel readings to what they would have been if the fuel temperature had been 30 C (86 F) at the time of each reading. A temperature of 30 C was chosen for this purpose since it was approximately the average fuel temperature during the period of the tests. Because an accurate stop watch was used to measure the over-all run times from end marker to end marker, it was not necessary to apply any correction to the recorded run times.

APPLICATION OF RESULTS

Corrected fuel consumption values in gallons per mile were computed for each constant speed run on both the paved and gravel surfaces. The average of these values for runs on the paved surface at each speed was determined for each vehicle type and weight and plotted against true speed in Figure 1. Similarly, the average of the corrected fuel

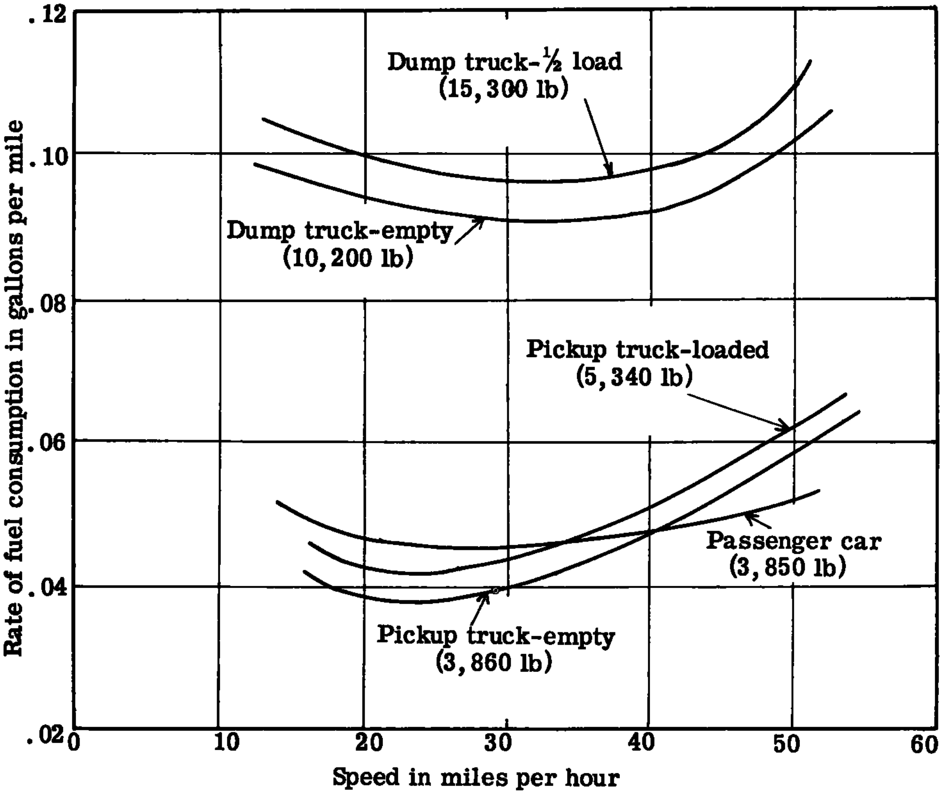

Figure 1. Fuel consumption rates at constant speed on a level, straight, concrete pavement.

consumption values in gallons per mile for runs on the gravel surface were plotted against true speed in Figure 2.

Figures 1 and 2 may be used to estimate the change in rate of fuel consumption in gallons per mile which will result when nominal highway speeds are increased through highway improvement on roads carrying traffic volumes somewhat less than their capacity volume. Since nominal highway speed is the operating speed between points where vehicles are slowed or stopped by highway impedances, the application of these curves is not restricted by the effect of such highway impedances. Wider lanes and improved sight distance are examples of highway improvements which will result in higher nominal highway speeds; the amount of speed increase to be achieved from such improvements can be estimated from previously published curves (1).

Where more lanes are added to a route to provide greater capacity when capacity before improvement is less than the 30th-hr volume, Figures 1 and 2 may be used to estimate the fuel consumption after improvement when vehicle speeds are relatively uniform. However, the lower speeds before improvement are largely due to congestion and are not uniform but include the frequent decelerations and accelerations associated with traffic congestion. The rate of fuel consumption before improvement ma be estimated by adding to the values given in Figures 1 and 2 the amount of additional fuel consumed by slowdowns. The average number of slowdowns may be determined b

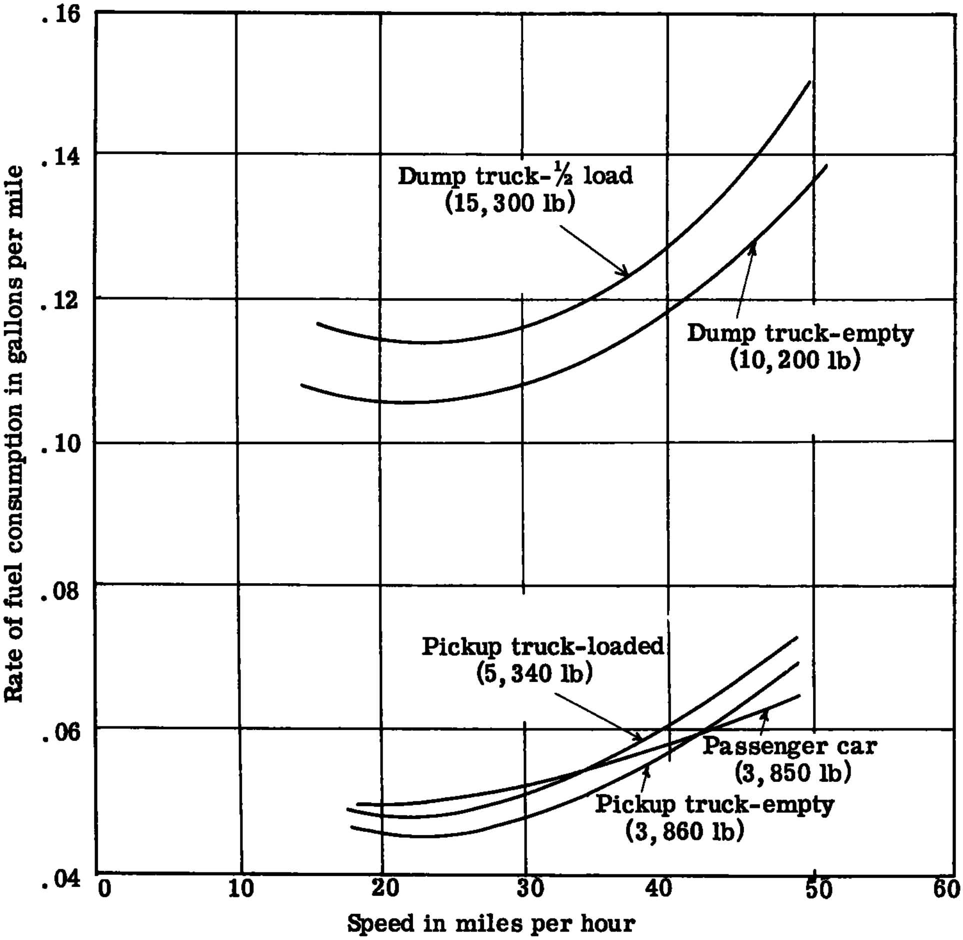

Figure 2. Fuel consumption rates at constant speed on a level, straight, gravel surface.

making suitable speed-delay studies over the route before improvement and the additional fuel consumption due to a slowdown may be estimated using Figure 6.

Figure 3 shows the fuel saving in gallons per mile for operation on a paved surface rather than on a gravel surface at each speed. Most users take advantage of a reduction in road roughness to operate at increased speed on the better surface even though speeds above 35 mph increase fuel consumption. It is at the user's discretion whether he operates on the improved surface at the same speed as on the loose surface and saves on fuel use, or operates at a higher speed and pays for the higher speed and time saving through increased fuel consumption. In either case this saving is made available to the user. The nominal highway speed of modern vehicles on a gravel or loose-surfaced road is between 30 and 35 mph; for any particular loose-surfaced road it should be obtained by making a spot speed study.

The fuel consumed for a stop-and-go operation was found by dividing the number of such operations on each stop-and-go run into the difference between the amount of fuel used for the stop-and-go run and the average amount of fuel used for the constant speed runs on the paved surface at the same speed. This is the amount of fuel used by a vehicle to come to a stop and accelerate back to speed which would be saved if the vehicle could proceed without stopping. Fuel consumption for stop-and-go operations at various speeds is shown in Figure 4. For example, Figure 4 shows that a passenger car uses 0.009 gal of fuel to come to a stop from 30 mph and accelerate back to this speed. At 30 cents per gal, the stop-and-go operation would cost approximately ¼ cent.

The procedure used to compute the time consumption for a stop-and-go operation was the same as that used to compute stop-and-go fuel consumption. Figure 5 shows stop-and-go time consumption as a function of true speed. Time consumption as well as fuel consumption for stop-and-go operations does not include the time or fuel consumed while a vehicle is stopped but only that consumed for the actual stop-and-go maneuver itself.

Idling fuel consumption is given in Table 2. The data were obtained with the vehicle stationary and the engine warm. In the case of trucks, idling fuel consumption was obtained in forward gear with the clutch disengaged. The idling fuel consumption of the passenger car was measured with the transmission in (a) drive position with the brakes set, and (b) neutral position. Idling fuel consumption values in gallons per minute are given for four different engine speeds; the average of these should be used in benefit studies.

TABLE 2

IDLING FUEL CONSUMPTION

Vehicle	Fuel Consumption (gpm)				
	450 rpm	550 rmp	650 rpm	750 rpm	Average
Passenger car:					
Transmission in neutral	0.005	0.006	0.006	0.007	0.006
Transmission in drive	0.005	0.008	0.009	0.014	0.009
Average	0.005	0.007	0.007	0.010	0.007
Pickup truck	0.006	0.007	-	0.008	0.007
Dump truck	0.009	0.010	0.011	0.013	0.011

Figures 4 and 5 and Table 2 are useful for estimating the fuel and time savings which will result if an intersection at grade, controlled by traffic signals or stop signs, is eliminated through construction of a grade separation structure. Additional information needed for computation of benefits in this case are: traffic volumes, nominal highway speed, average length of stopped delays, and percentage of vehicles stopped by traffic signals.

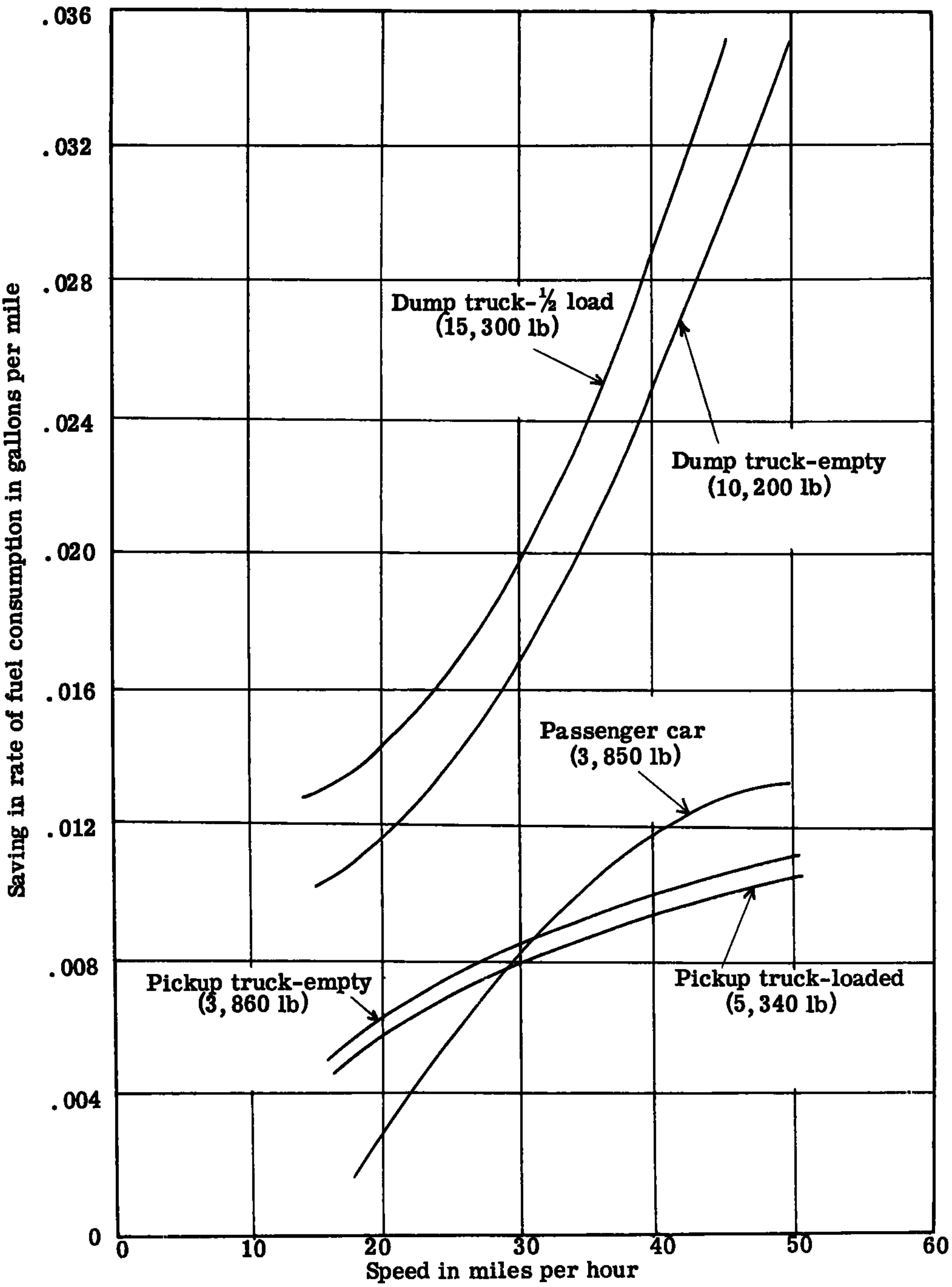

Figure 3. Saving in fuel consumption for operation on concrete pavement rather than on a gravel surface at constant speed.

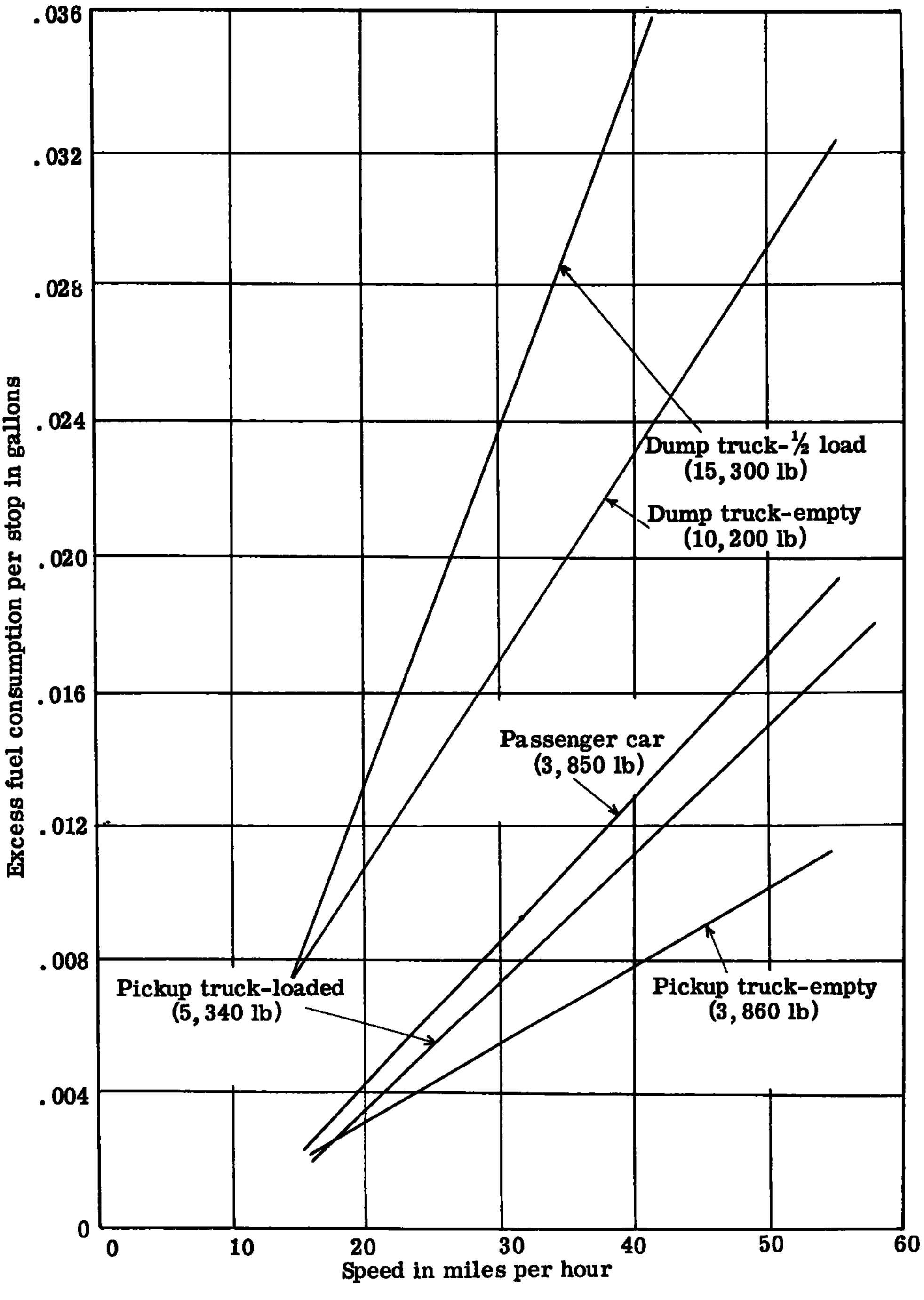

Figure 4. Fuel consumed for coming to a stop from a given speed and immediately accelerating back to that speed in excess of the fuel consumption if given speed were maintained.

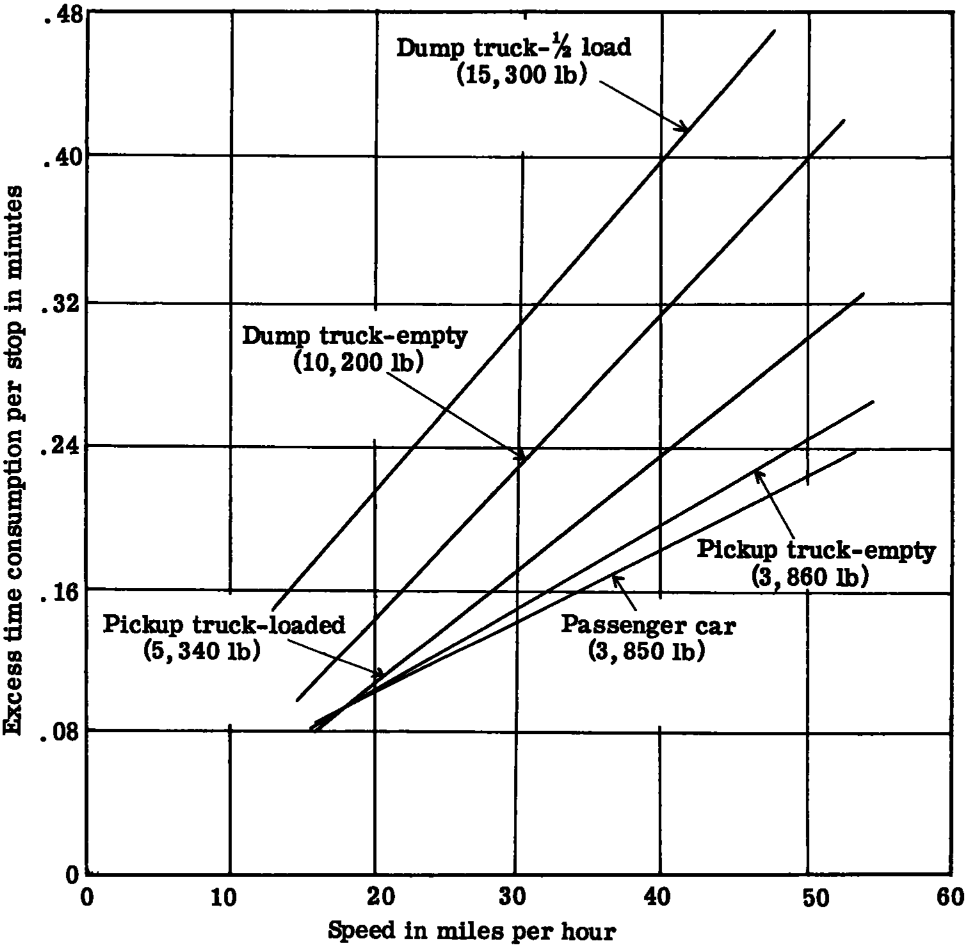

Figure 5. Time consumed for coming to a stop from a given speed and immediately accelerating back to that speed in excess of time consumption if given speed were maintained.

Figure 6 shows the additional fuel consumption for a slowdown of 10 mph at various speeds; Figure 7, the additional time consumption. The procedures used for computin the fuel and time consumption due to slowdowns were similar to those described previously.

Figure 6 shows that the fuel consumption for slowdowns for passenger cars increas continuously for all speeds while the corresponding fuel consumption for trucks decreases somewhat at higher speeds. This difference is largely due to the passenger c being the only vehicle equipped with automatic transmission. A slowdown is a reductio of speed followed immediately by acceleration back to original speed; it does not include any period of operation at the reduced speed. The applicability of these curves is limited to improvements that eliminate highway impedances which cause vehicles to reduce speed by about 10 mph. This limitation is not serious because most slowdowns of importance in benefit studies are on the order of 10 mph. Preliminary analysis of data taken from extensive speed-delay studies made with a passenger car during the summer months of 1958 and 1959 shows: (a) speed reductions of up to 3 mph are p of uniform driving and are not eliminated through highway improvements, and (b) the average of the speed reductions in excess of 3 mph is about 10 mph. Furthermore, it has recently been established that the average speed reduction of motor trucks when slowed by highway or traffic impedances is 11.4 mph (7).

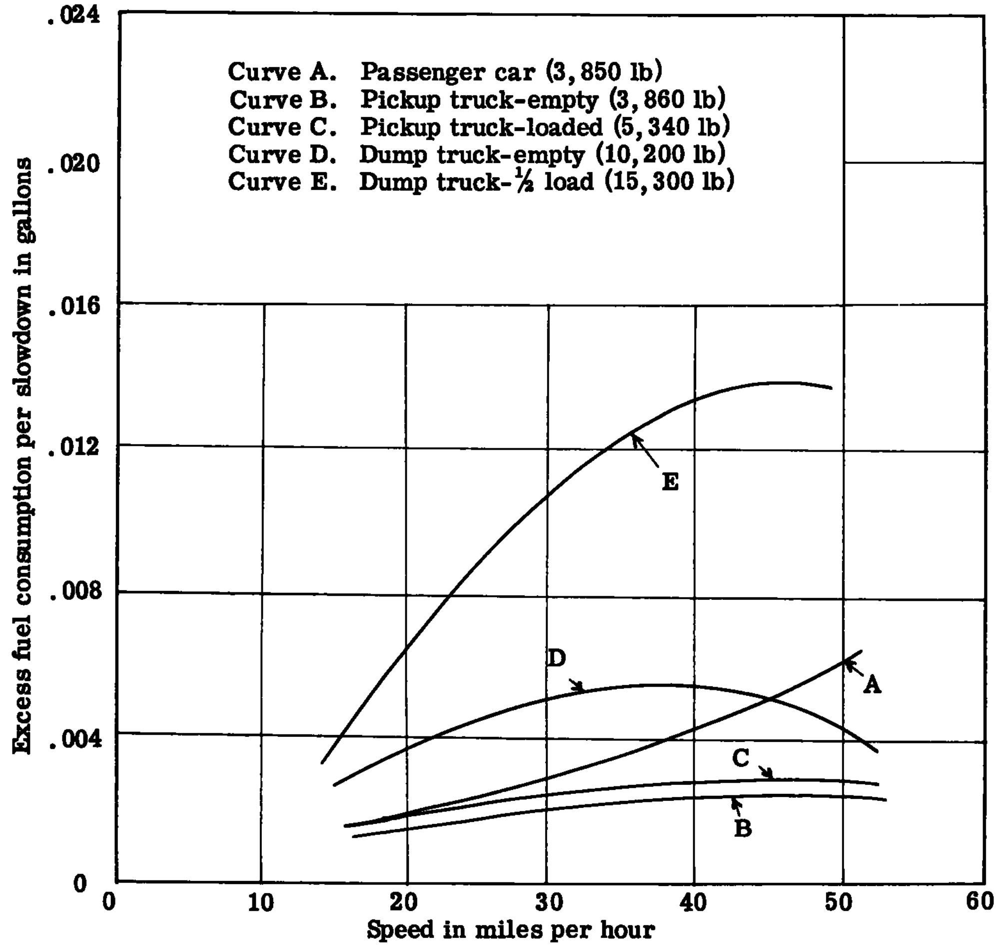

Figure 6. Fuel consumed for reducing speed by 10 mph from a given speed and immediately accelerating back to that speed in excess of fuel consumption if given speed were maintained.

Figures 6 and 7 may be used to estimate the fuel and time consumption saved through the elimination of sharp curves and driveway entrances. In the case of a curve elimination, test runs should be made before improvement to determine the average amount of slowdown caused by the presence of the curve. Where driveway entrances are to be eliminated, test runs should be made beforehand to establish the average percentage of driveways at which through vehicles are forced to reduce speeds and the average value of such speed slowdowns. When the analyses of the speed-delay studies are completed, average values of speed reductions for curves and driveway entrances and the average percentage of driveways at which the movement of through vehicles is affected will be available for use in benefit studies. If the average speed reductions found for curves and driveway entrances are between 8 and 12 mph, Figures 6 and 7 may be used to compute fuel and time savings. If the average speed reduction is more than 12 mph or less than 8 mph, the fuel and time savings may be estimated from Figures 6 and 7 assuming that the magnitude of these savings is proportionate to the magnitude of the speed change.

Two examples will illustrate how Figures 1 through 7 and Table 2 may be used to compute the fuel and time savings arising from particular improvements.

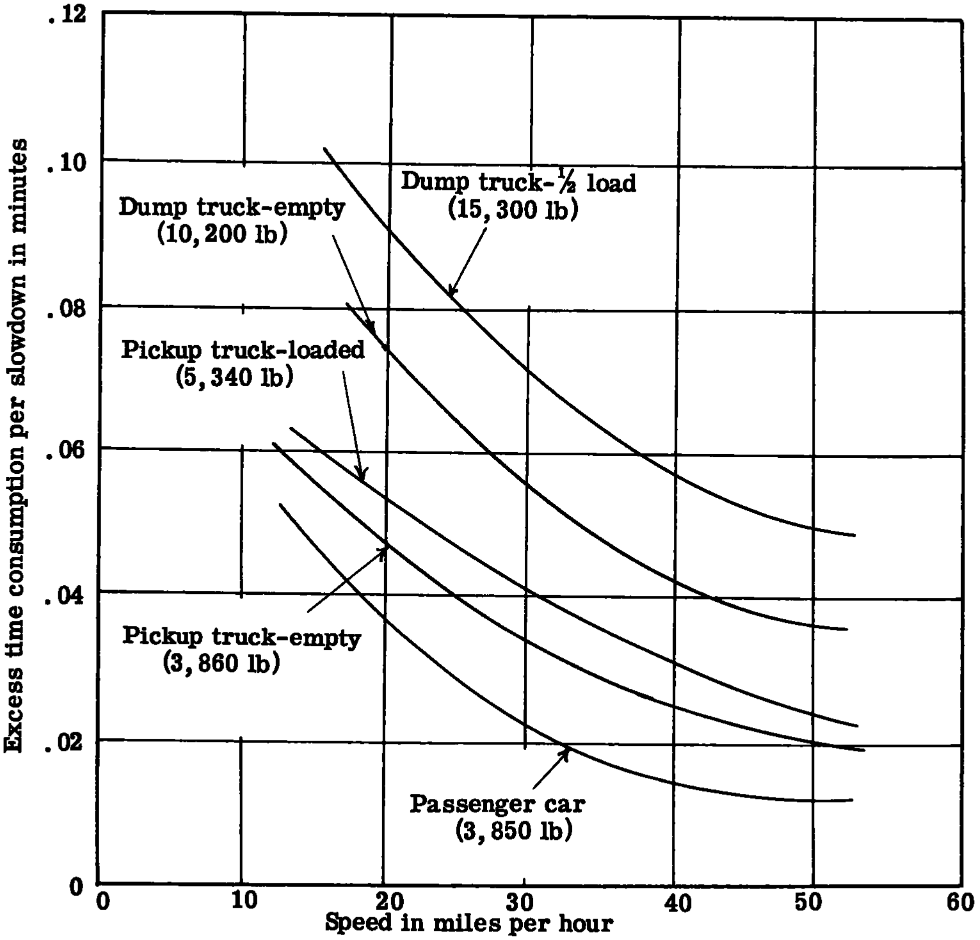

Figure 7. Time consumed for reducing speed by 10 mph from a given speed and immediately accelerating back to that speed in excess of time consumption if given speed were maintained.

Example 1

A 2-lane gravel surfaced road 24 ft wide is to be surfaced with a concrete pavement for 10 mi. Average annual daily traffic on the route is 4,000 vehicles per day. Eighty percent of the vehicles are passenger cars and 20 percent are two-axle single unit trucks having an average gross vehicle weight of 10,000 lb. The nominal highway spee on the route before improvement was 35 mph for all vehicles. It is expected that this will be increased to 45 mph after improvement. Compute the average annual fuel savings which may be attributed to this improvement.

Total number of vehicles using route per year:

Passenger cars	4,000 x 0.80 x 365 = 1,168,000
Trucks	4,000 x 0.20 x 365 = 292,000

Savings in fuel use per vehicle mile due to surface improvement at nominal highway speed of 35 mph (Fig. 3):

Passenger cars	0.010 gal per mi
Trucks	0.021 gal per mi

Increase in fuel consumption per vehicle mile due to speed increase from 35 to 45 mph on paved surface (Fig. 1):

Passenger cars 0.003 gal per mi
Trucks 0.004 gal per mi
Annual saving in fuel use (10 mi):
Passenger cars 1,168,000 (10) (0.010-0.003) = 81,760 gal
Trucks 292,000 (10) (0.021-0.004) = 49,640 gal
Total 131,400 gal

Example 2

A grade separation is planned at the intersection of a 4-lane divided parkway and a 2-lane crossroad where traffic signals now control vehicle movements. The average annual daily traffic volumes on the 4-lane and 2-lane routes are 20,000 vehicles per day and 4,000 vehicles per day, respectively. All vehicles on the parkway are passenger cars. Eighty percent of the vehicles on the crossroad are passenger cars and 20 percent are 2-axle single unit trucks having an average gross weight of 10,000 lb. The nominal highway speed on the 4-lane route is 45 mph and on the 2-lane route, 30 mph (all vehicles). Turning movements at this intersection are so few that they may be neglected. It was determined from a study of traffic movements that on both routes traffic signals caused 25 percent of the vehicles to stop with an average delay per stop per vehicle of 20 sec (0.33 min). Compute the annual fuel and time savings which will result from this improvement.

Annual number of vehicles stopped at the intersection:
Four-lane divided highway:
Passenger cars 20,000 (365) (0.25) = 1,825,000
Two-lane crossroad:
Passenger cars 4,000 (0.80) (365) (0.25) = 292,000
Trucks 4,000 (0.20) (365) (0.25) = 73,000
Unit fuel and time savings:
Passenger cars: Fuel savings per stop-and-go at nominal highway speed of 45 mph (Fig. 4) = 0.015 gal
Time savings per stop-and-go at nominal highway speed of 45 mph (Fig. 5) = 0.21 min
Fuel savings per stop-and-go at nominal highway speed of 30 mph (Fig. 4) = 0.009 gal
Time savings per stop-and-go at nominal highway speed of 30 mph (Fig. 5) = 0.14 min
Fuel use while idling (Table 2) = 0.007 gal per min

Trucks: Fuel savings per stop-and-go at nominal highway speed of 30 mph (Fig. 4) = 0.017 gal
Time Savings per stop-and-go at nominal highway speed of 30 mph (Fig. 5) = 0.23 min
Fuel use while idling (Table 2) = 0.011 gal per min

Annual fuel savings:
Four-lane divided highway:
Passenger car (stop-and-go) = 1,825,000 (0.015) = 27,375 gal
Passenger car (idling) = 1,825,000 (0.33) (0.007) = 4,216 gal

Two-lane crossroad:
Passenger car (stop-and-go) = 292,000 (0.009) = 2,628 gal
Passenger car (idling) = 292,000 (0.33) (0.007) = 674 gal
Trucks (stop-and-go) = 73,000 (0.017) = 1,241 gal
Trucks (idling) = 73,000 (0.33) (0.011) = 265 gal
Total 36,399 gal

Annual time savings:
Four-lane divided highway:

Passenger car (stop-and-go) = 1,825,000 (0.21) = 383,250 min
Passenger car (idling) = 1,825,000 (0.33) = 602,250 min

Two-lane crossroad:
Passenger car (stop-and-go) = 292,000 (0.14) = 40,880 min
Passenger car (idling) = 292,000 (0.33) = 96,360 min
Trucks (stop-and-go) = 73,000 (0.23) = 16,790 min
Trucks (idling) = 73,000 (0.33) = 24,090 min
Total 1,163,620 min = (19,394 hr)

SUMMARY

Much of the saving in time and fuel as a result of highway improvement arises because of increased vehicle speeds, upgrading of pavement surface, and reduction of the frequency of stop-and-go and slowdown operations. On paved surfaces the rate of fuel consumption of passenger cars and single unit trucks decreases as speed increases fro 15 mph to between 25 and 35 mph depending on vehicle type and gross weight. At highe speeds the rate of fuel consumption increases. On gravel roads the relationship betwee rate of fuel consumption and speed for these vehicles is similar to that for paved surfaces except that the lowest rate of fuel consumption is between 20 and 25 mph.

The effect of upgrading a gravel surface to a concrete surface on the rate of fuel consumption of passenger cars and single unit trucks increases with vehicle speed. At speeds of 15 mph the increase in fuel consumption for the gravel surface is less than 7 percent but at 45 mph it is over 20 percent for passenger cars and pickup trucks and over 30 percent for single unit trucks with gross weights of 10,000 lb or more.

The additional time and fuel consumption for stop-and-go operations increases uniformly with speed. At any speed the additional time consumption is greater for the vehicles with the greater weight horsepower ratio. The additional fuel consumption increases as vehicle gross weight increases except that the passenger car uses more fuel than the heavier pickup truck at all speeds. This was probably due to the fact that the passenger car used for the study was equipped with an automatic transmission and the pickup truck had a manual transmission.

The additional time consumption for a slowdown of 10 mph decreases with increased vehicle speed. The additional fuel consumption of passenger cars for slowdowns increases with speed up to at least 50 mph. The additional fuel consumption of single unit trucks increases with speed up to between 35 and 50 mph but decreases somewhat at higher speeds.

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