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Vehicle operating costs, fuel consumption, and pavement type and condition factors

June 1982

Final Report

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16. Abstract

This report presents updated vehicle operating cost tables which may be used by a highway agency for estimation of vehicle operating costs as a function of operational and roadway variables. These results, partially based on fuel consumption tests on a group of late model vehicles and on a survey of truck fleet owners, are representative of the advancement in vehicle propulsion technology and increase in unit prices since the last comprehensive study of vehicle operating cost was conducted in the United States. To make the procedure flexible to changes in unit prices, consumption rates of the major vehicle cost components are presented in tables of constant speed on vertical grades, constant speed on horizontal curves, speed change cycles, and idling for each vehicle classification. Thus, current unit prices may be used with the procedure to achieve updated estimates of cost. Emission rates of vehicles operating at constant speed and for speed change cycles are also presented.

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VEHICLE OPERATING COSTS, FUEL CONSUMPTION, AND PAVEMENT TYPE AND CONDITION FACTORS

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
OFFICE OF HIGHWAY PLANNING

MARCH 1982

PREFACE

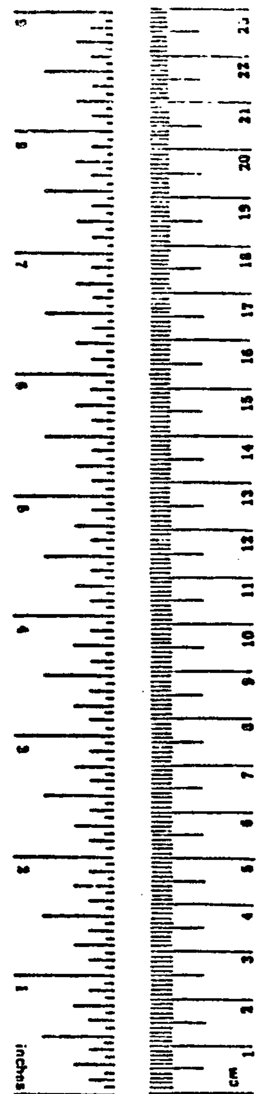
This final project report presents the findings of a comprehensive study of vehicle operating costs in the United States. The work presented in this report was supported by the Federal Highway Administration, Office of Highway Planning under contract No. DOT-FH-11-9678. We are grateful to our contract manager, Mr. Cliff Comeau, who provided technical coordination throughout the study. The work presented in this report was the results of a study team headed by Dr. J. P. Zaniewski, consisting of G. E. Elkins, B. C. Butler, M. S. Paggi, G. Cunningham, and R. Machemehl. Valuable assistance and support was also received from Mr. R. Winfrey whose general expertise and background in this field was very beneficial.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

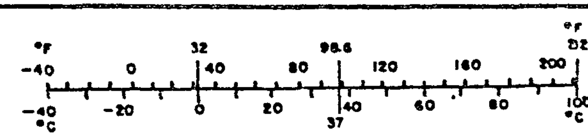
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER 1. VEHICLE OPERATING COSTS RELATED TO ROADWAY CHARACTERISTICS

The last comprehensive study of vehicle operating costs in the United States was reported by Claffey in 1971 (Ref 1). This work and other information was used by Winfrey to prepare a comprehensive set of vehicle operating cost tables (Ref 2). These two references are the basis for most vehicle operating cost calculations performed by highway agencies. Since the publication of these reports. vehicle operating costs have changed dramatically due both to inflation and changes in motor vehicle technology. Because vehicle operating costs are a significant portion of highway transportation costs, the Federal Highway Administration, Office of Highway Planning, sponsored research to update information on the interactions between roadway characteristics and vehicle operating parameters.

The objectives of this research were to:

1. Determine the operating costs and fuel consumption of motor vehicles as a function of vehicle and roadway characteristics.

2. Determine the effect of pavement type and condition on selected performance parameters, and develop an adjustment procedure for these performance parameters as a function of pavement type and condition.

The performance parameters investigated in this research were:

1. running speed,
2. vehicle operating costs,
3. fuel consumption,
4. vehicle emissions, and
5. accidents.

Vehicle operating costs include consumption of fuel and oil, tire wear, vehicle maintenance and repair, and use-related depreciation. Major emphasis was placed on fuel consumption due to its importance as a component of vehicle operating costs and as a major factor in the energy posture of the United States.

RESEARCH APPROACH

This research was designed to take maximum advantage of information available in the literature. Thus, the first phase of the research was a comprehensive literature survey as reported in the project interim report (Ref 3). More than 600 references were reviewed during the first phase. Based on the information developed in this phase, a research plan for the remainder of the project was developed.

Fuel Consumption

The last experimental investigation in the United States of the relationship between roadway characteristics and fuel consumption was performed over ten years ago. Since that time there have been significant changes in vehicle technology, e.g., unleaded fuel, radial tires, better aerodynamics, more efficient motors, etc. Thus, it was decided to collect primary data on fuel consumption.

Oil Consumption

This is a relatively unimportant component of vehicle operating cost, thus, no primary data was sought in this research for oil consumption. The basic division of oil consumption for speeds and roadway characteristics was updated based on longer oil change intervals of the current automobile population. Oil consumption information provided by trucking firms was used to update truck oil consumption estimates.

Tire Wear

The Forest Service developed the slip-energy theory for computing tire wear based on the forces required for a given operating situation. This theory was used to estimate tire wear differentials between different surface types, grades, curves, and speeds. The tire wear predicted with the theory were checked against automobile tire wear estimates measured by the National Highway Traffic Safety Administration and truck tire wear information collected from trucking firms.

Maintenance and Repair

The basic procedure used by Winfrey for differentiating vehicle maintenance and repair was updated with current cost estimates. Automobile maintenance costs were obtained from the Federal Highway Administration. Trucking firms participating in the Volunteer Fuel Economy Program were surveyed to obtain current cost information for trucks.

Use-Related Depreciation

In order to split vehicle depreciation into use and time related portions, a procedure developed by Daniels was selected (Ref 4) for trucks. Truck use census data collected in 1977 was used with registration data to establish survivor curves for trucks. The survival curves for automobiles were established from U.S. Department of Transportation data. The use-related depreciation costs were then differentiated for speed using Winfrey's procedure. Published information from a research project conducted in Brazil was then used to differentiate depreciation by surface type and condition.

Accidents

In order to determine the influence of pavement condition on accident rates, data from the Texas State Department of Highways and Public

Transportation were analyzed. Separate data files on accident occurrence and road roughness were merged to create the data base.

Emissions

Only very limited data are available for predicting vehicle emissions as a function of roadway characteristics. The "bag value" emissions data collected by the EPA for automobile certification are too gross to be used in this research. Therefore, the equations in the Modal Analysis Model (Ref 5) were used to estimate automobile emissions. Research performed by Southwest Research Institute (Ref 6) was used to estimate truck emissions.

Running Speeds

Under the scope of this project, running speeds are considered to be an input to the economic analysis procedure. Therefore, little emphasis was given to studying running speeds, and no primary data were collected. The results of the literature survey performed under the first phase of this report are summarized in the final chapter to give guidance on the selection of a running speed for the economic analysis.

Another aspect of speed calculations is the acceleration and deceleration models used to generate the tables for speed changes. These models are documented in Appendix D.

VEHICLE CLASSES

During the first phase of the project, vehicle characteristics and production trends were carefully analyzed to determine vehicle classes for representing the vehicle population. Once the vehicle classes were established, representative characteristics were selected for each class. These classes and characteristics are described in Table 1.

Table 1. Typical vehicle characteristics.

Features	Cars			Trucks				
					Single Unit		Semi's	
	Small	Medium	Large	Pickup	2 axle	3 axle	4 axle	5 axle
Road Weight (lbs)	2800	3800	4700	5,000	12,000	35,000	40,000	62,500
Curb Weight (lbs)	2500	3500	4400	3,500	5,700	15,000	20,000	25,000
Engine Displacement (ci)	120	230	350	350	350	400	800	800
Number of Cylinders	4	6	8	8	8	8	6	6
Fuel	Unleaded	Unleaded	Unleaded	Gas	Gas	Diesel	Diesel	Diesel
Frontal Area	23.7	27.5	29.8	30.8	36.9	55.0	90.0	90.0
Transmission	Manual	Automatic	Automatic	Auto-matic	Manual	Manual	Manual	Manual
Number of Forward Gears	4	3	3	3	4	5	10	10
Body Style	Sedan	Sedan	Sedan	Box	Flatbed	Flatbed	Van	Van
Options								
Air Conditioning	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Power Steering	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Power Brakes	No*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Steel Belted Radial	Yes	Yes	Yes	Yes	No	No	No	No
Fuel Economy Ranges mpg.								
EPA city cycle	20-25	15-20	9-16					
EPA highway cycle	28-37	22-35	13-25					

* may be power assist

COMPONENT PRICES

Throughout this research, our approach has been to identify quantities of consumption as a function of roadway characteristics so that unit prices could be applied to consumption to obtain costs. Under this approach, the operating cost tables may be readily updated for changes in price which occur more frequently than changes in technology which influence consumption rates. Table 2 gives the component prices used to generate the cost tables in this research. These prices reflect 1980 prices. Gasoline and diesel prices were obtained from the December 1980 issue of Monthly Energy Review (Ref 7). A survey of oil prices found a range of $0.80 to $3.00 per quart. A price of $1.00 was assigned to commercial vehicles, assuming oil could be purchased in bulk. It was assumed that private vehicle owners have oil changed at garages and service stations and, therefore, pay a premium price. Tire prices for automobiles were surveyed from newspaper advertisements, and averages were computed for the select tire size for each class. Commercial vehicle tire costs were obtained from a limited survey of fleet operators and were adjusted for recapping.

Automobile and pickup truck maintenance and repair cost were taken from a Department of Transportation publication by Ulman (Ref 8). Maintenance and repair cost for 3-S2 trucks were obtained from a survey of trucking fleets. Current maintenance and repair cost for two and three axle single unit trucks and four axle single unit trucks were not available, so they were estimated from Winfrey's data, based on the ratio of the maintenance and repair cost of these classes to the maintenance and repair cost of five axle semi-truck. Winfrey reported maintenance and repair cost for 12 kip single unit trucks to be 68% the cost of 3-S2 trucks; so cost of $99 was used in Table 2. Winfrey did not report cost information for three axle single unit trucks; it was assumed that the costs would be slightly less for the 3-S2, so a value of $140 was assumed. Winfrey's maintenance and repair cost for 2-S2 trucks were 8 per cent greater than for 3-S2 trucks. This was attributed to the use of gasoline motors in 2-S2 trucks when Winfrey compiled his cost tables. Since diesel motors are now more common in all semi-trucks, it was decided to set the

Table 2. Component prices (1980).

Item	Vehicle Type								Units
	Cars			Trucks					
					Single Unit		Semi's		
	Small	Medium	Large	Pickup	2 axle	3 axle	4 axle	5 axle	
Fuel *	1.098	1.098	1.098	1.098	1.098	0.886	0.886	0.886	$/gal
Oil	2.50	2.50	2.50	2.50	1.00	1.00	1.00	1.00	$/quart
Tires **	43	68	75	75	194	465	465*	465	$/tire
Maintenance and Repairs	34.30	41.60	48.04	52.81	99.	140	145	145	$/1000 mi
Depreciable Value	6,360	7,501	9,990	6,625	8,673	45,350	48,687	51,630	S/vehicle

* Gas Price = $1.221 - .123 (tax), Diesel Price = 1.01 - .124 (tax)

** Truck tire cost includes recaps.
2.5 recaps per tire for all trucks
except 2 axle single unit which has 1.5 recaps.

maintenance and repair cost for 2-S2 trucks equal to the costs for 3-S2 trucks.

Depreciable value was calculated as retail price minus tire costs and a 10% salvaged value. Dealers were surveyed to obtain the retail price of vehicles.

SCOPE AND ORGANIZATION

The results and conclusions presented in this report are based on using the information available in the literature to the greatest possible extent. Primary data were obtained only for fuel consumption. Experimentation on the other performance parameters addressed herein was beyond the scope of the research. Furthermore, some components of vehicle operating costs, e.g., depreciation, and maintenance and repair cannot be measured experimentally. Differentiating these costs by operational conditions can only be done by judgement and logic. In these cases, the procedures developed and applied by Winfrey were adopted to the greatest extent possible.

In order to present a complete set of tables, it was necessary to extrapolate the data and information for the extreme conditions. Allocation of vehicle operating costs to different operating speeds and roadway conditions is intuitively acceptable and gives highway planners and analysts a tool for making economic decisions. To quote Winfrey, (Ref 2),

> . . . allocating costs by judgement was preferable to the decision not to allocate. For instance, considerable personal judgement was exercised in allocating maintenance expense to vehicle speed. The allocations made, even though not substained by test data, should produce comparative results in economic studies which are an improvement over what would be obtained under the decision to hold vehicle maintenance expense constant for all speeds and all elements of highway design.

The remainder of the report documents the research performed on fuel consumption, other components of vehicle operating costs, vehicle emissions, accidents, and running speed. The final chapter presents recommendations and conclusions developed in this research. Because the Project Interim Report has been submitted for publication, references are limited to citing information actually used in this research.

Vehicle operating cost tables are presented in Appendix A. The component consumption tables are in Appendix B. The fuel consumption data are in Appendix C, acceleration and deceleration models in Appendix D, and models for computing horsepower are in Appendix E. Tables of vehicle emissions as a function of speed, speed changes, grade, and horizontal curvature are in Appendix F.

CHAPTER 2. FUEL CONSUMPTION

The most recent experiments in the United State of the effect of roadway characteristics to fuel economy are over ten years old (Ref 1). Since vehicle designs have undergone major changes in the past decade, fuel consumption tests were performed during this research. Fuel consumption of eight vehicles was measured on test sections selected to be homogenous with respect to grade, surface type, and roughness. Constant speed tests were performed in 10 mph increments from 10 mph to 70 mph. Some test runs could not be performed because of either vehicle performance or safety reasons. In addition, acceleration, deceleration, and coast down tests were performed on select test sections.

TEST VEHICLES

The fuel consumption tests were performed with the eight vehicles described in Table 3. Four automobiles were included in the fleet. an economy car, two mid-size cars, and a large luxury car. These vehicles were selected to have characteristics similar to those specified in Table 1. All cars had a minimum of 5000 mi (8000 km) on the odometer at the start of the test.

Two mid-size cars were included in the experiment so the variance between the two identical automobiles could be used in the statistical analysis for significant factors. However, since the statistical tests on the effect of surface type showed no significance when tested with the repeat variance on tests, it was not necessary to use the variance between the repeat vehicles.

Four trucks were tested, a pickup, a two axle single unit truck, a three axle single unit truck, and a four axle semi. Due to time constraints and vehicle availability, it was not possible to match the truck characteristics to the specifications in Table 1 exactly. All trucks had a minimum of 20,000 mi (30,000 km) at the start of the test.

Table 3. Test fleet characteristics.

	1980 Ford Escort	1980 Ford Fairmont	1980 Ford Fairmont	1979 Oldsmobile Delta 88
Road Weight (lbs.)	2412	3006	3006	4350
Curb Weight (lbs.)	2112	2706	2706	4050
Engine Displacement (CI)	98	200	200	350
Number of Cylinders	4	6	6	8
Fuel Type	Unleaded	Unleaded	Unleaded	Unleaded
Frontal Area (SF)	20.7	22.1	22.1	29.2
Transmission	Manual	Automatic	Automatic	Automatic
Number of Forward Gears	4	3	3	3
Body Style	S.W.	Sedan	Sedan	Sedan
Options				
Air Conditioning	Yes	Yes	Yes	Yes
Power Steering	No	Yes	Yes	Yes
Power Brakes	No	Yes	Yes	Yes
Steel Belted Radials	Yes	Yes	Yes	Yes
EPA Fuel Consumption (mpg)				
City Cycle	28	18	18	-
Highway Cycle	44	24	24	-
Combined	32	20	20	16
Test Vehicle Number	1	2	3	4
Vehicle Category	Small Car	Medium Car	Medium Car	Large Car

Table 3. Test fleet characteristics (continued).

	1980 Ford Pickup	2A-SU GMC	3A-SU GMC (Brigadier)	2-S2 Freightliner
Road Weight (lbs.)	3678	17120	35,870	56,000
Curb Weight (lbs.)	3378	10720	15,760	24,680
Engine Displacement (CI)	350	366	426	855
Number of Cylinders	8	8	6	6
Fuel Type	Unleaded	Leaded	Diesel	Diesel
Frontal Area (SF)	31.0	38.7	57.3	95.7
Transmission	Automatic	Manual	Manual	Manual
Number of Forward Gears	3	5	8	9
Body Style	Box	Van	Dump	Flat Bed
Options				
Air Conditioning	Yes	No	Yes	Yes
Power Steering	Yes	No	Yes	Yes
Power Brakes	Yes	No	Yes	Yes
Steel Belted Radials	Yes	No	No	No
EPA Fuel Economy (mpg)				
City Cycle	16	N/A	N/A	N/A
Highway Cycle	18	N/A	N/A	N/A
Combined	17	N/A	N/A	N/A
Load Material	N/A	Scrap Iron	Sand	Bricks
Test Vehicle Number	5	6	7	8
Vehicle Category	Pickup Truck	2A-SU Truck	3A-SU Truck	2-S2

All tests with the trucks. except the pickup. were run in the "loaded" condition. A load was selected which was typical for the model of truck being tested. Hence, the road weight values in Table 3 do not correspond with the typical vehicle weights given in Table 1. In order to have a common vehicle weight basis for the operating cost tables. it was necessary to extrapolate the fuel consumption data to different weight classes.

It was also necessary to extrapolate the fuel consumption data collected with the 2-S2 to estimate fuel consumption for the 3-S2. Data from previous studies were used to make this extrapolation. While exptrapolating data is not a desirable situation, steps were taken to minimize the amount of extrapolation. This included the use of a test weight for the 2-S2 vehicle which was only 6,500 lbs. short of the typical loaded weight for a 3-S2 as given in Table 1.

TEST SECTIONS

Test sections were selected to be homogenous with respect to grade, surface type. and roughness. The test section properties are summarized in Table 4. Grades were determined from as-constructed plan sheets on file at the Texas State Department of Highways and Public Transportation. Roughness was measured by Austin Testing Engineers using a Maysmeter calibrated against the Texas calibration sections in the Austin. Texas area.

A total of 12 test sections were used during the experiments. Tests to determine the effect of curvature were performed on a large parking-lot with the economy car, the large car, and the pick-up. The parking lot owners prohibited further testing. fearing the test would damage the pavement. No other acceptable area was found to continue these tests with the other vehicles.

After the tests had been completed with three of the vehicles, two sections with more desirable characteristics were located. Test sections used with each vehicle are shown in Table 4. Section 10 was used to

Table 4. Test section characteristics.

Location	Section Number	Surface[1] Type	Grade %	Length	Serviceability Index	Vehicles[2] Tested
US 281	1	AC	2.6	0.5	4.2	All
SH 71	2	AC	0	0.4	4.4	All
US 281	3	AC	5.6	0.4	4.5	All
FM 2222	4	AC	11	0.4	4.0	All
Old Hwy. 20	5	AC	∿0	0.8	1.5	All
FM 973	6	AC	∿0	0.8	3.8	1,3,4
FM 973	7	AC	∿0	0.5	3.7	1,3,4
Burger Center	8	AC	∿0	*	1.5	1,3,4
IH-10	9	PCC	∿0	2.1	3.4	All
Littig Rd	10	AC	∿0	0.5	3.2	2,5,6,7,8
Hays Co	11	ST	∿0	0.6	3.5	2,5,6,7,8
CC#229	12	Gravel	∿0	0.6	1.8	All

[1]AC - Asphaltic Concrete PCC - Portland Cement Concrete ST - Surface Treatment

[2]See vehicle number in Table 3

*Constant speed circle tests

replace Section 6 since the serviceability index of Section 6 was closer to the middle of the range of serviceability. Section 11 replaced Section 7 since the new section had a surface treatment in relatively good condition and would allow a direct comparison of the influence of surface type on fuel consumption.

EQUIPMENT

Criteria for the selection of equipment were:

1. Transferability. To minimize costs, the equipment had to be easy to install and remove from the vehicle without damaging the vehicle.
2. Accuracy. Speed measurements to the closest mile per hour and fuel consumption measurements with a resolution of 0.001 gal (3.8 ml) were required.
3. Automatic data recording and playback directly into a computer.

Based on these criteria, a Fluidyne 1214F fuel meter (Ref 9), a Lamar System fifth wheel (Ref 10), and two digital recorders were selected from the available hardware. The digital recorders were mounted in a "black box" which also contained counters for the distance and fuel measurement, a crystal clock, and a microprocessor for data management. The recording unit had 12 thumbwheels which could be used to identify the test run and select the sample-time interval. After initial testing, a sampling interval of two seconds was selected. An inverter was used to power the recording unit.

The fuel meter had a resolution of 0.001 gal over a flow range of 10 to 1200 ml/sec. This unit could be used with either gasoline or diesel fuels.

The fifth wheel had a design resolution of 50 counts per foot (164 counts per meter). However, careful tests of the distance measurements indicated that only 36 counts per foot (118 counts per meter) were recorded. Furthermore, the number of counts per foot seemed to vary with speed and the tire-surface interaction. A gas-spring of the type used on hatch back doors of automobiles was mounted on a fabricated bracket to try to eliminate wheel bounce problems, but this did not correct the problem. Thus, the distance data were not as reliable as desired.

For the constant speed tests, the vehicle speedometer was used to determine speed. Radar was used to test the accuracy of the speedometer. Data from the fifth wheel were reliable enough to establish that the test was performed at constant speed. By reviewing these distance measurements, it was possible to eliminate test runs when there was a speed change.

In the acceleration and deceleration tests, it was necessary to use the data from the fifth wheel. In this case, the best estimate between distance recordings and actual distance traveled, as determined by measuring speed and computing distance, was used to establish the relationship between speed and fuel consumption during acceleration and deceleration. Thus, these relationships have an inherent source of unquantified error. While this is an undesireable situation, it could not be avoided or altered with the resources available. Due to the lack of any better data source, the fuel consumption relationships for acceleration and deceleration seemed reasonable and were useful on this project.

A wood box was fabricated to hold the fuel meter. The meter was mounted to the front bumper of the vehicles with a bicycle rack as shown in Figure 1. Quick-connects were used to attach the fuel lines so the fuel meter could be removed when not in use. Mounting the fuel meter on the front bumper disrupts the aerodynamic design of the vehicle and hence alters fuel consumption. However, this was a constant factor in all tests, so it did not influence the effects investigated in this research.

To connect the fuel meter, the fuel lines in the vehicle had to be interrupted and substitute fuel lines with quick connects inserted. This was always done by a dealer of the vehicle being tested. In the case of

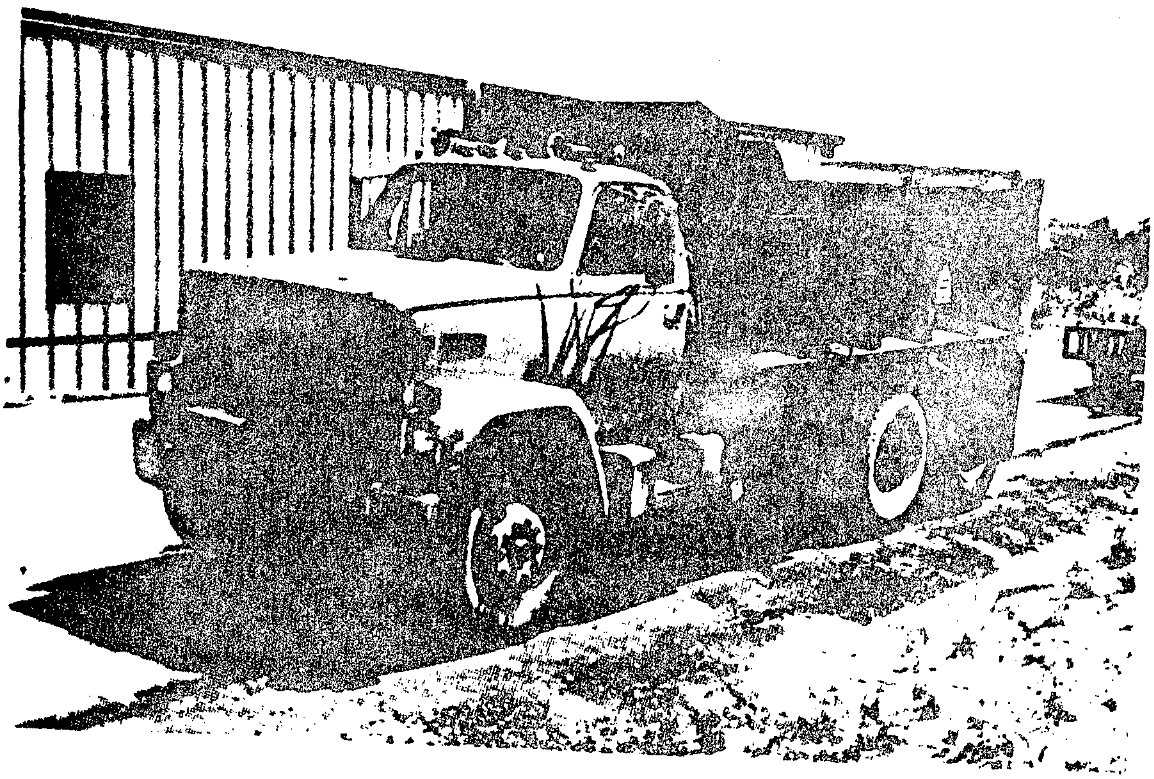


Figure 1. Picture of fuel meter mounted on vehicle.

diesel motors, the return line was routed through an oil cooler and vapor trap mounted between the fuel meter and the fuel injectors.

METHODOLOGY

The first test performed after the fuel meter was installed in a vehicle was to measure idle fuel consumption. With gasoline vehicles. an exhaust analyzer was used to measure HC and NOx. This measure showed all the vehicles were properly tuned.

The vehicles were driven a minimum of 12 miles to the test section. The equipment was installed and the vehicle was idled for a minimum of three minutes while air temperature and wind were measured. Acceleration, deceleration, and coast-down tests were then performed. Finally. the constant speed tests were performed.

Constant speed tests were performed in the sequence 10, 30, 50, 70, 20, 40, and 60 mph in each direction. The sequence was repeated three times. Occasionally, traffic would require aborting a test before the end of the section. These occurrences were noted in a field book and were subsequently screened during data processing.

Vehicles with automatic transmissions were tested in "D". The driver used his discretion for selecting the gear for manual shift vehicles. The gear used was always recorded in the log book.

Using the automatic data recording box, one technician could both drive and operate the equipment for all vehicles except the two heaviest trucks. Professional truck drivers were hired to operate these trucks while the technician operated the equipment.

RESULTS OF FUEL CONSUMPTION EXPERIMENTS

Experiments were performed to determine the effect of speed, grade, pavement type, and roughness on fuel consumption at constant speed. In addition, fuel consumption was measured during idling, acceleration, and deceleration.

Fuel Consumption While Idling

Average fuel consumption per minute was calculated from the idling tests performed before each test session on the various sections. These values were converted to gallons per hour and summarized in Table 5. The fuel consumption rates, especially for automobiles, are substantially higher than the values reported by Winfrey (Ref 2). This is attributed to emission reduction equipment on the automobiles. Modern cars have a much higher idling speed than the vehicles used for the idling consumption rates reported by Winfrey.

Fuel Consumption During Acceleration and Deceleration

Fuel consumption was measured as the vehicles accelerated from a stop to 70 mph or the top speed of the vehicle and then decelerated back to a stop. These tests were started with the third vehicle so no acceleration and deceleration data were collected for the heavy car and pickup truck.

For the analysis, the raw fuel consumption and distance counts per time interval were plotted to show the trends in the data. Since these data could be linearly transformed to obtain gallons per hour and speed, there was no need to convert the individual data points. The appropriate transformations were applied to the final equations. The conversion factor to convert distance counts per interval to miles per hour is 0.606; e.g., 10 counts per time interval is 6.06 mph. The conversion factor to convert fuel counts per interval to gallons per hour is 0.1033; e.g., 10 fuel counts per interval is 1.033 gal per hour.

A typical graph of the raw data for a medium class car during acceleration and deceleration tests are shown in Figures 2 and 3, respectively. The fuel consumption tests during acceleration start with a low number of distance counts per time interval. and as speed, i.e. number of counts per foot increase, the fuel consumption per unit time increases.

Table 5. Fuel consumption during idling.

Vehicle	Fuel Consumption (gal/hr)
Small cars	0.271
Medium cars	0.563
Large cars	0.563
Pickups	0.756
2 ax single unit	1.198
3 ax single unit	0.398
2-S2 semi	0.470
3-S2 semi	0.470 *

* assumed

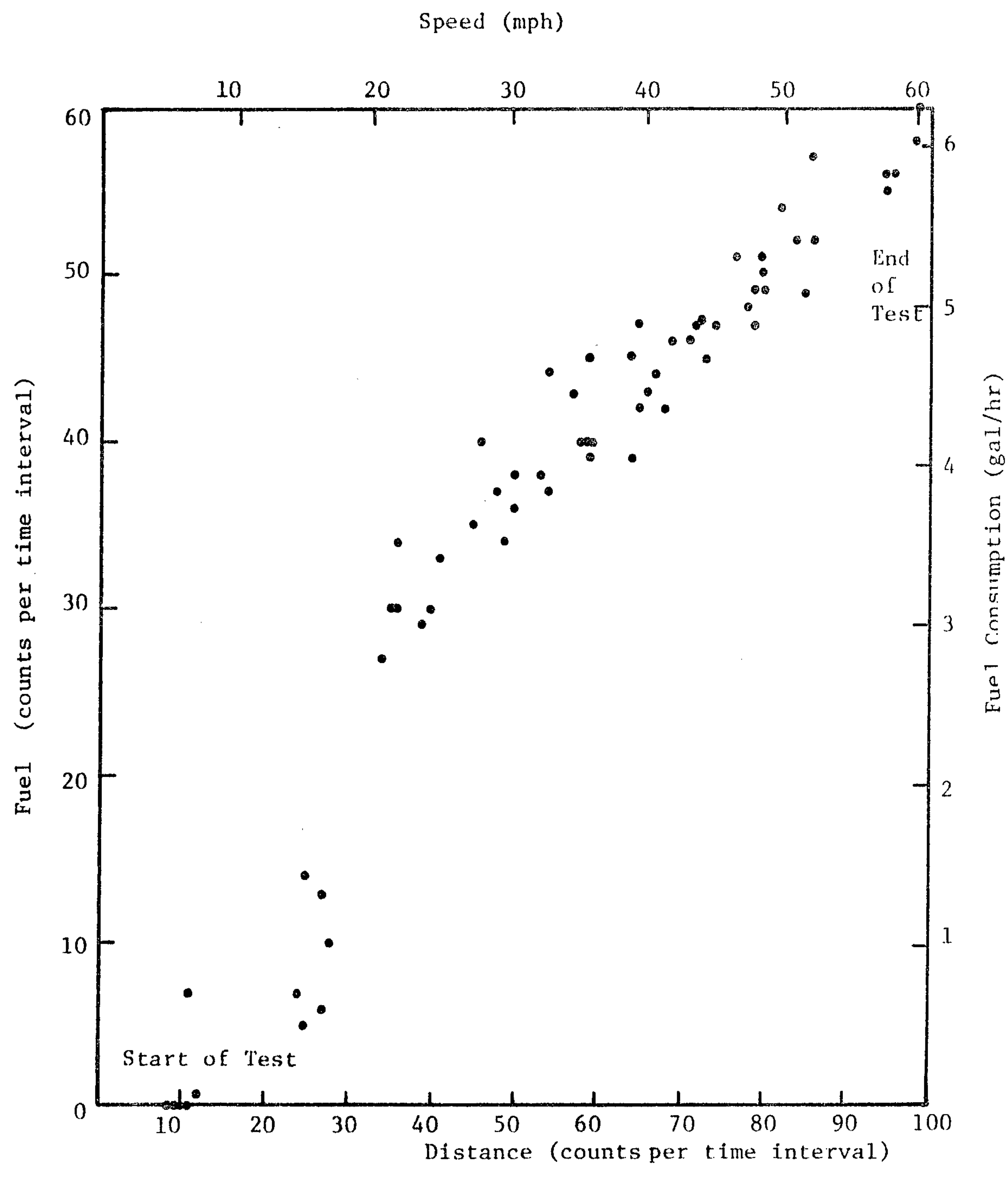


Figure 2. Fuel consumption of medium car during acceleration (raw data).

(Note: Test starts at low distance counts per time interval.)

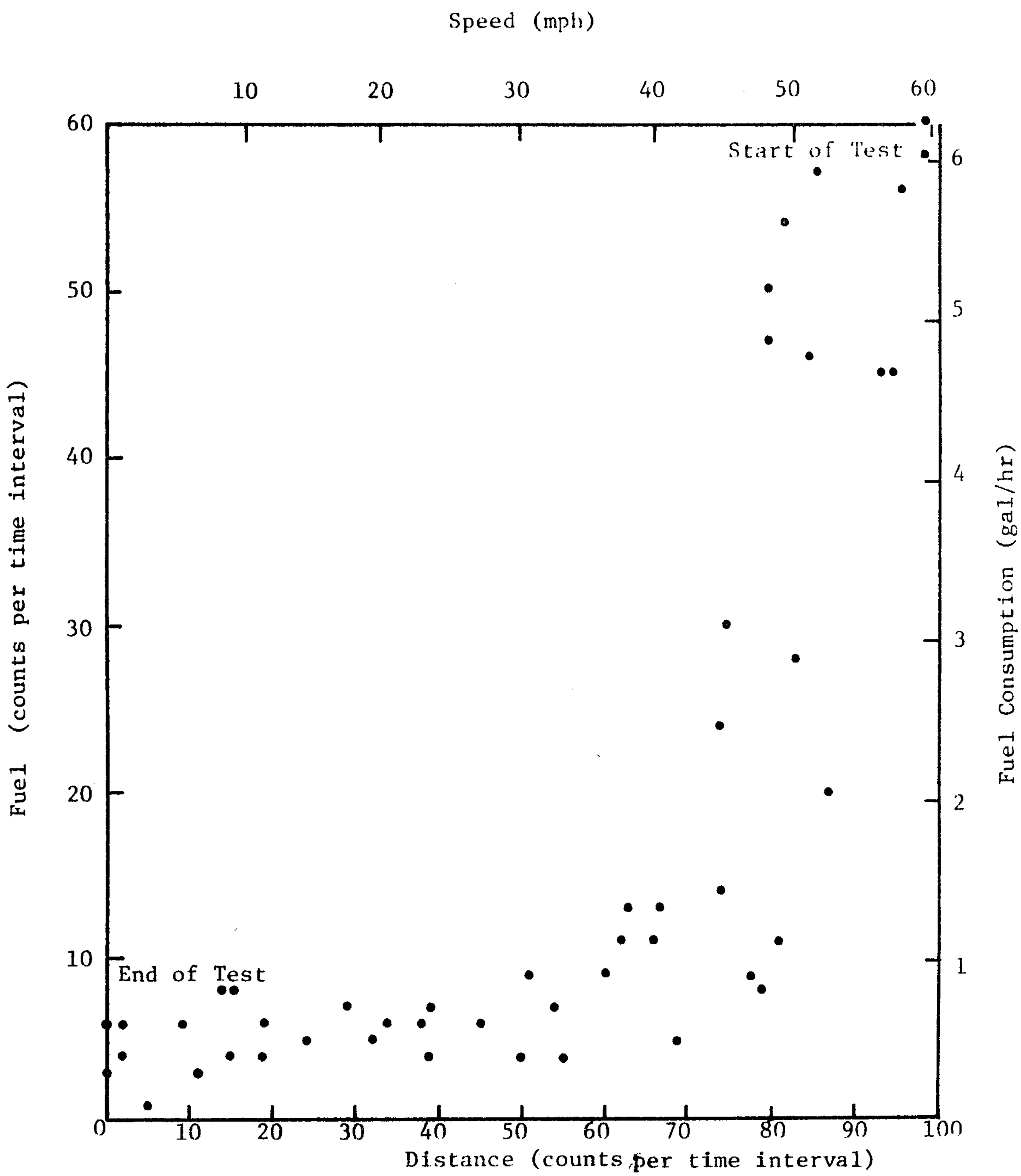


Figure 3. Fuel consumption of medium car during deceleration (raw data).
(Note: Test starts at high distance counts per time interval)

Fuel consumption during deceleration, Figure 3, start at a high speed, i.e., many distance counts per time interval and reduce to zero fuel consumption. The variance in these plots is the result of repeated tests.

Careful review of the acceleration data showed a linear relationship between fuel consumption and speed in all cases. Due to time constraints, it was decided to generate these equations by visual inspection of the data. For the automobiles and pickup truck, linear equations, passing through the origin, did a good job of modeling the data. However, this type of model was not adequate for the trucks because it underestimated the fuel consumption at low speeds and overestimated consumption at high speeds. For trucks, a maximum fuel flow rate during acceleration was identified at approximately 45 mph. In addition, a minimum fuel flow rate was identified at low speeds. These equations are summarized in Table 6. The fuel rate equations were integrated with respect to speed to obtain equations for estimating fuel consumption during acceleration.

The procedure used to generate the acceleration portion of fuel consumption for speed change cycles was to calculate the volume of fuel required for each 5 mph increase in speed and then sum the appropriate values for acceleration phases of more than 5 mph. An example of this calculation procedure is shown in Table 7. The models used for acceleration rates are described in Appendix D.

The fuel consumption tests during decleration showed that for the automobiles there was about a 6 second lag between the time the driver started deceleration and when the fuel consumption reached a steady state condition. This may be attributed to dash pots (or vaccum actuated switches) which are used on modern carburetors to keep the throttle from closing rapidly to reduce hydrocarbons. After this phase the fuel consumption reached a steady-state condition. The two phases are clearly shown in Figure 3.

A two step function was used to model the fuel data for deceleration. One step covers the transition phase of deceleration while the throttle is closing as shown in Figure 3. Even though the data on this figure

Table 6. Acceleration fuel consumption models*.

	Coefficients a	Coefficients b	Max Speed	FR Max
Small Car	0.0	0.062	-	-
Medium Car	0.0	0.102	-	-
Large Car**	0.0	0.136	-	-
Pickup**	0.0	0.136	-	-
2 Axle Single Unit	1.34	0.260	45	13.0
3 Axle Single Unit	2.07	0.263	45	13.9
2-S2 Semi	6.20	0.180	45	14.6
3-S2 Semi**	6.80	0.240	45	17.6

* FR = a + bv
If V$\leq$max speed
  FT = at + bs
If>V max speed
  FT = (FR max)t

Where:

FR = fuel rate (gal/hr)
v = speed (mph)
FT = Total fuel for acceleration (gal) obtained by integrating the equation for fuel rate.
t = time for acceleration (hr)
s = distance for acceleration (mi)

** Assumed

Table 7. Example of fuel consumption calculations for acceleration (Large automobile).

Start Speed (mph)	Time for Acceleration 5 mph, (hr.) *(t)	Distance for acceleration 5 mph (mi.) (s)	**Fuel for 5 mph Acceleration (Gal.)	Cumulat... Fuel (Gal.)
0	.00026	.00066	.00009	.00009
5	.00028	.00211	.00029	.00038
10	.00029	.00368	.00050	.00088
15	.00031	.00539	.00075	.00163
20	.00034	.00757	.00103	.00266
25	.00036	.00986	.00134	.00400
30	.00039	.01256	.00171	.00571
35	.00042	.01575	.00213	.00784
40	.00045	.01938	.00264	.01048
45	.00050	.02377	.00324	.01372
50	.00055	.02919	.00397	.01769
55	.00063	.03597	.00489	.02258
60	.00071	.04466	.00607	.02865
65	.00083	.05612	.00763	.03628

$$*t = (\ln(A-B(v_1*C)) - \ln(A-B(v_o*C)))/3600(-B)$$

$$S = (\frac{A}{B}t - \frac{A}{B^2}(1-e^{-Bt}) + \frac{v_oC}{B}(1-e^{-Bt}))/5280$$

where:

$A = 7.9$
$B = 0.055$
$C = 1.467$
v_o = initial speed (mph)
v_1 = end speed (mph)

$FT = at+bs$

where:

FT = Total Fuel (gal.)
$a = 0.0$
$b = 0.136$

indicates that the fuel consumption during the transition phase is a function of speed, such a conclusion based on these data would be incorrect. The throttle is regulated such that it closes at a constant time rate which is not dependent on speed. It should be noted that the fuel supply to a diesel motor is completely shut off, as shown on Figure 4, whenever there is a negative horsepower such as during deceleration or on negative grades.

The models generated by analyzing the plots of the fuel data during deceleration are given in Table 8. In using these models to generate the speed change fuel consumption tables, the transition phase model was used for the first six seconds for automobiles and the first three seconds for trucks. The remainder of the time during deceleration was modeled with the steady state models. The rates of deceleration were calculated with the models described in Appendix D.

Fuel Consumption at Constant Speed

Three parameters were studied in the constant speed fuel consumption experiments, the effects of (1) speed, (2) grade, and (3) pavement type and surface condition. The major emphasis in the fuel consumption was placed on the constant speed experiments. The data collected during these experiments are summarized in Appendix C.

Due to the fact that the fuel experiments with the 2A single unit and the 2-S2 semi trucks were not tested at the typical vehicle weights, it was necessary to adjust the measured fuel consumption rates in Appendix C to typical fuel consumption rates in Appendix B. In addition, it was necessary to extrapolate the data from the 2-S2 experimental vehicle to the 3-S2 truck. The best source of data for making these adjustments was developed by France (Ref 11) in a direct study of truck fuel economy on a dynomoneter.

France tested several trucks at different test weights. One of these vehicles had the same type of motor as the 2-S2 used in this research. Graphs of fuel economy versus weight at each speed were plotted from

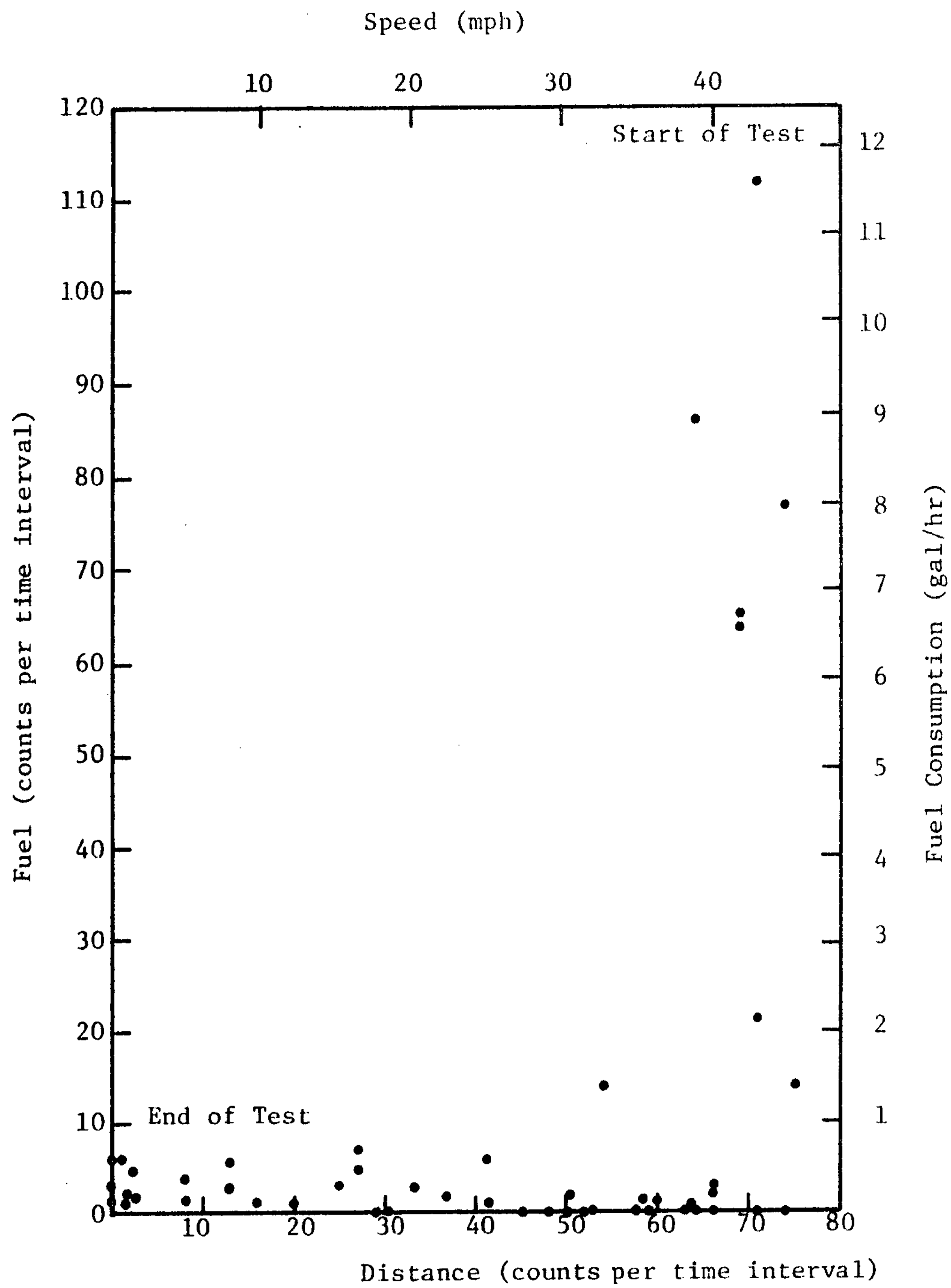


Figure 4. Fuel consumption of a diesel motor during deceleration.
(Note: Test starts at high distance counts per time interval)

Table 8. Deceleration fuel consumption model*.

	Coefficients	
	C_1	C_2
Small Car	.52	2.07
Medium Car	.72	3.62
Large Car	.93**	4.13**
Pickup	.93**	4.13**
2 Axle Single-Unit	1.45	7.23
3 Axle Single-Unit	0	7.23
2-S2 Semi	0	7.23
3-S2 Semi	0	7.23**

*$f = (C_2 t_2 + C_1 (t - t_2))/3600$

Where:

f = fuel consumption (gal)

C_2 = fuel consumption during initial deceleration

t_2 = time of initial deceleration (sec)
for automobiles and pickups
$t_2 = \min(6,t)$
for other trucks
$t_2 = \min(3,t)$

C_1 = fuel consumption during stable deceleration

t = time of deceleration

Note: if $(t - t_2) < 0$; $(t - t_2) = 0$

** Assumed.

France's data. These plots were then entered with the test weight and the desired typical weight for this research to determine fuel consumption at these weights for each speed. The ratio of the fuel consumption at the typical weight to the fuel consumption at the test weight was multiplied by the fuel consumption measured in this research to obtain the fuel consumption for the typical vehicles. The data used for these calculations are summarized in Table 9.

Effect of Speed and Grade on Fuel Consumption. Plots of fuel consumption versus grade and speed were generated from the data. These graphs were then used to generate the fuel consumption tables for each grade level as given.

Effect of Pavement Type and Condition on Fuel Consumption. Measurements were taken on portland cement concrete. asphalt concrete, surface treatment, and gravel sections to determine if surface type had an influence on fuel consumption. Three asphalt concrete sections were used to test for the influence of surface condition on fuel consumption. Student's t values were computed for each of the individual combinations of speed and section to determine if there were any significant differences on fuel consumption. In general, there were no statistically significant differences at the 95% level between the fuel consumption on the paved sections. Fuel consumption on the unpaved section was slightly higher than the fuel consumption on the paved sections, as shown in the tables in Appendix C.

COMPARISON WITH PREVIOUS RESEARCH

There have been four prior studies on the effect of roadway characteristics on fuel consumption, Claffey. Zaniewski. et al.. Hide. and Ross (Refs 1, 12, 13, and 14). The effect of grade and speed were investigated by Claffey and Zaniewski with results similar to the findings of this research. Since the findings of this research are for the current vehicle fleet and essentially agree with prior results. it is recommended that the current results be used in future economic analysis.

Table 9. Fuel Adjustment Factors and Consumption Rates for 2ASU, 2-S2, 3-S2

	SPEED (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
2ASU Truck														
Fuel Consumption (gal/1000mi)														
Estimated @ 12 kips*	435	244	141	145		111		114			152			
Estimated @ 17.1 kips*	444	256	152	156		121		127			172			
Ratio (12kips/17.1kips)	.98	.95	.93	.93	.92	.92	.90	.89	.88	.88	.88	.87	.87	.87
Measured @ 17.1 kips	217	217	180	143	132	122	126	129	140	151	159	166	172	178
Adjusted to 12 kips	212	207	167	132	122	112	113	115	123	133	139	144	150	163
Semi Trucks														
Fuel Consumption (gal/1000mi)														
Estimated @ 62.5 kips*	408	353	227	204		196		210			250			
Estimated @ 56.0 kips*	408	353	227	204		192		204			238			
Estimated @ 40.0 kips*	404	350	225	202		186		188			209			
Ratio (62.5kips/56.0kips)	1.00	1.00	1.00	1.00	1.01	1.02	1.03	1.03	1.04	1.05	1.05	1.06	1.07	1.08
Ratio (40.0kips/56.0kips)	.99	.99	.99	.99	.98	.97	.94	.92	.91	.89	.88	.87	.87	.87
Measured @ 56.0 kips	470	370	287	205	202	200	197	195	192	190	192	195	197	200
Adjusted to 62.5 kips (3-S2)	470	370	287	205	204	204	202	201	199	199	202	207	210	215
Adjusted to 40.0 kips (2-S2)	465	367	284	203	198	193	186	180	174	169	168	170	171	173

*Estimated from data collected by France (Ref. 11)

The findings of this research relative to the effect of pavement roughness are in direct conflict with the findings of Claffey and Zaniewski, where pavement roughness was found to influence fuel consumption by as much as 30% and 10%, respectively. However, the rough paved sections in each of these studies were badly broken, potholed, and patched and, thus, are not representative of realistic operating conditions in the United States. Use of this data requires interpolation beween the extreme conditions of pavement roughness. In Kenya (Ref 13), no effect of pavement roughness on fuel consumption was found, reportedly because the range of roughness was too small.

Ross (Ref 14) studied the fuel consumption of three automobiles at 55 mph on five bituminous test sections with a range in roughness of 0.9 to 4.4 on the Serviceability Index, SI, scale. Ross reported that for a practical range of roughness, 1.5 to 4.5 SI, fuel consumption is 1.5% higher on the rough section. In developing this conclusion, Ross used very strict criteria for eliminating outlaying data and hence the variance of the data used in the analysis was much smaller than would be anticipated in the real world. Under his criteria, Ross eliminated 28% of the observations from the analysis. During analysis, Ross found that the measured fuel consumption on a section with an SI of 2.1 was less than the fuel consumption on sections with SIs of 4.4 and 3.6 for all three vehicles. Because of these apparent "anomalous" measures, these data were removed from the final analysis. Considering the fact that Ross eliminated so much data from the final analysis and still only found a very minor influence of roughness on fuel consumption, we believe that analysis of the complete data base would support our findings that roughness does not have a measurable effect on real world fuel economy.

CHAPTER 3 - NON-FUEL VEHICLE OPERATING COST

The non-fuel components of vehicle operating cost are addressed in this chapter, including the costs of oil consumption, tire wear, maintenance and repair of vehicles. and the depreciation of the value of the vehicle attributable to operation on the road. For each component, a procedure was developed to estimate the respective level of current cost. The current cost estimates are used to update the running cost tables developed by Winfrey in 1969 (Ref 2). Where possible, the updated estimates have been adjusted to reflect changes in relative prices and technological advancements.

First, the sources of information used to provide estimates for current running cost of passenger vehicles and trucks are explained. Next, the procedures developed to derive the updated cost estimates for each component are presented.

Under the guidelines of the statement of work, a minimum amount of data collection was desired. In addition, the major emphasis of primary data collection was limited to truck operations. For passenger vehicles, secondary information was utilized, primarily the U.S.D.O.T., Cost of Owning and Operating Automobiles and Vans, 1979 (Ref. 8). Additional data sources used in preparing specific estimates are discussed in the appropriate component cost section.

To determine the current level of cost for trucks operating on the road. a survey of trucking fleet managers was conducted. In order to minimize the search for trucking firms with good records and to provide a representative sample of operating areas, the firms contacted were members of the U.S. Department of Energy's Voluntary Fuel Economy Program. A telephone request was used by members of the research team to contact fleet managers and request as much running cost information as they had readily available and were willing to release. Twenty percent of the 245 members of the program were contacted, and 30% of those responded with detailed summaries of their vehicle running cost. The information received summarized records for 12,489 trucks in fleets ranging in siz from 100 to 5191 vehicles operating across the contiguous United States The data from the survey respondents was sufficient to provide update cost estimates for all cost components except use-related depreciation.

To determine the appropriate level of use-related depreciation for the various truck classes required construction of survivor curves for the truck population. To derive survivor curves required an extensive data base containing vehicle ages and mileages. The most complete data base available was used for this effort, the Truck Inventory and Use Survey from the U.S. Department of Commerce. Bureau of Census, 1977 Census of Transportation (Ref. 15). A computer tape obtained from the Census Bureau allowed the data to be analyzed using the Statistical Package for Social Sciences. Vehicle registration data to correspond to the census information was obtained from various issues of the Automotive News, Market Data Book.

The establishment of current estimates for vehicle running costs was made assuming operation on high type level pavement in good condition. Additional analysis was conducted to adjust the baseline estimates for operating conditions where road surface roughness were different from base conditions. The methodology used to adjust for roughness of the roadway was developed by research in Brazil and is summarized in various publications from that work (Refs. 16, 17, 18, and 19). In this formulation, roughness is measured in terms of a correlation measure of output from a Mays Meter and a GM Profilometer expressed as QI counts per km. To make the comparisons necessary to utilize information from the Brazil study, the roadway surface assumed for the base condition must be quantified. The road roughness measure for the conditions represented by the base consumption values is assumed to be a serviceability index (SI) value of 3.5. To make our analysis compatible with the experimental results from Brazil, the SI value needed to be converted to the quarter car index (QI), which is based on the output of the quarter car simulator used by the Surface Dynamics Profilometer. The conversion equation was given as:

$$QI = 175e^{(-.469(SI))} \quad \ldots\ldots\ldots\ldots \quad (1)$$

which yields a QI of 33.9 for the road surface associated with the base cost estimates.

In general, allocation of the non-fuel components of vehicle operating costs must be determined by judgement and theoretical considerations. When judgement was the sole basis for cost allocation, we invariably used the distributions originally developed by Winfrey. When theoretical considerations could be used to augment purely subjective judgements, force and horsepower were calculated using the models described in Appendix E. The acceleration and deceleration models described in Appendix D were used in calculating costs for speed change cycles.

For the remainder of this chapter, each non-fuel component of vehicle operating cost is addressed. For each. the procedures used to determine current cost estimates are presented.

ENGINE OIL

At normal operating speeds engine oil consumption generates the least cost of the non-fuel cost components. To determine estimates of current cost for oil consumption and update the running cost tables prepared by Winfrey, the base consumption rates used to develop those tables had to be determined.

For all passenger cars and pickup trucks the initial oil consumption values for various speeds were developed from the cost tables presented by Winfrey. The data in the cost tables were converted to consumption per 1000 miles by dividing the values by the unit cost reported by Winfrey. This procedure supplied the initial consumption estimates which were subsequently modified. First. Winfrey's estimates were adjusted to reflect current conditions in vehicle technology which have decreased the consumption of oil. Such adjustment is suggested by AASHTO (Ref. 20) where the authors recommend that a new composite oil consumption curve is needed because of significant changes in technology that have reduced oil consumption. For single unit truck, the Red Book suggests a 10 percent uniform reduction in oil consumption rates be applied to consumption rates reported in NCHRP Report 133 (Ref. 21) because of improved performance characteristics such as better sealing, piston rings, etc.

For this study it was assumed that improved technology is reflected in the increased mileage interval for recommended oil changes between the time of Winfrey's study and today. Accordingly, the consumption rates were uniformly decreased to reflect the 46 percent decrease in oil consumption reflected by the increase in mileage between oil changes from every 4,000 miles in 1962 to every 7,500 miles currently as reported by the DOT Office of Highway Planning, Highway Statistics Division (Ref. 8). Although the estimate provided by Winfrey includes a component for oil consumed in topping off between oil changes, a lack of appropriate information prevented construction of a separate adjustment procedure for that component. Oil consumption was assumed to be the same for all automobile classes.

Similar estimates of oil consumption are also required for a range of truck configurations used predominantly in commercial enterprises. For these vehicles a different procedure was used to represent current technology improvements over the conditions existing in 1969. A survey of line haul commercial trucking firms was made, and one product of this survey was information concerning oil consumption. From the survey respondents it was determined that average oil consumption per 1,000 miles was 5 quarts. It is known that the firms supplying information are line haul carriers of inter-city cargo operating primarily on interstate highways. Assuming an average speed of 50 mph. this consumption rate may be compared with Winfrey's table value to determine the change that has occurred since the 1969 study period. From the Winfrey table for 3-S2 commercial diesel tractor, the consumption per 1,000 miles is given as 6.6 quarts. Based on this value and the survey estimate, the consumption of oil per 1,000 miles has decreased by 24% since the 1969 based tables were constructed. Accordingly, the values for oil consumption provided in Winfrey's original tables may be converted by a factor of .76 to reflect today's improved technology in piston ring sealing, etc.

To complete our oil consumption estimates for the range of vehicles included in this study requires an adjustment procedure for single-unit trucks and 2-S2 tractor-semitrailer combination. A method of adjusting for the effects of improved technology on engine oil consumption for these vehicle classes was required. It was assumed that for this study, the technological adjustment factor applied to 3-S2 tractor-semitrailers based on survey data would be applicable for the additional truck classes.

The oil consumption rates on level tangent sections in good condition are presented in Table 10 for each vehicle class. Winfrey's procedure was used to estimate oil consumption during speed change cycles. The data in Table 10 were converted to quarts of oil consumed per hour for each speed. This rate was multiplied by the time required for the speed change cycle minus the time required to go the same distance at the initial speed.

Oil consumption on grades were adjusted by the ratio of the horsepower requirement on the grade to the horsepower required for the same speed on a level tangent section. In the case of negative grades, the absolute value of the horsepower to descend the grade was used. In the cases on negative grades where the absolute value of the horsepower ratio was less than 1, the oil consumption for zero grade was used in the consumption tables. No correction was made for oil consumption on horizontal curves.

The effect of pavement condition on oil consumption was studied in Brazil. Although this information is not directly applicable to conditions in the United States, it does represent the best available data base. The extent of variation in oil consumption by surface condition is indicated in Figure 5 for automobiles and trucks. The factors for automobiles should be used in estimating the oil consumption of pickups since the design of pickups is more similar to cars than to heavy duty commercial vehicles. Caution should be used in applying the information in Figure 5. In Brazil, an extreme range of pavement roughness was studied, including unpaved roads. The fuel consumption relationships discussed in the previous chapter indicate that interpolation between the extreme conditions may be incorrect.

Table 10. Oil consumption rates on level high type,
pavement in good condition.
(Quarts per 1,000 miles)

Speed (MPH)	Passenger Car	Pickup Trucks	Single-Unit Trucks		Combination Trucks	
			2 ax	3 ax	2-S2	3-S2
5	3.8	3.5	6.5	9.6	9.6	19.6
10	2.4	2.2	4.1	6.2	6.2	12.7
15	1.8	1.7	3.4	4.9	4.9	10.1
20	1.6	1.5	3.0	4.4	4.4	9.0
25	1.5	1.4	2.8	4.1	4.1	8.3
30	1.4	1.3	2.7	3.8	3.8	7.7
35	1.4	1.3	2.5	3.6	3.6	7.2
40	1.4	1.3	2.3	3.4	3.4	6.5
45	1.4	1.2	2.1	3.1	3.1	5.7
50	1.3	1.1	2.0	3.0	3.0	5.
55	1.2	1.0	2.1	3.2	3.2	5.
60	1.3	.9	2.4	3.6	3.6	5.8
65	1.4	1.0	2.7	4.0	4.0	6.4
70	1.7	1.2	3.0	4.4	4.4	7.2

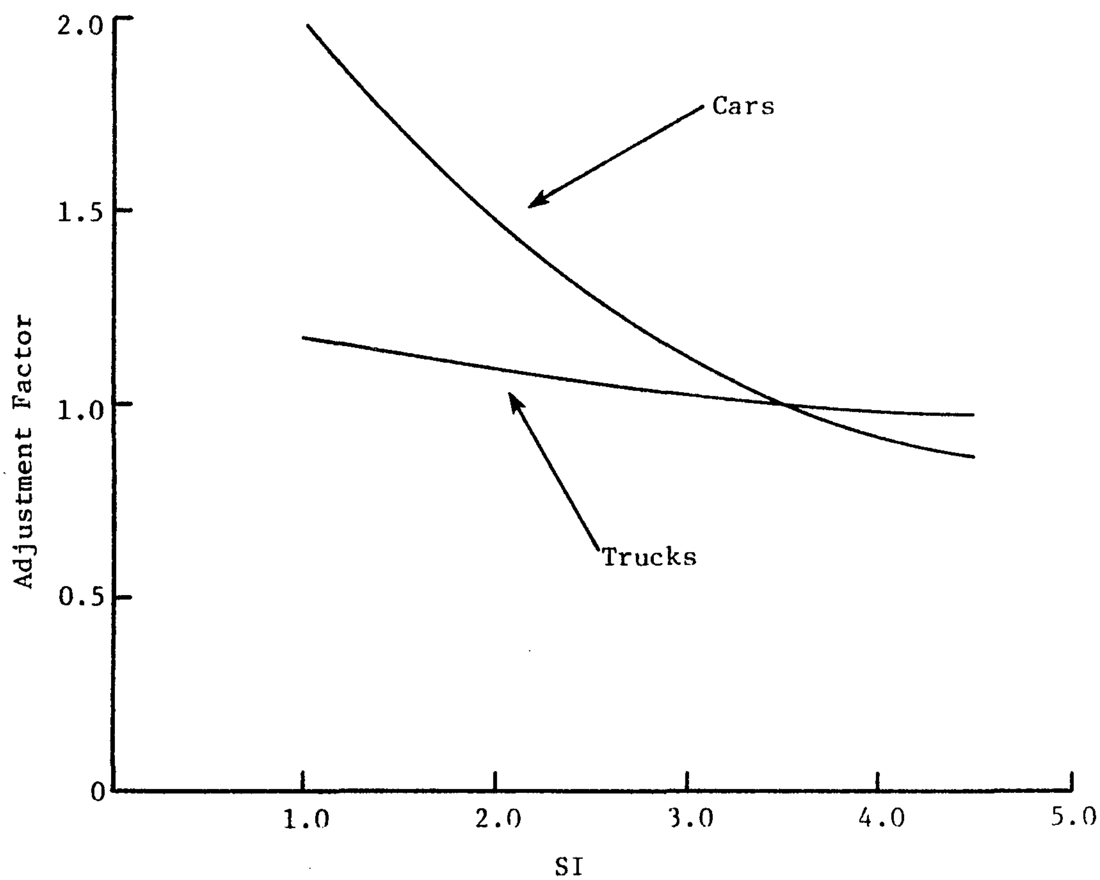


Figure 5. Influence of pavement condition on oil consumption (Ref. 17).

TIRES

Cost associated with tire wear has been effected by a change in tire design and the improved technology in tire manufacturing since Winfrey compiled his running cost tables. Radial design and belted construction have increased the life mileage of tires, but increased prices have offset these gains to some extent. Two procedures were used for estimating tire wear, (1) updating Winfrey's tables and (2) the slip-energy model developed by the Forest Service.

The Slip-Energy Model

In 1973, the Forest Service funded a project to develop tire wear predictions from meaningful tire-road interactions for use in an operating cost model for the National Forest Service road system (Refs. 22 and 23). After study of relevant factors, the approach arrived at was to relate tire wear to the level of tractive force exerted by a vehicle and the tire slip which occurs at the tire-road interface. The best tire wear model was produced by relating the volume of tread rubber worn to the amount of slip energy expended at the pavement-tire interface. That is:

$$V_{WR} = E_{SLIP}/S_{WE}$$

where:

V_{WR} = volume of worn tread rubber, in^3
E_{SLIP} = slip energy, lb-mi
S_{WE} = slip energy-volume wear coefficient, $(lb\text{-}mi)/in^3$

The slip energy, E_{SLIP}, in the above expression is simply the product of the total distance slipped by the tires and the level of horizontal force:

$$E_{SLIP} = D_S F_H$$

where:

D_S = distance slipped, mi.

F_H = total force in the horizontal plane at the pavement-tire interface, lb. (Appendix E)

To predict the distance slipped by a tire over a specific driving course, a slip ratio, S, is defined as a function of the tractive force applied to the tires:

$$S = M/K$$

where:

S = slip ratio = distance slipped/distance traveled

M = tractive force ratio, also called Mu

M = F_H/F_V, where F_V is the vertical load, lb

K = Mu-slip coefficient, $\frac{lb/lb}{ft/ft}$

Rewriting the above equations and making substitutions, the volume of rubber worn may be expressed as:

$$V_{WR} = (D_T F_H^2)/(F_V K S_{WE})$$

where:

D_T = total distance traveled, mi.

In this model two coefficients must be experimentally quantified to be representative of specific tire type and pavement surface type. The Mu-slip coefficient is derived by measuring the horizontal and vertical forces on a test tire, the distance traveled by the tire and the distance traveled by the vehicle. The slip energy-volume wear coefficient is found by plotting the measured volume of tread rubber worn against the slip energy expended. Thus, to properly use this model requires the quantification of data from tires, surfaces, and vehicles for which predicitions are to be made. However, once quantified, this model allows particular freedom in the estimation of the effects of highway geometrics and vehicle operating modes on tire wear through the prediction of the force levels induced by geometrics and operating modes.

An example Mu-slip curve for a standard size passenger car steel belted radial tire is shown in Figure 6. Slip is expressed in units of feet/mile. The pavement surface was in Nevada and consisted of bituminous concrete containing some crushed and some sifted aggregate from natural bank deposits. This material reportedly tested 20-25% in the ASTM Standard Abrasion Test (C535). Texture mesurements were not reported. The 1977 Oldsmobile Cutlass used in this test program were operated under typical driving conditions and had a Mu level varying between .05 and .08.

A tire volume loss-slip energy curve from Reference 23 is shown in Figure 7. This curve shows the results for a 10.00-20 nylon 12 ply bias tire on a 5-ton dump truck on an asphaltic concrete surface. This truck had powered front wheels with adjustable toe-in. The points labeled F_S represent measurements taken with the front wheels angled inwards by equal amounts. The points labeled F_L were obtained with the front wheels aligned straight ahead. The points labeled ablative wear represent rubber loss due to cutting by sharp projections as opposed to surface fatigue of the rubber. The scatter in the data was attributed to the rolling resistance of the unpowered rear wheels of the test vehicle, which had opposite effects in the longitudinal and side force tests.

Mu-slip and slip energy-volume wear coefficients from all available sources are summarized in Table 11 along with the vehicle, surface, and the tire types used in the experiments. These results are for bituminous road surfaces. No corresponding data could be located for portland cement concrete pavement surfaces.

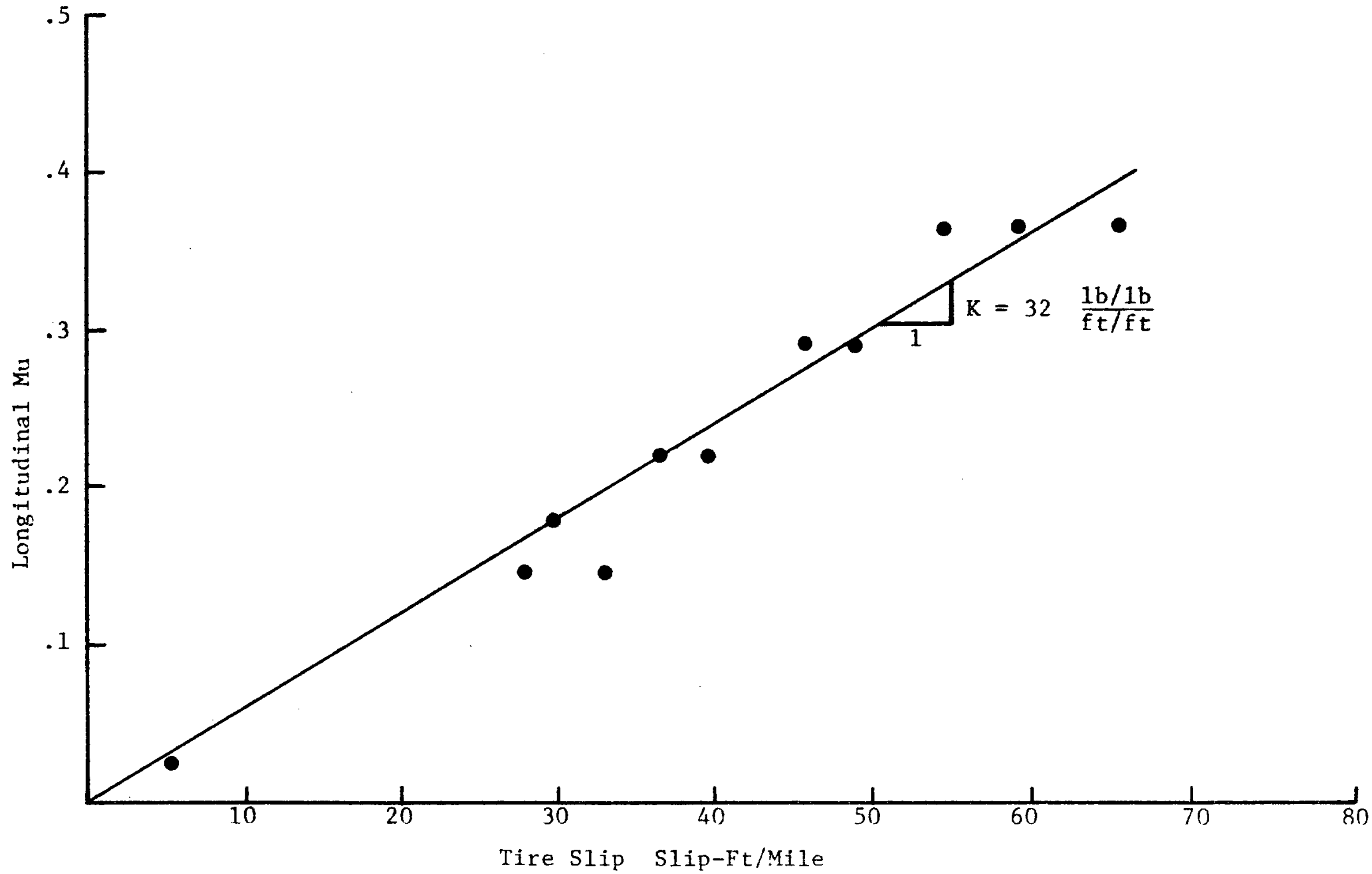


Figure 6. Mu-slip curve for radial tire on bituminous concrete in Nevada (Ref. 23).

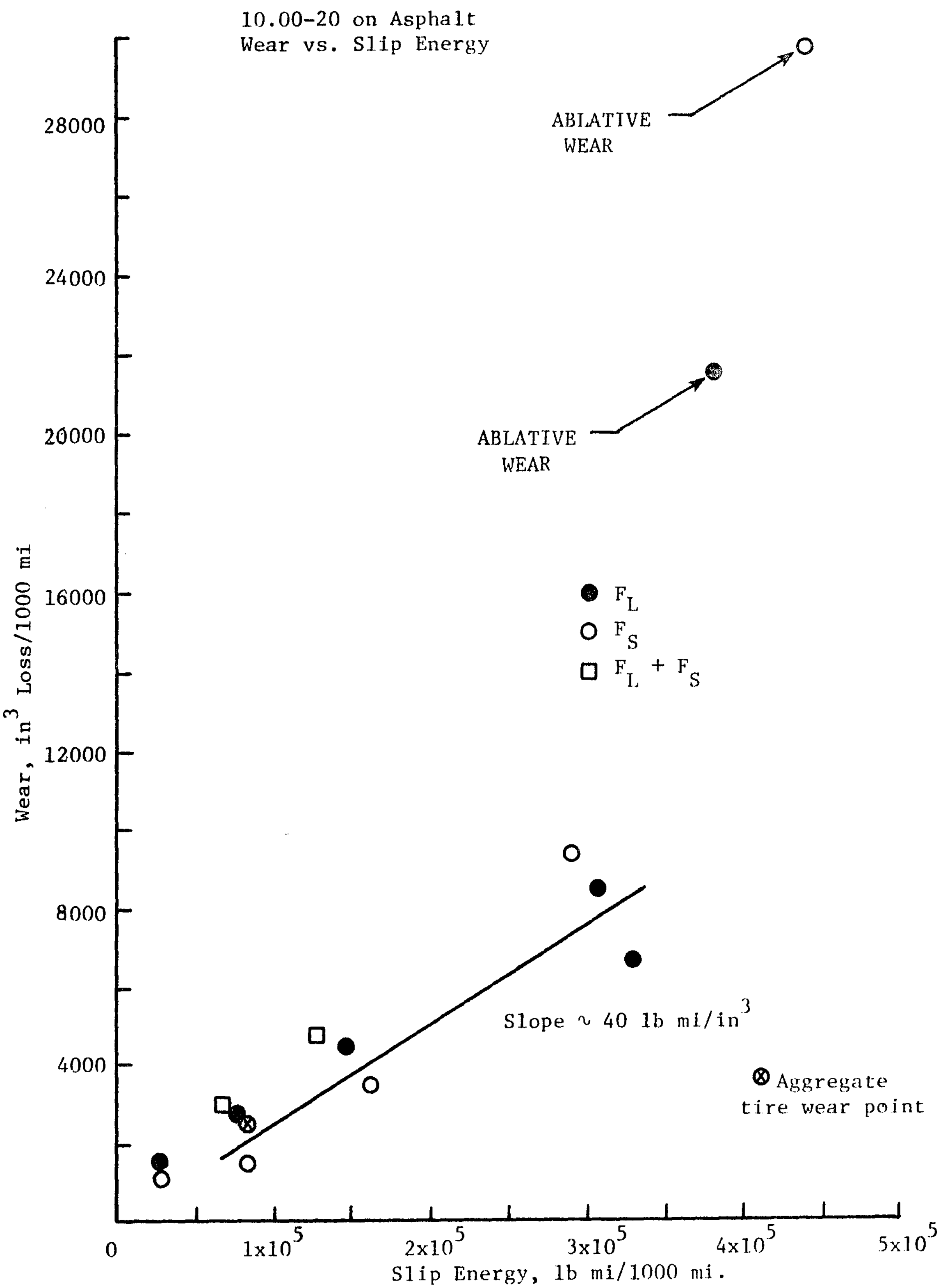


Figure 7. Volume loss - slip energy curve for a 10.00-20 12 ply nylon bias tire on asphaltic concrete (Ref. 22).

Table 11. Summary of available slip-energy tire wear model coefficients.

Test Vehicle	Surface Type Aggregate	Tire Type	Mu-Slip Coefficient, k $\left\{\frac{lb/lb}{ft/ft}\right\}$	Slip-Energy Volume Wear Coefficient S_{we} $\left\{\frac{lb\text{-}mi}{in^3}\right\}$
1976 Jeep Wagoneer Modified 4-Wheel Drive (Ref. 24)	Bituminous Concrete; Crushed and Sifted Aggregate Natural Bank Deposit Abrasion 20-25%** Nevada	1*	32	83
		2	26	104
		3	15	95
		4	18	99
		5	22	80
		6	17	83
	Bituminous Concrete; Gravel from Natural Bank Deposits; Abrasion 35-37% Connecticut	1	41	196
		2	38	218
		3	20	298
		4	17	291
		5	25	222
		6	24	217
	Bituminous Concrete; Crushed Limestone Aggregate Abrasion 26-29% Texas	1	34	174
		2	43	131
		3	16	199
		4	20	206
		5	20	215
		6	24	162
5 Ton Dump Truck 6 x 6 M-51 (Ref. 22)	Bituminous Concrete; Crushed Basalt, 1" Nevada	10.00-20 12 ply, Bias Nylon-Goodyear Super High Mil.	10	40

Table 11. Summary of available slip-energy tire wear model coefficients (continued).

Test Vehicle	Surface Type Aggregate	Tire Type	Mu-Slip Coefficient, $k \left\{\frac{lb/lb}{ft/ft}\right\}$	Slip-Energy Volume Wear Coefficient $S_{we} \left\{\frac{lb\text{-}mi}{in^3}\right\}$
Light Truck GVW 8,000 lb (Ref. 22)	Bituminous Concrete Crushed Basalt, 1" Nevada	7.50-16 10 ply, Bias Goodyear Super High Mil.	11	37
1970 Jeep Wagoneer (Ref. 22)	Bituminous Concrete; Crushed Basalt, 1" Nevada	G78-14; B Polyester/ Fiberglass Bias Belted	22	46
1977 Jeep Wagoneer Modified 4 Wheel Drive (Ref. 25)	Open Graded Asphalt Concrete Overlay California	10R15LT Recap Logging Truck Tires Radial	13	31
	Dense Graded Asphalt Concrete Road-Mixed California		11	101

* Tire Types - All mounted on 6.0 x 15.0 Rims - Passenger Car Tires

1. Goodyear Steel Belted Radial - 76.5 in^3 (total volume of available tread rubber)
2. Firestone Steel Radial 500 - 78.3 in^3
3. Uniroyal Tiger Paw - Polyester Bias - 82.0 in^3
4. Goodyear Power Cushion Polyester Bias 119.5 in^3
5. B.F. Goodrich Long Miler - Polyester/Fiberglass Bias Belted - 79.8 in^3
6. Cooper Lifeliner Premium 78 - Polyester/Fiberglass Belted - 101.5 in^3

** ASTM Standard Abrasion Test C535

The data from Reference 24 allows comparison of the different types of passenger car tires over a range of pavement surfaces. The Mu-slip coefficients for the radial tires were consistently greater indicating better traction. Hence, radial tires must slip less than than conventional tires to develop an equivalent horizontal force. The Mu-slip coefficients for the polyester/fiberglass bias belted tires were slightly greater than the polyester bias ply tires. In general, the slip energy volume coefficients for the radial tires tended to be less than the bias tires on the same surfaces. This would indicate that it takes less slip energy to wear a cubic inch of rubber off a radial tire as opposed to a bias ply tire. As illustrated in Figure 8, as S_{WE} decreases for a particular tire construction, the tread life decreases and wear rate increases. However, comparison across tire constructions shows that even though S_{WE} tended to be less for radial tires, the tread life was greater and the wear rate less than the bias ply tires. This is most likely due to the higher Mu-slip coefficient. Since the tire slips less, its slip energy per unit distance is less.

The coefficients determined from the other literature sources were in, general, less than the corresponding coefficients from Reference 23. These coefficients are for truck tires, which typically operate under greater load levels and higher inflation pressures. except the G78-14 nylon bias ply tires. The Mu-slip coefficients for the 10.00-20 and 7.50-16 nylon bias ply tires, and the 10RI5LT radial tires are all comparatively low. This may be due to the fact that they were determined at greater Mu levels than the passenger car tires in Reference 24. The G78-14 bias ply tire, which was tested under loads similar to those tires from Reference 24, had a Mu-slip coefficient within the same range. However, the slip energy-volume wear coefficient was much lower.

Jones and Della-Moretta (Ref. 25) performed a series of tests comparing the tire wear on dense and open graded asphalt concrete. Logging companies were complaining of excessive tire wear on the open graded road. The investigators found the Mu-slip coefficients on the two roads were similar, but the slip-energy-tire wear coefficient on the open

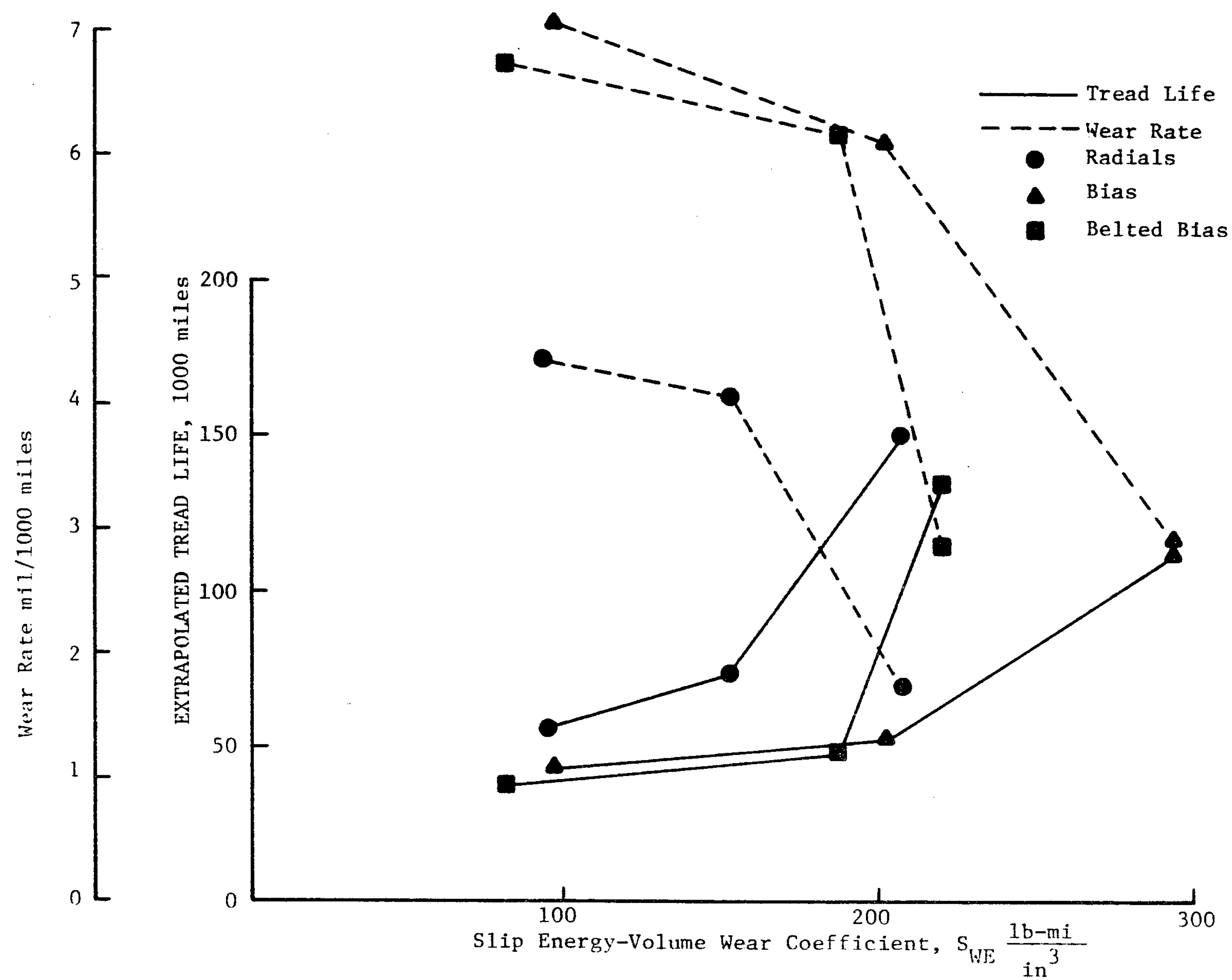


Figure 8. Influence of slip energy-volume coefficient on extrapolated tread life and wear ra
(Ref. 23).

graded road was approximately three times larger than on the dense graded road.

It is difficult to choose coefficients for the slip energy tire wear model which are typical of a particular tire construction on a particular surface. All of the available data was collected on bituminous concrete road surfaces. Thus, little is known concerning the magnitude of these coefficients on a portland cement concrete pavement surface. Also, the wide variation in results on the bituminous concrete surfaces complicates selection of tyical values. Therefore, the approach taken in the selection of "typical" values was exercise the models using coefficients within the range of values shown in Table 11. Final selection was based on comparison of results against those obtained by adjusting Winfrey's original values.

<u>Adjustment to Winfrey's Tire Costs</u>

The first step in adjusting Winfrey's tire costs was to determine the impact of decreased tire tread wear resulting from the use of radial design and improved material composition. Winfrey used a cost per mil of usable tire tread as the basis for allocating expense. The cost per mil of $.08712 for passenger car tires can be used to estimate the assumed standard tread wear rate. Examining the tire expense estimate provided by Winfrey for the EPA composite speed of 26 mph, provides a tread wear rate as follows:

$$(\$1.11/1000 \text{ miles})/(\$.08712/\text{mil}) = 12.74 \text{ mils}/1000 \text{ miles}$$

The estimated tread wear rate was compared to current estimates provided by Brenner et al., for radial passenger car tires of 7.00 mil/1000 miles (Ref. 26). An adjustment factor was determined by dividing the old estimate by the current one:

$$(12.74 \text{ mils}/1000 \text{ miles})/(7.00 \text{ mils}/1000 \text{ miles}) = 1.82$$

Accordingly, Winfrey's estimates must be divided by 1.82 to adjust for increased expected tire life.

Although technology has increased the expected life of a tire which would greatly reduce tire expense, the increase in cost of tires over the period since Winfrey's original estimates more than offsets the gain. Currently, passenger cars have radial tires for original equipment. Cost per tire data were collected for a wide range of radial tires commonly used for large passenger cars, the average price was $75 per tire with a standard deviation of $25. The usable tread depth reported by Brenner et al. for radial tires of 278 mils allows a cost per mil estimate of $.270 (Ref. 26). Comparing this current price with the value of $.08712/mil used by Winfrey suggest an adjustment to tire expense of 3.10 times the original estimate to reflect the increase in passenger car tire cost. The estimates provided by Winfrey were adjusted by an overall factor of 1.70 to obtain the current cost per 1000 miles.

The same procedure used for determining the baseline estimates for passenger cars may be followed for pickup trucks. The tread wear rate of 7.00 mils/1000 miles is assumed for radial designed tires while the wear rate assumed by Winfrey was determined to be:

$$(\$1.33/1000 \text{ miles})/(\$.09846/\text{mil}) = 13.51 \text{ mils}/1000 \text{ miles}$$

The adjustment factor for decreasing tread wear rate effected by the use of radial design is:

$$(13.51 \text{ mils}/1000 \text{ miles})/(7.00 \text{ mils}/1000 \text{ miles}) = 1.93$$

The average cost for pickup tires was found to be $75. Using this average price and the usable tread depth of 278 mils yields a $.270 cost per mil. Comparing the updated cost per mil to Winfrey's value provides the adjustment factor for price increase of:

$$(\$.270/\text{mil})/(\$.09846/\text{mil}) = 2.74$$

For 3-S2 tractor semi-trailer commercial trucks, Winfrey used a cost of $.15658 per mil of usable tire tread. Winfrey includes the fact that a tire in regular commercial use will be recapped more than once such that the $.15658 per mil of usable tire tread included the cost of the added tread from recaps. Winfrey assumed that on average a tire is recapped 2.5 times before being removed from service. Winfrey reported a usable tread associated with one tire to be 1405 mils. This estimate was based on 75 percent of the 562 mils of tread being usable for new tires and 70 percent for retreads. The per mil tire expense was based on the total usable tread and a purchase price of $120.00 for new tires, $40.00 for each retread, for a cost per tire of $220.00.

Current information on tire expense was obtained in the survey of commercial trucking fleet operators. The average price for a new 11R24.5 14 ply or G rated radial was $278.00 and $75.00 for a recap. Measurement of tread depths indicated an average total tread of 531 mils. Applying the percentage of tread that is usable from new and recapped tires as reported by Winfrey and 2.5 retreads per tire the current usable tread estimate is 1327 mils. The 1327 mils and a life time cost per tire of $465.50 combines to produce an estimated current cost of $.3508 per mil of usable tread. Comparing the current estimate to that presented by Winfrey indicated that tire expense due to increased purchase price for new and recapped tires has increased 2.24 times. Increased tire cost raise the overall tire expense from 1962; however, improved technology and design have improved the rate of wear thus leading to a decline in tire expense as more mileage is obtained. To determine an adjustment for increased mileage the change in wear rates must be estimated.

Winfrey expressed tire expense in his estimate as dollars per 1000 miles. By using the reported cost per mil and total usable tread depth an estimate of mileage per tire may be made. At an operating speed of 50 mph Winfrey reported tire cost per 50 kip 3-S2 tractor semi-trailers per 1000 miles as $20.83. Dividing the reported expense by the cost per mil of usable tread, $.15658, produced an estimated wear rate of 133 mils per

1000 miles for the vehicle, with 18 tires. for a 7.4 mil per 1000 mile wear rate per tire. Dividing the wear rate estimate into the usable tread depth for a new tire project a life mileage of 56,960 miles per tire for new tires. The improved technology and radial design in tires since Winfrey's estimates were made has greatly increased tire average life mileages. Information supplied by commercial fleet managers indicated the average mileage per tire to be 109,000 miles. Comparing the current estimate to that supplied by Winfrey implies a 1.9 increase in expected tire mileage.

Thus, to adjust for increased cost the estimates are multiplied by 2.24. To adjust for increased tire mileage resulting from radial design and improved technology the estimates were divided by 1.92. The adjustment factors developed above were assumed to be applicable to the 2-S2 category which use the same tire size and types. For 12-kip single-unit trucks a separate adjustment for cost was required due to the difference in tire size. The change for technology and design was assumed to be applicable to this truck tire class since life mileage data on 8.25 x 20 10 ply tires was not available. The adjustment suggested for difference in cost is based on an estimated average tread depth of 515 mils, and an average price of $143.91. Assuming the percentage of usable tread of 75 percent and one recap at $50 with 70 percent usable tread the updated cost per mil of usable tread is $.2596. Comparing this value to the $.13235 per mil used by Winfrey indicated a cost adjustment factor of 1.96.

<u>Comparison of Adjusted Winfrey and Slip-Energy Tire Costs</u>

Figures 9 and 10 show the comparison between the adjusted Winfrey tire costs and the costs computed by the slip-energy model. In general, the costs are similar, however, the adjusted Winfrey values are greater than the cost computed with the slip energy model. This may be attributed to the uncertainties associated with selecting the baseline speed for adjusting Winfrey's costs.

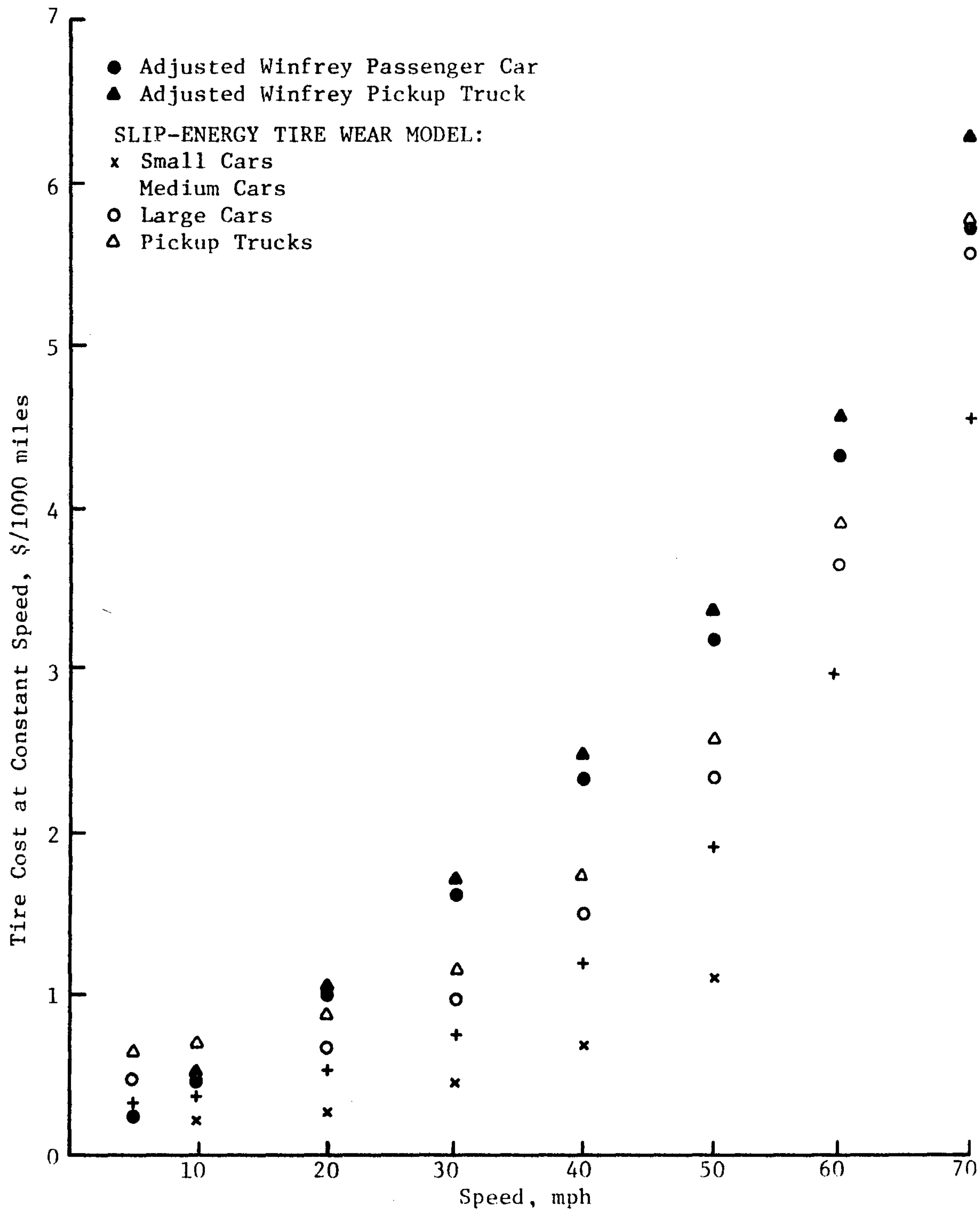


Figure 9. Comparison of constant speed tire costs predicted by the slip-energy tire wear model to the adjusted Winfrey values.

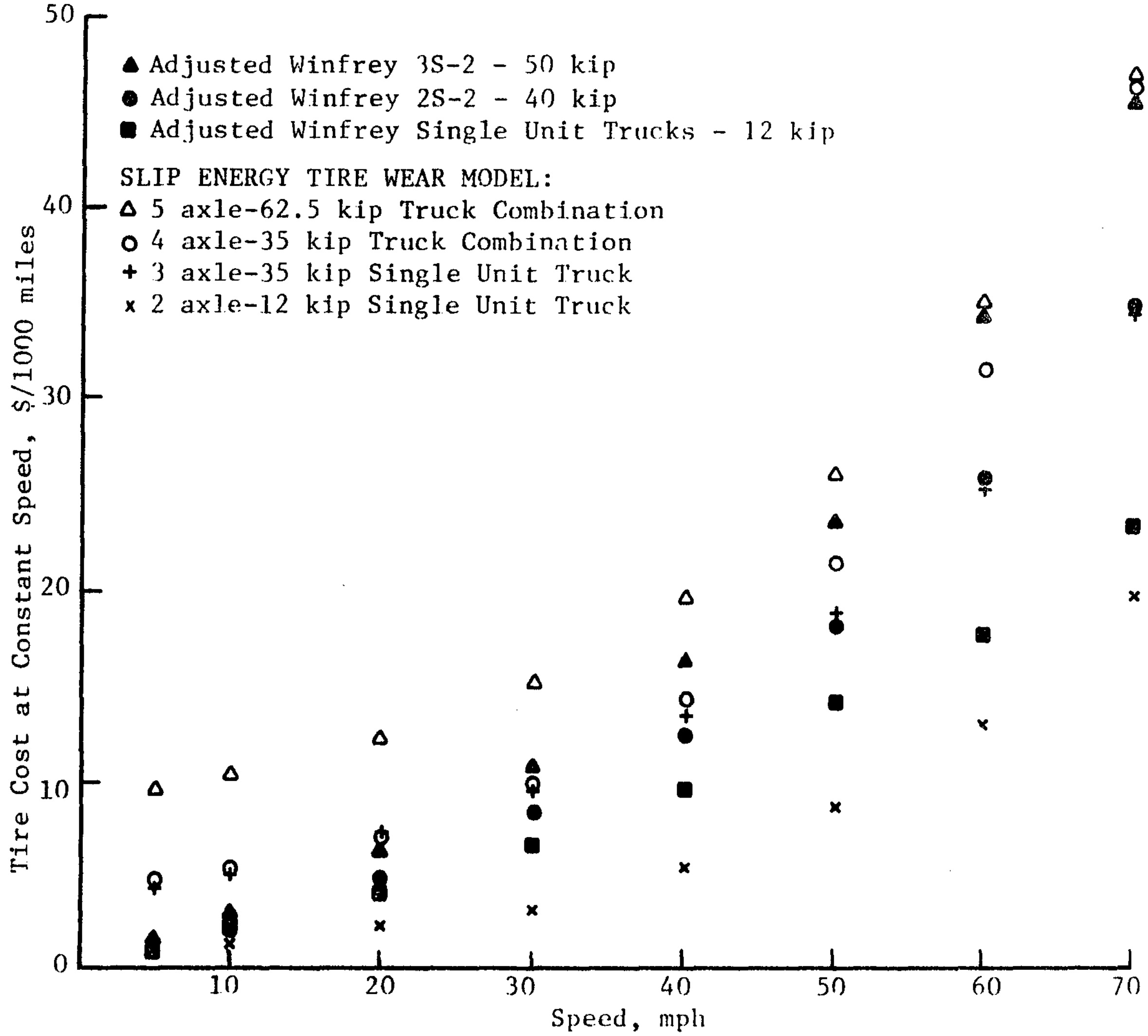


Figure 10. Comparison of constant speed tire costs predicted by slip-energy model to the adjusted Winfrey values.

The slip-energy method was selected for computing tire wear for the total vehicle operating cost tables. This procedure gives reasonable results and has the advantage of producing estimates of tire wear based on operational, roadway, and vehicle characteristics.

Roadway Effects on Tire Costs

The slip-energy model can be used to analyze the effect of speed, speed-change cycles, grade, and horizontal curvature on tire wear. Conceptually, the model could also be used to evaluate the effect of surface type and condition on tire wear; however, there are no data to support the selection of coefficients for analyzing different pavement types or condition.

Adjustments for changes in roadway surface conditions and the associated effects on tire tread wear were developed from information based on recent studies in Brazil. Relationships developed in Brazil were used to determine the proportionate change in tire consumption as roadway surfaces vary from the assumed baseline condition of 3.5 SI. Roughness adjustment factors were determined for passenger cars and pickup trucks and trucks are presented in Table 12.

MAINTENANCE AND REPAIR

Maintenance and repair expenditures are a major portion of vehicle operating cost and a difficult one to measure accurately. For an individual vehicle the exact maintenance and repair expense incurred will depend on the care taken by the owner and the specific conditions under which the vehicle operates. The information and procedures used here provide updated estimates for maintenance and repair expenditures which are representative for the general vehicle classes described. The estimates were based on information concerning total parts and labor costs for a collection of vehicle components. The particular component areas used to derive the expenses were suggested by Winfrey and are summarized in Table 13. Using the categories suggested, data supplied from the working papers used to produce the FHWA maintenance and repair expense

Table 12. Tire expense adjustment factors for roadway surface condition.

Serviceability Index	Passenger Cars and Pickup Trucks	Single Unit Trucks 2-S2 & 3-S2 Semi's
1.0	2.40	1.67
1.5	1.97	1.44
2.0	1.64	1.27
2.5	1.37	1.16
3.0	1.16	1.07
3.5	1.00	1.00
4.0	0.86	0.95
4.5	0.76	0.92

Table 13, Classification of maintenance and repair expense components.

Body:
- Bumpers
- Doors
- Fenders
- Glass
- Heater
- Instruments
- Interior
- Keys and Lock
- Paint
- Rattles
- Wash and Polish
- Windshield Wipers

Brakes:
- Adjustments
- Cylinders
- Drums
- Fluid
- Inspection
- Lining
- Shoes

Power Train:
- Clutch
- Differential
- Drive Shaft
- Transmission
- Transmission Fluid
- Universal Joints

Tires:
- Balance
- Chains
- Flats

Chassis:
- Grease Fittings
- Hub Caps
- Muffler
- Tailpipe
- Shock Absorbers
- Steering
- Suspension System
- Tire Rims
- Wheels
- Axles
- Frame
- Gasoline Tank

Electrical:
- Battery
- Generator
- Bulbs
- Regulator
- Starter
- Turn Signal
- Wiring
- Coil
- Radio
- Belts and Cables

Engine:
- Air Cleaner
- Antifreeze
- Bug Screen
- Carburetor
- Distributor
- Fuel Pump
- Fan and Belt
- Internal Work
- Oil Filter
- Radiator
- Spark Plugs
- Steam Cleaning
- Tune Up
- Water Pump
- Emissions Control
- Water Hose
- Heater Hose
- Thermostat
- Fuel Filter

Note: Categories suggested by Winfrey (Ref. 2). Tire expenses are reported in a separate section.

estimates were analyzed to produce percentage costs breakdowns. It was assumed the data for vans applies to pickups. Information supplied by survey respondents provided the basis for dividing expenditures for 3-S2 class trucks. These percentages were used for all trucks except pickups. The percent cost of the major categories are presented in Table 14 along with the average maintenance costs per mile.

The distributions of maintenance costs in Table 14 were multiplied by the average maintenance and repair costs to obtain the average cost per mile for three categories:

1. General - body, chassis, and electrical,
2. Brake. and
3. Drive train - engine and power train.

The general costs were assumed to apply to each mile of travel. The brake costs were assumed to apply only to deceleration and holding speeds on negative grades, i.e., negative horsepower situations. The drive train costs were applied to the times when the brakes were not in use, i.e., positive horsepower situations.

Winfrey's costs for maintenance and repair at constant speed on level tangent roads in good condition were updated by multiplying Winfey's costs by the ratio of current overall maintenance and repair costs (without brakes) to Winfrey's overall maintenance and repair cost. Drive train costs for 5 mph constant speed increments were computed based on the percentages of the engine and power train costs in Table 14 and the updated maintenance and repair costs. The equations in Appendix E were used to compute horsepower required at each of the constant speed increments. A linear regression analysis was performed to establish an equation for computing drive train costs as a function of horsepower for each vehicle class. The horsepower required to accelerate, climb grades, or negotiate curves in excess of the horsepower required for constant speed was computed with the equations in Appendix E for 5 mph speed increments. The excess horsepower was multiplied by the slope of the

Table 14. Percentage breakdown of maintenance and repair expenditures.

Component Cost Area	Subcompact	Compact	Standard	Passenger Vans	3-S2 Trucks
Power Train	2%	1%	1%	2%	13%
Engine	41%	45%	45%	44%	51%
Body	3%	2%	2%	7%	6%
Chassis	23%	22%	22%	19%	2%
Electrical	18%	17%	18%	15%	19%
Brakes	13%	13%	12%	13%	9%
Total Percent	100%	100%	100%	100%	100%
Average Cost ($/1000 mi)	34.30	41.60	48.04	52.81	145.0

regression equation to obtain excess maintenance and repair costs for acceleration, grades and horizontal curves.

Maintenance and repair costs for the three diesel fueled trucks was developed form Winfrey's costs for a 3-S2 diesel truck. The maintenance costs were updated using the ratio of the current to Winfreys overall maintenance costs. These update costs for the 3-S2 vehicle class were then separated into general and drive train costs using the percentages shown in Table 14. To generate the general and drive train costs at zero grade for the 2-S2 and 3ASU truck classes, two linear regression equations were developed between each of the two 3-S2 maintenance cost categories and required horsepower at constant speed on a level tangent grade. Using these two regression equations, maintenance costs for the 2-S2 and 3ASU truck categories were determined at each speed by evaluating the equations with the required horsepower on a level tangent for the vehicle.

Brake costs were distributed across the negative horsepower situations, i.e., deceleration and holding constant speed on negative grades. The average brake cost per 1000 mi. was computed by multiplying the overall maintenance and repair costs by the percent brake cost in Table 14. It was then necessary to convert the brake cost per 1000 mi. to a brake cost per unit work.

There are very few data indicting how frequently or what percentage of the time brakes are in use. Data collected by Hodges and Koch (Ref. 24) indicate that cars use brakes 1 percent of the travel distance on rural roads in central Texas. Operating speed data collected in Los Angeles indicated that on arterial streets cars average between 1 and 2 stops per mile at an average operating speed of 25 mph (Ref. 27). A sensitivity analysis of various assumptions about the use of brakes indicated that reasonable maintenance and repair cost estimates could be obtained by assuming that brakes are used for an average of 1.5 stops per mile from an average operating speed of 25 mph. The cost per stop was then computed and was divided by the work per stop to obtain a brake cost coefficient in units of dollars per lb./mi. These coefficients were then multiplied by the brake work per mile to hold constant speed on negative grades to get the brake cost on negative grades. Similarly. excess brake costs for speed change cycles were computed as the product of the brake work for deceleration and the brake cost coefficient.

To adjust the updated expenditures estimated for changes in roadway surface conditions, the information from recent studies in Brazil were used. In these studies, separate relationships were established to estimate parts and labor expenses as surface roughness changes. The relations compiled for passenger cars and trucks were evaluated for ranges of surface conditions and the results then compared to the baseline case where it is assumed roughness was 3.5 SI. The proportionate change from the baseline condition to the respective roughness level was the adjustment factor applied to the updated estimates. The adjustment factors for each vehicle class are presented in Table 15.

DEPRECIATION EXPENSE

Depreciation expense is one of the most difficult of all non-fuel running costs to estimate accurately. The major area of contention in the debate concerning depreciation expense is what, if any, portion of the expense should be assigned to operation on the road. As Winfrey notes, only the portion of the new price of a vehicle that is assignable to road use is germaine to discussion related to highway design alternatives. Accordingly, it is the use related depreciation expense that was estimated and included in the running cost tables in this study. The first task was to determine a methodology for apportioning depreciation expense between use and time. Next, the updated depreciation expenses had to be estimated, and, finally, the depreciation expenses had to be adjusted to reflect changes in roadway surface condition.

An extensive literature review was conducted in the interim report to identify an operational methodology to determine a time/use division for depreciation expense. The methodology adopted for this study was that used by the Economic Intelligence Unit in work on vehicle operating cost in Africa (Ref. 4). In this work, Daniels outlined a procedure for using information from vehicle survivor curves to proportion vehicle

Table 15. Maintenance and repair expense adjustment factors for roadway surface conditions.

Serviceability Index	Passenger Cars & Pickup Trucks	Single Unit Trucks	2-S2 & 3-S2 Semi Trucks
1.0	2.30	1.73	2.35
1.5	1.98	1.48	1.82
2.0	1.71	1.30	1.50
2.5	1.37	1.17	1.27
3.0	1.15	1.07	1.11
3.5	1.00	1.00	1.00
4.0	0.90	0.94	0.92
4.5	0.83	0.90	0.86

depreciation between time and use. The necessary variables to identify are the life mileage and age for vehicles in the fleet. The portion of depreciation expense due to time may be approximated by the reciprocal of the maximum vehicle age. This would represent the rate of depreciation if it were all solely dependent on the passage of time. The use related depreciation expense may be approximated by the reciprocal of maximum vehicle life mileage. This would represent the rate of depreciation if it were all solely dependent on use of the vehicle on the road. The approach used in this study was to quantify the life mileage of vehicles in the highest 3% annual mileage category. The depreciation of these vehicles was assumed to be totally assignable to use.

Estimates of expected life mileage and age for vehicles in the U.S. population, required knowledge of the number of vehicles registered and surviving from one year to the next. For this information the Census of Transportation, 1977 Truck Inventory and Use Survey Tape was used (Ref. 15) and represented the most extensive data base available concerning the age and accumulated mileage for the U.S. truck fleet population. Registration data were compiled from issues of the Automotive News Almanac from 1945 through 1977. This information was used to develop survivor curves for the pickup, single-unit, and semi truck configurations. The survivor curves were then used to determine average values for extreme life mileage for each truck class. These measures were accomplished by applying the survivor curve for an entire class to the high annual mileage category for each truck class.

The data and calculation procedures for pickups, single-unit and semi trucks are given in Tables 16, 17, and 18. First, 32 model years were recorded in column (1), the number of vehicles in the 1977 truck inventory for each model year was recorded in column (2). The number of new vehicles registered in each model year was obtained from issues of the Automotive News Almanac from 1945 to 1977 and recorded in column (3) in thousands. The ratio of the sample size to the number of new vehicles registered was computed and recorded in column (4). In theory, the highest value in column 4 represents the sampling factor for the survey used to establish column (2) because it represents a year when all of the

Table 16. Turnover method to estimate service life, and maximum life mileage for pickups.

Model Year (1)	Sample Total S (2)	Reg's (1000) R (3)	S/R (4)	P (5)	High Mileage Sample (M) (6)	P x M (7)
1977	1790	1218	1.47	1.00	22	22
1976	2191	1284	1.71*	1.00	30	30
1975	1645	1204	1.37	0.80	18	14.4
1974	2423	1616	1.50	0.88	14	12.3
1973	2251	1843	1.22	0.71	14	9.9
1972	2099	1471	1.43	0.84	7	5.9
1971	1455	1210	1.20	0.70	5	3.5
1970	1411	1049	1.35	0.79	8	6.3
1969	1448	1117	1.30	0.76	6	4.6
1968	1140	1069	1.07	0.63	5	3.2
1967	1059	919	1.15	0.67	5	3.3
1966	991	970	1.02	0.60	4	2.4
1965	843	940	.90	0.53	5	2.7
1964	659	844	.78	0.46	2	.9
1963	510	745	.68	0.40	1	.4
1962	392	625	.63	0.37	2	.7
1961	260	541	.48	0.28	1	.3
1960	256	521	.49	0.29	0	0
1959	435	505	.86	0.50	0	0
1958	263	382	.69	0.40	0	0
1957	317	451	.70	0.41	0	0
1956	304	407	.75	0.44	0	0
1955	372	460	.81	0.47	1	.5
1954	276	437	.63	0.37	0	0
1953	322	461	.70	0.41	0	0
1952	235	251	.94	0.55	0	0
1951	258	469	.55	0.32	0	0
1950	289	362	.80	0.47	0	0
1949	211	336	.63	0.37	0	0
1948	139	308	.45	0.26	0	0
1947	56	281	.20	0.12	0	0
1946	76	258	.29	0.17	0	0
				$\Sigma = 16.97$		$\Sigma = 123.3$

* sample factor

$$\text{Average service life} = \frac{123.3}{(22+30)/2} = 4.74 \text{ yr.}$$

Table 17. Turnover method to estimate service life and maximum life mileage for single unit trucks.

Model Year (1)	Sample Total (S) (2)	Reg. (R) (3)	S/R (4)	P (5)	High Mileage Sample (M) (6)	(P x M) (7)
1977	407	784	0.52	1.00	27	29
1976	744	719	1.03*	1.00	55	55
1975	944	331	2.85*	1.00	131	131
1974	1154	371	3.10*	1.00	63	63
1973	1213	680	1.78*	0.81	76	61.6
1972	1019	927	1.10	0.50	27	13.5
1971	862	694	1.24	0.56	12	6.7
1970	1046	756	1.38	0.62	17	10.5
1969	1058	943	1.12	0.50	8	4.0
1968	870	969	0.90	0.40	9	3.6
1967	807	109.7	0.74	0.33	1	3.3
1966	824	144.8	0.57	0.26	4	1.0
1965	701	148.4	0.42	0.21	3	.6
1964	564	142.3	0.40	0.18	3	.6
1963	540	142.7	0.38	0.17	3	.5
1962	397	146.4	0.27	0.12	1	.1
1961	297	140.5	0.21	0.09	1	.1
1960	329	173.0	0.19	0.09	1	.1
1959	321	190.0	0.17	0.08	0	0
1958	213	151.6	0.14	0.06	1	.1
1957	243	190.1	0.13	0.06	0	0
1956	206	226.4	0.09	0.04	1	0
1955	225	248.9	0.09	0.04	1	0
1954	165	203.0	0.08	0.04	0	0
1953	172	232.9	0.07	0.03	0	0
1952	171	247.8	0.07	0.03	0	0
1951	192	277.1	0.07	0.03	0	0
1950	152		0.06@	0.03	0	0
1949	130		0.06@	0.03	0	0
1948	180		0.06@	0.03	0	0
1947	83		0.06@	0.03	0	0
1946	76		0.06@	0.03	0	0
			Σ	9.40		Σ= 384.3

* average (2.19) used for sample factor

@ assumed

$$\text{Average service life} = \frac{384.3}{(55+131+63)/3} = 4.63 \text{ yr.}$$

Table 18. Turnover method to estimate service life and maximum life mileage for semi trucks.

Model Year (1)	Sample Total (S) (2)	Reg. (R) (3)	S/R (4)	P (5)	High Mileage Sample (M) (6)	P x M (7)
1977	1139	1564	.73	1.00	33	33
1976	1350	1131	1.19	1.00	57	57
1975	1878	1079	1.74*	1.00	20	20
1974	2403	1681	1.42	.82	30	24.6
1973	2432	1838	1.32	.76	12	9.1
1972	1997	1458	1.39	.80	6	4.8
1971	1476	1258	1.17	.67	2	1.3
1970	1422	1253	1.13	.65	0	0
1969	1377	1248	1.10	.63	1	.6
1968	1052	1105	.95	.55	0	0
1967	882	1000	.88	.51	0	0
1966	813	1119	.73	.42	0	0
1965	619	954	.65	.37	0	0
1964	465	808	.57	.33	0	0
1963	379	765	.49	.28	0	0
1962	268	671	.40	.23	0	0
1961	167	537	.31	.18	0	0
1960	175	614	.28	.16	0	0
1959	165	648	.25	.15	0	0
1958	95	496	.19	.11	0	0
1957	93	557	.17	.09	0	0
1956	92	633	.14	.08	0	0
1955	55	483	.11	.06	0	0
1954	24	459	.05	.03	0	0
1953	33	274	.12	.07	0	0
1952	52	225	.23	.13	0	0
1951	26	213	.12	.07	0	0
1950	18	193	.09	.05	0	0
1949	7	179	.04	.02	0	0
1948	15	164	.09	.05	0	0
1947	9	155	.06	.03	0	0
1946	9	135	.07	.04	0	0
				Σ 11.34		Σ = 150.5

* sample factor

$$\text{Average service life} = \frac{150.5}{(33+57+20)/3} = 4.10 \text{ yr.}$$

registered vehicles were still in the population. Generally, this occurs in the year prior to the survey, e.g.. 1976 in this analysis, because of partial year sampling of the model year of the survey. In reality, the sampling factor cannot always be established as the highest value in column (4) as shown in Table 17. In this case, logic had to be used to arrive an acceptable sampling factor.

The survival curve, column (5), was established by dividing column (4) by the sampling factor. Years prior to the occurrence of the sampling factor are given a value of 1.0 in column (5). The number of vehicles in the highest 3 percentile class of mileage from the truck inventory was recorded in column (6). The product of the survivor and high mileage sample was computed and recorded in column (7). The values in column (7) are each model year's contribution to the current average life of the vehicle type. The total of the column is divided by the average number of sample units which have a survivability factor in column (5) of 1.0 to obtain the average service life of the high mileage vehicles. as shown in the tables. Once the average service life of the high mileage vehicles has been established, it is multiplied by the average annual mileage of the vehicles to obtain the average life mileage. In this analysis, the average annual mileage is based only on the vehicles in the highest 3 percentile of annual mileage; these average annual mileages were:

1) Pickups - 57,600 miles/year.
2) Single unit trucks - 53,900 miles/year, and
3) Semi trucks - 190,300 miles/year.

Multiplying these average annual mileages by the average service life for each vehicle class yields average life time mileages of 273,000 miles for pickups, 250,000 miles for single units, and 781,00 miles for semi's.

The life mileage was divided into the depreciable value of the vehicle times 1000 to obtain a current estimate of the depreciation expense per 1000 miles. The current expense was divided by Winfrey's depreciation expense per 1000 miles to obtain an adjustment factor for updating Winfrey's depreciation cost tables for constant speed.

For standard passenger cars, the information supplied by U.S.D.O.T. indicated a current use-related depreciation expense of $56.62 per 1000 miles at 26 mph assumed operating speed. Comparison with Winfrey's base rate of $16.32 per 1000 miles indicated an update adjustment factor of 3.46. Application of the relative adjustment factors to the estimate provided by Winfrey for the range of operating speeds produced the updated estimates.

Depreciation expenses were not distributed to grades and horizontal curves. Excess time consumed for speed change cycles, over the time required for constant speed travel, was used to establish excess depreciation expense for speed change cycles. Information from Brazil was used to adjust depreciation expenses for pavement surface condition. In the Brazilian studies, the relationship between vehicle depreciation and roadway surface was established for passenger cars, buses, and trucks. The proportionate change for roughness was used to adjust our updated estimates of depreciation for different roadway condition. The adjustment factor for passenger cars was applied to pickup trucks. For single-unit trucks the adjustment factor for buses was applied, and for 3-S2 and 2-S2 combination the adjustment factor for trucks was applied. A further discussion of depreciation expense and roadway surface conditions is available from Harrison and Swait (Ref. 16). The results of the roughness adjustment procedures produced the estimates for use related depreciation expense as surface roughness changes that are presented in Table 19.

SUMMARY OF NON-FUEL VEHICLE OPERATING COSTS

The procedures described above were used to generate the component consumption tables in Appendix B. Oil consumption is expressed in quarts. The other components are expressed in fractions of overall costs as:

1) Tires - percent of the cost of a set of tires
2) Maintenance and Repair - percent of the average cost per mile of operation
3) Depreciation- percent of the depreciable value of a new vehicle

Table 19. Use related depreciation adjustment factors for roadway surface condition.

Serviceability Index	Passenger Cars & Pickup Trucks	Single Unit Trucks	2-S2 and 3-S2 Semi Trucks
1.0	1.14	1.33	1.32
1.5	1.09	1.23	1.22
2.0	1.06	1.15	1.14
2.5	1.04	1.09	1.09
3.0	1.02	1.04	1.04
3.5	1.00	1.00	1.00
4.0	0.99	0.97	0.97
4.5	0.98	0.94	0.94

These dependent variables were selected because they are readily available and hence operating costs can be readily updated or computed for specific regions.

Comparing the cost tables in Appendix A to Winfrey's costs, shows that the current cost for operating a large automobile is approximately four times greater than Winfrey's costs. This is very reasonable since fuel prices have increased by a factor of 4.8, oil by 4.2, tires by 3.3, and depreciation value has increased by a factor 4.3. Comparisons of the cost increases for the other vehicles shows that the current operating costs at constant speed are in the range of three to five times greater than the operating cost estimated by Winfrey.

The consumption of the non-fuel components during idling are difficult to quantify. Table 20 provides the consumption parameters which can be used to estimate cost while idling. For oil consumption, Winfrey's consumption rate for cars, commercial delivery, and single unit trucks were used for all three car types in this study, the pick-up truck and two axle single unit truck. Winfrey's oil consumption rate for 3-S2's was used for the other truck types. The maintenance and repair consumption was estimated based on converting Winfrey's estimates to the units used in this study. Depreciation rates were based on the fraction of new vehicle cost as assigned by Winfrey, then updated to reflect the greater lifetime mileage found in this study.

Total operating costs while idling, including fuel, are also given in Table 20. The most expensive vehicle for idling is the two-axle single unit truck. This is due to the high gasoline consumption of the vehicle. The three-axle single unit truck has higher idling costs than the larger trucks due to the greater rate of depreciation assigned to this vehicle.

Table 20. Consumption of non-fuel components and total cost while idling.

Item	Automobile			Truck				
	Small	Medium	Large	Pickup	2A-SU	3A-SU	2-S2	3-S2
Oil (1)	5.80	5.80	5.80	3.50	3.20	3.46	3.46	3.46
Maintenance (2)	57	57	59	60	23	26	24	24
Depreciation (3)	0.81	0.81	0.81	0.50	1.10	1.10	0.38	0.38
Total Cost (4)	383	717	740	904	1437	891	640	650
Winfrey Costs (Ref.2)	-	-	114.86	132.54	200.03	-	249.45	196.[illegible]

(1) quarts/1000 hrs.
(2) percent of average cost per 1000 mi/1000 hrs.
(3) percent of new price/1000 hrs.
(4) dollars/1000 hrs.

For comparison, Winfrey's (Ref. 2) costs for idling are included in the table. The new cost for idling cars is about 6.5 times larger than Winfrey's. This reflects a substantial increase in the price of fuel and a higher idling fuel consumption rate due to current emission controls on vehicles.

CHAPTER 4. EMISSION PREDICTION

As noted in the interim project report dated April 1980, there are considerable differences among available types and quantity of information for automobiles and trucks. An instantaneous emissions model exists for estimating automobile pollutants (Ref 5). Estimates of truck emissions were generated from a data base generated by Southwest Research Institute (Ref 6).

EMISSIONS OF AUTOMOBILES

Large quantities of published information are available for characterizing emissions from light duty vehicles. These data encompass the three passenger car classes and one light duty truck (pick-up) class chosen for study within this project.

The best available light duty vehicle emissions models are presented by Kunselman, et al. (Ref 5). This family of models is designed to produce instantaneous time-based emissions for 18 different light duty vehicular groups. These models are unique within the emissions forecasting field because they are based upon primary data collected explicitly for instantaneous emission model development. Group 18, encompassing the 1975 model year light duty vehicles for low altitude cities, was selected as the most representative of today's vehicle fleet.

The common form of the Modal Anaysis Model equation is:

$$\begin{aligned}\text{EMISSION} = {} & (1.0-\text{WF})\text{x}(B_1+B_2V+B_3A+B_4AV+B_5V^2+B_6A^2+B_7VA^2+B_8AV^2+B_9A^2V^2) + \\ & (\text{WF})\text{x}(S_1+S_2V+S_3V^2)\end{aligned}$$

where:

EMISSION - Quantity of emissions corresponding to the B and S coefficients, grams/sec

$B_1, B_2, \ldots B_9$ - Emission coefficients for speed change operating mode (Note: there are a unique set of coefficients, B_1-B_9, for each type of emission, Table 21).

S_1, S_2, S_3 - Emission coefficients for constant speed operating mode (Table 21).

V - Vehicle speed, mph

A - Vehicle Acceleration, mph/sec

WF - Weighting factor dependent on operation mode

WF = 0 FOR A less than AMIN or A greater than AMAX

WF = 1 FOR A=0

WF = -A/AMAX + 1 FOR A greater than 0 and less than AMAX

WF = -A/AMIN + 1 FOR A less than 0 and greater than AMIN

AMIN, AMAX - Minimum and maximum acceleration limits on ramp function, -1.2 mphps and 1.0 mphps, respectively (Ref. 5).

For prediction of each type of emission, a separate set of B and S coefficients are utilized as shown in Table 21. The ease with which this equation can be evaluated for the different emissions makes its use particularly desirable.

Emissions predicted by the modal analysis model are presented in Appendix F. Group 18 of the Modal Analysis Model was chosen to best represent the emissions of vehicles from the three passenger car classes and the pickup truck class developed in this report.

EMISSIONS FROM HEAVY DUTY GASOLINE-POWERED VEHICLES

Of the four heavy duty vehicle classes selected for study within the project, the two axle single-unit truck class is typically gasoline engine powered. The most typical power plant used in this class is a 350-cubic inch, eight-cylinder engine.

Table 21. Modal emissions model coefficient for group 18 (1975 49-state light duty vehicles)(Ref. 5).

Coefficients	POLLUTANT HC	CO	NO_x
B_1	0.80684014E-02	0.21578521E-00	0.1081600E-01
B_2	-0.40020002E-03	-0.12577798E-01	-0.1225000E-02
B_3	0.90040010E-03	0.51477298E-01	-0.73540001E-03
B_4	0.65000000E-04	-0.23425999E-02	0.53939992E-03
B_5	0.66000002E-05	0.16780000E-03	0.44400003E-04
B_6	-0.63569990E-03	-0.15755999E-02	-0.32972000E-02
B_7	0.89800000E-04	0.28229994E-03	0.52660005E-03
B_8	-0.30000001E-06	0.12529999E-03	0.31199997E-05
B_9	-0.60000002E-06	0.48500006E-04	-0.84000003E-05
S_1	0.53815991E-02	0.11655778E-00	0.26507999E-02
S_2	-0.14550000E-03	-0.46298988E-02	-0.35370002E-03
S_3	0.19999998E-05	0.69899994E-04	0.23400004E-04

The extensive literature review conducted as part of this project ha not yielded any satisfactory instantaneous emissions models for this typ of heavy duty vehicle. Two significant data sources were, however, located.

Southwest Research Institute, while working under contract to EPA, has collected significant quantities of emissions data for heavy duty vehicles (Ref 6). Most of these data collection efforts were designed to develop or test emissions certification procedures and not to produce emissions models. Data developed through engine dynamometer, chassis dynamometer, and full-scale road tests were documented in the interim report.

Although the San Antonio Road Route (Ref 6) was not necessarily designed to be a typical mix of road driving conditions, it did include elements of urban, freeway, and highway driving along its 7.2-mile length. These data, therefore, represent a good sample of realistic emission information. Inadequacies of the data are twofold and stem from the ag and type of vehicles tested. The model years of most tested vehicles ar early 1970's, and the gross vehicle weights are generally 16 to 20,000 pounds. The San Antonio Road Route Emission data are presented in Table 22 in terms of grams of pollutant per pound of fuel consumed for several typical vehicles.

Another data set which could be used to characterize heavy duty gasoline powered vehicle emissions is contained in information developed by EPA and published in Reference 28. These data were developed in an attempt to produce hydrocarbon and carbon monoxide emissions standards for the 1983 model year. All information was collected from engine dynamometer tests of 1969 and 1979 model year truck engines. The chief problem inherent in the data is the fact that it is based upon engine dynamometer testing and does not exhibit effects of transmissions, drive train, and vehicle chassis-body. A summary of the data for engines typical of the type selected for this project are shown in Table 23 (Ref 29). Each engine-both 1969 and 1979 models-was tested in the 9 Mode Federal Test Procedure, idle mode, and new transient cycle tests. Because

Table 22. Emission rates for selected heavy duty gasoline vehicles (Ref. 28).

Vehicle Make	Model Year	Gross Weight (lbs)	Engine Type/ Displacement (in^3)	Number Runs	Mean, Emissions Grams/lb of Fuel HC	CO	NOx
Chevrolet	1970	18,000	V-8/350	11	8.06	116	8.64
GMC	1970	19,500	6 cyl/351	9	17.90	285	3.74
Ford	1972	19,200	V-8/361	8	12.88	140	12.18
IHC	1970	17,000	V-8/304	8	12.90	155	11.25
IHC	1972	25,000	V-8/345	9	15.17	192	6.29

Table 23. Heavy duty gasoline engine transient emissions (Ref. 29).

Engine/Type Displacement (in^3)	Number of Tests	Mean Grams/Brake Horsepower-hour			Weighed Grams/lb of fuel		
		HC	CO	NOx	HC	CO	NOx
1969 MODEL YEAR ENGINES							
V-8/330	5	28.13	157.15	7.89	38.68	216.08	10.86
V-8/304	8	11.22	127.76	6.70	16.53	187.70	9.80
V-8/351	7	9.27	111.51	8.80	14.92	171.02	13.50
V-8/350	3	9.40	170.71	4.82	14.08	255.87	7.21
1970 MODEL YEAR ENGINES							
V-8/345	10	2.44	34.44	6.46	3.74	53.01	9.94
V-8/350	14	2.48	64.76	6.62	3.47	90.46	9.22
V-8/360	3	2.67	96.10	4.36	3.88	139.25	6.34
V-8/350	3	2.66	114.02	6.58	6.14	158.17	8.99

the transient cycle tests are most representative of real-world driving conditions. only these data are presented here.

To determine an emission rate characteristic of this broad class of vehicles based on the available information. the most current nation-wide truck registration data was used. Emission rates for equivalent model year trucks and engines were averaged together using weighting factors based on the number of tests conducted on each machine. These averages were then combined to get a composite average based on the number of trucks of each model year registered in 1979. The composite rates for this truck class are shown in Table 24.

Emission predictions for the 2-axle single unit truck class using the composite rates expressed in terms of grams per brake horsepower-hour are presented in Appendix F. The factors used to predict the vehicle's required horsepower are presented in Appendix E.

EMISSIONS FROM VEHICLES POWERED BY DIESEL FUEL ENGINES

Three classes of diesel fueled vehicles have been selected for study within the project. These include a three-axle single unit and four- and five-axle semi-trailer (articulated) trucks. Possibly the best available source of emissions data for vehicles typical of these classes was developed by Southwest Research Institute on the San Antonio Road Route (Refs. 29 and 29). A summary of these vehicle specifications and emissions data is presented in Tables 25 and 26. Also included are chassis dynamometer test results developed for the same vehicles, utilizing the 13 mode diesel FTP. Due to the narrow range of model years, simple averages are shown in Tables 25 and 26. The overall averages shown at the bottom of these tables are for all of the heavy duty diesel powered trucks tested on the San Antonio Road Route.

The small number of vehicles tested from each class and vehicle model year constitute primary problems. However, the quantity of diesel powered heavy duty vehicle emission data currently available is very limited since these vehicle types have not been the subjects of strenuous emission

Table 24. Composite average emission rates for heavy duty gasoline powered trucks.

Model Year	Number of Trucks Registered[1] (thousands)	Weighting Factors #Trucks/Total	Mean Emission Rates Grams/lb of fuel[2] HC	CO	NOx
1979	3600*	.417	3.87	89.6	9.15
1972	2140	.248	9.26	168.	9.06
1970	1435	.166	12.6	201.	7.81
1969	1460	.169	20.5	198.	10.8
	TOTAL 8635	Composite Average	9.47	146.	9.19

Model Year	Number of Trucks Registered[1] (thousands)	Weighting Factors #trucks/Total	Mean Emission Rates Grams/Bhp-hr[2] HC	CO	NOx
1979	3600*	.711	2.50	62.7	6.34
1969	1460	.289	14.2	135.	7.35
	TOTAL 5060	Composite Average	5.89	83.6	6.63

(1) Ref. 30.

(2) Based on averages from Ref. 29.

* Extrapolated

Table 25. Emissions data for heavy duty diesel powered vehicles (Road Test). (Ref. 29).

Engine	Model	Engine Configuration/ Displacement (in^3)	Transmission	GVW (lbs)	Test Weight	San Antonio Road Route Mean Grams/lb of Fuel HC	CO	NOx
Three-Axle Single Unit								
D-1 Catepillar	1972	I-4/573	5-speed	24,000	18,820	6.97	8.42	10.98
D-10 Det. Diesel	1970	I-4/212	5-speed	17,000	14,430	3.55	47.57	14.08
Average	-	-	-	-	-	5.26	28.0	12.5
Four-Axle Semi-Trailer								
D-3 Det. Diesel	1971	I-6/426	10-speed	58,000	42,800	1.13	60.30	12.50
D-4 Cummins	1970	I-6/855	10-speed	58,000	39,400	1.71	9.46	10.07
D-8 Mack	1970	I-6/672	10-speed	58,000	41,090	6.71	7.71	20.97
Average	-	-	-	-	-	3.81	25.8	14.5
Five-Axle Semi-Trailer								
D-6 Mack	1973	I-6/672	10-speed	72,000	49,460	0.98	9.04	13.75
D-9 Cummins	1973	I-6/855	10-speed	72,000	50,980	1.58	10.48	13.70
Average	-	-	-	-	-	1.28	9.76	13.7
Overall Average of all Heavy Duty Diesel Powered Trucks on San Antonio Road Route						3.01	18.6	13.6

Table 26. Emissions data for heavy duty diesel powered vehicles (Dynamometer). (Ref.29).

Engine Make	Model Year	Engine Configuration/ Displacement (in^3)	Transmission	GVW (lbs)	Test Weight	13 Mode FTP Mean Grams/Brake horsepower-hr HC	CO	NO2
Three-Axle Single Unit								
D-1 Caterpillar	1972	V-8/573	5-speed	24,000	18,820	3.11	6.49	6.63
D-10 Det. Diesel	1970	I-4/212	5-speed	17,000	14,430	3.10	9.10	11.28
Average	-	-	-	-	-	3.10	7.80	8.96
Four-Axle Semi Trailer								
D-3 Det. Diesel	1971	I-6/426	10-speed	58,000	42,000	0.32	12.28	10.97
D-4 Cummins	1970	I-6/855	10-speed	58,000	39,400	0.24	5.30	6.72
D-8 Mack	1970	I-6/672	10-speed	58,000	41,090	2.39	2.94	19.16
Average	-	-	-	-	-	0.98	6.84	12.3
Five-Axle Semi-Trailer								
D-6 Mack	1973	I-6/672	10-speed	72,000	49,460	0.54	1.59	9.53
D-9 Cummins	1973	I-6/855	10-speed	72,000	50,980	0.38	2.31	12.92
Average	-	-	-	-	-	0.46	1.95	11.2
Overall Average for all Heavy Duty Diesel Power Trucks on San Antonio Road Route						1.29	5.62	9.90

control efforts.

The average emission rates shown in Table 24 were used in conjunction with the horsepower estimation procedure to generate the emission tables presented in Appendix F for the three-axle single unit, four axle semi-trailer, and five axle semi-trailer heavy duty diesel powered truck classes.

SUMMARY OF EMISSIONS PREDICTIONS

The tables for emissions generated in this report are based on the best available information. However. although a great amount of emissions data are routinely collected by the EPA and other agencies, these data are too aggregated for use on this study. The tables generated for this report could be greatly improved by a detailed study of vehicle emissions by mode of operation and horsepower requirements.

CHAPTER 5. ACCIDENT RATES

This phase of the project has been concerned with defining the relationship, if any, between the "condition" of a pavement and the number of accidents on that pavement. "Condition" of the pavement is defined in the Work Plan of the project in terms analagous to what is often known as Present Serviceability Index (PSI). In the early work of the project it was determined that a data base could be put together from which it would be possible to explore the relationship of interest here.

DATA BASE

From 1975 to 1978 the Texas State Department of Highways and Public Transportation (SDHPT) made measurements of the condition of various rural pavements with Mays Meters (Ref 31). The Mays Meters were calibrated against a Surface Dynamic Profilometer using the standard Texas method (Refs 32 and 33), so the roughness measures could be converted to PSI values. The PSI values, along with section number and highway classification were stored on a permanent computer file. Accident occurences, average daily traffic, and percent trucks were stored on another computer file, which could be coordinated with the roughness file.

Data from 1976 were selected for the analysis since there were more roughness measurements in 1976 than in other years. Table 27 summarizes the information available concerning a total of 1,898 pavement sections, with a total length of 9,266 miles, on which there were 10,063 recorded accidents. The table also indicates the classes of highways for purposes of the analyses. Class 1 consists of Interregional Highways only; Class 2 is made up of U.S. and State Highways; and Class 3 consists of Farm to Market and Ranch Road Highways.

ANALYSIS

Early in the analysis it was determined that percent trucks in the traffic stream was not a meaningful variable, therefore, the variables for the analysis consisted of:

Table 27. Summary of pavement sections and accident information.

		Highway Class*			
		1	2	3	Total
Number of Sections		215	855	828	1,898
Length in Miles	Total	986	4,740	3,540	9,266
	Mean	4.58	5.54	4.28	
	SD	3.98	4.84	3.60	
Number of Accidents	Total	1,653	6,486	1,924	10,063
	Mean	7.69	7.59	2.32	
	SD	10.26	12.20	4.62	
ADT	Mean	17,093	3,046	1,417	
	SD	17,335	6,224	2,703	
PSI	Mean	3.156	3.192	2.505	
	SD	.915	.719	.788	

*Class 1 = Interstate

Class 2 = Primary

Class 3 = Secondary

1. Number of accidents on the section (ACCNO), which is the number of accidents occurring in a period of one year.
2. Length of the section (LEN),
3. Average Daily Traffic on the section (ADT),
4. PSI of the section (PSI), and
5. Highway classification of the section.

The highway classifications in the study consisted of Interregional Highways, U.S. Highways, State Highways, Farm to Market. and Ranch Roads, but all sections were "rural" as opposed to "urban".

The purpose of the study was to determine if there was a statistically significant relationship between accident rates per million vehicle miles and PSI. Because the data base was built without controlling for section length and ADT, it was felt that three approaches to the preliminary analysis were appropriate:

1. Number of Accidents = F(Section length, ADT, PSI),
2. Accidents per Mile = F(ADT, PSI). and
3. Accidents per Million Vehicle Miles = F(PSI).

Approach 1 makes no assumptions concerning the relationship between Number of Accidents, Section Length, and ADT; the effects of Section Length and ADT are determined statistically for the "best fitting" relationship. Approach 2 makes the assumption that Section Length is proportional to Number of Accidents. i.e., that if a particular section were twice as long, it would incur twice as many accidents. Approach 3 makes the assumption that Number of Accidents is proportional to both Section Length and ADT. Needless to say, if one's assumptions are invalid. making them can lead to erroneous interpretations.

A large number of regression runs were made on the computer in order to ascertain the most likely candidate equations following the approaches specified above. Table 28 summarizes the regression equation for each class of highway which were arrived at where Number of Accidents was

Table 28. Regression equations for number of accidents.

	Coefficients		
	Class 1	Class 2	Class 3
Section Length	-3.036	1.280	.397 E-1
$Length^2$	.726	-.943 E-1	
ADT			.142 E-3
ADT x Length	.359 E-3	-.433 E-3	.479 E-3
ADT x $Length^2$	-.589 E-4	.294 E-4	
PSI			.425
PSI x Length	1.420	-.101	-.348 E-1
PSI x $Length^2$	-.209	.315 E-1	
ADT x PSI			-.222 E-3
ADT x PSI x Length	-.114 E-3	.233 E-3	.804 E-5
ADT x PSI x $Length^2$	.176 E-4	-.105 E-4	
PSI^2 x Length		-.748 E-1	
ADT^2 x Length		-.727 E-8	
Constant	.426	1.866	.081
R^2	.410	.297	.404
F	17.899	35.689	79.450
Significance	.000	.000	.000
N	215	855	828

related to the three variables: Section Length, ADT, and PSI. An evaluation of these equations suggests the following:

For Class 1 Highways - At the lower ranges of ADT on Interregional Highways (10,000 to 15,000 vehicles per day) improving PSI makes no difference in the number of accidents occurring; however. at high ranges of ADT, as PSI increases the number of accidents decrease. and while the decrease is small (.16 accident decrease per million vehicle miles at 50,000 ADT. in moving from a PSI of 2 to a PSI of 4), it is a statistically significant change.

For Class 2 Highways - Across all ranges of ADT, as PSI increases the number of accidents occurring also increase.

For Class 3 Highways - The results are similar to that for Class 1 highways. i.e., at low ranges of ADT, PSI makes no difference in the occurrence of accidents, but at the upper ranges of ADT for this class the relationship between PSI and accidents is inverse.

Table 29 identifies the equations relating accidents per mile to ADT and PSI. An evaluation of these equations suggests:

For Class 1 Highways - For all ranges of ADT, as PSI increases so does accidents per mile.

For Class 2 Highways - For ADT's of 5,000 vehicles per day and above, there is no statistically significant relationship between PSI and accidents per mile.

For Class 3 Highways - For all ranges of ADT, the relationship between PSI and accidents per mile is inverse.

Table 29. Regression equations for accidents per mile.

	Class 1	Class 2: ADT Under 5,000	Class 2: ADT 5,000 and Over	Class 3
ADT		1.45 E-2		.115 E-2
ADT^2				-.345 E-7
ADT x PSI	-.218 E-4	-.221 E-3		-.122 E-3
ADT^2 x PSI	-.288 E-9			
Constant	1.133	-.192	3.343	-.768
R^2	.031	.240		.206
F	3.388	92.765		71.065
Significance	.036	.000		.000
N	215	592	263	828

The equations relating accidents per million vehicle miles and PSI are:

Class 1 Highways - Accidents/million veh miles = .0937 X PSI + .166
R^2 = .032 F = 7.011 Significance = .009

Class 2 Highways - Accidents/million veh miles = -.292 X PSI + 2.454
R^2 = .010 F = 8.688 Significance = .003

Class 3 Highways - Accidents/million veh miles = -.333 X PSI + 2.676
R^2 = .001 F = 5.80 Significance = .016

Since the interpretations are different, depending upon which analysis approach one uses. a good deal of effort was undertaken to determine the "correct" relationship between PSI and accidents. The contradictory results of the three regression equation approaches indicate that the underlying assumptions made in this report were incorrect. Division of accident number by ADF and section length does not adequately correct for their effects on the dependent variable. Furthermore, when investigating accident number per year for the cases where surface condition, PSI, was significant, one could have chosen an equation, with equal predictive ability. without the PSI term.

To overcome the difficulties encountered in the regression analysis approaches, the data were reanalyzed by splitting the data set into factors and levels of the significant variables. The factors and levels chosen for this analysis were:

Factor	Level
Highway Type	Class 1, Class 2, Class 3
ADT	Low, Medium, High
Section Length	0-1.33. 1.33-2, 2-3. 3-4.5. 4.5-7, 7-10, 10+
SI	0-2.3, 2.3-3.3. 3.3-5

The levels for ADT varied by highway class as:

Highway Class	ADT Level		
	Low	Medium	High
Interregional	to 1500	1500-25000	over 25000
U.S. and State	to 5000	5000-8000	over 8000
Farm to Market	to 700	700-1000	over 1000

This breakdown of the data generated 189 unique combinations of factors and levels. termed cells. The mean, standard deviation, and number of observations were calculated per cell for all dependent and independent variables.

The cell means of accident number and section length were plotted for the combinations of ADT, SI, and highway type to identify the effect of section length for the various combinations. Across SI level, but within the levels for the other factors. the section length mean per cell varied a little. Using the section length effects found in the graphs of accident number versus section length, the actual accident numbers were adjusted to represent the accident number for the average section length at each level. This was a minor adjustment because the range of lengths was not very large.

In a similar manner, the accident number was corrected for the traffic effect. This procedure produced mean accident numbers per cell which was corrected for the section length and traffic effects. At this point, some outliers in the data were identified and removed from further consideration. Student's t tests were then performed for testing the difference in means across cells which varied only with respect to PSI. The individual t tests showed no significant effect of SI in the vast majority of cases, hence an aggregate t test would also show an insignificant effect for SI. However, some trends in the data were apparent as summarized in Table 30.

Table 30. Trends in the Texas Accident Data

Highway Class	ADT Level	Observed Trend
Interstate	to 15,000	Low SI roads have fewer accidents than high SI roads
Interstate	over 15,000	Too little data to show a pattern
Primary	to 15,000	Low SI roads show slightly fewer accidents than high SI roads
Primary	5,000 - 8,000	Medium SI roads tended to have fewer accidents than high SI roads
Primary	over 8,000	Range of ADT too large to permit adjustment to show SI effect, and insufficie data to permit more level of ADT
Secondary	to 700	Slight trend that medium to high SI roads have fewer accidents than low SI roads
Secondary	over 1,000	Low SI roads have fewer accidents than medium and high SI roads

CONCLUSIONS OF THE ACCIDENT ANALYSIS

The analyses in this study suggest that there is a statistically significant relationship between PSI and accidents, but that the relationship is small, and the direction of the relationship depends upon which analysis approach one believes. Tignor and Lindley (Ref 34) in before and after type studies, found that there was no statistically significant relationship between accident rates and pavement improvements, but that the direction is toward increasing accident rates as pavements are improved.

Perhaps the relationship is so small as to be trivial, but we do not believe this to be the case in view of the many billions of miles of vehicle travel on our highways today. In order to find the answers to the relationship it is obvious that a larger and more controlled study will be necessary than that conducted here. The answers sought here should be readily available as states continue to add reliable PSI measurements to their pavement management systems in view of the fact that good accident data is already a part of most state systems.

CHAPTER 6. RUNNING SPEEDS

The speed vehicles attain when traversing various highway elements is of prime importance to economic studies. Vehicle running costs are a direct function of vehicle speed. Differences between proposed highway design elements, such as horizontal curvature, affect users costs through its influence on vehicle speed. Thus, it is desirable to be able to predict the average speed of representative vehicle classes as a function of horizontal curvature, vertical grade, and pavement roughness.

The approach taken for vehicle speeds on this project is to let the average speeds on tangent sections be input by the user. Speed change cycles will be introduced by changes in horizontal and vertical alignment. Guidance for the appropriate speeds on tangents as a function of roughness will be provided.

This literature review highlights the most recent information sources on vehicle speeds. An extensive review of literature on variables influencing spot speed characteristics covering the factors of the driver, vehicle, roadway, traffic, and environment was reported in 1966 by Oppenlander (Ref 35). Perhaps the most complete and up-to-date general reference on vehicle speeds and traffic characteristics is the 1976 edition of Transportation and Traffic Engineering Handbook (Ref 36). A very general source of information on average speeds and distribution of speeds on main rural highways across the United States is the U.S. Department of Transportation's annually published Highway Statistics (Ref. 37).

The discussion of vehicle speeds is divided into sections on the relationship between vehicle speed and horizontal curvature, vertical grade, roughness, and traffic. Current information sources are discussed and recommendations on their use and further development are presented.

HORIZONTAL CURVATURE

In general, vehicles slow down to negotiate sharp horizontal curves. Studies of vehicle operational characteristics around curves have found a wide variation in driver behavior. Vehicle speed profiles vary around curves depending on the driver, vehicle, and road conditions. The average of the minimum speed attained by vehicles traveling around curves, irrespective of where the minimum speed occurs on the curve, is of interest to economic studies. As assumed by Winfrey (Ref 2), this minimum speed is applied to the total length of the curve section with deceleration and acceleration taking place on the adjacent tangent sections.

Using research performed during the mid 1950s and 1960s, (Ref 38, 39, 40, and 41) Winfrey developed Figure 11 of the probable minimum road speed of passenger cars for curves varying in radius from 5,730 to 164 feet (1750 to 50 m). The probable minimum speeds on large radius curves are in excess of 60 mph (96 kph). It would be desirable to know the shape of this curve for highways with lower speed limits, although it is reasonable to assume that when the probable minimum speed on a curve exceeds the average speed or speed limit, that no speed change occurs and the curve can be treated as a tangent.

Emmerson collected speed data on two-lane rural roads in England at sites which lacked other influencing factors such as vertical grades or restricted site distance (Ref 42). The curves studied had radii which ranged from 69 to 1,509 feet (21 to 460 m.). The regression plotted on Figure 11 shows very little influence of curvature on speeds for radii greater than approximately 1000 feet (300 m). The curve levels off at approximately 46 mph (74 kph) for large radius curves.

The most recent investigation into the relationship between horizontal curvature and vehicle speeds conducted in the United States was reported in 1971 by Neuhardt. et. al. (Ref 43). In this study test subjects were instructed to drive an instrumented vehicle over lengths of rural highway under one of the following scenarios:

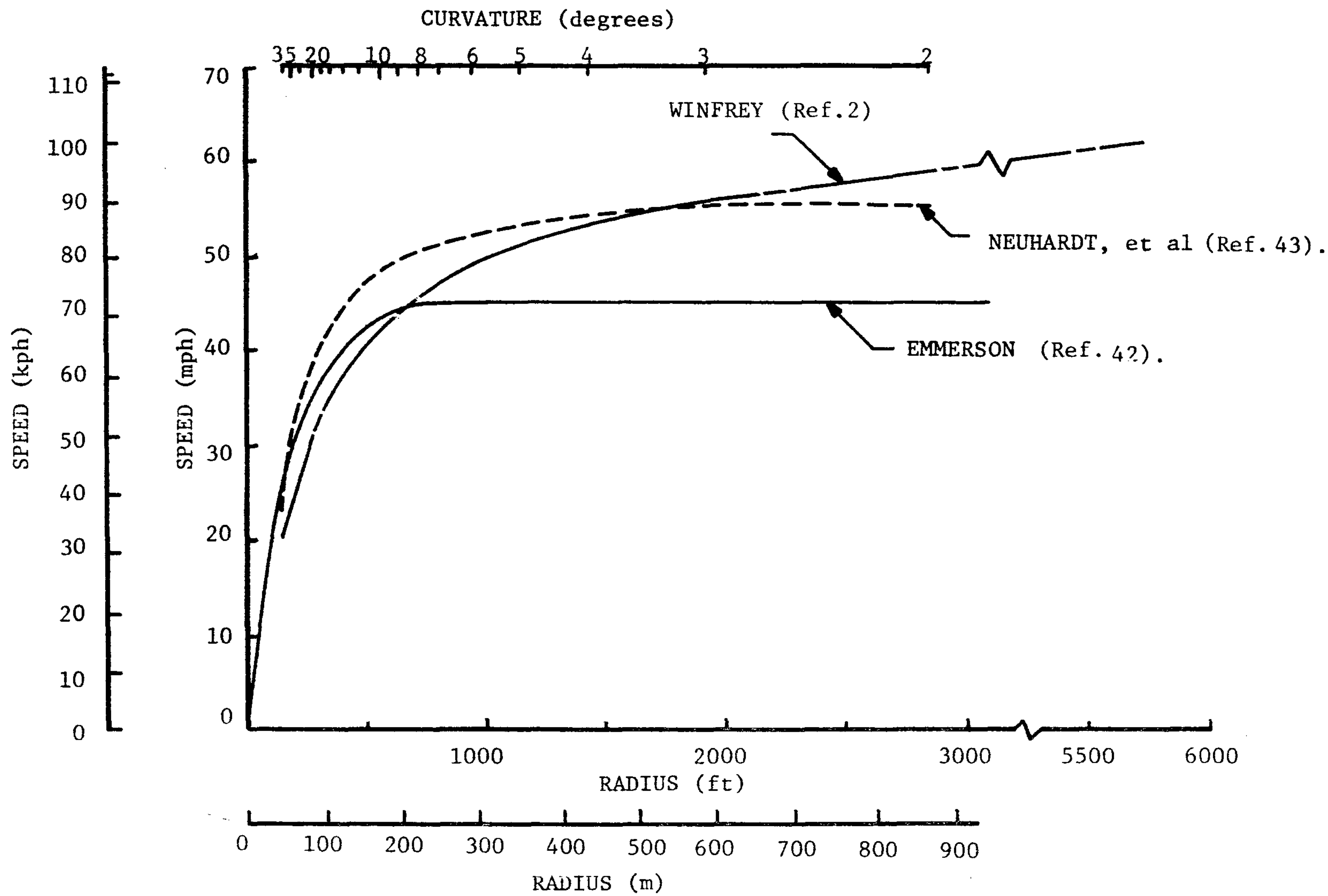


Figure 11 - Comparison of empirical relationships of passenger cars on horizontal curves.

1) Late for an important interview,
2) No instructions-return to start. and
3) A Sunday drive.

A number of test runs were made to incorporate the effect of driver familiarity with the highway sections.

The curve in Figure 11 labeled Neuhardt, et. al., is the regression equation derived from the no-instruction scenario with an intermediate level of familiarity. The dependent variable is the degree of roadway curvature. as shown on the scale at the top of Figure 11 which corresponds to the radius scale at the bottom of the figure. Neuhardt's curve levels out at an approximate radius of 2000 feet (600 m). This study was conducted during the early 1970s and shows an average speed a little greater than 55 mph (88.5 kph) on the lower degree curves.

All of the studies referenced above were conducted in the United States prior to the 1973 adoption of a national speed limit of 55 mph (88.5 kph). This has brought about a reduction in average speeds as well as reducing the variation in speeds. This raises the question of the appropriate threshold value of curvature at which the horizontal curves do not influence vehicle speeds. The Neuhardt, et. al., curve. which had a very low correlation coefficient, levels off 55 mph (88.5 kph) speed even though speed limits were different. The nonlinear curve developed by Emmerson becomes asymtotic at 46 mph (74kph) indicating the data were collected on a road with a 45 mph (72.4 kph) speed limit, but Emmerson did not state the speed limit of the road. The curves by Neuhardt, et. al., and Emmerson predict greater speeds at the lower radius curves than those presented by Winfrey.

VERTICAL GRADES

Vertical grades have a pronounced effect on the speed of trucks. On downgrades up to about 5 percent. trucks show an increase in speed; on grades of about 7 percent and steeper, a decrease in speed is observed (Ref 44). The maximum speed that trucks can maintain on upgrades is dependent primarily on the length, steepness of the grade, and weight to power ratio. Other influencing speeds on vertical grades include entry speed, wind resistance, and operator skill.

Several extensive investigations on truck performance on upgrades have been reported in the literature. Truck speeds on grade were found to exhibit a linear decrease with an increase in length of the grade, until a minimum speed was reached at which trucks complete the vertical rise. This minimum speed is termed the crawl speed.

Recent studies into vehicle performance on grades have centered around developing simulation models (Ref 45, 46). These micro-simulation models were developed primarily to assess the effects on traffic characteristics of various vehicles. These models account for effects of highway geometry, traffic interactions, and vehicle performance.

The most recent information concerning performance of trucks on grade in the United States is contained in NCHRP Report 185 (Ref 45). Speed-distance relations, based on modified SAE performance equations (Ref. 47), with simple approximation for gear shift delays are presented for five trucks using maximum available power in accleration and deceleration. Modification is based on comparisons with the 1969 test data reported in References 48 and 49.

Performance of vehicles on vertical grades was studied extensively in Brazil (Ref 50). The relationships in Figures 12 and 13 shows the crawl speed adopted by drivers on positive grades and speeds achieved on negative grades by vehicle class, respectively. The Brazil regression equations illustrated in these figures incorporates terms for roughness and pavement type (paved-unpaved). Speed changes of various vehicles on positive and negative grades are shown in Figures 14 and 15, respectively. The equations which these curves are based on do not have a term for initial speed. All of these equations are preliminary, revised equations and were developed based on a more extensive data base and analysis and are expected to be available soon.

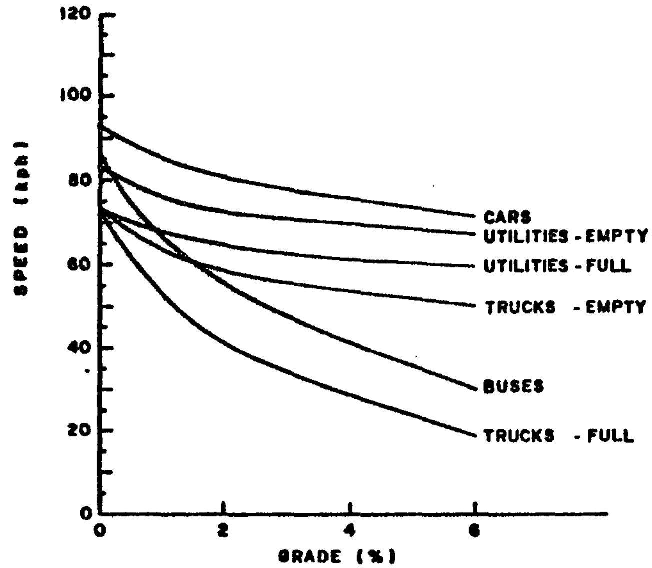


Figure 12 Constant speeds adopted by vehicles on paved highways with a roughness of 30 QI (Ref. 50).

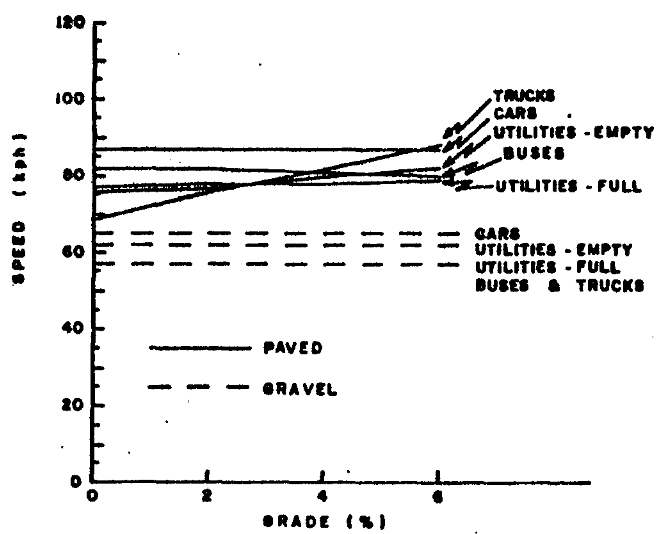


Figure 13 Constant speeds on negative grades with roughness of 30 QI for paved and 80 QI for unpaved (Ref. 50).

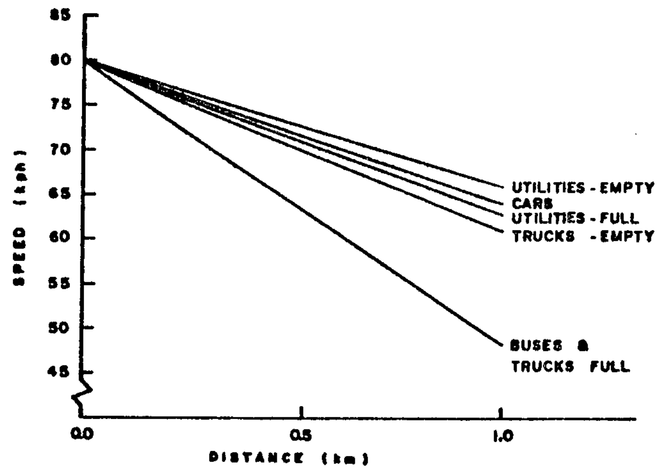


Figure 14- Speed change on +6 percent grades on a paved road with an arbitrary initial speed of 50 mph (80 kph) (Ref. 50).

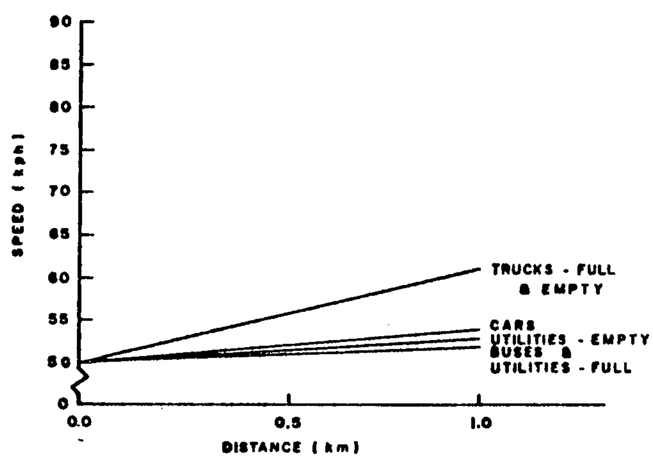


Figure 15- Speed change on a -6 grade on a paved road with an initial speed of 31 mph (50 kph) (Ref. 50).

PAVEMENT TYPE AND CONDITION

Very little research has been conducted into the relationship between pavement roughness and vehicle speed. There have been two principle studies to empirically quantify such a relationship. Karan, et. al. (Ref 51), studied two-lane asphalt concrete county highways in Canada which had both 50 and 60 mph (80 and 96 kph) speed limits. The major study of the interrelationships between costs of highway construction, maintenance, and utilization conducted in Brazil made extensive investigations into this relationship (Ref 50). Measurements in Brazil were performed on paved and unpaved two-lane rural roads with speed limits of 50 mph (80 kph).

Karan, et al., expressed pavement roughness in terms of a riding comfort index (RCI) from correlations with BPR roughometer measurements. The riding comfort index scale ranges from 10 for pavements in perfect condition to 0 for pavements in the poorest condition. It is common practice to assume that an RCI value is roughly twice a corresponding value on the present serviceability index (PSI) scale used in the United States.

Two of the regression equations presented by Karan, et. al., are plotted on Figure 16 showing the effects of the volume-capacity and speed limit. These equations characteristically approach the speed limit at the maximum RCI value of 10. The data indicates that a significant number of drivers exceed the speed limits on the county roads. The authors attributed speeding to lack of enforcement. Apparently, the equations were developed so that they would not greatly exceed the speed limit.

Additional work was performed to relate the QI to the present serviceability index (PSI). Of particular interest is the correlation between QI and output of a BPR roughometer. This will allow comparison of the relationships developed by Karan, et al., in Canada through the outputs of the BPR roughometer.

This effect of pavement roughness on vehicle speeds from the Brazil study is shown in the equations for vehicle free speeds on grades (Ref

No.	Regression Equation (Ref. 50)
①	$y = 2.596 \left(x_1^{.0928}\right)\left(x_2^{-.0275}\right)\left(x_3^{.704}\right)$
②	$y = 30.7368 + 1.0375x_1 - 11.2421x_2 + .0062x_3^2$

y = Avg. speed, kph x_2 = volume/capacity ratio

x_1 = Riding Comfort Index x_3 = speed limit, kph

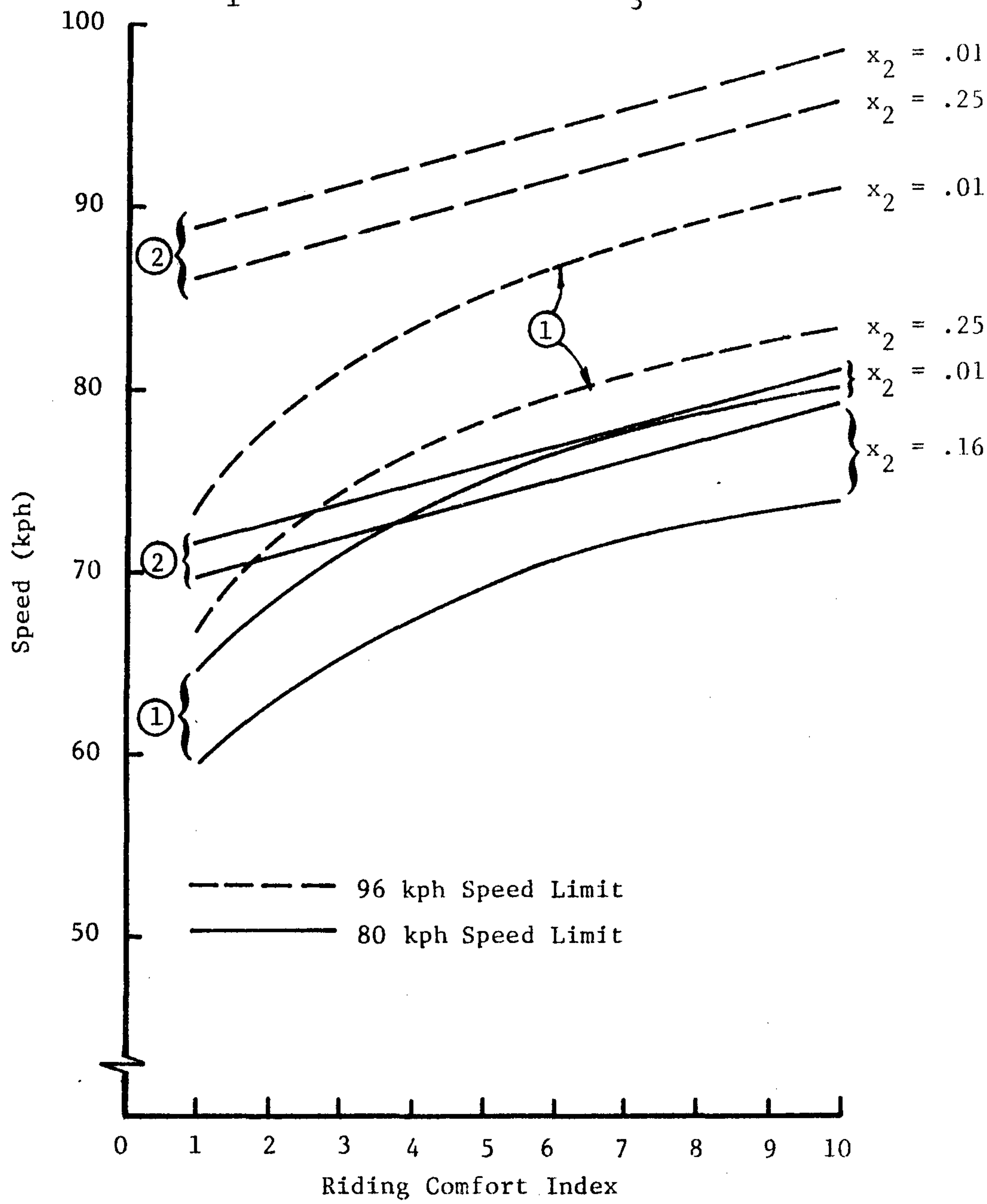


Figure 16 – Comparison of regression equations based on combined speed limit data reported by Karan, et al (Ref. 51).

50). The equations developed for speeds on positive and negative grades on paved roads are plotted in Figure 17 for zero grade. In general, roughness exhibited a greater influence on speed on negative grades. On positive grades. roughness was found to exert a greater influence on the speed of cars than on trucks or buses. The maximum value of QI on the abscissa in Figure 17 represents a very rough unpaved section. Typical values for paved roads were in the 30 to 90 counts/km range.

There have not been any studies of the effect of pavement type on operating speed, except for the Brazil and Kenya studies which included paved and gravel roads. The FHWA developed a methodology for distinguishing between pavement types and condition for use in the Highway Performance Monitoring System, HPMS (Ref 52). In this procedure. a speed adjustment factor, F_s, is computed as:

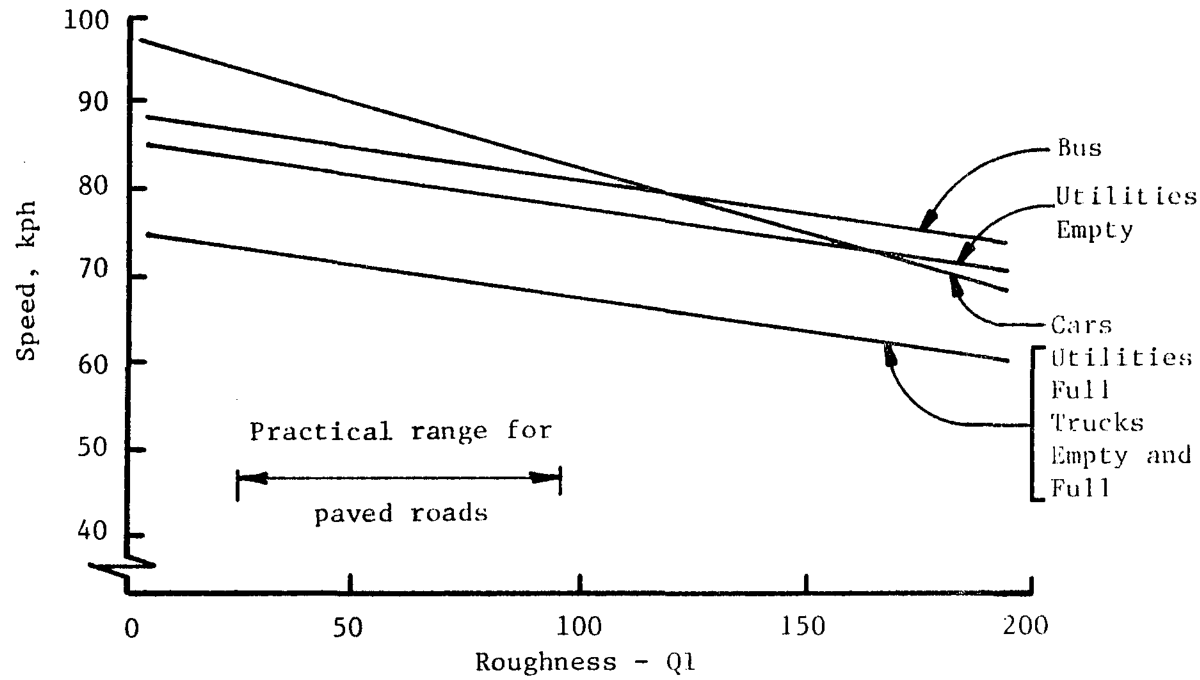
$$F_1 = G(PSR)^a \ (1 + H(ARS-35)) - H(ARS-35)$$

Where:

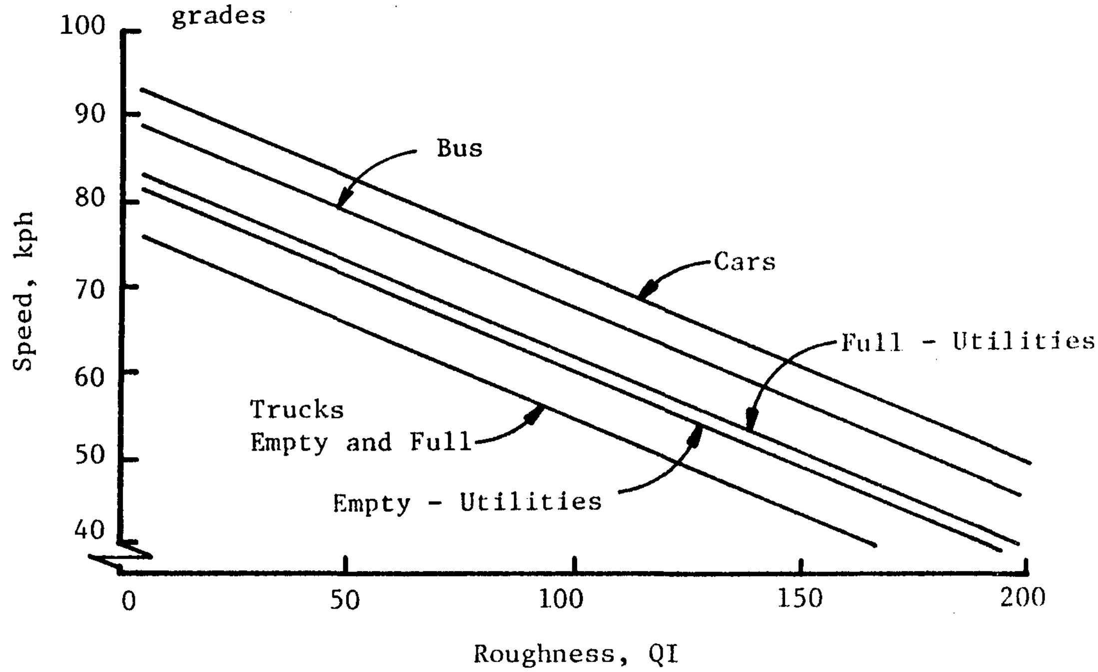
F_1 = speed adjustment factor
G = 0.8613
PSR = present serviceability rating
a = 0.0928
H = rate of change in Root Mean Square (RMS) vertical acceleration per unit change in speed, MPH
ARS = average running speed

This equation was developed in three distinct steps. First was the development of the "pure roughness" term, by defining the variables G and a. The highway and pavement type term, H, was then developed. Finally, the equation was modified to decrease the influence of roughness for low initial operating speeds.

1. The Karan equation was converted from Ride Comfort Index and kilometers per hour to PSR and miles per hour.



a) Regression equation developed for constant speed on positive grades



b) Regression equation developed for constant speed on negative grades

Figure 17 - Effect of pavement roughness on vehicle speed in Brazil, based on regression equations for constant speeds on grades, grade term set to zero. (Ref. 50)

2. The volume to capacity ratio and the speed limit terms were fixed at 0.10 and 50 mph. respectively.

3. G was then defined as the ratio of the speed predicted for PSR=1 to the speed predicted for PSR=5.

This was a relatively straightforward transformation of the Karan equation into a form readily usable by the FHWA. The formulation of the equation makes the choice of the levels for the volume to capacity and speed limit terms immaterial since these terms always cancel out, i.e. :

$$G = 1/(5)^{0.0028} = 0.8613.$$

There were no data to support the development of highway and pavement type factors. Therefore, Hazen (Ref 52) made use of some limited information from the United Kingdom by the Transportation and Road Research Laboratory (Ref 53 and 54) to hypothesize a relationship between highway and pavement types and operating speed. The TRRL reports describe a Root Mean Square RMS, vertical acceleration statistic which demonstrated the following properties:

1. RMS vertical acceleration is related to roughness and road uneveness.

2. For a given road section, RMS vertical acceleration increases linearly with speed.

3. The rate of change in RMS vertical acceleration as speed increases is greater on asphalt pavements than on concrete pavements by a factor of about two.

Based on these observations, Hazen elected to generate highway type and condition adjustment factors as follows:

Therefore, it was found most practical to use the British research findings to represent the likely change in the combination of pavement type and condition, highway geometrics, and access control as follows:

1. For interstate, freeway, and expressway highways, the basic relationship contained in equation 5 (the transformed Karan equation) is used to modify speed.

2. For non-freeways with high type pavements, no distinction can be made with confidence between rigid and flexible pavements. As speed increases and roughness increases, the increased RMS vertical acceleration on concrete pavements will be used to modify equation 5 (the transformed Karan equation).

3. For non-freeway highways with intermediate and low type pavements, as speed increases and roughness increases, the RMS vertical acceleration wil be used to modify the basic relationship. The pavement structure with a depth less than seven in. cannot resist surface deterioration.

Based on measured RSM vertical acceleration for different pavement types, Hazen assigned the following values of H for highway and pavement types:

For ARS less than 35 mph, H = 0.05 for all highways and pavement types.

For ARS greater than or equal to 35 mph, H = 0 for interstates, freeways, and expressways. H = 0.0065 for non-freeway highways with high type flexible and rigid pavements. H = 0.013 for intermediate and low type pavements.

The 35 mph pivot point for the equation represents a somewhat arbitrary selection of a speed where the influence of pavement roughness on speed diminishes. This is a logical concept, but there is no data to support the selection of a particular value. However, in Hazen's formulation of the problem, the 35 mph pivot point for the equation generates speed modification factors at 35 mph on intermediate and low pavement types which are equal to the factors generated for interstate roads, where the average running speed is much greater.

Several of the assumptions made in the development of the equation appear to be contradictory to the research findings, including:

1. The Karan, et al. study was performed on two-lane rural roads. Therefore, it seems inappropriate to accept this relationship for limited access and multi-lane roads and modify it for non-freeway highway types.

2. The TRRL data were collected on dual-carriageway (multi-lane - divided) roadways. Presumably these were high-type pavements. Assuming that the RMS vertical acceleration data does not apply to high-type pavements but does apply to a difference between high-type versus low and intermediate pavement types does not appear logical.

3. Modification of the operating speed with both PSR and RMS vertical acceleration is double accounting since both variables are measures of road roughness or unevenness. The fact that roughness measurements on rigid and flexible pavements have different serviceability interpretations is well-known and has been established in many studies. With respect to operating speed, serviceability is the prefered roughness statistic since, by definition, serviceability is a measure of the user's opinion of the road.

4. The assignment of values of a rate of change RMS vertical acceleration per unit change in speed to pavement types is erroneous. This statistic is a measure of the vehicle's response to an input signal generated by the surface profile. To assign a value of RMS vertical acceleration to a pavement type, denies that differences in pavement profile exist.

5. Separating roadway types into freeway and non-freeway types is not within the scope of a pavement type and condition factor. Difference in operating speeds due to roadway type, number of lanes, access control, etc. are included in the calculation of the initial average running speed.

Even though the report by Hazen makes a good attempt at getting the most value from limited data, use of the RMS vertical acceleration concept for adjusting speeds does not seem warranted without further research. On the other hand, Hazen's transformation of the equation generated by Karan et al. does appear to be useful and valid. Since this equation was generated for rural roads with speed limits of 50 and 55 mph, use of the equation for high speed facilities appears warranted.

Although there is no data to support the reduction of the influence of pavement condition at low speeds, the probability that this influence does exist is strong enough that some assumption in this area appears reasonable. The approach recommended is to linearly reduce the influence of the roughness term from 35 to 15 mph, assuming surface condition does not influence speed when the inital speed is less than 15 mph. Thus, the transformed Karan equation is modified as:

$ARS' = ARS * F$

For ARS greater than or equal to 35 mph,

$F = 0.0.8613\ (PSR)^{0.0928}$

For ARS between 15 and 35 mph,

$F = 0.8613\ (PSR)^{0.0928}$
$+ (1 - 0.8613(PSR)^{0.0928})\ (35 - ARS)/20$

For ARS less than 15 mph,

$F = 1$

The factors which are generated by this equation are shown in Table 31.

TRAFFIC

Traffic has a major effect on vehicle operating speeds. As traffic volume on a road increases, vehicle speeds decrease. When the capacity of the road is approached vehicle operations become intermittant. The 1965 Highway Capacity Manual (Ref 55) summarizes research to that date and presents typical speed-volume curves for various types of highways. One of the most recent sources of speed-volume relationships for various types of roads is contained in the Highway Investment Analysis Package User's

Table 31. Speed adjustment factors for surface conditions.

PSR	F				
	ARS > 35	ARS = 30	ARS = 25	ARS = 20	ARS < 15
1.0	0.86	0.90	0.93	0.97	1.0
1.5	0.89	0.92	0.95	0.97	1.0
2.0	0.97	0.94	0.96	0.98	1.0
2.5	0.94	0.95	0.97	0.98	1.0
3.0	0.95	0.97	0.98	0.99	1.0
3.5	0.97	0.98	0.98	0.99	1.0
4.0	0.98	0.98	0.99	0.99	1.0
4.5	0.99	0.99	1.00	1.00	1.0
5.0	1.0	1.0	1.0	1.0	1.0

Guide (Ref 56). These curves are drawn from the Federal Highway Administration's highway users study (Ref 57) and are based, in part, on the Highway Capacity Manual.

SUMMARY OF RUNNING SPEED LITERATURE

Speed studies reported in the literature have several limiting factors for use in determining speed relationships which model the current vehicle population. Investigations were typically performed for one vehicle class. For instance. horizontal curve speed studies were performed primarily on passenger cars, whereas, vertical grade speed studies have characteristically investigated large trucks. There is only limited information in the current literature upon which to derive relationships for all vehicle classes.

Another problem in the use of speed studies is the change in vehicle and operating conditions with time. Some of the information on which speed relationships are based was collected over 20 years ago. The adoption of the national 55 mph (88.5 kph) speed limit also introduces an uncertainty to the adoption of some of the previous studies.

CHAPTER 7. SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

SUMMARY

The determination of the influence of roadway conditions on vehicle operating costs, emissions, and accident rates is a very difficult task. The only component of vehicle operating cost which can be measured directly in experiments is fuel consumption. Allocation of the other components of vehicle operating costs must be done based on theory, logic, and judgement.

In terms of new contributions to the state of the art, this research produced significant advances in four areas. The experiments conducted during this research provide valuable new evidence on the effect of roadway characteristics on fuel consumption. The successful application of the slip-energy model for predicting tire wear provides a basis for updating tire costs in a judicious manner; as new tire technology is developed, this theory can be applied if two parameters are experimentally established. Similarly, the application of Daniel's theory on vehicle depreciation to the data collected by the U.S. Census Bureau establish a rational basis for computing depreciation costs. Finally, the assembly and analysis of a data base on the effect of roadway roughness on accident rates demonstrated that, in general, there is no significant relationship between pavement condition and accident rates.

Winfrey's original allocation of oil and maintenance and repair costs were updated with current price data. In addition, the procedures used for allocating these costs have been more completely documented so that these costs can be readily updated in the future.

Finally, new evidence from Brazil has been applied to quantify the influence of pavement condition on the non-fuel components of vehicle operating costs. The primary data base generated in Brazil is the first hard evidence of the interrelationship between vehicle operating costs and roadway characteristics.

TECHNIQUES FOR UPDATING COST TABLES

Due to changes in technology and costs, the total vehicle operating cost tables presented in this report will become dated. Therefore, considerations were given to updating the cost tables. If the cost tables become dated due to changes in unit prices, then the consumption tables given in Appendix B can be used to generate new total cost tables. However, this will require a lot of work due to the number of calculations required. If the change in prices is due to pure inflation, i.e., uniform increase in prices, then the costs in Appendix A can be updated by applying an inflation factor.

A quick method of updating the cost tables when there are differential changes in the unit prices could be developed by performing a sensitivity analysis on the tables with respect to how changes in the unit price of a component affect the total costs. From this analysis, weighting factors could be developed such that differential changes in unit prices could be appropriately incorporated in generating new operating cost tables from those presented in this report.

Changes in vehicle technology can have a major influence on how costs are assigned to the roadway. Generally, this will require regenerating the consumption tables as given in Appendix B. The approach described in this report provides a basis for estimating how the components of vehicle operating can be assigned to roadway characteristics.

In some cases, it may be desirable to use different vehicle types than included in this report. In these cases, the basic methodology used in this project can be used to allocate costs to new classes. New vehicle types will normally vary from the types reported herein by either having different weights, different motor types (gasoline or diesel), or a combination. If the only difference is the weights, then the ratio of horsepower for the new vehicle type to the existing type may be used to estimate the consumption rates from those in Appendix B. If the new vehicle type has a different fuel type, then the following considerations should be applied:

1. Fuel - The most important consideration in extrapolating fuel costs to different vehicle types is the type of fuel used, gasoline or diesel. In general, diesel motors get in the range of 40% to 80% better fuel economy than gasoline motors used in the same application. Differences in fuel economy between gasoline and diesel vehicles were examined in detail in the Interim Report. Based on this information, Table 32 was compiled for estimating the differences in fuel consumption between gasoline and diesel motors for equivalent applications.

2. Oil - Since oil consumption is a relatively small cost factor, using the ratio of the mileage between oil changes for a different vehicle class to the mileage between oil changes for the vehicle in this report which is similar to the new vehicle type, will be adequate for updating oil consumption.

3. Tires - The slip-energy theory can be used for estimating tire wear for any vehicle types.

4. Maintenance and Repair - It is known that on the average, maintenance and repair costs are lower for diesel powered vehicles than gasoline powered vehicles. Winfrey's cost tables (Ref 2) indicated that this factor may be 8% for semi-trucks. However, this number should be used with caution.

5. Depreciation - Diesel powered vehicles, especially trucks, generally have a longer service life than gasoline powered vehicles. This difference can be offset by using different maintenance schedules for the two vehicle types. In view of the lack of data for estimating different service lives based on motor types, and the complication generated by maintenance costs, no recommendations can be made for a differential use-related depreciation schedule for gasoline versus diesel powered vehicles.

Table 32. Factors for estimating the differences in fuel economy for gasoline and diesel vehicles.

Vehicle Type	Gasoline Consumption / Diesel Consumption (gpm)
Automobiles	
Small	1.38
Medium	1.72
Large	1.72
Trucks	
Pickup	1.39
Single Unit	1.50
Semi's	1.4 to 1.8

RECOMMENDATIONS

Although significant progress has been made on this research toward the correct allocation of vehicle operating costs across the various roadway characteristics, the greatest single improvement in the allocation procedure could be achieved through a detailed study of vehicle operational parameters. Little information is available to quantify the percent of time. or distance traveled, that is spent in the various modes of operation, and at particular operating speeds. This information is important for allocating all of the non-fuel cost components.

In this research, the effect of pavement condition on the cost of the non-fuel components was allocated based primarily on research performed in Brazil where extreme roughness conditions existed. However, the fuel experiments in this research did not substantiate the effect of roughness on fuel consumption which was defined in Brazil. Thus, the question of the transferability of the Brazil data to the United States is raised.

The emissions models used in this research are based on the best available information. However, the automobile emissions models were published in 1974, and the truck emissions data were not collected to be modeled in the manner used in this research. Hence, new data should be collected to improve the reliability of the estimates made in this research.

The accident analysis performed in this research was based on the best available data. However, since these data were not originally collected for the type of analysis which was performed, the level confidence of the results could be improved by a more in-depth data collection effort.

CONCLUSIONS

Aside from the updating of the vehicle operating cost tables for economic analysis, several significant results were established in this research:

1. Fuel consumption is not influenced by the type or condition of paved roads for the range of conditions commonly encountered in the United States.

2. Non-fuel vehicle operating costs are influenced by pavement condition.

3. The slip-energy model can be used to estimate tire wear as a function of vehicle, roadway, and operational characteristics.

4. Daniel's theory on the separation of vehicle depreciation into use and non-use portions is reasonable and can be applied to existing data.

5. Accident rates are not significantly influenced by pavement condition for the data set analyzed.

REFERENCES

1. Claffey, P.J. and Associates, "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," NCHRP Report 111, Highway Research Board, National Research Council, Division of Engineering, 1971.

2. Winfrey, R., Economic Analysis for Highways, Scranton, Pennsylvania: International Textbook Co., 1969.

3. Zaniewski, J.P., B.C. Butler, Jr., G. Cunningham, G.E. Elkins, and R. Machemehl, "Vehicle Operation Costs, Fuel Consumption, and Pavement Type and Condition Factors," Interim Report, prepared for Federal Highway Administration, June 1980.

4. Daniels, C., Vehicle Operating Costs in Transportation Studies, E.S.U. Technical Series No. 1, London: Spencer House, 1974.

5. Kunselman, P., H.T. McAdams, C.J. Domke, and M.E. Williams, "Automobiles Exhaust Emission Modal Analysis," EPA-460/3-74-005, Calspan Corporation, under contract to U.S. Environmental Protection Agency, Ann Arbor, Michigan, January 1974.

6. Ingalls, M.N. and K.J. Springer, "In-Use Heavy-Duty Gasoline Truck Emissions, Part I: Mass Emissions from Trucks Operated Over a Road Course," EPA-460/3-73-002-b, Southwest Research Institute under contract to U.S. Environmental Protection Agency, Ann Arbor, Michigan, February 1973.

7. Monthly Energy Review, Energy Information Administration, U.S. Department of Energy, Washington, D.C., December 1981.

8. Ullman, J.E., Cost of Owning and Operating Automobiles and Vans, U.S. Department of Transportation, Washington, D.C., 1980.

9. "1214D/1228 In Vehicle Diesel Fuel Economy Measurement System," Fluidyne Instrumentation, 2930 Lakeshore Ave., Oakland, CA, February 1978.

10. "Computerized Road Test System," Lamar Instruments, 2107 Artesia Blvd., Redondo Beach, CA.

11. France, C., "Fuel Economy of Heavy Duty Vehicles," Environmental Protection Agency, Ann Arbor, Michigan, September 1976.

12. Zaniewski, J.P., B.K. Moser, P.J. de Morais, and R.L. Kaesehagen, "Fuel Consumption Related to Vehicle Type and Road Conditions," Transportation Research Record 702, Transportation Research Board, National Academy of Sciences.

13. Hide, H., "An Improved Data Base for Estimating Vehicle Operating Costs in Developing Countries," TRRL Supplementary Report 223 UC, Transport and Road Research Laboratory, Department of the Environment.

14. Ross, F.R., "The Effect of Pavement Roughness on Vehicle Fuel Consumption," Research Unit, Materials Section, Division of Highways and Transportation Facilities, Wisconsin Department of Transportation, June 1981.

15. "Truck Inventory and Use Survey," Census of Transportation, Bureau of Census, Department of Commerce, 1977.

16. Harrison, R. and J.D. Swait, Jr., "Relating Vehicle Use to Highway Characteristics: Evidence from Brazil," Economic and Social Aspects of Transportation, Transportation Research Record 747, Transportation Research Board, Washington, D.C., 1980.

17. Butler, B.C., Jr., J.T. de Carvalho, and W.R. Hudson, "Relating Vehicle Operating Costs to Low Volume Road Parameters in Brazil," paper prepared for the Second International Conference on Low Volume Roads, Ames, Iowa, 1979.

18. Cheser, A., R. Harrison, and J.D. Swait, "Vehicle Depreciation and Interest Costs: Some Evidence from Brazil," paper delivered to the World Conference on Transportation Research, London, England, April 1980.

19. Zaniewski, J.P., B.K. Moser, and J.D. Swait, "Predicting Travel Time and Fuel Consumption for Vehicles on Low Volume Roads," paper prepared for the Second International Conference on Low Volume Roads, Ames, Iowa, 1979.

20. American Association of State Highway and Transportation Officials, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements 1977, Washington, D.C., 1978.

21. Curry, D.A. and D.G. Anderson, "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects," NCHRP Report 133, Washington, D.C., 1972.

22. Barreire, W., T.E. Smith, and H.C. Hodges, "Transportation Cost Study, Tire Wear Test," Draft Final Report, U.S. Department of Agriculture, Forest Service, 1974.

23. Della-Moretta, L., "Relating Operational Variables to Tire Wear," International Society for Terrain Vehicle Systems," Regional Meeting, Carson City, Nevada, October 1974.

24. Hodges, H.C. and K.D. Koch, "Tire Tread Wear Validation, Volume 1: Technical Report," Final Report DOT HS-804 792, National Highway Traffic Safety Administration, April 1979.

25. Jones, D. and L. Della-Moretta, "Truck Tire Wear Rates on Open-Vs. Dense-Graded Asphalt Pavement," No. 7977 1210, U.S. Department of Agriculture, Forest Service, November 1979.

26. Brenner, F.C., A. Kondo, and F.W. Burton, "Establishment and Calibration of a Tread Wear Test Course," Tire and Science Technology, T.S.T.C.A., Vol. 3, No. 3, August 1975, pp. 164-188.

27. Nepsund, L.P., "Data Resources," City of Los Angeles, Department of Transportation, September 1979.

28. Cax, T.P., et al., "1969 Heavy Duty Engine Baseline Program and 1983 Emission Standards Development," Technical Report. Office of Mobile Source Air Pollution Control, U.S. Environmental Protection Agency, Ann Arbor, Michigan, May 1979.

29. Ingalls, M.N. and K.J. Springer, "Summary and Comparison of Mass Emissions for All Gasoline and Diesel Powered Trucks Tested on the San Antonio Road Route," Southwest Research Institute, under contract to U.S. Environmental Protection Agency, Ann Arbor, Michigan, March 1975.

30. Motor Vehicle Manufacturers Assoc., "MVMA Motor Vehicle Facts and Figures," MVMA, 300 New Center Bldg., Detroit, Michigan, 48202, years 1975, 1977, and 1979.

31. "Mays Ride Meter Booklet," 3rd Edition, Rainhart Co., Austin, Texas, 1973, 23 pp.

32. Walker, R.S. and W.R. Hudson, "Use of Profile Wave Amplitude Estimates for Pavement Serviceability Measures, Highway Research Record 471, 1973, pp. 110-117.

33. Spangler, E.B. and W.J. Kelley, "GMR Road Profilometer-A Method for Measuring Road Profile," Highway Research Record 121, 1966, pp. 27-54.

34. Tignor, S.C. and J.A. Lindley, "Accident Rates on Two-Lane Rural Highways Before and After Resurfacing," Public Roads, Vol. 44, No. 4.

35. Oppenlander, J.G., "Variables Influencing Spot-Speed Characteristics Review of Literature," Special Report 89, NAS-NRC Publication 1332, Highway Research Board, 1966.

36. Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers, Prentice-Hall, 1976.

37. "Highway Statistics-Summary to 1975," U.S. Department of Transportation, Federal Highway Administration, 1975.

38. Taragin, A., "Driver Performance on Horizontal Curves," Proceedings, Highway Research Board, Vol. 33, 1954.

39. Bezkorovainy, G., "Effects of Advisory Speed Limits at Horizontal Curves of Two-Lane Rural Highways," Traffic Engineering Series Report No. 17R, Department of Civil Engineering, University of Illinois, December 1964.

40. Ku, C., "Driver Characteristics Correlated with Speeds Observed on Horizontal Curves of Two-Lane Rural Highways," Traffic Engineering, University of Illinois, 1965.

41. Reeder, E.J., "Critical Speeds on Highway Curves," Highway Research Abstracts, No. 19, April 1935.

42. Emmerson, J., "Speeds of Cars on Sharp Horizontal Curves," Traffic Engineering Control, Vol. 11, No. 3, 1969.

43. Neuhardt, J.B., G.D. Herrin, and T.H. Rockwell, "Demonstration of a Test-Driver Technique to Assess the Effects of Roadway Geometrics and Development on Speed Selection," Project 326B, Ohio State University, Systems Research Group, 1971.

44. A Policy on Geometric Design of Rural Highways - 1965, American Association of State Highway Officials, 1967.

45. St. John, A.D. and D.R. Kobett, "Grade Effects on Traffic Flow Stability and Capacity," National Cooperative Highway Research Program Report 185, Transportation Research Board, 1978.

46. Botha, J.L. and A.D. May, "A Decision-Making Framework for the Evaluation of Climbing Lanes on Two-Lane Two-Way Rural Roads, Preliminary Evaluation of Candidate Models for Use in the Project," Working Paper UCB-ITS-WP-78-12, Institute of Transportation Studies, University of California, 1978.

47. "Truck Ability Prediction Procedure - J688," SAE Handbook Supplement 82, Society of Automotive Engineers, 1965.

48. "Horsepower Considerations for Trucks and Truck Combinations, 1969, Acceleration Tests", Supplement No. 1, Research Committee Report No. 2, Western Highway Institute, 1970.

49. Everall, P.F., "Social Benefits from Minimum Power-Weight Ratios for Goods Vehicles," Road Research Laboratory Report LR291, Ministry of Transport, 1969.

50. Zaniewski, J.P., B.K. Moser, and J.D. Swait, "Predicting Travel Time and Fuel Consumption for Vehicles on Low-Volume Roads," Transportation Research Record 702, TRB, 1979.

51. Karan, M.A., R. Haas, and R. Kher, "Effects of Pavement Roughness on Vehicle Speeds," Transportation Research Record 602, NAS, Washington, 1976.

52. Hazen, P.I., "Speed and Pavement Condition Relationship," Highway Performance Monitoring System, Technical Report No. 4, February 1980.

53. Cooper, D.R.C., P.G. Jordan, and J.C. Young, "Road Surface Irregularities and Vehicle Ride: Part 1, Verification and Interpretation of Ride Measurements," Transport and Road Research Laboratory, Supplementary Report 341, Great Britain, 1978.

54. Cooper, D.R.C., and J.C. Young, "Road Surface Irregularity and Vehicle Ride: Part 2 - Riding Comfort in Cars Driven by the Public," Transport and Road Research Laboratory, Supplementary Report 400, Great Britain, 1978.

55. Highway Capacity Manual, Special Report 87, Highway Research Board, National Academy of Sciences, National Research Council, Publication 1328, 1965.

56. Juster, R. D. and J. H. Batchelder, "Highway Investment Analysis Package (HIAP) Volume: Users Guide," Federal Highway Administration, March 1976.

57. Gruver, J. E., "Highway User Investment Study," Transportation Research Record No. 490, Transportation Research Board, 1974.

58. Drew, D.R., "Traffic Flow Theory and Control," McGraw-Hill Book Co., 1968.

59. Heorner, S.F., "Fluid-Dynamic Drag," Midland Park, N.J., 1958.

60. White, R.A. and H.H. Korst, "The Determination of Vehicle Drag Contributions from Coast Down Tests," Paper 720099, SAE Automotive Engineering Congress, 1972.

61. "Horsepower Considerations for Trucks and Truck Combinations," Western Highway Institute, Second Edition, February 1978.

62. Anderson, V.W., V.C. Firey, and W.C. Kieling, "Road Resistance of Large Transport Trucks," Highway Research Record 49, 1964.

63. Holmes, K. E. and R. D. Stone, "Tyre Forces as Functions of Cornering and Braking Slip on Wet Road Surfaces," LR254, Road Research Laboratory, 1969.

APPENDIX A. VEHICLES OPERATING COST TABLES

The following table indicates the table numbers of the vehicle operating cost tables presented in this appendix. For operating cost at constant speed, the tables are arranged by vehicle type and serviceability index of the highway. The table numbers for excess vehicle operating cost for speed change cycles and on horizontal curves are arranged by vehicle only.

	SI	Vehicle Class							
		Automobiles			Trucks				
		Small	Medium	Large	Pickup	2A SU	3A SU	2-S2	3-S2
Constant Speed	4.5	1	2	3	4	5	6	7	8
	4.0	9	10	11	12	13	14	15	16
	3.5	17	18	19	20	21	22	23	24
	3.0	25	26	27	28	29	30	31	32
	2.5	33	34	35	36	37	38	39	40
	2.0	41	42	43	44	45	46	47	48
	1.5	49	50	51	52	53	54	55	56
	1.0	57	58	59	60	61	62	63	64
Speed change cycles		65	66	67	68	69	70	71	72
Horizontal Curves		73	74	75	76	77	78	79	80

TABLE A. 1 Total cost at constant speed on grades - small automobile - SI = 4.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	271.	230.	189.	166.	153.	141.	142.	142.	141.	140.	144.	150.	156.	164.
7	262.	223.	172.	158.	146.	134.	134.	134.	133.	132.	135.	140.	147.	156.
6	253.	217.	167.	154.	143.	131.	129.	128.	128.	128.	130.	134.	140.	148.
5	245.	210.	165.	150.	140.	128.	126.	125.	125.	124.	126.	129.	135.	142.
4	235.	205.	168.	145.	136.	124.	123.	122.	121.	120.	122.	126.	130.	135.
3	225.	198.	169.	142.	133.	122.	120.	119.	118.	118.	119.	121.	125.	130.
2	216.	191.	164.	138.	129.	118.	116.	114.	114.	112.	114.	116.	120.	124.
1	204.	183.	157.	134.	123.	111.	110.	109.	107.	105.	107.	110.	114.	118.
0	194.	173.	148.	126.	115.	108.	104.	101.	101.	100.	100.	103.	107.	113.
-1	183.	165.	139.	116.	107.	99.	99.	99.	97.	94.	95.	98.	102.	107.
-2	173.	154.	127.	106.	96.	95.	96.	96.	93.	90.	91.	94.	96.	100.
-3	176.	155.	131.	110.	101.	92.	90.	87.	91.	87.	88.	90.	93.	97.
-4	184.	160.	137.	118.	108.	99.	96.	93.	86.	78.	86.	87.	91.	94.
-5	194.	167.	145.	127.	116.	106.	103.	99.	92.	83.	80.	78.	88.	92.
-6	206.	178.	154.	135.	124.	114.	110.	105.	97.	89.	86.	84.	82.	90.
-7	220.	189.	163.	143.	132.	122.	117.	113.	104.	95.	92.	89.	87.	85.
-8	234.	200.	172.	150.	140.	130.	125.	120.	110.	101.	97.	95.	93.	91.

TABLE A. 2 Total cost at constant speed on grades - medium automobile - SI = 4.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	271.	234.	209.	191.	186.	182.	183.	187.	191.	194.	205.	215.	219.	225.
7	254.	220.	197.	180.	175.	169.	169.	172.	177.	181.	193.	204.	208.	214.
6	241.	210.	188.	172.	166.	160.	159.	162.	167.	171.	183.	194.	198.	204.
5	230.	201.	180.	166.	159.	153.	152.	154.	159.	163.	173.	182.	188.	196.
4	222.	195.	176.	161.	154.	148.	146.	148.	152.	155.	162.	168.	178.	189.
3	213.	189.	170.	156.	149.	143.	142.	143.	146.	148.	152.	156.	168.	181.
2	203.	181.	163.	148.	143.	137.	136.	137.	139.	140.	144.	147.	159.	173.
1	189.	169.	152.	138.	134.	129.	126.	125.	128.	130.	135.	138.	148.	159.
0	175.	158.	141.	126.	122.	118.	114.	114.	116.	119.	126.	131.	138.	146.
-1	171.	154.	135.	117.	113.	108.	107.	108.	109.	110.	117.	122.	129.	137.
-2	167.	150.	128.	108.	100.	100.	100.	102.	103.	103.	108.	113.	121.	130.
-3	179.	160.	136.	115.	106.	96.	92.	89.	98.	99.	103.	107.	115.	124.
-4	195.	173.	148.	125.	115.	104.	97.	93.	91.	88.	99.	103.	110.	117.
-5	210.	186.	159.	136.	125.	113.	104.	98.	96.	94.	93.	92.	105.	111.
-6	226.	199.	171.	147.	135.	123.	112.	105.	103.	100.	105.	98.	97.	105.
-7	242.	213.	182.	157.	145.	132.	121.	113.	110.	106.	105.	102.	101.	100.
-8	258.	226.	194.	168.	155.	142.	130.	122.	117.	113.	110.	107.	105.	103.

TABLE A. 3 Total cost at constant speed on grades - large automobile - SI = 4.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	266.	230.	211.	201.	196.	193.	195.	198.	221.	243.	243.	246.	281.	318.
7	258.	224.	206.	196.	190.	185.	187.	189.	203.	217.	220.	225.	247.	270.
6	250.	218.	201.	192.	184.	177.	179.	181.	188.	194.	198.	205.	222.	239.
5	241.	212.	196.	186.	178.	171.	172.	173.	176.	180.	184.	191.	201.	213.
4	233.	207.	190.	180.	171.	163.	163.	164.	165.	166.	170.	177.	185.	194.
3	224.	200.	184.	174.	163.	153.	154.	155.	154.	154.	159.	165.	172.	180.
2	214.	193.	176.	165.	153.	142.	144.	146.	145.	145.	149.	154.	162.	170.
1	199.	180.	164.	153.	142.	132.	134.	136.	136.	137.	140.	145.	153.	161.
0	180.	164.	147.	134.	128.	124.	124.	125.	127.	130.	134.	139.	147.	155.
-1	177.	161.	140.	122.	120.	119.	118.	118.	121.	126.	129.	135.	143.	152.
-2	172.	155.	132.	113.	107.	114.	113.	111.	116.	121.	125.	131.	139.	148.
-3	183.	164.	139.	119.	113.	108.	102.	96.	110.	116.	120.	126.	134.	143.
-4	198.	176.	150.	128.	120.	113.	107.	100.	102.	104.	114.	119.	127.	136.
-5	213.	189.	161.	139.	129.	119.	112.	105.	106.	108.	105.	103.	116.	124.
-6	228.	201.	173.	150.	138.	127.	118.	110.	111.	113.	106.	101.	99.	97.
-7	244.	214.	184.	161.	147.	134.	124.	113.	114.	117.	110.	105.	101.	98.
-8	260.	228.	197.	173.	157.	142.	132.	122.	121.	121.	114.	109.	105.	101.

TABLE A. 4 Total cost at constant speed on grades - pickup truck - SI = 4.5 ($/1000 mi)

GRADE							SPEED mph							
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	257.	235.	218.	204.	193.	180.	189.	198.	217.	234.	245.	254.	267.	280.
7	240.	220.	191.	188.	178.	167.	174.	181.	200.	218.	230.	240.	255.	271.
6	225.	207.	189.	176.	168.	159.	163.	167.	185.	202.	215.	228.	244.	261.
5	213.	196.	181.	168.	160.	153.	156.	159.	173.	187.	202.	216.	230.	245.
4	201.	187.	170.	157.	153.	150.	150.	152.	163.	174.	188.	202.	219.	235.
3	192.	179.	162.	148.	146.	145.	145.	146.	153.	159.	174.	187.	206.	225.
2	180.	169.	151.	136.	137.	138.	138.	139.	143.	147.	158.	169.	190.	210.
1	163.	153.	137.	123.	125.	127.	128.	129.	132.	134.	142.	150.	168.	185.
0	149.	141.	123.	107.	107.	107.	109.	111.	117.	123.	127.	132.	147.	163.
-1	142.	134.	112.	92.	90.	89.	91.	94.	101.	109.	114.	119.	128.	138.
-2	133.	124.	99.	76.	85.	82.	83.	85.	90.	94.	99.	104.	110.	118.
-3	141.	133.	109.	87.	79.	71.	68.	80.	83.	87.	92.	96.	104.	111.
-4	155.	145.	121.	99.	90.	81.	77.	74.	72.	83.	87.	92.	99.	107.
-5	171.	159.	135.	113.	102.	91.	87.	84.	82.	80.	77.	88.	96.	105.
-6	189.	175.	150.	127.	115.	103.	99.	95.	92.	88.	86.	84.	84.	100.
-7	206.	190.	163.	140.	127.	115.	110.	105.	100.	96.	94.	92.	91.	89.
-8	223.	205.	177.	152.	140.	127.	121.	116.	110.	104.	102.	99.	95.	91.

TABLE A. 5 Total cost at constant speed on grades - 2A SU truck - SI = 4.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	705.	659.	566.	491.	477.	467.	483.	505.	489.	482.	498.	514.	536.	569.
7	652.	609.	519.	447.	437.	432.	449.	472.	458.	450.	466.	482.	502.	535.
6	600.	561.	480.	415.	407.	404.	420.	442.	428.	422.	437.	451.	472.	503.
5	560.	523.	397.	389.	381.	378.	389.	406.	397.	393.	397.	421.	442.	470.
4	521.	488.	420.	365.	357.	353.	360.	372.	367.	367.	372.	390.	409.	437.
3	483.	453.	391.	341.	333.	328.	330.	337.	335.	339.	346.	360.	379.	405.
2	442.	415.	358.	314.	304.	297.	297.	302.	304.	310.	319.	332.	348.	374.
1	394.	370.	317.	275.	259.	247.	253.	264.	275.	280.	291.	303.	318.	342.
0	342.	321.	270.	229.	217.	208.	212.	218.	231.	248.	261.	274.	289.	311.
-1	247.	227.	222.	198.	189.	183.	175.	171.	189.	210.	228.	245.	257.	277.
-2	234.	212.	192.	176.	160.	146.	131.	118.	160.	174.	195.	217.	230.	250.
-3	259.	234.	211.	192.	173.	156.	139.	126.	128.	133.	146.	194.	205.	221.
-4	290.	262.	235.	214.	192.	171.	152.	137.	139.	143.	153.	162.	165.	198.
-5	323.	291.	261.	239.	213.	188.	169.	153.	153.	155.	163.	170.	173.	180.
-6	357.	321.	289.	266.	235.	207.	189.	174.	172.	171.	177.	181.	184.	189.
-7	391.	352.	317.	290.	258.	228.	210.	195.	190.	187.	192.	196.	200.	206.
-8	428.	385.	345.	314.	281.	251.	234.	219.	212.	207.	212.	216.	218.	223.

TABLE A. 6 Total cost at constant speed on grades - 3A SU truck - SI = 4.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1484.	1233.	1033.	854.	854.	859.	864.	879.	904.	933.	952.	973.	1010.	1043.
7	1343.	1122.	950.	799.	797.	801.	805.	819.	839.	865.	881.	901.	934.	965.
6	1207.	1018.	873.	749.	744.	745.	748.	760.	776.	798.	814.	831.	861.	890.
5	1074.	916.	800.	704.	696.	692.	693.	704.	716.	735.	749.	763.	793.	817.
4	952.	823.	733.	661.	649.	642.	642.	650.	659.	673.	686.	700.	724.	747.
3	833.	732.	668.	620.	604.	592.	589.	596.	601.	611.	622.	635.	659.	678.
2	729.	651.	606.	577.	555.	538.	529.	530.	530.	537.	553.	570.	590.	607.
1	653.	580.	544.	523.	493.	468.	457.	455.	453.	458.	476.	495.	513.	528.
0	598.	515.	461.	421.	397.	377.	366.	364.	361.	364.	372.	381.	398.	412.
-1	521.	420.	346.	328.	307.	291.	277.	271.	275.	285.	285.	285.	294.	304.
-2	512.	411.	338.	279.	255.	235.	212.	199.	193.	192.	230.	232.	239.	243.
-3	530.	427.	356.	299.	275.	254.	227.	218.	209.	205.	200.	195.	193.	187.
-4	562.	456.	385.	329.	304.	283.	262.	248.	239.	233.	227.	221.	218.	211.
-5	599.	492.	421.	368.	342.	320.	298.	285.	275.	269.	261.	253.	248.	240.
-6	641.	533.	464.	412.	385.	362.	341.	328.	317.	310.	300.	290.	285.	275.
-7	691.	580.	512.	463.	434.	409.	389.	376.	364.	356.	345.	333.	326.	314.
-8	740.	631.	565.	518.	489.	464.	442.	429.	417.	407.	395.	381.	373.	361.

TABLE A. 7 Total cost at constant speed on grades - 2-S2 semi - SI = 4.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1187.	1058.	961.	879.	887.	897.	845.	804.	786.	778.	833.	891.	976.	1066.
7	1070.	952.	864.	792.	799.	808.	761.	725.	703.	691.	746.	804.	881.	962.
6	975.	870.	788.	719.	723.	729.	690.	659.	636.	623.	676.	730.	796.	868.
5	888.	795.	764.	660.	651.	668.	632.	604.	579.	563.	614.	666.	726.	790.
4	832.	738.	666.	607.	608.	618.	583.	555.	528.	511.	559.	608.	663.	723.
3	773.	687.	618.	561.	565.	569.	537.	512.	483.	463.	509.	556.	605.	658.
2	702.	624.	558.	502.	508.	513.	484.	463.	432.	409.	454.	498.	539.	585.
1	647.	558.	482.	415.	425.	433.	396.	366.	348.	338.	367.	395.	444.	493.
0	588.	476.	389.	311.	305.	300.	294.	295.	292.	297.	308.	318.	334.	354.
-1	444.	339.	252.	174.	206.	200.	197.	197.	195.	224.	232.	240.	267.	282.
-2	372.	255.	188.	109.	102.	94.	86.	83.	74.	118.	163.	168.	205.	216.
-3	302.	180.	160.	146.	136.	126.	117.	111.	102.	97.	92.	83.	117.	157.
-4	266.	226.	204.	188.	177.	166.	155.	148.	136.	129.	123.	112.	107.	101.
-5	322.	278.	253.	236.	224.	212.	199.	191.	177.	168.	160.	148.	140.	132.
-6	385.	335.	308.	290.	276.	262.	249.	239.	224.	214.	204.	190.	180.	170.
-7	454.	399.	370.	350.	334.	319.	304.	292.	276.	265.	254.	238.	226.	214.
-8	527.	468.	436.	415.	399.	382.	366.	353.	335.	322.	309.	292.	278.	265.

TABLE A. 8 Total cost at constant speed on grades - 3-S2 semi - SI = 4.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1494.	1331.	1231.	1158.	1187.	1229.	1191.	1154.	1141.	1135.	1201.	1255.	1309.	1379.
7	1329.	1182.	1093.	1027.	1054.	1092.	1060.	1030.	1010.	999.	1066.	1118.	1162.	1224.
6	1193.	1058.	978.	915.	937.	971.	946.	924.	903.	887.	952.	1000.	1033.	1083.
5	1067.	948.	923.	823.	827.	873.	851.	833.	810.	794.	852.	897.	921.	963.
4	975.	859.	791.	738.	754.	790.	769.	751.	724.	706.	761.	802.	819.	853.
3	882.	780.	715.	663.	681.	710.	690.	676.	649.	626.	677.	713.	723.	750.
2	785.	692.	628.	578.	595.	621.	604.	592.	562.	537.	584.	616.	621.	640.
1	705.	604.	528.	463.	479.	504.	473.	447.	431.	423.	449.	465.	484.	511.
0	623.	498.	410.	330.	324.	324.	325.	331.	333.	343.	357.	369.	384.	403.
-1	165.	129.	111.	99.	88.	153.	166.	179.	184.	214.	223.	227.	239.	246.
-2	208.	166.	145.	132.	119.	111.	104.	101.	93.	90.	88.	82.	134.	152.
-3	275.	223.	198.	182.	167.	156.	146.	141.	130.	126.	122.	113.	109.	106.
-4	351.	290.	261.	241.	224.	212.	200.	192.	180.	173.	166.	155.	149.	143.
-5	436.	365.	332.	311.	291.	277.	263.	253.	239.	229.	221.	208.	200.	191.
-6	531.	451.	413.	389.	368.	352.	336.	324.	307.	295.	286.	272.	261.	251.
-7	635.	546.	504.	477.	455.	435.	418.	403.	385.	371.	360.	344.	331.	320.
-8	749.	649.	604.	576.	549.	529.	510.	493.	472.	456.	443.	425.	412.	399.

TABLE A. 9 Total cost at constant speed on grades - small automobile - SI = 4.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	277.	234.	193.	169.	156.	144.	145.	146.	145.	143.	148.	154.	160.	168.
7	267.	227.	176.	161.	149.	138.	138.	137.	137.	136.	139.	144.	151.	160.
6	258.	221.	170.	157.	146.	134.	132.	131.	131.	131.	133.	137.	144.	152.
5	249.	214.	168.	153.	143.	130.	129.	128.	128.	127.	129.	133.	138.	145.
4	240.	208.	171.	148.	138.	127.	126.	125.	124.	123.	125.	129.	133.	139.
3	229.	201.	172.	144.	136.	124.	123.	122.	121.	120.	122.	125.	128.	133.
2	220.	194.	167.	140.	131.	120.	119.	117.	116.	115.	117.	119.	123.	128.
1	207.	186.	159.	137.	125.	114.	113.	112.	109.	107.	109.	112.	117.	122.
0	197.	175.	150.	129.	117.	111.	106.	103.	103.	103.	102.	106.	110.	116.
-1	186.	167.	141.	118.	109.	101.	101.	101.	99.	96.	98.	101.	105.	110.
-2	175.	156.	129.	107.	98.	97.	98.	98.	95.	92.	93.	96.	99.	103.
-3	179.	158.	134.	113.	103.	94.	92.	88.	93.	89.	90.	92.	95.	99.
-4	188.	164.	140.	121.	111.	101.	98.	95.	88.	80.	88.	90.	93.	97.
-5	199.	172.	149.	131.	120.	109.	105.	102.	94.	85.	82.	80.	91.	95.
-6	213.	183.	159.	140.	128.	118.	113.	109.	101.	92.	89.	86.	84.	92.
-7	227.	195.	168.	148.	137.	126.	121.	117.	108.	98.	95.	92.	89.	87.
-8	242.	207.	178.	156.	145.	135.	130.	124.	115.	105.	101.	98.	96.	94.

TABLE A.10 Total cost at constant speed on grades - medium automobile - SI = 4.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	277.	239.	213.	195.	190.	186.	187.	191.	195.	199.	209.	220.	225.	231.
7	260.	224.	201.	184.	179.	173.	173.	176.	181.	185.	197.	209.	213.	219.
6	247.	214.	191.	176.	170.	164.	163.	166.	170.	175.	187.	198.	203.	209.
5	235.	205.	184.	169.	163.	157.	156.	158.	163.	167.	177.	186.	193.	201.
4	227.	199.	179.	165.	158.	151.	150.	151.	156.	159.	166.	172.	182.	194.
3	217.	193.	173.	159.	152.	146.	145.	147.	149.	151.	156.	159.	172.	186.
2	206.	184.	166.	151.	146.	140.	139.	140.	142.	143.	147.	150.	163.	177.
1	192.	172.	155.	141.	136.	131.	128.	128.	131.	133.	138.	142.	152.	163.
0	178.	161.	144.	129.	125.	120.	117.	116.	119.	122.	129.	135.	141.	150.
-1	174.	157.	137.	120.	115.	111.	109.	110.	112.	113.	119.	125.	132.	140.
-2	170.	152.	130.	110.	101.	102.	102.	105.	105.	106.	111.	115.	124.	133.
-3	182.	163.	138.	118.	108.	98.	93.	91.	100.	101.	106.	110.	118.	127.
-4	199.	177.	151.	129.	118.	107.	100.	95.	93.	90.	102.	105.	112.	120.
-5	216.	191.	163.	140.	129.	117.	107.	101.	99.	96.	96.	94.	108.	114.
-6	233.	205.	176.	152.	139.	127.	116.	108.	106.	103.	108.	100.	99.	107.
-7	250.	219.	188.	163.	151.	137.	126.	118.	114.	110.	108.	105.	104.	102.
-8	267.	233.	202.	175.	161.	148.	136.	127.	122.	117.	114.	111.	109.	106.

TABLE A.11 Total cost at constant speed on grades - large automobile - SI = 4.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	273.	235.	216.	206.	201.	197.	200.	203.	226.	249.	249.	252.	288.	324.
7	264.	229.	210.	201.	194.	189.	192.	194.	208.	222.	225.	230.	253.	276.
6	255.	223.	205.	196.	188.	181.	184.	186.	192.	199.	203.	210.	227.	245.
5	246.	217.	200.	190.	182.	175.	176.	177.	180.	184.	189.	196.	206.	219.
4	238.	210.	194.	184.	174.	166.	167.	168.	169.	170.	174.	181.	190.	199.
3	228.	204.	187.	177.	166.	157.	158.	159.	158.	158.	163.	169.	177.	185.
2	218.	196.	179.	168.	156.	145.	147.	149.	148.	148.	153.	158.	166.	175.
1	203.	183.	167.	156.	145.	135.	137.	139.	140.	141.	144.	149.	156.	165.
0	183.	167.	149.	136.	131.	126.	127.	128.	130.	133.	137.	143.	151.	159.
-1	180.	163.	142.	125.	123.	121.	121.	121.	124.	129.	133.	138.	147.	156.
-2	175.	157.	134.	114.	109.	117.	115.	114.	119.	124.	128.	134.	142.	151.
-3	187.	167.	142.	121.	116.	110.	105.	98.	113.	118.	123.	129.	137.	146.
-4	203.	180.	154.	132.	124.	116.	110.	103.	104.	106.	117.	122.	130.	139.
-5	219.	194.	166.	143.	133.	123.	115.	108.	109.	111.	108.	105.	119.	127.
-6	235.	207.	179.	155.	143.	132.	123.	114.	115.	116.	110.	104.	101.	99.
-7	252.	222.	191.	167.	153.	140.	129.	118.	119.	121.	114.	108.	104.	101.
-8	269.	236.	204.	180.	164.	149.	138.	128.	127.	126.	119.	114.	109.	105.

TABLE A.12 Total cost at constant speed on grades - pickup truck - SI = 4.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	262.	240.	222.	209.	197.	185.	194.	203.	222.	240.	250.	260.	273.	287.
7	245.	225.	195.	192.	182.	172.	178.	186.	204.	223.	235.	246.	261.	277.
6	229.	211.	193.	180.	171.	163.	167.	172.	189.	207.	219.	233.	250.	266.
5	217.	200.	184.	171.	164.	157.	159.	163.	177.	192.	207.	221.	236.	251.
4	205.	190.	174.	161.	157.	153.	154.	156.	167.	178.	193.	207.	223.	240.
3	195.	182.	165.	151.	149.	148.	148.	150.	156.	163.	178.	192.	210.	230.
2	183.	172.	154.	139.	140.	141.	141.	143.	146.	150.	162.	173.	194.	214.
1	166.	156.	140.	126.	128.	130.	131.	132.	135.	137.	146.	154.	172.	189.
0	151.	144.	126.	110.	110.	110.	111.	114.	120.	126.	131.	136.	151.	167.
-1	144.	137.	114.	94.	93.	92.	94.	97.	104.	112.	117.	122.	132.	142.
-2	135.	126.	101.	77.	87.	85.	86.	88.	92.	97.	102.	107.	113.	122.
-3	144.	135.	111.	89.	81.	73.	70.	82.	86.	90.	95.	99.	107.	114.
-4	159.	149.	125.	102.	93.	84.	80.	76.	74.	85.	90.	94.	102.	110.
-5	177.	164.	139.	117.	106.	94.	91.	87.	85.	82.	79.	90.	99.	108.
-6	195.	180.	155.	132.	120.	107.	103.	99.	95.	91.	89.	87.	87.	103.
-7	213.	197.	170.	146.	133.	121.	115.	110.	105.	100.	98.	95.	94.	92.
-8	232.	213.	185.	160.	147.	134.	128.	122.	116.	110.	107.	103.	99.	94.

TABLE A.13 Total cost at constant speed on grades - 2A SU truck - SI = 4.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	711.	664.	572.	497.	483.	473.	489.	511.	496.	489.	505.	522.	544.	578.
7	657.	614.	524.	452.	442.	437.	454.	478.	464.	456.	473.	489.	510.	543.
6	605.	566.	485.	419.	411.	408.	425.	447.	434.	427.	442.	458.	479.	510.
5	564.	527.	401.	392.	385.	382.	393.	411.	401.	398.	402.	426.	448.	476.
4	525.	491.	424.	369.	361.	356.	364.	376.	371.	371.	376.	395.	415.	443.
3	487.	456.	394.	344.	336.	331.	333.	340.	339.	343.	350.	365.	384.	410.
2	445.	418.	361.	317.	306.	299.	300.	305.	307.	313.	322.	336.	352.	378.
1	397.	372.	320.	277.	261.	249.	255.	266.	277.	283.	294.	306.	322.	345.
0	345.	324.	273.	231.	219.	210.	214.	221.	234.	251.	264.	277.	292.	314.
-1	249.	229.	224.	200.	191.	185.	177.	173.	191.	212.	231.	247.	260.	280.
-2	237.	215.	194.	178.	162.	147.	132.	120.	162.	176.	198.	219.	232.	252.
-3	263.	237.	213.	194.	175.	158.	141.	127.	130.	135.	148.	195.	207.	223.
-4	294.	265.	238.	217.	194.	173.	154.	139.	141.	145.	154.	164.	166.	200.
-5	327.	295.	264.	242.	216.	191.	172.	156.	156.	157.	165.	172.	175.	181.
-6	362.	326.	293.	269.	238.	210.	192.	177.	175.	174.	179.	184.	186.	191.
-7	397.	357.	322.	295.	262.	232.	214.	199.	194.	190.	195.	199.	202.	208.
-8	434.	391.	350.	319.	286.	256.	238.	224.	216.	211.	216.	220.	222.	226.

TABLE A.14 Total cost at constant speed on grades - 3A SU truck - SI = 4.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1504.	1251.	1049.	870.	870.	875.	880.	895.	920.	950.	970.	991.	1029.	1062.
7	1361.	1138.	965.	814.	811.	815.	819.	833.	853.	880.	897.	917.	951.	982.
6	1223.	1032.	887.	762.	757.	757.	761.	773.	789.	812.	828.	845.	876.	906.
5	1089.	929.	812.	715.	707.	703.	704.	715.	728.	747.	761.	776.	806.	830.
4	966.	835.	744.	672.	659.	652.	651.	660.	669.	684.	696.	711.	736.	759.
3	846.	743.	678.	629.	613.	601.	598.	605.	610.	620.	631.	645.	669.	688.
2	741.	661.	615.	586.	564.	546.	537.	538.	538.	545.	561.	579.	599.	616.
1	665.	590.	553.	531.	500.	475.	464.	462.	460.	466.	483.	502.	521.	536.
0	609.	525.	469.	429.	404.	384.	373.	370.	368.	371.	379.	387.	405.	419.
-1	532.	428.	354.	336.	314.	298.	283.	277.	281.	291.	291.	291.	300.	310.
-2	523.	420.	346.	286.	262.	241.	217.	204.	198.	197.	236.	237.	244.	249.
-3	542.	437.	365.	307.	282.	261.	234.	224.	215.	210.	205.	200.	197.	192.
-4	575.	467.	395.	338.	313.	291.	269.	255.	245.	239.	233.	227.	223.	216.
-5	613.	504.	432.	378.	351.	329.	306.	293.	282.	276.	268.	260.	254.	246.
-6	657.	546.	476.	423.	396.	372.	350.	337.	325.	319.	308.	298.	292.	282.
-7	708.	595.	526.	475.	446.	421.	400.	387.	374.	366.	354.	342.	334.	323.
-8	759.	647.	580.	532.	502.	477.	454.	441.	428.	418.	405.	391.	383.	371.

TABLE A.15 Total cost at constant speed on grades - 2-S2 semi - SI = 4.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1204.	1075.	978.	896.	906.	916.	865.	825.	808.	802.	858.	918.	1005.	1096.
7	1085.	967.	879.	807.	815.	825.	778.	744.	723.	712.	769.	828.	906.	990.
6	989.	884.	801.	732.	737.	744.	705.	676.	653.	642.	696.	751.	819.	893.
5	900.	807.	776.	672.	663.	681.	645.	619.	594.	579.	632.	684.	747.	811.
4	843.	748.	676.	618.	619.	629.	595.	568.	541.	525.	574.	625.	681.	742.
3	783.	696.	627.	570.	575.	578.	547.	523.	495.	475.	522.	570.	621.	674.
2	711.	632.	566.	510.	516.	522.	493.	473.	442.	420.	465.	510.	553.	600.
1	655.	565.	489.	422.	432.	441.	404.	374.	357.	347.	377.	405.	455.	505.
0	595.	483.	396.	317.	312.	306.	301.	302.	300.	305.	316.	327.	344.	365.
-1	449.	344.	256.	177.	212.	206.	202.	203.	202.	230.	239.	247.	275.	291.
-2	378.	260.	193.	114.	107.	98.	90.	86.	77.	121.	169.	175.	212.	224.
-3	311.	188.	167.	153.	143.	132.	122.	117.	107.	102.	96.	87.	121.	163.
-4	276.	236.	213.	197.	185.	174.	162.	155.	143.	136.	129.	118.	112.	106.
-5	335.	290.	265.	247.	234.	222.	209.	200.	186.	177.	168.	155.	147.	139.
-6	400.	350.	322.	303.	289.	275.	261.	250.	235.	225.	214.	199.	189.	179.
-7	472.	416.	386.	366.	350.	334.	318.	306.	290.	278.	267.	250.	237.	225.
-8	548.	488.	455.	433.	417.	400.	383.	369.	351.	337.	324.	307.	292.	278.

TABLE A.16 Total cost at constant speed on grades - 3-S2 semi - SI = 4.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1518.	1354.	1255.	1183.	1213.	1256.	1219.	1184.	1172.	1169.	1236.	1292.	1348.	1420.
7	1350.	1203.	1114.	1048.	1076.	1116.	1084.	1056.	1037.	1028.	1097.	1151.	1197.	1260.
6	1212.	1076.	996.	934.	956.	992.	967.	947.	927.	913.	979.	1029.	1063.	1115.
5	1083.	963.	938.	838.	844.	890.	869.	853.	830.	815.	875.	921.	947.	991.
4	989.	872.	804.	751.	767.	804.	784.	767.	741.	724.	781.	823.	842.	877.
3	894.	791.	726.	674.	692.	722.	703.	690.	663.	641.	694.	731.	742.	770.
2	796.	701.	638.	588.	605.	631.	615.	603.	574.	550.	598.	631.	636.	657.
1	714.	612.	536.	471.	487.	513.	481.	456.	441.	434.	461.	477.	497.	525.
0	632.	506.	417.	337.	330.	331.	332.	339.	342.	352.	366.	379.	395.	415.
-1	171.	133.	115.	103.	92.	159.	172.	185.	191.	221.	231.	235.	248.	255.
-2	216.	173.	151.	137.	124.	116.	109.	106.	98.	95.	92.	86.	141.	159.
-3	285.	232.	206.	190.	174.	163.	153.	147.	136.	132.	127.	119.	114.	111.
-4	364.	301.	271.	251.	233.	221.	209.	201.	188.	181.	174.	163.	156.	150.
-5	451.	379.	345.	324.	304.	289.	274.	264.	250.	240.	231.	218.	210.	200.
-6	550.	468.	430.	405.	383.	367.	350.	338.	321.	309.	299.	285.	274.	263.
-7	657.	567.	524.	497.	474.	454.	436.	421.	402.	387.	376.	360.	347.	335.
-8	775.	674.	627.	599.	572.	551.	531.	514.	493.	476.	462.	444.	431.	417.

TABLE A.17 Total cost at constant speed on grades - small automobile - SI = 3.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	285.	241.	199.	174.	161.	149.	150.	151.	150.	149.	153.	159.	166.	175.
7	275.	233.	181.	166.	154.	142.	142.	142.	141.	141.	144.	149.	157.	166.
6	265.	226.	175.	162.	150.	138.	137.	135.	136.	135.	138.	142.	149.	158.
5	256.	219.	172.	157.	147.	135.	133.	132.	132.	132.	133.	137.	143.	151.
4	246.	213.	175.	152.	142.	131.	130.	129.	128.	128.	130.	133.	138.	144.
3	234.	206.	175.	148.	139.	128.	127.	125.	125.	124.	126.	129.	133.	138.
2	225.	197.	170.	144.	134.	124.	122.	120.	120.	119.	120.	123.	127.	132.
1	211.	189.	162.	140.	128.	117.	116.	115.	112.	111.	113.	116.	121.	126.
0	200.	178.	153.	131.	120.	113.	109.	106.	107.	106.	106.	109.	114.	120.
-1	189.	170.	144.	121.	112.	104.	104.	104.	102.	99.	101.	104.	108.	114.
-2	178.	158.	132.	110.	99.	100.	101.	101.	98.	95.	96.	99.	102.	107.
-3	183.	161.	137.	115.	106.	97.	94.	90.	96.	92.	93.	96.	99.	103.
-4	193.	168.	145.	125.	115.	105.	102.	98.	90.	82.	91.	93.	96.	100.
-5	206.	178.	154.	136.	124.	114.	109.	106.	97.	88.	85.	82.	94.	98.
-6	221.	190.	165.	146.	134.	123.	118.	113.	105.	96.	92.	89.	86.	96.
-7	237.	203.	176.	155.	143.	133.	127.	122.	113.	103.	99.	95.	93.	90.
-8	254.	217.	187.	164.	153.	142.	136.	131.	121.	110.	106.	103.	100.	97.

TABLE A.18 Total cost at constant speed on grades - medium automobile - SI = 3.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	287.	246.	219.	201.	196.	192.	193.	197.	201.	205.	216.	227.	232.	239.
7	268.	231.	206.	190.	184.	179.	179.	182.	187.	191.	203.	216.	220.	227.
6	255.	220.	197.	181.	175.	169.	168.	171.	176.	181.	193.	205.	209.	216.
5	242.	211.	189.	174.	168.	162.	161.	163.	168.	172.	182.	192.	199.	208.
4	233.	204.	184.	169.	162.	155.	154.	156.	160.	164.	171.	178.	188.	200.
3	223.	197.	177.	163.	156.	150.	149.	151.	154.	156.	161.	165.	178.	192.
2	211.	188.	169.	155.	149.	144.	142.	144.	146.	147.	152.	155.	168.	183.
1	196.	176.	158.	144.	140.	135.	132.	132.	135.	137.	142.	146.	156.	168.
0	182.	164.	147.	132.	128.	124.	120.	120.	123.	125.	133.	139.	146.	155.
-1	178.	160.	140.	123.	118.	114.	113.	114.	115.	116.	123.	129.	137.	145.
-2	173.	155.	133.	112.	103.	105.	106.	108.	109.	109.	115.	119.	128.	138.
-3	187.	167.	142.	121.	111.	101.	96.	93.	103.	104.	109.	114.	122.	131.
-4	205.	182.	156.	133.	122.	110.	103.	98.	95.	92.	105.	109.	116.	124.
-5	224.	198.	170.	146.	134.	121.	112.	105.	103.	100.	99.	96.	111.	118.
-6	242.	213.	184.	159.	146.	133.	122.	114.	111.	108.	112.	104.	102.	111.
-7	261.	229.	197.	171.	158.	145.	133.	124.	120.	115.	113.	110.	108.	106.
-8	280.	244.	212.	184.	170.	157.	144.	135.	129.	124.	121.	116.	114.	111.

TABLE A.19 Total cost at constant speed on grades - large automobile - SI = 3.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	282.	243.	222.	212.	207.	204.	207.	210.	233.	256.	256.	260.	296.	333.
7	273.	236.	216.	207.	200.	196.	198.	201.	214.	229.	233.	238.	261.	285.
6	263.	229.	211.	201.	194.	187.	189.	192.	198.	205.	210.	217.	235.	253.
5	254.	223.	205.	195.	187.	180.	181.	183.	186.	190.	195.	202.	214.	226.
4	244.	216.	199.	189.	179.	171.	172.	174.	174.	176.	180.	188.	196.	207.
3	234.	209.	192.	182.	171.	161.	162.	164.	163.	164.	168.	175.	183.	192.
2	223.	200.	183.	172.	160.	149.	151.	154.	153.	153.	158.	164.	172.	181.
1	207.	187.	171.	160.	149.	139.	141.	143.	144.	145.	149.	154.	162.	171.
0	187.	170.	153.	140.	134.	130.	131.	132.	134.	138.	142.	148.	156.	165.
-1	184.	167.	146.	128.	126.	125.	125.	125.	128.	133.	137.	143.	151.	161.
-2	178.	160.	137.	117.	111.	120.	119.	118.	122.	128.	132.	138.	147.	156.
-3	191.	171.	146.	125.	119.	113.	107.	101.	116.	122.	127.	133.	142.	151.
-4	209.	186.	159.	137.	128.	120.	114.	107.	108.	109.	121.	126.	134.	143.
-5	227.	201.	173.	150.	139.	129.	121.	113.	114.	115.	111.	108.	123.	131.
-6	245.	216.	187.	163.	150.	138.	129.	120.	120.	121.	114.	108.	105.	102.
-7	264.	232.	200.	176.	162.	148.	137.	125.	126.	127.	120.	113.	109.	105.
-8	283.	248.	215.	190.	173.	158.	147.	136.	134.	133.	125.	120.	115.	110.

TABLE A.20 Total cost at constant speed on grades - pickup truck - SI = 3.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	270.	247.	228.	215.	203.	191.	200.	210.	229.	247.	258.	268.	282.	296.
7	253.	231.	201.	198.	187.	177.	184.	192.	211.	230.	242.	253.	269.	286.
6	236.	216.	198.	185.	177.	168.	172.	177.	195.	213.	226.	240.	257.	275.
5	223.	205.	189.	176.	169.	162.	165.	168.	183.	198.	213.	227.	243.	258.
4	211.	195.	178.	165.	161.	158.	159.	161.	172.	184.	199.	213.	230.	247.
3	200.	187.	169.	155.	154.	153.	153.	155.	161.	168.	183.	197.	217.	237.
2	188.	176.	157.	142.	144.	145.	146.	147.	151.	155.	167.	179.	200.	221.
1	170.	160.	143.	130.	132.	134.	135.	137.	139.	142.	151.	159.	177.	195.
0	155.	147.	129.	113.	113.	114.	115.	118.	124.	130.	135.	141.	156.	172.
-1	148.	140.	117.	97.	96.	95.	98.	101.	108.	116.	121.	127.	137.	147.
-2	137.	128.	103.	79.	90.	88.	89.	92.	96.	101.	106.	111.	118.	127.
-3	148.	139.	115.	92.	84.	76.	72.	86.	90.	94.	99.	104.	111.	119.
-4	165.	154.	129.	107.	97.	88.	83.	79.	77.	89.	93.	98.	106.	114.
-5	184.	171.	146.	123.	111.	99.	96.	92.	89.	85.	82.	94.	103.	112.
-6	204.	189.	163.	139.	127.	114.	109.	104.	101.	96.	93.	90.	89.	107.
-7	224.	207.	179.	155.	142.	129.	123.	117.	112.	107.	104.	100.	98.	95.
-8	245.	225.	196.	170.	157.	143.	137.	131.	124.	117.	114.	110.	105.	99.

TABLE A.21 Total cost at constant speed on grades - 2A SU truck - SI = 3.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	721.	674.	581.	506.	493.	484.	501.	524.	509.	503.	521.	538.	562.	597.
7	666.	623.	532.	461.	451.	447.	465.	489.	476.	469.	487.	504.	526.	560.
6	613.	573.	492.	427.	419.	417.	434.	457.	445.	439.	455.	471.	493.	525.
5	571.	534.	408.	399.	392.	390.	401.	420.	411.	409.	413.	438.	461.	490.
4	531.	497.	430.	375.	367.	363.	371.	384.	380.	380.	386.	405.	426.	456.
3	493.	461.	400.	350.	342.	337.	340.	347.	347.	351.	359.	374.	394.	421.
2	451.	423.	366.	322.	311.	305.	306.	312.	314.	320.	330.	344.	361.	388.
1	402.	377.	324.	282.	266.	254.	260.	272.	283.	290.	301.	314.	330.	354.
0	350.	328.	277.	235.	223.	215.	218.	226.	239.	256.	270.	283.	299.	322.
-1	252.	232.	228.	204.	195.	189.	181.	177.	196.	217.	236.	253.	266.	287.
-2	241.	218.	197.	181.	164.	150.	134.	122.	166.	180.	202.	224.	238.	258.
-3	268.	242.	217.	198.	179.	161.	144.	130.	133.	137.	150.	200.	212.	228.
-4	301.	271.	244.	222.	199.	178.	159.	143.	145.	149.	158.	167.	169.	204.
-5	335.	302.	271.	249.	222.	197.	178.	161.	161.	162.	169.	176.	179.	185.
-6	371.	335.	302.	277.	246.	217.	199.	184.	181.	180.	185.	189.	191.	196.
-7	408.	367.	332.	304.	271.	241.	222.	207.	202.	198.	203.	206.	209.	214.
-8	447.	403.	362.	330.	297.	266.	248.	233.	226.	220.	224.	228.	229.	233.

TABLE A.22 Total cost at constant speed on grades - 3A SU truck - SI = 3.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1531.	1276.	1075.	895.	895.	901.	907.	923.	949.	980.	1001.	1024.	1063.	1099.
7	1385.	1161.	987.	836.	834.	838.	843.	858.	879.	907.	925.	946.	981.	1014.
6	1246.	1053.	907.	782.	777.	778.	781.	795.	812.	835.	853.	871.	903.	934.
5	1109.	948.	830.	733.	725.	721.	723.	734.	747.	767.	782.	798.	830.	856.
4	985.	852.	760.	687.	675.	668.	668.	677.	687.	702.	715.	731.	757.	781.
3	863.	758.	692.	643.	627.	615.	612.	620.	625.	636.	648.	662.	687.	708.
2	757.	675.	628.	598.	576.	559.	550.	551.	551.	559.	576.	594.	615.	633.
1	680.	603.	565.	542.	512.	486.	475.	473.	472.	478.	496.	515.	534.	550.
0	623.	537.	481.	439.	415.	394.	383.	380.	378.	381.	390.	399.	417.	432.
-1	543.	438.	362.	346.	324.	307.	292.	286.	290.	300.	300.	301.	310.	321.
-2	536.	431.	356.	295.	270.	249.	224.	211.	205.	203.	244.	246.	254.	259.
-3	557.	450.	376.	318.	292.	270.	242.	233.	223.	217.	212.	207.	204.	198.
-4	592.	482.	408.	351.	324.	302.	279.	266.	255.	249.	242.	235.	232.	224.
-5	633.	521.	448.	393.	365.	342.	319.	305.	294.	288.	279.	270.	264.	256.
-6	679.	566.	495.	441.	413.	388.	366.	352.	340.	333.	322.	311.	305.	294.
-7	734.	618.	547.	496.	465.	440.	418.	405.	391.	383.	370.	358.	350.	337.
-8	788.	674.	605.	556.	525.	499.	475.	462.	448.	438.	424.	410.	401.	388.

TABLE A.23 Total cost at constant speed on grades - 2-S2 semi - SI = 3.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1228.	1099.	1002.	922.	932.	944.	894.	856.	840.	836.	895.	957.	1047.	1141.
7	1106.	988.	900.	829.	838.	849.	804.	771.	751.	743.	801.	862.	943.	1030.
6	1007.	902.	819.	751.	757.	765.	727.	699.	678.	668.	724.	781.	851.	928.
5	916.	823.	792.	689.	681.	699.	664.	639.	616.	602.	656.	711.	775.	842.
4	857.	762.	690.	632.	634.	644.	611.	585.	560.	545.	596.	648.	706.	769.
3	795.	708.	639.	582.	587.	591.	561.	538.	510.	492.	540.	590.	642.	698.
2	721.	642.	576.	521.	527.	533.	505.	485.	455.	434.	481.	527.	571.	620.
1	665.	574.	498.	431.	441.	450.	414.	385.	368.	359.	390.	420.	471.	523.
0	604.	491.	404.	325.	320.	315.	309.	311.	309.	315.	327.	339.	357.	379.
-1	455.	348.	260.	181.	219.	214.	210.	211.	210.	239.	249.	257.	286.	304.
-2	386.	267.	200.	120.	112.	104.	95.	91.	81.	125.	177.	183.	221.	234.
-3	321.	197.	176.	161.	151.	140.	130.	123.	113.	108.	102.	92.	126.	172.
-4	290.	248.	225.	208.	196.	184.	172.	164.	152.	144.	137.	125.	119.	112.
-5	352.	306.	280.	261.	248.	235.	222.	213.	198.	188.	179.	165.	156.	148.
-6	421.	369.	341.	321.	307.	292.	277.	266.	250.	239.	228.	212.	201.	191.
-7	497.	439.	409.	388.	371.	355.	338.	326.	308.	296.	284.	266.	253.	240.
-8	577.	516.	482.	459.	442.	425.	407.	393.	374.	359.	345.	327.	311.	297.

TABLE A.24 Total cost at constant speed on grades - 3-S2 semi - SI = 3.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1553.	1389.	1291.	1220.	1251.	1296.	1261.	1228.	1219.	1218.	1288.	1347.	1406.	1481.
7	1380.	1232.	1144.	1080.	1109.	1150.	1120.	1094.	1077.	1071.	1142.	1198.	1247.	1313.
6	1238.	1101.	1022.	960.	984.	1021.	998.	979.	962.	949.	1018.	1070.	1107.	1161.
5	1105.	984.	960.	861.	867.	914.	895.	880.	860.	847.	909.	956.	984.	1031.
4	1007.	890.	822.	770.	787.	825.	806.	790.	766.	751.	809.	853.	874.	911.
3	910.	806.	741.	689.	708.	739.	721.	709.	684.	663.	717.	756.	768.	798.
2	809.	713.	650.	600.	618.	645.	630.	619.	591.	568.	617.	651.	658.	681.
1	725.	622.	546.	481.	498.	524.	493.	469.	455.	449.	476.	494.	515.	544.
0	642.	515.	425.	346.	339.	340.	342.	349.	352.	363.	379.	392.	409.	430.
-1	177.	138.	120.	107.	95.	166.	180.	194.	199.	231.	241.	245.	259.	267.
-2	225.	181.	158.	144.	130.	122.	114.	111.	103.	100.	97.	90.	149.	168.
-3	297.	243.	217.	199.	183.	172.	161.	156.	144.	139.	135.	126.	121.	117.
-4	380.	316.	285.	265.	246.	234.	221.	213.	199.	192.	185.	173.	166.	160.
-5	472.	398.	363.	341.	320.	306.	290.	280.	265.	255.	246.	232.	223.	213.
-6	575.	492.	452.	427.	404.	388.	371.	358.	340.	328.	318.	302.	291.	279.
-7	688.	595.	551.	524.	500.	479.	462.	446.	426.	411.	400.	383.	368.	356.
-8	811.	708.	661.	632.	604.	583.	562.	544.	522.	505.	490.	472.	457.	443.

TABLE A.25 Total cost at constant speed on grades - small automobile - SI = 3.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	299.	251.	207.	183.	169.	157.	157.	158.	158.	156.	161.	168.	175.	184.
7	288.	243.	189.	174.	161.	149.	149.	149.	149.	148.	151.	157.	165.	175.
6	277.	235.	183.	169.	157.	145.	143.	142.	143.	143.	145.	150.	157.	166.
5	267.	227.	179.	164.	153.	141.	139.	138.	139.	138.	140.	144.	151.	159.
4	255.	220.	182.	158.	148.	137.	136.	135.	135.	134.	136.	140.	145.	152.
3	243.	212.	181.	154.	145.	133.	132.	131.	131.	130.	132.	135.	140.	145.
2	232.	204.	176.	149.	140.	129.	127.	126.	125.	125.	126.	130.	134.	139.
1	218.	195.	167.	145.	133.	122.	121.	120.	118.	116.	118.	122.	127.	133.
0	206.	183.	157.	136.	124.	118.	114.	111.	112.	111.	111.	115.	120.	126.
-1	195.	175.	148.	126.	117.	109.	109.	109.	107.	104.	106.	109.	114.	120.
-2	184.	163.	136.	113.	103.	105.	105.	106.	103.	100.	101.	104.	108.	112.
-3	190.	167.	142.	120.	110.	101.	98.	94.	100.	97.	98.	101.	104.	109.
-4	203.	176.	152.	132.	120.	110.	106.	103.	94.	85.	95.	98.	101.	106.
-5	217.	187.	163.	144.	132.	120.	116.	111.	102.	93.	89.	85.	99.	103.
-6	235.	202.	175.	155.	143.	131.	126.	120.	111.	102.	97.	93.	90.	101.
-7	253.	216.	187.	166.	154.	142.	136.	131.	120.	110.	105.	101.	98.	95.
-8	272.	232.	200.	177.	165.	153.	147.	140.	130.	118.	114.	110.	106.	103.

TABLE A.26 Total cost at constant speed on grades - medium automobile - SI = 3.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	302.	257.	229.	210.	205.	201.	202.	206.	211.	215.	226.	237.	243.	250.
7	282.	241.	215.	198.	192.	187.	187.	190.	196.	200.	213.	225.	230.	238.
6	267.	230.	205.	189.	182.	176.	176.	179.	184.	189.	202.	214.	219.	226.
5	254.	219.	197.	181.	175.	169.	168.	170.	176.	180.	191.	201.	208.	218.
4	243.	212.	191.	176.	169.	162.	161.	163.	168.	172.	179.	186.	197.	210.
3	232.	204.	184.	169.	163.	156.	155.	158.	160.	163.	168.	172.	186.	201.
2	219.	195.	175.	161.	155.	150.	149.	151.	153.	154.	159.	162.	176.	191.
1	203.	182.	164.	150.	145.	140.	138.	138.	141.	144.	149.	153.	164.	176.
0	188.	170.	152.	137.	133.	129.	125.	125.	128.	131.	139.	145.	153.	162.
-1	184.	165.	145.	128.	123.	119.	118.	119.	121.	122.	129.	135.	143.	152.
-2	179.	160.	137.	116.	107.	110.	111.	113.	114.	115.	120.	125.	134.	144.
-3	194.	173.	148.	126.	116.	105.	100.	97.	109.	110.	115.	119.	128.	137.
-4	215.	191.	164.	140.	128.	117.	109.	103.	100.	96.	110.	114.	122.	130.
-5	236.	208.	179.	155.	142.	129.	119.	112.	109.	105.	103.	100.	116.	124.
-6	257.	226.	195.	169.	156.	143.	131.	122.	119.	115.	118.	109.	107.	116.
-7	279.	244.	211.	184.	170.	156.	144.	134.	130.	124.	121.	117.	114.	111.
-8	300.	261.	227.	199.	184.	170.	157.	146.	140.	134.	130.	125.	121.	118.

TABLE A.27 Total cost at constant speed on grades - large automobile - SI = 3.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	298.	255.	233.	222.	217.	214.	217.	220.	244.	267.	267.	272.	309.	347.
7	287.	247.	226.	216.	210.	205.	207.	210.	224.	239.	243.	249.	273.	298.
6	277.	240.	220.	210.	202.	196.	198.	201.	208.	215.	220.	228.	246.	265.
5	266.	232.	213.	204.	195.	188.	190.	191.	195.	199.	205.	212.	224.	238.
4	255.	225.	207.	196.	187.	179.	180.	182.	183.	184.	189.	197.	206.	218.
3	244.	217.	199.	189.	178.	168.	170.	171.	171.	172.	177.	184.	192.	202.
2	232.	208.	190.	178.	166.	156.	158.	161.	161.	161.	166.	172.	181.	191.
1	215.	194.	177.	166.	155.	145.	148.	150.	151.	153.	156.	162.	170.	180.
0	194.	176.	158.	145.	140.	136.	137.	138.	141.	144.	149.	155.	164.	173.
-1	191.	173.	151.	134.	132.	130.	131.	131.	135.	139.	144.	150.	159.	169.
-2	184.	165.	141.	121.	115.	125.	124.	124.	128.	134.	139.	145.	154.	164.
-3	199.	178.	152.	131.	124.	118.	112.	105.	122.	128.	133.	139.	148.	158.
-4	220.	195.	167.	144.	135.	127.	120.	112.	113.	113.	127.	132.	141.	150.
-5	240.	213.	183.	159.	148.	137.	128.	120.	120.	121.	116.	113.	129.	137.
-6	261.	229.	199.	174.	161.	149.	139.	129.	128.	129.	121.	114.	110.	107.
-7	282.	248.	215.	190.	175.	160.	148.	136.	136.	136.	128.	121.	116.	111.
-8	304.	266.	231.	206.	188.	172.	160.	149.	146.	144.	136.	130.	123.	118.

TABLE A.28 Total cost at constant speed on grades - pickup truck - SI = 3.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	283.	256.	237.	223.	212.	200.	210.	220.	239.	257.	269.	279.	294.	309.
7	264.	240.	209.	206.	196.	186.	193.	201.	220.	240.	252.	264.	281.	298.
6	247.	225.	206.	193.	185.	177.	181.	186.	204.	223.	236.	250.	268.	287.
5	233.	213.	196.	184.	176.	170.	172.	176.	191.	207.	222.	237.	253.	270.
4	220.	203.	185.	172.	168.	165.	166.	169.	180.	192.	207.	222.	240.	258.
3	209.	193.	176.	162.	160.	159.	160.	162.	169.	176.	192.	206.	226.	247.
2	195.	182.	163.	148.	150.	152.	152.	154.	158.	163.	175.	187.	209.	230.
1	176.	165.	149.	135.	137.	140.	141.	143.	146.	149.	158.	167.	186.	204.
0	161.	152.	134.	118.	119.	119.	121.	124.	130.	137.	142.	148.	164.	181.
-1	154.	145.	122.	102.	101.	101.	103.	107.	114.	122.	128.	134.	144.	155.
-2	142.	132.	106.	82.	96.	93.	95.	97.	102.	107.	112.	118.	125.	135.
-3	154.	144.	120.	97.	89.	80.	76.	91.	95.	100.	105.	110.	118.	126.
-4	174.	162.	137.	114.	104.	93.	89.	84.	81.	95.	99.	104.	113.	121.
-5	195.	181.	155.	132.	120.	107.	103.	99.	95.	91.	87.	100.	109.	119.
-6	218.	201.	175.	151.	138.	124.	119.	113.	109.	103.	100.	96.	94.	113.
-7	241.	222.	193.	168.	155.	141.	134.	128.	122.	116.	112.	107.	104.	100.
-8	264.	242.	212.	186.	172.	158.	151.	144.	136.	128.	124.	119.	113.	106.

TABLE A.29 Total cost at constant speed on grades - 2A SU truck - SI = 3.0 ($/1000 mi)

GRADE						SPEED mph							
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	734.	686.	594.	519.	507.	498.	516.	540.	526.	522.	540.	559.	584.	621.
7	678.	634.	543.	472.	463.	459.	478.	503.	492.	486.	505.	522.	546.	581.
6	624.	583.	502.	437.	430.	428.	446.	470.	458.	454.	471.	488.	511.	545.
5	581.	543.	417.	408.	402.	400.	412.	431.	423.	422.	427.	454.	477.	507.
4	539.	505.	437.	383.	375.	372.	380.	394.	391.	392.	399.	419.	441.	471.
3	500.	468.	406.	357.	349.	345.	348.	356.	356.	361.	370.	386.	407.	435.
2	458.	429.	372.	328.	318.	312.	313.	319.	322.	329.	340.	355.	372.	400.
1	408.	383.	330.	287.	272.	260.	267.	279.	291.	297.	310.	323.	340.	365.
0	356.	334.	282.	240.	228.	220.	224.	232.	245.	263.	277.	291.	307.	331.
-1	256.	235.	233.	209.	200.	194.	186.	182.	201.	223.	242.	260.	274.	294.
-2	246.	222.	201.	184.	168.	153.	137.	124.	171.	186.	208.	230.	244.	264.
-3	275.	248.	223.	203.	183.	165.	148.	134.	136.	140.	153.	205.	218.	234.
-4	309.	278.	251.	229.	205.	184.	164.	148.	150.	153.	162.	170.	173.	209.
-5	345.	311.	280.	257.	230.	204.	185.	168.	167.	168.	175.	181.	183.	189.
-6	383.	346.	312.	287.	256.	227.	208.	192.	189.	187.	192.	196.	197.	201.
-7	422.	380.	344.	316.	282.	252.	233.	217.	211.	207.	211.	214.	216.	221.
-8	463.	418.	376.	344.	310.	279.	261.	245.	237.	231.	235.	238.	239.	242.

TABLE A.30 Total cost at constant speed on grades - 3A SU truck - SI = 3.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1568.	1311.	1108.	929.	929.	936.	942.	960.	987.	1019.	1042.	1067.	1108.	1146.
7	1419.	1192.	1017.	866.	864.	868.	874.	890.	912.	942.	961.	984.	1021.	1056.
6	1276.	1080.	933.	808.	803.	805.	809.	823.	841.	866.	884.	904.	939.	972.
5	1137.	972.	854.	756.	748.	745.	747.	759.	773.	794.	810.	828.	861.	888.
4	1009.	874.	781.	708.	695.	688.	688.	699.	709.	725.	740.	756.	784.	810.
3	886.	778.	711.	661.	645.	633.	631.	638.	644.	656.	669.	684.	711.	732.
2	778.	693.	645.	614.	592.	574.	566.	567.	568.	576.	594.	613.	636.	655.
1	699.	620.	580.	557.	526.	501.	489.	488.	487.	493.	512.	532.	552.	569.
0	642.	553.	495.	453.	428.	407.	395.	393.	391.	394.	403.	413.	432.	448.
-1	559.	450.	373.	358.	336.	319.	304.	297.	302.	312.	312.	313.	323.	335.
-2	554.	446.	369.	306.	280.	259.	233.	220.	213.	211.	255.	257.	265.	271.
-3	577.	466.	391.	331.	305.	282.	253.	243.	233.	227.	222.	216.	213.	206.
-4	615.	502.	426.	367.	340.	317.	293.	279.	267.	261.	253.	246.	242.	234.
-5	659.	544.	469.	412.	384.	360.	336.	321.	309.	302.	293.	284.	278.	268.
-6	709.	592.	519.	464.	434.	409.	386.	371.	358.	350.	339.	328.	321.	309.
-7	767.	649.	575.	522.	491.	464.	441.	427.	413.	404.	391.	377.	369.	356.
-8	826.	708.	637.	587.	555.	528.	503.	489.	474.	463.	449.	433.	424.	411.

TABLE A.31 Total cost at constant speed on grades - 2-S2 semi - SI = 3.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1262.	1133.	1036.	957.	969.	982.	935.	899.	886.	884.	946.	1012.	1105.	1203.
7	1136.	1018.	930.	860.	871.	882.	839.	809.	791.	785.	847.	910.	995.	1085.
6	1033.	927.	845.	778.	785.	794.	758.	732.	713.	705.	764.	824.	897.	977.
5	939.	845.	814.	712.	705.	724.	691.	667.	646.	634.	691.	748.	815.	885.
4	876.	781.	709.	651.	654.	666.	634.	609.	585.	572.	625.	679.	740.	806.
3	812.	724.	656.	599.	605.	610.	581.	558.	532.	516.	566.	617.	672.	730.
2	736.	656.	590.	535.	542.	548.	521.	503.	474.	454.	502.	550.	596.	648.
1	678.	587.	510.	443.	454.	464.	427.	399.	383.	376.	408.	439.	492.	546.
0	616.	502.	415.	336.	331.	326.	321.	323.	322.	329.	342.	355.	375.	399.
-1	462.	355.	265.	186.	229.	223.	220.	222.	221.	251.	261.	271.	301.	320.
-2	397.	277.	209.	128.	120.	111.	102.	97.	87.	130.	188.	194.	234.	248.
-3	336.	210.	188.	173.	162.	150.	139.	133.	122.	116.	110.	99.	132.	183.
-4	308.	266.	241.	224.	211.	199.	186.	178.	164.	156.	148.	136.	129.	121.
-5	376.	327.	301.	281.	268.	254.	239.	230.	214.	204.	194.	179.	169.	160.
-6	449.	396.	367.	346.	331.	315.	300.	288.	271.	259.	247.	230.	218.	207.
-7	531.	471.	440.	418.	400.	383.	365.	352.	334.	321.	308.	289.	275.	260.
-8	617.	554.	519.	495.	478.	459.	440.	425.	405.	389.	374.	355.	338.	322.

TABLE A.32 Total cost at constant speed on grades - 3-S2 semi - SI = 3.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1603.	1438.	1341.	1272.	1305.	1352.	1320.	1290.	1284.	1286.	1360.	1423.	1486.	1565.
7	1423.	1274.	1187.	1124.	1155.	1198.	1171.	1147.	1133.	1130.	1205.	1265.	1317.	1387.
6	1274.	1137.	1058.	998.	1023.	1062.	1041.	1025.	1010.	1000.	1072.	1127.	1168.	1225.
5	1136.	1014.	990.	892.	899.	949.	931.	919.	900.	890.	955.	1005.	1036.	1086.
4	1033.	914.	847.	796.	814.	853.	836.	822.	800.	787.	848.	894.	918.	958.
3	932.	826.	762.	711.	730.	762.	746.	736.	712.	693.	750.	791.	805.	837.
2	827.	730.	667.	618.	636.	664.	650.	640.	613.	593.	644.	680.	689.	713.
1	741.	637.	560.	495.	512.	539.	509.	486.	473.	468.	497.	516.	540.	571.
0	655.	527.	437.	357.	351.	352.	355.	363.	367.	379.	396.	410.	428.	451.
-1	186.	145.	126.	113.	101.	176.	190.	205.	211.	243.	254.	260.	274.	283.
-2	237.	191.	168.	153.	139.	130.	122.	119.	110.	107.	104.	97.	161.	180.
-3	314.	258.	231.	213.	196.	184.	173.	167.	155.	150.	145.	135.	131.	126.
-4	402.	336.	304.	283.	264.	251.	238.	229.	215.	207.	199.	187.	179.	173.
-5	500.	424.	388.	365.	344.	329.	312.	302.	286.	275.	265.	251.	241.	231.
-6	610.	525.	484.	458.	434.	417.	399.	386.	367.	354.	343.	327.	315.	302.
-7	731.	636.	590.	562.	537.	516.	497.	480.	459.	444.	432.	414.	398.	385.
-8	863.	757.	708.	677.	649.	626.	605.	586.	564.	545.	530.	510.	494.	479.

TABLE A.33 Total cost at constant speed on grades - small automobile - SI = 2.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	317.	264.	218.	193.	179.	167.	167.	169.	168.	167.	172.	179.	187.	197.
7	305.	255.	200.	184.	170.	159.	159.	159.	159.	158.	162.	168.	177.	187.
6	292.	246.	192.	178.	166.	154.	153.	151.	152.	152.	155.	160.	168.	178.
5	281.	238.	189.	173.	162.	149.	148.	147.	148.	147.	150.	154.	161.	170.
4	268.	230.	190.	167.	156.	145.	144.	143.	143.	143.	145.	150.	155.	162.
3	254.	221.	189.	161.	152.	141.	140.	139.	139.	139.	140.	144.	149.	156.
2	242.	212.	183.	156.	147.	136.	135.	133.	133.	133.	134.	138.	143.	149.
1	227.	202.	174.	151.	139.	128.	128.	127.	125.	124.	126.	130.	135.	142.
0	213.	189.	163.	142.	131.	124.	120.	118.	118.	118.	119.	123.	128.	135.
-1	202.	181.	154.	131.	123.	115.	115.	115.	113.	111.	113.	117.	122.	128.
-2	190.	168.	141.	118.	107.	110.	111.	112.	109.	107.	108.	112.	115.	121.
-3	199.	175.	149.	127.	116.	106.	102.	98.	107.	104.	105.	107.	111.	116.
-4	215.	186.	161.	140.	128.	117.	113.	109.	100.	90.	102.	104.	108.	113.
-5	233.	200.	174.	155.	142.	130.	124.	119.	110.	99.	94.	90.	105.	110.
-6	253.	217.	189.	168.	155.	142.	137.	130.	120.	110.	104.	100.	96.	107.
-7	274.	234.	204.	181.	168.	156.	149.	142.	131.	120.	114.	109.	105.	101.
-8	296.	252.	219.	194.	181.	169.	162.	154.	143.	130.	124.	120.	115.	111.

TABLE A.34 Total cost at constant speed on grades - medium automobile - SI = 2.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	321.	272.	242.	222.	217.	213.	214.	219.	223.	228.	239.	251.	258.	267.
7	300.	255.	227.	210.	204.	198.	198.	202.	208.	213.	225.	239.	245.	253.
6	283.	242.	216.	199.	193.	187.	187.	190.	196.	201.	214.	227.	233.	241.
5	268.	231.	207.	191.	185.	179.	178.	181.	186.	191.	202.	213.	221.	232.
4	256.	223.	200.	185.	178.	171.	171.	173.	178.	182.	190.	197.	209.	223.
3	244.	214.	193.	178.	171.	165.	164.	167.	170.	173.	178.	183.	198.	213.
2	230.	203.	184.	169.	163.	158.	157.	159.	162.	163.	168.	173.	187.	203.
1	212.	190.	171.	157.	153.	148.	145.	146.	150.	152.	158.	163.	174.	187.
0	195.	177.	159.	144.	140.	136.	133.	133.	136.	140.	147.	154.	162.	172.
-1	191.	172.	152.	134.	130.	126.	125.	126.	128.	130.	137.	144.	152.	162.
-2	186.	166.	142.	121.	111.	117.	117.	120.	121.	122.	128.	133.	143.	154.
-3	204.	182.	155.	133.	123.	111.	105.	102.	116.	117.	122.	127.	136.	146.
-4	229.	202.	174.	150.	137.	125.	116.	110.	106.	101.	117.	122.	130.	138.
-5	253.	223.	192.	167.	154.	140.	129.	121.	117.	112.	110.	106.	124.	132.
-6	278.	243.	211.	184.	170.	156.	143.	133.	129.	124.	127.	117.	113.	124.
-7	302.	264.	229.	202.	187.	172.	159.	148.	142.	136.	132.	127.	123.	119.
-8	327.	285.	249.	219.	204.	188.	174.	163.	156.	148.	143.	137.	132.	128.

TABLE A.35 Total cost at constant speed on grades - large automobile - SI = 2.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	318.	270.	247.	236.	230.	227.	230.	234.	258.	282.	283.	288.	326.	366.
7	306.	262.	239.	229.	222.	217.	220.	223.	238.	254.	258.	264.	289.	315.
6	294.	253.	232.	222.	214.	208.	210.	213.	221.	229.	234.	243.	262.	282.
5	281.	245.	225.	215.	206.	199.	201.	203.	207.	212.	218.	226.	239.	254.
4	269.	236.	217.	207.	197.	189.	191.	193.	194.	196.	202.	210.	220.	233.
3	257.	227.	209.	198.	187.	178.	180.	182.	182.	183.	188.	196.	205.	216.
2	243.	217.	199.	187.	175.	165.	168.	171.	171.	172.	177.	184.	193.	204.
1	225.	203.	185.	174.	163.	154.	156.	159.	160.	163.	167.	173.	182.	193.
0	202.	184.	166.	153.	148.	144.	145.	147.	150.	154.	159.	166.	175.	185.
-1	199.	180.	158.	141.	139.	138.	139.	139.	143.	148.	153.	160.	169.	180.
-2	192.	172.	147.	127.	120.	133.	132.	132.	137.	142.	147.	154.	164.	174.
-3	210.	187.	160.	138.	132.	125.	118.	110.	130.	136.	141.	148.	158.	168.
-4	234.	207.	179.	155.	145.	136.	128.	120.	120.	119.	135.	141.	150.	160.
-5	258.	228.	197.	172.	160.	149.	139.	130.	130.	129.	124.	119.	138.	146.
-6	282.	248.	216.	191.	176.	163.	153.	141.	140.	140.	131.	123.	118.	113.
-7	308.	270.	235.	209.	193.	177.	165.	151.	150.	150.	140.	132.	126.	120.
-8	333.	291.	255.	228.	209.	192.	179.	167.	163.	160.	150.	143.	136.	129.

TABLE A.36 Total cost at constant speed on grades - pickup truck - SI = 2.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	299.	270.	250.	236.	224.	213.	223.	233.	253.	272.	284.	295.	311.	328.
7	280.	253.	221.	218.	207.	198.	205.	214.	234.	254.	267.	279.	297.	316.
6	261.	237.	217.	204.	196.	188.	193.	199.	217.	236.	250.	265.	284.	303.
5	246.	224.	207.	194.	187.	180.	184.	188.	204.	219.	235.	251.	268.	286.
4	232.	213.	195.	182.	178.	175.	177.	180.	192.	204.	220.	235.	254.	273.
3	220.	203.	185.	171.	170.	169.	170.	172.	180.	188.	203.	219.	240.	261.
2	205.	191.	172.	157.	159.	161.	162.	164.	169.	174.	186.	199.	222.	244.
1	185.	173.	156.	143.	145.	148.	150.	152.	156.	159.	169.	178.	197.	217.
0	168.	159.	141.	126.	126.	127.	129.	132.	140.	147.	152.	159.	175.	193.
-1	161.	152.	129.	110.	109.	108.	111.	115.	123.	131.	137.	144.	155.	167.
-2	148.	137.	111.	86.	103.	101.	103.	105.	110.	116.	121.	127.	135.	146.
-3	163.	152.	127.	104.	95.	85.	81.	99.	103.	108.	113.	119.	128.	137.
-4	186.	173.	147.	123.	113.	102.	97.	91.	87.	103.	108.	113.	122.	131.
-5	211.	195.	169.	145.	132.	119.	114.	108.	104.	98.	93.	108.	118.	128.
-6	238.	219.	192.	167.	153.	139.	132.	126.	120.	114.	109.	103.	100.	122.
-7	265.	243.	214.	188.	173.	158.	151.	144.	136.	129.	124.	118.	113.	108.
-8	292.	267.	236.	209.	194.	179.	170.	162.	153.	144.	139.	132.	125.	117.

TABLE A.37 Total cost at constant speed on grades - 2A SU truck - SI = 2.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	751.	703.	610.	537.	525.	517.	536.	562.	550.	547.	567.	588.	615.	653.
7	693.	648.	558.	488.	480.	477.	497.	523.	513.	508.	529.	548.	574.	611.
6	638.	596.	515.	451.	444.	443.	462.	487.	477.	474.	492.	511.	536.	571.
5	593.	554.	428.	420.	414.	414.	426.	447.	440.	440.	446.	474.	500.	531.
4	551.	515.	448.	393.	387.	384.	393.	408.	405.	408.	416.	437.	460.	492.
3	511.	478.	416.	366.	359.	355.	359.	368.	369.	375.	385.	403.	425.	453.
2	467.	438.	380.	336.	327.	321.	323.	330.	334.	342.	353.	369.	388.	417.
1	417.	390.	337.	295.	279.	268.	276.	288.	301.	308.	321.	335.	353.	379.
0	364.	341.	289.	247.	235.	227.	232.	240.	254.	273.	288.	302.	319.	344.
-1	261.	239.	240.	215.	206.	200.	193.	190.	209.	231.	251.	270.	284.	306.
-2	253.	228.	206.	189.	172.	157.	141.	128.	178.	193.	216.	238.	253.	274.
-3	284.	256.	230.	210.	190.	171.	154.	139.	141.	145.	157.	212.	225.	242.
-4	320.	289.	260.	238.	214.	192.	172.	155.	156.	159.	167.	176.	177.	216.
-5	359.	323.	291.	268.	240.	214.	194.	177.	176.	176.	182.	188.	190.	195.
-6	400.	361.	326.	301.	269.	239.	220.	203.	200.	198.	202.	205.	206.	209.
-7	441.	398.	361.	332.	298.	267.	247.	231.	224.	220.	223.	225.	227.	231.
-8	486.	438.	396.	363.	329.	297.	278.	262.	253.	246.	249.	251.	252.	254.

TABLE A.38 Total cost at constant speed on grades - 3A SU truck - SI = 2.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1616.	1356.	1152.	973.	974.	981.	989.	1008.	1037.	1071.	1096.	1124.	1168.	1209.
7	1462.	1232.	1056.	904.	903.	909.	915.	933.	957.	988.	1009.	1034.	1075.	1112.
6	1315.	1116.	968.	842.	838.	840.	845.	861.	880.	906.	927.	949.	986.	1021.
5	1172.	1005.	885.	786.	779.	776.	778.	792.	807.	830.	848.	867.	903.	932.
4	1042.	903.	809.	735.	722.	716.	716.	728.	739.	756.	772.	790.	820.	848.
3	915.	805.	736.	685.	668.	657.	655.	664.	670.	683.	697.	714.	742.	766.
2	805.	717.	667.	636.	613.	596.	587.	589.	591.	600.	619.	639.	663.	684.
1	724.	642.	601.	576.	545.	519.	508.	507.	506.	513.	533.	554.	576.	594.
0	666.	574.	514.	470.	445.	424.	412.	410.	408.	412.	422.	432.	452.	469.
-1	578.	466.	386.	375.	352.	335.	319.	313.	317.	327.	328.	330.	341.	353.
-2	576.	464.	385.	321.	294.	271.	245.	231.	223.	221.	269.	272.	281.	287.
-3	603.	488.	411.	349.	321.	298.	268.	257.	246.	240.	234.	228.	224.	217.
-4	645.	527.	449.	389.	360.	336.	311.	296.	284.	277.	268.	261.	257.	248.
-5	693.	574.	496.	438.	408.	383.	358.	343.	330.	322.	312.	302.	295.	285.
-6	748.	627.	551.	494.	463.	437.	412.	397.	383.	374.	362.	350.	343.	330.
-7	812.	689.	613.	558.	525.	497.	473.	458.	442.	433.	418.	404.	395.	381.
-8	876.	754.	680.	628.	594.	566.	540.	525.	509.	497.	482.	465.	455.	440.

TABLE A.39 Total cost at constant speed on grades - 2-S2 semi - SI = 2.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1308.	1178.	1083.	1005.	1019.	1035.	990.	957.	947.	950.	1016.	1086.	1184.	1288.
7	1176.	1057.	970.	902.	914.	928.	887.	860.	845.	843.	908.	976.	1066.	1161.
6	1068.	962.	880.	814.	823.	833.	800.	776.	760.	756.	818.	882.	959.	1044.
5	969.	874.	844.	743.	737.	759.	727.	706.	687.	678.	738.	798.	870.	945.
4	903.	806.	735.	678.	682.	695.	665.	642.	621.	610.	666.	724.	788.	858.
3	835.	747.	678.	622.	629.	635.	607.	586.	562.	548.	601.	655.	713.	776.
2	757.	676.	610.	555.	562.	570.	544.	527.	499.	482.	532.	583.	632.	686.
1	696.	604.	527.	460.	472.	482.	447.	420.	405.	400.	434.	467.	522.	579.
0	633.	518.	430.	351.	346.	342.	337.	341.	340.	349.	364.	378.	401.	427.
-1	472.	363.	273.	193.	243.	237.	234.	237.	236.	268.	279.	290.	322.	344.
-2	411.	290.	221.	139.	130.	121.	111.	105.	95.	137.	203.	211.	251.	268.
-3	356.	228.	206.	189.	177.	165.	153.	146.	134.	127.	120.	109.	141.	200.
-4	334.	290.	264.	245.	232.	219.	205.	196.	181.	172.	164.	150.	142.	134.
-5	408.	358.	330.	309.	295.	280.	264.	254.	237.	226.	215.	199.	188.	178.
-6	488.	433.	402.	381.	365.	348.	331.	318.	300.	287.	274.	256.	243.	230.
-7	578.	516.	483.	460.	441.	423.	404.	390.	370.	356.	341.	320.	305.	289.
-8	672.	606.	569.	544.	526.	506.	486.	470.	448.	431.	415.	393.	375.	357.

TABLE A.40 Total cost at constant speed on grades - 3-S2 semi - SI = 2.5 ($/1000 mi)

GRADE							SPEED mph							
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1670.	1504.	1407.	1341.	1377.	1428.	1399.	1374.	1372.	1379.	1458.	1527.	1595.	1680.
7	1481.	1330.	1244.	1183.	1217.	1263.	1240.	1220.	1210.	1211.	1290.	1355.	1413.	1488.
6	1323.	1184.	1106.	1048.	1075.	1117.	1100.	1087.	1075.	1070.	1146.	1206.	1251.	1313.
5	1178.	1054.	1031.	934.	944.	995.	981.	971.	956.	950.	1018.	1072.	1107.	1162.
4	1069.	948.	881.	831.	850.	892.	877.	867.	847.	837.	901.	951.	979.	1023.
3	962.	854.	790.	740.	761.	794.	780.	772.	751.	735.	795.	839.	856.	892.
2	853.	754.	690.	641.	661.	690.	678.	670.	645.	627.	681.	719.	731.	758.
1	762.	656.	579.	515.	532.	560.	532.	511.	499.	496.	528.	548.	574.	608.
0	674.	544.	453.	374.	367.	370.	373.	382.	388.	401.	420.	436.	456.	480.
-1	197.	155.	134.	120.	108.	191.	205.	221.	228.	261.	273.	280.	296.	306.
-2	253.	206.	182.	166.	151.	142.	133.	130.	120.	116.	113.	105.	177.	198.
-3	337.	279.	250.	231.	214.	201.	190.	183.	170.	165.	160.	149.	144.	139.
-4	433.	364.	331.	309.	289.	275.	261.	252.	237.	228.	220.	206.	198.	191.
-5	539.	460.	423.	399.	376.	360.	343.	332.	315.	303.	293.	277.	267.	255.
-6	659.	570.	527.	500.	475.	457.	438.	424.	404.	390.	378.	361.	347.	334.
-7	789.	691.	644.	614.	588.	565.	546.	528.	506.	489.	476.	456.	439.	425.
-8	933.	823.	772.	740.	710.	686.	664.	644.	620.	600.	583.	562.	545.	528.

TABLE A.41 Total cost at constant speed on grades - small automobile - SI = 2.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	340.	281.	233.	207.	193.	180.	181.	183.	183.	182.	187.	195.	204.	215.
7	325.	271.	213.	197.	183.	171.	172.	172.	173.	172.	176.	183.	193.	205.
6	311.	261.	205.	191.	178.	166.	165.	164.	165.	166.	169.	175.	184.	195.
5	298.	251.	201.	185.	173.	161.	160.	159.	160.	160.	163.	169.	176.	186.
4	284.	243.	202.	177.	167.	156.	155.	155.	155.	155.	158.	163.	170.	178.
3	268.	233.	200.	172.	163.	151.	151.	150.	151.	151.	153.	157.	163.	170.
2	255.	222.	193.	166.	156.	146.	145.	144.	144.	144.	146.	150.	156.	163.
1	237.	212.	183.	160.	148.	138.	137.	137.	135.	134.	137.	142.	148.	155.
0	223.	198.	172.	150.	139.	133.	129.	127.	128.	128.	129.	134.	140.	147.
-1	211.	190.	162.	140.	131.	123.	124.	124.	123.	121.	124.	128.	133.	140.
-2	199.	176.	147.	124.	112.	119.	120.	121.	119.	116.	118.	122.	126.	132.
-3	211.	185.	158.	136.	125.	114.	109.	104.	115.	113.	114.	117.	122.	127.
-4	231.	201.	174.	152.	139.	127.	123.	117.	107.	96.	111.	114.	118.	124.
-5	253.	218.	191.	170.	156.	143.	136.	130.	120.	108.	101.	96.	115.	121.
-6	278.	238.	209.	186.	172.	159.	152.	144.	133.	121.	115.	109.	103.	117.
-7	304.	260.	227.	203.	189.	175.	167.	160.	147.	134.	127.	121.	115.	109.
-8	330.	281.	246.	220.	205.	191.	183.	174.	162.	148.	140.	134.	128.	122.

TABLE A.42 Total cost at constant speed on grades - medium automobile - SI = 2.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	345.	291.	258.	238.	233.	229.	231.	236.	241.	246.	259.	272.	280.	290.
7	322.	272.	243.	225.	219.	213.	214.	218.	225.	230.	244.	258.	265.	276.
6	304.	258.	231.	214.	207.	201.	202.	205.	212.	217.	231.	245.	252.	262.
5	287.	246.	221.	205.	198.	192.	192.	195.	202.	207.	219.	230.	240.	252.
4	274.	237.	213.	198.	191.	184.	184.	186.	192.	197.	206.	214.	227.	242.
3	259.	227.	205.	189.	183.	177.	177.	180.	184.	187.	193.	199.	214.	231.
2	243.	215.	195.	180.	175.	169.	169.	172.	174.	177.	182.	187.	203.	220.
1	224.	200.	182.	167.	163.	159.	157.	157.	162.	165.	171.	177.	189.	203.
0	206.	186.	168.	153.	149.	146.	143.	144.	148.	152.	160.	168.	177.	187.
-1	202.	182.	161.	144.	140.	136.	135.	137.	139.	141.	149.	156.	166.	176.
-2	195.	174.	150.	128.	117.	127.	127.	130.	132.	133.	140.	145.	156.	167.
-3	218.	193.	166.	143.	132.	120.	113.	108.	126.	127.	133.	139.	148.	159.
-4	247.	218.	189.	164.	150.	137.	127.	120.	115.	108.	128.	133.	141.	151.
-5	276.	243.	211.	185.	171.	155.	143.	134.	129.	123.	119.	113.	135.	143.
-6	306.	268.	234.	206.	191.	175.	161.	150.	145.	138.	139.	128.	123.	135.
-7	336.	293.	256.	227.	212.	195.	181.	168.	162.	153.	148.	141.	135.	130.
-8	365.	319.	280.	249.	232.	215.	200.	187.	178.	169.	162.	155.	148.	142.

TABLE A.43 Total cost at constant speed on grades - large automobile - SI = 2.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	344.	291.	265.	254.	249.	246.	250.	254.	279.	304.	305.	312.	351.	393.
7	330.	281.	256.	246.	239.	235.	238.	242.	258.	274.	279.	287.	313.	341.
6	316.	271.	248.	238.	230.	224.	227.	231.	239.	248.	254.	264.	285.	306.
5	302.	261.	240.	230.	221.	215.	217.	220.	225.	230.	237.	247.	261.	277.
4	287.	251.	231.	221.	212.	204.	206.	209.	211.	213.	220.	229.	241.	255.
3	273.	241.	222.	211.	201.	192.	194.	197.	198.	199.	205.	214.	225.	237.
2	258.	230.	211.	200.	188.	178.	181.	185.	186.	187.	193.	201.	211.	224.
1	238.	214.	197.	185.	175.	166.	169.	173.	174.	177.	182.	189.	199.	211.
0	214.	194.	176.	164.	159.	155.	157.	159.	163.	167.	173.	181.	191.	203.
-1	210.	191.	169.	152.	150.	149.	150.	151.	156.	161.	167.	174.	185.	197.
-2	202.	181.	155.	134.	127.	144.	143.	143.	149.	155.	160.	168.	178.	190.
-3	224.	200.	172.	150.	142.	135.	127.	118.	142.	148.	154.	161.	171.	183.
-4	253.	225.	195.	170.	159.	149.	141.	131.	130.	128.	147.	153.	163.	174.
-5	283.	250.	217.	192.	178.	166.	155.	145.	143.	141.	134.	128.	150.	160.
-6	312.	275.	241.	214.	199.	184.	173.	160.	157.	156.	145.	136.	129.	123.
-7	343.	301.	264.	237.	220.	203.	189.	174.	171.	169.	158.	149.	141.	133.
-8	374.	327.	288.	260.	240.	221.	207.	194.	188.	183.	172.	163.	154.	146.

TABLE A.44 Total cost at constant speed on grades - pickup truck - SI = 2.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	321.	288.	267.	253.	242.	231.	242.	253.	274.	294.	307.	319.	337.	355.
7	300.	270.	237.	234.	224.	215.	223.	233.	254.	275.	289.	302.	322.	342.
6	280.	253.	232.	219.	211.	204.	210.	216.	236.	256.	2/1.	286.	307.	328.
5	264.	239.	221.	208.	202.	196.	200.	205.	221.	238.	255.	272.	290.	309.
4	248.	227.	208.	195.	192.	190.	192.	196.	209.	222.	238.	255.	275.	296.
3	234.	216.	197.	184.	183.	183.	185.	188.	196.	204.	221.	237.	259.	283.
2	218.	203.	184.	169.	171.	174.	176.	179.	184.	190.	203.	217.	241.	264.
1	197.	185.	168.	154.	157.	160.	163.	166.	170.	174.	185.	195.	215.	237.
0	179.	170.	152.	136.	137.	139.	142.	145.	153.	161.	167.	174.	192.	211.
-1	172.	163.	140.	120.	120.	120.	123.	127.	136.	145.	152.	159.	171.	184.
-2	156.	144.	117.	92.	113.	112.	114.	117.	123.	129.	135.	142.	151.	162.
-3	175.	164.	138.	114.	104.	94.	88.	111.	116.	121.	126.	133.	142.	152.
-4	204.	189.	162.	138.	127.	115.	108.	101.	95.	115.	120.	126.	136.	146.
-5	234.	217.	189.	164.	150.	136.	129.	123.	117.	109.	102.	121.	131.	142.
-6	267.	246.	217.	191.	176.	160.	153.	145.	138.	129.	122.	115.	109.	135.
-7	299.	275.	244.	217.	201.	185.	176.	167.	158.	149.	142.	133.	127.	119.
-8	331.	304.	271.	243.	227.	210.	200.	191.	179.	169.	161.	152.	143.	133.

TABLE A.45 Total cost at constant speed on grades - 2A SU truck - SI = 2.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	772.	723.	631.	558.	548.	541.	562.	589.	579.	578.	601.	624.	653.	695.
7	712.	666.	577.	507.	500.	498.	519.	548.	539.	537.	559.	581.	608.	648.
6	654.	612.	532.	468.	462.	462.	483.	509.	500.	499.	520.	541.	568.	605.
5	608.	569.	443.	435.	430.	431.	444.	466.	461.	462.	471.	500.	528.	561.
4	564.	528.	461.	407.	401.	399.	409.	425.	424.	428.	438.	461.	486.	519.
3	523.	489.	427.	378.	371.	368.	373.	384.	385.	393.	405.	423.	447.	478.
2	478.	448.	391.	347.	338.	333.	335.	343.	348.	357.	370.	387.	408.	438.
1	428.	400.	347.	305.	289.	279.	287.	300.	313.	322.	336.	351.	371.	398.
0	374.	350.	298.	256.	244.	237.	242.	250.	266.	285.	301.	316.	334.	360.
-1	267.	244.	248.	224.	215.	209.	202.	199.	219.	242.	263.	282.	297.	320.
-2	261.	236.	213.	195.	178.	162.	145.	132.	187.	202.	226.	249.	264.	286.
-3	295.	265.	239.	218.	197.	179.	161.	146.	147.	150.	162.	222.	235.	253.
-4	334.	301.	272.	249.	224.	202.	181.	164.	165.	167.	175.	182.	183.	225.
-5	376.	339.	306.	282.	254.	227.	206.	189.	187.	186.	192.	197.	198.	202.
-6	420.	379.	344.	318.	285.	255.	235.	218.	213.	211.	214.	216.	216.	219.
-7	465.	420.	382.	352.	318.	286.	265.	248.	241.	236.	238.	240.	240.	243.
-8	513.	464.	421.	387.	352.	319.	299.	283.	273.	265.	268.	269.	268.	269.

TABLE A.46 Total cost at constant speed on grades - 3A SU truck - SI = 2.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1673.	1410.	1205.	1026.	1028.	1037.	1047.	1068.	1099.	1136.	1164.	1195.	1242.	1287.
7	1514.	1281.	1104.	952.	951.	958.	966.	986.	1011.	1045.	1069.	1097.	1141.	1182.
6	1362.	1160.	1010.	884.	881.	884.	890.	907.	928.	957.	980.	1004.	1045.	1083.
5	1214.	1044.	922.	824.	816.	814.	818.	833.	849.	874.	894.	916.	955.	986.
4	1080.	938.	842.	768.	756.	749.	751.	763.	776.	795.	813.	833.	865.	896.
3	951.	836.	766.	714.	698.	687.	685.	695.	702.	717.	732.	751.	782.	807.
2	837.	746.	695.	662.	639.	622.	613.	616.	619.	629.	649.	671.	697.	720.
1	755.	669.	625.	600.	568.	543.	531.	531.	531.	538.	559.	582.	605.	625.
0	695.	599.	537.	492.	466.	445.	433.	431.	429.	434.	445.	456.	478.	496.
-1	602.	485.	403.	396.	372.	354.	338.	332.	336.	347.	349.	351.	363.	377.
-2	603.	487.	405.	339.	311.	287.	259.	245.	236.	233.	287.	290.	300.	307.
-3	634.	515.	434.	371.	342.	317.	286.	275.	263.	256.	249.	242.	238.	230.
-4	681.	559.	478.	415.	385.	360.	334.	318.	305.	297.	287.	279.	274.	265.
-5	734.	610.	530.	470.	438.	412.	385.	369.	355.	346.	335.	325.	317.	306.
-6	795.	670.	591.	532.	499.	471.	445.	429.	414.	404.	391.	378.	369.	356.
-7	866.	738.	659.	602.	567.	538.	512.	496.	479.	468.	453.	438.	427.	412.
-8	937.	810.	733.	678.	643.	614.	586.	570.	552.	539.	523.	505.	494.	478.

TABLE A.47 Total cost at constant speed on grades - 2-S2 semi - SI = 2.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1363.	1234.	1141.	1065.	1083.	1102.	1061.	1032.	1028.	1036.	1108.	1184.	1289.	1400.
7	1225.	1106.	1021.	955.	970.	987.	950.	927.	916.	919.	990.	1063.	1159.	1261.
6	1111.	1004.	924.	860.	871.	885.	855.	835.	822.	823.	890.	959.	1042.	1134.
5	1007.	912.	883.	783.	780.	803.	775.	757.	741.	736.	801.	866.	943.	1024.
4	936.	839.	769.	713.	719.	734.	706.	686.	668.	661.	721.	783.	852.	928.
3	864.	775.	707.	652.	660.	668.	642.	624.	603.	592.	648.	707.	769.	837.
2	783.	701.	635.	581.	590.	598.	574.	559.	534.	519.	573.	627.	680.	739.
1	720.	627.	550.	483.	495.	507.	472.	448.	435.	431.	469.	504.	564.	625.
0	654.	538.	450.	371.	367.	363.	359.	364.	365.	376.	393.	410.	436.	466.
-1	484.	373.	282.	201.	261.	256.	254.	257.	257.	290.	304.	317.	352.	376.
-2	429.	306.	236.	154.	144.	133.	122.	116.	104.	146.	224.	233.	276.	295.
-3	381.	252.	228.	210.	197.	184.	171.	163.	150.	142.	135.	122.	153.	222.
-4	367.	321.	294.	274.	260.	245.	230.	220.	204.	194.	185.	169.	160.	151.
-5	449.	397.	368.	346.	330.	314.	298.	286.	268.	255.	243.	225.	213.	202.
-6	539.	482.	449.	427.	409.	391.	373.	359.	339.	325.	310.	290.	275.	261.
-7	638.	574.	540.	516.	495.	476.	455.	439.	418.	402.	386.	363.	346.	328.
-8	743.	675.	636.	610.	591.	569.	547.	529.	506.	487.	469.	446.	425.	406.

TABLE A.48 Total cost at constant speed on grades - 3-S2 semi - SI = 2.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1749.	1583.	1490.	1427.	1468.	1524.	1501.	1481.	1486.	1501.	1586.	1663.	1739.	1832.
7	1549.	1399.	1315.	1257.	1295.	1346.	1328.	1313.	1309.	1317.	1403.	1474.	1539.	1622.
6	1382.	1243.	1166.	1111.	1142.	1188.	1176.	1168.	1161.	1162.	1244.	1309.	1361.	1431.
5	1228.	1104.	1082.	988.	1000.	1055.	1045.	1040.	1030.	1028.	1102.	1162.	1203.	1264.
4	1111.	990.	924.	876.	898.	942.	932.	925.	909.	904.	973.	1027.	1060.	1110.
3	997.	889.	825.	777.	800.	836.	825.	821.	803.	791.	855.	903.	925.	965.
2	883.	783.	720.	672.	693.	725.	715.	710.	688.	674.	731.	772.	788.	820.
1	789.	681.	604.	540.	559.	588.	562.	543.	534.	534.	568.	592.	621.	658.
0	697.	565.	474.	395.	389.	393.	397.	409.	416.	432.	452.	471.	494.	521.
-1	210.	166.	144.	130.	117.	210.	225.	242.	250.	285.	299.	307.	325.	338.
-2	273.	224.	198.	182.	166.	157.	147.	144.	134.	129.	126.	117.	200.	222.
-3	366.	305.	275.	255.	237.	224.	211.	205.	191.	185.	179.	167.	161.	156.
-4	471.	399.	365.	342.	321.	306.	292.	281.	266.	256.	247.	232.	223.	215.
-5	588.	506.	467.	442.	419.	402.	383.	371.	353.	341.	329.	312.	301.	288.
-6	719.	627.	583.	555.	529.	509.	489.	475.	454.	438.	425.	406.	392.	376.
-7	863.	761.	712.	681.	654.	630.	609.	590.	567.	549.	534.	513.	494.	478.
-8	1020.	907.	854.	821.	789.	765.	741.	719.	694.	673.	654.	631.	612.	594.

TABLE A.49 Total cost at constant speed on grades - small automobile - SI = 1.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	362.	298.	247.	220.	206.	193.	194.	196.	196.	195.	201.	210.	219.	232.
7	346.	287.	227.	209.	196.	183.	184.	185.	185.	185.	190.	197.	208.	221.
6	330.	275.	218.	202.	190.	177.	177.	176.	177.	178.	182.	188.	198.	210.
5	315.	265.	212.	196.	184.	172.	171.	170.	172.	172.	175.	181.	189.	201.
4	299.	255.	212.	188.	177.	166.	166.	165.	166.	166.	169.	175.	182.	191.
3	282.	244.	210.	181.	172.	161.	160.	160.	161.	161.	164.	169.	175.	183.
2	267.	232.	202.	175.	165.	155.	154.	153.	154.	154.	156.	161.	167.	175.
1	248.	221.	191.	168.	157.	146.	146.	146.	145.	144.	147.	152.	159.	167.
0	232.	206.	179.	158.	147.	141.	137.	135.	137.	137.	138.	143.	150.	158.
-1	221.	198.	170.	147.	139.	131.	132.	133.	131.	130.	132.	137.	143.	151.
-2	207.	183.	154.	130.	118.	126.	127.	129.	127.	124.	126.	131.	136.	142.
-3	223.	195.	167.	144.	132.	121.	115.	109.	123.	121.	122.	126.	131.	137.
-4	246.	213.	185.	163.	149.	137.	131.	125.	114.	102.	119.	122.	127.	133.
-5	272.	234.	205.	183.	168.	154.	147.	140.	129.	116.	108.	101.	123.	129.
-6	301.	258.	226.	203.	187.	173.	165.	156.	144.	132.	124.	116.	110.	126.
-7	330.	282.	247.	222.	207.	192.	183.	174.	160.	147.	139.	131.	124.	117.
-8	361.	307.	269.	241.	226.	211.	201.	191.	178.	162.	154.	147.	139.	132.

TABLE A.50 Total cost at constant speed on grades - medium automobile - SI = 1.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	369.	309.	275.	254.	248.	244.	246.	252.	258.	263.	276.	290.	299.	311.
7	344.	289.	258.	239.	233.	228.	229.	233.	240.	246.	260.	276.	284.	296.
6	324.	274.	245.	227.	221.	215.	215.	219.	226.	232.	247.	261.	270.	281.
5	306.	261.	234.	217.	211.	205.	205.	208.	215.	221.	233.	246.	257.	269.
4	290.	250.	225.	209.	202.	196.	196.	199.	205.	210.	219.	229.	242.	259.
3	274.	239.	216.	200.	194.	188.	188.	191.	196.	199.	206.	213.	229.	247.
2	257.	226.	205.	190.	185.	179.	179.	182.	186.	188.	195.	200.	216.	235.
1	236.	210.	191.	177.	173.	168.	166.	168.	172.	176.	183.	189.	202.	217.
0	216.	195.	177.	162.	158.	155.	152.	153.	158.	162.	171.	179.	189.	201.
-1	212.	190.	170.	152.	148.	144.	144.	146.	149.	151.	159.	167.	177.	189.
-2	204.	181.	157.	134.	123.	135.	136.	139.	141.	143.	149.	156.	166.	179.
-3	230.	204.	176.	153.	141.	128.	120.	114.	135.	136.	143.	148.	159.	170.
-4	264.	232.	202.	176.	162.	147.	137.	129.	123.	115.	137.	142.	151.	161.
-5	297.	261.	228.	200.	185.	169.	156.	146.	140.	132.	127.	120.	144.	154.
-6	331.	290.	254.	225.	208.	192.	177.	164.	158.	150.	150.	137.	131.	145.
-7	365.	319.	280.	249.	232.	214.	199.	186.	178.	168.	161.	153.	146.	140.
-8	399.	348.	307.	275.	256.	238.	221.	207.	198.	187.	179.	170.	162.	154.

TABLE A.51 Total cost at constant speed on grades - large automobile - SI = 1.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	369.	311.	283.	271.	266.	263.	267.	272.	298.	323.	326.	333.	374.	417.
7	353.	299.	273.	262.	255.	251.	255.	259.	276.	292.	298.	307.	335.	364.
6	337.	288.	264.	253.	245.	239.	243.	247.	256.	265.	272.	283.	305.	328.
5	321.	277.	254.	244.	235.	229.	232.	235.	240.	247.	254.	264.	280.	297.
4	305.	266.	244.	234.	225.	217.	220.	223.	225.	229.	236.	246.	259.	274.
3	289.	255.	234.	223.	213.	204.	207.	210.	211.	214.	220.	230.	242.	255.
2	272.	242.	222.	211.	199.	189.	193.	197.	198.	200.	207.	216.	227.	241.
1	250.	225.	207.	196.	185.	176.	180.	184.	186.	190.	195.	203.	214.	227.
0	225.	204.	186.	173.	169.	165.	168.	170.	174.	179.	185.	194.	205.	217.
-1	221.	201.	178.	161.	159.	159.	160.	161.	166.	172.	178.	186.	198.	211.
-2	211.	189.	163.	141.	133.	153.	153.	153.	159.	166.	172.	180.	191.	203.
-3	237.	212.	183.	160.	151.	143.	135.	125.	152.	159.	164.	173.	183.	196.
-4	271.	240.	209.	183.	171.	161.	151.	141.	138.	136.	157.	164.	174.	186.
-5	305.	269.	235.	208.	194.	181.	169.	158.	155.	152.	144.	136.	161.	171.
-6	339.	298.	262.	234.	218.	202.	190.	176.	172.	169.	157.	147.	139.	131.
-7	374.	328.	289.	260.	242.	224.	209.	193.	189.	186.	173.	163.	153.	144.
-8	410.	358.	317.	287.	266.	246.	231.	216.	210.	203.	190.	180.	169.	160.

TABLE A.52 Total cost at constant speed on grades - pickup truck - SI = 1.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	342.	305.	283.	269.	258.	247.	259.	271.	292.	313.	327.	340.	359.	379.
7	319.	286.	252.	249.	239.	230.	239.	250.	271.	292.	307.	322.	343.	365.
6	298.	268.	246.	233.	225.	218.	225.	232.	252.	273.	288.	305.	327.	350.
5	280.	253.	234.	221.	215.	209.	214.	220.	237.	254.	272.	289.	309.	330.
4	263.	240.	220.	207.	205.	202.	205.	210.	223.	237.	254.	272.	293.	315.
3	248.	228.	208.	195.	194.	195.	197.	201.	209.	219.	236.	253.	276.	301.
2	231.	214.	194.	180.	182.	185.	187.	191.	197.	203.	217.	232.	256.	282.
1	208.	195.	177.	164.	167.	171.	174.	178.	182.	187.	198.	209.	230.	253.
0	189.	179.	161.	145.	147.	149.	152.	156.	165.	173.	180.	188.	207.	227.
-1	182.	171.	149.	129.	129.	129.	133.	138.	147.	157.	164.	171.	185.	199.
-2	163.	150.	123.	97.	122.	121.	124.	127.	133.	140.	146.	154.	163.	176.
-3	186.	174.	147.	122.	112.	101.	94.	120.	125.	131.	137.	144.	154.	165.
-4	219.	203.	175.	150.	138.	125.	118.	110.	103.	124.	130.	137.	147.	158.
-5	254.	235.	206.	180.	165.	150.	143.	135.	127.	119.	110.	131.	142.	154.
-6	291.	268.	238.	211.	195.	178.	169.	160.	152.	142.	134.	124.	117.	146.
-7	328.	301.	269.	241.	224.	207.	197.	187.	175.	165.	156.	146.	138.	129.
-8	365.	335.	300.	271.	254.	236.	225.	214.	201.	189.	180.	169.	158.	146.

TABLE A.53 Total cost at constant speed on grades - 2A SU truck - SI = 1.5 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	804.	753.	662.	590.	581.	577.	599.	629.	622.	624.	650.	676.	709.	754.
7	741.	694.	604.	535.	529.	529.	553.	583.	578.	578.	603.	628.	659.	702.
6	680.	636.	556.	493.	488.	490.	512.	541.	534.	536.	559.	583.	613.	653.
5	631.	590.	464.	457.	453.	455.	471.	494.	491.	495.	506.	538.	568.	605.
4	585.	547.	480.	426.	421.	420.	432.	450.	451.	457.	469.	494.	522.	558.
3	541.	506.	444.	395.	389.	387.	393.	405.	409.	418.	432.	453.	479.	512.
2	495.	464.	406.	362.	353.	349.	353.	363.	369.	380.	394.	413.	436.	468.
1	443.	414.	360.	318.	303.	293.	302.	317.	331.	341.	357.	374.	395.	424.
0	388.	362.	310.	268.	257.	250.	255.	265.	281.	302.	319.	336.	356.	383.
-1	276.	251.	259.	235.	226.	221.	214.	212.	233.	257.	279.	299.	315.	339.
-2	273.	246.	222.	204.	185.	169.	152.	138.	199.	216.	240.	264.	280.	303.
-3	311.	279.	252.	230.	209.	189.	170.	155.	155.	158.	169.	235.	249.	267.
-4	354.	319.	289.	265.	239.	216.	194.	176.	176.	178.	185.	191.	191.	237.
-5	401.	361.	327.	302.	273.	245.	224.	205.	202.	201.	205.	209.	210.	213.
-6	450.	407.	370.	342.	309.	277.	256.	238.	233.	229.	231.	233.	232.	233.
-7	500.	452.	413.	382.	346.	313.	291.	273.	265.	258.	260.	260.	259.	261.
-8	554.	502.	457.	421.	385.	352.	330.	313.	302.	293.	293.	293.	291.	291.

TABLE A.54 Total cost at constant speed on grades - 3A SU truck - SI = 1.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1760.	1491.	1285.	1106.	1109.	1120.	1132.	1156.	1191.	1232.	1264.	1299.	1352.	1402.
7	1592.	1353.	1174.	1022.	1023.	1031.	1041.	1063.	1092.	1129.	1157.	1189.	1239.	1284.
6	1431.	1224.	1072.	946.	943.	948.	955.	975.	999.	1030.	1057.	1085.	1130.	1173.
5	1277.	1100.	977.	878.	871.	870.	875.	892.	911.	938.	961.	986.	1030.	1065.
4	1136.	988.	890.	815.	803.	798.	800.	815.	829.	850.	871.	895.	931.	965.
3	1001.	881.	808.	756.	739.	729.	728.	739.	748.	765.	783.	804.	839.	867.
2	884.	787.	733.	699.	676.	658.	650.	655.	658.	670.	693.	717.	746.	772.
1	798.	706.	660.	633.	600.	575.	563.	564.	565.	574.	597.	621.	647.	669.
0	735.	633.	568.	522.	495.	474.	461.	461.	459.	465.	477.	490.	514.	534.
-1	634.	511.	425.	424.	399.	380.	364.	358.	362.	374.	376.	380.	394.	409.
-2	640.	518.	432.	363.	333.	308.	279.	264.	254.	250.	312.	316.	326.	334.
-3	677.	552.	468.	402.	370.	344.	311.	299.	286.	277.	269.	262.	257.	248.
-4	732.	603.	518.	452.	420.	393.	365.	348.	333.	324.	314.	304.	299.	288.
-5	794.	663.	578.	514.	481.	452.	424.	407.	391.	381.	368.	356.	348.	336.
-6	864.	731.	647.	585.	550.	520.	492.	474.	457.	446.	432.	417.	407.	392.
-7	945.	809.	725.	665.	627.	596.	568.	551.	532.	519.	502.	485.	474.	457.
-8	1027.	892.	810.	752.	714.	682.	652.	634.	615.	600.	581.	562.	549.	531.

TABLE A.55 Total cost at constant speed on grades - 2-S2 semi - SI = 1.5 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1450.	1320.	1229.	1157.	1179.	1202.	1166.	1144.	1147.	1162.	1243.	1328.	1442.	1565.
7	1301.	1182.	1098.	1035.	1054.	1075.	1043.	1026.	1020.	1031.	1109.	1191.	1296.	1409.
6	1177.	1070.	991.	930.	944.	962.	936.	921.	914.	921.	995.	1071.	1163.	1265.
5	1065.	969.	940.	843.	843.	870.	845.	831.	820.	821.	893.	964.	1050.	1139.
4	986.	888.	819.	765.	773.	791.	766.	751.	736.	735.	801.	869.	945.	1029.
3	908.	818.	750.	696.	707.	717.	694.	679.	662.	656.	717.	781.	850.	925.
2	821.	739.	673.	619.	629.	640.	618.	606.	584.	573.	632.	690.	749.	815.
1	754.	660.	582.	516.	530.	542.	510.	487.	477.	477.	518.	558.	623.	690.
0	686.	568.	479.	401.	396.	394.	391.	398.	401.	414.	435.	455.	486.	521.
-1	502.	389.	296.	214.	288.	283.	281.	286.	288.	323.	339.	355.	394.	422.
-2	456.	331.	258.	174.	164.	152.	139.	132.	119.	160.	253.	265.	311.	334.
-3	418.	286.	260.	241.	227.	212.	198.	188.	174.	164.	155.	140.	170.	254.
-4	416.	367.	337.	316.	300.	284.	267.	255.	237.	226.	215.	197.	187.	175.
-5	511.	455.	424.	400.	383.	365.	346.	333.	312.	297.	283.	263.	249.	235.
-6	615.	553.	518.	494.	474.	454.	434.	418.	396.	379.	362.	339.	322.	305.
-7	729.	660.	624.	597.	574.	553.	529.	512.	487.	469.	451.	425.	405.	385.
-8	849.	777.	735.	706.	685.	661.	636.	616.	589.	568.	548.	521.	497.	475.

TABLE A.56 Total cost at constant speed on grades - 3-S2 semi - SI = 1.5 ($/1000 mi)

GRADE							SPEED mph							
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1878.	1709.	1618.	1560.	1606.	1669.	1654.	1643.	1656.	1680.	1776.	1863.	1951.	2055.
7	1660.	1507.	1424.	1371.	1414.	1471.	1460.	1453.	1457.	1473.	1569.	1650.	1725.	1818.
6	1476.	1334.	1260.	1208.	1243.	1295.	1289.	1288.	1288.	1296.	1388.	1462.	1523.	1602.
5	1308.	1181.	1160.	1069.	1085.	1145.	1141.	1142.	1138.	1144.	1226.	1293.	1342.	1412.
4	1179.	1054.	989.	943.	969.	1018.	1012.	1010.	1000.	1002.	1078.	1139.	1179.	1236.
3	1054.	943.	880.	833.	858.	898.	891.	892.	879.	872.	942.	997.	1025.	1072.
2	931.	828.	764.	718.	741.	775.	769.	768.	751.	741.	803.	849.	871.	909.
1	829.	718.	640.	578.	598.	629.	606.	591.	584.	589.	627.	655.	689.	730.
0	732.	597.	505.	426.	421.	426.	433.	446.	456.	475.	499.	521.	547.	579.
-1	230.	183.	160.	144.	130.	237.	254.	273.	282.	320.	336.	347.	367.	383.
-2	304.	251.	224.	206.	189.	178.	168.	164.	153.	148.	144.	134.	232.	256.
-3	410.	344.	313.	291.	271.	257.	243.	236.	221.	214.	207.	194.	187.	180.
-4	530.	453.	416.	391.	368.	352.	336.	325.	308.	297.	287.	270.	260.	250.
-5	663.	575.	534.	507.	481.	463.	443.	429.	409.	396.	383.	364.	350.	335.
-6	813.	715.	667.	637.	608.	587.	565.	549.	526.	508.	494.	473.	456.	438.
-7	977.	868.	815.	782.	753.	726.	703.	682.	656.	636.	620.	596.	575.	556.
-8	1156.	1034.	978.	943.	908.	881.	855.	831.	803.	779.	758.	732.	711.	690.

TABLE A.57 Total cost at constant speed on grades - small automobile - SI = 1.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	394.	322.	267.	239.	223.	210.	211.	213.	214.	213.	219.	228.	239.	253.
7	376.	309.	245.	227.	212.	200.	200.	201.	202.	202.	207.	215.	227.	241.
6	358.	296.	235.	219.	205.	193.	192.	192.	193.	194.	198.	205.	216.	229.
5	340.	284.	228.	211.	199.	186.	185.	185.	187.	187.	191.	197.	206.	219.
4	322.	272.	227.	202.	191.	179.	179.	179.	180.	181.	184.	191.	199.	209.
3	303.	260.	224.	194.	185.	174.	173.	173.	174.	175.	178.	183.	190.	200.
2	285.	247.	215.	187.	177.	167.	166.	166.	166.	167.	170.	175.	182.	191.
1	264.	234.	203.	180.	168.	157.	157.	158.	157.	156.	160.	165.	173.	182.
0	245.	217.	190.	168.	157.	151.	148.	146.	148.	149.	150.	156.	163.	173.
-1	234.	209.	180.	157.	149.	141.	142.	143.	142.	141.	144.	149.	156.	164.
-2	220.	194.	163.	138.	125.	136.	138.	139.	137.	135.	138.	142.	148.	155.
-3	239.	208.	179.	155.	142.	130.	124.	116.	134.	131.	133.	137.	142.	150.
-4	267.	231.	201.	177.	162.	149.	142.	135.	123.	109.	129.	133.	138.	145.
-5	298.	255.	224.	201.	185.	169.	161.	153.	140.	126.	117.	109.	134.	141.
-6	331.	283.	249.	223.	207.	191.	182.	171.	158.	145.	135.	127.	119.	137.
-7	366.	312.	273.	246.	229.	213.	203.	193.	177.	162.	153.	144.	135.	127.
-8	401.	341.	299.	269.	252.	235.	225.	213.	198.	181.	171.	162.	153.	145.

TABLE A.58 Total cost at constant speed on grades - medium automobile - SI = 1.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	403.	335.	297.	275.	269.	264.	266.	272.	279.	285.	298.	313.	324.	338.
7	376.	313.	279.	259.	252.	247.	248.	253.	260.	266.	281.	298.	307.	321.
6	353.	296.	264.	246.	239.	232.	233.	238.	245.	252.	267.	282.	292.	305.
5	332.	281.	251.	234.	227.	221.	222.	226.	233.	239.	252.	265.	277.	292.
4	314.	269.	242.	225.	218.	211.	211.	215.	222.	227.	237.	247.	262.	280.
3	295.	256.	231.	215.	208.	202.	203.	206.	211.	215.	223.	230.	247.	267.
2	275.	241.	219.	203.	198.	193.	193.	196.	200.	203.	210.	217.	234.	253.
1	252.	224.	204.	189.	185.	181.	179.	181.	186.	190.	197.	204.	218.	234.
0	230.	207.	188.	173.	170.	166.	164.	166.	170.	175.	184.	193.	204.	217.
-1	225.	202.	181.	163.	159.	156.	155.	158.	161.	164.	173.	181.	192.	204.
-2	217.	192.	166.	143.	131.	146.	147.	151.	153.	155.	162.	169.	180.	194.
-3	247.	218.	189.	165.	152.	138.	129.	122.	146.	148.	155.	161.	172.	185.
-4	286.	251.	219.	192.	176.	161.	149.	140.	133.	124.	148.	154.	163.	175.
-5	325.	285.	249.	220.	203.	186.	171.	160.	153.	144.	137.	129.	156.	166.
-6	365.	318.	280.	249.	231.	213.	196.	182.	174.	165.	164.	149.	141.	157.
-7	404.	352.	310.	277.	259.	239.	222.	207.	198.	186.	178.	169.	160.	152.
-8	444.	386.	341.	307.	287.	267.	248.	233.	221.	209.	199.	188.	179.	170.

TABLE A.59 Total cost at constant speed on grades - large automobile - SI = 1.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	405.	338.	307.	294.	288.	285.	290.	296.	322.	348.	351.	360.	403.	448.
7	386.	325.	295.	283.	276.	272.	276.	281.	298.	316.	322.	332.	361.	393.
6	367.	312.	285.	273.	265.	259.	263.	268.	277.	287.	295.	307.	330.	355.
5	349.	298.	273.	262.	254.	247.	251.	254.	260.	267.	275.	287.	304.	323.
4	330.	286.	262.	251.	242.	234.	237.	241.	244.	248.	256.	267.	281.	298.
3	312.	273.	251.	239.	229.	220.	223.	227.	229.	232.	239.	250.	263.	278.
2	292.	258.	237.	225.	214.	204.	208.	213.	215.	217.	224.	235.	247.	262.
1	267.	240.	221.	209.	199.	190.	194.	199.	202.	206.	211.	220.	233.	247.
0	239.	217.	198.	186.	181.	178.	181.	184.	189.	194.	201.	210.	222.	236.
-1	236.	214.	190.	173.	172.	171.	173.	175.	180.	187.	193.	202.	214.	229.
-2	224.	200.	173.	151.	142.	165.	165.	166.	172.	179.	186.	195.	206.	220.
-3	255.	227.	197.	172.	163.	154.	145.	134.	164.	172.	178.	187.	198.	212.
-4	294.	260.	227.	200.	187.	175.	165.	154.	150.	145.	170.	177.	188.	201.
-5	334.	294.	258.	230.	214.	199.	186.	174.	170.	165.	155.	147.	174.	185.
-6	374.	328.	290.	260.	242.	225.	211.	196.	190.	186.	173.	160.	151.	141.
-7	415.	363.	321.	291.	271.	251.	234.	217.	211.	206.	192.	180.	169.	158.
-8	457.	399.	354.	322.	299.	277.	261.	244.	236.	227.	212.	201.	188.	178.

TABLE A.60 Total cost at constant speed on grades - pickup truck - SI = 1.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	371.	328.	303.	289.	278.	267.	280.	293.	315.	336.	351.	366.	386.	409.
7	346.	307.	272.	268.	258.	250.	259.	271.	292.	315.	331.	346.	369.	393.
6	322.	287.	264.	251.	243.	237.	243.	252.	272.	294.	310.	328.	351.	376.
5	302.	271.	251.	238.	232.	226.	231.	238.	256.	274.	292.	311.	332.	355.
4	283.	256.	236.	223.	220.	218.	222.	227.	241.	255.	274.	292.	315.	339.
3	266.	243.	223.	209.	209.	209.	213.	217.	226.	236.	254.	272.	297.	323.
2	247.	228.	208.	193.	196.	199.	202.	206.	213.	220.	234.	250.	276.	303.
1	222.	207.	190.	177.	180.	184.	187.	192.	197.	203.	214.	226.	249.	273.
0	202.	190.	172.	157.	159.	161.	165.	170.	178.	187.	195.	204.	224.	245.
-1	194.	183.	160.	140.	140.	141.	145.	151.	160.	170.	178.	187.	201.	216.
-2	173.	159.	130.	104.	133.	132.	135.	140.	146.	153.	160.	168.	179.	193.
-3	200.	186.	159.	133.	122.	109.	102.	132.	138.	144.	150.	158.	169.	181.
-4	238.	220.	191.	165.	152.	138.	129.	120.	112.	137.	143.	150.	161.	173.
-5	279.	257.	227.	200.	184.	167.	159.	150.	141.	130.	119.	143.	155.	168.
-6	322.	296.	264.	236.	218.	200.	190.	179.	169.	158.	147.	136.	126.	160.
-7	365.	334.	300.	270.	252.	233.	222.	210.	197.	185.	174.	162.	152.	140.
-8	408.	373.	336.	305.	286.	267.	255.	242.	227.	213.	202.	189.	176.	161.

TABLE A.61 Total cost at constant speed on grades - 2A SU truck - SI = 1.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	844.	792.	701.	632.	625.	624.	650.	683.	680.	686.	717.	748.	785.	836.
7	776.	728.	639.	572.	569.	571.	598.	631.	629.	633.	663.	692.	727.	775.
6	712.	667.	587.	525.	523.	527.	552.	584.	581.	585.	613.	640.	675.	719.
5	660.	617.	492.	486.	484.	488.	506.	532.	532.	539.	554.	590.	624.	664.
4	610.	572.	504.	452.	448.	449.	463.	483.	487.	496.	511.	540.	571.	611.
3	564.	528.	466.	418.	413.	413.	421.	435.	441.	453.	469.	493.	523.	559.
2	516.	483.	425.	382.	374.	372.	377.	388.	397.	410.	427.	449.	474.	509.
1	462.	432.	378.	336.	322.	313.	323.	339.	356.	368.	386.	405.	429.	460.
0	406.	379.	326.	284.	273.	267.	274.	285.	303.	325.	344.	363.	385.	414.
-1	286.	260.	275.	250.	241.	236.	231.	230.	252.	277.	300.	322.	340.	366.
-2	288.	259.	234.	215.	195.	179.	160.	146.	216.	233.	259.	284.	302.	326.
-3	331.	298.	269.	246.	223.	203.	183.	167.	166.	168.	178.	252.	267.	287.
-4	380.	343.	311.	286.	259.	235.	212.	193.	192.	193.	198.	204.	202.	254.
-5	432.	391.	355.	328.	298.	269.	247.	227.	223.	220.	224.	226.	225.	227.
-6	488.	442.	404.	375.	340.	308.	285.	266.	259.	254.	255.	255.	252.	251.
-7	545.	494.	454.	421.	384.	349.	327.	307.	298.	289.	289.	287.	285.	285.
-8	606.	551.	504.	467.	430.	395.	372.	353.	340.	330.	329.	327.	323.	321.

TABLE A.62 Total cost at constant speed on grades - 3A SU truck - SI = 1.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1869.	1595.	1388.	1210.	1216.	1230.	1245.	1274.	1313.	1359.	1398.	1440.	1500.	1557.
7	1689.	1445.	1265.	1114.	1116.	1127.	1140.	1167.	1200.	1242.	1275.	1314.	1370.	1422.
6	1518.	1305.	1152.	1027.	1025.	1032.	1042.	1066.	1093.	1129.	1161.	1194.	1245.	1295.
5	1355.	1173.	1047.	948.	942.	943.	950.	971.	993.	1024.	1052.	1081.	1131.	1172.
4	1206.	1053.	952.	877.	866.	862.	865.	883.	900.	925.	950.	978.	1018.	1058.
3	1065.	939.	863.	810.	794.	784.	784.	798.	810.	829.	850.	875.	915.	948.
2	942.	839.	782.	747.	723.	707.	700.	706.	711.	726.	751.	778.	811.	841.
1	852.	754.	704.	676.	643.	617.	606.	608.	610.	622.	646.	674.	703.	728.
0	786.	678.	610.	561.	533.	511.	499.	499.	498.	506.	520.	534.	561.	584.
-1	674.	544.	454.	461.	434.	415.	398.	392.	397.	409.	413.	418.	435.	452.
-2	687.	557.	467.	395.	363.	335.	304.	288.	277.	271.	344.	349.	362.	371.
-3	732.	599.	510.	441.	407.	379.	344.	330.	315.	305.	296.	287.	282.	272.
-4	796.	659.	570.	501.	466.	436.	406.	388.	371.	360.	348.	338.	331.	319.
-5	869.	730.	640.	573.	537.	506.	475.	456.	438.	426.	412.	398.	389.	375.
-6	951.	810.	721.	655.	617.	585.	555.	535.	515.	502.	486.	469.	458.	441.
-7	1045.	901.	812.	747.	707.	673.	643.	623.	602.	587.	568.	549.	536.	516.
-8	1142.	998.	911.	849.	808.	773.	740.	720.	698.	681.	660.	638.	623.	603.

TABLE A.63 Total cost at constant speed on grades - 2-S2 semi - SI = 1.0 ($/1000 mi)

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1567.	1440.	1354.	1288.	1317.	1349.	1322.	1310.	1323.	1351.	1444.	1544.	1673.	1812.
7	1404.	1287.	1208.	1150.	1176.	1204.	1180.	1172.	1176.	1198.	1289.	1383.	1503.	1631.
6	1268.	1163.	1087.	1031.	1051.	1075.	1056.	1050.	1051.	1069.	1154.	1242.	1347.	1464.
5	1145.	1050.	1024.	931.	936.	968.	950.	944.	941.	950.	1032.	1115.	1213.	1316.
4	1057.	959.	892.	841.	854.	877.	857.	848.	841.	847.	923.	1001.	1088.	1185.
3	971.	880.	814.	763.	777.	791.	773.	764.	752.	753.	823.	895.	975.	1062.
2	877.	794.	729.	677.	690.	704.	685.	679.	661.	657.	723.	789.	857.	933.
1	805.	709.	632.	567.	582.	597.	568.	550.	543.	549.	596.	643.	716.	792.
0	733.	613.	524.	446.	443.	442.	441.	451.	457.	475.	501.	527.	565.	608.
-1	526.	411.	316.	232.	329.	325.	325.	332.	336.	375.	395.	415.	460.	496.
-2	495.	367.	292.	206.	194.	180.	166.	157.	141.	180.	300.	315.	366.	395.
-3	473.	338.	310.	288.	272.	255.	239.	227.	210.	198.	187.	169.	197.	305.
-4	488.	435.	404.	380.	362.	343.	324.	310.	289.	275.	261.	241.	228.	213.
-5	602.	542.	508.	482.	463.	442.	421.	405.	381.	363.	347.	323.	305.	289.
-6	726.	661.	623.	596.	574.	551.	528.	509.	484.	464.	443.	416.	396.	375.
-7	862.	788.	750.	720.	694.	670.	644.	623.	594.	574.	551.	521.	497.	473.
-8	1005.	929.	884.	852.	828.	801.	773.	749.	718.	693.	669.	638.	609.	583.

TABLE A.64 Total cost at constant speed on grades - 3-S2 semi - SI = 1.0 ($/1000 mi)

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	2045.	1878.	1794.	1746.	1803.	1878.	1875.	1878.	1906.	1946.	2058.	2162.	2267.	2389.
7	1804.	1652.	1576.	1531.	1584.	1651.	1653.	1658.	1674.	1706.	1817.	1912.	2003.	2113.
6	1600.	1459.	1390.	1345.	1389.	1451.	1455.	1465.	1478.	1498.	1604.	1691.	1767.	1862.
5	1414.	1287.	1270.	1185.	1209.	1277.	1282.	1294.	1301.	1318.	1412.	1491.	1553.	1637.
4	1269.	1144.	1082.	1041.	1073.	1129.	1131.	1139.	1137.	1150.	1237.	1309.	1360.	1430.
3	1131.	1019.	957.	914.	945.	991.	991.	1000.	995.	996.	1076.	1140.	1178.	1236.
2	996.	891.	829.	786.	813.	852.	851.	858.	847.	845.	915.	969.	1000.	1047.
1	886.	773.	695.	635.	657.	692.	673.	664.	663.	674.	719.	753.	795.	844.
0	783.	644.	551.	473.	470.	478.	488.	506.	520.	544.	573.	601.	632.	670.
-1	258.	207.	182.	164.	149.	280.	299.	321.	333.	375.	395.	410.	434.	455.
-2	347.	290.	260.	241.	222.	211.	200.	195.	182.	176.	171.	160.	283.	311.
-3	471.	401.	368.	344.	322.	307.	292.	283.	266.	259.	250.	235.	226.	218.
-4	612.	531.	491.	464.	439.	422.	404.	392.	372.	360.	348.	329.	316.	304.
-5	769.	676.	632.	602.	574.	554.	532.	517.	495.	479.	464.	442.	426.	409.
-6	944.	841.	790.	757.	726.	703.	679.	661.	635.	615.	598.	574.	554.	533.
-7	1135.	1022.	965.	929.	898.	868.	844.	820.	791.	768.	750.	722.	697.	675.
-8	1345.	1217.	1158.	1120.	1082.	1053.	1024.	997.	967.	940.	915.	885.	860.	835.

TABLE A.65 Excess cost for speed change cycles ($/1000 cycles) - small automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.8													
10.	1.5	.8												
15.	2.4	1.6	.9											
20.	3.5	2.7	2.0	1.1										
25.	4.8	4.1	3.3	2.4	1.3									
30.	6.3	5.6	4.8	3.9	2.8	1.5								
35.	8.2	7.4	6.7	5.8	4.7	3.4	1.9							
40.	10.2	9.5	8.7	7.8	6.7	5.4	3.9	2.1						
45.	12.5	11.7	11.0	10.1	9.0	7.7	6.2	4.3	2.3					
50.	15.1	14.3	13.5	12.7	11.6	10.3	8.7	6.9	4.8	2.6				
55.	18.1	17.2	16.3	15.6	14.5	13.2	11.7	9.8	7.7	5.5	2.9			
60.	21.3	20.4	19.8	18.8	17.7	16.4	15.0	13.0	11.0	8.7	6.2	3.2		
65.	25.0	24.2	23.4	22.6	21.4	20.2	18.7	16.8	14.8	12.4	9.9	7.0	3.7	
70.	29.3	28.6	27.9	26.9	25.8	24.6	23.0	21.2	19.1	16.9	14.3	11.3	8.1	4.4

TABLE A.66 Excess cost for speed change cycles ($/1000 cycles) - medium automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	1.4													
10.	2.8	1.4												
15.	4.4	3.1	1.6											
20.	6.4	5.0	3.6	2.0										
25.	8.6	7.2	5.8	4.1	2.2									
30.	11.0	9.7	8.2	6.6	4.7	2.5								
35.	14.0	12.7	11.3	9.6	7.6	5.4	3.0							
40.	17.2	15.8	14.5	12.8	10.9	8.7	6.2	3.2						
45.	20.9	19.5	17.9	16.2	14.3	12.1	9.7	6.7	3.5					
50.	24.6	23.3	21.9	20.1	18.1	16.0	13.6	10.6	7.4	3.9				
55.	28.8	27.4	26.0	24.5	22.3	20.0	17.7	14.7	11.5	8.0	4.1			
60.	33.2	31.9	30.5	28.9	26.9	24.7	22.3	19.2	16.0	12.5	8.6	4.5		
65.	38.6	37.2	35.8	34.2	32.2	29.9	27.5	24.6	21.3	17.8	14.0	9.8	5.3	
70.	45.6	44.1	42.8	41.2	39.2	36.9	34.6	31.5	28.3	24.8	21.0	16.7	12.2	7.0

TABLE A.67 Excess cost for speed change cycles ($/1000 cycles) - large automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	1.5													
10.	3.2	1.7												
15.	5.3	3.8	2.0											
20.	7.7	6.2	4.5	2.5										
25.	10.5	9.0	7.3	5.2	2.8									
30.	13.7	12.2	10.4	8.4	5.9	3.2								
35.	17.5	15.9	14.1	12.1	9.7	6.9	3.7							
40.	21.5	19.9	18.2	16.1	13.7	10.9	7.7	4.0						
45.	25.8	24.2	22.3	20.4	18.0	15.2	12.1	8.3	4.3					
50.	30.3	28.7	27.1	25.0	22.5	19.9	16.7	13.0	8.9	4.6				
55.	35.2	33.6	32.0	30.0	27.4	24.8	21.6	17.9	13.9	9.6	4.9			
60.	40.4	38.9	37.1	35.2	32.6	30.1	26.7	23.1	19.0	14.8	10.2	5.3		
65.	45.9	44.4	42.7	40.7	38.3	35.5	32.5	28.6	24.6	20.3	15.8	10.8	5.6	
70.	51.8	50.3	48.6	46.7	44.1	41.5	38.3	34.6	30.6	26.2	21.6	16.7	11.5	6.0

TABLE A.68 Excess cost for speed change cycles ($/1000 cycles) - pickup truck

INITIAL SPEED mpn	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	1.4													
10.	3.0	1.6												
15.	4.9	3.4	1.9											
20.	7.1	5.7	4.1	2.2										
25.	9.6	8.2	6.6	4.8	2.5									
30.	12.5	11.0	9.4	7.6	5.3	2.8								
35.	15.8	14.4	12.7	11.0	8.7	6.2	3.3							
40.	19.5	18.1	16.4	14.6	12.5	9.9	7.0	3.7						
45.	23.5	22.0	20.4	18.5	16.3	13.8	11.0	7.6	4.0					
50.	27.8	26.4	24.6	22.8	20.7	18.0	15.3	11.9	8.2	4.3				
55.	32.7	31.3	29.8	27.9	25.6	23.1	20.2	16.9	13.2	9.2	4.9			
60.	38.7	37.4	35.7	33.9	31.7	29.1	26.1	22.9	19.1	15.2	10.9	6.0		
65.	45.9	44.5	42.8	41.0	38.8	36.3	33.4	30.1	26.1	22.3	18.0	13.2	7.2	
70.	56.9	55.5	54.0	52.0	49.8	47.4	44.4	41.1	37.4	33.4	29.2	24.2	18.1	11.0

TABLE A.69 Excess cost for speed change cycles ($/1000 cycles) - 2A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	3.9													
10.	8.9	4.9												
15.	15.3	11.5	6.6											
20.	24.0	20.1	15.2	8.7										
25.	35.0	30.9	26.1	19.4	10.9									
30.	48.4	44.3	39.4	33.0	24.2	13.4								
35.	63.3	59.4	54.4	47.7	39.1	28.3	14.9							
40.	80.8	76.8	71.9	65.3	56.5	45.8	32.3	17.5						
45.	101.0	97.0	92.2	85.4	76.9	65.9	52.5	37.6	20.2					
50.	122.0	119.0	114.0	107.0	98.3	87.7	74.1	59.3	41.7	21.6				
55.	145.0	141.0	136.0	129.0	121.0	110.0	96.7	81.6	64.2	44.0	22.5			
60.	168.0	165.0	159.0	153.0	145.0	134.0	120.0	106.0	88.1	67.8	46.2	23.9		
65.	194.0	190.0	185.0	180.0	172.0	160.0	146.0	131.0	113.0	93.9	72.2	49.8	25.7	
70.	220.0	215.0	211.0	205.0	196.0	185.0	171.0	157.0	140.0	119.0	97.8	75.3	51.4	25.7

TABLE A.70 Excess cost for speed change cycles ($/1000 cycles) - 3A SU truck

INITIAL SPEED mpn	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	6.7													
10.	15.5	8.8												
15.	27.4	20.6	11.8											
20.	42.5	35.7	26.9	15.2										
25.	61.2	54.5	45.8	33.9	18.8									
30.	84.1	77.5	68.7	56.9	41.7	22.9								
35.	107.0	100.0	91.5	79.8	64.6	45.7	22.8							
40.	134.0	126.0	118.0	107.0	91.3	72.5	49.5	26.7						
45.	165.0	158.0	149.0	137.0	123.0	104.0	80.8	57.8	31.0					
50.	200.0	193.0	184.0	172.0	156.0	139.0	116.0	92.6	65.8	34.7				
55.	236.0	230.0	221.0	210.0	193.0	175.0	152.0	129.0	102.0	71.3	36.5			
60.	274.0	269.0	259.0	248.0	232.0	213.0	191.0	167.0	142.0	110.0	74.9	38.3		
65.	315.0	308.0	300.0	287.0	272.0	252.0	230.0	207.0	180.0	149.0	115.0	78.2	39.8	
70.	356.0	350.0	340.0	329.0	314.0	295.0	272.0	248.0	221.0	190.0	156.0	120.0	81.0	41.3

TABLE A.71 Excess cost for speed change cycles ($/1000 cycles) - 2 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	9.0													
10.	20.8	11.6												
15.	35.4	26.2	14.7											
20.	54.3	45.3	33.6	19.0										
25.	76.4	67.5	56.0	41.2	22.2									
30.	102.0	92.9	81.5	66.8	47.7	25.6								
35.	126.0	117.0	105.0	91.1	72.2	49.9	24.4							
40.	155.0	145.0	134.0	118.0	99.9	77.9	52.2	27.8						
45.	186.0	177.0	164.0	150.0	131.0	110.0	83.7	59.2	31.3					
50.	221.0	212.0	200.0	185.0	167.0	145.0	119.0	94.8	66.9	35.3				
55.	259.0	250.0	237.0	223.0	204.0	183.0	156.0	133.0	104.0	73.1	37.6			
60.	298.0	289.0	278.0	262.0	244.0	221.0	196.0	172.0	144.0	112.0	77.3	39.6		
65.	340.0	332.0	319.0	305.0	287.0	263.0	239.0	214.0	185.0	155.0	119.0	81.8	42.1	
70.	386.0	378.0	365.0	350.0	332.0	310.0	284.0	259.0	232.0	201.0	165.0	128.0	88.0	45.8

TABLE A.72 Excess cost for speed change cycles ($/1000 cycles) - 3 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	11.0													
10.	26.0	14.9												
15.	46.8	35.7	20.8											
20.	74.2	63.1	48.1	27.2										
25.	107.0	95.7	80.6	59.9	32.4									
30.	145.0	134.0	119.0	97.8	70.5	38.0								
35.	180.0	169.0	154.0	133.0	107.0	73.5	35.6							
40.	221.0	210.0	195.0	175.0	146.0	115.0	76.5	40.8						
45.	267.0	256.0	242.0	221.0	193.0	161.0	123.0	87.2	46.2					
50.	317.0	307.0	292.0	272.0	244.0	212.0	174.0	139.0	97.0	50.7				
55.	371.0	361.0	345.0	324.0	297.0	265.0	227.0	191.0	150.0	103.0	53.0			
60.	426.0	416.0	400.0	380.0	351.0	320.0	281.0	246.0	205.0	159.0	108.0	55.0		
65.	485.0	475.0	460.0	438.0	412.0	378.0	340.0	304.0	265.0	218.0	168.0	114.0	58.8	
70.	546.0	535.0	520.0	499.0	473.0	440.0	402.0	365.0	325.0	278.0	227.0	174.0	120.0	60.7

TABLE A.73 Excess cost on horizontal curves ($/1000 mi) - small automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	4.3	8.6	12.2	14.3	15.9	17.9	18.8	18.6	18.4	18.2	17.9	17.7	17.2	16.6
10	0.0	4.2	8.3	11.6	13.4	14.7	16.0	16.3	15.4	14.6	13.8	13.1	12.3	10.6	8.9
15	.1	3.8	7.3	10.1	11.4	12.1	12.3	11.7	10.1	8.7	7.3	6.1	5.0	2.8	1.2
20	.2	3.3	6.1	8.1	8.7	8.8	7.9	6.5	4.5	3.0	1.8	.9	.3	.9	3.8
25	.4	2.6	4.7	5.9	5.8	5.4	3.8	2.1	.7	.1	1.0	2.6	5.1	14.9	31.3
30	.6	1.9	3.2	3.6	3.1	2.3	.8	.2	2.1	5.3	10.5	17.5	26.8	57.5	104.0
35	1.0	1.3	1.9	1.8	1.0	.3	1.3	4.9	12.5	23.1	38.3	57.1	81.2	157.0	
40	1.6	.6	.7	.3	.5	1.8	7.5	18.4	37.5	62.2	96.3	138.0	189.0		
45	2.4	.1	.4	1.4	3.7	7.5	21.5	45.2	83.7	132.0	199.0				
50	3.6	1.2	2.3	5.1	10.5	18.9	47.1	92.3	164.0	257.0					
55	5.2	3.1	6.1	12.2	23.2	39.4	91.9	174.0	307.0						
60	7.3	6.3	12.4	24.0	43.6	71.9	162.0	307.0							
65	10.1	11.0	22.1	42.1	74.9	122.0	275.0	553.0							
70	13.6	17.8	36.3	68.8	121.0	198.0	474.0								

TABLE A.74 Excess cost on horizontal curves ($/1000 mi) - medium automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	8.0	16.0	22.7	26.7	29.7	33.4	35.1	34.7	34.3	33.9	33.4	33.0	32.0	31.0
10	.1	7.6	15.1	21.1	24.5	26.9	29.2	29.7	28.1	26.7	25.2	23.8	22.4	19.3	16.2
15	.2	7.0	13.5	18.5	20.8	22.2	22.6	21.4	18.5	15.9	13.4	11.3	9.2	5.2	2.3
20	.4	6.0	11.3	15.0	16.1	16.3	14.7	11.9	8.3	5.5	3.2	1.6	.5	1.6	7.0
25	.6	4.9	8.7	10.9	10.8	9.9	6.9	3.9	1.2	.1	1.8	4.8	9.4	27.5	58.0
30	1.1	3.6	6.0	6.8	5.8	4.3	1.5	.4	3.9	9.9	19.9	33.1	50.9	109.0	198.0
35	1.8	2.4	3.5	3.2	1.9	.6	2.3	9.0	23.1	42.8	71.2	106.0	151.0	293.0	
40	2.9	1.1	1.3	.5	.9	3.3	13.7	33.6	68.7	114.0	177.0	253.0	349.0		
45	4.4	.1	.7	2.5	6.8	13.8	40.0	84.2	156.0	247.0	372.0				
50	6.5	2.1	4.2	9.4	19.5	35.2	88.3	173.0	308.0	477.0					
55	9.3	5.6	11.1	22.2	42.3	72.2	169.0	320.0	562.0						
60	13.0	11.2	22.3	43.2	78.9	131.0	295.0	561.0							
65	18.1	19.9	40.2	76.9	137.0	224.0	508.0	1030.0							
70	24.7	32.4	66.8	127.0	226.0	369.0	882.0								

TABLE A.75 Excess cost on horizontal curves ($/1000 mi) - large automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	10.4	20.6	29.3	34.4	38.3	43.1	45.3	44.8	44.2	43.7	43.2	42.6	41.4	40.0
10	.1	9.8	19.4	27.3	31.6	34.7	37.7	38.3	36.3	34.4	32.5	30.7	28.9	24.9	20.9
15	.2	9.0	17.4	23.9	27.0	28.7	29.3	27.7	23.9	20.6	17.4	14.5	11.9	6.7	2.9
20	.4	7.8	14.6	19.3	20.8	21.0	18.9	15.4	10.7	7.1	4.2	2.1	.7	2.1	9.1
25	.8	6.2	11.1	13.8	13.7	12.6	8.8	4.9	1.6	.2	2.3	6.0	12.0	35.0	74.0
30	1.4	4.6	7.6	8.5	7.3	5.5	1.8	.5	4.9	12.5	25.0	41.7	64.1	138.0	249.0
35	2.3	3.0	4.4	4.1	2.4	.7	2.9	11.4	29.1	54.0	89.8	134.0	191.0	370.0	
40	3.6	1.4	1.7	.7	1.1	4.2	17.3	42.5	86.9	144.0	224.0	320.0	441.0		
45	5.5	.2	.8	3.1	8.5	17.3	50.2	106.0	197.0	311.0	468.0				
50	8.1	2.7	5.3	11.7	24.3	44.0	110.0	217.0	385.0	600.0					
55	11.6	7.0	13.8	27.8	53.1	90.6	212.0	403.0	710.0						
60	16.3	14.1	28.0	54.5	99.7	165.0	374.0	712.0							
65	22.6	24.8	50.1	96.1	172.0	281.0	638.0								
70	30.6	40.1	82.6	158.0	280.0	458.0	1110.0								

TABLE A.76 Excess cost on horizontal curves ($/1000 mi) - pickup truck

SPEED	DEGREE OF CURVATURE													
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	9.1	17.9	25.2	29.6	32.9	37.0	38.9	38.4	37.9	37.5	37.0	36.6	35.5	34.4
10	.1	8.7	16.9	23.5	27.2	29.8	32.4	32.9	31.2	29.6	28.0	26.5	25.0	21.5	18.2
15	.2	8.0	15.2	20.8	23.4	24.9	25.3	24.0	20.7	17.9	15.2	12.8	10.5	6.1	2.8
20	.5	7.0	12.9	17.0	18.2	18.4	16.6	13.6	9.6	6.5	3.9	2.0	.7	2.0	8.2
25	.8	5.8	10.1	12.5	12.4	11.4	8.1	4.6	1.5	.2	2.3	5.6	10.9	31.0	64.9
30	1.4	4.4	7.1	8.0	6.8	5.2	1.8	.5	4.6	11.6	22.8	37.7	57.5	123.0	222.0
35	2.2	2.9	4.2	3.9	2.3	.7	2.8	10.5	26.3	48.4	80.1	119.0	169.0	327.0	
40	3.5	1.4	1.6	.7	1.1	4.0	15.8	38.1	77.2	128.0	198.0	282.0			
45	5.2	.2	.8	3.0	7.9	15.8	44.7	93.4	173.0	273.0	409.0				
50	7.5	2.5	5.0	10.7	21.9	39.1	97.0	189.0	336.0	522.0					
55	10.8	6.6	12.8	25.3	47.8	80.9	188.0	356.0							
60	15.2	13.1	25.8	49.6	90.1	149.0	335.0								
65	20.9	22.9	46.0	87.5	156.0	254.0	574.0								
70	28.3	37.0	75.8	144.0	255.0	416.0									

TABLE A.77 Excess cost on horizontal curves ($/1000 mi) - 2A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	46.8	95.7	137.0	161.0	180.0	203.0	213.0	210.0	208.0	205.0	203.0	200.0	194.0	188.0
10	.2	44.0	89.3	126.0	147.0	161.0	176.0	179.0	169.0	160.0	151.0	143.0	134.0	115.0	96.5
15	.5	39.1	78.4	109.0	123.0	131.0	134.0	126.0	109.0	93.3	78.3	65.0	52.6	28.6	11.3
20	1.2	32.5	64.0	85.9	92.6	93.6	84.0	67.8	46.1	29.7	16.3	7.3	1.8	7.2	38.6
25	2.3	24.9	47.4	60.0	59.4	54.2	36.8	19.3	5.0	.4	8.0	24.3	51.5	158.0	338.0
30	4.2	17.1	30.6	34.9	29.1	21.1	5.9	1.4	18.4	53.1	111.0	189.0	293.0	633.0	1150.0
35	7.2	9.9	15.8	14.3	7.5	1.9	9.7	46.2	127.0	242.0	407.0	609.0			
40	11.8	4.0	4.8	1.7	3.0	13.9	70.7	185.0	388.0	649.0	1010.0				
45	18.3	.4	2.1	9.5	30.3	68.6	217.0	469.0	877.0						
50	27.3	7.5	16.7	41.8	96.1	183.0	481.0	954.0							
55	39.7	22.2	48.5	107.0	218.0	384.0	920.0	1750.0							
60	56.1	47.2	104.0	218.0	416.0										
65	77.7	86.4	192.0	390.0	717.0										
70	105.0	144.0	321.0												

TABLE A.78 Excess cost on horizontal curves ($/1000 mi) - 3A SU truck

SPEED	DEGREE OF CURVATURE													
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	.1	133.0	270.0	385.0	454.0	506.0	569.0	599.0	591.0	585.0	577.0	570.0	563.0	546.0	529.0
10	.6	126.0	253.0	357.0	415.0	456.0	496.0	504.0	477.0	453.0	427.0	403.0	379.0	326.0	273.0
15	1.7	113.0	224.0	310.0	350.0	373.0	380.0	359.0	309.0	266.0	223.0	186.0	151.0	83.0	33.7
20	3.6	94.8	184.0	246.0	265.0	268.0	241.0	195.0	133.0	86.5	48.3	22.2	5.7	22.0	112.0
25	7.0	73.1	137.0	173.0	171.0	157.0	107.0	57.0	15.2	1.2	24.2	71.3	149.0	452.0	963.0
30	12.6	50.6	89.4	102.0	85.0	62.0	17.6	4.0	54.2	154.0	319.0	540.0	835.0	1800.0	3260.0
35	21.3	29.2	46.3	42.0	22.1	5.6	28.5	133.0	364.0	690.0	1160.0	1730.0			
40	34.1	11.3	13.8	4.8	8.6	40.3	202.0	527.0	1100.0	1840.0	2850.0				
45	52.5	1.1	5.6	27.0	87.1	196.0	616.0	1330.0	2490.0						
50	77.9	20.6	47.2	120.0	275.0	524.0	1370.0	2720.0							
55	113.0	62.0	138.0	307.0	625.0	1100.0	2630.0	5000.0							
60	159.0	133.0	296.0	623.0	1190.0										
65	218.0	243.0	547.0	1110.0	2060.0										
70	295.0	404.0	914.0												

TABLE A.79 Excess cost on horizontal curves ($/1000 mi) - 2-S2 semi

SPEED	DEGREE OF CURVATURE													
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	.2	158.0	319.0	454.0	535.0	596.0	670.0	704.0	696.0	688.0	679.0	671.0	663.0	643.0	622.0
10	.7	150.0	300.0	422.0	490.0	537.0	585.0	594.0	563.0	534.0	504.0	476.0	448.0	385.0	323.0
15	1.9	134.0	265.0	365.0	413.0	440.0	448.0	424.0	365.0	314.0	264.0	220.0	179.0	99.1	40.7
20	4.3	113.0	218.0	291.0	313.0	317.0	285.0	231.0	158.0	103.0	58.2	27.0	6.8	26.8	134.0
25	8.5	88.5	165.0	207.0	205.0	188.0	129.0	69.2	18.6	1.4	29.7	86.3	178.0	535.0	1140.0
30	15.5	62.3	109.0	124.0	104.0	76.1	21.8	4.8	66.6	186.0	382.0	643.0	992.0	2130.0	3850.0
35	26.5	36.5	57.4	52.2	27.6	6.8	35.6	162.0	435.0	818.0	1370.0	2040.0			
40	42.9	14.2	17.3	5.8	10.7	50.7	245.0	626.0	1300.0	2160.0	3340.0				
45	66.5	1.3	6.9	34.6	109.0	240.0	732.0	1570.0	2920.0						
50	99.2	26.7	60.8	150.0	336.0	629.0	1620.0	3190.0							
55	144.0	80.9	175.0	378.0	753.0	1310.0	3100.0	5870.0							
60	204.0	172.0	371.0	760.0	1430.0										
65	283.0	314.0	681.0	1360.0	2470.0										
70	384.0	519.0	1140.0												

TABLE A.80 Excess cost on horizontal curves ($/1000 mi) - 3-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	.3	259.0	519.0	738.0	868.0	967.0	1090.0	1140.0	1130.0	1120.0	1100.0	1090.0	1080.0	1040.0	1010.0
10	1.2	245.0	487.0	685.0	795.0	872.0	948.0	964.0	913.0	866.0	818.0	773.0	727.0	625.0	526.0
15	3.2	219.0	431.0	593.0	670.0	713.0	727.0	687.0	592.0	510.0	430.0	359.0	292.0	162.0	67.3
20	7.0	185.0	355.0	472.0	508.0	514.0	463.0	375.0	258.0	169.0	95.4	44.3	11.2	43.9	218.0
25	13.6	144.0	267.0	335.0	332.0	304.0	209.0	112.0	30.0	2.1	48.1	140.0	289.0	866.0	1840.0
30	24.6	100.0	176.0	200.0	167.0	123.0	34.8	7.5	107.0	300.0	617.0	1040.0	1600.0	3440.0	6220.0
35	41.7	57.5	91.3	83.0	43.4	10.4	56.2	261.0	702.0	1320.0	2210.0	3300.0			
40	66.8	21.5	26.4	8.6	16.1	79.2	393.0	1010.0	2100.0	3490.0	5410.0				
45	103.0	1.9	10.1	52.5	171.0	382.0	1180.0	2530.0	4720.0						
50	153.0	39.4	92.2	234.0	533.0	1010.0	2610.0	5160.0							
55	221.0	121.0	270.0	595.0	1200.0	2100.0	5000.0	9490.0							
60	310.0	261.0	576.0	1200.0	2270.0										
65	428.0	476.0	1060.0	2130.0	3910.0										
70	578.0	788.0	1760.0												

APPENDIX B. COMPONENT CONSUMPTION TABLES

In this appendix, consumption tables for the various cost components are presented. The tables are grouped into categories of constant speed, speed change, and horizontal curvature. The consumption rates indicated in the following tables are multiplied by the unit cost factors in Tables 2 to obtain cost. Summing the costs for the individual components provides the total cost for the tables in Appendix A. The following tables are presented.

Type of table	Vehicle Class							
	Automobiles			Trucks				
Constant Speed	Small	Medium	Large	Pickup	2A SU	3A SU	2-S2	3-S2
Fuel	1	2	3	4	5	6	7	8
Oil	9	10	11	12	13	14	15	16
Tires	17	18	19	20	21	22	23	2[illegible]
M & R	25	26	27	28	29	30	31	3[illegible]
Dep.	33	33	33	33	33	33	33	3[illegible]
Speed Change								
Fuel	34	35	36	37	38	39	40	41
Oil	42	43	44	45	46	47	48	49
Tires	50	51	52	53	54	55	56	57
M & R	58	59	60	61	62	63	64	65
Dep.	66	67	68	69	70	71	72	73
Horizontal Curves								
Fuel	74	75	76	77	78	79	80	81
Tires	82	83	84	85	86	87	88	89
M & R	90	91	92	93	94	95	96	97

TABLE B. 1 Constant speed fuel consumption (gal/1000 mi) - small automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	87.00	85.00	65.00	52.50	46.80	41.00	44.30	47.50	47.50	47.50	52.30	57.00	61.80	66.50
7	85.00	83.00	52.50	48.00	42.50	37.00	39.80	41.50	42.00	42.50	46.30	50.00	55.50	61.00
6	83.00	81.00	50.50	47.00	42.00	36.00	37.00	38.00	39.00	40.00	43.00	46.00	51.00	56.00
5	82.00	79.00	51.50	46.00	41.50	35.00	36.00	37.00	37.80	38.50	41.00	43.50	47.80	52.00
4	80.00	78.00	57.50	44.00	40.00	34.00	35.30	36.50	36.80	37.00	39.50	42.00	45.20	48.30
3	77.00	76.00	61.00	43.00	39.80	33.50	34.50	35.50	35.80	36.00	38.00	40.00	42.50	45.00
2	75.00	73.00	59.50	42.00	38.00	32.00	32.50	33.00	33.00	33.00	35.00	37.00	39.50	42.00
1	70.00	70.00	55.50	41.00	34.50	28.00	29.00	30.00	28.30	27.50	30.00	32.50	35.50	38.50
0	67.00	64.00	50.00	36.00	29.50	27.00	24.80	24.00	24.80	25.00	25.50	28.00	31.50	35.00
-1	57.00	57.00	42.00	27.00	23.00	19.00	21.00	23.00	21.50	20.00	22.30	24.50	27.80	31.00
-2	49.00	49.00	35.00	22.00	19.00	16.00	18.50	21.00	19.00	17.00	19.00	21.30	23.50	26.00
-3	43.00	43.00	32.00	20.00	17.50	15.00	17.30	19.50	17.50	15.50	17.30	19.00	21.50	24.00
-4	38.00	38.00	29.00	20.00	17.40	14.80	16.90	19.00	16.50	14.00	15.80	17.50	20.30	23.00
-5	35.00	35.00	27.50	20.00	17.00	14.50	16.50	18.50	15.30	12.00	14.30	16.50	19.30	22.00
-6	34.50	34.50	26.80	19.00	16.50	14.00	15.80	17.50	14.50	11.50	13.50	15.50	18.30	21.00
-7	34.50	34.50	26.00	17.50	15.50	13.50	15.20	17.00	13.80	10.50	12.30	14.00	16.50	19.00
-8	35.00	35.00	25.50	16.00	14.50	13.00	14.50	16.00	12.50	9.00	11.00	13.00	15.50	18.00

TABLE B. 2 Constant speed fuel consumption (gal/1000 mi) - medium automobile

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	91.00	91.00	83.30	75.00	76.00	77.00	82.00	86.50	90.00	93.50	102.00	110.00	112.00	113.00
7	82.00	82.00	75.50	68.50	68.30	68.00	71.80	75.50	80.00	84.00	93.50	103.00	104.00	106.00
6	77.50	77.50	70.80	64.00	63.00	62.00	65.30	68.50	73.00	77.30	87.00	96.00	97.80	99.50
5	74.00	74.00	67.50	61.00	59.80	58.50	61.30	64.00	68.50	72.50	80.30	87.50	91.50	95.50
4	73.00	73.00	66.50	60.00	57.80	55.50	58.30	60.50	64.50	68.00	73.00	77.50	84.80	92.00
3	71.50	71.50	64.50	57.50	55.50	53.50	56.30	58.80	61.00	63.00	66.00	68.50	78.30	87.50
2	68.00	68.00	60.80	53.50	52.30	50.50	53.00	55.50	56.80	58.00	60.50	62.50	72.50	82.50
1	61.50	61.50	54.30	47.00	46.30	45.00	46.00	46.50	49.30	51.50	54.50	57.00	64.50	72.00
0	55.40	55.40	47.30	38.70	38.00	37.30	37.60	38.00	40.50	43.00	47.90	52.80	57.60	62.70
-1	52.00	52.00	41.80	31.00	30.30	29.50	31.80	33.50	34.80	36.00	41.00	45.50	51.00	56.00
-2	50.80	50.80	39.70	28.00	25.80	22.50	26.30	29.50	30.30	31.00	34.80	38.50	45.00	51.50
-3	51.30	51.30	38.90	26.90	23.70	20.50	23.30	25.50	26.50	27.80	31.50	35.00	41.30	47.30
-4	52.00	52.00	39.90	27.30	24.00	20.30	20.70	21.00	23.00	25.00	28.80	32.00	37.50	42.50
-5	53.00	53.00	40.00	27.30	23.80	20.00	19.30	18.50	20.50	22.80	26.00	29.50	34.50	39.00
-6	53.50	53.50	40.60	27.30	23.50	19.80	18.00	16.30	18.90	21.00	29.00	27.00	30.80	34.00
-7	54.30	54.30	40.70	27.30	23.80	19.50	17.30	15.00	17.30	19.00	21.30	23.50	26.80	30.00
-8	54.50	54.50	41.20	27.30	23.00	19.30	16.80	14.30	15.40	16.50	18.30	20.00	22.80	25.50

TABLE B. 3 Constant speed fuel consumption (gal/1000 mi) - large automobile

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	84.00	84.00	82.30	80.50	81.30	82.00	86.00	90.00	111.00	131.00	131.00	131.00	161.00	190.00
7	83.50	83.50	81.50	79.50	78.80	78.00	81.50	85.00	97.50	110.00	113.00	115.00	133.00	150.00
6	83.00	83.00	80.80	78.50	76.30	74.00	77.30	80.50	86.30	92.00	96.00	100.00	113.00	125.00
5	82.20	82.20	79.60	77.00	74.00	71.00	73.30	75.50	78.50	81.50	85.80	90.00	97.50	105.00
4	81.30	81.30	77.90	74.50	70.30	66.00	68.30	70.50	71.00	71.50	75.80	80.00	85.50	91.00
3	79.80	79.80	75.70	71.50	65.80	60.00	62.30	64.50	64.20	63.80	67.80	71.80	76.60	81.30
2	77.00	77.00	71.50	66.00	59.00	52.00	55.30	58.50	58.00	57.50	61.30	65.00	70.00	75.00
1	70.00	70.00	64.00	58.00	51.80	45.50	48.80	52.00	52.50	53.00	56.00	59.00	64.20	69.40
0	59.00	59.00	51.10	43.20	41.80	40.30	42.30	44.30	46.50	48.70	52.50	56.30	61.60	66.90
-1	56.50	56.50	45.00	33.50	35.00	36.50	37.80	39.00	42.50	46.00	50.00	54.00	60.00	66.00
-2	54.80	54.80	42.90	31.00	32.00	33.00	33.50	34.00	38.50	43.00	47.50	52.00	58.00	64.00
-3	54.00	54.00	41.30	28.50	29.30	30.00	29.50	29.00	34.30	39.50	44.30	49.00	55.40	61.80
-4	53.50	53.50	40.70	27.80	27.20	26.50	25.50	24.50	30.30	36.00	40.30	44.50	50.80	57.00
-5	53.00	53.00	40.00	27.20	25.00	23.00	21.60	20.20	26.00	31.80	34.40	37.00	42.30	47.50
-6	52.50	52.50	39.80	27.00	23.50	20.00	18.00	16.00	22.00	28.00	27.50	27.00	29.50	32.00
-7	52.50	52.50	39.50	26.50	22.00	17.50	13.90	10.20	16.60	23.00	22.50	22.00	23.50	25.00
-8	52.50	52.50	39.50	26.50	20.50	14.50	11.30	8.50	13.30	18.00	18.00	18.00	19.00	20.00

TABLE B. 4 Constant speed fuel consumption (gal/1000 mi) - pickup truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	137.00	137.00	129.00	120.00	111.00	101.00	109.00	116.00	132.00	147.00	155.00	162.00	170.00	178.00
7	127.00	127.00	108.00	108.00	100.00	92.00	97.50	103.00	119.00	135.00	144.00	152.00	162.00	172.00
6	118.00	118.00	109.00	100.00	93.50	87.00	90.00	93.00	108.00	123.00	133.00	143.00	155.00	166.00
5	112.00	112.00	104.00	95.00	89.50	84.00	85.80	87.50	99.80	112.00	124.00	135.00	145.00	155.00
4	107.00	107.00	97.50	88.00	85.50	83.00	83.50	84.00	93.00	102.00	114.00	125.00	137.00	148.00
3	103.00	103.00	92.50	82.00	81.50	81.00	81.00	81.00	86.00	91.00	103.00	114.00	128.00	142.00
2	97.00	97.00	85.00	73.00	75.00	77.00	77.00	77.00	79.50	82.00	91.00	100.00	116.00	131.00
1	86.00	86.00	75.00	64.00	66.50	69.00	69.50	70.00	71.30	72.50	78.80	85.00	98.00	111.00
0	77.90	77.90	64.80	51.60	52.30	53.00	54.00	55.00	59.70	64.40	67.50	70.60	81.90	93.20
-1	72.00	72.00	55.00	38.00	37.80	37.50	39.30	41.00	47.00	53.00	56.50	60.00	66.50	73.00
-2	70.00	70.00	52.30	34.50	33.30	32.00	33.00	34.00	37.50	41.00	44.50	48.00	51.50	57.00
-3	68.00	68.00	51.30	34.50	31.30	28.00	29.00	30.00	33.00	36.00	39.50	43.00	47.50	52.00
-4	68.00	68.00	52.00	36.00	31.50	27.00	27.50	28.00	30.50	33.00	36.50	40.00	45.00	50.00
-5	68.50	68.50	52.80	37.00	31.50	26.00	26.80	27.50	29.80	32.00	35.00	38.00	44.00	50.00
-6	70.00	70.00	54.20	38.30	32.20	26.00	26.60	27.00	28.50	30.00	33.50	37.00	42.00	47.00
-7	71.00	71.00	54.80	38.50	32.30	26.00	26.00	26.00	26.80	27.50	30.80	34.00	38.00	42.00
-8	72.50	72.50	55.50	38.50	32.30	26.00	25.50	25.00	25.00	25.00	28.00	31.00	32.50	34.00

TABLE B. 5 Constant speed fuel consumption (gal/1000 mi) - 2A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	416.00	406.00	330.00	263.00	247.00	231.00	238.00	248.00	223.00	203.00	202.00	201.00	204.00	216.00
7	389.00	380.00	306.00	242.00	230.00	219.00	228.00	240.00	217.00	197.00	198.00	198.00	201.00	214.00
6	362.00	354.00	288.00	230.00	220.00	212.00	221.00	232.00	211.00	194.00	194.00	194.00	198.00	211.00
5	343.00	335.00	228.00	222.00	213.00	206.00	210.00	218.00	201.00	188.00	179.00	189.00	194.00	206.00
4	324.00	317.00	263.00	215.00	206.00	198.00	200.00	204.00	192.00	182.00	176.00	182.00	187.00	200.00
3	305.00	298.00	249.00	206.00	197.00	189.00	187.00	187.00	179.00	174.00	171.00	174.00	180.00	192.00
2	281.00	275.00	230.00	192.00	182.00	173.00	170.00	169.00	165.00	163.00	163.00	166.00	171.00	184.00
1	249.00	243.00	202.00	166.00	151.00	138.00	141.00	146.00	151.00	150.00	153.00	156.00	161.00	174.00
0	212.00	207.00	167.00	132.00	121.00	112.00	113.00	115.00	123.00	133.00	139.00	144.00	150.00	163.00
-1	150.00	147.00	126.00	108.00	101.00	94.60	86.10	79.30	93.10	108.00	120.00	130.00	135.00	147.00
-2	121.00	118.00	109.00	101.00	91.20	82.60	73.10	65.10	73.80	83.70	99.70	115.00	122.00	135.00
-3	121.00	118.00	107.00	97.80	86.60	76.20	65.90	57.10	64.10	72.20	88.30	103.00	110.00	121.00
-4	124.00	121.00	109.00	98.80	84.80	71.60	60.50	50.80	58.00	66.10	79.10	92.00	98.50	110.00
-5	127.00	124.00	110.00	99.70	83.00	67.00	56.50	47.20	53.20	59.90	71.70	83.30	90.70	102.00
-6	130.00	127.00	112.00	101.00	81.10	62.40	53.40	45.50	50.10	55.50	66.40	76.30	83.70	94.30
-7	131.00	128.00	112.00	98.80	78.40	58.80	50.20	42.80	45.70	49.30	60.30	70.30	79.40	91.60
-8	133.00	130.00	110.00	94.20	74.30	55.10	47.50	41.00	42.60	44.90	56.80	67.70	75.90	87.90

TABLE B. 6 Constant speed fuel consumption (gal/1000 mi) - 3A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	885.00	705.00	525.00	344.00	351.00	357.00	360.00	363.00	378.00	393.00	392.00	390.00	399.00	407.00
7	789.00	640.00	491.00	342.00	348.00	353.00	357.00	360.00	373.00	386.00	384.00	382.00	389.00	397.00
6	694.00	576.00	458.00	340.00	344.00	347.00	351.00	354.00	365.00	375.00	374.00	372.00	379.00	386.00
5	596.00	510.00	424.00	338.00	339.00	339.00	342.00	345.00	353.00	361.00	360.00	359.00	366.00	372.00
4	505.00	448.00	391.00	333.00	331.00	328.00	331.00	333.00	339.00	344.00	344.00	343.00	349.00	355.00
3	412.00	383.00	354.00	324.00	318.00	312.00	314.00	315.00	318.00	320.00	321.00	322.00	328.00	333.00
2	330.00	323.00	316.00	308.00	297.00	285.00	282.00	278.00	278.00	278.00	287.00	295.00	300.00	304.00
1	274.00	270.00	272.00	273.00	254.00	235.00	230.00	225.00	225.00	225.00	238.00	250.00	255.00	260.00
0	236.00	217.00	198.00	179.00	168.00	156.00	153.00	149.00	149.00	149.00	153.00	156.00	163.00	169.00
-1	196.00	159.00	122.00	85.00	79.00	73.00	68.00	62.00	72.00	82.00	79.00	75.00	75.00	79.00
-2	153.00	119.00	85.00	50.00	45.00	40.00	30.00	24.00	30.00	37.00	37.00	37.00	37.00	38.00
-3	126.00	96.00	66.00	36.00	32.00	28.00	16.50	15.00	18.50	22.00	25.00	28.00	28.00	30.00
-4	110.00	82.00	54.50	27.00	23.50	20.00	15.50	11.00	15.00	19.00	21.80	24.60	25.00	26.00
-5	94.00	70.00	46.00	22.00	18.50	15.00	11.50	8.00	13.00	18.00	19.80	21.50	22.00	23.00
-6	78.00	58.00	38.00	18.00	14.50	11.00	9.00	7.00	12.00	17.00	17.80	18.50	19.00	20.00
-7	64.50	48.00	31.50	15.00	11.00	7.00	6.50	6.00	11.00	16.00	15.60	15.10	15.00	16.00
-8	46.50	35.00	23.50	12.00	8.50	5.00	5.00	5.00	10.00	15.00	13.70	12.30	12.00	14.00

TABLE B. 7 Constant speed fuel consumption (gal/1000 mi) - 2-S2 semi

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	742.00	655.00	564.00	475.00	477.00	478.00	406.00	337.00	296.00	258.00	286.00	318.00	373.00	428.00
7	683.00	605.00	524.00	446.00	448.00	449.00	384.00	323.00	281.00	240.00	271.00	305.00	353.00	402.00
6	643.00	575.00	500.00	426.00	426.00	425.00	370.00	318.00	276.00	236.00	267.00	301.00	340.00	381.00
5	604.00	546.00	529.00	416.00	402.00	415.00	365.00	318.00	276.00	236.00	267.00	301.00	336.00	372.00
4	594.00	531.00	467.00	406.00	404.00	410.00	364.00	318.00	276.00	236.00	267.00	301.00	334.00	368.00
3	574.00	516.00	455.00	396.00	399.00	400.00	359.00	318.00	276.00	236.00	267.00	301.00	330.00	359.00
2	534.00	481.00	423.00	366.00	372.00	376.00	340.00	305.00	263.00	222.00	254.00	288.00	312.00	337.00
1	505.00	436.00	366.00	297.00	309.00	318.00	274.00	231.00	206.00	182.00	199.00	218.00	252.00	285.00
0	465.00	367.00	284.00	203.00	198.00	193.00	186.00	180.00	174.00	169.00	168.00	170.00	171.00	173.00
-1	346.00	258.00	178.00	102.00	100.00	96.50	93.50	89.50	87.00	111.00	111.00	113.00	129.00	130.00
-2	228.00	129.00	74.20	0.00	0.00	0.00	0.00	0.00	0.00	53.40	54.30	56.70	86.80	86.50
-3	98.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.40	43.30
-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE B. 8 Constant speed fuel consumption (gal/1000 mi) - 3-S2 semi

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	756.00	679.00	599.00	523.00	553.00	588.00	528.00	463.00	426.00	389.00	424.00	445.00	460.00	490.00
7	694.00	627.00	557.00	489.00	518.00	551.00	498.00	443.00	402.00	360.00	399.00	424.00	432.00	456.00
6	655.00	593.00	531.00	467.00	491.00	520.00	478.00	434.00	393.00	350.00	388.00	413.00	411.00	426.00
5	615.00	563.00	562.00	455.00	462.00	505.00	468.00	431.00	389.00	347.00	384.00	407.00	400.00	410.00
4	604.00	547.00	495.00	443.00	462.00	496.00	463.00	426.00	384.00	342.00	378.00	400.00	390.00	396.00
3	581.00	531.00	481.00	430.00	453.00	480.00	451.00	420.00	378.00	335.00	370.00	390.00	375.00	377.00
2	543.00	494.00	444.00	395.00	418.00	444.00	419.00	392.00	350.00	306.00	340.00	361.00	342.00	340.00
1	512.00	447.00	381.00	315.00	339.00	365.00	325.00	285.00	261.00	239.00	252.00	258.00	260.00	271.00
0	470.00	370.00	287.00	205.00	204.00	204.00	202.00	201.00	199.00	199.00	202.00	207.00	210.00	215.00
-1	0.00	0.00	0.00	0.00	0.00	34.10	49.90	58.20	63.80	89.90	91.70	90.90	93.80	89.10
-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.10	24.20
-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE B. 9 Constant speed oil consumption (qts/1000 mi) - small automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	27.60	16.60	11.50	9.28	7.81	6.52	5.83	5.24	4.74	4.00	3.38	3.38	3.38	3.84
7	24.60	14.80	10.30	8.32	7.02	5.88	5.28	4.76	4.32	3.66	3.11	3.12	3.14	3.57
6	21.70	13.00	9.08	7.36	6.23	5.24	4.73	4.28	3.90	3.33	2.84	2.86	2.89	3.31
5	18.70	11.30	7.86	6.40	5.45	4.60	4.17	3.80	3.48	2.99	2.56	2.60	2.64	3.04
4	15.70	9.49	6.65	5.44	4.66	3.96	3.62	3.32	3.07	2.65	2.29	2.34	2.39	2.77
3	12.70	7.72	5.44	4.48	3.87	3.32	3.06	2.84	2.65	2.31	2.02	2.08	2.14	2.50
2	9.76	5.94	4.23	3.52	3.08	2.68	2.51	2.36	2.23	1.98	1.75	1.82	1.90	2.24
1	6.78	4.17	3.01	2.56	2.29	2.04	1.95	1.88	1.82	1.64	1.47	1.56	1.65	1.97
0	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-1	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-2	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-3	5.13	2.92	1.84	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-4	8.11	4.69	3.05	2.24	1.66	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-5	11.10	6.46	4.26	3.20	2.45	1.80	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-6	14.10	8.23	5.48	4.16	3.23	2.44	1.93	1.48	1.40	1.30	1.20	1.30	1.40	1.70
-7	17.00	10.00	6.69	5.12	4.02	3.08	2.48	1.96	1.52	1.30	1.20	1.30	1.40	1.70
-8	20.00	11.80	7.90	6.08	4.81	3.72	3.03	2.44	1.94	1.40	1.20	1.30	1.40	1.70

TABLE B.10 Constant speed oil consumption (qts/1000 mi) - medium automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	27.70	16.70	11.60	9.41	7.96	6.67	5.99	5.39	4.88	4.13	3.49	3.49	3.49	3.96
7	24.70	14.90	10.40	8.43	7.15	6.01	5.41	4.89	4.44	3.77	3.20	3.22	3.23	3.68
6	21.70	13.10	9.15	7.46	6.34	5.35	4.84	4.40	4.01	3.42	2.92	2.94	2.97	3.40
5	18.70	11.30	7.93	6.48	5.54	4.69	4.27	3.90	3.57	3.07	2.63	2.67	2.71	3.11
4	15.70	9.53	6.70	5.51	4.73	4.04	3.69	3.40	3.14	2.71	2.35	2.40	2.45	2.83
3	12.70	7.74	5.48	4.53	3.92	3.38	3.12	2.90	2.70	2.36	2.06	2.12	2.18	2.55
2	9.76	5.96	4.25	3.55	3.11	2.72	2.55	2.40	2.27	2.01	1.77	1.85	1.92	2.27
1	6.78	4.18	3.03	2.58	2.31	2.06	1.97	1.90	1.83	1.65	1.49	1.57	1.66	1.98
0	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-1	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-2	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-3	5.15	2.94	1.88	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-4	8.13	4.73	3.10	2.31	1.73	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-5	11.10	6.51	4.33	3.28	2.54	1.89	1.47	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-6	14.10	8.29	5.55	4.26	3.34	2.55	2.04	1.60	1.40	1.30	1.20	1.30	1.40	1.70
-7	17.10	10.10	6.78	5.23	4.15	3.21	2.61	2.09	1.64	1.30	1.20	1.30	1.40	1.70
-8	20.10	11.90	8.01	6.21	4.96	3.87	3.19	2.59	2.08	1.53	1.20	1.30	1.40	1.70

TABLE B.11 Constant speed oil consumption (qts/1000 mi) - large automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	27.70	16.70	11.70	9.47	8.03	6.75	6.07	5.47	4.95	4.19	3.55	3.55	3.55	4.02
7	24.70	14.90	10.40	8.49	7.22	6.08	5.48	4.96	4.51	3.83	3.25	3.27	3.28	3.73
6	21.70	13.10	9.19	7.51	6.40	5.41	4.90	4.45	4.07	3.47	2.96	2.98	3.01	3.44
5	18.70	11.30	7.96	6.52	5.58	4.74	4.32	3.94	3.62	3.11	2.67	2.70	2.74	3.15
4	15.70	9.54	6.73	5.54	4.77	4.07	3.73	3.43	3.18	2.75	2.37	2.42	2.47	2.86
3	12.80	7.76	5.50	4.55	3.95	3.40	3.15	2.93	2.73	2.38	2.08	2.14	2.20	2.57
2	9.77	5.97	4.26	3.57	3.13	2.74	2.57	2.42	2.29	2.02	1.79	1.86	1.94	2.28
1	6.78	4.19	3.03	2.58	2.32	2.07	1.98	1.91	1.84	1.66	1.49	1.58	1.67	1.99
0	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-1	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-2	3.80	2.40	1.80	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-3	5.15	2.96	1.90	1.60	1.50	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-4	8.14	4.74	3.13	2.34	1.77	1.40	1.40	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-5	11.10	6.53	4.36	3.32	2.58	1.94	1.52	1.40	1.40	1.30	1.20	1.30	1.40	1.70
-6	14.10	8.32	5.59	4.31	3.40	2.61	2.10	1.65	1.40	1.30	1.20	1.30	1.40	1.70
-7	17.10	10.10	6.82	5.29	4.22	3.28	2.68	2.16	1.71	1.30	1.20	1.30	1.40	1.70
-8	20.10	11.90	8.05	6.27	5.03	3.95	3.27	2.67	2.15	1.59	1.20	1.30	1.40	1.70

TABLE B.12 Constant speed oil consumption (qts/1000 mi) - pickup truck

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	20.70	12.60	9.17	7.53	6.47	5.50	5.02	4.59	3.88	3.28	2.76	2.31	2.40	2.70
7	18.60	11.30	8.24	6.78	5.83	4.97	4.55	4.18	3.55	3.01	2.54	2.13	2.22	2.52
6	16.40	9.98	7.31	6.02	5.20	4.45	4.09	3.77	3.21	2.73	2.32	1.96	2.05	2.33
5	14.30	8.68	6.37	5.27	4.57	3.92	3.62	3.36	2.88	2.46	2.10	1.78	1.87	2.14
4	12.10	7.38	5.44	4.51	3.93	3.40	3.16	2.95	2.54	2.19	1.88	1.60	1.70	1.95
3	9.96	6.09	4.50	3.76	3.30	2.87	2.69	2.53	2.21	1.92	1.66	1.43	1.52	1.76
2	7.81	4.79	3.57	3.01	2.67	2.35	2.23	2.12	1.87	1.64	1.44	1.25	1.35	1.58
1	5.65	3.50	2.63	2.25	2.03	1.82	1.76	1.71	1.54	1.37	1.22	1.08	1.17	1.39
0	3.50	2.20	1.70	1.50	1.40	1.30	1.30	1.30	1.20	1.10	1.00	.90	1.00	1.20
-1	3.50	2.20	1.70	1.50	1.40	1.30	1.30	1.30	1.20	1.10	1.00	.90	1.00	1.20
-2	3.50	2.20	1.70	1.50	1.40	1.30	1.30	1.30	1.20	1.10	1.00	.90	1.00	1.20
-3	3.50	2.20	1.70	1.50	1.40	1.30	1.30	1.30	1.20	1.10	1.00	.90	1.00	1.20
-4	5.12	2.98	2.04	1.51	1.40	1.30	1.30	1.30	1.20	1.10	1.00	.90	1.00	1.20
-5	7.27	4.28	2.97	2.27	1.77	1.32	1.30	1.30	1.20	1.10	1.00	.90	1.00	1.20
-6	9.43	5.58	3.91	3.02	2.40	1.85	1.49	1.30	1.20	1.10	1.00	.90	1.00	1.20
-7	11.60	6.87	4.84	3.78	3.03	2.37	1.95	1.58	1.20	1.10	1.00	.90	1.00	1.20
-8	13.70	8.17	5.77	4.53	3.67	2.90	2.42	1.99	1.48	1.10	1.00	.90	1.00	1.20

TABLE B.13 Constant speed oil consumption (qts/1000 mi) - 2A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	70.00	40.40	30.20	23.80	19.70	17.00	14.00	11.60	9.54	8.25	7.92	8.32	8.66	8.95
7	62.10	35.90	26.80	21.20	17.60	15.20	12.60	10.40	8.61	7.47	7.19	7.58	7.91	8.21
6	54.10	31.30	23.50	18.60	15.50	13.40	11.10	9.26	7.68	6.69	6.46	6.84	7.17	7.46
5	46.20	26.80	20.10	16.00	13.40	11.60	9.70	8.10	6.75	5.91	5.74	6.10	6.42	6.72
4	38.30	22.20	16.80	13.40	11.30	9.83	8.26	6.94	5.82	5.13	5.01	5.36	5.68	5.98
3	30.30	17.70	13.40	10.80	9.15	8.05	6.82	5.78	4.89	4.35	4.28	4.62	4.93	5.23
2	22.40	13.20	10.10	8.19	7.03	6.26	5.38	4.62	3.96	3.56	3.55	3.88	4.19	4.49
1	14.40	8.64	6.75	5.60	4.92	4.48	3.94	3.46	3.03	2.78	2.83	3.14	3.44	3.74
0	6.50	4.10	3.40	3.00	2.80	2.70	2.50	2.30	2.10	2.00	2.10	2.40	2.70	3.00
-1	6.50	4.10	3.40	3.00	2.80	2.70	2.50	2.30	2.10	2.00	2.10	2.40	2.70	3.00
-2	9.38	4.97	3.40	3.00	2.80	2.70	2.50	2.30	2.10	2.00	2.10	2.40	2.70	3.00
-3	17.30	9.51	6.64	4.79	3.55	2.70	2.50	2.30	2.10	2.00	2.10	2.40	2.70	3.00
-4	25.30	14.00	9.98	7.38	5.67	4.43	3.26	2.34	2.10	2.00	2.10	2.40	2.70	3.00
-5	33.20	18.60	13.30	9.98	7.79	6.21	4.70	3.50	2.55	2.00	2.10	2.40	2.70	3.00
-6	41.10	23.10	16.70	12.60	9.90	7.99	6.14	4.66	3.48	2.69	2.26	2.40	2.70	3.00
-7	49.10	27.70	20.00	15.20	12.00	9.77	7.58	5.82	4.41	3.47	2.99	2.78	2.70	3.00
-8	57.00	32.20	23.40	17.80	14.10	11.60	9.02	6.98	5.34	4.25	3.72	3.52	3.26	3.00

TABLE B.14 Constant speed oil consumption (qts/1000 mi) - 3A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	104.00	62.70	45.90	37.90	32.40	27.60	24.00	20.80	17.50	15.60	15.50	16.20	16.70	17.20
7	92.40	55.70	40.70	33.70	28.90	24.60	21.40	18.60	15.70	14.10	13.90	14.60	15.20	15.60
6	80.50	48.60	35.60	29.50	25.40	21.60	18.90	16.50	13.90	12.50	12.40	13.00	13.60	14.00
5	[illegible]	41.50	30.50	25.30	21.80	18.70	16.30	14.30	12.10	10.90	10.90	11.50	12.00	12.40
4	56.90	34.50	25.40	21.20	18.30	15.70	13.80	12.10	10.30	9.32	9.33	9.88	10.40	10.80
3	45.10	27.40	20.30	17.00	14.70	12.70	11.20	9.93	8.50	7.74	7.80	8.31	8.78	9.22
2	33.20	20.30	15.10	12.80	11.20	9.75	8.70	7.76	6.70	6.16	6.26	6.74	7.19	7.61
1	21.40	13.30	10.00	8.59	7.64	6.77	6.15	5.58	4.90	4.58	4.73	5.17	5.59	6.01
0	9.60	6.20	4.90	4.40	4.10	3.80	3.60	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-1	9.60	6.20	4.90	4.40	4.10	3.80	3.60	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-2	14.00	7.93	5.34	4.40	4.10	3.80	3.60	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-3	25.90	15.00	10.50	8.17	6.53	5.12	4.04	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-4	37.70	22.10	15.60	12.40	10.10	8.09	6.59	5.31	4.09	3.32	3.20	3.60	4.00	4.40
-5	49.50	29.10	20.70	16.50	13.60	11.10	9.14	7.49	5.89	4.90	4.46	4.25	4.00	4.40
-6	61.30	36.20	25.80	20.70	17.20	14.00	11.70	9.67	7.69	6.48	5.99	5.82	5.56	5.23
-7	73.20	43.30	30.90	24.90	20.70	17.00	14.20	11.80	9.49	8.06	7.52	7.39	7.16	6.84
-8	85.00	50.30	36.10	29.10	24.20	20.00	16.80	14.00	11.30	9.64	9.05	8.96	8.75	8.44

TABLE B.15 Constant speed oil consumption (qts/1000 mi) - 2-S2 semi

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	108.00	66.30	48.90	40.30	34.10	28.60	24.40	20.80	17.20	15.10	14.70	15.10	15.40	15.70
7	95.60	58.80	43.40	35.80	30.40	25.50	21.80	18.60	15.40	13.60	13.20	13.70	14.00	14.30
6	83.30	51.30	37.90	31.30	26.60	22.40	19.20	16.50	13.60	12.10	11.80	12.20	12.60	12.90
5	71.00	43.80	32.40	26.80	22.90	19.30	16.60	14.30	11.90	10.50	10.40	10.80	11.20	11.50
4	58.80	36.30	26.90	22.40	19.10	16.20	14.00	12.10	10.10	9.04	8.93	9.35	9.72	10.10
3	46.50	28.70	21.40	17.90	15.40	13.10	11.40	9.93	8.37	7.53	7.50	7.91	8.29	8.64
2	34.20	21.20	15.90	13.40	11.60	10.00	8.81	7.75	6.62	6.02	6.06	6.48	6.86	7.23
1	21.90	13.70	10.40	8.89	7.85	6.90	6.20	5.58	4.86	4.51	4.63	5.04	5.43	5.81
0	9.60	6.20	4.90	4.40	4.10	3.80	3.60	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-1	9.60	6.20	4.90	4.40	4.10	3.80	3.60	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-2	15.00	8.83	6.09	4.58	4.10	3.80	3.60	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-3	27.30	16.30	11.60	9.06	7.16	5.50	4.21	3.40	3.10	3.00	3.20	3.60	4.00	4.40
-4	39.60	23.90	17.10	13.60	10.90	8.60	6.81	5.31	3.93	3.04	3.20	3.60	4.00	4.40
-5	51.80	31.40	22.60	18.00	14.70	11.70	9.42	7.49	5.69	4.55	3.96	3.60	4.00	4.40
-6	64.10	38.90	28.10	22.50	18.40	14.80	12.00	9.66	7.45	6.06	5.39	5.03	4.58	4.40
-7	76.40	46.40	33.60	27.00	22.20	17.90	14.60	11.80	9.20	7.57	6.82	6.47	6.01	5.50
-8	88.70	53.90	39.10	31.50	25.90	21.00	17.20	14.00	11.00	9.08	8.25	7.90	7.44	6.92

TABLE B.16 Constant speed oil consumption (qts/1000 mi) - 3-S2 semi

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	221.00	138.00	105.00	87.60	75.30	64.70	55.90	46.40	37.50	30.30	29.10	30.00	30.70	32.10
7	196.00	123.00	92.80	77.80	67.00	57.60	49.80	41.50	33.50	27.10	26.10	27.00	27.60	29.00
6	171.00	107.00	81.00	68.00	58.60	50.50	43.70	36.50	29.50	24.00	23.10	23.90	24.60	25.90
5	146.00	91.20	69.20	58.20	50.20	43.40	37.60	31.50	25.60	20.80	20.10	20.90	21.60	22.80
4	120.00	75.50	57.40	48.30	41.80	36.20	31.50	26.50	21.60	17.60	17.10	17.90	18.50	19.60
3	95.30	59.80	45.50	38.50	33.40	29.10	25.40	21.50	17.60	14.50	14.10	14.90	15.50	16.50
2	70.00	44.10	33.70	28.70	25.10	22.00	19.40	16.50	13.60	11.30	11.20	11.80	12.50	13.40
1	44.80	28.40	21.90	18.80	16.70	14.80	13.30	11.50	9.67	8.16	8.18	8.82	9.43	10.30
0	19.60	12.70	10.10	9.00	8.30	7.70	7.20	6.50	5.70	5.00	5.20	5.80	6.40	7.20
-1	19.60	12.70	10.10	9.00	8.30	7.70	7.20	6.50	5.70	5.00	5.20	5.80	6.40	7.20
-2	30.80	18.70	13.50	10.70	8.46	7.70	7.20	6.50	5.70	5.00	5.20	5.80	6.40	7.20
-3	56.10	34.40	25.30	20.50	16.80	13.70	11.00	8.48	6.22	5.00	5.20	5.80	6.40	7.20
-4	81.30	50.10	37.20	30.30	25.20	20.80	17.10	13.50	10.20	7.65	6.73	6.29	6.40	7.20
-5	106.00	65.80	49.00	40.20	33.60	28.00	23.20	18.50	14.20	10.80	9.71	9.31	8.77	8.36
-6	132.00	81.50	60.80	50.00	42.00	35.10	29.30	23.50	18.10	14.00	12.70	12.30	11.80	11.50
-7	157.00	97.20	72.60	59.80	50.40	42.20	35.40	28.50	22.10	17.10	15.70	15.40	14.80	14.60
-8	182.00	113.00	84.40	69.60	58.70	49.30	41.50	33.40	26.10	20.30	18.70	18.40	17.90	17.70

TABLE B.17 Constant speed tire wear (% worn/1000 mi) - small automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	1.76	1.79	1.84	1.91	2.00	2.11	2.25	2.41	2.61	2.83	3.09	3.39	3.73	4.11
7	1.42	1.45	1.49	1.55	1.64	1.74	1.86	2.01	2.19	2.40	2.64	2.91	3.23	3.59
6	1.12	1.14	1.18	1.24	1.31	1.40	1.52	1.65	1.81	2.00	2.22	2.47	2.76	3.10
5	.85	.88	.91	.96	1.02	1.10	1.20	1.32	1.47	1.64	1.84	2.07	2.34	2.64
4	.63	.64	.67	.71	.77	.84	.93	1.03	1.16	1.31	1.49	1.70	1.95	2.22
3	.43	.45	.47	.51	.55	.61	.69	.78	.89	1.03	1.18	1.37	1.59	1.84
2	.27	.28	.30	.33	.37	.42	.48	.56	.66	.77	.91	1.07	1.27	1.50
1	.15	.16	.17	.20	.23	.26	.32	.38	.46	.55	.67	.81	.99	1.19
0	.06	.07	.08	.10	.12	.14	.18	.23	.29	.37	.47	.59	.74	.91
-1	.01	.02	.02	.03	.04	.06	.09	.12	.17	.23	.31	.40	.53	.68
-2	.03	.03	.02	.02	.01	.01	.03	.05	.08	.12	.17	.25	.35	.47
-3	.10	.09	.08	.07	.05	.04	.02	.01	.02	.04	.08	.13	.21	.31
-4	.20	.19	.18	.16	.14	.11	.08	.06	.03	.01	.02	.05	.10	.18
-5	.34	.33	.31	.28	.25	.22	.18	.14	.10	.06	.03	.01	.04	.08
-6	.51	.50	.48	.44	.40	.36	.31	.25	.20	.15	.10	.05	.02	.02
-7	.72	.71	.68	.64	.59	.54	.47	.41	.34	.27	.20	.14	.08	.04
-8	.97	.95	.92	.87	.82	.75	.68	.60	.51	.42	.34	.25	.17	.11

TABLE B.18 Constant speed tire wear (% worn/1000 mi) - medium automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	2.07	2.10	2.15	2.23	2.33	2.45	2.60	2.78	2.99	3.24	3.52	3.84	4.21	4.62
7	1.67	1.70	1.75	1.82	1.91	2.02	2.16	2.32	2.51	2.74	3.00	3.29	3.63	4.02
6	1.32	1.34	1.39	1.45	1.53	1.63	1.75	1.90	2.07	2.28	2.51	2.79	3.10	3.46
5	1.01	1.03	1.06	1.12	1.19	1.28	1.39	1.52	1.68	1.86	2.07	2.32	2.61	2.94
4	.73	.75	.79	.83	.89	.97	1.07	1.18	1.32	1.48	1.68	1.90	2.16	2.46
3	.51	.52	.55	.59	.64	.70	.79	.89	1.01	1.15	1.32	1.52	1.76	2.03
2	.32	.33	.36	.39	.43	.48	.55	.63	.74	.86	1.01	1.18	1.39	1.63
1	.18	.19	.20	.23	.26	.30	.36	.42	.51	.61	.74	.89	1.07	1.28
0	.08	.08	.09	.11	.13	.16	.20	.26	.32	.41	.51	.64	.79	.97
-1	.02	.02	.03	.03	.05	.07	.09	.13	.18	.24	.32	.43	.55	.71
-2	.04	.03	.03	.02	.01	.01	.03	.05	.08	.12	.18	.26	.36	.49
-3	.12	.11	.10	.08	.07	.05	.03	.02	.02	.04	.08	.13	.21	.30
-4	.24	.23	.21	.19	.16	.14	.10	.07	.05	.02	.02	.05	.09	.16
-5	.40	.39	.37	.34	.30	.26	.22	.17	.13	.09	.05	.02	.03	.07
-6	.60	.59	.56	.53	.48	.43	.38	.32	.25	.19	.14	.08	.04	.01
-7	.85	.83	.80	.76	.71	.65	.58	.50	.42	.34	.26	.19	.12	.07
-8	1.14	1.12	1.08	1.03	.97	.90	.82	.73	.63	.53	.43	.34	.24	.16

TABLE B.19 Constant speed tire wear (% worn/1000 mi) - large automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	2.40	2.43	2.49	2.58	2.69	2.83	3.00	3.20	3.43	3.71	4.02	4.38	4.78	5.24
7	1.94	1.97	2.02	2.10	2.20	2.33	2.48	2.66	2.88	3.13	3.42	3.75	4.12	4.55
6	1.53	1.56	1.60	1.67	1.76	1.87	2.01	2.18	2.37	2.60	2.86	3.17	3.51	3.91
5	1.17	1.19	1.23	1.29	1.37	1.47	1.59	1.74	1.91	2.12	2.36	2.63	2.95	3.31
4	.85	.87	.91	.96	1.03	1.12	1.22	1.35	1.51	1.69	1.90	2.15	2.44	2.77
3	.59	.61	.64	.68	.74	.81	.90	1.01	1.15	1.31	1.49	1.72	1.97	2.27
2	.37	.39	.41	.44	.49	.55	.63	.72	.84	.97	1.14	1.33	1.56	1.82
1	.21	.22	.23	.26	.30	.34	.40	.48	.57	.69	.83	.99	1.19	1.43
0	.09	.10	.11	.13	.15	.19	.23	.29	.36	.45	.57	.71	.88	1.08
-1	.02	.02	.03	.04	.05	.07	.10	.14	.20	.27	.36	.47	.61	.78
-2	.04	.04	.03	.03	.02	.01	.03	.05	.08	.13	.19	.28	.39	.53
-3	.14	.13	.12	.10	.08	.06	.04	.02	.02	.04	.08	.14	.22	.32
-4	.28	.26	.25	.22	.19	.16	.13	.09	.06	.03	.02	.05	.10	.17
-5	.46	.45	.43	.39	.35	.31	.26	.21	.16	.11	.07	.03	.02	.07
-6	.70	.68	.65	.62	.57	.51	.45	.38	.31	.24	.17	.11	.06	.02
-7	.99	.97	.93	.88	.83	.76	.68	.59	.50	.41	.32	.24	.16	.09
-8	1.32	1.30	1.26	1.20	1.13	1.05	.96	.86	.75	.64	.53	.41	.31	.21

TABLE B.20 Constant speed tire wear (% worn/1000 mi) - pickup truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	2.26	2.30	2.35	2.43	2.53	2.66	2.82	3.01	3.23	3.48	3.77	4.10	4.48	4.90
7	1.85	1.88	1.93	2.00	2.10	2.21	2.36	2.53	2.73	2.96	3.23	3.54	3.89	4.28
6	1.48	1.51	1.55	1.61	1.70	1.80	1.93	2.09	2.27	2.48	2.73	3.01	3.34	3.71
5	1.15	1.17	1.21	1.27	1.34	1.44	1.55	1.69	1.86	2.05	2.28	2.53	2.83	3.17
4	.86	.88	.91	.96	1.03	1.11	1.21	1.34	1.48	1.66	1.86	2.10	2.37	2.68
3	.61	.63	.66	.70	.76	.83	.92	1.02	1.15	1.31	1.49	1.70	1.94	2.23
2	.41	.42	.45	.48	.53	.59	.66	.75	.86	1.00	1.16	1.34	1.56	1.82
1	.24	.26	.27	.30	.34	.39	.45	.52	.62	.73	.87	1.03	1.22	1.45
0	.12	.13	.14	.16	.19	.23	.28	.34	.41	.50	.62	.76	.92	1.12
-1	.04	.05	.06	.07	.09	.11	.14	.19	.25	.32	.41	.53	.67	.84
-2	.03	.03	.02	.01	.02	.04	.06	.08	.12	.18	.25	.34	.45	.59
-3	.10	.09	.08	.07	.05	.04	.02	.02	.04	.08	.13	.19	.28	.39
-4	.21	.20	.19	.17	.14	.12	.09	.06	.03	.02	.04	.09	.15	.23
-5	.36	.35	.33	.30	.27	.23	.19	.15	.11	.07	.04	.02	.06	.11
-6	.56	.54	.52	.48	.44	.39	.34	.28	.23	.17	.11	.07	.03	.04
-7	.79	.78	.75	.71	.66	.60	.53	.46	.38	.31	.23	.16	.10	.05
-8	1.07	1.05	1.02	.97	.91	.84	.76	.67	.58	.49	.39	.30	.22	.14

TABLE B.21 Constant speed tire wear (% worn/1000 mi) - 2A SU truck

GRADE							SPEED mph							
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	6.77	6.92	7.11	7.35	7.63	7.97	8.35	8.79	9.29	9.85	10.50	11.20	11.90	12.80
7	5.36	5.49	5.67	5.88	6.13	6.43	6.78	7.18	7.63	8.13	8.71	9.34	10.00	10.80
6	4.12	4.23	4.39	4.57	4.80	5.06	5.37	5.72	6.13	6.58	7.10	7.67	8.32	9.03
5	3.04	3.14	3.27	3.43	3.63	3.86	4.13	4.44	4.79	5.20	5.65	6.17	6.75	7.39
4	2.12	2.21	2.32	2.45	2.62	2.81	3.04	3.31	3.62	3.97	4.37	4.83	5.34	5.92
3	1.37	1.44	1.53	1.64	1.77	1.93	2.13	2.35	2.61	2.91	3.26	3.65	4.10	4.61
2	.78	.83	.90	.99	1.09	1.22	1.37	1.56	1.77	2.02	2.31	2.64	3.02	3.46
1	.36	.39	.44	.50	.58	.67	.78	.92	1.09	1.29	1.52	1.79	2.11	2.48
0	.10	.12	.14	.18	.22	.28	.36	.46	.57	.72	.90	1.11	1.36	1.66
-1	.02	.01	.01	.02	.03	.06	.10	.15	.22	.32	.44	.59	.77	1.00
-2	.17	.16	.13	.11	.08	.06	.03	.01	.03	.08	.14	.23	.35	.51
-3	.49	.46	.43	.38	.33	.27	.22	.16	.10	.06	.02	.04	.09	.18
-4	.98	.94	.88	.82	.74	.66	.56	.47	.37	.28	.19	.12	.06	.02
-5	1.62	1.57	1.50	1.42	1.32	1.20	1.08	.94	.80	.66	.53	.39	.27	.17
-6	2.43	2.37	2.29	2.18	2.05	1.91	1.75	1.58	1.40	1.21	1.02	.84	.65	.48
-7	3.41	3.34	3.23	3.11	2.96	2.78	2.59	2.38	2.16	1.92	1.68	1.44	1.20	.96
-8	4.55	4.46	4.35	4.20	4.02	3.82	3.59	3.35	3.08	2.80	2.51	2.21	1.91	1.61

TABLE B.22 Constant speed tire wear (% worn/1000 mi) - 3A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	5.04	5.14	5.26	5.39	5.54	5.71	5.90	6.11	6.34	6.59	6.86	7.15	7.47	7.81
7	4.01	4.10	4.21	4.33	4.46	4.62	4.79	4.97	5.18	5.40	5.65	5.92	6.21	6.52
6	3.10	3.18	3.28	3.38	3.50	3.64	3.79	3.95	4.14	4.34	4.56	4.80	5.06	5.35
5	2.31	2.38	2.46	2.55	2.66	2.77	2.91	3.05	3.21	3.39	3.59	3.80	4.04	4.29
4	1.64	1.69	1.76	1.84	1.93	2.03	2.14	2.27	2.41	2.56	2.73	2.92	3.12	3.35
3	1.08	1.12	1.18	1.24	1.32	1.40	1.49	1.60	1.72	1.85	1.99	2.15	2.33	2.52
2	.63	.67	.71	.76	.82	.89	.96	1.05	1.14	1.25	1.37	1.50	1.65	1.81
1	.31	.33	.36	.40	.44	.49	.55	.61	.68	.77	.86	.97	1.09	1.22
0	.10	.11	.13	.15	.18	.21	.25	.29	.34	.40	.47	.55	.64	.75
-1	.03	.02	.02	.02	.03	.05	.07	.09	.12	.15	.20	.25	.31	.39
-2	.16	.16	.15	.13	.12	.10	.09	.07	.06	.04	.04	.07	.10	.14
-3	.42	.40	.39	.37	.35	.32	.29	.26	.23	.19	.16	.13	.10	.07
-4	.79	.77	.75	.72	.69	.65	.61	.56	.52	.47	.41	.36	.31	.26
-5	1.27	1.25	1.22	1.19	1.15	1.10	1.04	.99	.92	.85	.78	.71	.63	.56
-6	1.88	1.85	1.82	1.77	1.72	1.66	1.60	1.52	1.44	1.36	1.27	1.17	1.08	.98
-7	2.60	2.57	2.53	2.48	2.41	2.34	2.27	2.18	2.08	1.98	1.87	1.76	1.64	1.51
-8	3.43	3.40	3.35	3.29	3.22	3.14	3.05	2.95	2.84	2.72	2.59	2.46	2.31	2.17

TABLE B.23 Constant speed tire wear (% worn/1000 mi) - 2-S2 semi

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	4.25	4.30	4.37	4.45	4.57	4.70	4.86	5.04	5.25	5.49	5.75	6.05	6.38	6.74
7	3.39	3.43	3.49	3.57	3.67	3.79	3.93	4.10	4.29	4.50	4.74	5.01	5.31	5.65
6	2.62	2.66	2.71	2.78	2.87	2.98	3.11	3.25	3.42	3.61	3.83	4.07	4.34	4.64
5	1.96	1.99	2.03	2.10	2.17	2.27	2.38	2.50	2.65	2.82	3.01	3.23	3.47	3.74
4	1.39	1.41	1.45	1.50	1.57	1.65	1.74	1.85	1.98	2.13	2.30	2.48	2.70	2.93
3	.92	.94	.97	1.01	1.07	1.13	1.21	1.30	1.41	1.53	1.67	1.84	2.02	2.23
2	.54	.56	.58	.62	.66	.71	.77	.85	.93	1.03	1.15	1.29	1.44	1.62
1	.27	.28	.29	.32	.35	.39	.43	.49	.55	.63	.73	.83	.96	1.10
0	.09	.09	.10	.12	.14	.16	.19	.23	.27	.33	.40	.48	.58	.69
-1	.03	.03	.02	.02	.02	.03	.05	.07	.09	.13	.17	.22	.29	.37
-2	.15	.15	.14	.12	.11	.09	.07	.05	.03	.02	.04	.06	.10	.15
-3	.37	.36	.35	.33	.30	.27	.24	.20	.17	.13	.09	.06	.03	.03
-4	.69	.68	.66	.63	.59	.55	.50	.45	.39	.34	.28	.22	.17	.11
-5	1.11	1.09	1.07	1.03	.98	.93	.87	.80	.72	.64	.56	.48	.39	.31
-6	1.62	1.60	1.57	1.53	1.47	1.40	1.33	1.24	1.15	1.05	.94	.83	.72	.61
-7	2.24	2.21	2.17	2.12	2.05	1.97	1.88	1.78	1.67	1.55	1.42	1.28	1.14	1.00
-8	2.95	2.92	2.87	2.81	2.74	2.64	2.54	2.42	2.29	2.14	1.99	1.83	1.66	1.49

TABLE B.24 Constant speed tire wear (% worn/1000 mi) - 3-S2 semi

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	5.40	5.45	5.51	5.59	5.69	5.80	5.94	6.09	6.26	6.45	6.67	6.91	7.17	7.45
7	4.31	4.35	4.41	4.48	4.57	4.67	4.79	4.93	5.08	5.26	5.45	5.67	5.90	6.16
6	3.34	3.38	3.43	3.49	3.57	3.66	3.77	3.89	4.03	4.18	4.36	4.55	4.76	4.99
5	2.50	2.53	2.57	2.63	2.69	2.77	2.87	2.97	3.09	3.23	3.38	3.55	3.74	3.95
4	1.78	1.80	1.84	1.88	1.94	2.01	2.09	2.18	2.28	2.40	2.53	2.68	2.84	3.02
3	1.18	1.20	1.23	1.26	1.31	1.37	1.43	1.51	1.60	1.69	1.80	1.93	2.07	2.22
2	.70	.72	.74	.77	.81	.85	.90	.96	1.03	1.11	1.20	1.30	1.42	1.54
1	.35	.36	.37	.40	.42	.45	.49	.54	.59	.65	.72	.80	.89	.99
0	.12	.12	.13	.15	.16	.18	.21	.23	.27	.31	.36	.42	.48	.56
-1	.04	.04	.04	.03	.03	.03	.04	.06	.07	.10	.12	.16	.20	.25
-2	.20	.20	.19	.18	.17	.15	.13	.11	.09	.07	.05	.04	.04	.06
-3	.49	.48	.47	.45	.43	.40	.37	.34	.30	.27	.23	.19	.15	.12
-4	.90	.89	.87	.84	.81	.78	.74	.69	.64	.59	.53	.47	.41	.35
-5	1.43	1.41	1.39	1.36	1.32	1.28	1.22	1.16	1.10	1.03	.95	.87	.79	.70
-6	2.08	2.07	2.04	2.00	1.95	1.90	1.83	1.76	1.68	1.59	1.50	1.40	1.29	1.18
-7	2.86	2.84	2.81	2.76	2.71	2.64	2.57	2.48	2.38	2.28	2.16	2.04	1.91	1.78
-8	3.76	3.74	3.70	3.65	3.59	3.51	3.42	3.32	3.21	3.09	2.95	2.81	2.66	2.51

TABLE B.25 Constant speed maintenance and repair costs (% avg cost/1000 mi) - small automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	48.70	51.70	55.30	59.50	64.30	69.40	74.60	80.00	85.50	91.20	97.10	103.00	110.00	118.00
7	48.50	51.20	54.50	58.50	63.10	67.90	72.80	78.00	83.30	88.70	94.30	100.00	107.00	115.00
6	48.20	50.70	53.80	57.50	61.80	66.40	71.10	76.00	81.00	86.20	91.60	97.40	104.00	111.00
5	48.00	50.20	53.00	56.50	60.60	64.90	69.30	73.90	78.80	83.70	88.80	94.30	100.00	108.00
4	47.70	49.70	52.30	55.50	59.30	63.40	67.60	71.90	76.50	81.20	86.10	91.30	97.20	104.00
3	47.50	49.20	51.50	54.50	58.10	61.90	65.80	69.90	74.30	78.70	83.30	88.30	94.00	101.00
2	47.20	48.70	50.80	53.50	56.80	60.40	64.10	67.90	72.00	76.20	80.60	85.30	90.70	97.10
1	47.00	48.20	50.00	52.50	55.60	58.80	62.30	65.90	69.70	73.70	77.80	82.30	87.50	93.60
0	46.70	47.70	49.30	51.50	54.30	57.30	60.60	63.90	67.50	71.20	75.10	79.30	84.20	90.10
-1	46.50	47.20	48.50	50.50	53.10	55.80	58.80	61.90	65.20	68.70	72.30	76.30	80.90	86.60
-2	40.00	38.60	36.30	33.10	29.00	54.30	57.00	59.90	63.00	66.20	69.60	73.30	77.70	83.10
-3	63.60	62.20	59.90	56.70	52.60	47.30	40.90	33.30	60.70	63.70	66.80	70.30	74.40	79.60
-4	87.10	85.80	83.50	80.30	76.20	70.90	64.50	56.90	48.20	38.40	64.10	67.30	71.20	76.10
-5	111.00	109.00	107.00	104.00	99.80	94.50	88.10	80.50	71.80	62.00	51.00	39.00	67.90	72.60
-6	134.00	133.00	131.00	127.00	123.00	118.00	112.00	104.00	95.40	85.60	74.60	62.50	49.60	69.10
-7	158.00	157.00	154.00	151.00	147.00	142.00	135.00	128.00	119.00	109.00	98.20	86.10	73.20	59.50
-8	182.00	180.00	178.00	175.00	171.00	165.00	159.00	151.00	143.00	133.00	122.00	110.00	96.70	83.10

TABLE B.26 Constant speed maintenance and repair costs (% avg cost/1000 mi) - medium automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	49.20	52.20	56.10	60.60	65.60	70.90	76.30	82.00	87.80	93.70	99.80	106.00	113.00	122.00
7	48.90	51.70	55.20	59.50	64.20	69.20	74.40	79.70	85.30	90.90	96.80	103.00	110.00	118.00
6	48.60	51.10	54.40	58.30	62.80	67.50	72.40	77.50	82.70	88.10	93.70	99.60	106.00	114.00
5	48.30	50.60	53.60	57.20	61.40	65.80	70.50	75.20	80.20	85.30	90.60	96.30	103.00	110.00
4	48.10	50.00	52.70	56.10	60.00	64.20	68.50	73.00	77.70	82.50	87.50	92.90	98.90	106.00
3	47.80	49.40	51.90	55.00	58.60	62.50	66.50	70.80	75.20	79.70	84.40	89.50	95.30	102.00
2	47.50	48.90	51.00	53.90	57.20	60.80	64.60	68.50	72.70	76.90	81.40	86.20	91.60	98.10
1	47.20	48.30	50.20	52.70	55.80	59.10	62.60	66.30	70.10	74.10	78.30	82.80	88.00	94.20
0	46.90	47.80	49.40	51.60	54.40	57.40	60.60	64.00	67.60	71.30	75.20	79.40	84.30	90.20
-1	46.70	47.20	48.50	50.50	53.00	55.70	58.70	61.80	65.10	68.50	72.10	76.10	80.70	86.30
-2	39.10	37.80	35.70	32.70	28.90	54.10	56.70	59.60	62.60	65.70	69.00	72.70	77.00	82.40
-3	62.50	61.20	59.10	56.20	52.40	47.50	41.60	34.70	60.10	62.90	65.90	69.40	73.40	78.50
-4	86.00	84.70	82.60	79.70	75.90	71.00	65.10	58.20	50.10	41.00	62.90	66.00	69.80	74.60
-5	109.00	108.00	106.00	103.00	99.40	94.50	88.60	81.60	73.60	64.50	54.30	43.30	66.10	70.60
-6	133.00	132.00	130.00	127.00	123.00	118.00	112.00	105.00	97.10	88.00	77.80	66.70	54.70	66.70
-7	156.00	155.00	153.00	150.00	146.00	141.00	136.00	129.00	121.00	111.00	101.00	90.20	78.20	65.60
-8	180.00	179.00	177.00	174.00	170.00	165.00	159.00	152.00	144.00	135.00	125.00	114.00	102.00	89.10

TABLE B.27 Constant speed maintenance and repair costs (% avg cost/1000 mi) - large automobile

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	49.70	52.90	56.80	61.40	66.50	71.90	77.40	83.20	89.10	95.10	101.00	108.00	115.00	123.00
7	49.40	52.40	55.90	60.20	65.10	70.20	75.40	80.90	86.50	92.20	98.20	104.00	111.00	119.00
6	49.10	51.80	55.10	59.10	63.60	68.40	73.40	78.60	83.90	89.30	95.00	101.00	108.00	115.00
5	48.80	51.20	54.20	57.90	62.20	66.70	71.40	76.30	81.30	86.50	91.90	97.60	104.00	111.00
4	48.50	50.60	53.40	56.80	60.80	65.00	69.40	74.00	78.80	83.60	88.70	94.20	100.00	107.00
3	48.20	50.10	52.50	55.70	59.30	63.30	67.40	71.70	76.20	80.70	85.60	90.70	96.50	103.00
2	48.00	49.50	51.60	54.50	57.90	61.60	65.40	69.40	73.60	77.80	82.40	87.30	92.80	99.40
1	47.70	48.90	50.80	53.40	56.50	59.80	63.40	67.10	71.00	75.00	79.20	83.80	89.10	95.30
0	47.40	48.30	49.90	52.20	55.00	58.10	61.40	64.80	68.40	72.10	76.10	80.40	85.30	91.30
-1	47.10	47.80	49.10	51.10	53.60	56.40	59.40	62.50	65.80	69.20	72.90	76.90	81.60	87.30
-2	38.50	37.50	35.70	33.20	30.00	54.70	57.30	60.20	63.30	66.40	69.80	73.50	77.90	83.30
-3	60.20	59.20	57.40	54.90	51.70	47.60	42.50	36.50	60.70	63.50	66.60	70.10	74.10	79.30
-4	81.90	80.90	79.10	76.60	73.40	69.30	64.20	58.20	51.30	43.40	63.50	66.60	70.40	75.20
-5	104.00	103.00	101.00	98.40	95.10	91.00	85.90	79.90	73.00	65.10	56.30	46.60	66.70	71.20
-6	125.00	124.00	123.00	120.00	117.00	113.00	108.00	102.00	94.70	86.80	78.00	68.40	58.00	47.10
-7	147.00	146.00	144.00	142.00	139.00	134.00	129.00	123.00	116.00	109.00	99.70	90.10	79.70	68.80
-8	169.00	168.00	166.00	164.00	160.00	156.00	151.00	145.00	138.00	130.00	121.00	112.00	101.00	90.50

TABLE B.28 Constant speed maintenance and repair costs (% avg cost/1000 mi) - pickup truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	49.70	52.80	56.60	60.90	65.90	71.10	76.50	82.10	87.80	93.70	99.80	106.00	113.00	121.00
7	49.40	52.30	55.80	59.90	64.50	69.50	74.60	80.00	85.50	91.00	96.90	103.00	110.00	118.00
6	49.20	51.80	55.00	58.80	63.20	67.90	72.80	77.80	83.10	88.40	93.90	99.90	106.00	114.00
5	48.90	51.20	54.20	57.70	61.90	66.30	70.90	75.70	80.70	85.70	91.00	96.70	103.00	110.00
4	48.60	50.70	53.40	56.70	60.60	64.70	69.10	73.60	78.30	83.10	88.10	93.50	99.50	107.00
3	48.40	50.20	52.60	55.60	59.20	63.20	67.20	71.50	75.90	80.40	85.20	90.30	96.10	103.00
2	48.10	49.60	51.80	54.60	57.90	61.60	65.40	69.40	73.50	77.80	82.30	87.20	92.60	99.20
1	47.80	49.10	51.00	53.50	56.60	60.00	63.50	67.20	71.10	75.10	79.40	84.00	89.20	95.50
0	47.60	48.60	50.20	52.40	55.30	58.40	61.70	65.10	68.80	72.40	76.40	80.80	85.70	91.70
-1	47.30	48.10	49.40	51.40	53.90	56.80	59.80	63.00	66.40	69.80	73.50	77.60	82.30	88.00
-2	31.40	30.10	27.90	24.90	52.60	55.20	57.90	60.90	64.00	67.10	70.60	74.40	78.80	84.30
-3	55.30	54.00	51.90	48.80	44.90	39.90	33.90	58.80	61.60	64.50	67.70	71.30	75.40	80.60
-4	79.30	78.00	75.80	72.80	68.80	63.90	57.80	50.70	42.50	61.80	64.80	68.10	71.90	76.90
-5	103.00	102.00	99.80	96.70	92.80	87.80	81.80	74.60	66.40	57.10	46.60	64.90	68.50	73.20
-6	127.00	126.00	124.00	121.00	117.00	112.00	106.00	98.60	90.40	81.00	70.60	59.20	46.90	69.50
-7	151.00	150.00	148.00	145.00	141.00	136.00	130.00	123.00	114.00	105.00	94.60	83.20	70.90	58.00
-8	175.00	174.00	172.00	169.00	165.00	160.00	154.00	147.00	138.00	129.00	119.00	107.00	94.80	81.90

TABLE B.29 Constant speed maintenance and repair costs (% avg cost/1000 mi) - 2A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	51.50	56.40	63.00	70.80	79.70	89.20	99.50	110.00	121.00	133.00	145.00	156.00	168.00	180.00
7	50.80	54.90	60.80	67.90	76.00	84.90	94.40	104.00	115.00	126.00	137.00	147.00	158.00	169.00
6	50.00	53.40	58.60	65.00	72.40	80.50	89.30	98.60	108.00	118.00	129.00	139.00	149.00	159.00
5	49.30	52.00	56.50	62.10	68.70	76.10	84.20	92.80	102.00	111.00	121.00	130.00	140.00	149.00
4	48.60	50.50	54.30	59.20	65.10	71.80	79.10	86.90	95.20	104.00	113.00	121.00	130.00	139.00
3	47.80	49.10	52.10	56.30	61.50	67.40	74.00	81.10	88.70	96.50	105.00	113.00	121.00	129.00
2	47.10	47.60	49.90	53.40	57.80	63.00	68.90	75.30	82.10	89.20	96.50	104.00	111.00	119.00
1	46.40	46.20	47.70	50.50	54.20	58.70	63.80	69.50	75.60	81.90	88.50	95.10	102.00	108.00
0	45.70	44.70	45.50	47.60	50.60	54.30	58.70	63.70	69.10	74.70	80.50	86.40	92.30	98.20
-1	16.60	14.90	43.40	44.70	46.90	49.90	53.70	57.90	62.50	67.40	72.50	77.60	82.80	88.00
-2	32.50	30.80	29.30	27.70	25.90	24.00	21.80	19.40	56.00	60.10	64.50	68.90	73.40	77.80
-3	48.30	46.70	45.20	43.60	41.80	39.90	37.70	35.20	32.50	29.40	25.90	60.20	63.90	67.60
-4	64.20	62.60	61.00	59.40	57.70	55.70	53.60	51.10	48.40	45.30	41.80	38.00	33.60	57.40
-5	80.10	78.40	76.90	75.30	73.60	71.60	69.50	67.00	64.30	61.20	57.70	53.80	49.50	44.80
-6	96.00	94.30	92.80	91.20	89.50	87.50	85.30	82.90	80.10	77.00	73.60	69.70	65.40	60.70
-7	112.00	110.00	109.00	107.00	105.00	103.00	101.00	98.80	96.00	92.90	89.50	85.60	81.30	76.60
-8	128.00	126.00	125.00	123.00	121.00	119.00	117.00	115.00	112.00	109.00	105.00	101.00	97.20	92.40

TABLE B.30 Constant speed maintenance and repair costs (% avg cost/1000 mi) - 3A SU truck

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	51.90	58.80	65.80	73.10	80.70	88.60	96.80	105.00	115.00	124.00	134.00	145.00	156.00	168.00
7	51.20	57.30	63.60	70.20	77.00	84.20	91.70	99.60	108.00	117.00	126.00	136.00	147.00	158.00
6	50.40	55.90	61.40	67.30	73.40	79.80	86.50	93.70	101.00	109.00	118.00	127.00	137.00	148.00
5	49.70	54.40	59.20	64.30	69.70	75.40	81.40	87.80	94.70	102.00	110.00	118.00	128.00	137.00
4	49.00	52.90	57.00	61.40	66.00	71.00	76.30	82.00	88.10	94.70	102.00	110.00	118.00	127.00
3	48.20	51.50	54.80	58.50	62.40	66.60	71.10	76.10	81.50	87.40	93.90	101.00	109.00	117.00
2	47.50	50.00	52.60	55.50	58.70	6[illegible].20	66.00	70.20	74.90	80.10	85.80	92.10	99.00	107.00
1	46.80	48.50	50.40	52.60	55.00	57.80	60.90	64.40	68.30	72.70	77.70	83.30	89.50	96.30
0	46.10	47.10	48.20	49.70	51.40	53.40	55.70	58.50	61.70	65.40	69.70	74.50	79.90	86.00
-1	16.60	15.90	15.10	46.70	47.70	49.00	50.60	52.60	55.10	58.10	61.60	65.70	70.40	75.80
-2	31.30	30.60	29.80	28.90	27.80	26.60	25.40	24.00	22.60	21.10	53.50	56.90	60.90	65.50
-3	46.00	45.30	44.50	43.50	42.50	41.30	40.00	38.70	37.30	35.80	34.30	32.70	31.20	29.60
-4	60.60	60.00	59.20	58.20	57.20	56.00	54.70	53.40	51.90	50.50	49.00	47.40	45.90	44.30
-5	75.30	74.60	73.80	72.90	71.80	70.60	69.40	68.00	66.60	65.10	63.60	62.10	60.50	59.00
-6	90.00	89.30	88.50	87.60	86.50	85.30	84.10	82.70	81.30	79.80	78.30	76.80	75.20	73.60
-7	105.00	104.00	103.00	102.00	101.00	100.00	98.70	97.40	96.00	94.50	93.00	91.40	89.90	88.30
-8	119.00	119.00	118.00	117.00	116.00	115.00	113.00	112.00	111.00	109.00	108.00	106.00	105.00	103.00

TABLE B.31 Constant speed maintenance and repair costs (% avg cost/1000 mi) - 2-S2 semi

GRADE %	SPEED mph 5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	51.00	58.50	66.20	74.10	82.40	91.10	100.00	110.00	121.00	132.00	144.00	157.00	170.00	185.00
7	50.20	56.90	63.80	70.90	78.40	86.30	94.70	104.00	113.00	124.00	135.00	147.00	160.00	174.00
6	49.40	55.30	61.30	67.70	74.30	81.40	89.00	97.10	106.00	116.00	126.00	137.00	149.00	163.00
5	48.60	53.70	58.90	64.40	70.30	76.50	83.30	90.70	98.70	107.00	117.00	127.00	139.00	151.00
4	47.80	52.00	56.50	61.20	66.20	71.70	77.70	84.20	91.40	99.30	108.00	118.00	128.00	140.00
3	47.00	50.40	54.10	58.00	62.20	66.80	72.00	77.70	84.10	91.30	99.20	108.00	118.00	129.00
2	46.20	48.80	51.60	54.70	58.10	62.00	66.30	71.30	76.80	83.20	90.30	98.30	107.00	117.00
1	45.40	47.20	49.20	51.50	54.10	57.10	60.70	64.80	69.60	75.10	81.40	88.60	96.90	106.00
0	44.60	45.60	46.80	48.20	50.00	52.30	55.00	58.30	62.30	67.00	72.50	78.90	86.30	94.80
-1	16.90	16.50	15.80	14.80	46.00	47.40	49.30	51.80	55.00	58.90	63.60	69.20	75.80	83.40
-2	32.70	32.30	31.60	30.60	29.40	27.90	26.30	24.40	22.40	20.30	54.70	59.50	65.30	72.10
-3	48.50	48.10	47.40	46.40	45.20	43.70	42.10	40.20	38.20	36.10	33.90	31.50	29.10	60.80
-4	64.30	63.90	63.20	62.20	61.00	59.50	57.90	56.00	54.10	51.90	49.70	47.30	44.90	42.50
-5	80.10	79.70	79.00	78.00	76.80	75.40	73.70	71.90	69.90	67.70	65.50	63.10	60.70	58.30
-6	95.90	95.50	94.80	93.80	92.60	91.20	89.50	87.70	85.70	83.50	81.30	78.90	76.50	74.10
-7	112.00	111.00	111.00	110.00	108.00	107.00	105.00	103.00	101.00	99.30	97.10	94.70	92.40	89.90
-8	127.00	127.00	126.00	125.00	124.00	123.00	121.00	119.00	117.00	115.00	113.00	111.00	108.00	106.00

TABLE B.32 Constant speed maintenance and repair costs (% avg cost/1000 mi) - 3-S2 semi

GRADE	SPEED mph													
%	5	10	15	20	25	30	35	40	45	50	55	60	65	70
8	56.10	65.70	76.80	88.90	102.00	116.00	130.00	145.00	161.00	177.00	192.00	209.00	225.00	241.00
7	54.80	63.20	73.00	83.80	95.60	108.00	122.00	135.00	149.00	164.00	179.00	193.00	208.00	223.00
6	53.50	60.60	69.20	78.80	89.30	101.00	113.00	125.00	138.00	151.00	165.00	178.00	192.00	206.00
5	52.30	58.10	65.40	73.70	83.00	93.00	104.00	115.00	127.00	139.00	151.00	163.00	175.00	188.00
4	51.00	55.60	61.60	68.60	76.70	85.40	95.00	105.00	115.00	126.00	137.00	148.00	159.00	170.00
3	49.70	53.10	57.80	63.60	70.30	77.80	86.10	94.90	104.00	113.00	123.00	133.00	142.00	152.00
2	48.50	50.50	54.00	58.50	64.00	70.20	77.30	84.70	92.50	101.00	109.00	117.00	126.00	135.00
1	47.20	48.00	50.20	53.50	57.70	62.70	68.40	74.60	81.20	88.10	95.10	102.00	110.00	117.00
0	45.90	45.50	46.40	48.40	51.40	55.10	59.60	64.50	69.80	75.40	81.20	87.20	93.10	99.30
-1	17.30	16.70	16.20	15.90	15.60	47.50	50.70	54.40	58.40	62.80	67.30	72.00	76.70	81.60
-2	33.10	32.50	32.00	31.70	31.40	31.10	30.80	30.40	29.90	29.20	28.40	27.40	60.20	63.90
-3	48.90	48.30	47.90	47.50	47.20	46.90	46.60	46.20	45.70	45.10	44.20	43.20	42.00	40.60
-4	64.80	64.10	63.70	63.30	63.00	62.70	62.40	62.00	61.50	60.90	60.10	59.10	57.80	56.50
-5	80.60	79.90	79.50	79.10	78.90	78.50	78.20	77.80	77.30	76.70	75.90	74.90	73.70	72.30
-6	96.40	95.80	95.30	95.00	94.70	94.30	94.10	93.70	93.20	92.50	91.70	90.70	89.50	88.10
-7	112.00	112.00	111.00	111.00	111.00	110.00	110.00	109.00	109.00	108.00	108.00	107.00	105.00	104.00
-8	128.00	127.00	127.00	127.00	126.00	126.00	126.00	125.00	125.00	124.00	123.00	122.00	121.00	120.00

Table B.33 Use Related Depreciation expense on level tangent pavements (SI = 3.5) (Percent depreciable value/ 1000 miles).

	AUTOMOBILES			TRUCKS				
Speed	Small	Medium	Large	Pickup	2ASU	3ASU	2S2	3S2
5	1.59	1.22	0.90	0.53	0.74	0.74	0.23	0.25
10	1.34	1.03	0.76	0.45	0.59	0.59	0.18	0.19
15	1.20	0.93	0.68	0.40	0.50	0.50	0.15	0.16
20	1.10	0.85	0.63	0.37	0.44	0.44	0.13	0.14
25	1.02	0.79	0.58	0.34	0.40	0.40	0.12	0.12
30	0.95	0.73	0.54	0.31	0.37	0.37	0.11	0.11
35	0.90	0.66	0.51	0.29	0.34	0.34	0.10	0.10
40	0.85	0.63	0.48	0.28	0.33	0.33	0.10	0.10
45	0.82	0.61	0.46	0.27	0.31	0.31	0.09	0.09
50	0.79	0.59	0.45	0.26	0.30	0.30	0.09	0.09
55	0.76	0.59	0.43	0.25	0.29	0.29	0.09	0.09
60	0.74	0.57	0.42	0.24	0.28	0.28	0.08	0.08
65	0.72	0.56	0.41	0.24	0.28	0.28	0.08	0.08
70	0.70	0.55	0.40	0.23	0.27	0.27	0.08	0.08

TABLE B.34 Excess fuel consumption for speed change cycles (gal/1000 cycles) - small automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.53													
10.	.97	.44												
15.	1.43	.90	.46											
20.	2.01	1.48	1.04	.58										
25.	2.70	2.17	1.73	1.27	.69									
30.	3.50	2.97	2.53	2.07	1.49	.80								
35.	4.63	4.10	3.66	3.20	2.62	1.93	1.13							
40.	5.91	5.38	4.94	4.48	3.90	3.21	2.41	1.28						
45.	7.32	6.79	6.35	5.89	5.31	4.62	3.82	2.69	1.41					
50.	8.94	8.41	7.97	7.51	6.93	6.24	5.44	4.31	3.03	1.62				
55.	10.90	10.30	9.88	9.42	8.84	8.15	7.35	6.22	4.94	3.53	1.91			
60.	13.10	12.50	12.10	11.60	11.00	10.30	9.52	8.39	7.11	5.70	4.08	2.17		
65.	15.60	15.00	14.60	14.10	13.50	12.80	12.00	10.90	9.61	8.20	6.58	4.67	2.50	
70.	18.70	18.10	17.70	17.20	16.60	15.90	15.10	14.00	12.70	11.30	9.66	7.75	5.58	3.08

TABLE B.35 Excess fuel consumption for speed change cycles (gal/1000 cycles) - medium automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	1.00													
10.	1.98	.98												
15.	3.02	2.02	1.04											
20.	4.18	3.18	2.20	1.16										
25.	5.43	4.43	3.45	2.41	1.25									
30.	6.81	5.81	4.83	3.79	2.63	1.38								
35.	8.68	7.68	6.70	5.66	4.50	3.25	1.87							
40.	10.70	9.71	8.73	7.69	6.53	5.28	3.90	2.03						
45.	12.90	11.90	10.90	9.87	8.71	7.46	6.08	4.21	2.18					
50.	15.30	14.30	13.30	12.30	11.10	9.86	8.48	6.61	4.58	2.40				
55.	17.90	16.90	15.90	14.90	13.70	12.40	11.10	9.19	7.16	4.98	2.58			
60.	20.80	19.80	18.80	17.80	16.60	15.30	14.00	12.10	10.10	7.87	5.47	2.89		
65.	24.30	23.30	22.30	21.30	20.10	18.80	17.50	15.60	13.60	11.40	8.98	6.40	3.51	
70.	29.20	28.20	27.20	26.20	25.00	23.70	22.40	20.50	18.50	16.30	13.90	11.30	8.40	4.89

TABLE B.36 Excess fuel consumption for speed change cycles (gal/1000 cycles) - large automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	1.16													
10.	2.35	1.19												
15.	3.63	2.47	1.28											
20.	5.08	3.92	2.73	1.45										
25.	6.68	5.52	4.33	3.05	1.60									
30.	8.46	7.30	6.11	4.83	3.38	1.78								
35.	10.80	9.64	8.45	7.17	5.72	4.12	2.34							
40.	13.30	12.10	10.90	9.65	8.20	6.60	4.82	2.48						
45.	15.90	14.70	13.50	12.30	10.80	9.24	7.46	5.12	2.64					
50.	18.70	17.50	16.30	15.10	13.60	12.10	10.30	7.96	5.48	2.84				
55.	21.70	20.50	19.30	18.10	16.60	15.10	13.30	11.00	8.50	5.86	3.02			
60.	24.90	23.70	22.50	21.30	19.80	18.30	16.50	14.20	11.70	9.10	6.26	3.24		
65.	28.30	27.10	25.90	24.70	23.20	21.70	19.90	17.60	15.10	12.50	9.70	6.68	3.44	
70.	32.00	30.80	29.60	28.40	26.90	25.40	23.60	21.30	18.80	16.20	13.40	10.40	7.16	3.72

TABLE B.37 Excess fuel consumption for speed change cycles (gal/1000 cycles) - pickup truck

INITIAL SPEED mpn	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	1.13													
10.	2.23	1.10												
15.	3.41	2.28	1.18											
20.	4.77	3.64	2.54	1.36										
25.	6.24	5.11	4.01	2.83	1.47									
30.	7.85	6.72	5.62	4.44	3.08	1.61								
35.	9.99	8.86	7.76	6.58	5.22	3.75	2.14							
40.	12.30	11.20	10.10	8.93	7.57	6.10	4.49	2.35						
45.	14.80	13.70	12.60	11.40	10.10	8.61	7.00	4.86	2.51					
50.	17.60	16.50	15.40	14.20	12.90	11.40	9.75	7.61	5.26	2.75				
55.	20.90	19.80	18.70	17.50	16.20	14.70	13.00	10.90	8.53	6.02	3.27			
60.	25.10	24.00	22.90	21.70	20.40	18.90	17.20	15.10	12.70	10.20	7.48	4.21		
65.	30.20	29.10	28.00	26.80	25.50	24.00	22.30	20.20	17.80	15.30	12.60	9.35	5.14	
70.	38.60	37.50	36.40	35.20	33.90	32.40	30.70	28.60	26.20	23.70	21.00	17.70	13.50	8.39

TABLE B.38 Excess fuel consumption for speed change cycles (gal/1000 cycles) - 2A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	2.96													
10.	5.95	2.99												
15.	9.58	6.62	3.63											
20.	14.40	11.40	8.42	4.79										
25.	20.30	17.30	14.40	10.70	5.95									
30.	27.80	24.80	21.90	18.20	13.40	7.46								
35.	37.30	34.30	31.40	27.70	22.90	17.00	9.50							
40.	48.60	45.60	42.70	39.00	34.20	28.30	20.80	11.30						
45.	61.90	58.90	56.00	52.30	47.50	41.60	34.10	24.60	13.30					
50.	76.10	73.10	70.20	66.50	61.70	55.80	48.30	38.80	27.50	14.20				
55.	90.70	87.70	84.80	81.10	76.30	70.40	62.90	53.40	42.10	28.80	14.60			
60.	106.00	103.00	100.00	96.60	91.80	85.90	78.40	68.90	57.60	44.30	30.10	15.50		
65.	123.00	120.00	117.00	114.00	109.00	103.00	95.40	85.90	74.60	61.30	47.10	32.50	17.00	
70.	140.00	137.00	134.00	131.00	126.00	120.00	112.00	103.00	91.60	78.30	64.10	49.50	34.00	17.00

TABLE B.39 Excess fuel consumption for speed change cycles (gal/1000 cycles) - 3A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	4.35													
10.	8.94	4.59												
15.	14.20	9.81	5.22											
20.	20.50	16.10	11.60	6.34										
25.	28.20	23.80	19.30	14.00	7.71									
30.	37.90	33.50	29.00	23.70	17.40	9.67								
35.	50.00	45.60	41.10	35.80	29.50	21.70	12.10							
40.	64.80	60.40	55.90	50.60	44.30	36.50	26.90	14.80						
45.	82.80	78.40	73.90	68.60	62.30	54.50	44.90	32.80	18.00					
50.	103.00	98.80	94.30	89.00	82.70	74.90	65.30	53.20	38.40	20.40				
55.	124.00	120.00	115.00	110.00	103.00	95.60	86.00	73.90	59.10	41.10	20.70			
60.	146.00	142.00	137.00	132.00	125.00	117.00	108.00	95.50	80.70	62.70	42.30	21.60		
65.	168.00	164.00	159.00	154.00	147.00	139.00	130.00	117.00	102.00	84.20	63.80	43.10	21.50	
70.	190.00	186.00	181.00	176.00	169.00	161.00	152.00	139.00	124.00	106.00	85.80	65.10	43.50	22.00

TABLE B.40 Excess fuel consumption for speed change cycles (gal/1000 cycles) - 2 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	8.10													
10.	15.40	7.26												
15.	23.00	14.90	7.65											
20.	32.50	24.40	17.20	9.53										
25.	42.60	34.50	27.30	19.60	10.10									
30.	53.40	45.30	38.10	30.40	20.90	10.80								
35.	65.70	57.60	50.40	42.70	33.20	23.10	12.30							
40.	79.60	71.50	64.30	56.60	47.10	37.00	26.20	13.90						
45.	95.90	87.80	80.60	72.90	63.40	53.30	42.50	30.20	16.30					
50.	115.00	107.00	99.80	92.10	82.60	72.50	61.70	49.40	35.50	19.20				
55.	135.00	127.00	120.00	112.00	103.00	92.60	81.80	69.50	55.60	39.30	20.10			
60.	156.00	148.00	141.00	133.00	124.00	113.00	103.00	90.30	76.40	60.10	40.90	20.80		
65.	179.00	171.00	164.00	156.00	147.00	136.00	126.00	113.00	99.00	82.70	63.50	43.40	22.60	
70.	205.00	197.00	190.00	182.00	173.00	162.00	152.00	139.00	125.00	109.00	89.50	69.40	48.60	26.00

TABLE B.41 Excess fuel consumption for speed change cycles (gal/1000 cycles) - 3 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	8.96													
10.	17.50	8.54												
15.	26.90	18.00	9.41											
20.	38.80	29.90	21.30	11.90										
25.	51.70	42.80	34.20	24.80	12.90									
30.	65.90	57.00	48.40	39.00	27.10	14.20								
35.	82.00	73.10	64.50	55.10	43.20	30.30	16.10							
40.	100.00	91.30	82.70	73.30	61.40	48.50	34.30	18.20						
45.	121.00	113.00	104.00	94.50	82.60	69.70	55.50	39.40	21.20					
50.	144.00	136.00	127.00	118.00	106.00	93.00	78.80	62.70	44.50	23.30				
55.	168.00	160.00	151.00	142.00	130.00	117.00	102.00	86.40	68.20	47.00	23.70			
60.	192.00	184.00	175.00	166.00	154.00	141.00	126.00	110.00	92.00	70.80	47.50	23.80		
65.	217.00	209.00	200.00	191.00	179.00	166.00	151.00	135.00	117.00	95.80	72.50	48.80	25.00	
70.	243.00	235.00	226.00	217.00	205.00	192.00	177.00	161.00	143.00	122.00	98.80	75.10	51.30	26.30

TABLE B.42 Excess oil consumption for speed change cycles (qts/1000 cycles) - small automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.005													
10.	.009	.004												
15.	.012	.007	.003											
20.	.015	.010	.006	.003										
25.	.017	.012	.008	.005	.002									
30.	.019	.014	.010	.007	.004	.002								
35.	.022	.017	.013	.010	.007	.005	.003							
40.	.025	.020	.016	.013	.010	.008	.006	.003						
45.	.028	.023	.019	.016	.013	.011	.009	.006	.003					
50.	.032	.027	.023	.020	.017	.015	.013	.010	.007	.004				
55.	.036	.031	.027	.024	.021	.019	.017	.014	.011	.008	.004			
60.	.040	.035	.031	.028	.025	.023	.021	.018	.015	.012	.008	.004		
65.	.046	.041	.037	.034	.031	.029	.027	.024	.021	.018	.014	.010	.006	
70.	.054	.049	.045	.042	.039	.037	.035	.032	.029	.026	.022	.018	.014	.008

TABLE B.43 Excess oil consumption for speed change cycles (qts/1000 cycles) - medium automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.005													
10.	.008	.003												
15.	.011	.006	.003											
20.	.013	.008	.005	.002										
25.	.015	.010	.007	.004	.002									
30.	.017	.012	.009	.006	.004	.002								
35.	.020	.015	.012	.009	.007	.005	.003							
40.	.023	.018	.015	.012	.010	.008	.006	.003						
45.	.026	.021	.018	.015	.013	.011	.009	.006	.003					
50.	.029	.024	.021	.018	.016	.014	.012	.009	.006	.003				
55.	.032	.027	.024	.021	.019	.017	.015	.012	.009	.006	.003			
60.	.036	.031	.028	.025	.023	.021	.019	.016	.013	.010	.007	.004		
65.	.042	.037	.034	.031	.029	.027	.025	.022	.019	.016	.013	.010	.006	
70.	.051	.046	.043	.040	.038	.036	.034	.031	.028	.025	.022	.019	.015	.009

TABLE B.44 Excess oil consumption for speed change cycles (qts/1000 cycles) - large automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.005													
10.	.008	.003												
15.	.011	.006	.003											
20.	.013	.008	.005	.002										
25.	.015	.010	.007	.004	.002									
30.	.017	.012	.009	.006	.004	.002								
35.	.020	.015	.012	.009	.007	.005	.003							
40.	.023	.018	.015	.012	.010	.008	.006	.003						
45.	.026	.021	.018	.015	.013	.011	.009	.006	.003					
50.	.029	.024	.021	.018	.016	.014	.012	.009	.006	.003				
55.	.032	.027	.024	.021	.019	.017	.015	.012	.009	.006	.003			
60.	.035	.030	.027	.024	.022	.020	.018	.015	.012	.009	.006	.003		
65.	.039	.034	.031	.028	.026	.024	.022	.019	.016	.013	.010	.007	.004	
70.	.044	.039	.036	.033	.031	.029	.027	.024	.021	.018	.015	.012	.009	.005

TABLE B.45 Excess oil consumption for speed change cycles (qts/1000 cycles) - pickup truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.005													
10.	.008	.003												
15.	.010	.005	.002											
20.	.012	.007	.004	.002										
25.	.014	.009	.006	.004	.002									
30.	.016	.011	.008	.006	.004	.002								
35.	.019	.014	.011	.009	.007	.005	.003							
40.	.022	.017	.014	.012	.010	.008	.006	.003						
45.	.025	.020	.017	.015	.013	.011	.009	.006	.003					
50.	.028	.023	.020	.018	.016	.014	.012	.009	.006	.003				
55.	.031	.026	.023	.021	.019	.017	.015	.012	.009	.006	.003			
60.	.034	.029	.026	.024	.022	.020	.018	.015	.012	.009	.006	.003		
65.	.039	.034	.031	.029	.027	.025	.023	.020	.017	.014	.011	.008	.005	
70.	.048	.043	.040	.038	.036	.034	.032	.029	.026	.023	.020	.017	.014	.009

TABLE B.46 Excess oil consumption for speed change cycles (qts/1000 cycles) - 2A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.017													
10.	.028	.011												
15.	.038	.021	.010											
20.	.047	.030	.019	.009										
25.	.056	.039	.028	.018	.009									
30.	.066	.049	.038	.028	.019	.010								
35.	.077	.060	.049	.039	.030	.021	.011							
40.	.088	.071	.060	.050	.041	.032	.022	.011						
45.	.099	.082	.071	.061	.052	.043	.033	.022	.011					
50.	.111	.094	.083	.073	.064	.055	.045	.034	.023	.012				
55.	.126	.109	.098	.088	.079	.070	.060	.049	.038	.027	.015			
60.	.148	.131	.120	.110	.101	.092	.082	.071	.060	.049	.037	.022		
65.	.182	.165	.154	.144	.135	.126	.116	.105	.094	.083	.071	.056	.034	
70.	.247	.230	.219	.209	.200	.191	.181	.170	.159	.148	.136	.121	.099	.065

TABLE B.47 Excess oil consumption for speed change cycles (qts/1000 cycles) - 3A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.034													
10.	.058	.024												
15.	.078	.044	.020											
20.	.097	.063	.039	.019										
25.	.116	.082	.058	.038	.019									
30.	.135	.101	.077	.057	.038	.019								
35.	.156	.122	.098	.078	.059	.040	.021							
40.	.178	.144	.120	.100	.081	.062	.043	.022						
45.	.200	.166	.142	.122	.103	.084	.065	.044	.022					
50.	.225	.191	.167	.147	.128	.109	.090	.069	.047	.025				
55.	.256	.222	.198	.178	.159	.140	.121	.100	.078	.056	.031			
60.	.299	.265	.241	.221	.202	.183	.164	.143	.121	.099	.074	.043		
65.	.361	.327	.303	.283	.264	.245	.226	.205	.183	.161	.136	.105	.062	
70.	.462	.428	.404	.384	.365	.346	.327	.306	.284	.262	.237	.206	.163	.101

TABLE B.48 Excess oil consumption for speed change cycles (qts/1000 cycles) - 2 - S2 semi

INITIAL SPEED	SPEED REDUCED TO AND RETURNED FROM, mph													
mph	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.034													
10.	.058	.024												
15.	.078	.044	.020											
20.	.097	.063	.039	.019										
25.	.116	.082	.058	.038	.019									
30.	.135	.101	.077	.057	.038	.019								
35.	.156	.122	.098	.078	.059	.040	.021							
40.	.178	.144	.120	.100	.081	.062	.043	.022						
45.	.200	.166	.142	.122	.103	.084	.065	.044	.022					
50.	.225	.191	.167	.147	.128	.109	.090	.069	.047	.025				
55.	.256	.222	.198	.178	.159	.140	.121	.100	.078	.056	.031			
60.	.299	.265	.241	.221	.202	.183	.164	.143	.121	.099	.074	.043		
65.	.361	.327	.303	.283	.264	.245	.226	.205	.183	.161	.136	.105	.062	
70.	.462	.428	.404	.384	.365	.346	.327	.306	.284	.262	.237	.206	.163	.101

TABLE B.49 Excess oil consumption for speed change cycles (qts/1000 cycles) - 3 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.070													
10.	.118	.048												
15.	.159	.089	.041											
20.	.198	.128	.080	.039										
25.	.237	.167	.119	.078	.039									
30.	.276	.206	.158	.117	.078	.039								
35.	.318	.248	.200	.159	.120	.081	.042							
40.	.360	.290	.242	.201	.162	.123	.084	.042						
45.	.401	.331	.283	.242	.203	.164	.125	.083	.041					
50.	.442	.372	.324	.283	.244	.205	.166	.124	.082	.041				
55.	.493	.423	.375	.334	.295	.256	.217	.175	.133	.092	.051			
60.	.562	.492	.444	.403	.364	.325	.286	.244	.202	.161	.120	.069		
65.	.662	.592	.544	.503	.464	.425	.386	.344	.302	.261	.220	.169	.100	
70.	.828	.758	.710	.669	.630	.591	.552	.510	.468	.427	.386	.335	.266	.166

TABLE B.50 Excess tire wear for speed change cycles (% worn/1000 cycles) - small automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.02													
10.	.08	.06												
15.	.18	.16	.10											
20.	.32	.30	.24	.14										
25.	.50	.48	.42	.32	.18									
30.	.71	.69	.63	.53	.39	.21								
35.	.90	.88	.82	.72	.58	.40	.19							
40.	1.11	1.09	1.03	.93	.79	.61	.40	.21						
45.	1.34	1.32	1.26	1.16	1.02	.84	.63	.44	.23					
50.	1.59	1.57	1.51	1.41	1.27	1.09	.88	.69	.48	.25				
55.	1.85	1.83	1.77	1.67	1.53	1.35	1.14	.95	.74	.51	.26			
60.	2.13	2.11	2.05	1.95	1.81	1.63	1.42	1.23	1.02	.79	.54	.28		
65.	2.43	2.41	2.35	2.25	2.11	1.93	1.72	1.53	1.32	1.09	.84	.58	.30	
70.	2.76	2.74	2.68	2.58	2.44	2.26	2.05	1.86	1.65	1.42	1.17	.91	.63	.33

TABLE B.51 Excess tire wear for speed change cycles (% worn/1000 cycles) - medium automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.24	.21	.13											
20.	.42	.39	.31	.18										
25.	.64	.61	.53	.40	.22									
30.	.90	.87	.79	.66	.48	.26								
35.	1.14	1.11	1.03	.90	.72	.50	.24							
40.	1.40	1.37	1.29	1.16	.98	.76	.50	.26						
45.	1.68	1.65	1.57	1.44	1.26	1.04	.78	.54	.28					
50.	1.98	1.95	1.87	1.74	1.56	1.34	1.08	.84	.58	.30				
55.	2.29	2.26	2.18	2.05	1.87	1.65	1.39	1.15	.89	.61	.31			
60.	2.62	2.59	2.51	2.38	2.20	1.98	1.72	1.48	1.22	.94	.64	.33		
65.	2.97	2.94	2.86	2.73	2.55	2.33	2.07	1.83	1.57	1.29	.99	.68	.35	
70.	3.35	3.32	3.24	3.11	2.93	2.71	2.45	2.21	1.95	1.67	1.37	1.06	.73	.38

TABLE B.52 Excess tire wear for speed change cycles (% worn/1000 cycles) - large automobile

INITIAL SPEED	SPEED REDUCED TO AND RETURNED FROM, mph													
mph	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.12	.09												
15.	.27	.24	.15											
20.	.48	.45	.36	.21										
25.	.74	.71	.62	.47	.26									
30.	1.05	1.02	.93	.78	.57	.31								
35.	1.33	1.30	1.21	1.06	.85	.59	.28							
40.	1.65	1.62	1.53	1.38	1.17	.91	.60	.32						
45.	2.00	1.97	1.88	1.73	1.52	1.26	.95	.67	.35					
50.	2.37	2.34	2.25	2.10	1.89	1.63	1.32	1.04	.72	.37				
55.	2.77	2.74	2.65	2.50	2.29	2.03	1.72	1.44	1.12	.77	.40			
60.	3.19	3.16	3.07	2.92	2.71	2.45	2.14	1.86	1.54	1.19	.82	.42		
65.	3.64	3.61	3.52	3.37	3.16	2.90	2.59	2.31	1.99	1.64	1.27	.87	.45	
70.	4.11	4.08	3.99	3.84	3.63	3.37	3.06	2.78	2.46	2.11	1.74	1.34	.92	.47

TABLE B.53 Excess tire wear for speed change cycles (% worn/1000 cycles) - pickup truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.24	.21	.13											
20.	.42	.39	.31	.18										
25.	.64	.61	.53	.40	.22									
30.	.90	.87	.79	.66	.48	.26								
35.	1.13	1.10	1.02	.89	.71	.49	.23							
40.	1.39	1.36	1.28	1.15	.97	.75	.49	.26						
45.	1.66	1.63	1.55	1.42	1.24	1.02	.76	.53	.27					
50.	1.95	1.92	1.84	1.71	1.53	1.31	1.05	.82	.56	.29				
55.	2.26	2.23	2.15	2.02	1.84	1.62	1.36	1.13	.87	.60	.31			
60.	2.58	2.55	2.47	2.34	2.16	1.94	1.68	1.45	1.19	.92	.63	.32		
65.	2.93	2.90	2.82	2.69	2.51	2.29	2.03	1.80	1.54	1.27	.98	.67	.35	
70.	3.36	3.33	3.25	3.12	2.94	2.72	2.46	2.23	1.97	1.70	1.41	1.10	.78	.43

TABLE B.54 Excess tire wear for speed change cycles (% worn/1000 cycles) - 2A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.04													
10.	.16	.12												
15.	.36	.32	.20											
20.	.63	.59	.47	.27										
25.	.97	.93	.81	.61	.34									
30.	1.38	1.34	1.22	1.02	.75	.41								
35.	1.72	1.68	1.56	1.36	1.09	.75	.34							
40.	2.10	2.06	1.94	1.74	1.47	1.13	.72	.38						
45.	2.52	2.48	2.36	2.16	1.89	1.55	1.14	.80	.42					
50.	2.97	2.93	2.81	2.61	2.34	2.00	1.59	1.25	.87	.45				
55.	3.45	3.41	3.29	3.09	2.82	2.48	2.07	1.73	1.35	.93	.48			
60.	3.95	3.91	3.79	3.59	3.32	2.98	2.57	2.23	1.85	1.43	.98	.50		
65.	4.46	4.42	4.30	4.10	3.83	3.49	3.08	2.74	2.36	1.94	1.49	1.01	.51	
70.	4.93	4.89	4.77	4.57	4.30	3.96	3.55	3.21	2.83	2.41	1.96	1.48	.98	.47

TABLE B.55 Excess tire wear for speed change cycles (% worn/1000 cycles) - 3A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.24	.21	.13											
20.	.42	.39	.31	.18										
25.	.65	.62	.54	.41	.23									
30.	.93	.90	.82	.69	.51	.28								
35.	1.16	1.13	1.05	.92	.74	.51	.23							
40.	1.42	1.39	1.31	1.18	1.00	.77	.49	.26						
45.	1.71	1.68	1.60	1.47	1.29	1.06	.78	.55	.29					
50.	2.03	2.00	1.92	1.79	1.61	1.38	1.10	.87	.61	.32				
55.	2.37	2.34	2.26	2.13	1.95	1.72	1.44	1.21	.95	.66	.34			
60.	2.73	2.70	2.62	2.49	2.31	2.08	1.80	1.57	1.31	1.02	.70	.36		
65.	3.11	3.08	3.00	2.87	2.69	2.46	2.18	1.95	1.69	1.40	1.08	.74	.38	
70.	3.49	3.46	3.38	3.25	3.07	2.84	2.56	2.33	2.07	1.78	1.46	1.12	.76	.38

TABLE B.56 Excess tire wear for speed change cycles (% worn/1000 cycles) - 2 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.02													
10.	.09	.07												
15.	.20	.18	.11											
20.	.35	.33	.26	.15										
25.	.54	.52	.45	.34	.19									
30.	.77	.75	.68	.57	.42	.23								
35.	.96	.94	.87	.76	.61	.42	.19							
40.	1.18	1.16	1.09	.98	.83	.64	.41	.22						
45.	1.42	1.40	1.33	1.22	1.07	.88	.65	.46	.24					
50.	1.68	1.66	1.59	1.48	1.33	1.14	.91	.72	.50	.26				
55.	1.96	1.94	1.87	1.76	1.61	1.42	1.19	1.00	.78	.54	.28			
60.	2.26	2.24	2.17	2.06	1.91	1.72	1.49	1.30	1.08	.84	.58	.30		
65.	2.57	2.55	2.48	2.37	2.22	2.03	1.80	1.61	1.39	1.15	.89	.61	.31	
70.	2.88	2.86	2.79	2.68	2.53	2.34	2.11	1.92	1.70	1.46	1.20	.92	.62	.31

TABLE B.57 Excess tire wear for speed change cycles (% worn/1000 cycles) - 3 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.25	.22	.14											
20.	.44	.41	.33	.19										
25.	.68	.65	.57	.43	.24									
30.	.97	.94	.86	.72	.53	.29								
35.	1.21	1.18	1.10	.96	.77	.53	.24							
40.	1.49	1.46	1.38	1.24	1.05	.81	.52	.28						
45.	1.80	1.77	1.69	1.55	1.36	1.12	.83	.59	.31					
50.	2.14	2.11	2.03	1.89	1.70	1.46	1.17	.93	.65	.34				
55.	2.50	2.47	2.39	2.25	2.06	1.82	1.53	1.29	1.01	.70	.36			
60.	2.88	2.85	2.77	2.63	2.44	2.20	1.91	1.67	1.39	1.08	.74	.38		
65.	3.29	3.26	3.18	3.04	2.85	2.61	2.32	2.08	1.80	1.49	1.15	.79	.41	
70.	3.70	3.67	3.59	3.45	3.26	3.02	2.73	2.49	2.21	1.90	1.56	1.20	.82	.41

TABLE B.58 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - small automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.04													
10.	.15	.11												
15.	.33	.29	.18											
20.	.58	.54	.43	.25										
25.	.91	.87	.76	.58	.33									
30.	1.31	1.27	1.16	.98	.73	.40								
35.	1.75	1.71	1.60	1.42	1.17	.84	.44							
40.	2.25	2.21	2.10	1.92	1.67	1.34	.94	.50						
45.	2.81	2.77	2.66	2.48	2.23	1.90	1.50	1.06	.56					
50.	3.42	3.38	3.27	3.09	2.84	2.51	2.11	1.67	1.17	.61				
55.	4.08	4.04	3.93	3.75	3.50	3.17	2.77	2.33	1.83	1.27	.66			
60.	4.78	4.74	4.63	4.45	4.20	3.87	3.47	3.03	2.53	1.97	1.36	.70		
65.	5.51	5.47	5.36	5.18	4.93	4.60	4.20	3.76	3.26	2.70	2.09	1.43	.73	
70.	6.26	6.22	6.11	5.93	5.68	5.35	4.95	4.51	4.01	3.45	2.84	2.18	1.48	.75

TABLE B.59 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - medium automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.04													
10.	.15	.11												
15.	.33	.29	.18											
20.	.58	.54	.43	.25										
25.	.91	.87	.76	.58	.33									
30.	1.31	1.27	1.16	.98	.73	.40								
35.	1.76	1.72	1.61	1.43	1.18	.85	.45							
40.	2.27	2.23	2.12	1.94	1.69	1.36	.96	.51						
45.	2.84	2.80	2.69	2.51	2.26	1.93	1.53	1.08	.57					
50.	3.46	3.42	3.31	3.13	2.88	2.55	2.15	1.70	1.19	.62				
55.	4.13	4.09	3.98	3.80	3.55	3.22	2.82	2.37	1.86	1.29	.67			
60.	4.85	4.81	4.70	4.52	4.27	3.94	3.54	3.09	2.58	2.01	1.39	.72		
65.	5.61	5.57	5.46	5.28	5.03	4.70	4.30	3.85	3.34	2.77	2.15	1.48	.76	
70.	6.40	6.36	6.25	6.07	5.82	5.49	5.09	4.64	4.13	3.56	2.94	2.27	1.55	.79

TABLE B.60 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - large automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.13	.10												
15.	.30	.27	.17											
20.	.54	.51	.41	.24										
25.	.84	.81	.71	.54	.30									
30.	1.21	1.18	1.08	.91	.67	.37								
35.	1.63	1.60	1.50	1.33	1.09	.79	.42							
40.	2.11	2.08	1.98	1.81	1.57	1.27	.90	.48						
45.	2.65	2.62	2.52	2.35	2.11	1.81	1.44	1.02	.54					
50.	3.24	3.21	3.11	2.94	2.70	2.40	2.03	1.61	1.13	.59				
55.	3.88	3.85	3.75	3.58	3.34	3.04	2.67	2.25	1.77	1.23	.64			
60.	4.56	4.53	4.43	4.26	4.02	3.72	3.35	2.93	2.45	1.91	1.32	.68		
65.	5.28	5.25	5.15	4.98	4.74	4.44	4.07	3.65	3.17	2.63	2.04	1.40	.72	
70.	6.03	6.00	5.90	5.73	5.49	5.19	4.82	4.40	3.92	3.38	2.79	2.15	1.47	.75

TABLE B.61 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - pickup truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.04													
10.	.15	.11												
15.	.33	.29	.18											
20.	.58	.54	.43	.25										
25.	.91	.87	.76	.58	.33									
30.	1.31	1.27	1.16	.98	.73	.40								
35.	1.75	1.71	1.60	1.42	1.17	.84	.44							
40.	2.25	2.21	2.10	1.92	1.67	1.34	.94	.50						
45.	2.81	2.77	2.66	2.48	2.23	1.90	1.50	1.06	.56					
50.	3.42	3.38	3.27	3.09	2.84	2.51	2.11	1.67	1.17	.61				
55.	4.08	4.04	3.93	3.75	3.50	3.17	2.77	2.33	1.83	1.27	.66			
60.	4.78	4.74	4.63	4.45	4.20	3.87	3.47	3.03	2.53	1.97	1.36	.70		
65.	5.52	5.48	5.37	5.19	4.94	4.61	4.21	3.77	3.27	2.71	2.10	1.44	.74	
70.	6.28	6.24	6.13	5.95	5.70	5.37	4.97	4.53	4.03	3.47	2.86	2.20	1.50	.76

TABLE B.62 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - 2A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.24	.21	.13											
20.	.43	.40	.32	.19										
25.	.69	.66	.58	.45	.26									
30.	1.02	.99	.91	.78	.59	.33								
35.	1.41	1.38	1.30	1.17	.98	.72	.39							
40.	1.87	1.84	1.76	1.63	1.44	1.18	.85	.46						
45.	2.40	2.37	2.29	2.16	1.97	1.71	1.38	.99	.53					
50.	3.00	2.97	2.89	2.76	2.57	2.31	1.98	1.59	1.13	.60				
55.	3.68	3.65	3.57	3.44	3.25	2.99	2.66	2.27	1.81	1.28	.68			
60.	4.44	4.41	4.33	4.20	4.01	3.75	3.42	3.03	2.57	2.04	1.44	.76		
65.	5.28	5.25	5.17	5.04	4.85	4.59	4.26	3.87	3.41	2.88	2.28	1.60	.84	
70.	6.20	6.17	6.09	5.96	5.77	5.51	5.18	4.79	4.33	3.80	3.20	2.52	1.76	.92

TABLE B.63 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - 3A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.02													
10.	.09	.07												
15.	.22	.20	.13											
20.	.40	.38	.31	.18										
25.	.65	.63	.56	.43	.25									
30.	.96	.94	.87	.74	.56	.31								
35.	1.33	1.31	1.24	1.11	.93	.68	.37							
40.	1.77	1.75	1.68	1.55	1.37	1.12	.81	.44						
45.	2.29	2.27	2.20	2.07	1.89	1.64	1.33	.96	.52					
50.	2.89	2.87	2.80	2.67	2.49	2.24	1.93	1.56	1.12	.60				
55.	3.57	3.55	3.48	3.35	3.17	2.92	2.61	2.24	1.80	1.28	.68			
60.	4.33	4.31	4.24	4.11	3.93	3.68	3.37	3.00	2.56	2.04	1.44	.76		
65.	5.18	5.16	5.09	4.96	4.78	4.53	4.22	3.85	3.41	2.89	2.29	1.61	.85	
70.	6.12	6.10	6.03	5.90	5.72	5.47	5.16	4.79	4.35	3.83	3.23	2.55	1.79	.94

TABLE B.64 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - 2 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.25	.22	.14											
20.	.45	.42	.34	.20										
25.	.72	.69	.61	.47	.27									
30.	1.06	1.03	.95	.81	.61	.34								
35.	1.47	1.44	1.36	1.22	1.02	.75	.41							
40.	1.95	1.92	1.84	1.70	1.50	1.23	.89	.48						
45.	2.51	2.48	2.40	2.26	2.06	1.79	1.45	1.04	.56					
50.	3.16	3.13	3.05	2.91	2.71	2.44	2.10	1.69	1.21	.65				
55.	3.89	3.86	3.78	3.64	3.44	3.17	2.83	2.42	1.94	1.38	.73			
60.	4.71	4.68	4.60	4.46	4.26	3.99	3.65	3.24	2.76	2.20	1.55	.82		
65.	5.63	5.60	5.52	5.38	5.18	4.91	4.57	4.16	3.68	3.12	2.47	1.74	.92	
70.	6.64	6.61	6.53	6.39	6.19	5.92	5.58	5.17	4.69	4.13	3.48	2.75	1.93	1.01

TABLE B.65 Excess maintenance and repair cost for speed change cycles (% avg cost/1000 cycles) - 3 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.03													
10.	.11	.08												
15.	.26	.23	.15											
20.	.48	.45	.37	.22										
25.	.78	.75	.67	.52	.30									
30.	1.16	1.13	1.05	.90	.68	.38								
35.	1.63	1.60	1.52	1.37	1.15	.85	.47							
40.	2.20	2.17	2.09	1.94	1.72	1.42	1.04	.57						
45.	2.88	2.85	2.77	2.62	2.40	2.10	1.72	1.25	.68					
50.	3.67	3.64	3.56	3.41	3.19	2.89	2.51	2.04	1.47	.79				
55.	4.58	4.55	4.47	4.32	4.10	3.80	3.42	2.95	2.38	1.70	.91			
60.	5.61	5.58	5.50	5.35	5.13	4.83	4.45	3.98	3.41	2.73	1.94	1.03		
65.	6.78	6.75	6.67	6.52	6.30	6.00	5.62	5.15	4.58	3.90	3.11	2.20	1.17	
70.	8.09	8.06	7.98	7.83	7.61	7.31	6.93	6.46	5.89	5.21	4.42	3.51	2.48	1.31

TABLE B.66 Excess depreciation for speed change cycles (% new price/1000 cycles) - small automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.002													
10.	.004	.002												
15.	.006	.004	.002											
20.	.008	.006	.004	.002										
25.	.010	.008	.006	.004	.002									
30.	.012	.010	.008	.006	.004	.002								
35.	.014	.012	.010	.008	.006	.004	.002							
40.	.016	.014	.012	.010	.008	.006	.004	.002						
45.	.018	.016	.014	.012	.010	.008	.006	.004	.002					
50.	.020	.018	.016	.014	.012	.010	.008	.006	.004	.002				
55.	.022	.020	.018	.016	.014	.012	.010	.008	.006	.004	.002			
60.	.024	.022	.020	.018	.016	.014	.012	.010	.008	.006	.004	.002		
65.	.027	.025	.023	.021	.019	.017	.015	.013	.011	.009	.007	.005	.003	
70.	.030	.028	.026	.024	.022	.020	.018	.016	.014	.012	.010	.008	.006	.003

TABLE B.67 Excess depreciation for speed change cycles (% new price/1000 cycles) - medium automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.002													
10.	.003	.001												
15.	.004	.002	.001											
20.	.005	.003	.002	.001										
25.	.006	.004	.003	.002	.001									
30.	.007	.005	.004	.003	.002	.001								
35.	.008	.006	.005	.004	.003	.002	.001							
40.	.009	.007	.006	.005	.004	.003	.002	.001						
45.	.010	.008	.007	.006	.005	.004	.003	.002	.001					
50.	.012	.010	.009	.008	.007	.006	.005	.004	.003	.002				
55.	.014	.012	.011	.010	.009	.008	.007	.006	.005	.004	.002			
60.	.016	.014	.013	.012	.011	.010	.009	.008	.007	.006	.004	.002		
65.	.018	.016	.015	.014	.013	.012	.011	.010	.009	.008	.006	.004	.002	
70.	.021	.019	.018	.017	.016	.015	.014	.013	.012	.011	.009	.007	.005	.003

TABLE B.68 Excess depreciation for speed change cycles (% new price/1000 cycles) - large automobile

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.001													
10.	.002	.001												
15.	.003	.002	.001											
20.	.004	.003	.002	.001										
25.	.005	.004	.003	.002	.001									
30.	.006	.005	.004	.003	.002	.001								
35.	.007	.006	.005	.004	.003	.002	.001							
40.	.008	.007	.006	.005	.004	.003	.002	.001						
45.	.009	.008	.007	.006	.005	.004	.003	.002	.001					
50.	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001				
55.	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001			
60.	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001		
65.	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001	
70.	.014	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001

TABLE B.69 Excess depreciation for speed change cycles (% new price/1000 cycles) - pickup truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.001													
10.	.002	.001												
15.	.003	.002	.001											
20.	.004	.003	.002	.001										
25.	.005	.004	.003	.002	.001									
30.	.006	.005	.004	.003	.002	.001								
35.	.007	.006	.005	.004	.003	.002	.001							
40.	.008	.007	.006	.005	.004	.003	.002	.001						
45.	.009	.008	.007	.006	.005	.004	.003	.002	.001					
50.	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001				
55.	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001			
60.	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001		
65.	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001	
70.	.015	.014	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002

TABLE B.70 Excess depreciation for speed change cycles (% new price/1000 cycles) - 2A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.002													
10.	.004	.002												
15.	.005	.003	.001											
20.	.006	.004	.002	.001										
25.	.007	.005	.003	.002	.001									
30.	.008	.006	.004	.003	.002	.001								
35.	.009	.007	.005	.004	.003	.002	.001							
40.	.011	.009	.007	.006	.005	.004	.003	.002						
45.	.013	.011	.009	.008	.007	.006	.005	.004	.002					
50.	.015	.013	.011	.010	.009	.008	.007	.006	.004	.002				
55.	.017	.015	.013	.012	.011	.010	.009	.008	.006	.004	.002			
60.	.020	.018	.016	.015	.014	.013	.012	.011	.009	.007	.005	.003		
65.	.024	.022	.020	.019	.018	.017	.016	.015	.013	.011	.009	.007	.004	
70.	.030	.028	.026	.025	.024	.023	.022	.021	.019	.017	.015	.013	.010	.006

TABLE B.71 Excess depreciation for speed change cycles (% new price/1000 cycles) - 3A SU truck

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.003													
10.	.005	.002												
15.	.007	.004	.002											
20.	.009	.006	.004	.002										
25.	.011	.008	.006	.004	.002									
30.	.013	.010	.008	.006	.004	.002								
35.	.015	.012	.010	.008	.006	.004	.002							
40.	.017	.014	.012	.010	.008	.006	.004	.002						
45.	.019	.016	.014	.012	.010	.008	.006	.004	.002					
50.	.021	.018	.016	.014	.012	.010	.008	.006	.004	.002				
55.	.024	.021	.019	.017	.015	.013	.011	.009	.007	.005	.003			
60.	.027	.024	.022	.020	.018	.016	.014	.012	.010	.008	.006	.003		
65.	.031	.028	.026	.024	.022	.020	.018	.016	.014	.012	.010	.007	.004	
70.	.037	.034	.032	.030	.028	.026	.024	.022	.020	.018	.016	.013	.010	.006

TABLE B.72 Excess depreciation for speed change cycles (% new price/1000 cycles) - 2 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.001													
10.	.002	.001												
15.	.003	.002	.001											
20.	.004	.003	.002	.001										
25.	.005	.004	.003	.002	.001									
30.	.006	.005	.004	.003	.002	.001								
35.	.007	.006	.005	.004	.003	.002	.001							
40.	.008	.007	.006	.005	.004	.003	.002	.001						
45.	.009	.008	.007	.006	.005	.004	.003	.002	.001					
50.	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001				
55.	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001			
60.	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001		
65.	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001	
70.	.015	.014	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002

TABLE B.73 Excess depreciation for speed change cycles (% new price/1000 cycles) - 3 - S2 semi

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.001													
10.	.002	.001												
15.	.003	.002	.001											
20.	.004	.003	.002	.001										
25.	.005	.004	.003	.002	.001									
30.	.006	.005	.004	.003	.002	.001								
35.	.007	.006	.005	.004	.003	.002	.001							
40.	.008	.007	.006	.005	.004	.003	.002	.001						
45.	.009	.008	.007	.006	.005	.004	.003	.002	.001					
50.	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001				
55.	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001			
60.	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001		
65.	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002	.001	
70.	.015	.014	.013	.012	.011	.010	.009	.008	.007	.006	.005	.004	.003	.002

TABLE B.74 Excess fuel consumption on horizontal curves (gal/1000 mi) - small automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	.1	.2	.2	.3	.3	.3	.4	.4	.4	.4	.3	.3	.3	.3
10	0.0	.1	.3	.4	.5	.6	.6	.6	.6	.6	.5	.5	.5	.4	.3
15	0.0	.1	.2	.3	.4	.4	.4	.4	.3	.3	.2	.2	.2	.1	0.0
20	0.0	.1	.2	.2	.3	.3	.2	.2	.1	.1	0.0	0.0	0.0	0.0	.1
25	0.0	.1	.1	.2	.2	.2	.1	.1	0.0	0.0	0.0	.1	.1	.5	1.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.2	.4	.7
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.6	1.0	1.6	2.2	4.3	
40	0.0	0.0	0.0	0.0	0.0	0.0	.2	.7	1.4	2.4	3.7	5.4	6.7		
45	0.0	0.0	0.0	0.0	.1	.1	.5	1.0	1.9	3.1	5.0				
50	0.0	0.0	0.0	.1	.1	.3	.7	1.5	3.0	6.4					
55	.1	0.0	.1	.3	.6	1.1	2.6	5.2	9.6						
60	.1	.1	.3	.6	1.2	2.0	4.7	9.1							
65	.2	.2	.4	1.0	1.8	3.1	7.2	12.9							
70	.2	.3	.7	1.4	2.6	4.4	10.5								

TABLE B.75 Excess fuel consumption on horizontal curves (gal/1000 mi) - medium automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	.2	.3	.5	.6	.6	.7	.7	.7	.7	.7	.7	.7	.7	.7
10	0.0	.2	.3	.4	.5	.6	.6	.6	.6	.6	.5	.5	.5	.4	.3
15	0.0	.2	.3	.4	.5	.5	.5	.5	.4	.4	.3	.3	.2	.1	0.0
20	0.0	.2	.3	.4	.4	.4	.4	.3	.2	.1	.1	0.0	0.0	0.0	.2
25	0.0	.1	.2	.3	.3	.3	.2	.1	0.0	0.0	0.0	.1	.2	.8	1.7
30	0.0	.1	.1	.1	.1	.1	0.0	0.0	.1	.2	.5	.9	1.3	3.0	5.4
35	0.0	0.0	.1	.1	0.0	0.0	0.0	.2	.6	1.2	2.1	3.1	4.5	8.7	
40	0.0	0.0	0.0	0.0	0.0	.1	.3	.9	2.0	3.4	5.3	7.6	10.7		
45	.1	0.0	0.0	0.0	.1	.3	1.1	2.5	4.8	7.7	11.2				
50	.1	0.0	.1	.2	.5	.9	2.5	5.1	9.1	13.1					
55	.1	.1	.2	.4	.9	1.6	3.9	7.4	12.8						
60	.1	.1	.2	.5	1.1	1.9	4.5	9.9							
65	.3	.3	.8	1.6	3.1	5.3	13.3	25.3							
70	.5	.7	1.8	3.8	7.0	12.1	25.5								

TABLE B.76 Excess fuel consumption on horizontal curves (gal/1000 mi) - large automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	.3	.6	.9	1.0	1.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2
10	0.0	.3	.6	.8	.9	1.0	1.1	1.1	1.1	1.0	1.0	.9	.8	.7	.6
15	0.0	.3	.6	.8	.9	1.0	1.0	.9	.8	.7	.6	.5	.4	.2	.1
20	0.0	.3	.5	.7	.8	.8	.7	.6	.4	.2	.1	.1	0.0	.1	.3
25	0.0	.1	.3	.3	.3	.3	.2	.1	0.0	0.0	0.0	.1	.3	.9	2.0
30	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	.2	.3	.6	.9	2.0	3.7
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.5	.9	1.6	2.4	3.5	6.8	
40	0.0	0.0	0.0	0.0	0.0	0.0	.3	.8	1.8	3.1	4.8	6.9	9.3		
45	0.0	0.0	0.0	0.0	.1	.2	.8	1.7	3.3	5.2	7.8				
50	.1	0.0	0.0	.1	.2	.5	1.3	2.6	4.7	7.5					
55	.1	0.0	.1	.2	.5	.8	2.0	4.2	9.0						
60	.1	.1	.2	.3	.7	1.2	3.0	8.9							
65	.1	.1	.3	.6	1.2	2.0	7.2								
70	.1	.2	.5	1.0	1.9	4.0	15.8								

TABLE B.77 Excess fuel consumption on horizontal curves (gal/1000 mi) - pickup truck

SPEED	DEGREE OF CURVATURE													
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	.2	.4	.6	.7	.8	.9	1.0	1.0	1.0	1.0	.9	.9	.9	.9
10	0.0	.2	.4	.6	.7	.8	.8	.8	.8	.7	.7	.7	.6	.5	.4
15	0.0	.2	.5	.6	.7	.8	.8	.7	.6	.5	.5	.4	.3	.2	.1
20	0.0	.2	.5	.6	.7	.7	.6	.5	.3	.2	.1	0.0	0.0	0.0	.3
25	0.0	.2	.4	.5	.5	.4	.3	.1	0.0	0.0	.1	.2	.4	1.3	2.9
30	0.0	.1	.3	.3	.3	.2	0.0	0.0	.2	.5	1.0	1.8	2.8	6.1	11.2
35	0.0	.1	.1	.1	0.0	0.0	.1	.4	1.2	2.2	3.8	5.7	8.2	15.8	
40	.1	0.0	0.0	0.0	0.0	.1	.6	1.6	3.5	6.0	9.3	13.4			
45	.1	0.0	0.0	0.0	.2	.4	1.5	3.3	6.3	10.1	14.3				
50	.1	0.0	.1	.2	.4	.9	2.4	4.9	8.9	14.8					
55	.2	.1	.3	.7	1.5	2.7	6.6	13.0							
60	.4	.3	.8	1.9	3.7	6.4	15.1								
65	.6	.7	1.8	3.8	7.3	12.4	30.5								
70	1.0	1.4	3.4	7.2	13.4	23.2									

TABLE B.78 Excess fuel consumption on horizontal curves (gal/1000 mi) - 2A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	1.0	2.0	2.9	3.4	3.8	4.3	4.5	4.5	4.4	4.4	4.3	4.3	4.1	4.0
10	0.0	.9	1.8	2.6	3.0	3.3	3.7	3.7	3.5	3.3	3.1	3.0	2.8	2.4	2.0
15	0.0	.8	1.6	2.2	2.5	2.7	2.7	2.6	2.2	1.9	1.6	1.3	1.0	.6	.2
20	0.0	.6	1.2	1.7	1.8	1.8	1.6	1.3	.9	.6	.3	.1	0.0	.1	.7
25	0.0	.4	.8	1.0	1.0	.9	.6	.3	.1	0.0	.1	.4	.9	2.8	6.0
30	0.0	.2	.4	.5	.4	.3	.1	0.0	.2	.8	1.7	2.9	4.6	10.0	18.3
35	.1	.1	.2	.2	.1	0.0	.1	.7	2.1	4.0	6.9	10.4			
40	.2	0.0	0.0	0.0	0.0	.2	1.2	3.4	7.3	12.3	19.3				
45	.2	0.0	0.0	.1	.4	1.1	3.6	8.0	15.3						
50	.2	0.0	.1	.4	.9	1.9	5.1	10.2							
55	.3	.1	.3	.8	1.8	3.3	8.2	15.4							
60	.3	.3	.7	1.6	3.1										
65	.4	.5	1.2	2.6	5.0										
70	.6	.9	2.1												

TABLE B.79 Excess fuel consumption on horizontal curves (gal/1000 mi) - 3A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	1.0	2.1	3.0	3.5	3.9	4.4	4.7	4.6	4.5	4.5	4.4	4.4	4.2	4.1
10	0.0	1.3	2.7	3.8	4.5	4.9	5.4	5.5	5.2	4.9	4.6	4.4	4.1	3.5	2.9
15	0.0	1.6	3.3	4.6	5.3	5.6	5.7	5.4	4.6	4.0	3.3	2.8	2.2	1.2	.4
20	0.0	1.7	3.4	4.7	5.0	5.1	4.6	3.7	2.5	1.5	.8	.3	.1	.3	2.0
25	.1	1.2	2.3	3.0	2.9	2.7	1.8	.9	.2	0.0	.3	1.1	2.5	8.0	17.3
30	.1	.7	1.3	1.5	1.2	.9	.2	0.0	.8	2.4	5.1	8.9	13.8	30.3	55.5
35	.2	.3	.6	.5	.2	0.0	.3	2.0	5.7	11.1	18.9	28.6			
40	.4	.1	.1	0.0	.1	.5	3.0	8.3	17.8	30.2	47.3				
45	.6	0.0	0.0	.3	1.2	2.9	9.8	21.8	41.4						
50	1.0	.2	.5	1.6	4.1	8.3	22.6	45.8							
55	1.6	.8	2.1	5.2	11.1	20.1	49.7	91.7							
60	2.6	2.1	5.4	12.2	24.1										
65	3.7	4.1	10.3	22.0	41.8										
70	5.0	7.2	17.6												

TABLE B.80 Excess fuel consumption on horizontal curves (gal/1000 mi) - 2-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	1.1	2.2	3.1	3.7	4.1	4.7	4.9	4.8	4.8	4.7	4.7	4.6	4.5	4.3
10	0.0	1.7	3.5	5.0	5.8	6.4	7.0	7.1	6.7	6.4	6.0	5.7	5.3	4.6	3.8
15	0.0	1.8	3.7	5.1	5.8	6.2	6.4	6.0	5.1	4.4	3.7	3.0	2.5	1.3	.5
20	0.0	1.7	3.4	4.7	5.0	5.1	4.6	3.7	2.5	1.5	.8	.3	.1	.3	2.0
25	.1	1.5	3.0	3.8	3.8	3.4	2.3	1.1	.2	0.0	.4	1.5	3.2	10.3	22.3
30	.2	1.1	2.1	2.4	2.0	1.4	.3	0.0	1.2	3.8	8.1	14.0	21.9	48.0	87.9
35	.3	.4	.7	.6	.3	0.0	.4	2.3	6.6	12.7	21.6	32.6			
40	.3	.1	.1	0.0	0.0	.3	2.0	5.6	12.0	20.2	31.7				
45	.3	0.0	0.0	.1	.5	1.2	4.1	9.2	17.4						
50	.2	0.0	.1	.3	.7	1.4	3.9	7.8							
55	.6	.3	.8	1.9	4.0	7.3	18.1	38.5							
60	1.3	1.1	2.8	6.2	12.3										
65	3.2	3.6	9.0	19.4	36.8										
70	6.2	8.8	21.6												

TABLE B.81 Excess fuel consumption on horizontal curves (gal/1000 mi) - 3-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	1.1	2.3	3.3	3.9	4.3	4.9	5.1	5.1	5.0	5.0	4.9	4.8	4.7	4.5
10	0.0	1.9	3.9	5.6	6.5	7.2	7.8	7.9	7.5	7.1	6.7	6.3	5.9	5.1	4.3
15	0.0	2.1	4.2	5.9	6.7	7.1	7.3	6.9	5.9	5.0	4.2	3.5	2.8	1.5	.6
20	0.0	2.0	4.0	5.4	5.9	6.0	5.3	4.3	2.9	1.8	1.0	.4	.1	.4	2.4
25	.1	1.8	3.6	4.6	4.6	4.2	2.8	1.4	.3	0.0	.5	1.8	4.0	12.5	27.2
30	.2	1.4	2.7	3.1	2.5	1.8	.4	0.0	1.5	4.8	10.5	18.0	28.2	61.8	113.2
35	.4	.5	.9	.8	.4	.1	.5	3.2	9.2	17.8	30.2	45.6			
40	.4	.1	.1	0.0	.1	.5	3.3	9.2	19.7	33.4	52.3				
45	.5	0.0	0.0	.2	.9	2.4	8.0	17.8	33.8						
50	.5	.1	.3	.9	2.2	4.4	11.9	24.1							
55	1.0	.5	1.2	3.0	6.5	11.8	29.2	62.0							
60	1.4	1.2	2.9	6.6	13.1										
65	2.0	2.3	5.6	12.0	22.7										
70	3.1	4.4	10.8												

TABLE B.82 Excess tire wear on horizontal curves (% worn/1000 mi) - small automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	2.5	4.9	6.9	8.1	9.1	10.2	10.7	10.6	10.5	10.3	10.2	10.1	9.8	9.5
10	0.0	2.3	4.6	6.4	7.5	8.2	8.9	9.1	8.6	8.1	7.7	7.3	6.8	5.9	5.0
15	.1	2.1	4.1	5.6	6.3	6.8	6.9	6.5	5.6	4.8	4.1	3.4	2.8	1.6	.7
20	.1	1.8	3.4	4.5	4.9	4.9	4.4	3.6	2.5	1.7	1.0	.5	.2	.5	2.1
25	.2	1.5	2.7	3.3	3.3	3.0	2.1	1.2	.4	0.0	.6	1.5	2.9	8.3	17.5
30	.3	1.1	1.9	2.1	1.8	1.3	.5	.1	1.2	3.0	6.1	10.1	15.4	33.1	59.9
35	.6	.7	1.1	1.0	.6	.2	.7	2.8	7.0	13.0	21.5	32.1	45.6	88.4	
40	.9	.4	.4	.2	.3	1.0	4.2	10.2	20.8	34.5	53.4	76.2	105.2		
45	1.4	0.0	.2	.8	2.1	4.3	12.2	25.5	47.2	74.6	112.1				
50	2.0	.7	1.3	2.9	6.0	10.8	26.8	52.4	92.9	144.4					
55	2.9	1.8	3.5	6.9	13.1	22.1	51.4	97.4	171.0						
60	4.1	3.6	7.0	13.5	24.5	40.3	90.7	171.6							
65	5.7	6.3	12.5	23.7	42.1	68.4	154.1	311.0							
70	7.8	10.1	20.5	38.8	68.4	111.4	266.4								

TABLE B.83 Excess tire wear on horizontal curves (% worn/1000 mi) - medium automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	2.9	5.7	8.1	9.6	10.7	12.0	12.6	12.4	12.3	12.1	12.0	11.9	11.5	11.1
10	0.0	2.7	5.4	7.6	8.8	9.6	10.5	10.7	10.1	9.6	9.0	8.5	8.0	6.9	5.8
15	.1	2.5	4.8	6.6	7.5	7.9	8.1	7.7	6.6	5.7	4.8	4.0	3.3	1.9	.8
20	.1	2.1	4.0	5.3	5.7	5.8	5.2	4.3	3.0	2.0	1.2	.6	.2	.6	2.5
25	.2	1.7	3.1	3.9	3.8	3.5	2.5	1.4	.4	0.0	.7	1.7	3.4	9.8	20.6
30	.4	1.3	2.2	2.4	2.1	1.6	.5	.2	1.4	3.5	7.1	11.8	18.1	38.9	70.4
35	.7	.9	1.3	1.2	.7	.2	.8	3.2	8.2	15.2	25.3	37.7	53.6	103.8	
40	1.0	.4	.5	.2	.3	1.2	4.9	11.9	24.4	40.5	62.7	89.5	123.5		
45	1.6	.1	.2	.9	2.4	4.9	14.2	29.8	55.4	87.5	131.7				
50	2.3	.8	1.5	3.4	7.0	12.5	31.3	61.4	109.0	169.5					
55	3.4	2.0	4.0	8.0	15.2	25.8	60.2	114.2	200.7						
60	4.7	4.1	8.1	15.6	28.5	47.0	106.2	201.2							
65	6.5	7.2	14.4	27.5	49.0	79.9	180.5	364.7							
70	8.9	11.6	23.7	45.1	79.7	130.1	312.1								

TABLE B.84 Excess tire wear on horizontal curves (% worn/1000 mi) - large automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	3.3	6.7	9.4	11.1	12.4	13.9	14.6	14.4	14.3	14.1	13.9	13.7	13.3	12.9
10	0.0	3.2	6.3	8.8	10.2	11.2	12.2	12.3	11.7	11.1	10.5	9.9	9.3	8.0	6.8
15	.1	2.9	5.6	7.7	8.6	9.2	9.4	8.9	7.7	6.6	5.6	4.7	3.8	2.2	.9
20	.1	2.5	4.7	6.2	6.6	6.7	6.0	4.9	3.4	2.3	1.3	.7	.2	.7	2.9
25	.3	2.0	3.6	4.5	4.4	4.1	2.9	1.6	.5	.1	.8	2.0	3.9	11.3	23.9
30	.5	1.5	2.5	2.8	2.4	1.8	.6	.2	1.6	4.1	8.2	13.7	21.0	45.0	81.6
35	.8	1.0	1.5	1.3	.8	.2	1.0	3.7	9.5	17.6	29.3	43.7	62.1	120.4	
40	1.2	.5	.6	.2	.4	1.4	5.6	13.8	28.2	46.9	72.6	103.7	143.2		
45	1.8	.1	.3	1.0	2.8	5.7	16.4	34.5	64.1	101.4	152.6				
50	2.7	.9	1.8	3.8	8.0	14.4	36.2	71.1	126.3	196.3					
55	3.8	2.3	4.6	9.2	17.5	29.8	69.6	132.2	232.4						
60	5.4	4.7	9.3	18.0	32.8	54.3	122.9	233.0							
65	7.5	8.2	16.5	31.7	56.6	92.4	208.8								
70	10.1	13.2	27.2	51.9	92.1	150.5	361.1								

TABLE B.85 Excess tire wear on horizontal curves (% worn/1000 mi) - pickup truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	3.0	5.8	8.2	9.6	10.7	12.0	12.6	12.4	12.3	12.1	12.0	11.8	11.5	11.1
10	0.0	2.8	5.5	7.6	8.8	9.7	10.5	10.7	10.1	9.6	9.1	8.6	8.1	7.0	5.9
15	.1	2.6	4.9	6.7	7.5	8.0	8.1	7.7	6.7	5.8	4.9	4.1	3.4	2.0	.9
20	.2	2.3	4.1	5.4	5.8	5.9	5.3	4.4	3.1	2.1	1.3	.7	.2	.7	2.6
25	.3	1.8	3.2	4.0	3.9	3.6	2.6	1.5	.5	.1	.7	1.8	3.5	9.8	20.5
30	.5	1.4	2.3	2.5	2.2	1.7	.6	.2	1.5	3.7	7.2	11.9	18.1	38.6	69.8
35	.7	.9	1.4	1.3	.8	.2	.9	3.4	8.3	15.3	25.2	37.5	53.2	102.9	
40	1.1	.5	.5	.2	.4	1.3	5.0	12.1	24.4	40.3	62.2	88.7			
45	1.7	.1	.3	1.0	2.6	5.1	14.3	29.8	55.1	86.9	130.5				
50	2.5	.8	1.6	3.5	7.1	12.7	31.3	61.1	108.2	167.9					
55	3.5	2.2	4.1	8.1	15.3	25.9	59.9	113.3							
60	4.9	4.2	8.3	15.8	28.5	46.9	105.5								
65	6.7	7.3	14.6	27.6	49.0	79.6	179.0								
70	9.0	11.8	23.9	45.1	79.4	129.3									

TABLE B.86 Excess tire wear on horizontal curves (% worn/1000 mi) - 2A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	3.9	8.0	11.5	13.5	15.1	17.0	17.9	17.7	17.4	17.2	17.0	16.8	16.3	15.8
10	0.0	3.7	7.5	10.6	12.3	13.5	14.7	15.0	14.2	13.4	12.7	12.0	11.3	9.7	8.1
15	0.0	3.3	6.6	9.1	10.3	11.0	11.2	10.6	9.1	7.8	6.6	5.5	4.4	2.4	.9
20	.1	2.7	5.4	7.2	7.8	7.9	7.1	5.7	3.9	2.5	1.4	.6	.2	.6	3.2
25	.2	2.1	4.0	5.0	5.0	4.6	3.1	1.6	.4	0.0	.7	2.0	4.3	13.3	28.4
30	.4	1.4	2.6	2.9	2.5	1.8	.5	.1	1.6	4.5	9.4	15.9	24.7	53.3	96.4
35	.6	.8	1.3	1.2	.6	.2	.8	3.9	10.7	20.4	34.2	51.2			
40	1.0	.3	.4	.1	.3	1.2	5.9	15.5	32.5	54.4	84.3				
45	1.5	0.0	.2	.8	2.6	5.8	18.2	39.4	73.6						
50	2.3	.6	1.4	3.5	8.1	15.5	40.7	80.6							
55	3.4	1.9	4.1	9.1	18.5	32.5	77.8	147.8							
60	4.8	4.0	8.8	18.5	35.2										
65	6.6	7.3	16.3	33.0	60.8										
70	9.0	12.2	27.2												

TABLE B.87 Excess tire wear on horizontal curves (% worn/1000 mi) - 3A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	2.8	5.8	8.2	9.7	10.8	12.2	12.8	12.6	12.5	12.3	12.2	12.0	11.7	11.3
10	0.0	2.7	5.4	7.6	8.8	9.7	10.6	10.7	10.2	9.6	9.1	8.6	8.1	6.9	5.8
15	0.0	2.4	4.7	6.6	7.4	7.9	8.1	7.6	6.6	5.6	4.7	3.9	3.2	1.8	.7
20	.1	2.0	3.9	5.2	5.6	5.7	5.1	4.1	2.8	1.8	1.0	.5	.1	.5	2.4
25	.2	1.5	2.9	3.7	3.6	3.3	2.3	1.2	.3	0.0	.5	1.5	3.2	9.6	20.4
30	.3	1.1	1.9	2.2	1.8	1.3	.4	.1	1.2	3.3	6.8	11.4	17.7	38.1	68.9
35	.5	.6	1.0	.9	.5	.1	.6	2.8	7.7	14.6	24.5	36.6			
40	.7	.2	.3	.1	.2	.9	4.3	11.2	23.3	38.9	60.2				
45	1.1	0.0	.1	.6	1.8	4.2	13.0	28.1	52.6						
50	1.7	.4	1.0	2.5	5.8	11.1	29.1	57.6							
55	2.4	1.3	2.9	6.5	13.2	23.2	55.6	105.6							
60	3.4	2.8	6.3	13.1	25.1										
65	4.6	5.1	11.5	23.5	43.3										
70	6.2	8.5	19.3												

TABLE B.88 Excess tire wear on horizontal curves (% worn/1000 mi) - 2-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	2.4	4.9	6.9	8.2	9.1	10.2	10.8	10.6	10.5	10.4	10.2	10.1	9.8	9.5
10	0.0	2.3	4.6	6.4	7.4	8.2	8.9	9.0	8.5	8.1	7.7	7.2	6.8	5.8	4.9
15	0.0	2.0	4.0	5.5	6.3	6.7	6.8	6.4	5.5	4.8	4.0	3.3	2.7	1.5	.6
20	.1	1.7	3.3	4.4	4.7	4.8	4.3	3.5	2.4	1.6	.9	.4	.1	.4	2.0
25	.1	1.3	2.5	3.1	3.1	2.8	1.9	1.0	.3	0.0	.4	1.3	2.7	8.1	17.1
30	.2	.9	1.6	1.9	1.6	1.1	.3	.1	1.0	2.8	5.7	9.7	14.9	32.1	57.9
35	.4	.6	.9	.8	.4	.1	.5	2.5	6.6	12.4	20.7	30.9			
40	.7	.2	.3	.1	.2	.8	3.7	9.5	19.7	32.8	50.8				
45	1.0	0.0	.1	.5	1.7	3.7	11.2	23.9	44.5						
50	1.5	.4	.9	2.3	5.1	9.6	24.8	48.8							
55	2.2	1.2	2.7	5.8	11.5	20.0	47.3	89.5							
60	3.1	2.6	5.7	11.6	21.7										
65	4.3	4.8	10.3	20.5	37.3										
70	5.8	7.8	17.1												

TABLE B.89 Excess tire wear on horizontal curves (% worn/1000 mi) - 3-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	3.1	6.2	8.8	10.3	11.5	12.9	13.6	13.4	13.3	13.1	13.0	12.8	12.4	12.0
10	0.0	2.9	5.8	8.1	9.4	10.3	11.2	11.4	10.8	10.3	9.7	9.2	8.6	7.4	6.2
15	0.0	2.6	5.1	7.0	7.9	8.4	8.6	8.1	7.0	6.0	5.1	4.2	3.5	1.9	.8
20	.1	2.2	4.2	5.6	6.0	6.1	5.5	4.4	3.1	2.0	1.1	.5	.1	.5	2.6
25	.2	1.7	3.1	4.0	3.9	3.6	2.5	1.3	.4	0.0	.6	1.7	3.4	10.2	21.6
30	.3	1.2	2.1	2.3	2.0	1.4	.4	.1	1.3	3.5	7.3	12.2	18.8	40.4	73.0
35	.5	.7	1.1	1.0	.5	.1	.7	3.1	8.3	15.6	26.0	38.9			
40	.8	.3	.3	.1	.2	.9	4.7	12.0	24.8	41.3	64.0				
45	1.2	0.0	.1	.6	2.0	4.5	14.0	30.0	55.9						
50	1.8	.5	1.1	2.8	6.3	11.9	31.0	61.3							
55	2.6	1.4	3.2	7.1	14.2	24.9	59.2	112.4							
60	3.7	3.1	6.8	14.2	26.9										
65	5.1	5.7	12.5	25.3	46.4										
70	6.9	9.3	20.9												

TABLE B.90 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - small automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.3	.6	1.1
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.4	.7	.9	1.8	
40	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.5	.8	1.2	1.8	2.5		
45	0.0	0.0	0.0	0.0	0.0	.1	.3	.6	1.2	2.0	3.0				
50	0.0	0.0	0.0	.1	.1	.3	.7	1.5	2.7	4.3					
55	.1	0.0	.1	.2	.4	.7	1.6	3.1	5.6						
60	.1	.1	.2	.4	.8	1.3	3.1	6.1							
65	.1	.1	.4	.8	1.5	2.5	5.9	12.1							
70	.2	.3	.7	1.4	2.6	4.4	11.0								

TABLE B.91 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - medium automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	.1	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.2	.3	.6	1.2
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.3	.5	.7	1.0	2.0	
40	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.5	.9	1.4	2.0	2.8		
45	0.0	0.0	0.0	0.0	0.0	.1	.3	.7	1.4	2.2	3.3				
50	0.0	0.0	0.0	.1	.2	.3	.8	1.7	3.0	4.8					
55	.1	0.0	.1	.2	.4	.7	1.8	3.5	6.2						
60	.1	.1	.2	.4	.9	1.5	3.5	6.8							
65	.1	.2	.4	.9	1.7	2.8	6.6	13.5							
70	.2	.3	.8	1.6	3.0	5.0	12.3								

TABLE B.92 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - large automobile

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	.1	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	.1	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.2	.3	.7	1.2
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.3	.5	.7	1.1	2.1	
40	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.5	.9	1.4	2.1	2.9		
45	0.0	0.0	0.0	0.0	0.0	.1	.3	.7	1.4	2.3	3.4				
50	0.0	0.0	0.0	.1	.2	.3	.9	1.7	3.1	4.9					
55	.1	0.0	.1	.2	.4	.7	1.8	3.6	6.4						
60	.1	.1	.2	.4	.9	1.5	3.6	7.0							
65	.1	.2	.4	.9	1.7	2.9	6.7								
70	.2	.3	.8	1.6	3.0	5.1	12.6								

TABLE B.93 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - pickup truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.3	.6	1.1
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.5	.7	1.0	1.9	
40	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.5	.8	1.3	1.9			
45	0.0	0.0	0.0	0.0	0.0	.1	.3	.7	1.3	2.1	3.2				
50	0.0	0.0	0.0	.1	.1	.3	.8	1.6	2.9	4.5					
55	.1	0.0	.1	.2	.4	.7	1.7	3.3							
60	.1	.1	.2	.4	.8	1.4	3.3								
65	.1	.2	.4	.8	1.6	2.6	6.2								
70	.2	.3	.7	1.5	2.8	4.7									

TABLE B.94 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - 2A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
10	0.0	0.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
15	0.0	0.0	.1	.1	.2	.2	.2	.2	.1	.1	.1	.1	.1	0.0	0.0
20	0.0	.1	.1	.1	.2	.2	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	.1
25	0.0	0.0	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	.1	.3	.7
30	0.0	0.0	.1	.1	.1	0.0	0.0	0.0	0.0	.1	.3	.5	.8	1.7	3.1
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.4	.7	1.3	1.9			
40	0.0	0.0	0.0	0.0	0.0	0.0	.2	.6	1.4	2.3	3.6				
45	.1	0.0	0.0	0.0	.1	.2	.8	1.9	3.6						
50	.1	0.0	0.0	.2	.4	.8	2.2	4.4							
55	.2	.1	.2	.5	1.0	1.9	4.7	9.1							
60	.2	.2	.5	1.1	2.2										
65	.4	.4	1.1	2.3	4.3										
70	.6	.8	2.0												

TABLE B.95 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - 3A SU truck

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
10	0.0	0.0	.1	.1	.1	.1	.1	.2	.1	.1	.1	.1	.1	.1	.1
15	0.0	0.0	.1	.1	.2	.2	.2	.2	.1	.1	.1	.1	.1	0.0	0.0
20	0.0	.1	.1	.1	.2	.2	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	.1
25	0.0	0.0	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	.1	.3	.7
30	0.0	0.0	.1	.1	.1	0.0	0.0	0.0	0.0	.1	.3	.5	.8	1.7	3.1
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.4	.7	1.3	1.9			
40	0.0	0.0	0.0	0.0	0.0	0.0	.2	.6	1.4	2.3	3.6				
45	.1	0.0	0.0	0.0	.1	.3	.9	1.9	3.6						
50	.1	0.0	.1	.2	.4	.8	2.2	4.4							
55	.2	.1	.2	.5	1.1	1.9	4.7	9.2							
60	.2	.2	.5	1.1	2.3										
65	.4	.4	1.1	2.3	4.3										
70	.6	.8	2.0												

TABLE B.96 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - 2-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	0.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
10	0.0	0.0	.1	.1	.1	.2	.2	.2	.2	.1	.1	.1	.1	.1	.1
15	0.0	.1	.1	.2	.2	.2	.2	.2	.2	.1	.1	.1	.1	0.0	0.0
20	0.0	.1	.1	.2	.2	.2	.2	.1	.1	.1	0.0	0.0	0.0	0.0	.1
25	0.0	.1	.1	.1	.1	.1	.1	0.0	0.0	0.0	0.0	.1	.1	.4	.8
30	0.0	0.0	.1	.1	.1	.1	0.0	0.0	0.0	.1	.3	.5	.9	1.9	3.4
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.4	.8	1.4	2.1			
40	0.0	0.0	0.0	0.0	0.0	0.0	.3	.7	1.5	2.6	4.0				
45	.1	0.0	0.0	0.0	.1	.3	.9	2.1	4.0						
50	.1	0.0	.1	.2	.4	.9	2.4	4.9							
55	.2	.1	.2	.5	1.2	2.1	5.2	10.1							
60	.3	.2	.6	1.3	2.5										
65	.4	.5	1.2	2.5	4.8										
70	.6	.9	2.2												

TABLE B.97 Excess maintenance and repair costs on horizontal curves (% avg cost/1000 mi) - 3-S2 semi

SPEED	DEGREE OF CURVATURE														
mph	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	0.0	0.0	.1	.1	.1	.1	.1	.2	.2	.2	.1	.1	.1	.1	.1
10	0.0	.1	.1	.2	.2	.2	.3	.3	.2	.2	.2	.2	.2	.2	.1
15	0.0	.1	.2	.2	.3	.3	.3	.3	.2	.2	.2	.1	.1	.1	0.0
20	0.0	.1	.2	.3	.3	.3	.2	.2	.1	.1	0.0	0.0	0.0	0.0	.1
25	0.0	.1	.2	.2	.2	.2	.1	.1	0.0	0.0	0.0	.1	.2	.6	1.3
30	0.0	.1	.1	.1	.1	.1	0.0	0.0	.1	.2	.5	.9	1.3	2.9	5.3
35	0.0	0.0	.1	.1	0.0	0.0	0.0	.2	.7	1.3	2.2	3.3			
40	.1	0.0	0.0	0.0	0.0	.1	.4	1.1	2.4	4.0	6.3				
45	.1	0.0	0.0	0.0	.2	.4	1.5	3.3	6.2						
50	.2	0.0	.1	.3	.7	1.4	3.8	7.6							
55	.3	.1	.3	.8	1.8	3.3	8.1	15.8							
60	.4	.3	.9	2.0	3.9										
65	.7	.7	1.8	3.9	7.5										
70	1.0	1.4	3.4												

APPENDIX C. FUEL ECONOMY DATA

The summary statistics from the fuel consumption tests conducted on the fleet of vehicles described in Table 3 are presented in this appendix. Tables are presented for each vehicle at constant speed and arranged by measurements taken on test sections with vertical grade and level sections with different surface types and level of roughness. Specifically, the tables presented in this appendix are:

VERTICAL GRADES

C.1 Fuel economy data on vehicle grades - vehicle 1, small car
C.2 Fuel economy data on vertical grades - vehicle 2, medium car
C.3 Fuel economy data on vertical grades - vehicle 3, medium car
C.4 Fuel economy data on vertical grades - vehicle 4, large car
C.5 Fuel economy data on vertical grades - vehicle 5, pickup truck
C.6 Fuel economy data on vertical grades - vehicle 6, 2A SU truck
C.7 Fuel economy data on vertical grades - vehicle 7, 3A SU truck
C.8 Fuel economy data on vertical grades - vehicle 8, 2-S2 truck

DIFFERENT SURFACES

C.9 Fuel economy data on different surfaces - vehicle 1, small car
C.10 Fuel economy data on different surfaces - vehicle 2, medium car
C.11 Fuel economy data on different surfaces - vehicle 3, medium car
C.12 Fuel economy data on different surfaces - vehicle 4, large car
C.13 Fuel economy data on different surfaces - vehicle 5, pickup truck
C.14 Fuel economy data on different surfaces - vehicle 6, 2A SU truck
C.15 Fuel economy data on different surfaces - vehicle 7, 3A SU truck
C.16 Fuel economy data on different surfaces - vehicle 8, 2-S2 truck

Table C.1. Fuel enomony data on verticle grades-
vehicle 1, small car

Speed mph	Statistic	% Grade -11	-5.6	- 2.6	0	2.6	5.6	11
10	$\overline{mpg}$	26.18	23.04	29.96	15.88	18.23	13.09	10.26
	σ	2.08	3.25	0.00	0.63	8.06	0.09	0.52
	n	2	3	1	5	2	2	3
20	$\overline{mpg}$	112.12	40.14	41.34	28.54	20.96	21.65	13.31
	σ	32.88	0.57	2.17	0.70	0.49	0.31	0.44
	n	3	2	3	6	3	2	2
30	$\overline{mpg}$	94.05	66.43	68.21	42.05	28.50	29.73	13.50
	σ	27.72	3.42	1.38	2.05	1.14	0.75	0.52
	n	3	3	3	6	2	3	3
40	$\overline{mpg}$	84.36	52.04	56.08	37.67	27.47	28.35	12.86
	σ	42.46	2.55	2.63	0.78	3.02	0.79	1.31
	n	2	3	3	6	3	3	3
50	$\overline{mpg}$	150.87	62.93	78.73	42.78	25.36	28.13	11.37
	σ	8.05	5.11	4.76	2.57	2.07	3.16	1.02
	n	2	3	2	5	4	3	3
60	$\overline{mpg}$	108.72	51.86	63.22	35.52	22.18	25.63	11.25
	σ	8.90	2.31	0.86	2.16	0.56	1.37	0.25
	n	3	3	3	6	3	3	3
70	$\overline{mpg}$	76.23	40.11	47.15	29.25	18.33	22.81	12.51
	σ	1.35	2.49	3.31	1.87	1.84	0.78	0.19
	n	2	3	3	6	3	3	3

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data

Table C.2. Fuel economy data on vertical grades-vehicle 2, medium car.

Speed mph	Statistic	% Grade -11	-5.6	-2.6	0	2.6	5.6	11
10	$\overline{mpg}$	18.67	18.52	19.56	17.93	13.85	12.35	5.48
	σ	1.26	2.17	0.00	0.39	2.30	3.95	0.85
	n	3	3	1	6	2	4	3
20	$\overline{mpg}$	37.21	34.98	34.48	25.47	19.21	15.22	6.67
	σ	2.61	0.84	0.00	0.97	0.00	1.02	0.60
	n	3	3	1	6	1	3	3
30	$\overline{mpg}$	52.58	46.91	43.77	25.30	19.98	15.87	6.60
	σ	3.37	1.29	0.00	2.84	0.00	0.20	0.11
	n	3	3	1	6	1	3	3
40	$\overline{mpg}$	70.85	72.92	38.05	26.39	19.07	14.52	7.17
	σ	3.19	2.43	0.00	0.63	0.00	0.21	0.34
	n	3	2	1	6	1	3	3
50	$\overline{mpg}$	89.09	56.81	33.19	23.88	17.15	12.71	7.13
	σ	12.92	0.18	0.00	0.83	0.00	0.31	0.17
	n	3	2	1	6	1	3	3
60	$\overline{mpg}$	108.44	39.80	28.16	19.43	16.33	10.28	7.45
	σ	12.12	1.26	0.00	1.29	0.00	0.23	0.07
	n	3	3	1	5	1	3	2
70	$\overline{mpg}$	93.98	30.80	20.49	15.92	11.87	9.86	9.09
	σ	9.37	0.21	0.00	0.85	0.00	0.12	0.58
	n	3	2	1	6	1	3	3

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data

Table C.3. Fuel economy data on verticle grades-vehicle 3, medium car.

Speed mph	Statistic	% Grade -11	-5.6	-2.6	0	2.6	5.6	11
10	$\overline{mpg}$	18.64	19.94	18.77	17.99	14.20	14.25	6.69
	σ	2.21	1.50	1.02	1.36	3.99	3.98	0.35
	n	2	3	3	5	4	4	3
20	$\overline{mpg}$	38.25	42.34	38.06	26.23	16.80	16.26	7.66
	σ	0.58	0.00	1.11	4.52	1.02	0.38	0.15
	n	3	1	3	6	3	2	3
30	$\overline{mpg}$	54.70	54.85	56.05	28.17	17.31	17.78	6.98
	σ	1.61	5.62	4.60	3.76	0.77	0.69	0.08
	n	2	3	3	6	3	3	3
40	$\overline{mpg}$	82.48	36.32	48.15	26.63	15.90	16.02	7.12
	σ	1.53	12.27	3.69	2.05	0.68	0.58	0.21
	n	3	4	3	5	3	2	3
50	$\overline{mpg}$	94.28	36.37	37.77	22.78	13.89	15.21	7.15
	σ	3.54	0.59	1.36	3.16	0.26	0.38	0.16
	n	2	2	3	6	3	3	3
60	$\overline{mpg}$	99.86	27.48	31.85	18.84	11.31	13.91	7.63
	σ	10.86	1.19	1.12	1.61	1.42	1.00	0.01
	n	2	2	3	6	4	2	2
70	$\overline{mpg}$	93.78	20.72	24.11	16.02	10.59	11.40	10.02
	σ	20.03	1.78	1.19	1.13	0.26	0.35	0.14
	n	3	3	3	6	3	3	3

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data

Table C.4. Fuel economy data on verticle grades-vehicle 4, large car.

Speed mph	Statistic	% Grade -11	-5.6	-2.6	0	2.6	5.6	11
10	$\overline{mpg}$	ND	18.73	18.49	16.95	12.69	12.09	ND
	σ		0.24	0.20	2.14	0.15	0.04	
	n		2	2	7	2	2	
20	$\overline{mpg}$	ND	36.98	34.24	23.13	14.38	12.83	ND
	σ		0.16	1.34	1.55	0.75	0.15	
	n		2	2	6	2	2	
30	$\overline{mpg}$	ND	46.37	31.98	24.84	17.13	13.67	ND
	σ		4.62	1.71	3.43	0.07	0.29	
	n		2	2	6	2	2	
40	$\overline{mpg}$	ND	55.88	31.31	22.57	15.91	12.67	ND
	σ		2.85	0.41	1.96	0.15	0.53	
	n		2	2	5	2	2	
50	$\overline{mpg}$	ND	33.55	24.17	20.54	16.30	11.36	ND
	σ		7.86	0.55	2.14	0.08	0.07	
	n		3	2	6	2	2	
60	$\overline{mpg}$	ND	34.67	19.91	17.76	14.39	10.34	ND
	σ		0.00	1.11	2.05	0.31	0.24	
	n		1	2	6	2	2	
70	$\overline{mpg}$	ND	28.90	15.84	14.94	12.70	8.41	ND
	σ		0.19	0.11	2.44	0.14	0.86	
	n		2	2	5	2	2	

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data

Table C.5. Fuel economy data on verticle grades-
vehicle 5, pickup truck.

Speed mph	Statistic	% Grade -11	-5.6	-2.6	0	2.6	5.6	11
10	$\overline{mpg}$	12.74	14.24	14.57	12.84	9.79	8.62	4.59
	σ	1.59	0.32	0.15	0.52	0.23	0.12	0.07
	n	3	2	3	6	3	3	3
20	$\overline{mpg}$	27.79	26.08	29.76	19.37	12.68	10.19	5.14
	σ	0.95	1.46	0.87	1.05	0.52	0.92	0.03
	n	3	3	3	5	3	3	3
30	$\overline{mpg}$	39.36	38.50	35.09	18.86	12.41	11.63	5.04
	σ	2.43	0.50	1.53	1.80	0.28	0.01	0.03
	n	3	2	3	5	3	3	2
40	$\overline{mpg}$	54.72	36.63	31.55	18.18	12.41	10.96	5.21
	σ	2.46	1.65	2.46	2.02	0.49	0.39	0.00
	n	2	3	3	6	3	3	3
50	$\overline{mpg}$	65.52	31.69	26.93	15.54	11.31	8.31	5.28
	σ	5.85	1.71	1.42	1.55	0.44	0.57	0.17
	n	3	3	3	5	3	3	3
60	$\overline{mpg}$	74.99	26.44	23.01	14.16	9.09	7.16	5.15
	σ	2.86	1.86	0.37	1.76	0.26	0.34	0.19
	n	3	3	3	6	3	3	3
70	$\overline{mpg}$	82.25	20.94	19.38	10.73	7.23	6.70	ND
	σ	8.40	1.97	0.84	2.75	0.16	0.06	
	n	3	2	3	6	3	2	

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data

Table C.6. Fuel economy data on vertical grades-
vehicle 6, 2A SU truck.

Speed mph	Statistic	% Grade -11	-5.6	-2.6	0	2.6	5.6	11
10	$\overline{mpg}$	7.21	7.57	8.12	4.60	3.25	2.77	1.85
	σ	0.26	1.63	0.32	0.37	0.10	0.16	0.04
	n	3	4	3	6	3	3	3
20	$\overline{mpg}$	13.66	9.14	9.39	7.02	4.56	4.06	2.19
	σ	0.35	0.36	0.00	0.81	0.03	0.07	0.02
	n	3	3	2	5	3	3	3
30	$\overline{mpg}$	20.40	14.25	11.93	8.18	5.02	4.39	2.27
	σ	3.11	1.04	0.21	1.25	0.01	0.11	0.01
	n	3	3	2	6	2	3	3
40	$\overline{mpg}$	24.90	19.78	15.12	7.75	4.89	3.91	ND
	σ	0.36	0.60	0.87	1.09	0.49	0.18	
	n	3	3	3	4	2	3	
50	$\overline{mpg}$	26.68	15.69	11.89	6.62	5.15	4.59	ND
	σ	3.42	0.62	0.60	1.25	0.04	0.20	
	n	3	3	2	6	2	3	
60	$\overline{mpg}$	ND	11.03	8.04	ND	5.19	5.14	ND
	σ		0.45	0.60		0.11	0.31	
	n		3	3		3	3	
70	$\overline{mpg}$	ND	ND	ND	ND	ND	ND	ND

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - NO DATA

Table C.7. Fuel economy data on vertical grades-vehicle 7, 3A SU truck.

Speed mph	Statistic	% Grade -11	-5.6	-2.6	0	2.6	5.6	11
10	$\overline{mpg}$	609.16	15.87	9.40	4.60	2.78	2.84	1.12
	σ	928.35	5.61	0.45	1.03	0.08	0.02	0.10
	n	3	4	3	6	3	3	3
20	$\overline{mpg}$	191.65	48.98	25.86	5.60	3.11	2.94	ND
	σ	170.64	10.46	3.35	1.08	0.08	0.09	
	n	3	2	3	6	3	3	
30	$\overline{mpg}$	598.00	91.22	31.54	6.40	3.26	2.91	ND
	σ	317.75	20.97	0.17	1.00	0.06	0.04	
	n	2	3	2	5	3	3	
40	$\overline{mpg}$	187.24	159.52	56.74	6.70	3.25	3.40	ND
	σ	87.49	23.26	7.04	1.39	0.05	0.06	
	n	3	2	2	6	3	3	
50	$\overline{mpg}$	77.15	56.69	39.59	ND	4.07	ND	ND
	σ	133.63	1.96	0.00		0.00		
	n	3	2	1		1		
60	$\overline{mpg}$	203.76	50.59	33.57	ND	ND	ND	ND
	σ	176.46	12.88	0.00				
	n	3	2	1				
70	$\overline{mpg}$	ND	ND	ND	ND	ND	ND	ND

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data

Table C8. Fuel economy data on verticle grades - vehicle 8, 2-S2 truck.

Speed mph	Stat.	% Grade -11	-5.6	-2.6	~0	+2.6	+5.6	+11
10	$\overline{mpg}$	73.5	6.85	5.91	2.70	1.98	1.77	0.907
	σ	4.81	0.03	0.35	.254	.064	0.03	0.04
	n	3	2	3	19	3	3	3
20	$\overline{mpg}$	INF	INF	INF	4.87	2.53	2.34	1.55
	σ				0.82	0.04	0.02	0.19
	n				20	3	3	3
30	$\overline{mpg}$	INF	INF	INF	4.95	2.43	2.30	2.72
	σ				0.82	0.007	0.08	0.02
	n				20	3	3	3
40	$\overline{mpg}$	INF	INF	INF	5.06	2.83	2.85	3.59
	σ				.86	.01	0.04	0
	n				20	3	3	1
50	$\overline{mpg}$	ND	INF	INF	5.34	3.78	3.84	ND
	σ				.84	0.04	0.36	
	n				12	3	3	
60	$\overline{mpg}$	ND	ND	ND	ND	ND	ND	ND
	σ							
	n							
70	$\overline{mpg}$	ND	ND	ND	ND	ND	ND	ND
	σ							
	n							

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
ND - No Data
Stat - Statistic
INF - Fuel Consumption drops to 0, Fuel Economy Approaches Infinity

Table C. 9 Fuel economy data on different surfaces,- vehicle 1, small car.

Speed mpg	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	AC/I (3.7)	AC/R (1.5)	GR (1.8)
10	$\overline{mpg}$	16.81	17.72	15.88	15.70	16.23	16.24
	σ	1.34	4.91	0.63	0.85	1.50	1.50
	n	5	6	5	6	6	6
20	$\overline{mpg}$	24.04	26.56	28.54	27.45	27.76	26.21
	σ	7.66	1.72	0.70	1.79	0.72	1.88
	n	6	5	6	6	7	6
30	$\overline{mpg}$	43.27	39.90	42.05	24.79	38.32	35.85
	σ	2.41	3.24	2.05	0.91	3.30	1.55
	n	6	6	6	5	6	6
40	$\overline{mpg}$	38.01	34.66	37.67	50.44	34.91	34.04
	σ	4.48	1.32	0.78	2.32	1.55	1.25
	n	6	6	6	6	7	6
50	$\overline{mpg}$	39.66	40.82	42.78	42.85	38.76	ND
	σ	2.26	2.23	2.57	1.46	0.78	
	n	5	6	5	6	6	
60	$\overline{mpg}$	34.39	34.66	35.52	35.23	32.32	ND
	σ	2.55	2.92	2.16	1.08	0.44	
	n	6	6	6	6	5	
70	$\overline{mpg}$	29.93	28.56	29.25	29.62	27.68	ND
	σ	2.48	0.55	1.87	1.63	2.32	
	n	6	6	6	6	6	

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C. 10 Fuel economy data on different surfaces - vehicle 2, medium car.

Speed mph	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	ST/I (3.5)	AC/R (1.5)	GR (1.8)
		Surface type/roughness level (SI Value)					
10	$\overline{mpg}$	16.78	15.31	17.93	18.21	16.42	14.91
	σ	0.98	1.55	0.39	0.80	2.89	0.79
	n	6	14	6	6	6	6
20	$\overline{mpg}$	27.55	24.11	25.47	27.10	24.20	20.01
	σ	4.91	1.46	0.97	2.66	1.30	1.66
	n	6	14	6	6	6	6
30	$\overline{mpg}$	31.05	25.96	25.30	28.88	25.76	21.26
	σ	0.60	1.69	2.84	2.13	1.56	0.62
	n	2	12	6	6	6	6
40	$\overline{mpg}$	26.39	25.91	26.39	26.31	25.35	20.54
	σ	1.71	1.69	0.63	1.35	1.16	1.93
	n	5	12	6	6	6	6
50	$\overline{mpg}$	24.92	24.10	23.88	24.45	22.58	18.26
	σ	2.12	2.16	0.83	1.43	1.60	1.89
	n	6	12	6	5	6	6
60	$\overline{mpg}$	20.11	19.35	19.43	21.67	19.01	ND
	σ	1.88	0.86	1.29	3.24	0.64	
	n	6	12	5	6	6	
70	$\overline{mpg}$	16.33	15.50	15.92	16.09	15.19	ND
	σ	1.45	1.02	0.85	0.65	0.65	
	n	6	12	6	6	5	

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
ST - Surface Treatment
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C. 11 Fuel economy data on different surfaces - vehicle 3, medium car.

Speed mph	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	ST/I (3.5)	AC/R (1.5)	GR (1.8)
		Surface type/roughness level (SI Value)					
10	$\overline{mpg}$	17.96	17.96	17.99	17.38	18.01	18.15
	σ	0.60	1.43	1.36	1.42	0.42	1.85
	n	5	6	5	5	6	6
20	$\overline{mpg}$	25.98	24.90	26.23	27.20	25.90	24.18
	σ	0.80	3.01	4.52	4.67	0.52	2.71
	n	6	7	6	6	5	6
30	$\overline{mpg}$	27.06	28.46	28.17	27.32	26.57	25.93
	σ	0.98	1.75	3.76	6.83	1.95	3.76
	n	5	6	6	5	6	6
40	$\overline{mpg}$	26.19	25.85	26.63	26.25	24.96	23.14
	σ	0.42	2.02	2.05	5.69	0.61	2.85
	n	6	6	5	6	5	6
50	$\overline{mpg}$	21.87	23.29	22.78	22.62	21.56	19.89
	σ	0.50	0.98	3.16	5.81	0.75	3.45
	n	5	6	6	4	6	6
60	$\overline{mpg}$	18.72	18.74	18.84	19.62	18.16	ND
	σ	0.43	1.46	1.61	4.72	0.41	
	n	6	6	6	5	6	
70	$\overline{mpg}$	15.09	15.09	16.02	15.61	14.93	ND
	σ	0.67	1.23	1.13	3.80	0.57	
	n	6	6	6	6	5	

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
ST - Surface Treatment
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C. 12 Fuel economy data on different surfaces - vehicle 4, large car

Speed mpg	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	AC/I (3.7)	AC/R (1.5)	GR (1.8)
10	$\overline{mpg}$	16.84	17.56	16.95	19.24	17.31	17.76
	σ	1.13	1.75	2.14	0.80	0.89	1.57
	n	6	3	7	6	6	2
20	$\overline{mpg}$	26.34	23.55	23.13	25.44	23.39	12.46
	σ	2.12	1.74	1.55	3.26	1.13	-
	n	6	4	6	6	6	1
30	$\overline{mpg}$	25.41	25.09	24.84	25.39	23.64	20.84
	σ	1.42	0.78	3.43	2.72	0.83	1.52
	n	6	6	6	6	6	2
40	$\overline{mpg}$	23.95	23.53	22.57	23.79	21.93	ND
	σ	0.85	1.41	1.96	2.77	1.45	
	n	6	6	5	6	6	
50	$\overline{mpg}$	21.39	21.13	20.54	21.49	19.60	17.23
	σ	0.47	0.51	2.14	3.07	0.53	1.95
	n	6	6	6	6	6	2
60	$\overline{mpg}$	18.51	18.09	17.76	17.93	17.05	ND
	σ	0.45	0.60	2.05	3.43	0.59	
	n	6	5	6	6	6	
70	$\overline{mpg}$	16.03	15.29	14.94	14.85	14.33	ND
	σ	1.13	1.83	2.44	2.64	0.94	
	n	5	5	5	6	6	

Surface type/roughness level (SI Value)

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C.13 Fuel economy data on different surfaces - vehicle 5, pickup truck.

Speed mpg	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	AC/I (3.7)	AC/R (1.5)	GR (1.8)
		Surface type/roughness level (SI Value)					
10	$\overline{mpg}$	13.71	12.84	ND	ND	13.47	13.0
	σ	1.69	0.52			0.48	0.78
	n	6	6			5	6
20	$\overline{mpg}$	20.64	19.37	ND	ND	19.61	18.72
	σ	1.41	1.05			0.67	1.90
	n	5	5			7	6
30	$\overline{mpg}$	20.50	18.86	ND	ND	19.35	18.27
	σ	1.62	1.80			1.09	2.21
	n	8	5			6	6
40	$\overline{mpg}$	19.35	18.18	ND	ND	17.52	17.63
	σ	1.47	2.02			0.47	1.86
	n	6	6			5	6
50	$\overline{mpg}$	17.82	15.54	ND	ND	16.48	14.62
	σ	1.20	1.55			0.90	2.17
	n	6	5			6	6
60	$\overline{mpg}$	15.33	14.16	ND	ND	14.36	ND
	σ	1.34	1.76			1.13	
	n	6	6			6	
70	$\overline{mpg}$	13.23	10.73	ND	ND	11.57	ND
	σ	0.95	2.75			0.81	
	n	8	6			6	

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C. 14 Fuel economy data on different surfaces - vehicle 6, 2A SU truck.

Speed mph	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	ST/I (3.5)	AC/R (1.5)	GR (1.8)
		Surface type/roughness level (SI Value)					
10	$\overline{mpg}$	4.65	4.14	4.60	4.97	4.28	4.64
	σ	0.14	0.43	0.37	0.18	0.48	0.07
	n	6	5	6	6	11	5
20	$\overline{mpg}$	7.34	7.00	7.02	6.74	6.98	6.65
	σ	0.39	0.55	0.81	0.40	0.35	0.11
	n	5	6	5	5	6	6
30	$\overline{mpg}$	9.20	8.37	8.18	8.21	8.15	7.72
	σ	0.65	0.90	1.25	0.96	0.57	0.32
	n	6	6	6	6	6	6
40	$\overline{mpg}$	8.44	7.95	7.75	7.76	7.71	7.20
	σ	0.86	0.67	1.09	0.92	0.66	0.60
	n	6	6	4	5	6	5
50	$\overline{mpg}$	7.53	7.05	6.62	6.79	6.63	6.37
	σ	0.80	1.13	1.25	1.23	0.40	0.21
	n	6	5	6	6	6	6
60	$\overline{mpg}$	ND	ND	ND	ND	ND	ND
	σ						
	n						
70	$\overline{mpg}$	ND	ND	ND	ND	ND	ND
	σ						
	n						

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
ST - Surface Treatment
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C. 15 Fuel economy data on different surfaces - vehicle 7, 3A SU truck.

Speed mph	Stat.	PCC 3.4	AC/S 4.4	AC/I 3.2	ST/I 3.5	AC/R 1.5	GR 1.8
		Surface type/roughness level (SI Value)					
10	$\overline{mpg}$	5.08	4.61	4.76	ND	5.12	4.53
	σ	0.50	0.21	1.03		0.12	0.18
	n	5	6	6		6	6
20	$\overline{mpg}$	9.82	7.62	5.71	ND	6.50	6.77
	σ	0.95	0.59	1.08		0.25	0.83
	n	6	6	6		6	6
30	$\overline{mpg}$	7.06	6.32	5.72	ND	5.94	6.46
	σ	0.40	0.41	1.00		0.28	0.36
	n	5	6	5		5	6
40	$\overline{mpg}$	7.80	6.69	5.84	ND	5.96	6.56
	σ	0.45	0.58	1.39		0.40	0.62
	n	5	5	6		6	5
50	$\overline{mpg}$	7.94	6.54	ND	ND	5.20	ND
	σ	0.28	0.93			0.40	
	n	6	6			6	
60	$\overline{mpg}$	6.25	ND	ND	ND	ND	ND
	σ	0.25					
	n	5					
70	$\overline{mpg}$	ND	ND	ND	ND	ND	ND
	σ						
	n						

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
ST - Surface Treatment
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND - No Data
Stat. - Statistic

Table C.16 Fuel economy data on different surfaces - vehicle 8, 2-S2 truck.

Speed mpg	Stat.	PCC (3.4)	AC/S (4.4)	AC/I (3.2)	ST/I (3.5)	AC/R (1.5)	GR (1.8)
		Surface type/roughness level (SI Value)					
10	$\overline{mpg}$	2.61	2.87	2.61	ND	2.64	2.40
	σ	0.291	0.099	0.354		0.032	0.190
	n	5	6	5		3	6
20	$\overline{mpg}$	5.62	5.07	4.62	ND	4.22	3.54
	σ	1.044	0.239	0.977		0.083	0.168
	n	4	6	6		4	6
30	$\overline{mpg}$	5.66	4.95	4.58	ND	3.98	4.00
	σ	0.628	0.320	0.943		0.399	0.452
	n	6	6	6		2	6
40	$\overline{mpg}$	5.87	4.99	4.69	ND	4.02	ND
	σ	0.671	0.217	0.929		0.658	
	n	6	6	6		2	
50	$\overline{mpg}$	5.69	4.98	ND	ND	ND	ND
	σ	1.086	0.276				
	n	6	6				
60	$\overline{mpg}$	ND	ND	ND	ND	ND	ND
	σ						
	n						
70	$\overline{mpg}$	ND	ND	ND	ND	ND	ND
	σ						
	n						

$\overline{mpg}$ - Average Fuel Economy, miles per gallon
σ - Standard Deviation
n - Number of Data Sets
PCC - Portland Cement Concrete
AC - Asphalt Concrete
ST - Surface Treatment
GR - Gravel
/S - Smooth
/I - Intermediate
/R - Rough
ND -No Data
Stat. - Statistic

APPENDIX D. ACCELERATION AND DECELERATION MODELS

A nonuniform acceleration model was used for the speed change computations presented in this report (Ref 58). For decelerations, a uniform deceleration model was used. In the nonuniform acceleration model, the acceleration varies as a linear function of speed. That is:

$$ACCEL = A - B(V)$$

where:

ACCEL = acceleration at velocity V, ft/sec^2

A,B = constants

V = speed, ft/sec

Using this formulation, the time to change from speed V_o to V_1 is:

$$t = (\ln(A-B(V_1)) - \ln(A-B(V_0)))/-B$$

where:

t = time, seconds

The distance traveled over the time interval t from initial speed V_o can be expressed as:

$$X = (A/B)t - (A/B^2)(1-e^{-Bt}) + (V_o/B)(1-e^{-Bt})$$

where:

X = distance, feet

Thus, to quantify this model only the two coefficients A and B need to be determined. Due to the formulation of this model, A represents the maximum acceleration and A/B is the maximum speed attainable. The values of A and B selected as representative of the vehicle classes used in this report are shown in Table D.1.

Table D.1. Coefficients for Nonuniform Acceleration Model

Coefficient	Small Auto	Medium Auto	Large Auto	Pickup Truck	2A SU Truck	3A SU Truck	2-S2 Truck	3-S2 Truck
A	7.2	8.60	7.9	7.9	2.8	1.8	1.8	1.8
B	.060	.076	.055	.08	.026	.016	.016	.016

The acceleration rates used in this project for automobiles are compared to the rates recommended by St. John and Korbit (Ref. 45) on Figure D.1.

A uniform deceleration model was chosen for braking for two primary reasons. First, sliding friction is theoretically indepenent of the relative speed of the surfaces in contact. The second reason is more pragmatical, in that it is difficult to quantify a typical braking pattern for the population of vehicles on the road. Much of the existing research in the area has quantified braking performance into levels of constant deceleration. The constant deceleration model may be expressed as:

$$D = dv/dt$$

where:

D = deceleration, ft/sec^2

dv/dt = change in speed with time

The time to change from speed V_o to V_1 is:

$$t = (V_o - V_1)/D$$

where:

t = time, seconds

V_o = initial speed, ft/sec

V_1 = final speed, ft/sec

The distance traveled in changing from speed V_o to V_1 is:

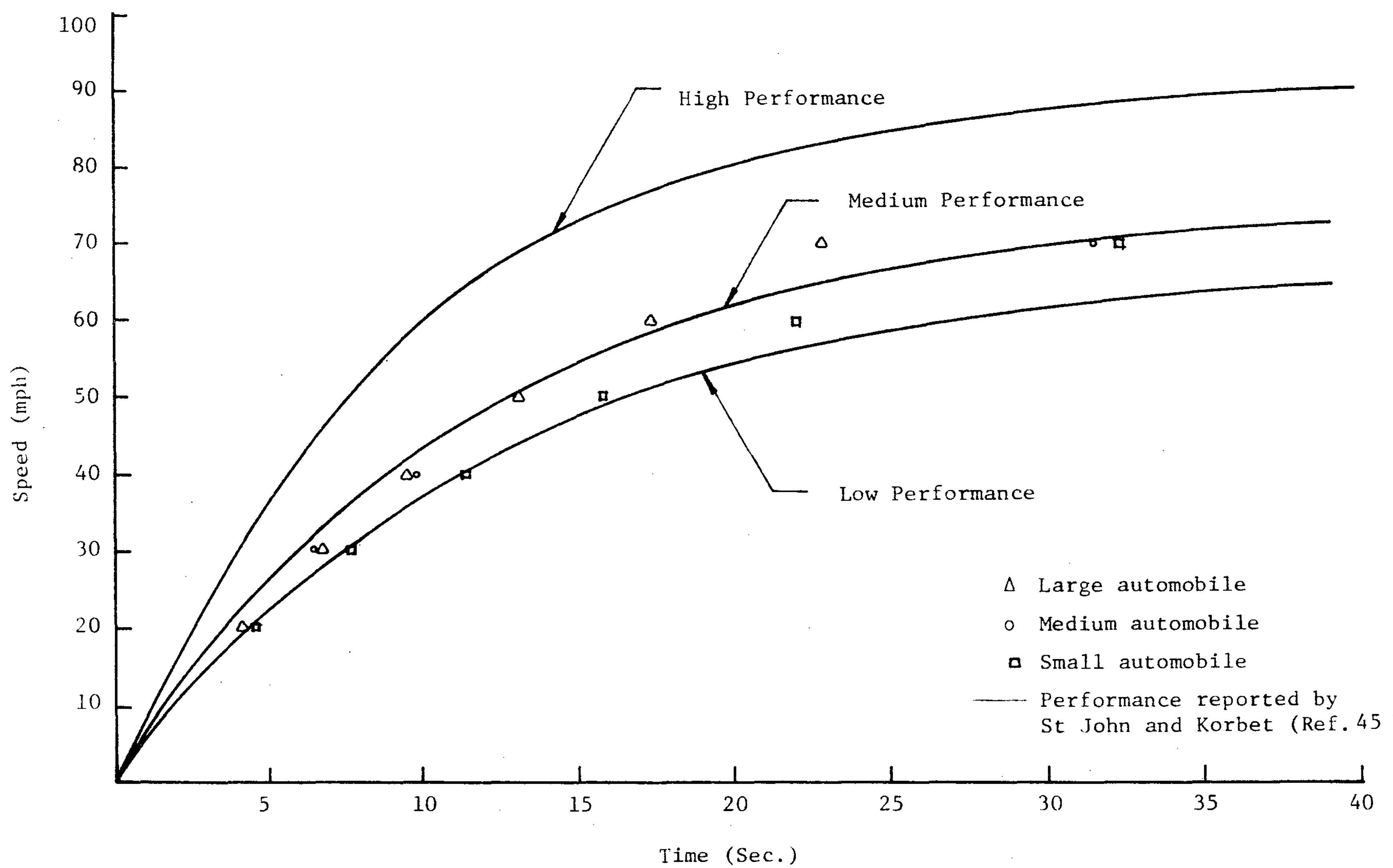


Figure D.1 Comparison of acceleration rates of St. John and Korbet to rates developed in this study for automobiles.

$$X = (1/(2D))(V_o{}^2 - V_1{}^2)$$

where:

X = distance traveled, feet

The distance traveled over time interval t from the initial speed V_o is:

$$X = V_o t - (1/2)Dt^2$$

In the above formulations, the deceleration has been expressed as a positive (+) quantity, i.e., negative acceleration equals positive deceleration. Based on information reported by Claffey in Reference 1 on normal deceleration rates used by drivers in traffic, a two level deceleration model was used. For decelerations at speeds below 30 mph. a 5.0 mphps (7.33 ft/sec^2) rate was used. For initial speeds greater than 30 mph, a 3.3 mphps (4.84 ft/sec^2) rate was used. These rates were used for all vehicle classes.

APPENDIX E. HORSEPOWER MODELS

For a vehicle to propel itself along a roadway, the engine must exert power to overcome the various retarding forces acting upon it. Ignoring various internal power losses within the engine and drive train, the required horsepower to propel a vehicle is conventionally expressed as:

$$HP = (FT)(V)/375$$

where:

FT = total external force acting on vehicle, lb.
V = vehicle speed, mph

The external forces acting on a vehicle may be classified as:

Rolling Resistance
Air Resistance
Grades
Inertial Resistance
Curves

The models used for the estimation of these forces for the vehicle classifications used in this report are presented in this appendix.

ROLLING RESISTANCE

Rolling resistance, produced by the vehicle tires, is generally expressed as:

$$FR = (R)(FV)$$

where:

FR = rolling resistance force, lb.
FV = vehicle weight, lb.
R = rolling resistance factor

The rolling resistance factor varies as a function of tire type, vehicle, and surface type. This factor is commonly expressed as:

$$R = CS + CV\,(V)^{n}$$

where:

CS, CV, n = constants
V = vehicle speed. mph

A value of n=2, which is based on old data (Ref. 59), is widely used. Data from the research reported by St. John and Kobett (Ref. 45). and White and Korst (Ref. 60), was used to establish typical values for the coefficients in the rolling resistance model for the passenger car and pickup truck vehicle class. A value of n=2 was used for these classes. The coefficients used are shown in Table E.1.

For large trucks, the Western Highway Institute (Ref. 61) recommends a value of n=1 in the above equation. A constant value of CS = .0076 was found for all large trucks. A value of $CV = 9 \times 10^{-5}$ was found for large single unit trucks ranging in gross weight from 10,000 to 30,000 lbs. For large tractor-trailer combinations with gross weights up to 70,000 lbs, Anderson, et al. (Ref. 62) found a value of 2.0×10^{-5}. These values. as shown in Table E.1, were adopted for the 2 and 3 axle single units and 2S-2 and 3S-2 tractor-trailer combinations. respectively.

AIR RESISTANCE

The resisting force imposed on an object moving through air due to air drag is conventionally expressed as:

$$F_A = (1/2)pAC_DV^2$$

where:

F_A = air resistance force, lb.
p = mass density of air, slug/ft^2
C_D = aerodynamic drag coefficient
A = projected frontal area. ft^2
V = relative air speed, ft/sec^2

Table E.1 Vehicle related factors

FACTOR	Small Auto	Medium Auto	Large Auto	Pickup Truck	2A SU Truck	3A SU Truck	2-S2 Semi	3-S2 Semi
Rolling Resistance CS	.0125	.0125	.0125	.0125	.0076	.0076	.0076	.0076
Rolling Resistance CV	6.5×10^{-7}	6.5×10^{-7}	6.5×10^{-7}	6.5×10^{-7}	9×10^{-5}	9×10^{-5}	2×10^{-5}	2×10^{-5}
Frontal Area Sq. Ft.	23.7	27.5	29.8	30.8	36.9	55	90	90
Drag Coeffecient	.46	.50	.55	.59	.70	.70	.80	.80

The mass density of air at standard atmospheric pressure varies as a function of air temperature from .00268 slug/ft^2 at 0°F to .00220 slug/ft^2 at 100°F. A value of p = .00233 slug/ft^2 was used for the calculations presented in this report.

The values for the projected frontal area and drag coefficients used for each vehicle group in this study are presented in Table E.1.

GRADES

Additional force is developed at the tire-pavement interface when a vehicle operates on vertical grades. The force developed in the horizontal plane in the longitudinal direction and may be simply added with the longitudinal forces due to rolling, air, and inertia resistance. On negative grades this force acts in opposition to these forces. The force, due to grades, may be expressed as:

$$F_G = -FVG$$

where:

F_G = force due to grade, lb.

FV = vehicle weight, lb.

G = grade ratio, + for positive grade (rise)
- for negative grade

INERTIA

Inertia forces are generated when a vehicle changes speed. This force is commonly expressed as:

$$F_I = (a/g)FV + R_{ir}$$

where:

F_I = inertial force, lb.

FV = vertical force. lb.

a = acceleration or deceleration rate, ft/sec^2 (negative sign indicates deceleration)

g = acceleration due to gravity, ft/sec^2

R_{ir} = inertia of rotating parts

During acceleration, this force acts in the same direction as the rolling resistance and air resistance forces making the total force the sum of these forces. During deceleration, the inertial force acts in opposition to rolling and air resistance forces, making the total horizontal tractive force the difference between rolling and air resistance forces and inertia. This is accomplished by expressing the deceleration rate as a negative value.

The inertia resistance due to the inertia of rotating components is usually ignored for automobiles. For large trucks and tractor-trailer combinations, the inertial resistance of rotating parts has been estimated to have the same effect as a 3-1/2% increase in the gross weight (Ref. 1). The contribution of the inertia of the rotating parts was ignored in this analysis.

The other resistive forces during speed changes were computed for 5 mph intervals. The resistive forces were computed for the average speed for each interval then were accumulated to determine the total resistive force for the speed change cycle.

CURVES

The force a vehicle must overcome to negotiate a curve is estimated as:

$$F_c = FV \sin a$$

where:

F_c = force on the curve
FV = vehicle weight
a = slip angle.

The slip angle is computed as a function of the side friction. The side friction is calculated as:

$$FS = (V^2/15R) - e$$

where:

FS = side friction
V = vehicle speed (mph)
R = radius of curve (ft)
e = super elevation

The values of R and e used for computing side force are given in Table E.2. The absolute value of side friction is then used to compute the slip angle. The equation for slip angle is:

$$FS = B_1 a^2 + B_2 a$$

where:

B_1 and B_2 = experimentally derived coefficients

Table E. 2 Curve Parameters Used in Computing Forces on Curves

Degree of Curve	Radius ft.	Radius meters	Superelevation
1	5,730	1,746	0
2	2,865	973	.046
3	1,910	582	.066
4	1,432	436	.079
5	1,146	349	.086
6	955	291	.091
7	819	250	.095
8	716	218	.097
9	637	194	.099
10	573	175	.1
12	477	145	.1
14	409	125	.1
16	358	109	.1
18	318	97	.1
20	286	87	.1
25	229	70	.1
30	191	58	.1

B_1 and B_2 are sensitive to speed so equations were generated for 10 and 60 mph.

$$FS_{10} = 0.0056a^2 + 0.136a$$

$$FS_{60} = 0.0684a^2 + 0.112a$$

Coefficients for other speed were interpolated as:

$$B_{1,v} = B_{1,10} - [(B_{1,10} - B_{1,60})/50]\ (V - 10)$$

$$B_{2,v} = B_{2,10} - [(B_{2,10} - B_{2,60})/50]\ (V - 10)$$

The data used to estimate B_1 and B_2 were taken from a study by Holmes and Stone (Ref. 63). Figure E.1 shows how the equation fits the data.

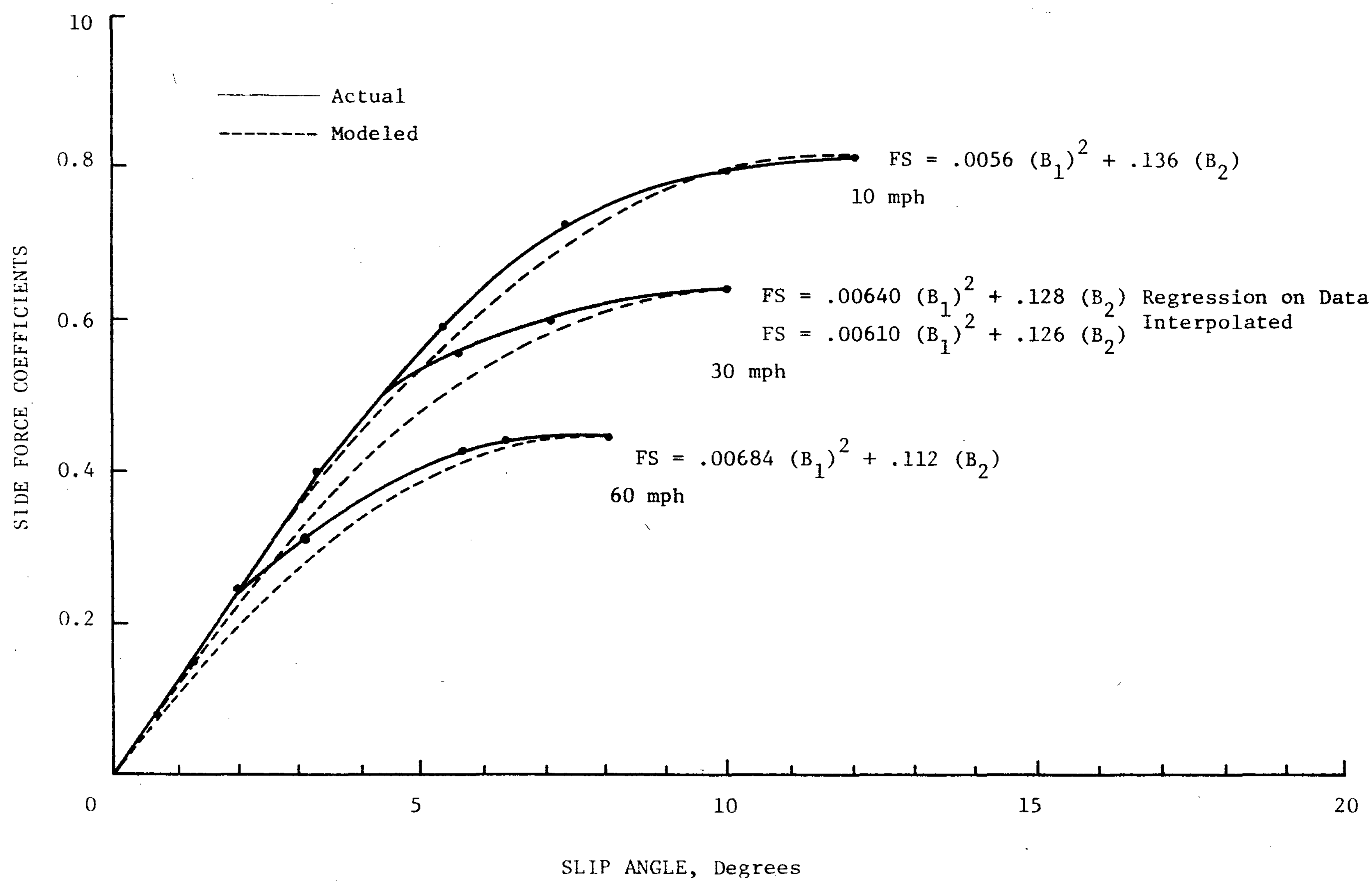


Figure E.1 Comparison of measured and quadratic model for side force coefficient - slip angle curve for bias tire on a smoc˙ ˙˙hed texture surface.

APPENDIX F. EXHAUST EMISSIONS

The following tables are presented on the exhaust emissions of vehicles at constant speed and over speed change cycles.

CONSTANT SPEED

F.1 Constant speed emission rates for automobiles and pickup trucks

F.2 Constant speed emission rates for 2A SU truck

F.3 Constant speed emission rates for 3A SU truck

F.4 Constant speed emission rates for 2-S2 semi

F.5 Constant speed emission rates for 3-S2 semi

SPEED CHANGE

F.6 Excess emissions for speed change cycles - small auto
Excess tons hydrocarbons/1000 cycles

F.7 Excess emissions for speed change cycles - small auto
Excess tons carbon monoxide/1000 cycles

F.8 Excess emissions for speed change cycles - small auto
Excess tons nitrous oxides/1000 cycles

F.9 Excess emissions for speed change cycles - medium auto
Excess tons hydrocarbons/1000 cycles

F.10 Excess emissions for speed change cycles - medium auto
Excess tons carbon monoxide/1000 cycles

F.11 Excess emissions for speed change cycles - medium auto
Excess tons nitrous oxides/1000 cycles

F.12 Excess emissions for speed change cycles - large auto
Excess tons hydrocarbons/1000 cycles

F.13 Excess emissions for speed change cycles - large auto
Excess tons carbon monoxide/1000 cycles

F.14 Excess emissions for speed change cycles - large auto
Excess tons nitrous oxides/1000 cycles

F.15 Excess emissions for speed change cycles - pickup truck
Excess tons hydrocarbons/1000 cycles

F.16 Excess emissions for speed change cycles - pickup truck
Excess tons carbon monoxide/1000 cycles

F.17 Excess emissions for speed change cycles - pickup truck
Excess tons nitrous oxides/1000 cycles

F.18 Excess emissions for speed change cycles - 2A SU truck
Excess tons hydrocarbons/1000 cycles

F.19 Excess emissions for speed change cycles - 2A SU truck
Excess tons carbon monoxide/1000 cycles

F.20 Excess emissions for speed change cycles - 2A SU truck
Excess tons nitrous oxides/1000 cycles

F.21 Excess emissions for speed change cycles - 3A SU truck
Excess tons hydrocarbons/1000 cycles

F.22 Excess emissions for speed change cycles - 3A SU truck
Excess tons carbon monoxide/1000 cycles

F.23 Excess emissions for speed change cycles - 3A SU truck
Excess tons nitrous oxides/1000 cycles

F.24 Excess emissions for speed change cycles - 2-S2 semi
Excess tons hydrocarbons/1000 cycles

F.25 Excess emissions for speed change cycles - 2-S2 semi
Excess tons carbon monoxide/1000 cycles

F.26 Excess emissions for speed change cycles - 2-S2 semi
Excess tons nitrous oxides/1000 cycles

F.27 Excess emissions for speed change cycles - 3-S2 semi
Excess tons hydrocarbons/1000 cycles

F.28 Excess emissions for speed change cycles - 3-S2 semi
Excess tons carbon monoxide/1000 cycles

F.29 Excess emissions for speed change cycles - 3-S2 semi
Excess tons nitrous oxides/1000 cycles

Table F.1 Constant Speed Emission Rates for Automobiles and Pickup Trucks

SPEED mph	HC tons/1000 miles	CO tons/1000 miles	NOX tons/1000 miles
5.	.373E-02	.755E-01	.116E-02
10.	.164E-02	.307E-01	.577E-03
15.	.965E-03	.166E-01	.690E-03
20.	.649E-03	.103E-01	.980E-03
25.	.475E-03	.706E-02	.134E-02
30.	.373E-03	.537E-02	.173E-02
35.	.310E-03	.455E-02	.215E-02
40.	.274E-03	.429E-02	.257E-02
45.	.254E-03	.439E-02	.301E-02
50.	.247E-03	.475E-02	.345E-02
55.	.247E-03	.529E-02	.390E-02
60.	.255E-03	.598E-02	.434E-02
65.	.267E-03	.677E-02	.479E-02
70.	.283E-03	.765E-02	.525E-02

Table F.2 Constant Speed Emission Rates for 2A SU Truck

SPEED mph	HC tons/1000 miles	CO tons/1000 miles	NOX tons/1000 miles
5.	.170E-02	.241E-01	.191E-02
10.	.188E-02	.267E-01	.211E-02
15.	.211E-02	.300E-01	.238E-02
20.	.240E-02	.341E-01	.270E-02
25.	.275E-02	.390E-01	.309E-02
30.	.315E-02	.447E-01	.354E-02
35.	.361E-02	.512E-01	.406E-02
40.	.412E-02	.585E-01	.464E-02
45.	.469E-02	.666E-01	.528E-02
50.	.531E-02	.754E-01	.598E-02
55.	.600E-02	.851E-01	.675E-02
60.	.673E-02	.956E-01	.758E-02
65.	.753E-02	.107E+00	.848E-02
70.	.838E-02	.119E+00	.943E-02

Table F.3 Constant Speed Emission Rates for 3A SU Truck

SPEED mph	HC tons/1000 miles	CO tons/1000 miles	NOX tons/1000 miles
5.	.259E-02	.651E-02	.748E-02
10.	.280E-02	.704E-02	.809E-02
15.	.305E-02	.768E-02	.882E-02
20.	.335E-02	.843E-02	.968E-02
25.	.369E-02	.929E-02	.107E-01
30.	.408E-02	.103E-01	.118E-01
35.	.451E-02	.113E-01	.130E-01
40.	.498E-02	.125E-01	.144E-01
45.	.550E-02	.138E-01	.159E-01
50.	.606E-02	.152E-01	.175E-01
55.	.666E-02	.168E-01	.193E-01
60.	.731E-02	.184E-01	.211E-01
65.	.800E-02	.201E-01	.231E-01
70.	.874E-02	.220E-01	.253E-01

Table F.4. Constant Speed Emission Rates for 2-S2 Truck

SPEED mph	HC tons/1000 miles	CO tons/1000 miles	NOX tons/1000 miles
5.	.792E-03	.551E-02	.991E-02
10.	.841E-03	.585E-02	.105E-01
15.	.916E-03	.638E-02	.115E-01
20.	.102E-02	.708E-02	.127E-01
25.	.115E-02	.797E-02	.143E-01
30.	.130E-02	.903E-02	.162E-01
35.	.148E-02	.103E-01	.185E-01
40.	.168E-02	.117E-01	.211E-01
45.	.192E-02	.133E-01	.240E-01
50.	.217E-02	.151E-01	.272E-01
55.	.246E-02	.171E-01	.307E-01
60.	.277E-02	.192E-01	.346E-01
65.	.310E-02	.216E-01	.388E-01
70.	.346E-02	.241E-01	.433E-01

Table F.5 Constant Speed Emission Rates for 3-S2 Truck

SPEED mph	HC tons/1000 miles	CO tons/1000 miles	NOX tons/1000 miles
5.	.657E-03	.278E-02	.160E-01
10.	.684E-03	.290E-02	.166E-01
15.	.722E-03	.306E-02	.176E-01
20.	.774E-03	.328E-02	.188E-01
25.	.837E-03	.355E-02	.204E-01
30.	.912E-03	.387E-02	.222E-01
35.	.100E-02	.424E-02	.244E-01
40.	.110E-02	.466E-02	.268E-01
45.	.121E-02	.514E-02	.295E-01
50.	.134E-02	.567E-02	.325E-01
55.	.147E-02	.625E-02	.359E-01
60.	.162E-02	.687E-02	.395E-01
65.	.178E-02	.756E-02	.434E-01
70.	.196E-02	.829E-02	.476E-01

Table F.6. Excess emission for speed change cycles - small auto
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.15E-04	.15E-04												
15.	.79E-04	.79E-04	.65E-04											
20.	.22E-03	.22E-03	.20E-03	.14E-03										
25.	.46E-03	.46E-03	.44E-03	.38E-03	.24E-03									
30.	.82E-03	.82E-03	.81E-03	.74E-03	.60E-03	.36E-03								
35.	.13E-02	.13E-02	.13E-02	.13E-02	.11E-02	.88E-03	.51E-03							
40.	.20E-02	.20E-02	.20E-02	.19E-02	.18E-02	.16E-02	.12E-02	.69E-03						
45.	.29E-02	.29E-02	.29E-02	.28E-02	.27E-02	.25E-02	.21E-02	.16E-02	.89E-03					
50.	.40E-02	.40E-02	.40E-02	.40E-02	.38E-02	.36E-02	.32E-02	.27E-02	.20E-02	.11E-02				
55.	.54E-02	.54E-02	.54E-02	.53E-02	.52E-02	.49E-02	.46E-02	.41E-02	.34E-02	.25E-02	.14E-02			
60.	.71E-02	.71E-02	.70E-02	.70E-02	.68E-02	.66E-02	.62E-02	.57E-02	.50E-02	.41E-02	.30E-02	.17E-02		
65.	.90E-02	.90E-02	.90E-02	.90E-02	.88E-02	.86E-02	.82E-02	.77E-02	.70E-02	.61E-02	.50E-02	.36E-02	.20E-02	
70.	.11E-01	.11E-01	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.97E-02	.90E-02	.81E-02	.70E-02	.56E-02	.39E-02	.20E-02

Table F.7. Excess emissions for speed change cycles - small auto
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.34E-03													
10.	.70E-03	.36E-03												
15.	.12E-02	.89E-03	.54E-03											
20.	.21E-02	.17E-02	.14E-02	.83E-03										
25.	.33E-02	.30E-02	.26E-02	.21E-02	.12E-02									
30.	.50E-02	.47E-02	.43E-02	.38E-02	.29E-02	.17E-02								
35.	.73E-02	.69E-02	.66E-02	.60E-02	.52E-02	.40E-02	.23E-02							
40.	.10E-01	.98E-02	.95E-02	.89E-02	.81E-02	.69E-02	.52E-02	.29E-02						
45.	.14E-01	.13E-01	.13E-01	.13E-01	.12E-01	.10E-01	.88E-02	.65E-02	.36E-02					
50.	.18E-01	.18E-01	.17E-01	.17E-01	.16E-01	.15E-01	.13E-01	.11E-01	.79E-02	.43E-02				
55.	.23E-01	.23E-01	.23E-01	.22E-01	.21E-01	.20E-01	.18E-01	.16E-01	.13E-01	.95E-02	.51E-02			
60.	.29E-01	.29E-01	.29E-01	.28E-01	.27E-01	.26E-01	.24E-01	.22E-01	.19E-01	.15E-01	.11E-01	.60E-02		
65.	.36E-01	.36E-01	.35E-01	.35E-01	.34E-01	.33E-01	.31E-01	.29E-01	.26E-01	.22E-01	.18E-01	.13E-01	.69E-02	
70.	.43E-01	.43E-01	.42E-01	.42E-01	.41E-01	.40E-01	.38E-01	.36E-01	.33E-01	.29E-01	.25E-01	.20E-01	.14E-01	.69E-02

Table F.8. Excess emissions for speed change cycles - small auto
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.80E-04	.80E-04												
15.	.45E-03	.45E-03	.37E-03											
20.	.12E-02	.12E-02	.12E-02	.80E-03										
25.	.26E-02	.26E-02	.25E-02	.22E-02	.14E-02									
30.	.47E-02	.47E-02	.46E-02	.42E-02	.35E-02	.21E-02								
35.	.76E-02	.76E-02	.76E-02	.72E-02	.64E-02	.50E-02	.29E-02							
40.	.12E-01	.12E-01	.12E-01	.11E-01	.10E-01	.90E-02	.69E-02	.40E-02						
45.	.17E-01	.17E-01	.17E-01	.16E-01	.16E-01	.14E-01	.12E-01	.91E-02	.51E-02					
50.	.23E-01	.23E-01	.23E-01	.23E-01	.22E-01	.21E-01	.19E-01	.16E-01	.12E-01	.65E-02				
55.	.31E-01	.31E-01	.31E-01	.31E-01	.30E-01	.29E-01	.27E-01	.24E-01	.20E-01	.14E-01	.80E-02			
60.	.41E-01	.41E-01	.41E-01	.40E-01	.40E-01	.38E-01	.36E-01	.33E-01	.29E-01	.24E-01	.18E-01	.97E-02		
65.	.52E-01	.52E-01	.52E-01	.52E-01	.51E-01	.50E-01	.48E-01	.45E-01	.41E-01	.36E-01	.29E-01	.21E-01	.12E-01	
70.	.64E-01	.64E-01	.64E-01	.64E-01	.63E-01	.62E-01	.60E-01	.57E-01	.53E-01	.47E-01	.41E-01	.33E-01	.23E-01	.12E-01

Table F.9. Excess emissions for speed change cycles - medium auto
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.10E-04	.10E-04												
15.	.71E-04	.71E-04	.61E-04											
20.	.21E-03	.21E-03	.20E-03	.14E-03										
25.	.44E-03	.44E-03	.43E-03	.37E-03	.24E-03									
30.	.80E-03	.80E-03	.79E-03	.73E-03	.60E-03	.36E-03								
35.	.13E-02	.13E-02	.13E-02	.12E-02	.11E-02	.87E-03	.51E-03							
40.	.20E-02	.20E-02	.20E-02	.19E-02	.18E-02	.16E-02	.12E-02	.68E-03						
45.	.29E-02	.29E-02	.29E-02	.28E-02	.27E-02	.24E-02	.21E-02	.16E-02	.89E-03					
50.	.40E-02	.40E-02	.40E-02	.39E-02	.38E-02	.36E-02	.32E-02	.27E-02	.20E-02	.11E-02				
55.	.54E-02	.54E-02	.54E-02	.53E-02	.52E-02	.49E-02	.46E-02	.41E-02	.34E-02	.25E-02	.14E-02			
60.	.70E-02	.70E-02	.70E-02	.69E-02	.68E-02	.66E-02	.62E-02	.57E-02	.50E-02	.41E-02	.30E-02	.17E-02		
65.	.90E-02	.90E-02	.90E-02	.89E-02	.88E-02	.86E-02	.82E-02	.77E-02	.70E-02	.61E-02	.50E-02	.36E-02	.20E-02	
70.	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.10E-01	.99E-02	.94E-02	.87E-02	.78E-02	.67E-02	.53E-02	.37E-02	.17E-02

Table F.10. Excess emissions for speed change cycles - medium auto
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.31E-03													
10.	.66E-03	.34E-03												
15.	.12E-02	.90E-03	.55E-03											
20.	.21E-02	.18E-02	.14E-02	.88E-03										
25.	.34E-02	.31E-02	.27E-02	.22E-02	.13E-02									
30.	.52E-02	.49E-02	.46E-02	.40E-02	.31E-02	.18E-02								
35.	.76E-02	.73E-02	.70E-02	.64E-02	.55E-02	.42E-02	.24E-02							
40.	.11E-01	.10E-01	.10E-01	.95E-02	.86E-02	.73E-02	.54E-02	.30E-02						
45.	.14E-01	.14E-01	.14E-01	.13E-01	.12E-01	.11E-01	.92E-02	.68E-02	.37E-02					
50.	.19E-01	.19E-01	.18E-01	.18E-01	.17E-01	.15E-01	.14E-01	.11E-01	.82E-02	.45E-02				
55.	.24E-01	.24E-01	.23E-01	.23E-01	.22E-01	.21E-01	.19E-01	.16E-01	.13E-01	.97E-02	.52E-02			
60.	.30E-01	.30E-01	.29E-01	.29E-01	.28E-01	.27E-01	.25E-01	.22E-01	.19E-01	.16E-01	.11E-01	.60E-02		
65.	.37E-01	.37E-01	.36E-01	.36E-01	.35E-01	.33E-01	.32E-01	.29E-01	.26E-01	.23E-01	.18E-01	.13E-01	.69E-02	
70.	.43E-01	.42E-01	.42E-01	.41E-01	.41E-01	.39E-01	.37E-01	.35E-01	.32E-01	.28E-01	.24E-01	.19E-01	.13E-01	.58E-02

Table F.11. Excess emissions for speed change cycles - medium auto
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.62E-04	.62E-04												
15.	.41E-03	.41E-03	.35E-03											
20.	.12E-02	.12E-02	.11E-02	.78E-03										
25.	.25E-02	.25E-02	.25E-02	.21E-02	.13E-02									
30.	.46E-02	.46E-02	.45E-02	.42E-02	.34E-02	.21E-02								
35.	.75E-02	.75E-02	.74E-02	.71E-02	.63E-02	.50E-02	.29E-02							
40.	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.89E-02	.68E-02	.39E-02						
45.	.17E-01	.17E-01	.16E-01	.16E-01	.15E-01	.14E-01	.12E-01	.90E-02	.51E-02					
50.	.23E-01	.23E-01	.23E-01	.23E-01	.22E-01	.20E-01	.18E-01	.15E-01	.12E-01	.64E-02				
55.	.31E-01	.31E-01	.31E-01	.31E-01	.30E-01	.28E-01	.26E-01	.23E-01	.19E-01	.14E-01	.80E-02			
60.	.41E-01	.41E-01	.41E-01	.40E-01	.39E-01	.38E-01	.36E-01	.33E-01	.29E-01	.24E-01	.18E-01	.97E-02		
65.	.52E-01	.52E-01	.52E-01	.52E-01	.51E-01	.50E-01	.48E-01	.45E-01	.41E-01	.36E-01	.29E-01	.21E-01	.12E-01	
70.	.62E-01	.62E-01	.62E-01	.62E-01	.61E-01	.60E-01	.58E-01	.55E-01	.51E-01	.46E-01	.39E-01	.31E-01	.22E-01	.10E-01

Table F.12. Excess emissions for speed change cycles - large auto
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mpn	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.12E-04	.12E-04												
15.	.74E-04	.74E-04	.62E-04											
20.	.21E-03	.21E-03	.20E-03	.14E-03										
25.	.45E-03	.45E-03	.43E-03	.37E-03	.24E-03									
30.	.81E-03	.81E-03	.79E-03	.73E-03	.60E-03	.36E-03								
35.	.13E-02	.13E-02	.13E-02	.12E-02	.11E-02	.87E-03	.51E-03							
40.	.20E-02	.20E-02	.20E-02	.19E-02	.18E-02	.15E-02	.12E-02	.68E-03						
45.	.29E-02	.29E-02	.29E-02	.28E-02	.27E-02	.24E-02	.21E-02	.16E-02	.88E-03					
50.	.40E-02	.40E-02	.40E-02	.39E-02	.38E-02	.35E-02	.32E-02	.27E-02	.20E-02	.11E-02				
55.	.53E-02	.53E-02	.53E-02	.53E-02	.51E-02	.49E-02	.45E-02	.40E-02	.33E-02	.25E-02	.14E-02			
60.	.70E-02	.70E-02	.70E-02	.69E-02	.68E-02	.65E-02	.62E-02	.57E-02	.50E-02	.41E-02	.30E-02	.16E-02		
65.	.89E-02	.89E-02	.89E-02	.88E-02	.87E-02	.85E-02	.81E-02	.76E-02	.69E-02	.60E-02	.49E-02	.36E-02	.19E-02	
70.	.11E-01	.11E-01	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.99E-02	.92E-02	.83E-02	.72E-02	.59E-02	.42E-02	.23E-02

Table F.13. Excess emissions for speed change cycles - large auto
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.33E-03													
10.	.67E-03	.35E-03												
15.	.12E-02	.90E-03	.55E-03											
20.	.21E-02	.18E-02	.14E-02	.87E-03										
25.	.34E-02	.31E-02	.27E-02	.22E-02	.13E-02									
30.	.52E-02	.49E-02	.46E-02	.40E-02	.32E-02	.18E-02								
35.	.77E-02	.74E-02	.70E-02	.65E-02	.56E-02	.43E-02	.25E-02							
40.	.11E-01	.11E-01	.10E-01	.97E-02	.88E-02	.75E-02	.56E-02	.32E-02						
45.	.15E-01	.15E-01	.14E-01	.14E-01	.13E-01	.11E-01	.96E-02	.71E-02	.40E-02					
50.	.20E-01	.19E-01	.19E-01	.18E-01	.18E-01	.16E-01	.14E-01	.12E-01	.87E-02	.48E-02				
55.	.25E-01	.25E-01	.25E-01	.24E-01	.23E-01	.22E-01	.20E-01	.18E-01	.14E-01	.10E-01	.57E-02			
60.	.32E-01	.32E-01	.31E-01	.31E-01	.30E-01	.29E-01	.27E-01	.24E-01	.21E-01	.17E-01	.12E-01	.66E-02		
65.	.40E-01	.39E-01	.39E-01	.38E-01	.38E-01	.36E-01	.34E-01	.32E-01	.29E-01	.25E-01	.20E-01	.14E-01	.77E-02	
70.	.48E-01	.48E-01	.48E-01	.47E-01	.46E-01	.45E-01	.43E-01	.41E-01	.37E-01	.34E-01	.29E-01	.23E-01	.16E-01	.87E-02

Table F.14. Excess emissions for speed change cycles - large auto
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.69E-04	.69E-04												
15.	.42E-03	.42E-03	.35E-03											
20.	.12E-02	.12E-02	.11E-02	.78E-03										
25.	.25E-02	.25E-02	.25E-02	.21E-02	.13E-02									
30.	.46E-02	.46E-02	.45E-02	.42E-02	.34E-02	.20E-02								
35.	.75E-02	.75E-02	.74E-02	.71E-02	.63E-02	.50E-02	.29E-02							
40.	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.89E-02	.68E-02	.39E-02						
45.	.16E-01	.16E-01	.16E-01	.16E-01	.15E-01	.14E-01	.12E-01	.90E-02	.51E-02					
50.	.23E-01	.23E-01	.23E-01	.22E-01	.22E-01	.20E-01	.18E-01	.15E-01	.11E-01	.64E-02				
55.	.31E-01	.31E-01	.31E-01	.30E-01	.29E-01	.28E-01	.26E-01	.23E-01	.19E-01	.14E-01	.78E-02			
60.	.40E-01	.40E-01	.40E-01	.40E-01	.39E-01	.38E-01	.36E-01	.33E-01	.29E-01	.24E-01	.17E-01	.95E-02		
65.	.51E-01	.51E-01	.51E-01	.51E-01	.50E-01	.49E-01	.47E-01	.44E-01	.40E-01	.35E-01	.29E-01	.21E-01	.11E-01	
70.	.65E-01	.65E-01	.65E-01	.64E-01	.63E-01	.62E-01	.60E-01	.57E-01	.53E-01	.48E-01	.42E-01	.34E-01	.25E-01	.13E-01

Table F.15. Excess emissions for speed change cycles - pickup truck
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.10E-04	.10E-04												
15.	.71E-04	.71E-04	.61E-04											
20.	.21E-03	.21E-03	.20E-03	.14E-03										
25.	.44E-03	.44E-03	.43E-03	.37E-03	.24E-03									
30.	.80E-03	.80E-03	.79E-03	.73E-03	.60E-03	.36E-03								
35.	.13E-02	.13E-02	.13E-02	.12E-02	.11E-02	.87E-03	.51E-03							
40.	.20E-02	.20E-02	.20E-02	.19E-02	.18E-02	.16E-02	.12E-02	.69E-03						
45.	.29E-02	.29E-02	.29E-02	.28E-02	.27E-02	.24E-02	.21E-02	.16E-02	.89E-03					
50.	.40E-02	.40E-02	.40E-02	.39E-02	.38E-02	.36E-02	.32E-02	.27E-02	.20E-02	.11E-02				
55.	.54E-02	.54E-02	.54E-02	.53E-02	.52E-02	.49E-02	.46E-02	.41E-02	.34E-02	.25E-02	.14E-02			
60.	.70E-02	.70E-02	.70E-02	.70E-02	.68E-02	.66E-02	.62E-02	.57E-02	.50E-02	.42E-02	.30E-02	.17E-02		
65.	.87E-02	.87E-02	.87E-02	.87E-02	.85E-02	.83E-02	.79E-02	.74E-02	.67E-02	.58E-02	.47E-02	.33E-02	.17E-02	
70.	.98E-02	.98E-02	.98E-02	.97E-02	.96E-02	.93E-02	.90E-02	.85E-02	.78E-02	.69E-02	.58E-02	.44E-02	.27E-02	.10E-02

Table F.16. Excess emissions for speed change cycles - pickup truck
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED	SPEED REDUCED TO AND RETURNED FROM, mph													
mph	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.31E-03													
10.	.66E-03	.34E-03												
15.	.12E-02	.89E-03	.55E-03											
20.	.21E-02	.18E-02	.14E-02	.87E-03										
25.	.34E-02	.31E-02	.27E-02	.22E-02	.13E-02									
30.	.52E-02	.49E-02	.45E-02	.40E-02	.31E-02	.18E-02								
35.	.75E-02	.72E-02	.69E-02	.63E-02	.55E-02	.42E-02	.24E-02							
40.	.11E-01	.10E-01	.99E-02	.93E-02	.84E-02	.71E-02	.53E-02	.30E-02						
45.	.14E-01	.14E-01	.13E-01	.13E-01	.12E-01	.11E-01	.90E-02	.66E-02	.36E-02					
50.	.18E-01	.18E-01	.18E-01	.17E-01	.16E-01	.15E-01	.13E-01	.11E-01	.80E-02	.43E-02				
55.	.24E-01	.23E-01	.23E-01	.22E-01	.21E-01	.20E-01	.18E-01	.16E-01	.13E-01	.94E-02	.50E-02			
60.	.29E-01	.29E-01	.29E-01	.28E-01	.27E-01	.26E-01	.24E-01	.22E-01	.19E-01	.15E-01	.11E-01	.58E-02		
65.	.35E-01	.35E-01	.34E-01	.34E-01	.33E-01	.32E-01	.30E-01	.27E-01	.24E-01	.21E-01	.16E-01	.11E-01	.57E-02	
70.	.39E-01	.38E-01	.38E-01	.37E-01	.37E-01	.35E-01	.34E-01	.31E-01	.28E-01	.25E-01	.20E-01	.15E-01	.94E-02	.37E-02

Table F.17. Excess emissions for speed change cycles - pickup truck
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.00E+01													
10.	.63E-04	.63E-04												
15.	.41E-03	.41E-03	.35E-03											
20.	.12E-02	.12E-02	.11E-02	.78E-03										
25.	.25E-02	.25E-02	.25E-02	.21E-02	.13E-02									
30.	.46E-02	.46E-02	.45E-02	.42E-02	.34E-02	.21E-02								
35.	.75E-02	.75E-02	.75E-02	.71E-02	.63E-02	.50E-02	.29E-02							
40.	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.89E-02	.69E-02	.39E-02						
45.	.17E-01	.17E-01	.17E-01	.16E-01	.15E-01	.14E-01	.12E-01	.91E-02	.51E-02					
50.	.23E-01	.23E-01	.23E-01	.23E-01	.22E-01	.21E-01	.18E-01	.16E-01	.12E-01	.65E-02				
55.	.31E-01	.31E-01	.31E-01	.31E-01	.30E-01	.29E-01	.26E-01	.24E-01	.20E-01	.14E-01	.80E-02			
60.	.41E-01	.41E-01	.41E-01	.40E-01	.40E-01	.38E-01	.36E-01	.33E-01	.29E-01	.24E-01	.18E-01	.97E-02		
65.	.51E-01	.51E-01	.51E-01	.50E-01	.50E-01	.48E-01	.46E-01	.43E-01	.39E-01	.34E-01	.28E-01	.20E-01	.10E-01	
70.	.57E-01	.57E-01	.57E-01	.57E-01	.56E-01	.55E-01	.53E-01	.50E-01	.46E-01	.41E-01	.34E-01	.26E-01	.16E-01	.65E-02

Table F.18. Excess emissions for speed change cycles - 2A SU truck
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED	SPEED REDUCED TO AND RETURNED FROM, mph													
mph	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.45E-04													
10.	.14E-03	.95E-04												
15.	.31E-03	.26E-03	.17E-03											
20.	.55E-03	.50E-03	.41E-03	.24E-03										
25.	.86E-03	.82E-03	.72E-03	.56E-03	.32E-03									
30.	.13E-02	.12E-02	.11E-02	.96E-03	.72E-03	.40E-03								
35.	.18E-02	.17E-02	.16E-02	.15E-02	.12E-02	.90E-03	.50E-03							
40.	.24E-02	.23E-02	.22E-02	.21E-02	.18E-02	.15E-02	.11E-02	.61E-03						
45.	.31E-02	.31E-02	.30E-02	.28E-02	.26E-02	.22E-02	.18E-02	.14E-02	.74E-03					
50.	.40E-02	.40E-02	.39E-02	.37E-02	.35E-02	.32E-02	.28E-02	.23E-02	.17E-02	.92E-03				
55.	.52E-02	.52E-02	.51E-02	.49E-02	.47E-02	.43E-02	.39E-02	.34E-02	.28E-02	.21E-02	.12E-02			
60.	.68E-02	.67E-02	.66E-02	.65E-02	.62E-02	.59E-02	.55E-02	.50E-02	.44E-02	.37E-02	.27E-02	.16E-02		
65.	.90E-02	.90E-02	.89E-02	.87E-02	.85E-02	.81E-02	.77E-02	.73E-02	.66E-02	.59E-02	.50E-02	.38E-02	.22E-02	
70.	.13E-01	.13E-01	.13E-01	.12E-01	.12E-01	.12E-01	.11E-01	.11E-01	.10E-01	.96E-02	.87E-02	.75E-02	.59E-02	.37E-02

Table F.19. Excess emissions for speed change cycles - 2A SU truck
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.64E-03													
10.	.20E-02	.13E-02												
15.	.44E-02	.37E-02	.24E-02											
20.	.78E-02	.71E-02	.58E-02	.34E-02										
25.	.12E-01	.12E-01	.10E-01	.79E-02	.45E-02									
30.	.18E-01	.17E-01	.16E-01	.14E-01	.10E-01	.57E-02								
35.	.25E-01	.24E-01	.23E-01	.21E-01	.17E-01	.13E-01	.70E-02							
40.	.34E-01	.33E-01	.32E-01	.29E-01	.26E-01	.21E-01	.16E-01	.86E-02						
45.	.44E-01	.44E-01	.42E-01	.40E-01	.36E-01	.32E-01	.26E-01	.19E-01	.11E-01					
50.	.57E-01	.57E-01	.55E-01	.53E-01	.50E-01	.45E-01	.39E-01	.32E-01	.24E-01	.13E-01				
55.	.74E-01	.73E-01	.72E-01	.70E-01	.66E-01	.62E-01	.56E-01	.49E-01	.40E-01	.30E-01	.17E-01			
60.	.96E-01	.95E-01	.94E-01	.92E-01	.88E-01	.84E-01	.78E-01	.71E-01	.62E-01	.52E-01	.39E-01	.22E-01		
65.	.13E+00	.13E+00	.13E+00	.12E+00	.12E+00	.12E+00	.11E+00	.10E+00	.94E-01	.84E-01	.71E-01	.54E-01	.32E-01	
70.	.18E+00	.18E+00	.18E+00	.18E+00	.17E+00	.17E+00	.16E+00	.16E+00	.15E+00	.14E+00	.12E+00	.11E+00	.84E-01	.52E-01

Table F.20. Excess emissions for speed change cycles - 2A SU truck
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.51E-04													
10.	.16E-03	.11E-03												
15.	.35E-03	.29E-03	.19E-03											
20.	.62E-03	.56E-03	.46E-03	.27E-03										
25.	.97E-03	.92E-03	.82E-03	.63E-03	.36E-03									
30.	.14E-02	.14E-02	.13E-02	.11E-02	.81E-03	.45E-03								
35.	.20E-02	.19E-02	.18E-02	.16E-02	.14E-02	.10E-02	.56E-03							
40.	.27E-02	.26E-02	.25E-02	.23E-02	.21E-02	.17E-02	.12E-02	.68E-03						
45.	.35E-02	.35E-02	.33E-02	.32E-02	.29E-02	.25E-02	.21E-02	.15E-02	.84E-03					
50.	.45E-02	.45E-02	.44E-02	.42E-02	.39E-02	.36E-02	.31E-02	.26E-02	.19E-02	.10E-02				
55.	.59E-02	.58E-02	.57E-02	.55E-02	.52E-02	.49E-02	.44E-02	.39E-02	.32E-02	.24E-02	.13E-02			
60.	.76E-02	.76E-02	.75E-02	.73E-02	.70E-02	.66E-02	.62E-02	.56E-02	.50E-02	.41E-02	.31E-02	.18E-02		
65.	.10E-01	.10E-01	.10E-01	.98E-02	.95E-02	.92E-02	.87E-02	.82E-02	.75E-02	.66E-02	.56E-02	.43E-02	.25E-02	
70.	.14E-01	.14E-01	.14E-01	.14E-01	.14E-01	.13E-01	.13E-01	.12E-01	.12E-01	.11E-01	.98E-02	.84E-02	.67E-02	.42E-02

Table F.21. Excess emissions for speed change cycles - 3A SU truck
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.70E-04													
10.	.22E-03	.15E-03												
15.	.49E-03	.42E-03	.27E-03											
20.	.88E-03	.81E-03	.66E-03	.39E-03										
25.	.14E-02	.13E-02	.12E-02	.91E-03	.52E-03									
30.	.21E-02	.20E-02	.18E-02	.16E-02	.12E-02	.66E-03								
35.	.29E-02	.28E-02	.27E-02	.24E-02	.20E-02	.15E-02	.83E-03							
40.	.39E-02	.38E-02	.37E-02	.34E-02	.30E-02	.25E-02	.18E-02	.10E-02						
45.	.51E-02	.51E-02	.49E-02	.47E-02	.43E-02	.37E-02	.31E-02	.23E-02	.12E-02					
50.	.67E-02	.66E-02	.65E-02	.62E-02	.58E-02	.53E-02	.46E-02	.38E-02	.28E-02	.15E-02				
55.	.86E-02	.85E-02	.84E-02	.81E-02	.77E-02	.72E-02	.65E-02	.57E-02	.47E-02	.34E-02	.19E-02			
60.	.11E-01	.11E-01	.11E-01	.11E-01	.10E-01	.97E-02	.90E-02	.82E-02	.72E-02	.59E-02	.44E-02	.25E-02		
65.	.14E-01	.14E-01	.14E-01	.14E-01	.14E-01	.13E-01	.12E-01	.12E-01	.11E-01	.93E-02	.78E-02	.58E-02	.34E-02	
70.	.19E-01	.19E-01	.19E-01	.19E-01	.19E-01	.18E-01	.17E-01	.17E-01	.16E-01	.14E-01	.13E-01	.11E-01	.84E-02	.50E-02

Table F.22. Excess emissions for speed change cycles - 3A SU truck
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.18E-03													
10.	.56E-03	.38E-03												
15.	.12E-02	.11E-02	.68E-03											
20.	.22E-02	.20E-02	.17E-02	.98E-03										
25.	.35E-02	.34E-02	.30E-02	.23E-02	.13E-02									
30.	.52E-02	.50E-02	.46E-02	.40E-02	.30E-02	.17E-02								
35.	.73E-02	.71E-02	.67E-02	.60E-02	.51E-02	.37E-02	.21E-02							
40.	.98E-02	.96E-02	.93E-02	.86E-02	.76E-02	.63E-02	.46E-02	.25E-02						
45.	.13E-01	.13E-01	.12E-01	.12E-01	.11E-01	.94E-02	.77E-02	.57E-02	.31E-02					
50.	.17E-01	.17E-01	.16E-01	.16E-01	.15E-01	.13E-01	.12E-01	.95E-02	.70E-02	.38E-02				
55.	.22E-01	.21E-01	.21E-01	.20E-01	.19E-01	.18E-01	.16E-01	.14E-01	.12E-01	.87E-02	.48E-02			
60.	.28E-01	.28E-01	.27E-01	.27E-01	.26E-01	.24E-01	.23E-01	.21E-01	.18E-01	.15E-01	.11E-01	.62E-02		
65.	.36E-01	.36E-01	.36E-01	.35E-01	.34E-01	.33E-01	.31E-01	.29E-01	.26E-01	.23E-01	.20E-01	.15E-01	.85E-02	
70.	.49E-01	.49E-01	.48E-01	.48E-01	.47E-01	.45E-01	.44E-01	.42E-01	.39E-01	.36E-01	.32E-01	.27E-01	.21E-01	.13E-01

Table F.23. Excess emissions for speed change cycles - 3A SU truck
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.20E-03													
10.	.64E-03	.44E-03												
15.	.14E-02	.12E-02	.78E-03											
20.	.25E-02	.23E-02	.19E-02	.11E-02										
25.	.41E-02	.39E-02	.34E-02	.26E-02	.15E-02									
30.	.60E-02	.58E-02	.53E-02	.46E-02	.34E-02	.19E-02								
35.	.84E-02	.82E-02	.77E-02	.69E-02	.58E-02	.43E-02	.24E-02							
40.	.11E-01	.11E-01	.11E-01	.99E-02	.87E-02	.72E-02	.53E-02	.29E-02						
45.	.15E-01	.15E-01	.14E-01	.13E-01	.12E-01	.11E-01	.89E-02	.65E-02	.36E-02					
50.	.19E-01	.19E-01	.19E-01	.18E-01	.17E-01	.15E-01	.13E-01	.11E-01	.80E-02	.44E-02				
55.	.25E-01	.25E-01	.24E-01	.23E-01	.22E-01	.21E-01	.19E-01	.16E-01	.14E-01	.10E-01	.55E-02			
60.	.32E-01	.32E-01	.31E-01	.31E-01	.29E-01	.28E-01	.26E-01	.24E-01	.21E-01	.17E-01	.13E-01	.71E-02		
65.	.42E-01	.41E-01	.41E-01	.40E-01	.39E-01	.38E-01	.36E-01	.33E-01	.30E-01	.27E-01	.22E-01	.17E-01	.97E-02	
70.	.56E-01	.56E-01	.55E-01	.55E-01	.54E-01	.52E-01	.50E-01	.48E-01	.45E-01	.41E-01	.37E-01	.31E-01	.24E-01	.14E-01

Table F.24. Excess emissions for speed change cycles - 2-S2 semi
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mpn	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.25E-04													
10.	.80E-04	.55E-04												
15.	.18E-03	.15E-03	.97E-04											
20.	.32E-03	.29E-03	.24E-03	.14E-03										
25.	.51E-03	.48E-03	.42E-03	.33E-03	.19E-03									
30.	.74E-03	.72E-03	.66E-03	.57E-03	.43E-03	.24E-03								
35.	.10E-02	.10E-02	.96E-03	.86E-03	.72E-03	.54E-03	.30E-03							
40.	.14E-02	.14E-02	.13E-02	.12E-02	.11E-02	.90E-03	.66E-03	.37E-03						
45.	.19E-02	.18E-02	.18E-02	.17E-02	.15E-02	.14E-02	.11E-02	.82E-03	.45E-03					
50.	.24E-02	.24E-02	.23E-02	.22E-02	.21E-02	.19E-02	.17E-02	.14E-02	.10E-02	.56E-03				
55.	.31E-02	.31E-02	.30E-02	.30E-02	.28E-02	.26E-02	.24E-02	.21E-02	.17E-02	.13E-02	.71E-03			
60.	.41E-02	.40E-02	.40E-02	.39E-02	.37E-02	.36E-02	.33E-02	.30E-02	.27E-02	.22E-02	.16E-02	.93E-03		
65.	.54E-02	.53E-02	.53E-02	.52E-02	.50E-02	.48E-02	.46E-02	.43E-02	.39E-02	.35E-02	.29E-02	.22E-02	.13E-02	
70.	.73E-02	.73E-02	.72E-02	.71E-02	.70E-02	.68E-02	.66E-02	.63E-02	.59E-02	.55E-02	.49E-02	.42E-02	.33E-02	.20E-02

Table F.25. Excess emissions for speed change cycles - 2-S2 semi
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.18E-03													
10.	.56E-03	.38E-03												
15.	.12E-02	.11E-02	.67E-03											
20.	.22E-02	.20E-02	.17E-02	.98E-03										
25.	.35E-02	.33E-02	.30E-02	.23E-02	.13E-02									
30.	.52E-02	.50E-02	.46E-02	.39E-02	.30E-02	.17E-02								
35.	.72E-02	.71E-02	.67E-02	.60E-02	.50E-02	.37E-02	.21E-02							
40.	.98E-02	.96E-02	.92E-02	.85E-02	.76E-02	.63E-02	.46E-02	.25E-02						
45.	.13E-01	.13E-01	.12E-01	.12E-01	.11E-01	.94E-02	.77E-02	.57E-02	.31E-02					
50.	.17E-01	.17E-01	.16E-01	.16E-01	.15E-01	.13E-01	.12E-01	.96E-02	.70E-02	.39E-02				
55.	.22E-01	.22E-01	.21E-01	.21E-01	.20E-01	.18E-01	.17E-01	.15E-01	.12E-01	.88E-02	.49E-02			
60.	.28E-01	.28E-01	.28E-01	.27E-01	.26E-01	.25E-01	.23E-01	.21E-01	.18E-01	.15E-01	.11E-01	.65E-02		
65.	.37E-01	.37E-01	.37E-01	.36E-01	.35E-01	.34E-01	.32E-01	.30E-01	.27E-01	.24E-01	.20E-01	.15E-01	.90E-02	
70.	.51E-01	.51E-01	.50E-01	.50E-01	.49E-01	.47E-01	.46E-01	.44E-01	.41E-01	.38E-01	.34E-01	.29E-01	.23E-01	.14E-01

Table F.26. Excess emissions for speed change cycles - 2-S2 semi
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.32E-03													
10.	.10E-02	.69E-03												
15.	.22E-02	.19E-02	.12E-02											
20.	.40E-02	.37E-02	.30E-02	.18E-02										
25.	.63E-02	.60E-02	.53E-02	.41E-02	.23E-02									
30.	.93E-02	.90E-02	.83E-02	.71E-02	.53E-02	.30E-02								
35.	.13E-01	.13E-01	.12E-01	.11E-01	.90E-02	.67E-02	.37E-02							
40.	.18E-01	.17E-01	.17E-01	.15E-01	.14E-01	.11E-01	.83E-02	.46E-02						
45.	.23E-01	.23E-01	.22E-01	.21E-01	.19E-01	.17E-01	.14E-01	.10E-01	.56E-02					
50.	.30E-01	.30E-01	.29E-01	.28E-01	.26E-01	.24E-01	.21E-01	.17E-01	.13E-01	.70E-02				
55.	.39E-01	.39E-01	.38E-01	.37E-01	.35E-01	.33E-01	.30E-01	.26E-01	.22E-01	.16E-01	.89E-02			
60.	.51E-01	.50E-01	.50E-01	.49E-01	.47E-01	.44E-01	.42E-01	.38E-01	.33E-01	.28E-01	.21E-01	.12E-01		
65.	.67E-01	.67E-01	.66E-01	.65E-01	.63E-01	.61E-01	.58E-01	.54E-01	.49E-01	.44E-01	.37E-01	.28E-01	.16E-01	
70.	.92E-01	.91E-01	.91E-01	.89E-01	.88E-01	.85E-01	.82E-01	.79E-01	.74E-01	.68E-01	.61E-01	.52E-01	.41E-01	.25E-01

Table F.27. Excess emissions for speed change cycles - 3-S2 semi
Excess tons hydrocarbons/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.19E-04													
10.	.59E-04	.40E-04												
15.	.13E-03	.11E-03	.71E-04											
20.	.23E-03	.21E-03	.17E-03	.10E-03										
25.	.37E-03	.35E-03	.31E-03	.24E-03	.14E-03									
30.	.54E-03	.52E-03	.48E-03	.41E-03	.31E-03	.17E-03								
35.	.75E-03	.73E-03	.69E-03	.62E-03	.52E-03	.38E-03	.21E-03							
40.	.10E-02	.99E-03	.95E-03	.88E-03	.78E-03	.64E-03	.47E-03	.26E-03						
45.	.13E-02	.13E-02	.13E-02	.12E-02	.11E-02	.95E-03	.78E-03	.57E-03	.31E-03					
50.	.17E-02	.17E-02	.16E-02	.16E-02	.15E-02	.13E-02	.12E-02	.95E-03	.69E-03	.38E-03				
55.	.22E-02	.22E-02	.21E-02	.20E-02	.19E-02	.18E-02	.16E-02	.14E-02	.12E-02	.85E-03	.47E-03			
60.	.28E-02	.27E-02	.27E-02	.26E-02	.25E-02	.24E-02	.22E-02	.20E-02	.18E-02	.14E-02	.11E-02	.60E-03		
65.	.36E-02	.35E-02	.35E-02	.34E-02	.33E-02	.32E-02	.30E-02	.28E-02	.26E-02	.22E-02	.19E-02	.14E-02	.80E-03	
70.	.47E-02	.47E-02	.47E-02	.46E-02	.45E-02	.44E-02	.42E-02	.40E-02	.37E-02	.34E-02	.30E-02	.26E-02	.20E-02	.12E-02

Table F.28. Excess emissions for speed change cycles - 3-S2 semi
Excess tons carbon monoxide/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.79E-04													
10.	.25E-03	.17E-03												
15.	.55E-03	.47E-03	.30E-03											
20.	.98E-03	.90E-03	.73E-03	.43E-03										
25.	.16E-02	.15E-02	.13E-02	.10E-02	.58E-03									
30.	.23E-02	.22E-02	.20E-02	.17E-02	.13E-02	.73E-03								
35.	.32E-02	.31E-02	.29E-02	.26E-02	.22E-02	.16E-02	.90E-03							
40.	.43E-02	.42E-02	.40E-02	.37E-02	.33E-02	.27E-02	.20E-02	.11E-02						
45.	.56E-02	.55E-02	.53E-02	.50E-02	.46E-02	.40E-02	.33E-02	.24E-02	.13E-02					
50.	.72E-02	.71E-02	.70E-02	.67E-02	.62E-02	.56E-02	.49E-02	.40E-02	.29E-02	.16E-02				
55.	.92E-02	.91E-02	.89E-02	.86E-02	.82E-02	.76E-02	.69E-02	.60E-02	.49E-02	.36E-02	.20E-02			
60.	.12E-01	.12E-01	.11E-01	.11E-01	.11E-01	.10E-01	.94E-02	.85E-02	.75E-02	.61E-02	.45E-02	.25E-02		
65.	.15E-01	.15E-01	.15E-01	.15E-01	.14E-01	.14E-01	.13E-01	.12E-01	.11E-01	.95E-02	.79E-02	.59E-02	.34E-02	
70.	.20E-01	.20E-01	.20E-01	.20E-01	.19E-01	.19E-01	.18E-01	.17E-01	.16E-01	.14E-01	.13E-01	.11E-01	.84E-02	.50E-02

Table F.29. Excess emissions for speed change cycles - 3-S2 semi
Excess tons nitrous oxides/1000 cycles

INITIAL SPEED mph	SPEED REDUCED TO AND RETURNED FROM, mph 0	5	10	15	20	25	30	35	40	45	50	55	60	65
5.	.45E-03													
10.	.14E-02	.98E-03												
15.	.32E-02	.27E-02	.17E-02											
20.	.56E-02	.52E-02	.42E-02	.25E-02										
25.	.90E-02	.85E-02	.75E-02	.58E-02	.33E-02									
30.	.13E-01	.13E-01	.12E-01	.10E-01	.75E-02	.42E-02								
35.	.18E-01	.18E-01	.17E-01	.15E-01	.13E-01	.93E-02	.52E-02							
40.	.25E-01	.24E-01	.23E-01	.21E-01	.19E-01	.16E-01	.11E-01	.63E-02						
45.	.32E-01	.32E-01	.31E-01	.29E-01	.26E-01	.23E-01	.19E-01	.14E-01	.76E-02					
50.	.41E-01	.41E-01	.40E-01	.38E-01	.36E-01	.32E-01	.28E-01	.23E-01	.17E-01	.92E-02				
55.	.53E-01	.52E-01	.51E-01	.50E-01	.47E-01	.44E-01	.40E-01	.35E-01	.28E-01	.21E-01	.11E-01			
60.	.67E-01	.67E-01	.66E-01	.64E-01	.62E-01	.58E-01	.54E-01	.49E-01	.43E-01	.35E-01	.26E-01	.15E-01		
65.	.87E-01	.86E-01	.85E-01	.84E-01	.81E-01	.78E-01	.74E-01	.69E-01	.62E-01	.55E-01	.46E-01	.34E-01	.20E-01	
70.	.12E+00	.11E+00	.11E+00	.11E+00	.11E+00	.11E+00	.10E+00	.97E-01	.91E-01	.83E-01	.74E-01	.63E-01	.48E-01	.28E-01