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16. Abstract

Extensive research has been completed on the fuel efficiency of different types of vehicles, but this information is either out-of-date or scattered in many sources and available in different formats. Much of the more recent data are not in the correct format for use in economic and energy studies of transportation alternatives. The procedure generally used to estimate fuel consumption in benefit-cost manuals and computer programs is to use standard tables that show the energy consumption for various speed changes, stops, and travel at uniform speeds. A different approach has been developed for estimating energy consumption for different types of vehicles, based partially on automotive engineering models of vehicle fuel consumption as related to vehicle characteristics, speeds, and roadway profiles. This new approach has been used extensively by vehicle manufacturers and in Australia and Canada. This approach simulates vehicles of different types traveling in specified highway and traffic situations, and has been shown to be much more flexible and less expensive to use in updating than the methods that have been used in the past. In this research study, the ARFCOM computer program was used to develop an improved fuel consumption data set representing typical vehicles currently operating on highways in the U.S.A. Using this data set updated statistical equations for the MicroBENCOST computer program were developed. These new equations were used in the MicroBENCOST computer program with example problems to demonstrate the use of the data set.

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UPDATED FUEL CONSUMPTION ESTIMATES FOR BENEFIT-COST ANALYSIS OF TRANSPORTATION ALTERNATIVES

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Report 60013-1

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August, 1994

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

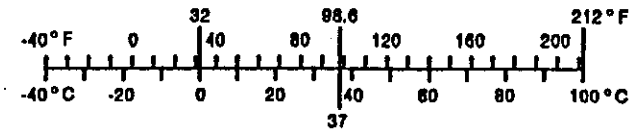
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
	AREA			
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
	VOLUME			
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3

	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements



ABSTRACT

Extensive research has been completed on the fuel efficiency of different types of vehicles, but this information is either out-of-date or scattered in many sources and available in different formats. Much of the more recent data are not in the correct format for use in economic and energy studies of transportation alternatives. The procedure generally used to estimate fuel consumption in benefit-cost manuals and computer programs is to use standard tables that show the energy consumption for various speed changes, stops, and travel at uniform speeds.

A different approach has been developed for estimating energy consumption for different types of vehicles, based partially on automotive engineering models of vehicle fuel consumption as related to vehicle characteristics, speeds, and roadway profiles. This new approach has been used extensively by vehicle manufacturers and in Australia and Canada. This approach simulates vehicles of different types traveling in specified highway and traffic situations, and has been shown to be much more flexible and less expensive to use in updating than the methods that have been used in the past.

The main purpose of this research was to use this new approach in the ARFCOM computer program using characteristics of typical vehicles in the United States to develop an improved fuel consumption data set to use in the MicroBENCOST computer program in comparing highway and transit improvement alternatives. This data set was developed and also was used in the MicroBENCOST computer program with example problems to show the use of the data set.

Key Words : Fuel Consumption, Vehicle Operating Costs, User Costs, Benefit-Cost Analysis, Evaluation of Transportation Alternatives, Cost-Effectiveness Analysis

EXECUTIVE SUMMARY

The goal of this research was to develop new, improved estimates of fuel consumption for use in benefit-cost analysis of transportation projects. To meet the needs for updated fuel consumption data and equations, the characteristics of modern vehicles were determined and up-to-date fuel consumption estimates were developed. These estimates can be used in the MicroBENCOST computer program for analyzing highway and transit investment projects. The MicroBENCOST computer program represents an updated and expanded computer version of the American Association of State Highway and Transportation Official's *Manual on User Benefit Analysis for Highway and Transit Improvements*, which was published in 1977. To develop estimates for a wide range of vehicles, a vehicle simulation program was used. This approach for estimating energy consumption for different types of vehicles is based partially on automotive engineering models of vehicle fuel consumption as related to vehicle characteristics, speeds, and roadway profiles. The approach has been used extensively by vehicle manufacturers and in Australia and Canada. With this approach, a computer program is used to simulate vehicles of different types traveling in specified highway and traffic situations. Development of fuel consumption estimates using the program have been shown to be much more flexible and less expensive, but also very accurate, for producing updated estimates than the detailed experimental trials methods that have been used in the past.

In this research, the ARFCOM computer program was calibrated for the characteristics of typical vehicles in the United States and used to develop improved fuel consumption data sets to use in the MicroBENCOST computer program in comparing highway and transit improvement alternatives. Two data sets were developed. The first data set was developed for evaluating the consumption values that are now used in MicroBENCOST, based on research conducted for the Federal Highway Administration by the Texas Research and Development Foundation (TRDF), simply to determine the accuracy of the TRDF data set. The comparison data set was developed using the ARFCOM computer program using vehicles with the same characteristics as the vehicles used in the TRDF data set.

The most important result of the project was the development of a second data set, which is developed using vehicles that represent the modern vehicle fleet. It is recommended that equations based on this data set be used to replace the current, out-of-date equations in the MicroBENCOST computer program. These revised equations will give more accurate and acceptable estimates of fuel consumption for various highway improvement alternatives and also can be used in other comparisons of energy-efficiency options in highway and transit programs. The statistical equations that were developed using this data set were installed in a test version of the MicroBENCOST computer program. Case studies were used to demonstrate the use of the new equations in MicroBENCOST.

In addition to being used in the MicroBENCOST computer program, the new data set can be used in other analyses that require fuel consumption data. In addition to the equations that were develop for use in MicroBENCOST or other computer programs, the complete data set is presented in appendix tables.

ACKNOWLEDGMENT

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Chapter 1. INTRODUCTION

Study Background and Objectives

Although there has been much research on the fuel efficiency of different types of vehicles, this information is scattered in many sources and much of the more recent data are not in the correct format for use in economic and energy studies of transportation alternatives. The procedure generally used to estimate fuel consumption is to use standard tables that show the energy consumption for various speed changes, stops, and travel at uniform speeds.

For use in comparison of highway and transit alternatives for saving energy, data on fuel efficiency must be developed in a very specific format. For example, four types of data are needed for most comparisons: (1) fuel use per mile for operation at different uniform speeds, (2) excess fuel use for making speed changes from one speed to a different speed, as compared to traveling the same distance at the initial speed, (3) excess fuel use for stopping from different initial speeds, as compared to continuing at the initial speed, and (4) fuel use for idling per vehicle-hour. These data must be developed for all different possible speeds and combinations of speeds, in the case of speed changes and stops, and for representative vehicles that will be encountered in the comparison of alternatives. Data in this format are not typically developed by vehicle manufacturers or by the Department of Energy or the Environmental Protection Agency, but must be developed in carefully designed and controlled tests. Unfortunately, funds have not been available for developing this data even though such data are necessary if good comparisons of alternatives are to be made.

A report by the Texas Research and Development Foundation (TRDF), published in 1982, contains the most up-to-date vehicle-operating-cost data set for several representative United States vehicles. TRDF's vehicle operating cost data set, which has been used in several benefit-cost computer programs since it became available, is discussed in more detail in the next section of this chapter. In addition to being somewhat dated, the TRDF data has been criticized as containing faulty estimates of fuel consumption for some vehicle types. The basic goal of this study is to evaluate the TRDF fuel consumption data and to develop an improved data set representing the current vehicle fleet. To accomplish this goal, the research had three principal objectives: (1) review and critique the existing literature on fuel efficiencies of different types of vehicles and evaluate computer simulation programs that are available for estimating fuel consumption for different vehicle types and highway conditions; (2) develop a procedure and related computer program for regularly updating fuel efficiencies in the MicroBENCOST computer program; and (3) test the procedure and program in case study projects.

Vehicle Operating Cost Studies

There are numerous studies of individual vehicle operating cost components, usually divided into areas of fuel, oil, tires, maintenance, and use-related depreciation; these individual studies concentrate on various elements of use. At various time in the past, various authors have combined these individual studies into synthesis reports that combined these studies into a procedure for estimating overall costs. Some of the more important syntheses of vehicle operating costs for use in highway benefit-cost analysis in the United States listed below with date of issue.

AASHO's original *Red Book*	- 1952, 1960
Winfrey's *Economic Analysis*	- 1969
McFarland's *Benefit Analysis*	- 1972
AASHTO Manual (or revised *Red Book*)	- 1977
TRDF report prepared for FHWA	- 1982

AASHO Red Book (1952, 1960)

The first synthesis of vehicle operating costs that was widely used in the United States was that included in the American Association of State Highway Officials' publication entitled *Road User Benefit Analysis for Highway Improvements; Part I: Passenger Cars in Rural Areas*. This benefit-cost manual was first published in 1952. In 1960, a revised version was published that was the same as the 1952 publication except for use of 1959 unit costs. This publication often was called the "Red Book" because of the color of its cover. Several earlier studies of fuel consumption, tire wear, and other factors were used in developing the cost tables in the manual. The manual was subtitled "Part I: Passenger Cars in Rural Areas" because it gave detailed vehicle operating costs only for passenger cars. Additional manuals in the series are suggested by the "Part I" subtitle of this report but these were never completed. The Part I manual did include various factors for extending the analysis to make a rough approximation for other vehicles.

Winfrey's Economic Analysis (1969)

Robley Winfrey made several studies of vehicle operating costs while at the Iowa Engineering Experiment Station and later with the U.S. Bureau of Public Roads. He synthesized numerous studies in his 1969 book entitled *Economic Analysis for Highways*. Winfrey was the first researcher in the United States to make a comprehensive synthesis

of vehicle operating costs for several representative vehicles. Winfrey's general framework was followed in several later syntheses, including AASHTO's revised Red Book in 1977 and the study completed by the Texas Research and Development Foundation for the Federal Highway Administration, both of which are discussed below. Winfrey developed detailed vehicle operating costs for five vehicle types: a 4-kip passenger car; a 5-kip commercial delivery vehicle; a 12-kip single-unit truck; a 40-kip, gasoline 2-S2 combination truck; and a 50-kip diesel 3-S2 combination truck.

McFarland's Benefit Analysis (1972)

Research conducted by researchers at the Texas Transportation Institute in the late 1960s and early 1970s resulted in two advancements in use of vehicle operating costs. First, a synthesis of previous vehicle operating cost and value of time studies was used in the Texas Flexible Pavement System developed for use in designing highway pavements in Texas [Scrivner, Moore, McFarland, and Carey, 1968]. This computer program, originally called FPS-1, was the first pavement design program that used life-cycle cost analysis considering multiple overlay and performance periods and also was the first to have procedures for considering user costs associated with delay during pavement overlay operations (Subroutine User). The original program has been modified and updated several times since 1968. The latest version of this program, FPS-19, is currently being used by the Texas Department of Transportation for design of flexible pavements.

The second advancement was the development of a comprehensive benefit analysis procedure for considering fuel consumption and other vehicle operating costs in pavement design decisions for different types of highways. This procedure and related speed and vehicle operating cost data was published in the report entitled *Benefit Analysis for Pavement Design Systems* [McFarland, 1972]. This procedure was unique in two respects: (1) it was the first to relate vehicle operating costs to the pavement's serviceability index, and (2) it developed estimates of the effects of the serviceability index on vehicle speeds. This general procedure was later followed in research by the World Bank in Brazil, by the Ontario Ministry of Transportation and Communications [Kher and Phang], and -- following Kher and Phang -- by Australia in the NIMPAC computer program. This procedure of considering the (simultaneous) effects of the serviceability index on vehicle speeds and vehicle operating costs also was followed in the later TRDF study for FHWA and has been incorporated into several computer programs in the U.S.A. (HIAP, HPMS, HUBAM, and MicroBENCOST).

1977 AASHTO Manual, or Revised Red Book (1977)

In 1977, the American Association of State Highway and Transportation Officials published an update of their 1960 manual for calculating highway user costs and benefits entitled *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements.* AASHTO (1977). This update was based on research performed on an NCHRP project by researchers at the Stanford Research Institute. The 1977 version used several individual vehicle operating cost studies, including the Winfrey data. This manual used only three vehicle types: a passenger car, a single-unit truck, and a combination truck. This simplification was used in an attempt to simplify the calculation techniques that made extensive use of nomographs. Because most of the data in this manual is presented in nomographs it is difficult to update accurately.

TRDF Study for FHWA (1982)

During the period from 1978 to 1981, researchers with the Texas Research and Development Foundation, or TRDF, developed new vehicle operating cost tables for use by the Federal Highway Administration and others. This comprehensive study was used by FHWA in the Highway Investment Analysis Package (HIAP) and in the Highway Performance Monitoring System (HPMS). In addition, the same data was used in the Highway User Benefit Analysis Model (HUBAM) in Canada and in the MicroBENCOST computer program.

TRDF developed their values through the collection of empirical data by measuring the fuel consumption of actual vehicles as they were driven over mostly homogeneous roadway sections. Each run was performed several times and in both directions in order to try to control for external variables such as wind which could have affected the results. In addition, two identical medium-sized cars were used in an attempt to develop a control for the variations that could occur between individual vehicles in a given class. The actual vehicles that were used are listed in Table 1-1.

In order to measure the fuel consumption of the vehicles, the TRDF researchers utilized a Fluidyne 1214F fuel meter installed between the fuel pump and the carburetor of each vehicle with "quick-connect" splices. These fittings were installed by factory authorized dealer service personnel for each vehicle tested. The measuring equipment was attached to each vehicle by mounting a bicycle rack on the front of the vehicle and attaching the flow meter to the rack. The same mounting system was used for each vehicle and the authors state that this should have mitigated any effects from the increase in aerodynamic drag that resulted from this arrangement.

Following the collection of empirical data, work commenced on the development of a comprehensive set of tables detailing fuel consumption at various speeds and grades and the excess fuel consumption as the result of accelerations, decelerations, and

Table 1-1. Actual Vehicles Used in TRDF Study

Vehicle Class	Make	Model	Year	Body Style
Small Car	Ford	Escort	1980	Station Wagon
Medium Car	Ford	Fairmont	1980	Sedan
Medium Car	Ford	Fairmont	1980	Sedan
Large Car	Oldsmobile	Delta 88	1979	Sedan
Pickup	Ford	n/a	1980	Box
2A-Single Unit	GMC	n/a	n/a	Van
3A-Single Unit	GMC	Brigadier	n/a	Dump
2-S2	Freightliner	n/a	n/a	Flat Bed

n/a: data was not presented in the TRDF report.

horizontal curvatures. The data points that were collected empirically for each vehicle class were used to derive equations for that vehicle class. In order to create a continuous function, the data needed to be smoothed and outlying data needed to be discarded. The resulting equations were then used to derive fuel consumption values for grades between +8 percent and -8 percent and at speeds from 5 miles per hour to 70 mph in 5 mph increments.

Additional empirical data was collected in order to identify the fuel consumption of the test vehicles during accelerations and decelerations. Finally, runs were made in a parking lot to determine the excess fuel consumption required for the vehicles to negotiate horizontal curvatures varying from 1 to 30 degrees of curvature. This data was also modeled mathematically and tables were developed to show the excess cost of these various maneuvers.

The same connection system was also utilized without modification for the heavy vehicles - i.e. the two single unit two and three axle vehicles and the 2-S2 articulated vehicle. The dump truck (single unit, 3-axle) and the flatbed tractor-trailer (2-S2) were both powered by diesel fuel power plants. Many large diesel vehicles utilize a fuel return system whereby fuel that is unused in the combustion cycle is returned to the fuel tank to be reused. Such a system on one or both of the test vehicles would have rendered the fuel flow readings for that vehicle too high and thus bias the ensuing calculations and values upwards.

Based on their study using the test vehicles and other studies by others, TRDF researchers developed vehicle operating data for a set of representative vehicles, shown in Table 1-2.

The TRDF fuel consumption values, especially the values for combination trucks, have been criticized on several grounds, including: (1) not using proper measurement techniques; (2) not testing large trucks directly; and (3) concluding that pavement roughness has no effect on fuel consumption, when there is considerable evidence to the contrary.

Use of ARFCOM to Develop New Equations

A relatively new approach for estimating energy consumption for different types of vehicles has been developed, based partially on automotive engineering models of vehicle fuel consumption as related to vehicle characteristics, speeds, and roadway profiles. This new approach has been used mainly by vehicle manufacturers and in a few studies, especially in studies using the ARFCOM computer program [Biggs], in Australia and Canada. The ARFCOM computer program can be used to simulate vehicles of different types traveling in various highway, pavement, and traffic conditions.

Using the ARFCOM computer program, new estimates of fuel consumption for representative United States vehicles were developed in simulation runs at different vehicle speeds and weights and for different degrees of pavement roughness.

The MicroBENCOST Computer Program

In 1993, the AASHTO user cost estimation procedure again was updated and also was expanded and computerized. This was accomplished on NCHRP Project 7-12 by researchers at the Texas Transportation Institute, who developed the MicroBENCOST computer program and the Update program. The MicroBENCOST program used the FHWA vehicle operating relationships developed by TRDF. However, the program was designed so that the vehicle operating costs could be updated in two ways. First, the basic consumption equations relating fuel and other components could be updated by changing the coefficients in the individual consumption equations for up to nine passenger vehicles and up to nine commercial vehicles. Second, the unit costs for individual components (fuel, oil, tires, maintenance and repairs, and use-related depreciation) can be updated, along with numerous items in the default data set, by using the Update computer program.

To facilitate the use of the fuel consumption estimates developed in the current research project, a new default data set for the MicroBENCOST computer program was developed that incorporates the new estimates. In addition, the new data set was used in

Table 1-2. Characteristics for TRDF's Representative Vehicle Data Set

Features	Cars			Trucks				
	Small	Med.	Large	Pick-up	Single Unit		Semi's	
					2 axle	3 axle	2 S2	3 S2
Road Wt.(lbs.)	2800	3800	4700	5,000	12,000	35,000	40,000	62,500
Curb Weight (lbs.)	2500	3500	4400	3500	5,700	15,000	20,000	25,000
Eng. Disp. ($in.^3$)	120	230	350	350	350	400	800	800
Cylinders	4	6	8	8	8	8	6	6
Fuel	Unld.	Unld.	Unld.	Gas.	Gas.	Diesel	Diesel	Diesel
Frontal Area ($ft.^2$)	23.7	27.5	29.8	30.8	36.9	55.0	90.0	90.0
Trans.	Man.	Auto.	Auto.	Auto.	Man.	Man.	Man.	Man.
Forward Gears	4	3	3	3	4	5	10	10
Body Style	Sedan	Sedan	Sedan	Box	Fltbed	Fltbed	Van	Van
Options								
-A/C	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-P/S	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-Power Brakes	No*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-Steel-belted radials	Yes	Yes	Yes	Yes	No	No	No	No
Fuel Econ. Ranges:								
-EPA City	20-25	15-20	9-16					
-EPA Hwy	28-37	22-35	13-25					

* may be power assist.

example problems to show the use of the new default data set. Comparisons of fuel consumption using the new approach with those using the traditional approach were made using case studies of added capacity and pavement overlay projects.

Contents of Report

The results of the study are summarized in the next four chapters. Detailed results are given in a series of appendices at the end of the report. Discussion in Chapter 2 provides background information on the ARFCOM model.

ARFCOM results for TRDF vehicles are presented in Chapter 3. The objective of this exercise was to develop a fuel consumption data set and equations for vehicles with the same basic characteristics as the TRDF reference vehicles that are used in MicroBENCOST and other benefit-cost models. This exercise initially was intended to provide ARFCOM-derived fuel consumption equations that could replace the original TRDF-based equations in MicroBENCOST. Thus, the main goal was to replace the original equations with revised equations that would no longer be subject to the criticisms, discussed in Chapter 1, that have been made of the TRDF data.

The initial goal was later replaced by the goal of replacing the equations based on TRDF data with corrected equations but also to update them to be more representative of the modern fleet. Therefore, ARFCOM was used to develop updated equations based on vehicles with characteristics representing the modern, early-1990s fleet. These results are presented in Chapter 4.

The MicroBENCOST computer program was used to make preliminary estimates of the effect of using the new fuel equations developed in this project as compared to the original MicroBENCOST equations that were estimated using the TRDF table values. These results are presented in Chapter 5. Two case study projects were used in these comparisons, and added-capacity project and a pavement overlay project. The first set of comparisons used the new fuel equations, discussed in Chapter 3, that were developed using ARFCOM with TRDF vehicle characteristics with the original fuel equations based on TRDF's original tabular values for fuel consumption. Next, the new ARFCOM fuel equations for the modern fleet were compared to the original fuel equations based on TRDF's original tabular values.

Chapter 2. USE OF THE ARFCOM COMPUTER PROGRAM TO MODEL U.S. VEHICLES

The AARB Road Fuel Consumption Model (ARFCOM)

The ARRB Road Fuel Consumption Model (ARFCOM) program was developed by David Biggs for the Australian Road Research Board (AARB). It was designed to provide a tool that could determine the amount of fuel consumed by various vehicles as they travel over a defined stretch of roadway. The goal was to create a program that would be able to assist highway planners in choosing alternatives that would minimize user fuel usage thereby saving both energy and reducing pollution. The first version was completed in 1988 and version 2.03 was released in May, 1993.

The ARFCOM Model is a detailed, power-based model suitable for use in the areas of traffic and transport management. It is similar to engine-map based models in that it includes detailed calculations of the components that contribute to fuel consumption. It has the advantage, however, of requiring only a small number of easily obtainable vehicle parameters. Model documentation includes discussion of relationships that can be used for calculating other model input parameters, if they are not known. [Biggs, p. 1] ARFCOM is comprised of three sub-models: (1) an instantaneous model; (2) a four mode elemental model; and (3) a running speed model. The ARFCOM documentation report gives the basic form of the instantaneous model, and the four mode elemental model and running forms of the model are described.

The instantaneous form of ARFCOM takes into account rolling resistance, aerodynamic resistance, inertial and grade forces, cornering resistance, drive-line efficiency, power for vehicle accessories, engine drag efficiency, negative tractive power and engine motoring, idle fuel consumption rate, and estimation of engine speed.

ARFCOM has a four-mode elemental submodel that uses a set of functions to estimate fuel consumption for each of four modes of driving: acceleration, cruise, deceleration, idling. It is suitable for estimating fuel consumption when: (1) a trip can be divided into distinct modes of driving; where initial and final acceleration and deceleration speeds, cruise speeds, and idle time are known; and (2) the cruise speed, number of stops, and idle time are known. One advantage of ARFCOM is that it has been extensively validated in two ways, by comparing the results with values predicted by three detailed engine map-based models and by comparing predictions with measured on-road data from several sources [Biggs, p. 12].

ARFCOM was designed with a great deal of flexibility built into it. It is able to provide either very accurate results by providing enough user-definable variables to model the proposed situation in great detail or to provide excellent estimated results with the specification of just a few key variables. The major categories of input variables

are of two types: Those that are used to define the vehicle fleet for which estimates are to be produced and those that define the environment in which the vehicles operate.

The specification of the vehicle fleet is made relatively simple for the user. The program includes three default vehicle files which provide information that can be used to specify vehicles circa 1985 in both developing and developed countries and also vehicles from around 1987-88 in developed countries. These default files form the basis of the data used by ARFCOM and, as such, are used to fill in any gaps in the information that is supplied by the user. This happens almost transparently to the user and makes it very difficult not to get fairly acceptable results with even the minimal amount of user-supplied information.

The user must supply, at a minimum, vehicle information to calibrate ARFCOM to the user's particular circumstances. This is accomplished by filling-in the blanks of the supplied input file template with the appropriate information using a text editor of the user's choosing. The input file provides three different methods for specifying the vehicles that are representative of the user's environment. The user is thus able to alter the operating characteristics of the vehicles to be simulated by the computer by providing new values for any of the available variables.

The first input option requires at least nine user-supplied variable values in order to produce results that represent the user's specific vehicle mix. In addition, it allows the user to further specify any or all of the available optional variables in order to make the input vehicles as specific or general as desired. The minimum required variables for vehicle specification are presented in Table 2-1 while the additional optional variables are presented in Table 2-2. This input option can produce very accurate results, but most users will probably discover a number of the optional variables are very difficult to obtain and they may not produce substantially more accurate results.

The second method for specifying vehicles for ARFCOM's use can only be used for automobiles. The required variables for this type of vehicle definition include: volume of this type of vehicle, mass of the vehicle, the vehicle's idle fuel usage rate or engine capacity, rolling and aerodynamic drag coefficients, and two energy efficiency parameters. These variables should provide a very accurate basis from which ARFCOM can estimate the automobile's fuel consumption. This option is limited, however since it only works for cars and some of the required input variables are, like some of those in the first input option, difficult to determine for most users.

The final method for defining vehicles for use in ARFCOM calculations is to utilize the default vehicle classes which are included with the program and modify them slightly in order to optimize the match with the actual vehicles using the facility under investigation. This is the easiest method for specifying an actual mix of vehicles using a

Table 2-1. Minimum Required ARFCOM Vehicle Parameters

Variable	Units [Range]
Vehicle Description	
Volume of Vehicle Type	[1 - 10,000]
Total Mass of Vehicle	Kg or metric tonne [0.5 - 100,000]
Number of Wheels (tires)	[4 - 66]
Fuel Type	**Petrol or Diesel**
Maximum Engine Power (or capacity)	kW or L [0.5 - 500]
Aerodynamic Drag Coefficient	C_d [0.3 - 2.0]
Frontal Area	m^2 [1 - 20]
Tire Type Factor	[0.5 - 2.0]

Table 2-2. Optional ARFCOM Vehicle Parameters

Maximum Gross Rated Mass
Tyre Radius
Number of Gears
Maximum Speed or Top Gear Ratio
Wheel Mass
Rolling Resistance
Accessory Constant
Drive-Train Efficiency
Radius of Gyration
Cornering Stiffness
Maximum Engine Speed
Idle Engine speed
Engine Efficiency
Idle Fuel Rate
Engine Drag Parameter
Engine Motoring Fuel Cut-off

given facility since it requires the least number of difficult to determine vehicle specific variables. The required inputs for this vehicle class definition method are presented in Table 2-3.

ARFCOM provides for very accurate motor vehicle specification. Vehicle representation is only one part of this program's function, however. Once the vehicles have been defined, the program must know exactly what kind of environment they are going to be operated in and the geometry of the roadway segment over which the vehicles are to be simulated. The program user is able to precisely define the geometry of the road segment over which the simulation is to be performed as well as some of the environmental factors that may be affecting vehicles in that area. (The program allows for the specification of prevailing wind speed and direction.)

Table 2-3. ARFCOM Vehicle Class Input Variables

Variable	Units [Range]
Class Number	[0 - 10]
Class Description	
Volume of Vehicles in Class or Type of Environment	[0 - 10,000] or [0 - 100%] or [Urban - Rural]
Laden Mass	kg or metric tonne [0.5 - 100,000]
Unladen Mass	kg or metric tonne [0.5 - 60,000]
Percent of Vehicles Laden	[0 - 100]
Maximum Engine Power (or capacity)	kW or L [0.5 - 500]
Number of Wheels (tires)	[4 - 66]
Tire Type Factor	[0.5 - 2.0]
Frontal Area	m^2 [1 - 20]
Aerodynamic Drag Coefficient	C_d [0.3 - 2.0]
Percent of Vehicles Using Diesel Fuel	[0 - 100]
Total Volume	[1 - 100,000] required for %

As with the vehicle specification aspect of the program, ARFCOM users are presented with several methods for providing roadway geometry data ranging from the very simple and general to highly detailed and specific. The most detailed method of data entry is to develop a separate data file that contains instantaneous speed and geometry data collected in set intervals over the specified roadway.

The easiest roadway definition type is the specification of running and average travel speed data. This definition type can be used for straight sections of roadway and require only the distance of the segment, total travel time, idle time, average and running speeds, average grade of the segment, speed fluctuation factors, and the road roughness factor. This ability makes ARFCOM valuable for comparing the difference in user fuel costs for various construction or remodeling options.

Use of ARFCOM for TRDF Vehicles

In order to evaluate ARFCOM's potential, the program's output had to be evaluated to determine if it produces results that are consistent with information that is already available. Then the program needed to be calibrated for use with present day vehicles. Finally, the flexibility of the program needed to be tested in order to determine its long-life feasibility for dealing with future technologies. To accomplish these three goals three major runs of ARFCOM were performed. The first was an attempt to compare ARFCOM's estimation of the consumption values that were presented in previous fuel consumption research by TRDF.

One of the major objectives of this research was compare ARFCOM results using vehicles with the same characteristics as the TRDF representative vehicles to TRDF's reported values. These results of using ARFCOM to model vehicles with the same characteristics as TRDF's representative vehicles are discussed in Chapter 3.

Use of ARFCOM for Today's Vehicles

A valuable use of the ARFCOM program involves the development of characteristic fuel consumption data for the vehicles that populate America's roadways today. Information from R. L. Polk and Co. presented in Oak Ridge National Laboratory's *Transportation Energy Data Book* (Edition 12, March, 1992, p. 3-19) indicates that the average age of motor vehicles on the road today is about 7.8 years old and the median age is approximately 6.5 years old. In order to account for the age of the present day motor vehicle fleet, typical vehicle characteristics were developed for vehicles of the late 1980s, which is about the same as median-aged vehicles in the current 1994 fleet. The use of ARFCOM to model today's vehicles is discussed in Chapter 4.

Heavy truck data tends to be very difficult to find because virtually every heavy truck is made to the customer's specifications. Customers have a wide range of choices when purchasing a truck including type of engine (e.g., Detroit Diesel, Cummins, Caterpillar, Mack), type of transmission (e.g., Allison), type of axle (e.g., Spicer, Rockwell), and numerous brands and types of tires. Each of these choices is further complicated by numerous options available on each model of engine, transmission, or rear axle. For example the Detroit Diesel Series 60 electronic engine is available in 11.1 Liter or 12.7 Liter versions. Furthermore, each version of the Series 60 is available in a wide range of horsepower ratings designed to meet the specific needs of the purchaser of the vehicle. Due to this virtually unlimited set of options, it is much more difficult to determine the characteristics for representative heavy trucks. Our specifications used in this report represent gradually improving characteristics such as wind resistance and slightly less horsepower to perform the same job due to improved engine efficiency. The characteristics used to represent the present road going truck fleet are presented in Chapter 4.

Chapter 3. ARFCOM RESULTS FOR TRDF VEHICLES

Characterization of TRDF Vehicles

The TRDF study classifies the highway fleet into eight different vehicle types. These vehicle types include three passenger vehicles, one pick-up and four trucks. In order to use ARFCOM to obtain the fuel consumption estimates, the vehicle characteristics presented in the TRDF report must be specified in a format that is required by ARFCOM. This entails converting the English units given in the TRDF report to the metric units and getting the necessary inputs in ARFCOM, such as the drag coefficients and maximum engine power, for each vehicle type.

Table 3-1 gives the TRDF vehicle types and their characteristics. Small, medium and large vehicle types represent small, medium and large passenger vehicles. Pickup refers to pickup trucks. 2axle and 3axle vehicle types represent two-axle single unit trucks (SU-2A) and three-axle single unit trucks (SU-3A), respectively, while 4axle and 5axle are the vehicle types for four-axle semis (2-S2) and five-axle semis (3-S2).

Table 3-1. Characteristics of TRDF Vehicles

Vehicle Type	Mass (kg)	No. of Wheels	Maximum Power (kW)	Drag Coefficient	Frontal Area (m^2)	Tire Type Factor
Small	1270	4	84	0.48	2.2	1.00
Medium	1720	4	100	0.50	2.6	1.00
Large	2130	4	130	0.52	2.8	1.00
Pickup	2270	4	100	0.55	2.9	1.00
2axle	5440	6	130	0.70	3.4	1.30
3axle	15880	10	170	0.75	5.1	1.30
4axle	18140	14	260	0.80	8.4	1.30
5axle	28350	18	260	0.81	8.4	1.30

Simulation Results

The vehicle parameters given in the Table 3-1 were used in the simulations using ARFCOM to obtain the effects of constant speed, grade and pavement roughness on fuel consumption. We also varied the weights of the 2-, 3-, 4-, and 5-axle trucks to study their effects on fuel consumption. The default data set DEFV01 in ARFCOM was used in the simulations. This data set is included in Appendix M.

The constant speed values range from 5 to 70 mph, inclusive, with a 5 mph increment. The grade values are integer numbers from -8 to 8 percent. The PSI values range from 1.0 to 5.0, inclusive, with a 0.5 increment.

Table 3-2 illustrates the fuel consumption results that we obtained using ARFCOM for the TRDF vehicles at various constant speeds and on pavement with 0 percent grade. We put a dash, '-', in the table whenever a vehicle is incapable of traveling at the specified constant speed and grade level. The complete fuel consumption results for the TRDF vehicles on all grade levels are given in Appendix B. All of these results were obtained by using a PSI values of 3.5

The results in Table 3-2 are depicted graphically in Figure 3-1. We observe from the graph that passenger vehicles and pickup consume fuel in basically the same pattern. Except for the two-axle truck, the heavy trucks also share a similar pattern in fuel consumption.

Table 3-3 shows the fuel consumption results that we obtained using ARFCOM for the TRDF 5-axle trucks of various weights and on 0 percent grade. Figure 3-2 shows the graph of these results. We observe from the graph that weight has no effect on the overall pattern of fuel consumption. However, as expected, the heavier the truck the more fuel it consumes.

The complete fuel consumption results for the TRDF trucks of various weights and on all grade levels are given in Appendix C.

Table 3-4 shows the fuel consumption results that we obtained using ARFCOM for the TRDF vehicles at various constant speeds and with a PSI value of 3.0. In Figures 3-3 and 3-4, we graphed the fuel consumption estimates for TRDF medium passenger vehicles and 5-axle trucks, respectively, at all PSI values to study the effect of pavement roughness on fuel consumption. The graphs show, as expected,that vehicles consume more fuel as pavement roughness increases.

The complete fuel consumption results for the TRDF vehicles at all PSI values are given in Appendix D. All of these results were obtained at 0 percent grade.

Table 3-2. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 0 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	104.17	62.07	49.74	45.07	43.37	43.37	33.16	35.71	38.69	42.52	46.77	51.45	56.55	62.50
Medium	122.45	73.13	58.67	53.15	51.02	51.45	39.54	42.52	46.34	50.60	55.27	61.22	67.18	74.40
Large	154.34	91.84	73.13	65.90	63.35	63.35	46.34	49.74	53.57	58.25	63.35	69.30	76.11	83.76
Pickup	151.36	75.68	61.22	55.70	54.42	55.27	44.64	48.47	53.15	58.67	64.63	71.43	79.51	88.01
2axle	239.37	119.90	91.41	83.76	81.63	82.06	82.06	89.29	97.79	107.57	118.62	130.95	143.28	149.66
3axle	170.07	119.47	105.02	100.34	99.49	101.62	105.44	110.54	104.17	113.52	124.15	136.05	148.81	157.74
4axle	229.17	156.04	135.63	128.83	127.98	131.38	137.76	146.26	134.35	148.38	164.54	182.40	202.81	220.24
5axle	263.18	188.78	167.52	160.71	160.29	164.12	170.92	179.85	165.39	180.70	197.70	216.84	238.10	-

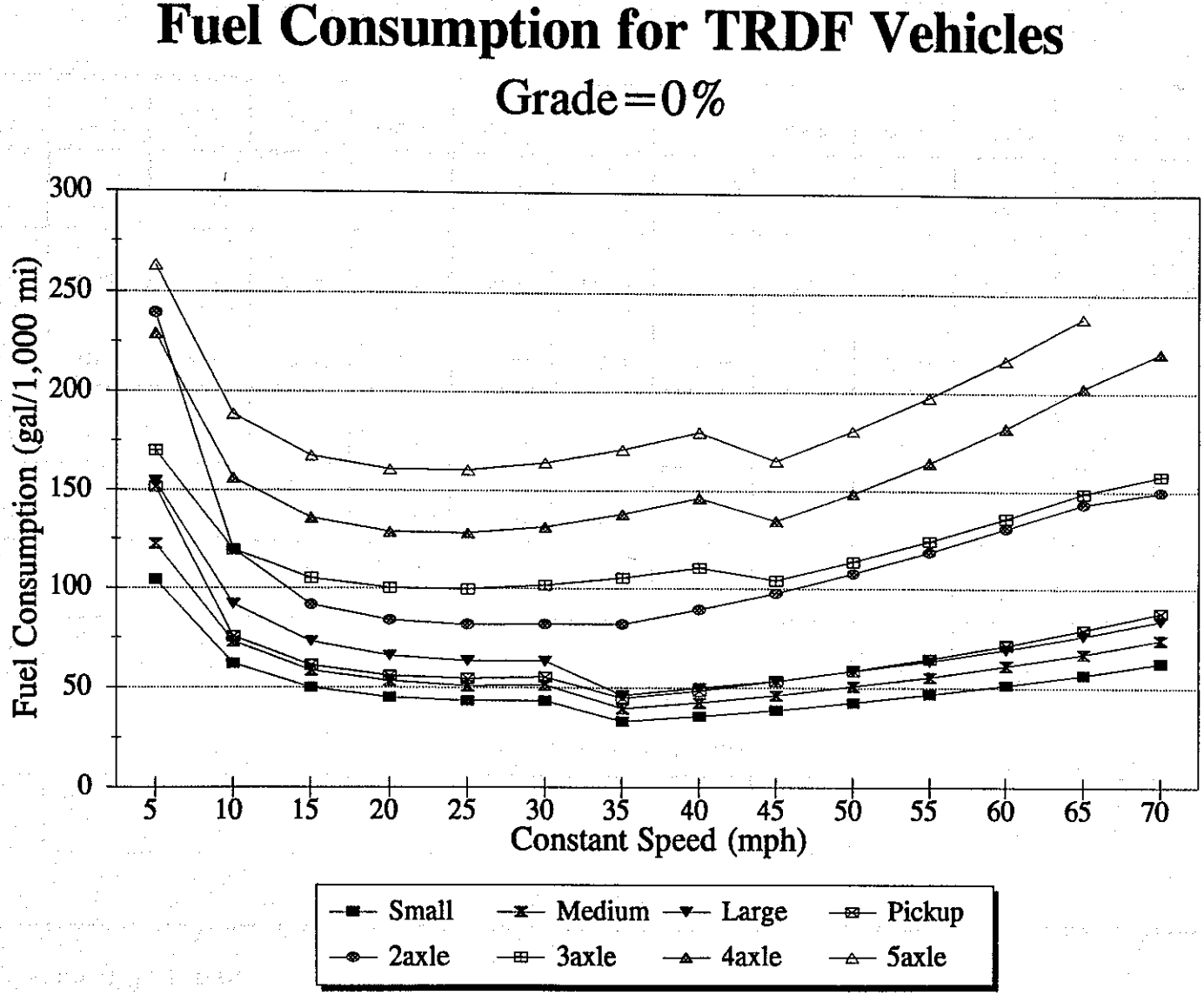

Figure 3-1. Constant Speed Fuel Consumption Estimates Using ARFCOM for TRDF Vehicle on Pavement with 0 Percent Grade

Table 3-3. Fuel Consumption (gallons/1,000 miles) for TRDF 5-Axle Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	221.51	234.27	247.02	259.78	272.53	285.29
10	148.81	161.14	173.47	185.80	198.13	210.46
15	128.40	140.31	152.64	164.54	176.87	189.20
20	121.60	133.50	145.83	157.74	170.07	181.97
25	121.17	133.50	145.41	157.31	169.64	181.55
30	125.00	136.90	148.81	161.14	173.04	185.37
35	131.38	143.28	155.61	167.52	179.85	192.18
40	139.88	152.21	164.54	176.87	189.20	201.53
45	128.83	139.88	151.36	162.84	173.89	186.22
50	143.28	154.76	166.24	177.72	189.63	201.96
55	159.86	171.34	183.25	194.73	206.63	219.39
60	177.72	189.63	201.96	213.86	226.19	238.95
65	198.13	210.46	222.79	235.12	247.45	-
70	216.41	228.74	241.50	-	-	-

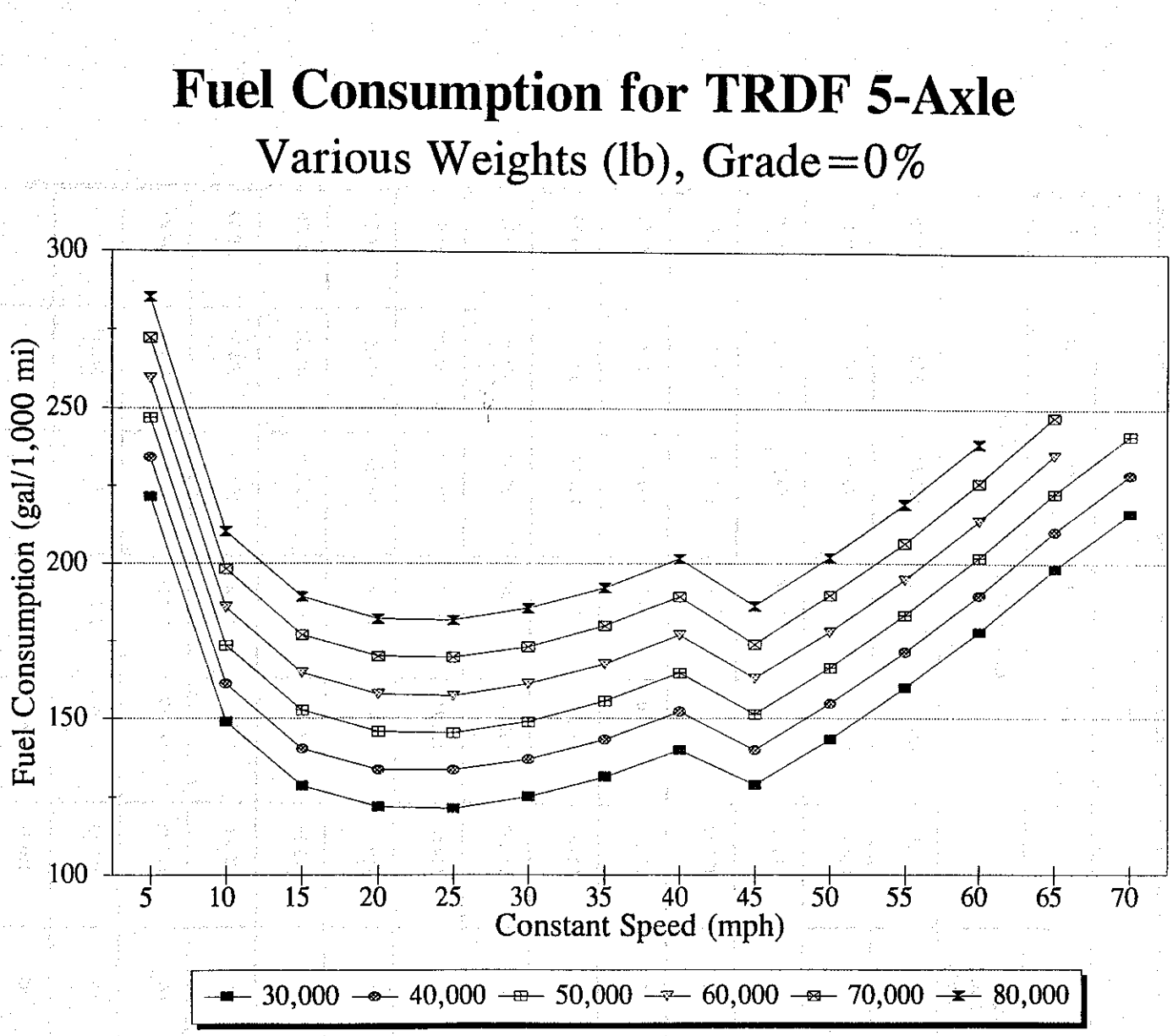

Figure 3-2. Constant Speed Fuel Consumption Estimates Using ARFCOM for TRDF 5-Axle Trucks of Various Weights on Pavement with 0 Percent Grade

Table 3-4. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 3.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	104.17	62.07	49.74	45.07	43.37	43.37	33.16	35.71	38.69	42.52	46.77	51.45	56.55	62.50
Medium	122.45	73.13	58.67	53.15	51.45	51.45	39.54	42.52	46.34	50.60	55.70	61.22	67.18	74.40
Large	154.76	91.84	73.13	65.90	63.35	63.35	46.34	49.74	53.57	58.25	63.35	69.30	76.11	83.76
Pickup	151.36	75.68	61.22	56.12	54.42	55.27	45.07	48.47	53.15	58.67	64.63	71.85	79.51	88.01
2axle	239.37	119.90	91.41	84.18	81.63	82.48	82.06	89.29	97.79	107.57	118.62	130.95	143.71	149.66
3axle	170.49	119.90	105.44	100.34	99.91	101.62	105.44	110.97	104.17	113.95	124.57	136.05	149.23	157.74
4axle	229.59	156.46	135.63	128.83	128.40	131.80	138.18	146.68	134.35	148.81	164.97	182.82	202.81	220.66
5axle	263.18	189.20	167.94	161.14	160.71	164.54	170.92	180.27	165.82	181.12	198.13	217.26	238.52	-

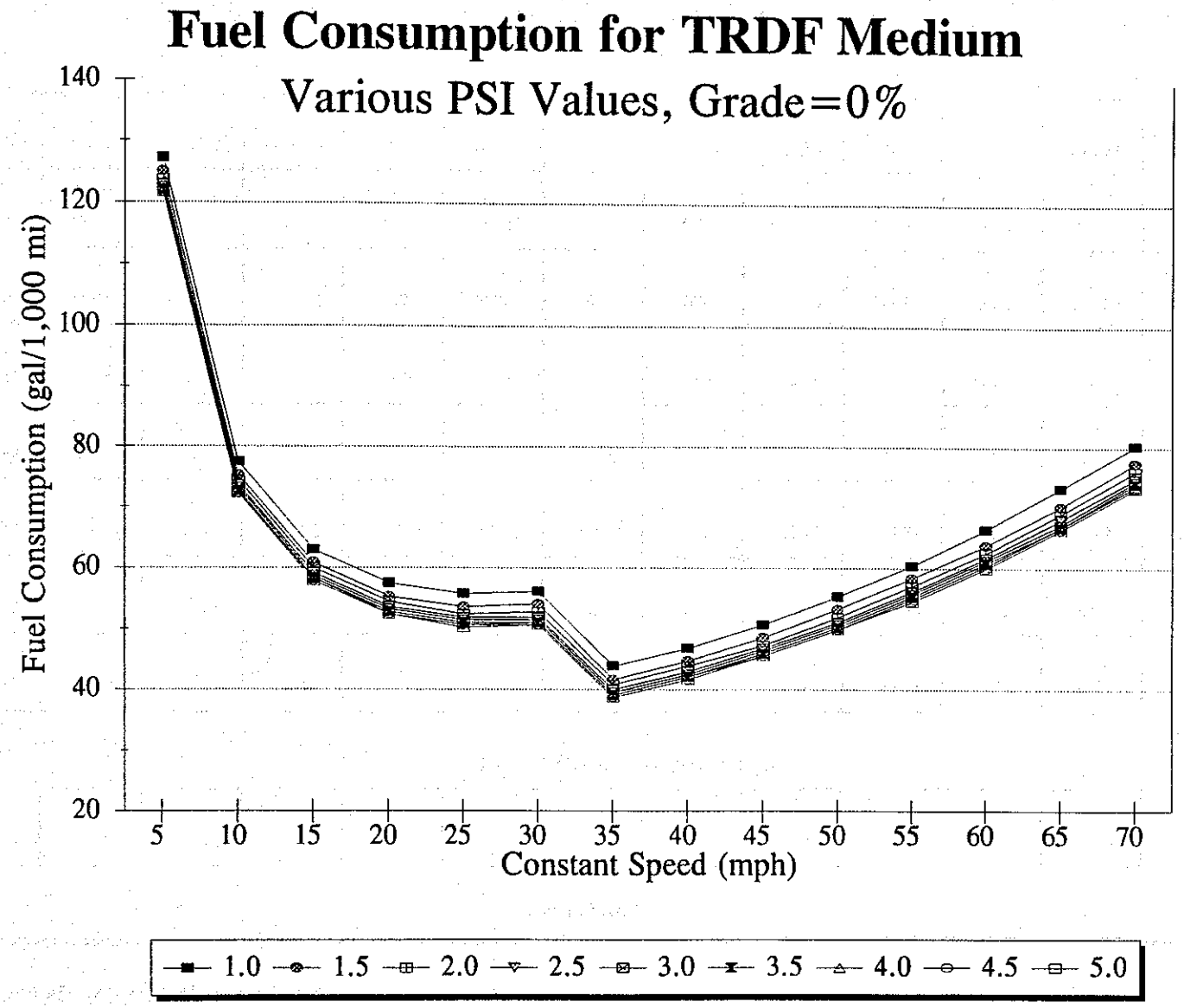

Figure 3-3. Constant Speed Fuel Consumption for TRDF Medium Passenger Vehicles at Various PSI Values

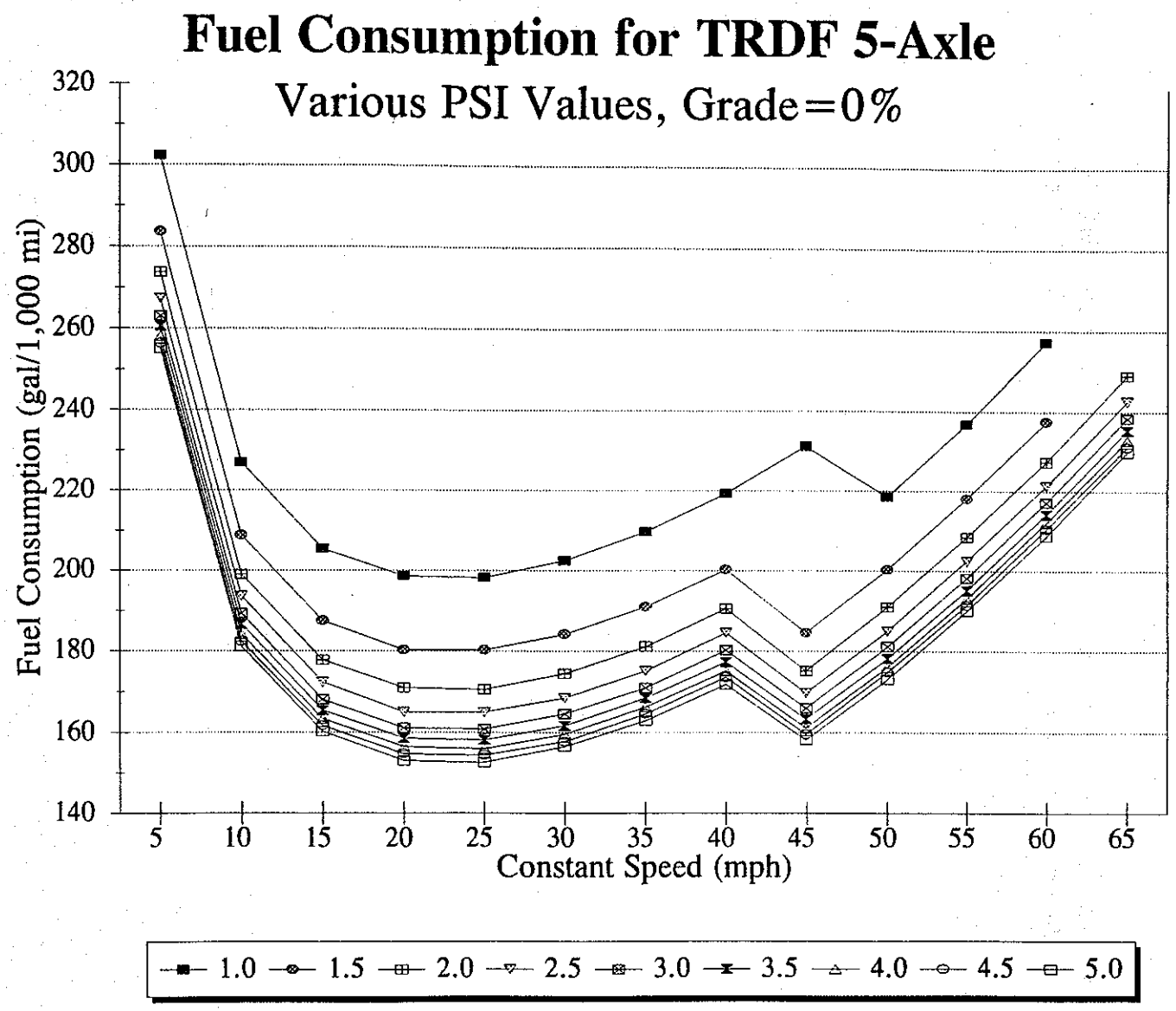

Figure 3-4. Constant Speed Fuel Consumption for TRDF 5-Axle Trucks at Various PSI Values

Comparison Between ARFCOM AND TRDF Results

Significant differences were found between the fuel consumption results for the TRDF vehicles that were obtained using ARFCOM and those developed by TRDF. The graphs in Figures 3-5 through 3-12 compare the discrepancies in the constant speed fuel consumption between TRDF and ARFCOM results for TRDF small passenger vehicles. These comparisons are made at 0 percent grade.

It can be observed from these graphs that for passenger vehicles, TRDF's estimates for the fuel consumption are consistently lower than ARFCOM's. On the other hand, the TRDF fuel consumption estimates for the heavy trucks tend to be higher at most constant speeds. For pickup trucks, the two estimates are in close agreement except at the minimum speed of 5 mph.

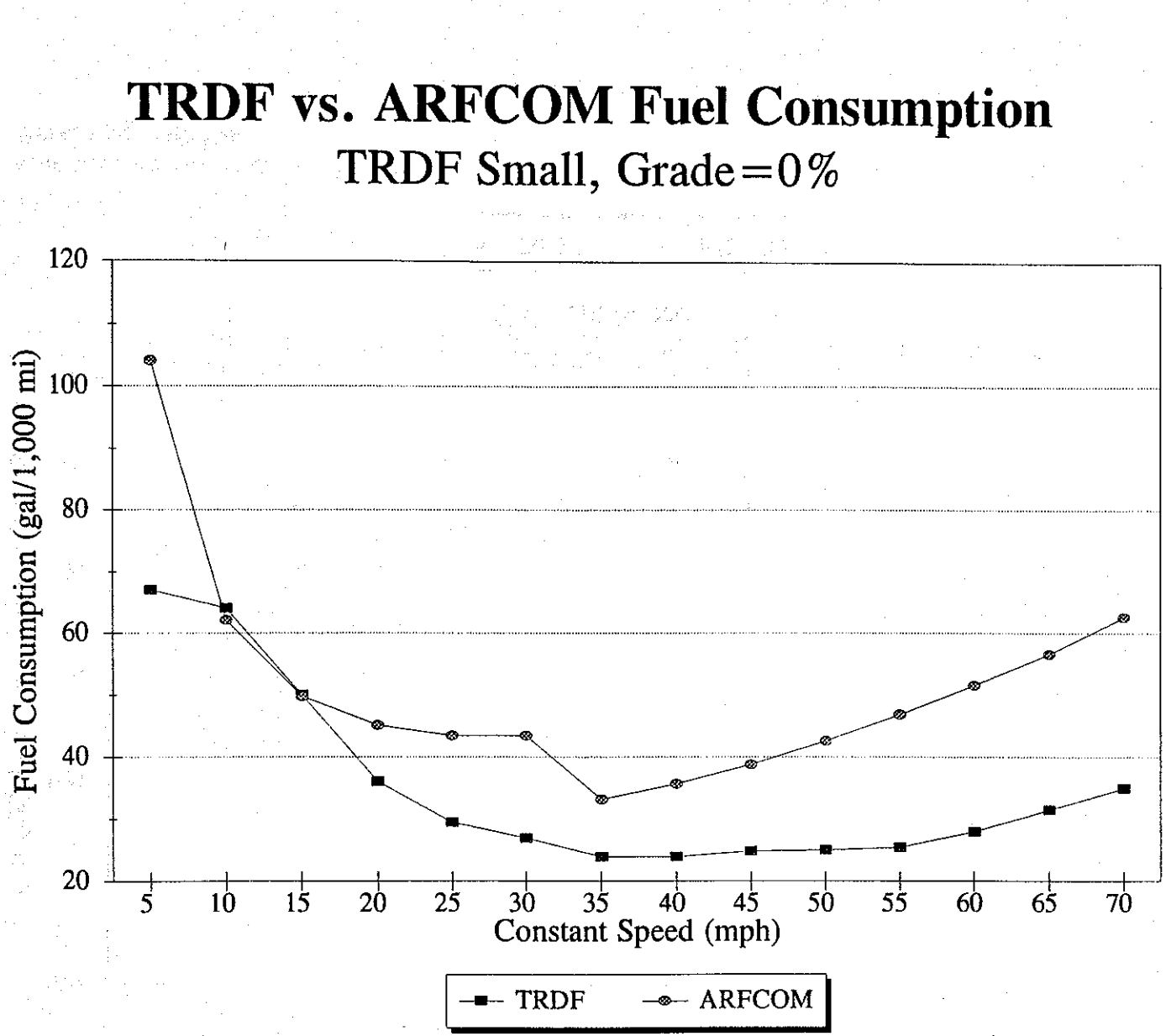

Figure 3-5. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF Small Passenger Vehicles

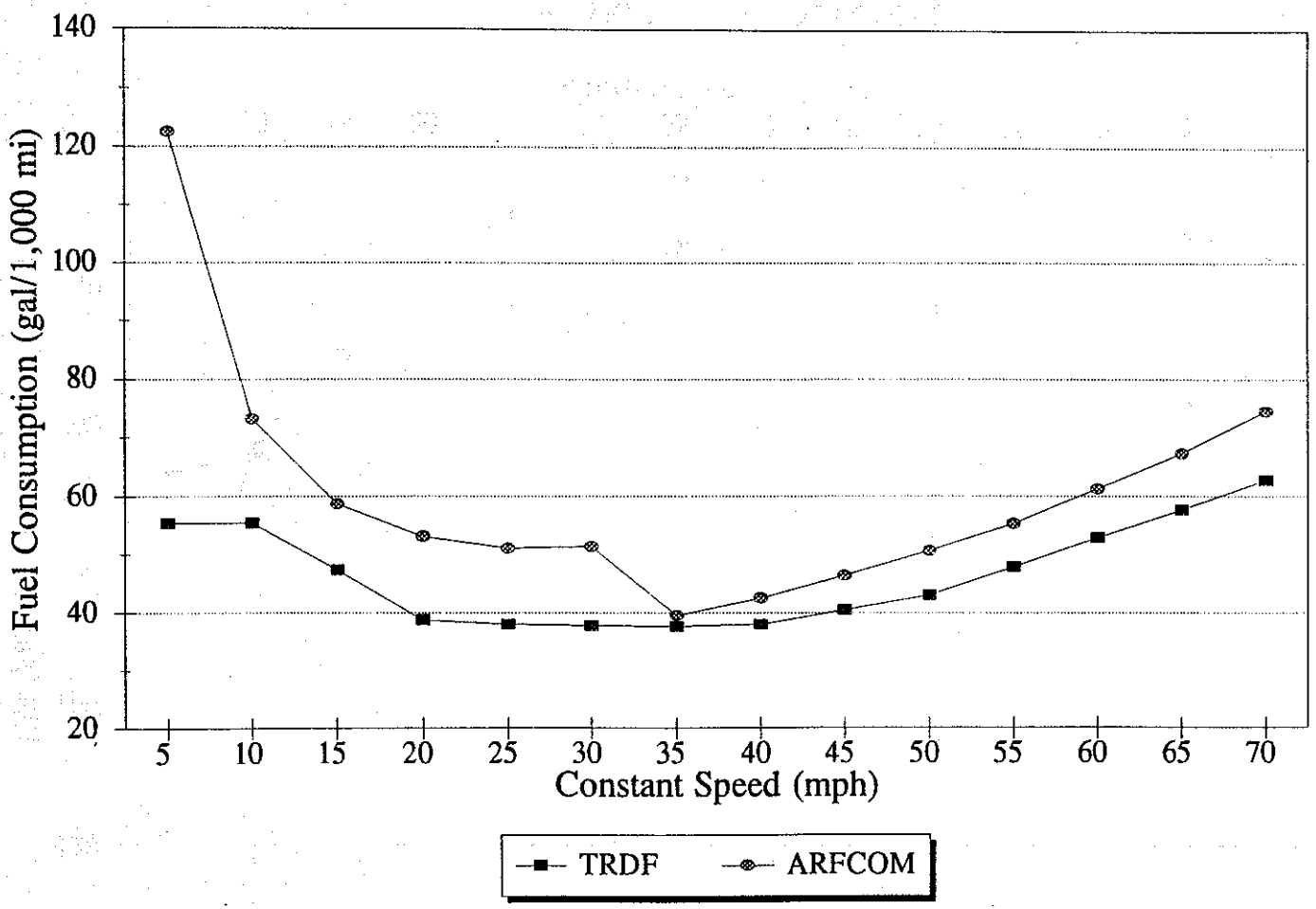

Figure 3-6. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF Medium Passenger Vehicles

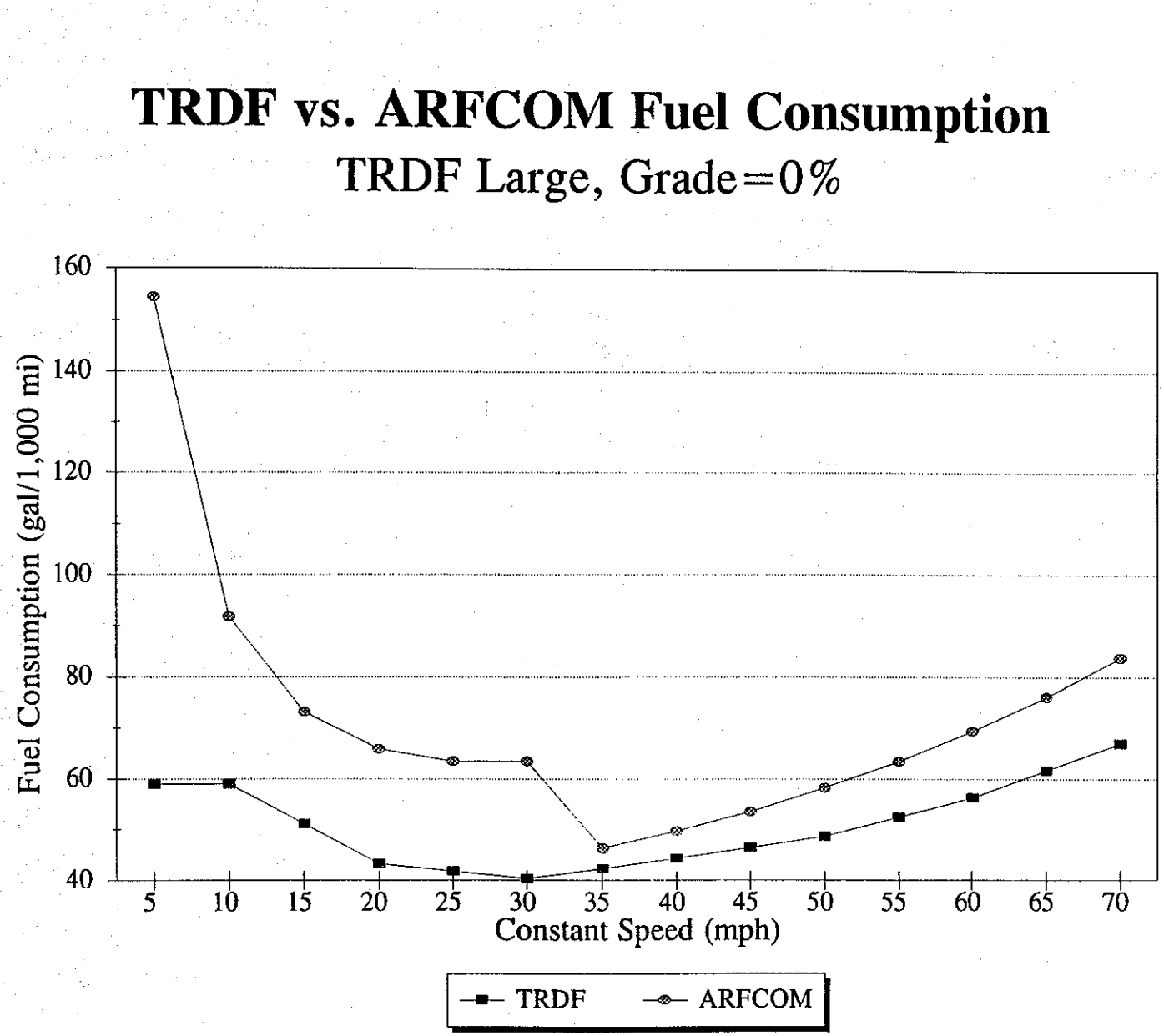

Figure 3-7. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF Large Passenger Vehicles

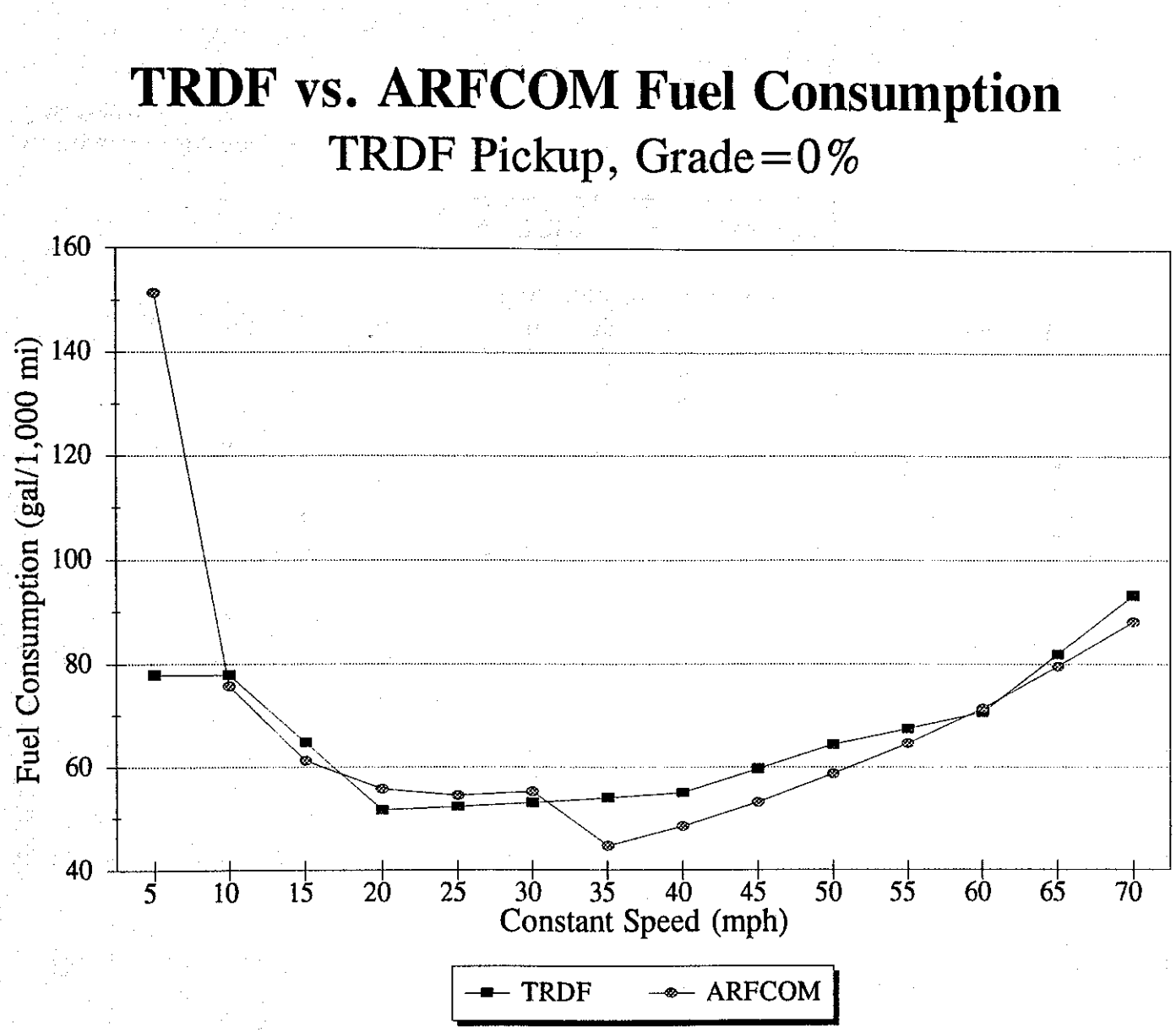

Figure 3-8. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF Pickup Trucks

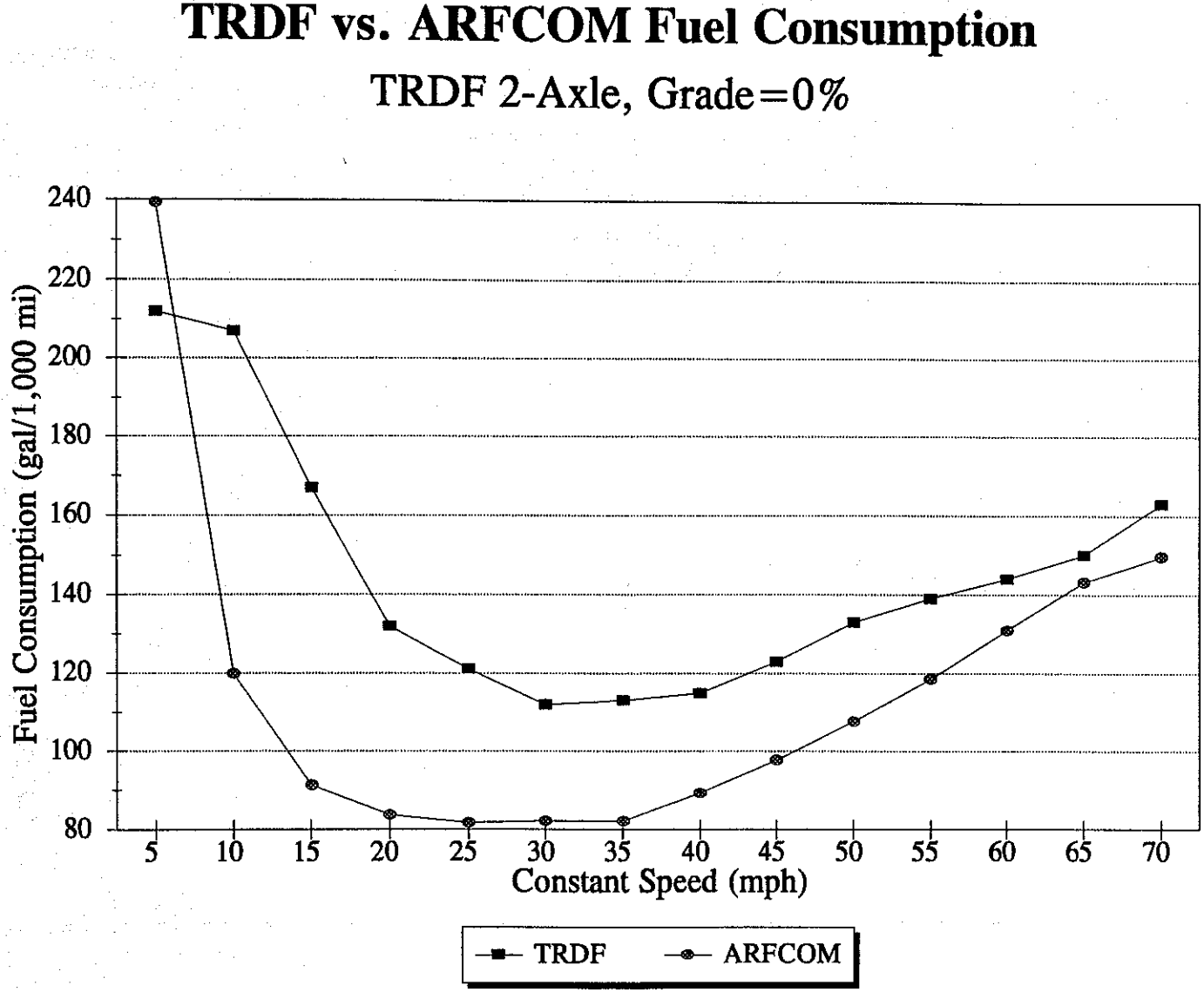

Figure 3-9. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF 2-Axle Trucks

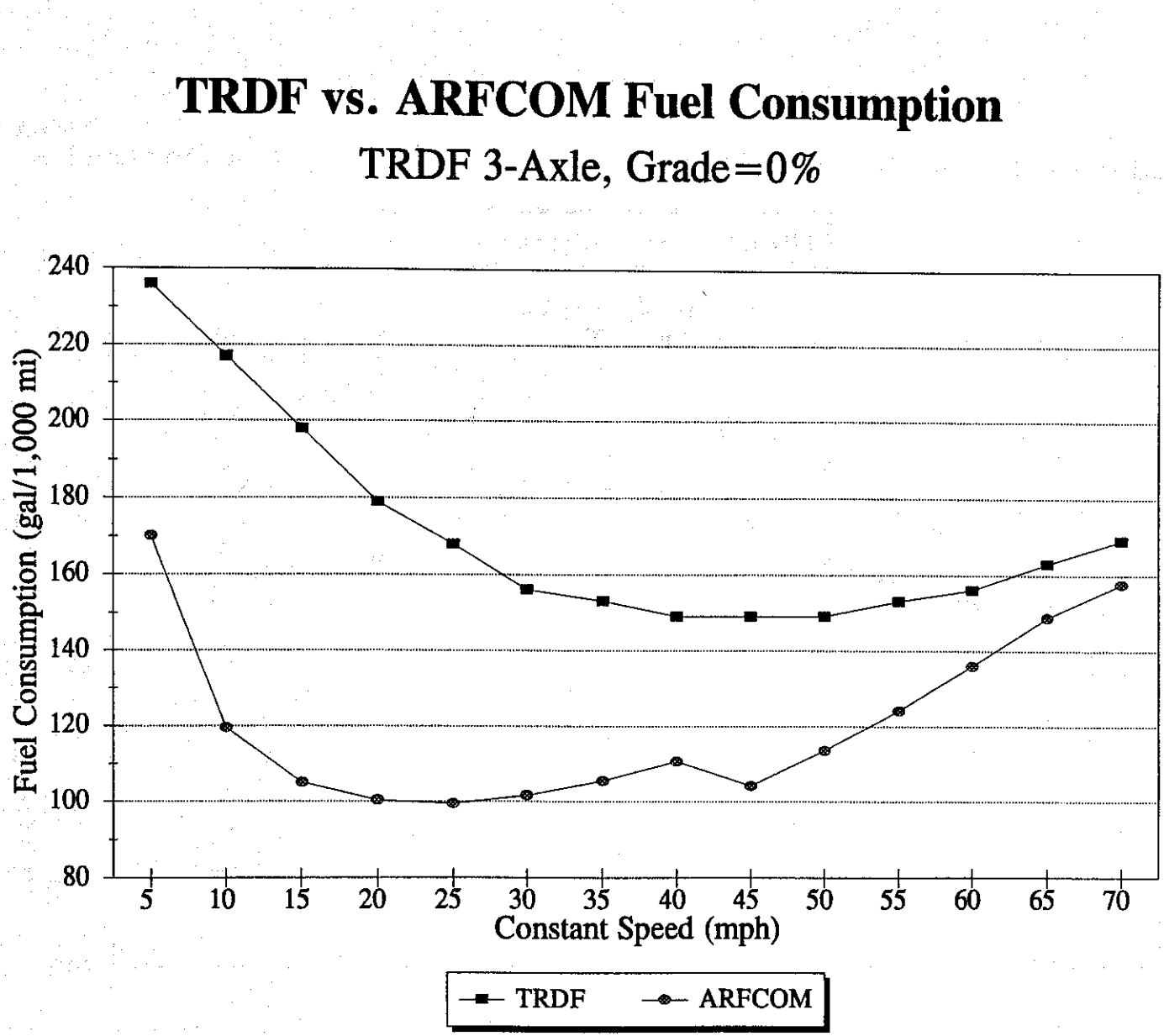

Figure 3-10. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF 3-Axle Trucks

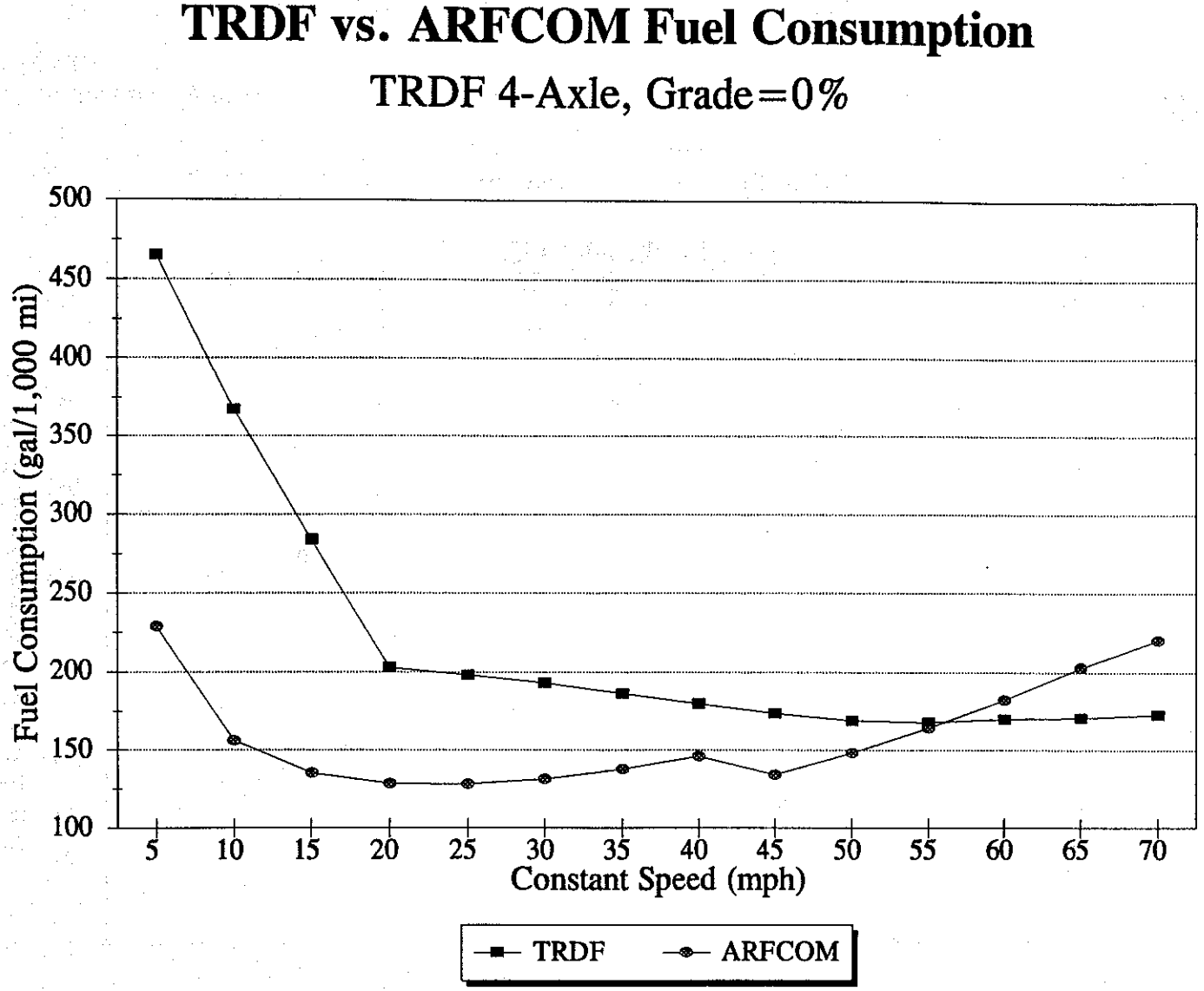

Figure 3-11. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF 4-Axle Trucks

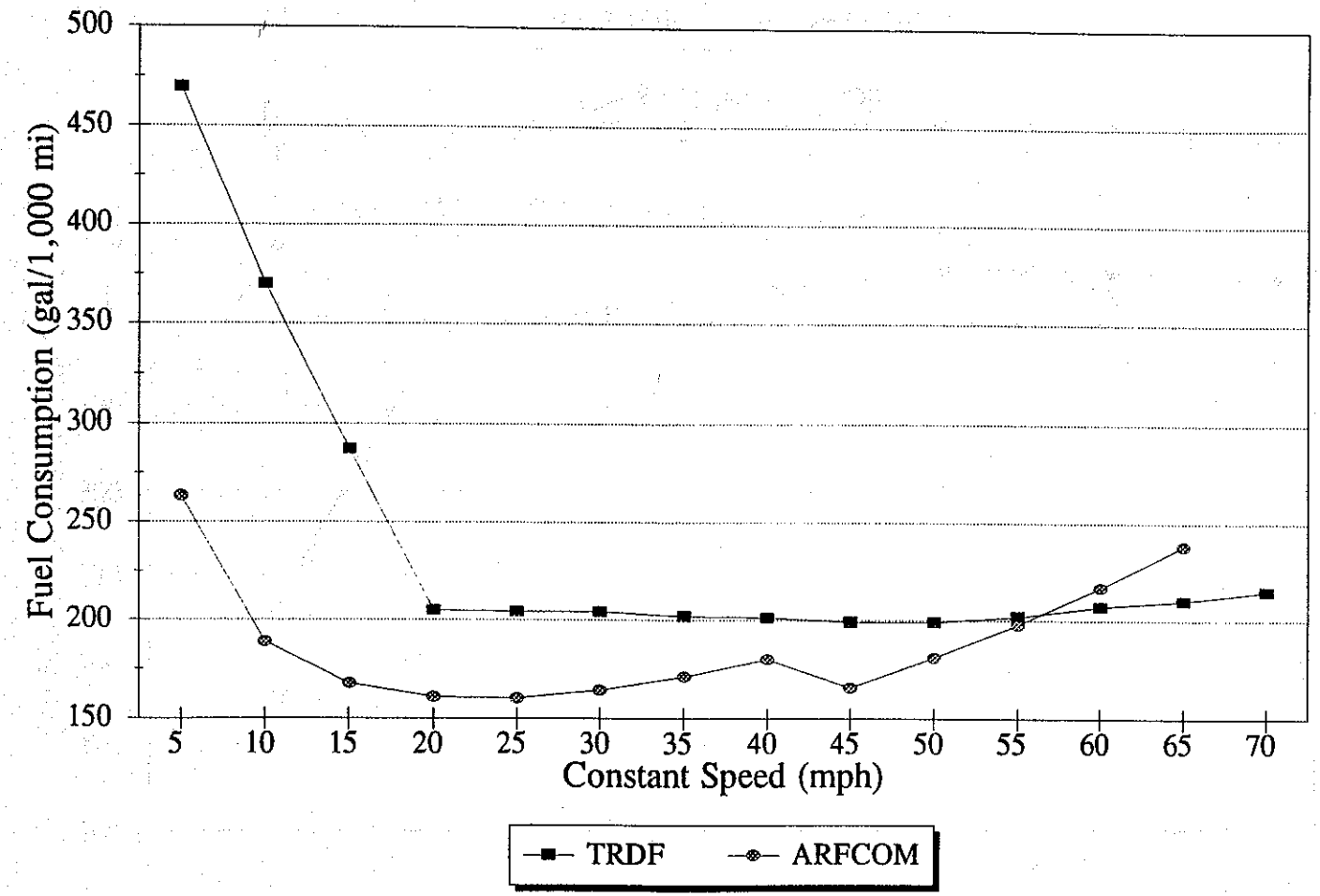

Figure 3-12. Comparison Between TRDF and ARFCOM Constant Speed Fuel Consumption Results for TRDF 5-Axle Trucks

Fuel Consumption Equations

By applying regression analysis to the fuel consumption results in Appendices B, C and D, equations are fitted to these values. Table 3-5 illustrates the coefficients of fuel consumption equations obtained from the regression analysis for TRDF small passenger vehicles at all grade levels. Figures 3-13 to 3-17 compare the fuel consumption estimates obtained from ARFCOM and the regression equations. As can be seen from these graphs, the fuel consumption values from the regression equations match the ARFCOM values quite satisfactorily in most cases. Appendix H contains the complete fuel consumption equations for TRDF vehicles.

Table 3-5. Coefficients of Fuel Consumption Equations for TRDF Small Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	$(Speed)^2$	Ln(Speed)	Grade	Ln(GVW)
Small	5	70	-8	Fuel	134.31743	1.49590	0.00000	-50.79023	0.00000	0.00000
Small	5	70	-4	Fuel	168.15972	1.87495	0.00000	-60.46021	0.00000	0.00000
Small	5	70	-3	Fuel	174.19197	1.88965	0.00000	-61.05491	0.00000	0.00000
Small	5	70	-2	Fuel	180.31475	1.90138	0.00000	-61.62588	0.00000	0.00000
Small	5	70	-1	Fuel	187.59589	1.92903	0.00000	-62.67653	0.00000	0.00000
Small	5	70	0	Fuel	193.84909	1.94530	0.00000	-63.28200	0.00000	0.00000
Small	5	70	1	Fuel	200.73828	1.96980	0.00000	-64.14712	0.00000	0.00000
Small	5	70	2	Fuel	206.56671	1.97605	0.00000	-64.50033	0.00000	0.00000
Small	5	70	3	Fuel	213.63824	2.00681	0.00000	-65.46145	0.00000	0.00000
Small	5	70	4	Fuel	213.13728	1.87655	0.00000	-62.07273	0.00000	0.00000
Small	5	65	8	Ln(Fuel)	5.96551	0.03013	-0.00006	-0.69730	0.00000	0.00000

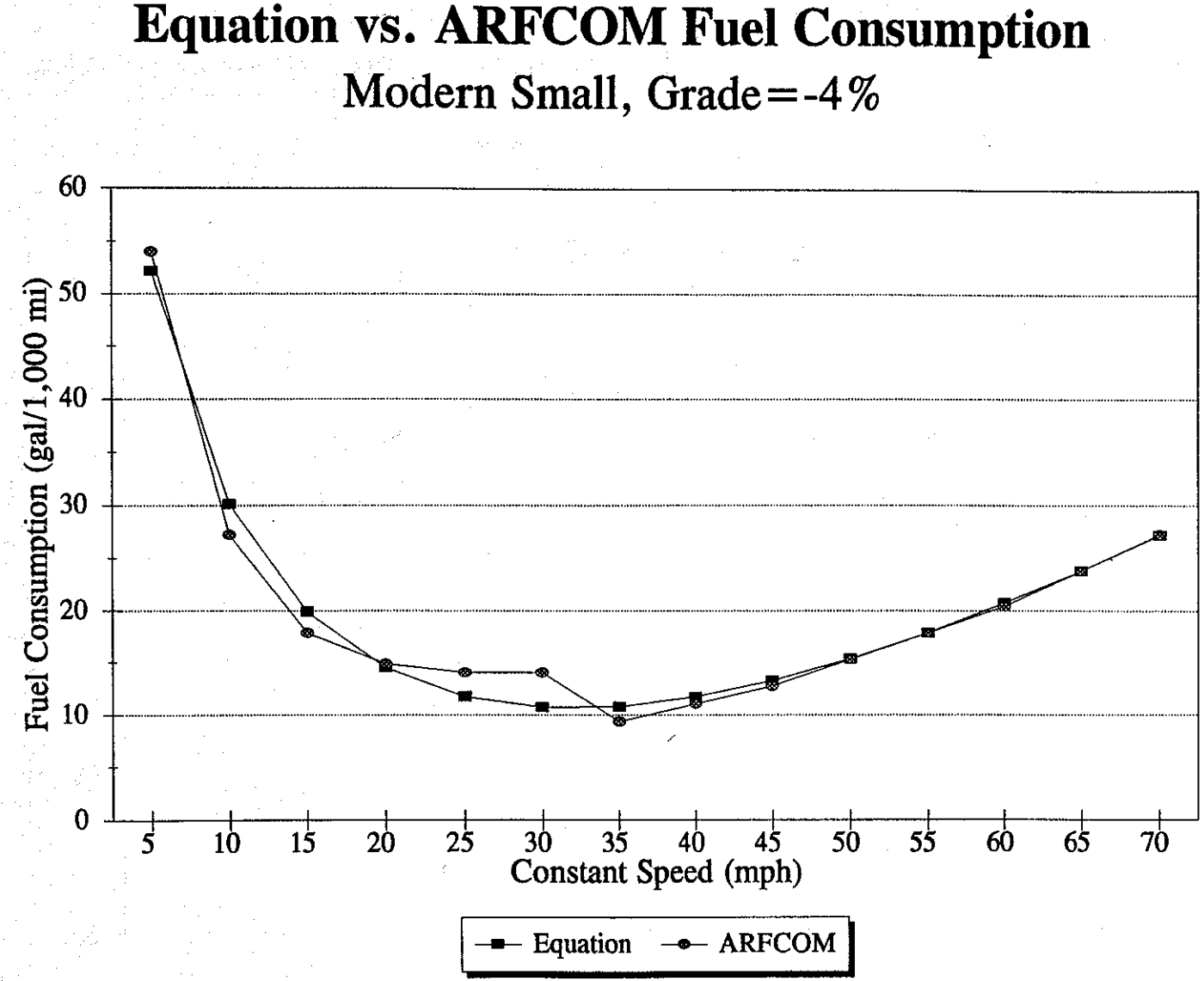

Figure 3-13. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for TRDF Small Passenger Vehicles on -4% Grade

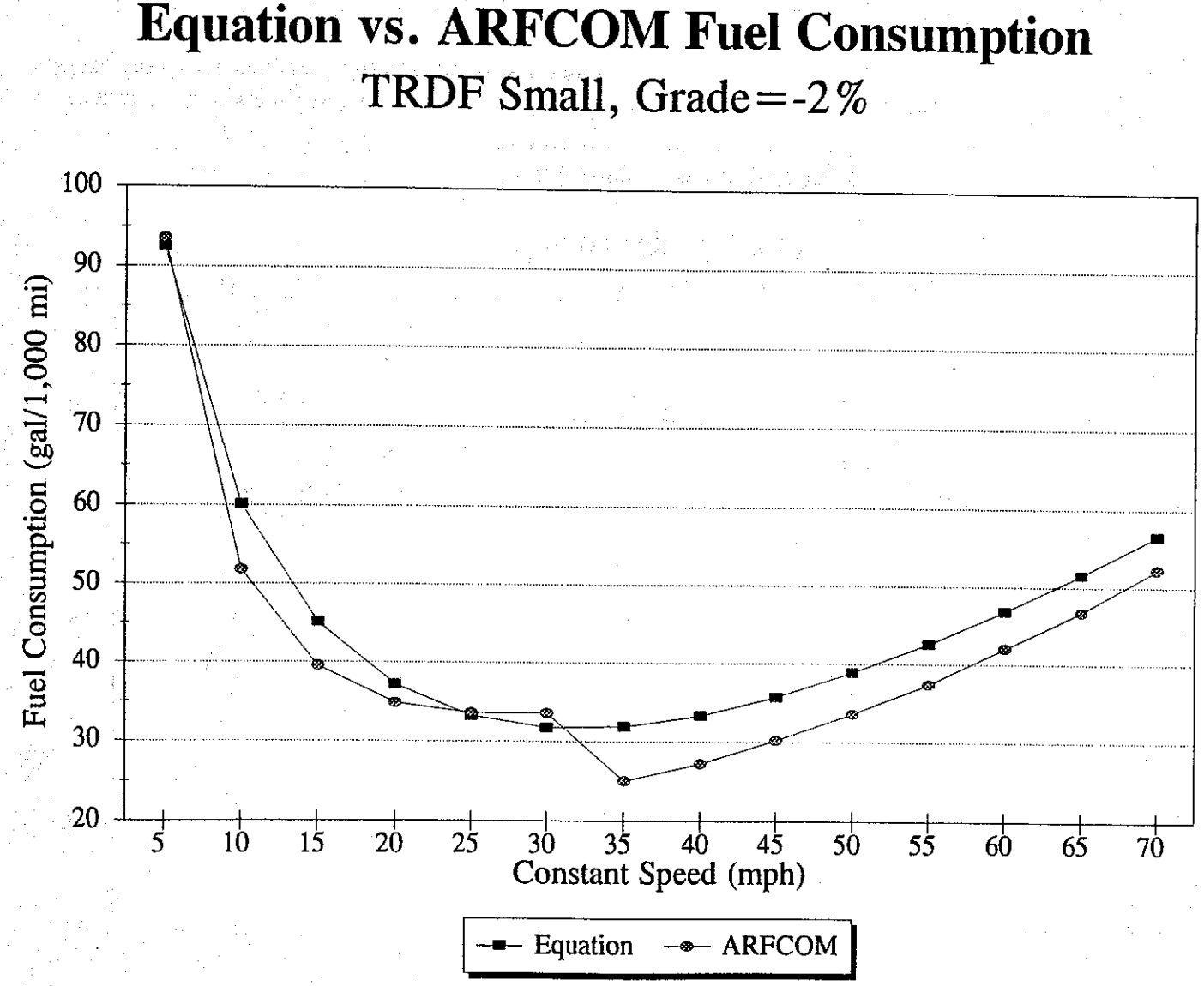

Figure 3-14. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for TRDF Small Passenger Vehicles on -2% Grade

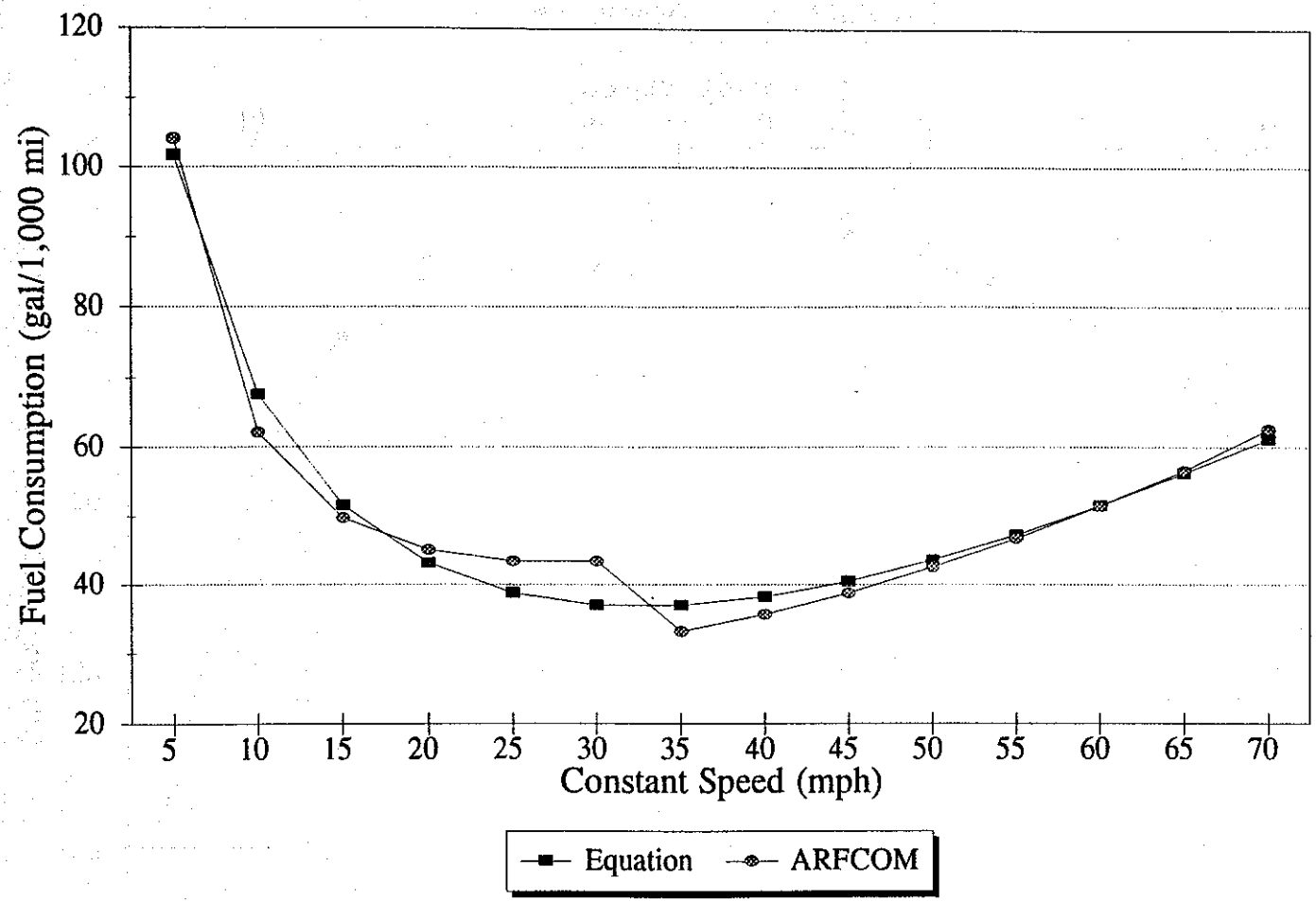

Figure 3-15. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for TRDF Small Passenger Vehicles on 0% Grade

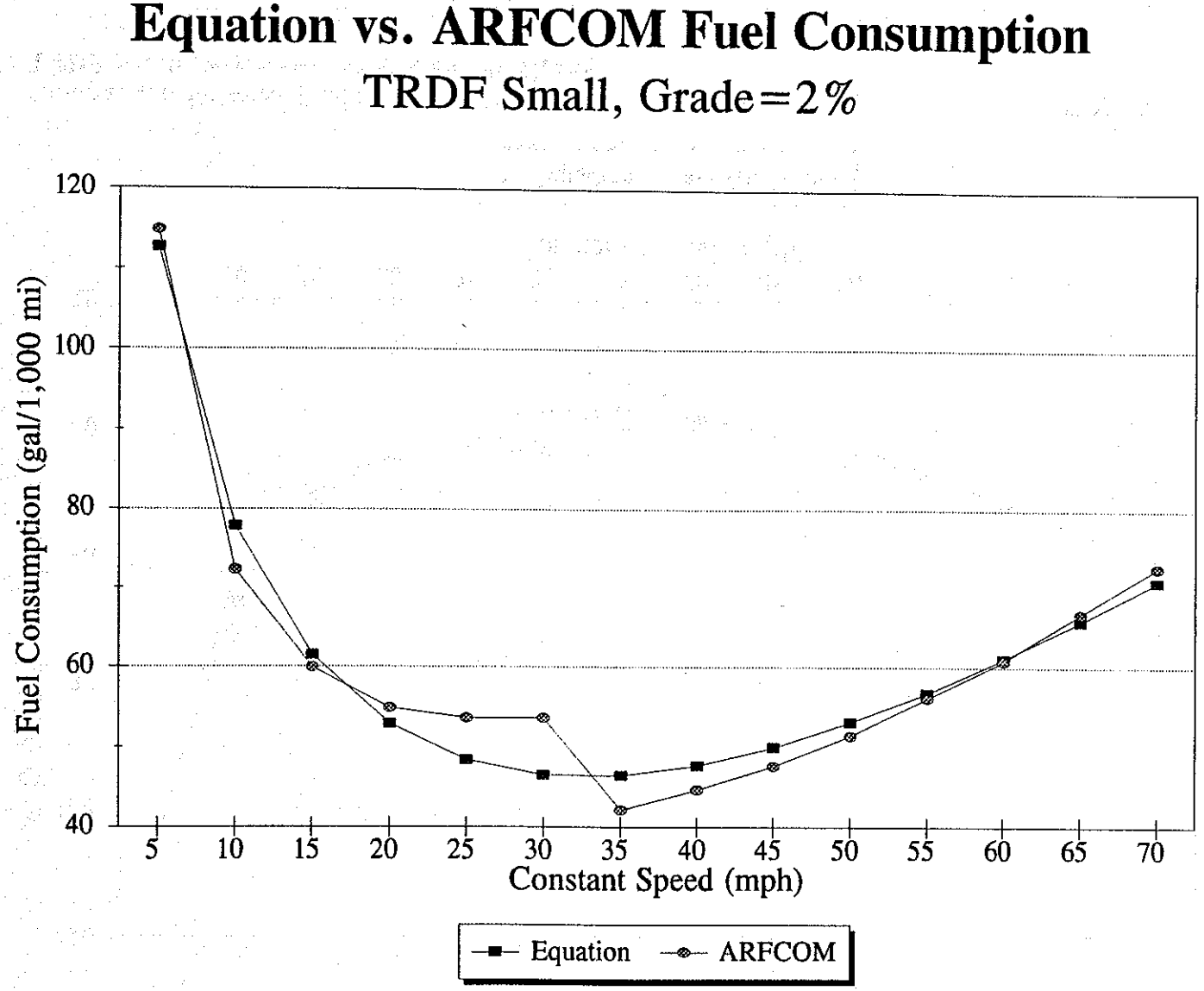

Figure 3-16. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for TRDF Small Passenger Vehicles on 2% Grade

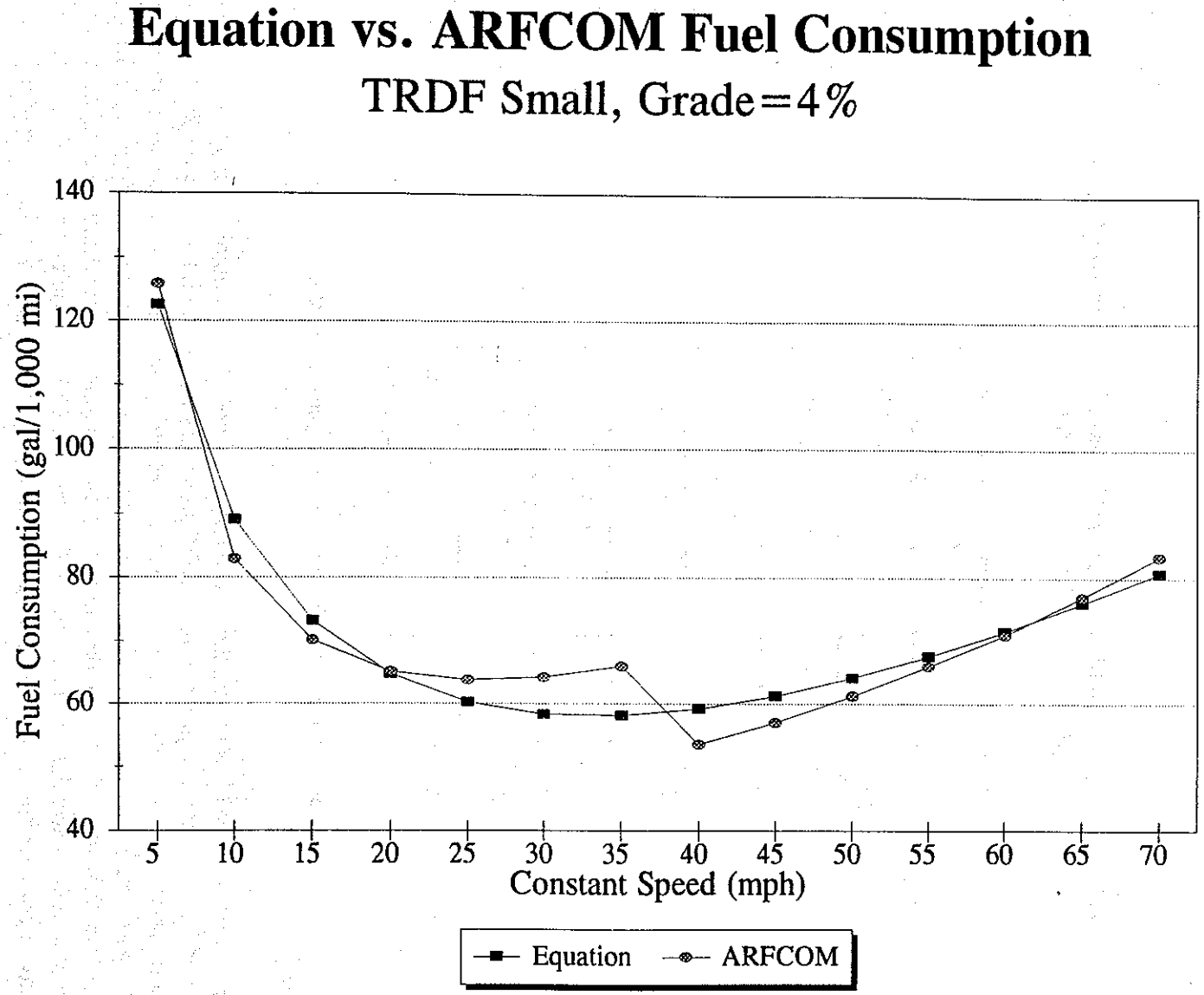

Figure 3-17. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for TRDF Small Passenger Vehicles on 4% Grade

Pavement Roughness Factor Equations

Table 3-6 shows the coefficients for the pavement roughness factor equations obtained from regression analysis, where only one independent variable, PSI, is specified. The dependent variable for these equations is linear.

Table 3-6. The Coefficients of the Pavement Roughness Factor Equations* for TRDF Vehicles

Vehicle Type	Constant	PSI
Small	1.0926	-0.0241
Medium-Large	1.0913	-0.0237
Pickup	1.0934	-0.0243
2axle	1.1138	-0.0302
3axle	1.1758	-0.0459
4axle	1.1600	-0.0416
5axle	1.2008	-0.0523

* one independent variable and linear dependent variable

Figures 3-18 to 3-19 compare the pavement roughness factors obtained from ARFCOM and the regression equations for TRDF small passenger vehicles. Figure 3-18 gives the comparison for the results of the regression equation with one independent variable, namely PSI, while in Figure 3-19, two independent variables, PSI and ln(PSI), were specified in the regression analysis. We conclude from these two graphs that the regression equation with two independent variables produce results that fit ARFCOM's results better. The complete pavement roughness factor equations for TRDF vehicles are given in Appendix I.

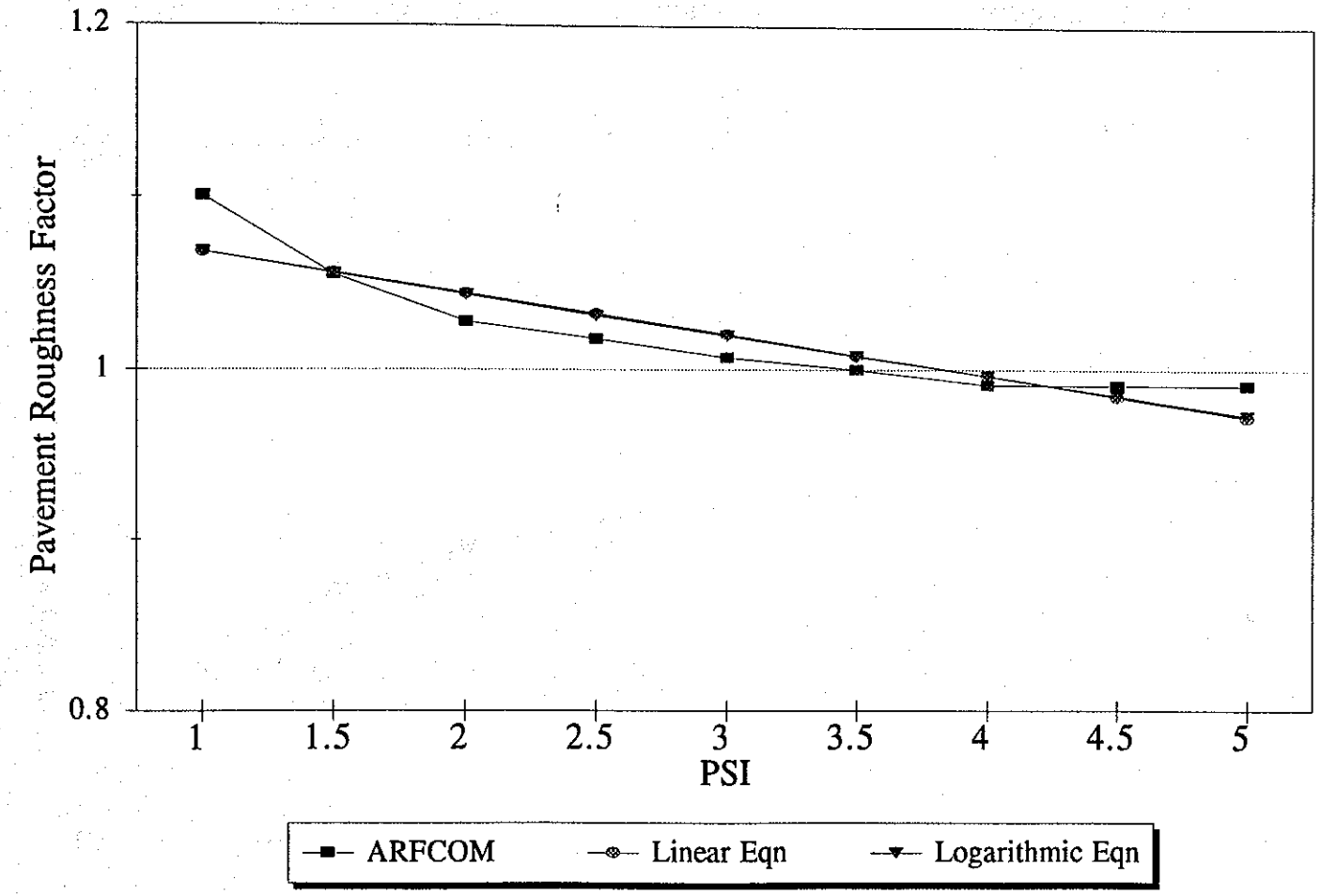

Figure 3-18. Comparison Between Pavement Roughness Factor from Regression Equation with One Independent Variable, PSI, and ARFCOM for TRDF Small Passenger Vehicles

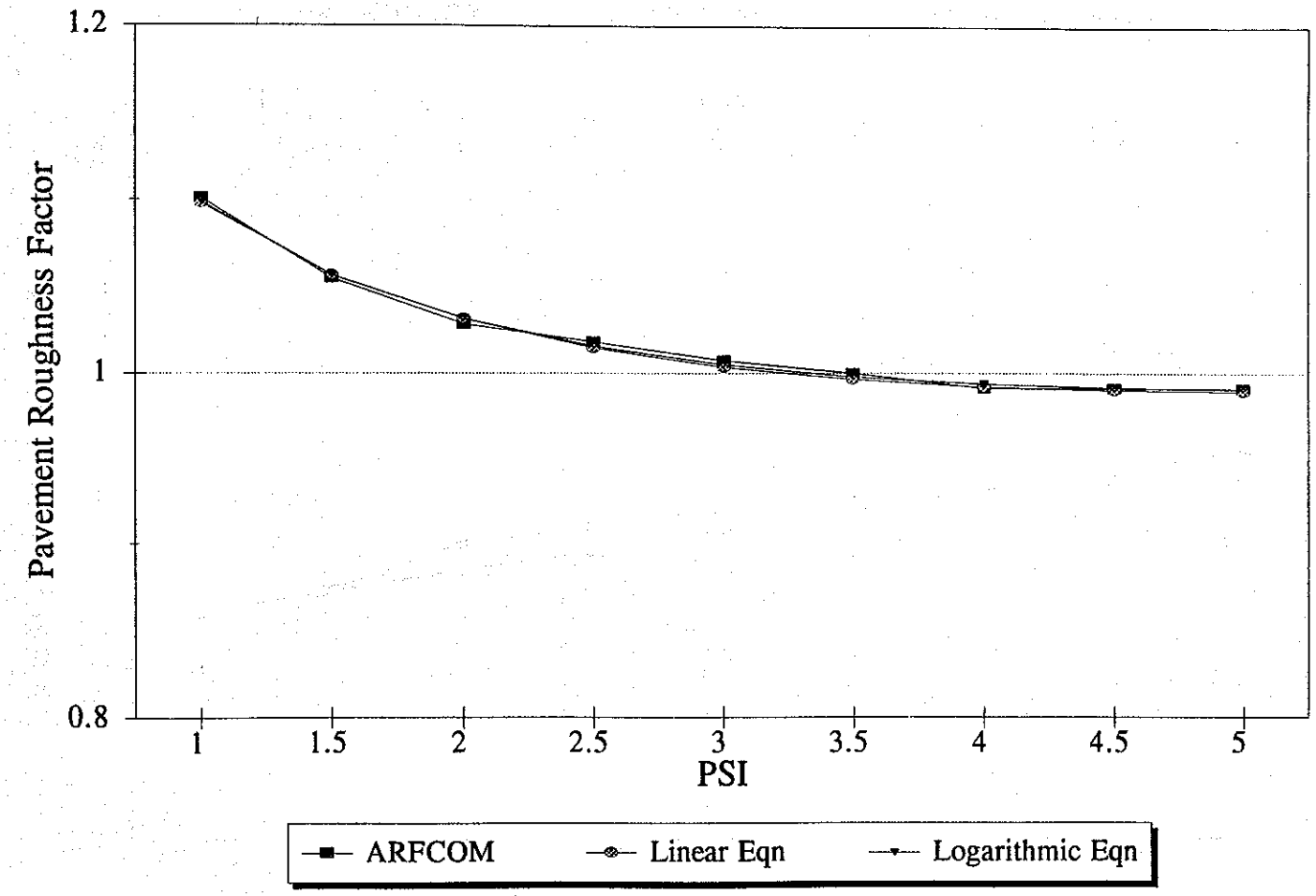

Figure 3-19. Comparison Between Pavement Roughness Factor from Regression Equation with Two Independent Variables, PSI and Ln(PSI), and ARFCOM for TRDF Small Passenger Vehicles

Chapter 4. ARFCOM RESULTS FOR MODERN VEHICLES

Characterization of Modern Vehicles

A new data set was developed to represent today's highway fleet in the United States. This fleet was expanded beyond the TRDF fleet to include several additional combination trucks. The modern vehicle fleet is divided into eleven vehicle types which include three passenger vehicles, one pickup and seven trucks. The small, medium, large, pickup, 2-axle, 3-axle, 4-axle and 5-axle vehicle types correspond to the same types of vehicles as discussed in Chapter 3, except that their characteristics have been updated. The 3-axle combination vehicle type denotes the three-axle semis (2-S1). The 7-axle and 9-axle combination vehicle types represent truck tractors with a semitrailer plus a full trailer, or 3-S2-2 and 3-S2-4.

Simulation Results

The vehicle parameters given in Table 4-1 were used in ARFCOM simulations to obtain the fuel consumption estimates for modern vehicles. Also studied was the the effect of constant speed, grade, pavement condition and weight (for 2-axle trucks onwards only) on fuel consumption. These simulations use definitions for constant speed range, grade values, and PSI as Chapter 3. The default data set DEFV03, representing the modern fleet was used in the simulations. This data set can be found in Appendix A.

Table 4-2 illustrates constant speed fuel consumption results that were obtained for modern passenger vehicles on pavement with 0 percent grade and a PSI of 3.5. These results are depicted graphically in Figure 4-1. The complete constant speed fuel consumption results for modern passenger vehicles at all grade levels are given in Appendix E.

Table 4-3 shows the fuel consumption results that were obtained using ARFCOM for modern 5-axle trucks of various weights and on 0 percent grade. Figure 4-2 gives the graph of these results. The complete results obtained for modern trucks at various weights and all grade levels are given in Appendix F.

Table 4-4 shows the constant speed fuel consumption results that were obtained for modern vehicles at PSI value of 3.0. In Figures 4-3 and 4-4, the fuel consumption estimates for modern medium passenger vehicles and 5axle trucks are shown to study the effect of pavement roughness on fuel consumption. These graphs show, as expected, that vehicle consumes more fuel as pavement roughness increases.

The complete fuel consumption results for the modern vehicles at all PSI values are given in Appendix G. All of these results were obtained at 0 percent grade.

Table 4-1. Characteristics of Modern Vehicles

Vehicle Type	Mass (kg)	No. of Wheels	Maximum Power (kW)	Drag Coefficient	Frontal Area (m^2)	Tire Type Factor
Small	1100	4	64	0.40	1.8	1.0
Medium	1250	4	80	0.40	2.0	1.0
Large	1500	4	110	0.42	2.2	1.0
Pickup	2000	4	80	0.52	2.6	1.05
2axle	2270-13610	6	130	0.58	5.0	1.25
3axle	4540-18140	10	170	0.60	6.0	1.20
3axle-comb	9070-31750	10	240	0.67	7.0	1.05
4axle	9070-31750	14	260	0.68	7.0	1.05
5axle	13610-36280	18	280	0.69	8.0	1.05
7axle-comb	13610-45350	22	300	0.72	8.0	1.05
9axle-comb	13610-45350	26	320	0.73	8.0	1.05

Table 4-2. Fuel Consumption (gallons/1,000 miles) for Modern Passenger Vehicles at Constant Speeds (mph) on Pavement with Grade of 0 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	68.45	41.67	34.01	31.0374	30.19	30.61	23.38	25.09	27.21	29.76	32.31	35.71	39.12	43.37
Medium	112.67	56.12	40.39	36.5646	35.71	35.71	26.36	28.06	30.61	33.16	36.14	39.54	43.37	47.62
Large	112.67	65.05	52.30	47.619	45.92	45.92	31.46	33.16	35.71	38.69	41.67	45.49	49.74	54.42
Pickup	151.36	75.68	50.60	40.8163	39.97	41.24	34.44	37.84	41.67	46.34	51.02	56.97	63.35	70.58

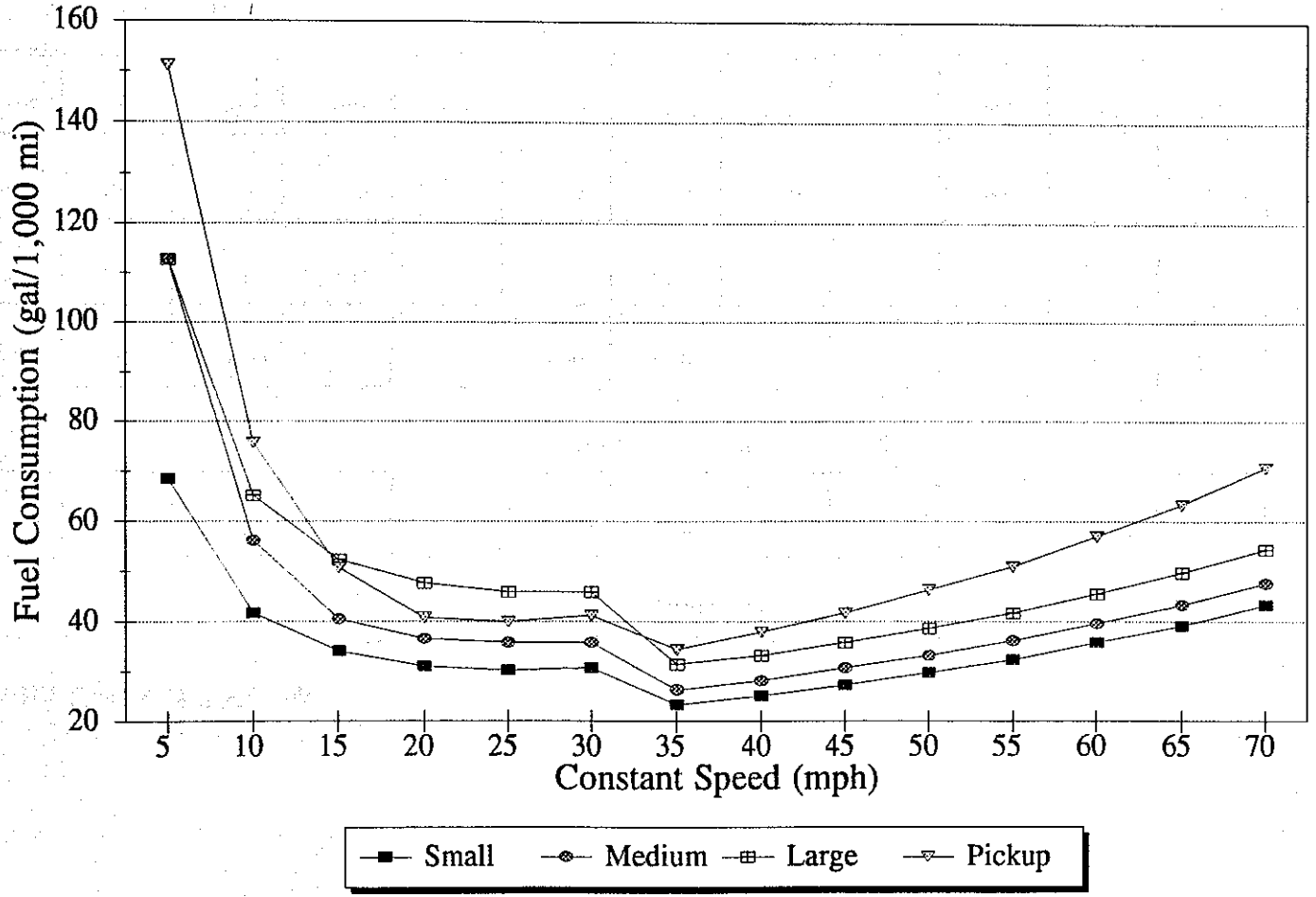

Figure 4-1. Constant Speed Fuel Consumption Estimates Using ARFCOM for Modern Passenger Vehicles on Pavement with Grade 0%

Table 4-3. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	191.33	200.68	209.61	218.96	227.89	237.24
10	125.85	134.78	143.71	152.64	161.56	170.49
15	106.29	115.22	124.15	132.65	141.58	150.51
20	99.49	107.99	116.92	125.43	134.35	143.28
25	97.79	106.72	115.22	124.15	132.65	141.58
30	99.49	108.42	116.92	125.85	134.35	143.28
35	103.74	112.24	121.17	130.10	138.61	147.53
40	109.69	118.62	127.13	136.05	144.98	153.91
45	103.74	112.24	120.32	128.83	137.33	145.83
50	114.37	122.87	131.38	139.88	148.38	156.89
55	126.70	135.20	143.71	152.21	161.14	169.64
60	139.88	148.38	157.31	165.82	174.74	183.67
65	154.76	163.27	172.19	181.12	190.05	199.40
70	167.94	176.87	186.22	195.15	204.51	213.44

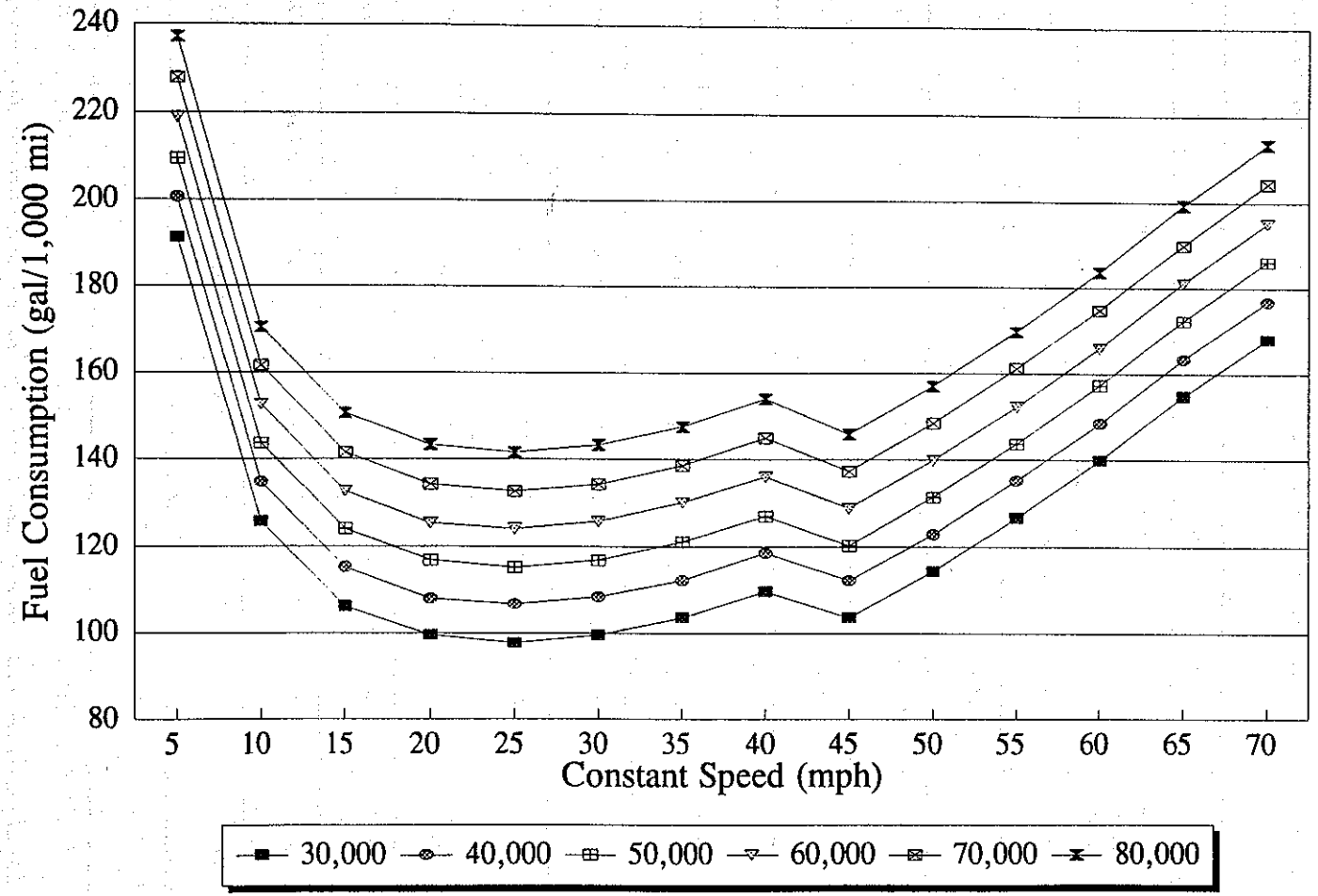

Figure 4-2. Constant Speed Fuel Consumption Estimates Using ARFCOM for Modern 5-Axle Trucks of Various Weights on Pavement with 0 Percent Grade

Table 4-4. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 3.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	68.45	41.67	34.01	31.04	30.19	30.61	23.38	25.09	27.21	29.76	32.74	35.71	39.12	43.37
Medium	112.67	56.12	40.39	36.56	35.71	35.71	26.36	28.06	30.61	33.16	36.14	39.54	43.37	47.62
Large	112.67	65.05	52.30	47.62	45.92	45.92	31.46	33.16	35.71	38.69	42.09	45.49	49.74	54.42
Pickup	151.36	75.68	50.60	40.82	40.39	41.24	34.44	37.84	41.67	46.34	51.45	56.97	63.35	70.58
2axle	239.37	119.90	79.93	73.55	72.70	74.40	76.53	84.61	93.54	104.17	116.07	129.68	143.71	151.36
3axle	154.34	107.14	93.96	89.29	88.86	90.56	93.96	86.73	94.39	103.32	113.10	124.15	136.05	143.71
3axle-comb	187.93	125.00	106.72	100.34	99.06	100.77	104.59	92.26	101.19	111.82	123.30	135.63	149.66	160.71
4axle	201.96	134.35	114.80	108.42	107.14	109.27	113.95	120.32	110.54	122.45	135.20	149.66	165.82	179.00
5axle	221.51	155.19	135.20	127.98	126.28	128.40	132.23	138.61	131.38	142.43	154.76	168.37	183.67	197.70
7axle-comb	248.30	178.15	157.31	149.66	147.96	149.66	154.34	160.71	151.79	163.69	176.87	191.33	207.91	222.79
9axle-comb	277.21	203.23	181.12	173.04	171.34	173.04	177.72	184.52	173.89	186.22	199.83	215.14	232.14	248.30

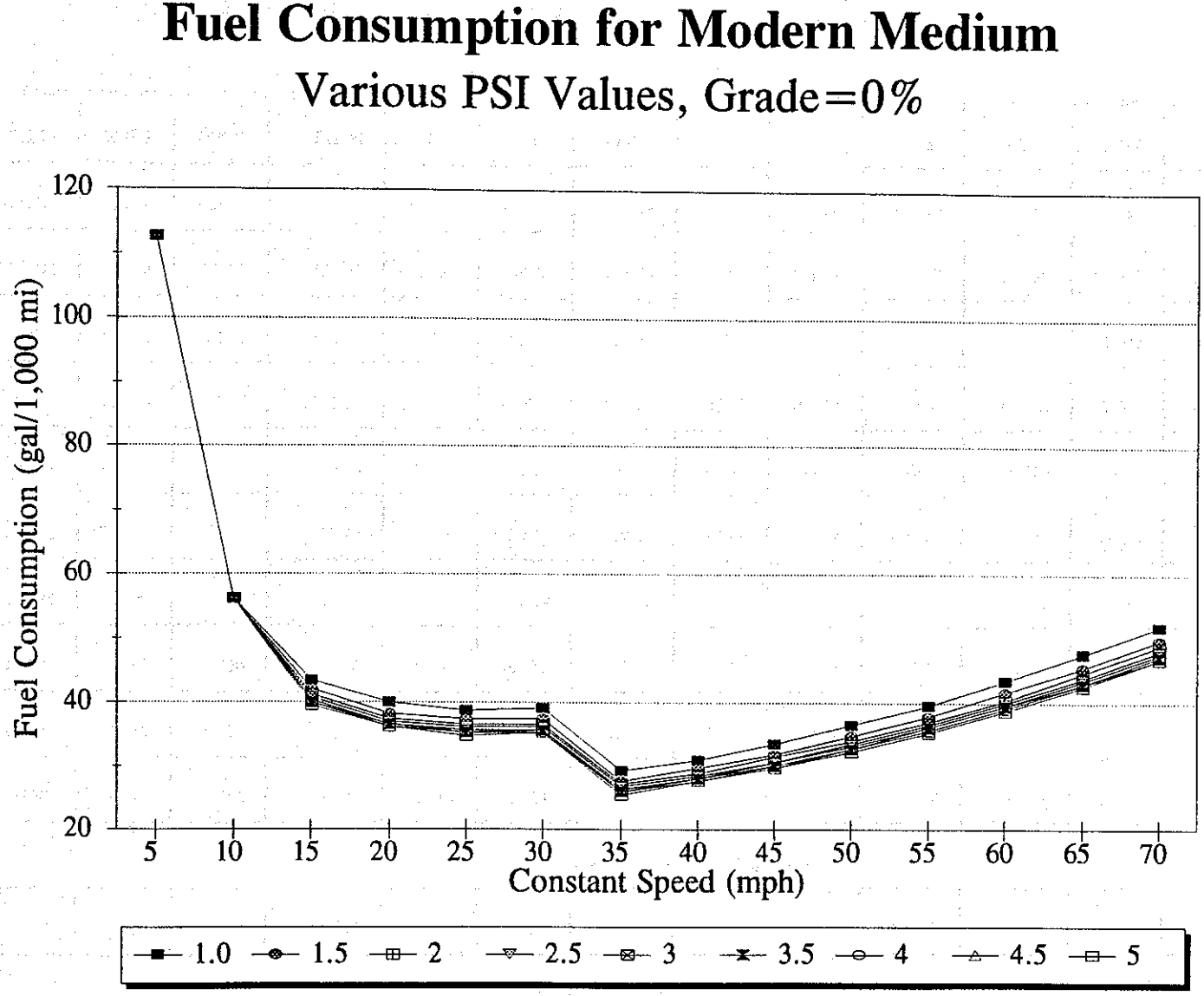

Figure 4-3. Constant Speed Fuel Consumption For Modern Medium Passenger Vehicles at Various PSI Values

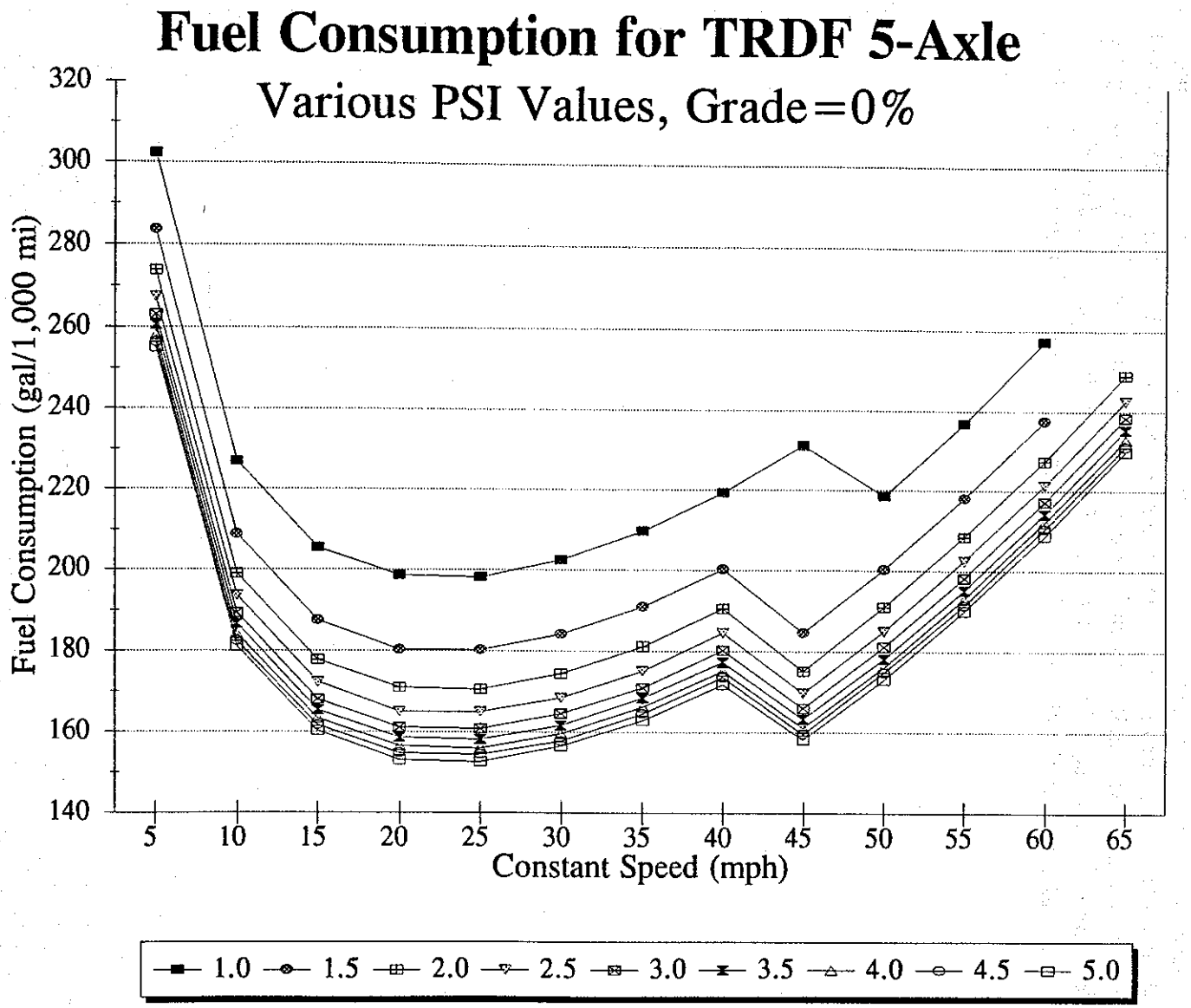

Figure 4-4. Constant Speed Fuel Consumption For Modern 5-Axle Trucks at Various PSI Values

Fuel Consumption Equations

Regression analysis is used to develop equations for the data in Appendices E and F. Results shown in Table 4-5 illustrate the coefficients of fuel consumption equations obtained from the regression analysis for modern small passenger vehicles at all grade levels. Figures 4-5 to 4-9 show a comparison of the fuel consumption estimates obtained from ARFCOM and the regression equations. The results shown in these graphs indicate that the fuel consumption estimates from the regression equations match the ARFCOM values quite satisfactorily in most cases. Appendix J gives the complete fuel consumption equations for modern vehicles.

Table 4-5. Coefficients of Fuel Consumption Equations for Modern Small Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Small	5	70	-8	Fuel	107.13038	0.88401	0.00000	-37.13442	0.00000	0.00000
Small	5	70	-4	Fuel	111.77917	1.28096	0.00000	-41.02061	0.00000	0.00000
Small	5	70	-3	Fuel	109.75674	1.22362	0.00000	-38.81647	0.00000	0.00000
Small	5	70	-2	Fuel	115.04036	1.24030	0.00000	-39.41889	0.00000	0.00000
Small	5	70	-1	Fuel	120.36422	1.25198	0.00000	-39.96826	0.00000	0.00000
Small	5	70	0	Fuel	125.77088	1.25958	0.00000	-40.44462	0.00000	0.00000
Small	5	70	1	Fuel	131.08277	1.28017	0.00000	-41.06200	0.00000	0.00000
Small	5	70	2	Fuel	136.64236	1.29354	0.00000	-41.62889	0.00000	0.00000
Small	5	70	3	Fuel	137.37791	1.20817	0.00000	-39.45343	0.00000	0.00000
Small	5	70	4	Fuel	137.86134	1.14512	0.00000	-37.43149	0.00000	0.00000
Small	5	65	8	Ln(Fuel)	5.50894	0.02768	-0.00005	-0.61949	0.00000	0.00000

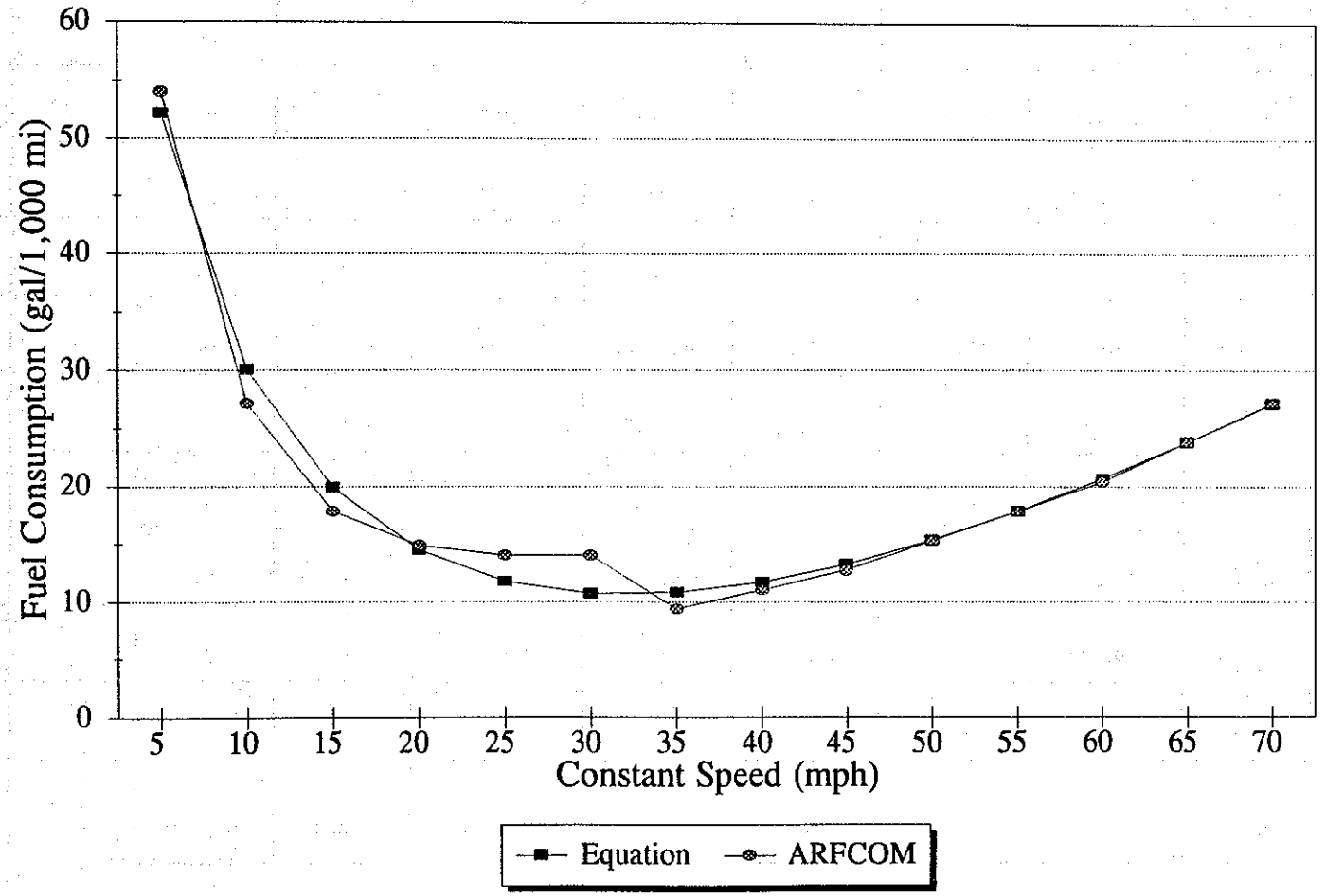

Figure 4-5. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for Modern Small Passenger Vehicles on -4% Grade

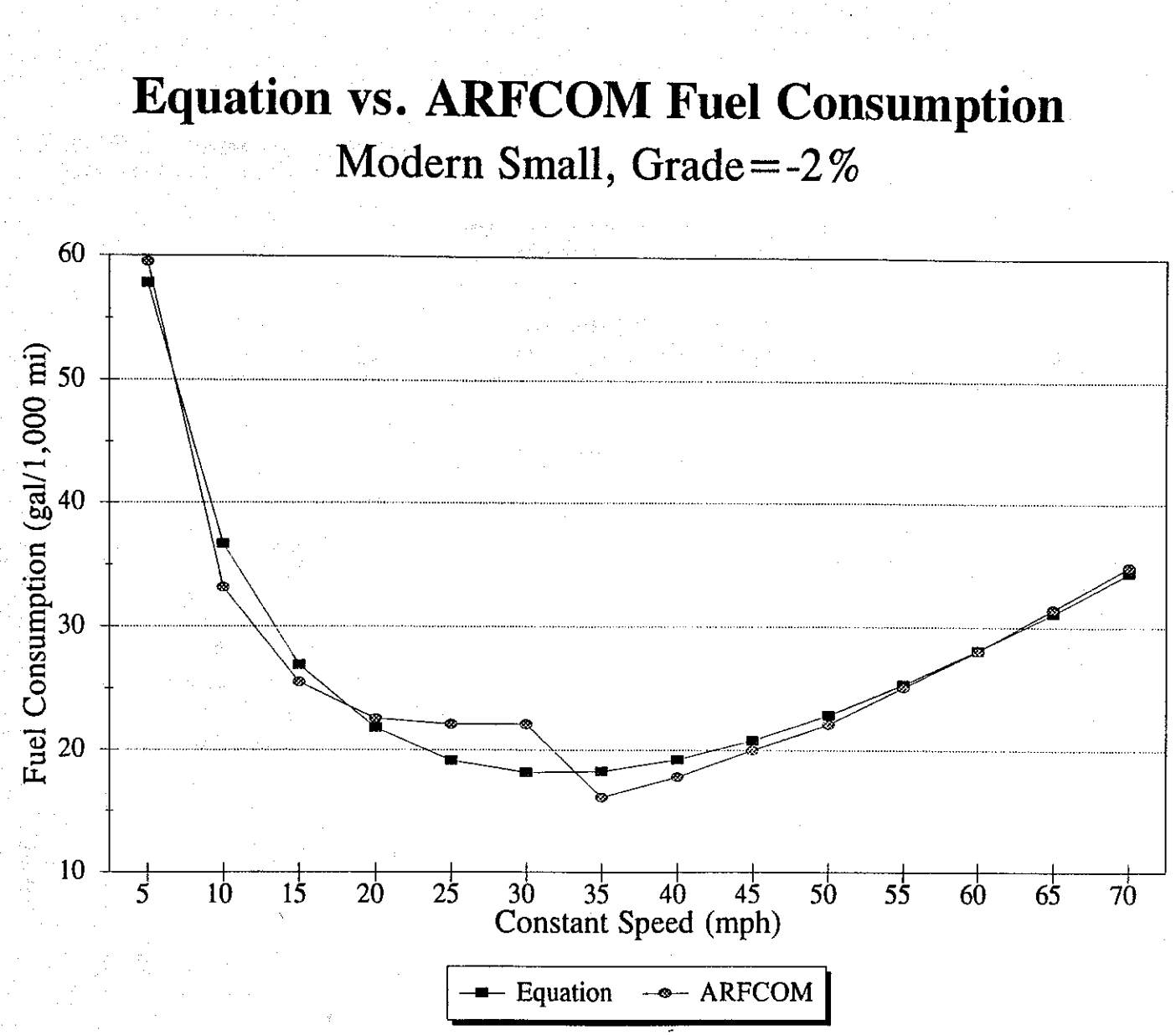

Figure 4-6. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for Modern Small Passenger Vehicles on -2% Grade

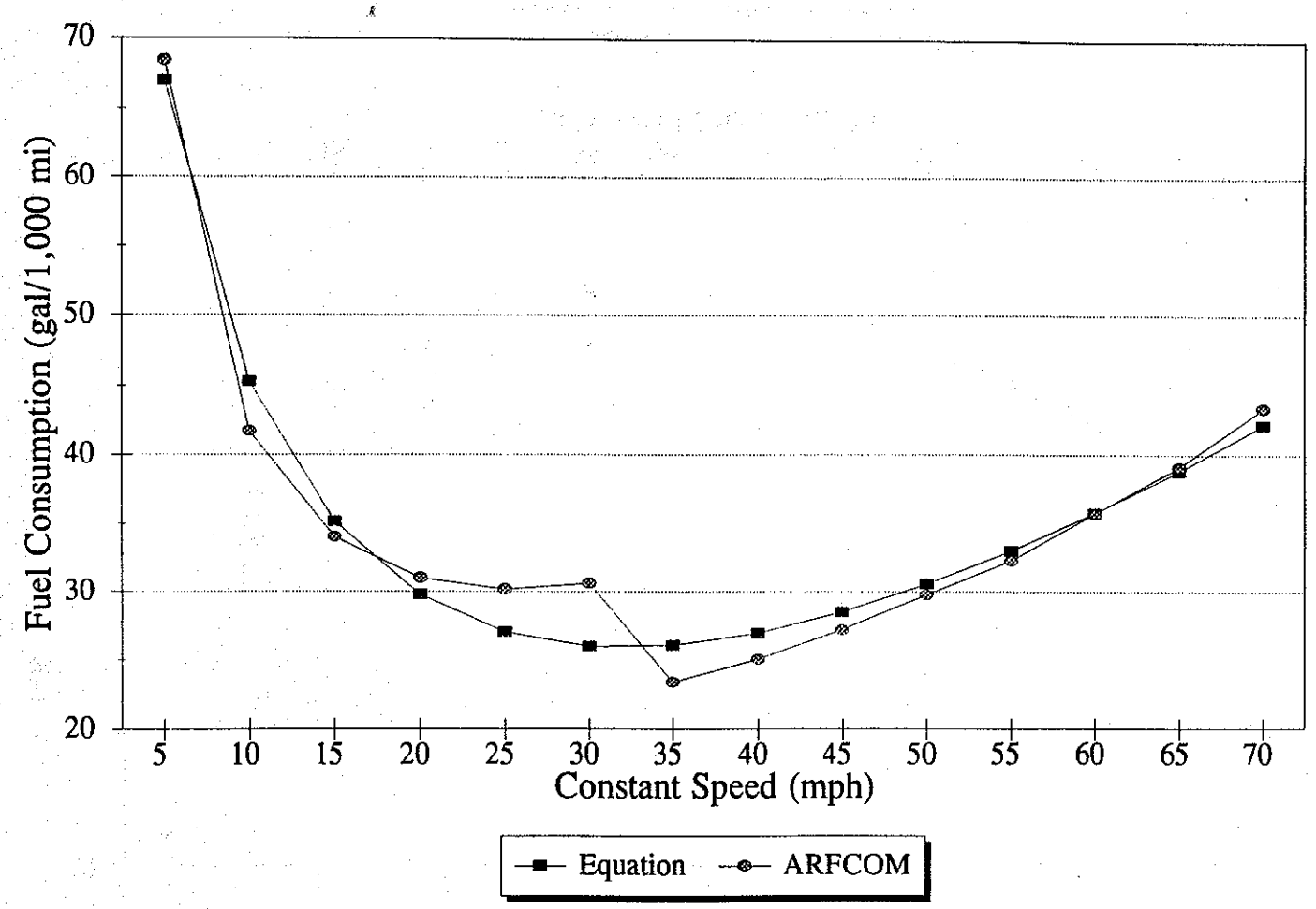

Figure 4-7. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for Modern Small Passenger Vehicles on 0% Grade

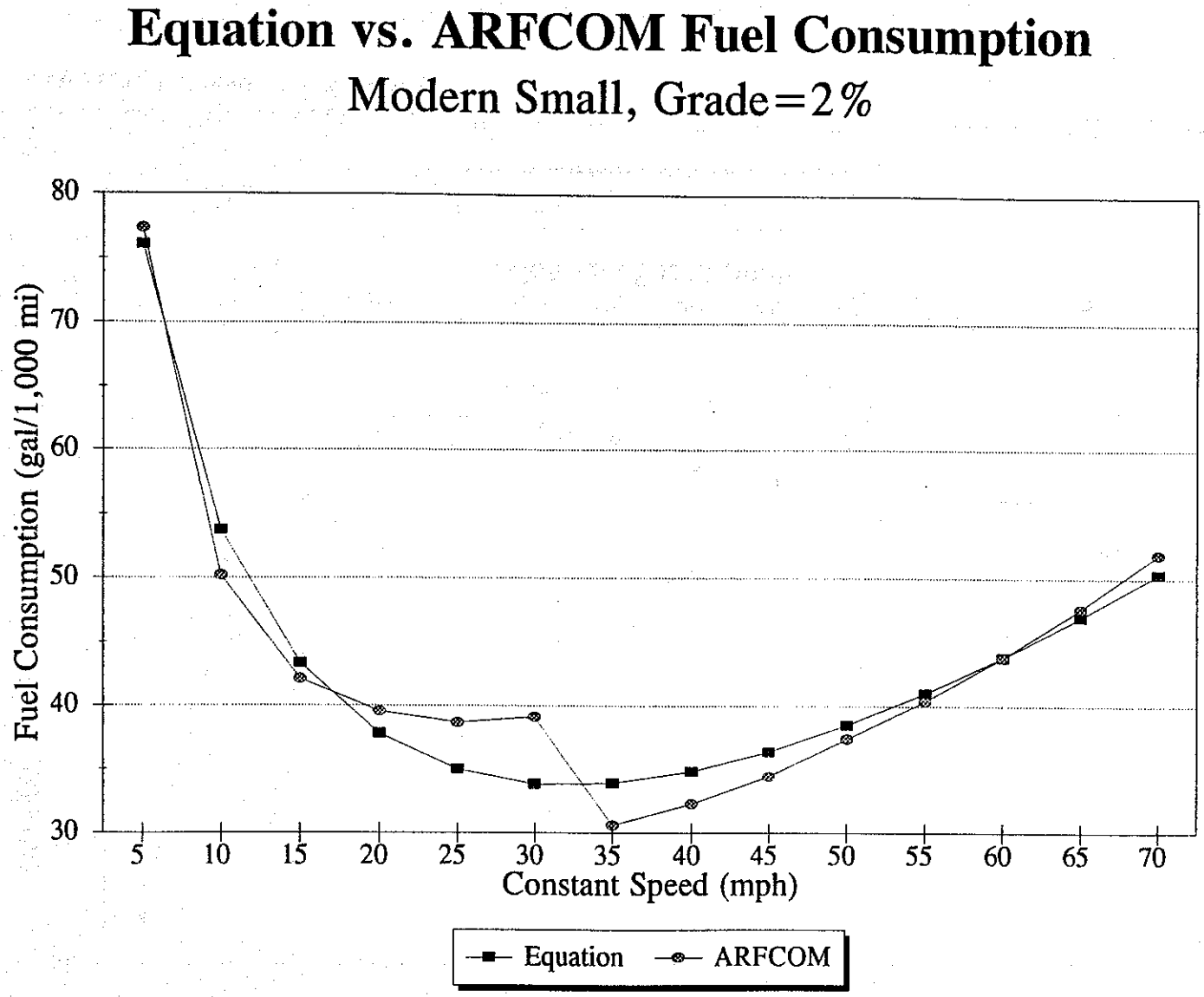

Figure 4-8. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for Modern Small Passenger Vehicles on 2% Grade

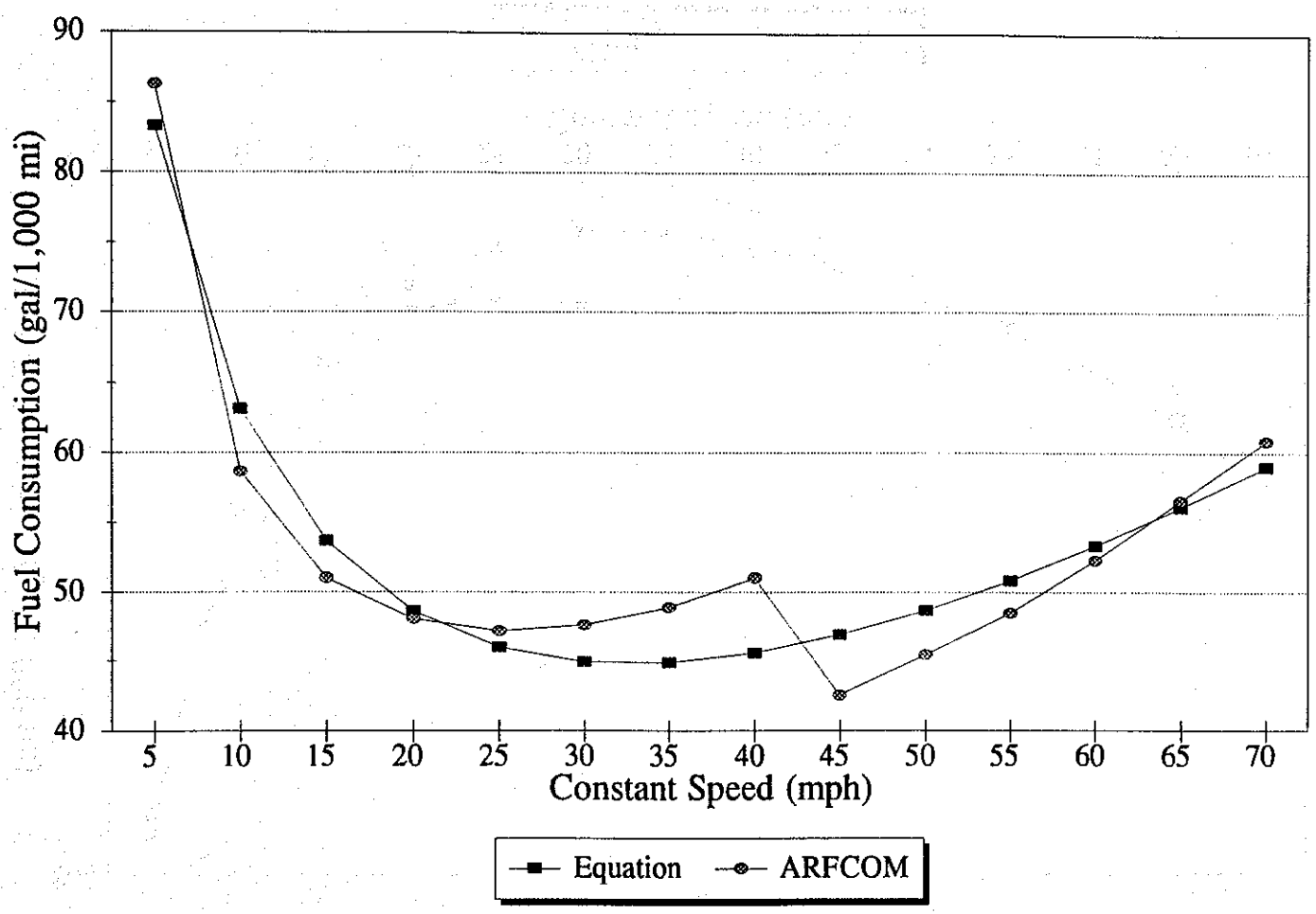

Figure 4-9. Comparison Between Fuel Consumption Results from Regression Equation and ARFCOM for Modern Small Passenger Vehicles on 4% Grade

Pavement Roughness Factor Equations

Table 4-6 shows the coefficients for the pavement roughness factor equations obtained from regression analysis where only one independent variable, PSI, is used. The complete pavement roughness factor equations for modern vehicles are given in Appendix K, including the regression equations with two independent variables, PSI and Ln(PSI).

Figure 4-10 shows a comparison of the pavement roughness factors obtained from ARFCOM and the regression equations with one and two independent variables for modern 2-axle trucks. Eqn-1 and Eqn-2 in Figure 4-10 indicate the graphs for the regression equations with one and two independent variables, respectively.

Table 4-6. Coefficients of Pavement Roughness Factor Equations (with One Independent Variable) for Modern Vehicles

Vehicle Type	Min. PSI	Max. PSI	Dep. Variable	Constant	PSI
Small	1.0	5.0	Ln(Fuel)	0.10111	-0.02671
Medium	1.0	5.0	Ln(Fuel)	0.08475	-0.02368
Large	1.0	5.0	Ln(Fuel)	0.08383	-0.02212
Pickup	1.0	5.0	Ln(Fuel)	0.08805	-0.02342
2axle	1.0	5.0	Ln(Fuel)	0.09533	-0.02455
3axle	1.0	5.0	Ln(Fuel)	0.15480	-0.04039
3axle-comb	1.0	5.0	Ln(Fuel)	0.13276	-0.03500
4axle	1.0	5.0	Ln(Fuel)	0.13445	-0.03505
5axle	1.0	5.0	Ln(Fuel)	0.17367	-0.04554
7axle-comb	1.0	5.0	Ln(Fuel)	0.19146	-0.05035
9axle-comb	1.0	5.0	Ln(Fuel)	0.20692	-0.05450

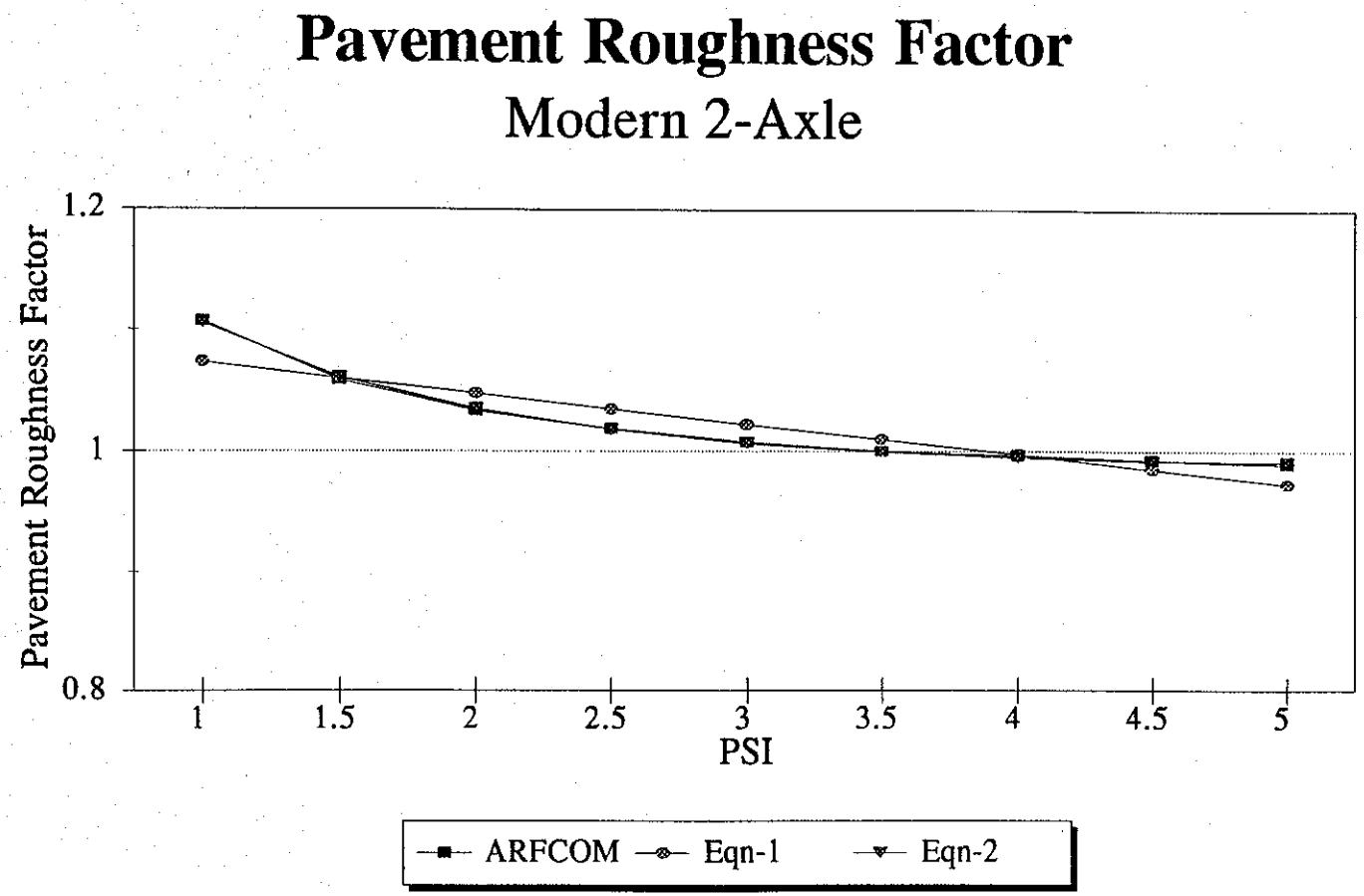

Figure 4-10. Comparison Between Pavement Roughness Factor from ARFCOM and Regression Equations for Modern 2-Axle Trucks

Chapter 5. EXAMPLE PROBLEMS USING UPDATED DATA SETS

Two example problems are used in this chapter to illustrate the effects of the new fuel equations on user cost calculations in the MicroBENCOST computer program. These examples are for an adding capacity to an existing roadway and for improving the pavement of an existing roadway by using a pavement overlay. A more detailed discussion of the added capacity problem, which includes project description, evaluation criteria, data requirements and output analysis, and a description of the pavement overlay problem can be found in the MicroBENCOST User's Manual. The data sets for both problems, ADDCAP.DAT for the added capacity problem and PAVEMENT.DAT for the pavement overlay problem, and other case studies are available on the MicroBENCOST disks.

To assist in updating the coefficients of vehicle operating cost equations used in MicroBENCOST, a DOS-based computer program called COVOC was developed. In COVOC, these coefficients are divided into seven different sets: Grade, Curvature, Speed Changes, Pavement, Number of Speed Change Cycles, Idling Consumption, and Emissions.

All vehicle operating cost components can be updated using the COVOC program including fuel consumption, oil consumption, tire wear, use-related depreciation, and maintenance and repair. COVOC allows the user to view the current coefficients, update them, and compare the results of the new coefficients, either numerically or graphically, to the current results to check if the new changes in the coefficients produce acceptable results. COVOC then combines the coefficients from all seven file types and converts them into a format that can be read by MicroBENCOST.

Revised Fuel Equations for TRDF Vehicles

Based on the results reported in Chapter 3, the coefficients of fuel consumption equations on all grade levels and the pavement roughness factor equations in MicroBENCOST, were replaced with the values presented in Appendices H and I. These values use the characteristics of the TRDF vehicles but the new equations are based on ARFCOM simulation runs.

Using the revised fuel equations, MicroBENCOST was used to run analyses on added capacity and pavement overlay problems using both current and updated equations for the TRDF vehicles to evaluate any changes and improvements in the user's benefit-cost.

Added Capacity Problem

A summary of the MicroBENCOST analysis results for the added capacity problem using the current equations for TRDF vehicles is given in Table 5-1. Table 5-2 gives a summary of the analysis results for the added capacity problem using the updated equations for TRDF vehicles.

By comparing the outputs from Tables 5-1 and 5-2, we observe that the updated equations yield an increase of 4.17% in the discounted user benefits, 352.52% in the fuel consumption savings, 6.73% in the net present value, 4.18% in the gross benefit-cost ratio, 3.63% in the netted benefit-cost ratio, 4.16% in the internal rate of return and a decrease of 74.17% in the carbon monoxide emission. The other values remain unchanged.

Pavement Overlay Problem

A summary of the analysis results for the pavement overlay problem using the current equations for TRDF vehicles is given in Table 5-3. Table 5-4 gives a summary of the analysis results for the pavement overlay problem using the updated equations for TRDF vehicles.

By comparing the values from Tables 5-3 and 5-4, it can be observed that the updated equations yield an increase of 7.28% in the total discounted user benefits, 187.68% in the fuel consumption savings, 9.27% in the net present value, 7.28% in the gross benefit-cost ratio, 6.93% in the netted benefit-cost ratio, 8.20% in the internal rate of return and a decrease of 70.45% in the carbon monoxide emission. The rest of the values remain unaffected.

Table 5-1. Summary of Analysis Results for Added Capacity Problem Using Current Equations for TRDF Vehicles

	99.160
Total Discounted User Benefits (Mill. $) :	52.381
Discounted Construction Cost (Mill. $) :	16.864
Discounted Salvage Value (Mill. $) :	2.148
Discounted Increase in Maint. and Rehab. (Mill. $) :	1.725
Fuel Consumption Savings (Mill. Gal.) :	1.866
Carbon Monoxide Emission Reduction (Mill . Kg.) :	61.495
Net Present Value (Mill. $) :	2.633
Gross Benefit-Cost Ratio :	2.174
Netted Benefit-Cost Ratio :	14.900
Internal Rate of Return (Percent) :	

Table 5-2. Summary of Analysis Results for Added Capacity Problem Using Updated Equations for TRDF Vehicles

Total Discounted User Benefits (Mill. $) :	103.300
Discounted Construction Cost (Mill. $) :	52.381
Discounted Salvage Value (Mill. $) :	16.864
Discounted Increase in Maint. and Rehab. (Mill. $) :	2.148
Fuel Consumption Savings (Mill. Gal.) :	7.806
Carbon Monoxide Emission Reduction (Mill . Kg.) :	0.482
Net Present Value (Mill. $) :	65.635
Gross Benefit-Cost Ratio :	2.743
Netted Benefit-Cost Ratio :	2.253
Internal Rate of Return (Percent) :	15.520

Table 5-3. Summary of Analysis Results for Pavement Roughness Problem Using Current Equations for TRDF Vehicles

Total Discounted User Benefits (Mill. $) :	13.590
Discounted Construction Cost (Mill. $) :	3.619
Discounted Salvage Value (Mill. $) :	0.719
Discounted Increase in Maint. and Rehab. (Mill. $) :	0.000
Fuel Consumption Savings (Mill. Gal.) :	-0.885
Carbon Monoxide Emission Reduction (Mill . Kg.) :	0.044
Net Present Value (Mill. $) :	10.690
Gross Benefit-Cost Ratio :	4.687
Netted Benefit-Cost Ratio :	3.954
Internal Rate of Return (Percent) :	30.543

Table 5-4. Summary of Analysis Results for Pavement Overlay Problem Using Updated Equations for TRDF Vehicles

Total Discounted User Benefits (Mill. $) :	14.580
Discounted Construction Cost (Mill. $) :	3.619
Discounted Salvage Value (Mill. $) :	0.719
Discounted Increase in Maint. and Rehab. (Mill. $) :	0.000
Fuel Consumption Savings (Mill. Gal.) :	0.776
Carbon Monoxide Emission Reduction (Mill . Kg.) :	0.013
Net Present Value (Mill. $) :	11.681
Gross Benefit-Cost Ratio :	5.028
Netted Benefit-Cost Ratio :	4.228
Internal Rate of Return (Percent) :	33.047

New Fuel Equations for the Modern Fleet

Based on the results reported in Chapter IV, the coefficients of fuel consumption equations on all grade levels and the pavement roughness factor equations in MicroBENCOST, were replaced with the values given in Appendices J and K. These values use the characteristics of the modern fleet based on ARFCOM simulation runs.

Using the revised fuel equations for the modern fleet, MicroBENCOST was used to run analyses on added capacity and pavement overlay problems using the updated equations for the modern fleet vehicles to evaluate any changes and improvements in the benefit-cost analysis.

Table 5-5 gives a summary of the analysis results for the added capacity problem using the equations for modern vehicles. Table 5-6 gives a summary of the analysis results for the pavement overlay problem using the equations for modern vehicles.

Comprehensive outputs of the MicroBENCOST analyses for the added capacity problem for both TRDF and modern vehicles have been included in Appendix L. Appendix M contains the complete outputs for the pavement overlay problem.

Table 5-5. Summary of Analysis Results for Added Capacity Problem Using the Equations for Modern Vehicles

Total Discounted User Benefits (Mill. $) :	103.312
Discounted Construction Cost (Mill. $) :	52.381
Discounted Salvage Value (Mill. $) :	16.864
Discounted Increase in Maint. and Rehab. (Mill. $) :	2.148
Fuel Consumption Savings (Mill. Gal.) :	7.827
Carbon Monoxide Emission Reduction (Mill . Kg.) :	0.482
Net Present Value (Mill. $) :	65.647
Gross Benefit-Cost Ratio :	2.743
Netted Benefit-Cost Ratio :	2.253
Internal Rate of Return (Percent) :	15.522

Table 5-6. Summary of Analysis Results for Pavement Overlay Problem Using the Equations for Modern Vehicles

Total Discounted User Benefits (Mill. $) :	14.427
Discounted Construction Cost (Mill. $) :	3.619
Discounted Salvage Value (Mill. $) :	0.719
Discounted Increase in Maint. and Rehab. (Mill. $) :	0.000
Fuel Consumption Savings (Mill. Gal.) :	0.507
Carbon Monoxide Emission Reduction (Mill . Kg.) :	0.013
Net Present Value (Mill. $) :	11.527
Gross Benefit-Cost Ratio :	4.975
Netted Benefit-Cost Ratio :	4.185
Internal Rate of Return (Percent) :	32.677

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Appendix A. Default Data Sets DEFV01 and DEFV03

Default Data Set DEFV01

The following are the default vehicle parameters in ARFCOM called DEFV01 that we used to run the simulations for the fuel consumption of TRDF vehicles.

Rolling resistance mass independent coef.	= 37.0
Tire resistance mass dependent coef.	= 0.064
Tire resistance speed dependent coef.	= 0.012
Drive-train efficiency	= 0.90
Density of air (kg/m3)	= 1.2
Proportional increase in Cd with yaw angle	= 0.012
Ratio radius of gyration to radius of wheel	= 0.75
Wheel mass for default tire diameter of 0.65	= 18.0
..... 0.72	= 28.0
..... 0.80	= 44.0
..... 1.00	= 90.0
..... 1.14	= 125.0
Vehicle classified as car if Rw less than	= 0.35
Cornering stiffness of radial car tire	= 45.0
..... const coef for $0.7<Dw<0.9$	= 8.8
..... coef of M/Nw for $0.7<Dw<0.9$	= 0.088
..... coef of M/Nw sq. for $0.7<Dw<0.9$	=-0.0000225
..... const coef for $Dw>0.9$	= 0.0
..... coef of M/Nw for $Dw>0.9$	= 0.0913
..... coef of M/Nw sq. for $Dw>0.9$	=-0.0000114
Const coef for est Pmax from eng cap -Diesel	= 28.0
Coef of eng capacity when est Pmax - Diesel	= 16.4
Const coef for est Pmax from eng cap -Petrol	= 38.0
Coef of eng capacity when est Pmax - Petrol	= 19.2
Const coef for est engine speed - Diesel	= 4600
Coef of pmax for est engine speed - Diesel	=-18.0
Coef of Pmax sq for est engine speed - Diesel	= 0.030
Const coef for est engine speed - Petrol trk	= 4500
Const coef for est engine speed - Petrol car	= 5400
Const coef for est Betab - Diesel	= 0.058
Coef of Pmax for est Betab -Diesel	=-0.00001
Value for ehp - Diesel	= 0.10
Const coef for est Betab - Petrol	= 0.067
Coef of Pmax for est Betab -Petrol	= 0.0000
Value for ehp - Petrol	= 0.25
Coef of Pmax for est ceng - Diesel	= 0.017
Const coef for est beng - Diesel	= 0.0
Coef of Pmax for est beng - Diesel	= 0.0287

Coef of Pmax for est ceng - Petrol	= 0.055
Const coef for est beng - Petrol	= 0.0
Coef of Pmax for est beng - Petrol	= 0.016
Value of idle engine speed	= 800
Value of low power eff factor elp - Diesel	= 1.5
Value of low power eff factor elp - Petrol	= 1.3
Constant coef for est max veh speed - Truck	= 27.7
Coef of Pmax for est max veh speed - Truck	= 0.008
Constant coef for est max veh speed - Car	= 36.0
Coef of Pmax for est max veh speed - Car	= 0.13
Speed veh changes to top gear, coef of Nt	= 1100
Speed veh changes to top gear, coef of Vmax	= 1.8
Constant coef for est number of gears - Truck	= 2.5
Coefficient of Pmax for est no. gears - Truck	= 0.03
Constant coef for est number of gears - Car	= 1.5
Coefficient of Pmax for est no. gears - Car	= 0.03
Value of r1 for est eng speed at < top gear	= 0.021
Value of r2 for est eng speed at < top gear	= 22.0
Wheel diameter for MG < mg1	= 0.65
Wheel diameter for mg1 < MG < mg2 & MPW < mpw1	= 0.72
Wheel diameter for mg1 < MG < mg2 & MPW > mpw1	= 0.80
Wheel diameter for mg2 < MG < mg3 & MPW < mpw2	= 0.80
Wheel diameter for mg2 < MG < mg3 & MPW > mpw2	= 1.00
Wheel diameter for MG > mg3 & MPW < mpw3	= 1.00
Wheel diameter for MG > mg3 & MPW > mpw3	= 1.14
Mass used in calculating wheel diameter & mass	= 2500
Mass used in calculating wheel diameter & mass	= 5000
Mass used in calculating wheel diameter & mass	= 10000
Mass used in calculating wheel diameter & mass	= 600
Mass used in calculating wheel diameter & mass	= 1600
Mass used in calculating wheel diameter & mass	= 2300
Coef. for rotating inertia of drive-train	= 1.05
Engine accessory load constant, XX for cars	= 2.0
Engine load constant, XX for trucks & Pmax < p1	= 4.0
Engine load constant, XX for trucks & Pmax > p1	= 8.0
Power value for trucks used in def. XX & YY	= 260
Engine cooling fan load constant, YY for cars	= 0.1
Cooling fan constant, YY for trucks & Pmax < p1	= 0.05
Cooling fan constant, YY for trucks & Pmax > p1	= 0.004
Car model default mass	= 1200
Car model default eng cap. for calc. idle rate	= 2.50
Car model default rolling resistance param	= 0.333
Car model default air resistance parameter	= 0.0008
Car model default efficiency parameter Beta1	= 0.09

Car model default efficiency parameter Beta2	= 0.03
Car model est of idle fuel coef. of engine cap	= 0.220
Car model est of idle fuel coef. of EC*EC	=-0.0193
Vehicle is in less than top gear if speed l.t.	= 50.0
Ratio of speed at TRPM for car in 5th & 4th gr	= 0.82
Car is in less than 5th gear if speed is l.t.	= 80.0
Car in l.t. 5th gear if (Vmax/V)2 x Pout/Pmax	= 1.6
15 character description of class	=SMALL CAR
Class - Small car: mass (loaded)	= 1100
: unloaded mass	= 1100
: maximum rated eng power	= 64
: number of wheels	= 4
: tire resistance coef Cr1	= 1.0
: frontal area	= 1.8
: aerodynamic drag coeffient	= 0.42
: % of vehicles using diesel	= 1.0
: % of vehicles laden	= 100
: % of all vehs in urban	= 26.9
: % of all vehs in rural	= 22.4
15 character description of class	=MEDIUM CAR
Class - Medium car: mass (loaded)	= 1250
: unloaded mass	= 1250
: maximum rated eng power	= 64
: number of wheels	= 4
: tire resistance coef Cr1	= 1.0
: frontal area	= 2.0
: aerodynamic drag coeffient	= 0.44
: % of vehicles using diesel	= 2.0
: % of vehicles laden	= 100
: % of all vehs in urban	= 26.9
: % of all vehs in rural	= 22.4
15 character description of class	=LARGE CAR
Class -Large car:mass (loaded)	= 1500
: unloaded mass	= 1500
:maximum rated eng power	= 110
:number of wheels	= 4
: tire resistance coef Cr1	= 1.0
: frontal area	= 2.2
: aerodynamic drag coeffient	= 0.46
: % of vehicles using diesel	= 2.0
: % of vehicles laden	= 100
: % of all vehs in urban	= 26.9
: % of all vehs in rural	= 22.4
15 character description of class	=VAN

Class - Van	: mass (loaded)	= 2000
	: unloaded mass	= 1300
	: maximum rated eng power	= 70
	: number of wheels	= 4
	: tire resistance coef Cr1	= 1.05
	: frontal area	= 2.6
	: aerodynamic drag coeffient	= 0.52
	: % of vehicles using diesel	= 13.0
	: % of vehicles laden	= 38.0
	: % of all vehs in urban	= 12.0
	: % of all vehs in rural	= 18.6
15 character description of class		=LIGHT RIGID
Class - Light rgd: mass (loaded)		= 2700
	: unloaded mass	= 1400
	: maximum rated eng power	= 75
	: number of wheels	= 4
	: tire resistance coef Cr1	= 1.25
	: frontal area	= 4.0
	: aerodynamic drag coeffient	= 0.55
	: % of vehicles using diesel	= 34.0
	: % of vehicles laden	= 67.0
	: % of all vehs in urban	= 0.90
	: % of all vehs in rural	= 1.60
15 character description of class		=LIGHT/MED RIGID
Class -Light/medium rgd: mass (loaded)		= 5500
	: unloaded mass	= 3000
	: maximum rated eng power	= 90
	: number of wheels	= 6
	: tire resistance coef Cr1	= 1.2
	: frontal area	= 5.0
	: aerodynamic drag coeffient	= 0.58
	: % of vehicles using diesel	= 48.0
	: % of vehicles laden	= 65.0
	: % of all vehs in urban	= 2.20
	: % of all vehs in rural	= 3.00
15 character description of class		=MEDIUM RIGID
Class - Medium rgd: mass (loaded)		= 10000
	: unloaded mass	= 5000
	: maximum rated eng power	= 120
	: number of wheels	= 6
	: tire resistance coef Cr1	= 1.15
	: frontal area	= 6.0
	: aerodynamic drag coeffient	= 0.60
	: % of vehicles using diesel	= 87.0

: % of vehicles laden	= 66.0
: % of all vehs in urban	= 0.60
: % of all vehs in rural	= 0.90
15 character description of class	=MED/HEAVY RIGID
Class - Medium/heavy rgd : mass (loaded)	=16000
: unloaded mass	= 8000
: maximum rated eng power	= 170
: number of wheels	= 10
: tire resistance coef Cr1	= 1.10
: frontal area	= 6.5
: aerodynamic drag coeffient	= 0.64
: % of vehicles using diesel	= 98.0
: % of vehicles laden	= 64.0
: % of all vehs in urban	= 1.00
: % of all vehs in rural	= 1.50
15 character description of class	=MEDIUM ARTIC
Class - Medium artic : mass (loaded)	= 28000
: unloaded mass	= 14000
: maximum rated eng power	= 260
: number of wheels	= 18
: tire resistance coef Cr1	= 1.05
: frontal area	= 7.0
: aerodynamic drag coeffient	= 0.68
: % of vehicles using diesel	= 100
: % of vehicles laden	= 73.0
: % of all vehs in urban	= 0.80
: % of all vehs in rural	= 1.00
15 character description of class	=HEAVY ARTIC
Class -Heavy artic : mass (loaded)	= 38000
: unloaded mass	= 16000
: maximum rated eng power	= 300
: number of wheels	= 22
: tire resistance coef Cr1	= 1.05
: frontal area	= 8.0
: aerodynamic drag coeffient	= 0.72
: % of vehicles using diesel	= 100
: % of vehicles laden	= 74.0
: % of all vehs in urban	= 0.50
: % of all vehs in rural	= 4.20

Default Data Set DEFV03

The following are the default vehicle parameters in ARFCOM called DEFV03 that we used to run the simulations for the fuel consumption of modern vehicles.

Rolling resistance mass independent coef.	= 30.0
Tire resistance mass dependent coef.	= 0.060
Tire resistance speed dependent coef.	= 0.008
Drive-train efficiency	= 0.90
Density of air (kg/m3)	= 1.2
Proportional increase in Cd with yaw angle	= 0.012
Ratio radius of gyration to radius of wheel	= 0.75
Wheel mass for default tire diameter of 0.65	= 18.0
..... 0.72	= 28.0
..... 0.80	= 44.0
..... 1.00	= 90.0
..... 1.14	= 125.0
Vehicle classified as car if Rw less than	= 0.35
Cornering stiffness of radial car tire	= 45.0
..... const coef for $0.7<Dw<0.9$	= 8.8
..... coef of M/Nw for $0.7<Dw<0.9$	= 0.088
..... coef of M/Nw sq. for $0.7<Dw<0.9$	=-0.0000225
..... const coef for $Dw>0.9$	= 0.0
..... coef of M/Nw for $Dw>0.9$	= 0.0913
..... coef of M/Nw sq. for $Dw>0.9$	=-0.0000114
Const coef for est Pmax from eng cap -Diesel	= 28.0
Coef of eng capacity when est Pmax - Diesel	= 16.4
Const coef for est Pmax from eng cap -Petrol	= 38.0
Coef of eng capacity when est Pmax - Petrol	= 19.2
Const coef for est engine speed - Diesel	= 4600
Coef of pmax for est engine speed - Diesel	=-18.0
Coef of Pmax sq for est engine speed - Diesel	= 0.030
Const coef for est engine speed - Petrol trk	= 4500
Const coef for est engine speed - Petrol car	= 5400
Const coef for est Betab - Diesel	= 0.058
Coef of Pmax for est Betab -Diesel	=-0.00001
Value for ehp - Diesel	= 0.10
Const coef for est Betab - Petrol	= 0.065
Coef of Pmax for est Betab -Petrol	= 0.0000
Value for ehp - Petrol	= 0.25
Coef of Pmax for est ceng - Diesel	= 0.017
Const coef for est beng - Diesel	= 0.0
Coef of Pmax for est beng - Diesel	= 0.0287
Coef of Pmax for est ceng - Petrol	= 0.046

Const coef for est beng - Petrol	= 0.0
Coef of Pmax for est beng - Petrol	= 0.016
Value of idle engine speed	= 750
Value of low power eff factor elp - Diesel	= 1.5
Value of low power eff factor elp - Petrol	= 1.3
Constant coef for est max veh speed - Truck	= 27.7
Coef of Pmax for est max veh speed - Truck	= 0.008
Constant coef for est max veh speed - Car	= 36.0
Coef of Pmax for est max veh speed - Car	= 0.13
Speed veh changes to top gear, coef of Nt	= 1100
Speed veh changes to top gear, coef of Vmax	= 1.8
Constant coef for est number of gears - Truck	= 2.5
Coefficient of Pmax for est no. gears - Truck	= 0.03
Constant coef for est number of gears - Car	= 1.5
Coefficient of Pmax for est no. gears - Car	= 0.03
Value of r1 for est eng speed at < top gear	= 0.021
Value of r2 for est eng speed at < top gear	= 22.0
Wheel diameter for MG < mg1	= 0.62
Wheel diameter for mg1 < MG < mg2 & MPW < mpw1	= 0.72
Wheel diameter for mg1 < MG < mg2 & MPW > mpw1	= 0.80
Wheel diameter for mg2 < MG < mg3 & MPW < mpw2	= 0.80
Wheel diameter for mg2 < MG < mg3 & MPW > mpw2	= 1.00
Wheel diameter for MG > mg3 & MPW < mpw3	= 1.00
Wheel diameter for MG > mg3 & MPW > mpw3	= 1.14
Mass used in calculating wheel diameter & mass	= 2500
Mass used in calculating wheel diameter & mass	= 5000
Mass used in calculating wheel diameter & mass	= 10000
Mass used in calculating wheel diameter & mass	= 600
Mass used in calculating wheel diameter & mass	= 1600
Mass used in calculating wheel diameter & mass	= 2300
Coef. for rotating inertia of drive-train	= 1.05
Engine accessory load constant, XX for cars	= 1.5
Engine load constant, XX for trucks & Pmax < p1	= 4.0
Engine load constant, XX for trucks & Pmax > p1	= 8.0
Power value for trucks used in def. XX & YY	= 260
Engine cooling fan load constant, YY for cars	= 0.1
Cooling fan constant, YY for trucks & Pmax < p1	= 0.05
Cooling fan constant, YY for trucks & Pmax > p1	= 0.004
Car model default mass	= 1200
Car model default eng cap. for calc. idle rate	= 2.50
Car model default rolling resistance param	= 0.333
Car model default air resistance parameter	= 0.0008
Car model default efficiency parameter Beta1	= 0.09
Car model default efficiency parameter Beta2	= 0.03

Car model est of idle fuel coef. of engine cap	= 0.220
Car model est of idle fuel coef. of EC*EC	=-0.0193
Vehicle is in less than top gear if speed l.t.	= 50.0
Ratio of speed at TRPM for car in 5th & 4th gr	= 0.82
Car is in less than 5th gear if speed is l.t.	= 80.0
Car in l.t. 5th gear if (Vmax/V)2 x Pout/Pmax	= 1.6
15 character description of class	=SMALL CAR
Class - Small car: mass (loaded)	= 1100
: unloaded mass	= 1100
: maximum rated eng power	= 64
: number of wheels	= 4
: tire resistance coef Cr1	= 1.0
: frontal area	= 1.8
: aerodynamic drag coeffient	= 0.40
: % of vehicles using diesel	= 1.0
: % of vehicles laden	= 100
: % of all vehs in urban	= 26.9
: % of all vehs in rural	= 22.4
15 character description of class	=MEDIUM CAR
Class -Medium car: mass (loaded)	= 1250
: unloaded mass	= 1250
: maximum rated eng power	= 64
: number of wheels	= 4
: tire resistance coef Cr1	= 1.0
: frontal area	= 2.0
: aerodynamic drag coeffient	= 0.41
: % of vehicles using diesel	= 2.0
: % of vehicles laden	= 100
: % of all vehs in urban	= 26.9
: % of all vehs in rural	= 22.4
15 character description of class	=LARGE CAR
Class - Large car: mass (loaded)	= 1500
: unloaded mass	= 1500
: maximum rated eng power	= 110
: number of wheels	= 4
: tire resistance coef Cr1	= 1.0
: frontal area	= 2.2
: aerodynamic drag coeffient	= 0.42
: % of vehicles using diesel	= 2.0
: % of vehicles laden	= 100
: % of all vehs in urban	= 26.9
: % of all vehs in rural	= 22.4
15 character description of class	=VAN
Class - Van : mass (loaded)	= 2000

: unloaded mass	= 1300
: maximum rated eng power	= 70
: number of wheels	= 4
: tire resistance coef Cr1	= 1.05
: frontal area	= 2.6
: aerodynamic drag coeffient	= 0.45
: % of vehicles using diesel	= 13.0
: % of vehicles laden	= 38.0
: % of all vehs in urban	= 12.0
: % of all vehs in rural	= 18.6
15 character description of class	=LIGHT RIGID
Class - Light rgd: mass (loaded)	= 2700
: unloaded mass	= 1400
: maximum rated eng power	= 75
: number of wheels	= 4
: tire resistance coef Cr1	= 1.25
: frontal area	= 4.0
: aerodynamic drag coeffient	= 0.55
: % of vehicles using diesel	= 34.0
: % of vehicles laden	= 67.0
: % of all vehs in urban	= 0.90
: % of all vehs in rural	= 1.60
15 character description of class	=LIGHT/MED RIGID
Class -Light/medium rgd: mass (loaded)	= 5500
: unloaded mass	= 3000
: maximum rated eng power	= 90
: number of wheels	= 6
: tire resistance coef Cr1	= 1.2
: frontal area	= 5.0
: aerodynamic drag coeffient	= 0.58
: % of vehicles using diesel	= 48.0
: % of vehicles laden	= 65.0
: % of all vehs in urban	= 2.20
: % of all vehs in rural	= 3.00
15 character description of class	=MEDIUM RIGID
Class - Medium rgd: mass (loaded)	= 10000
: unloaded mass	= 5000
: maximum rated eng power	= 120
: number of wheels	= 6
: tire resistance coef Cr1	= 1.15
: frontal area	= 6.0
: aerodynamic drag coeffient	= 0.60
: % of vehicles using diesel	= 87.0
: % of vehicles laden	= 66.0

: % of all vehs in urban	= 0.60
: % of all vehs in rural	= 0.90
15 character description of class	=MED/HEAVY RIGID
Class - Medium/heavy rgd : mass (loaded)	=16000
: unloaded mass	= 8000
: maximum rated eng power	= 170
: number of wheels	= 10
: tire resistance coef Cr1	= 1.10
: frontal area	= 6.5
: aerodynamic drag coeffient	= 0.64
: % of vehicles using diesel	= 98.0
: % of vehicles laden	= 64.0
: % of all vehs in urban	= 1.00
: % of all vehs in rural	= 1.50
15 character description of class	=MEDIUM ARTIC
Class - Medium artic : mass (loaded)	= 28000
: unloaded mass	= 14000
: maximum rated eng power	= 260
: number of wheels	= 18
: tire resistance coef Cr1	= 1.05
: frontal area	= 7.0
: aerodynamic drag coeffient	= 0.68
: % of vehicles using diesel	= 100
: % of vehicles laden	= 73.0
: % of all vehs in urban	= 0.80
: % of all vehs in rural	= 1.00
15 character description of class	=HEAVY ARTIC
Class -Heavy artic : mass (loaded)	= 38000
: unloaded mass	= 16000
: maximum rated eng power	= 300
: number of wheels	= 22
: tire resistance coef Cr1	= 1.05
: frontal area	= 8.0
: aerodynamic drag coeffient	= 0.72
: % of vehicles using diesel	= 100
: % of vehicles laden	= 74.0
: % of all vehs in urban	= 0.50
: % of all vehs in rural	= 4.20

Appendix B. ARFCOM Results with TRDF Vehicles by Grade, Speed and Vehicle Type

Table B-1. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of -8 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	62.50	27.21	17.86	13.61	10.63	8.93	7.65	6.80	5.95	8.50	11.90	15.73	19.98	24.66
Medium	112.67	56.12	37.41	28.06	22.53	18.71	16.16	14.03	12.33	11.05	10.20	13.61	18.71	23.81
Large	112.67	56.12	37.41	28.06	22.53	18.71	16.16	14.03	12.33	11.05	10.20	11.90	17.43	22.96
Pickup	151.36	75.68	50.60	37.84	30.19	25.09	21.68	18.71	17.01	15.31	13.61	12.76	14.88	20.83
2axle	239.37	119.90	79.93	59.95	48.04	39.97	34.01	29.76	26.79	23.81	21.68	19.98	18.28	17.01
3axle	79.51	39.54	26.36	19.98	15.73	13.18	11.48	9.78	8.93	8.08	7.23	6.80	5.95	5.53
4axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	10.63	9.35	8.50	7.65	7.23	6.80
5axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	10.63	9.35	8.50	7.65	7.23	6.80

Table B-2. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of -4 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	83.33	42.09	30.19	25.51	23.81	23.81	16.58	19.13	21.68	25.09	28.91	32.74	37.41	42.94
Medium	112.67	56.12	37.41	28.06	25.09	25.09	17.01	19.98	22.96	26.79	31.46	36.14	41.67	48.04
Large	119.47	58.25	40.39	33.59	31.04	31.04	18.71	21.68	25.09	29.34	34.01	39.54	45.49	51.87
Pickup	151.36	75.68	50.60	37.84	30.19	25.09	21.68	18.71	22.53	27.21	32.31	38.27	45.07	52.30
2axle	239.37	119.90	79.93	59.95	48.04	39.97	34.01	29.76	26.79	30.61	39.54	48.89	58.25	61.65
3axle	79.51	39.54	26.36	19.98	15.73	13.18	11.48	9.78	8.93	8.08	7.23	6.80	5.95	5.53
4axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	10.63	9.35	8.50	7.65	7.23	15.73
5axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	10.63	9.35	8.50	7.65	7.23	6.80

Table B-3. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of -3 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	88.44	46.77	34.86	30.19	28.49	28.91	20.83	22.96	25.94	29.34	33.16	37.41	42.09	47.62
Medium	112.67	56.12	38.69	33.16	31.46	31.46	22.53	25.51	28.91	32.74	36.99	42.09	48.04	54.42
Large	128.40	66.75	48.47	41.67	39.12	39.12	25.51	28.49	31.89	36.14	41.24	46.77	52.72	59.52
Pickup	151.36	75.68	50.60	37.84	30.19	28.91	22.53	25.94	29.76	34.86	40.39	46.34	53.15	60.80
2axle	239.37	119.90	79.93	59.95	48.04	39.97	34.01	33.59	40.39	48.47	57.82	68.03	77.81	82.06
3axle	79.51	39.54	26.36	19.98	15.73	13.18	11.48	9.78	8.93	8.08	7.23	6.80	13.61	19.98
4axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	10.63	9.35	16.58	31.89	48.89	63.35
5axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	10.63	9.35	8.50	7.65	7.23	14.03

Table B-4. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of -2 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	93.54	51.87	39.54	34.86	33.59	33.59	25.09	27.21	30.19	33.59	37.41	42.09	46.77	52.30
Medium	112.67	59.52	45.07	39.54	37.84	38.27	28.06	31.04	34.44	38.69	43.37	48.47	54.42	60.80
Large	136.90	74.83	56.55	49.74	47.19	46.77	32.31	35.29	39.12	43.37	48.47	54.00	60.37	67.18
Pickup	151.36	75.68	50.60	38.27	36.99	37.41	29.76	33.16	37.41	42.52	48.04	54.42	61.65	69.73
2axle	239.37	119.90	79.93	59.95	48.04	40.82	45.07	51.45	58.67	67.18	76.96	88.01	98.64	103.32
3axle	79.51	39.54	26.36	19.98	15.73	13.18	11.48	9.78	17.01	25.51	34.86	45.07	56.12	62.93
4axle	116.50	48.04	31.46	23.81	23.81	27.21	32.74	25.09	36.56	49.74	64.20	80.36	98.21	113.52
5axle	93.96	46.77	31.46	23.38	18.71	15.73	13.61	11.90	12.76	25.94	40.39	56.55	74.40	89.71

Table B-5. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of -1 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	99.06	56.97	44.64	39.97	38.27	38.69	28.91	31.46	34.44	37.84	42.09	46.34	51.87	57.40
Medium	115.22	66.33	51.87	46.34	44.64	44.64	34.01	36.56	40.39	44.64	49.32	54.85	60.80	67.60
Large	145.83	83.33	65.05	57.82	55.27	55.27	39.54	42.52	46.34	50.60	55.70	61.65	68.03	75.26
Pickup	151.36	75.68	52.30	47.19	45.49	46.34	37.41	40.82	45.49	50.60	56.12	62.93	70.58	78.66
2axle	239.37	119.90	79.93	62.93	60.80	61.22	63.35	69.73	77.81	87.16	97.36	108.84	120.32	125.85
3axle	118.20	69.73	56.55	51.87	51.45	53.57	44.64	51.87	59.52	68.45	78.66	89.29	101.19	108.84
4axle	172.62	101.62	82.06	75.68	75.26	78.66	84.61	72.70	84.61	98.21	113.52	130.53	149.23	165.82
5axle	173.89	103.32	83.76	77.38	77.38	80.78	86.73	95.24	87.16	101.19	116.92	134.35	153.49	170.92

Table B-6. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 0 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	104.17	62.07	49.74	45.07	43.37	43.37	33.16	35.71	38.69	42.52	46.77	51.45	56.55	62.50
Medium	122.45	73.13	58.67	53.15	51.02	51.45	39.54	42.52	46.34	50.60	55.27	61.22	67.18	74.40
Large	154.34	91.84	73.13	65.90	63.35	63.35	46.34	49.74	53.57	58.25	63.35	69.30	76.11	83.76
Pickup	151.36	75.68	61.22	55.70	54.42	55.27	44.64	48.47	53.15	58.67	64.63	71.43	79.51	88.01
2axle	239.37	119.90	91.41	83.76	81.63	82.06	82.06	89.29	97.79	107.57	118.62	130.95	143.28	149.66
3axle	170.07	119.47	105.02	100.34	99.49	101.62	105.44	110.54	104.17	113.52	124.15	136.05	148.81	157.74
4axle	229.17	156.04	135.63	128.83	127.98	131.38	137.76	146.26	134.35	148.38	164.54	182.40	202.81	220.24
5axle	263.18	188.78	167.52	160.71	160.29	164.12	170.92	179.85	165.39	180.70	197.70	216.84	238.10	-

Table B-7. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 1 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	109.69	67.18	54.85	49.74	48.47	48.47	37.41	39.97	43.37	47.19	51.45	56.12	61.65	67.60
Medium	129.68	79.93	65.48	59.95	57.82	58.25	45.49	48.47	52.30	56.55	61.65	67.60	73.98	81.21
Large	163.27	100.34	81.63	74.40	71.85	71.85	53.57	56.97	60.80	65.48	71.00	77.38	84.18	91.84
Pickup	151.36	84.61	70.15	65.05	63.35	64.20	52.72	56.55	61.22	66.75	73.13	80.36	88.44	97.79
2axle	239.37	133.08	112.67	105.44	103.32	104.17	101.19	109.27	118.20	128.83	140.73	153.91	167.52	174.74
3axle	223.21	170.49	155.19	150.09	149.23	151.36	155.61	161.14	168.37	177.30	184.52	190.90	-	-
4axle	286.56	211.31	190.05	182.82	182.40	185.80	192.18	201.53	184.95	200.26	217.69	236.82	-	-
5axle	353.32	276.36	253.83	246.60	246.60	250.85	258.08	268.28	278.49	264.03	282.74	-	-	-

Table B-8. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 2 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	114.80	72.28	59.95	54.85	53.57	53.57	42.09	44.64	47.62	51.45	56.12	60.80	66.75	72.70
Medium	136.90	86.73	72.28	66.75	65.05	65.05	51.02	54.42	58.25	62.93	68.45	74.40	80.78	88.44
Large	172.19	108.84	90.14	82.91	80.36	80.36	60.80	64.20	68.45	73.13	79.08	85.46	92.69	100.34
Pickup	151.36	93.96	79.51	73.98	72.70	73.55	60.37	64.63	69.73	75.26	82.06	89.71	98.21	107.57
2axle	239.37	155.19	134.78	127.13	125.43	126.70	121.17	129.68	139.46	150.94	163.69	178.15	193.03	200.68
3axle	277.21	222.79	206.63	201.11	200.68	202.81	207.48	213.86	221.94	228.74	-	-	-	-
4axle	344.39	267.43	245.32	238.10	237.67	241.50	248.72	258.08	269.13	253.83	-	-	-	-
5axle	445.58	366.07	342.69	335.46	335.88	340.99	349.49	357.57	364.80	-	-	-	-	-

Table B-9. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 3 Percent

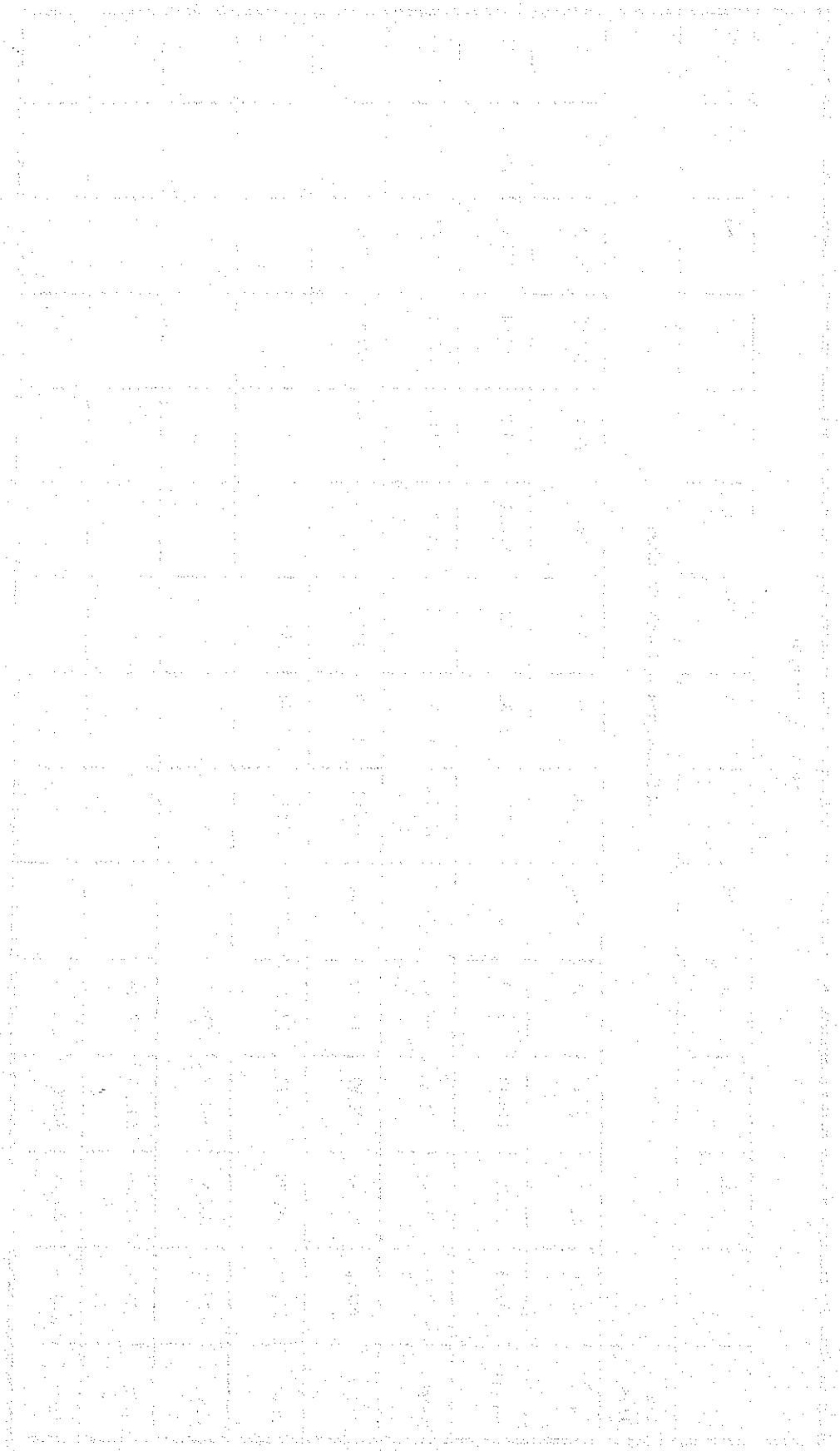
	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	120.32	77.38	65.05	59.95	58.67	58.67	46.34	48.89	52.30	56.12	60.80	65.90	71.85	78.23
Medium	144.13	93.96	79.08	73.55	71.85	72.28	56.97	60.37	64.63	69.30	74.83	81.21	88.01	95.66
Large	181.12	117.35	98.64	91.41	88.86	88.86	90.99	71.43	75.68	81.21	86.73	93.54	101.19	109.27
Pickup	153.91	103.32	88.86	83.33	82.06	82.91	85.46	72.70	78.23	84.18	90.99	99.06	107.99	117.77
2axle	247.02	177.30	157.31	149.66	147.96	150.09	142.01	150.94	161.56	173.89	187.93	203.23	219.39	-
3axle	332.06	275.94	258.93	253.40	253.40	256.38	261.48	269.13	-	-	-	-	-	-
4axle	403.06	324.40	301.45	294.22	294.22	298.47	306.12	316.75	-	-	-	-	-	-
5axle	539.12	457.48	433.67	426.87	428.15	434.52	439.63	-	-	-	-	-	-	-

Table B-10. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 4 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	125.85	82.91	70.15	65.05	63.78	64.20	65.90	53.57	56.97	61.22	65.90	71.00	76.96	83.33
Medium	151.79	101.19	86.31	80.78	79.08	79.51	81.63	66.75	71.00	75.68	81.63	88.01	95.24	103.32
Large	190.48	126.28	107.14	99.91	97.36	97.79	99.91	103.32	83.76	88.86	95.24	102.04	109.69	118.20
Pickup	163.69	112.67	98.21	92.69	91.41	92.69	95.24	99.49	104.59	93.11	100.34	108.42	136.48	147.11
2axle	270.41	200.26	179.85	173.04	171.77	173.89	178.57	185.37	194.30	204.51	216.84	-	-	-
3axle	387.76	330.36	312.93	307.40	307.82	311.65	317.60	-	-	-	-	-	-	-
4axle	462.16	382.23	358.84	351.62	351.62	356.72	365.65	-	-	-	-	-	-	-
5axle	634.35	551.02	527.21	520.83	523.38	525.51	-	-	-	-	-	-	-	-

Table B-11. Fuel Consumption (gallons/1,000 miles) for TRDF Vehicles at Constant Speeds (mph) on Pavement with Grade of 8 Percent

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	Fuel Consumption (gallons/1,000 miles)													
Small	147.96	104.17	91.41	86.31	85.03	85.88	87.59	90.99	94.81	99.49	105.02	111.39	118.62	126.70
Medium	181.55	130.10	114.80	109.27	107.99	109.27	111.82	115.65	120.32	126.28	133.08	141.16	150.09	160.29
Large	227.04	161.99	142.43	135.20	133.08	133.93	136.90	140.73	146.26	153.06	160.71	169.64	179.42	190.48
Pickup	203.66	151.79	136.90	131.80	131.38	133.08	136.90	142.01	148.38	156.04	164.97	175.60	-	-
2axle	367.35	296.34	276.79	271.26	272.53	278.06	286.14	296.77	-	-	-	-	-	-
3axle	620.75	559.52	542.52	539.12	-	-	-	-	-	-	-	-	-	-
4axle	705.78	621.60	597.79	592.26	-	-	-	-	-	-	-	-	-	-
5axle	1031.46	946.85	909.01	-	-	-	-	-	-	-	-	-	-	-



Appendix C. ARFCOM Results with TRDF Trucks by Weight

Table F-27. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of -1 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	160.29	160.29	160.29	160.29	160.29	160.29
10	82.06	79.93	79.93	79.93	79.93	79.93
15	64.63	57.82	53.57	53.57	53.57	53.57
20	58.67	51.45	47.62	43.37	39.97	39.97
25	57.40	50.60	46.34	42.09	32.74	31.89
30	59.10	52.30	48.04	43.79	34.44	29.34
35	62.93	56.12	51.87	47.62	38.27	33.16
40	54.00	47.62	43.79	39.97	31.04	26.36
45	62.93	56.12	52.30	48.47	39.54	34.86
50	73.13	65.90	62.07	58.25	49.32	44.22
55	84.18	76.96	72.70	68.88	59.52	54.85
60	96.51	88.86	84.61	80.78	71.43	66.33
65	109.69	102.04	97.79	93.96	84.18	79.08
70	120.32	111.82	107.99	103.74	93.96	88.86

Table F-28. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	171.34	178.15	187.50	197.28	201.11	209.61
10	108.84	115.65	124.57	133.93	137.76	145.83
15	90.99	97.36	106.72	115.65	119.47	127.55
20	85.03	90.99	99.91	109.27	112.67	120.75
25	83.76	89.71	98.64	107.99	111.39	119.47
30	85.46	91.41	100.34	109.69	113.10	121.17
35	89.29	95.24	104.17	113.52	116.92	125.00
40	78.23	83.76	92.26	119.05	122.45	130.53
45	87.59	92.69	101.19	109.69	113.10	120.32
50	97.79	102.89	111.39	119.90	123.30	130.95
55	109.27	114.37	122.87	131.80	134.78	142.43
60	121.60	126.70	135.63	144.56	147.53	155.61
65	135.63	140.73	149.66	158.59	161.99	169.64
70	146.68	151.36	160.71	169.64	173.04	181.12

Table F-29. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of 1 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	199.40	220.66	244.47	268.71	287.41	310.37
10	136.48	156.46	179.85	203.23	221.09	243.62
15	117.77	137.76	160.71	183.67	201.53	223.64
20	111.39	131.38	153.91	176.87	194.30	216.41
25	110.12	129.68	152.64	175.60	193.03	215.14
30	111.82	131.80	154.34	177.30	195.15	217.26
35	116.07	135.63	158.59	181.55	199.40	221.94
40	121.60	141.58	164.54	187.93	205.78	228.74
45	112.24	130.53	151.79	173.47	189.63	236.82
50	122.87	141.16	162.84	184.52	201.53	222.79
55	134.78	153.06	175.17	197.28	214.29	235.97
60	147.53	166.24	188.78	211.31	228.74	250.85
65	161.99	180.70	203.66	227.04	-	-
70	173.47	192.18	215.56	-	-	-

Table F-30. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of 2 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	227.89	263.61	302.30	341.41	375.00	413.27
10	163.69	198.13	235.97	273.81	306.12	343.96
15	144.98	179.00	215.99	253.40	285.71	323.13
20	138.18	172.19	208.76	246.60	278.49	315.90
25	136.90	170.49	207.48	245.32	277.64	315.05
30	139.03	172.62	209.61	247.87	280.19	318.45
35	142.86	176.87	214.29	252.55	285.71	323.98
40	148.81	182.82	220.66	259.78	292.94	332.06
45	137.33	168.79	229.17	268.71	300.60	336.73
50	148.38	179.85	215.56	252.13	283.16	-
55	160.71	192.60	228.74	266.16	-	-
60	174.32	206.63	243.62	-	-	-
65	189.20	221.94	-	-	-	-
70	201.11	-	-	-	-	-

Table F-31. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of 3 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	256.80	306.97	360.97	415.39	464.29	518.28
10	191.75	240.22	292.52	345.66	393.71	446.85
15	172.19	220.66	272.11	324.83	372.45	425.60
20	165.39	213.44	265.31	318.03	365.65	419.22
25	164.12	212.16	264.03	317.18	365.22	419.22
30	166.24	214.29	266.58	320.15	369.05	423.89
35	170.49	218.96	271.68	326.11	375.43	430.27
40	176.87	225.77	278.91	334.18	380.95	-
45	163.27	233.84	287.84	338.86	-	-
50	174.32	219.81	270.41	-	-	-
55	187.07	233.42	-	-	-	-
60	201.11	248.30	-	-	-	-
65	216.84	-	-	-	-	-
70	-	-	-	-	-	-

Table F-32. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of 4 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	285.71	350.77	420.07	490.22	554.85	625.85
10	219.39	283.16	350.34	419.22	482.99	552.72
15	199.83	262.76	329.51	397.96	461.73	531.89
20	193.03	255.53	322.70	391.16	455.36	526.36
25	191.75	254.68	321.85	391.16	456.21	528.06
30	193.88	256.80	324.83	395.41	461.31	-
35	198.55	261.90	330.78	402.21	-	-
40	204.93	269.13	339.29	-	-	-
45	189.20	278.06	343.54	-	-	-
50	200.68	261.05	-	-	-	-
55	213.86	-	-	-	-	-
60	228.74	-	-	-	-	-
65	-	-	-	-	-	-
70	-	-	-	-	-	-

Table F-33. Fuel Consumption (gallons/1,000 miles) for Modern 3-Axle Combination Trucks of Various Weights on Pavement with Grade of 8 Percent

	Vehicle Weight (x 1,000 lbs.)					
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	402.64	530.19	663.69	801.02	935.37	1078.23
10	333.76	458.76	590.56	727.47	862.24	1006.80
15	312.93	437.50	569.73	707.48	842.26	961.31
20	306.12	431.12	564.63	702.38	-	-
25	305.27	431.55	566.75	-	-	-
30	308.25	436.22	-	-	-	-
35	314.20	441.33	-	-	-	-
40	322.28	-	-	-	-	-
45	327.81	-	-	-	-	-
50	-	-	-	-	-	-
55	-	-	-	-	-	-
60	-	-	-	-	-	-
65	-	-	-	-	-	-
70	-	-	-	-	-	-

Table F-34. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of -8 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	93.96	93.96	93.96	93.96	93.96	93.96
10	46.77	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	18.71	18.71	18.71	18.71	18.71	18.71
30	15.73	15.73	15.73	15.73	15.73	15.73
35	13.61	13.61	13.61	13.61	13.61	13.61
40	11.90	11.90	11.90	11.90	11.90	11.90
45	10.63	10.63	10.63	10.63	10.63	10.63
50	9.35	9.35	9.35	9.35	9.35	9.35
55	8.50	8.50	8.50	8.50	8.50	8.50
60	7.65	7.65	7.65	7.65	7.65	7.65
65	7.23	7.23	7.23	7.23	7.23	7.23
70	6.80	6.80	6.80	6.80	6.80	6.80

Table F-35. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of -4 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	93.96	93.96	93.96	93.96	93.96	93.96
10	46.77	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	18.71	18.71	18.71	18.71	18.71	18.71
30	15.73	15.73	15.73	15.73	15.73	15.73
35	13.61	13.61	13.61	13.61	13.61	13.61
40	11.90	11.90	11.90	11.90	11.90	11.90
45	10.63	10.63	10.63	10.63	10.63	10.63
50	11.48	9.35	9.35	9.35	9.35	9.35
55	23.38	8.50	8.50	8.50	8.50	8.50
60	36.56	7.65	7.65	7.65	7.65	7.65
65	50.60	8.08	7.23	7.23	7.23	7.23
70	62.50	19.13	6.80	6.80	6.80	6.80

Table F-36. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of -3 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	101.19	93.96	93.96	93.96	93.96	93.96
10	46.77	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	18.71	18.71	18.71	18.71	18.71	18.71
30	16.16	15.73	15.73	15.73	15.73	15.73
35	20.83	13.61	13.61	13.61	13.61	13.61
40	14.46	11.90	11.90	11.90	11.90	11.90
45	24.23	10.63	10.63	10.63	10.63	10.63
50	35.29	9.35	9.35	9.35	9.35	9.35
55	47.19	17.01	8.50	8.50	8.50	8.50
60	60.37	29.76	7.65	7.65	7.65	7.65
65	75.26	43.37	16.16	7.23	7.23	7.23
70	87.16	54.85	27.21	6.80	6.80	6.80

Table F-37. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of -2 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	128.83	108.42	93.96	93.96	93.96	93.96
10	64.20	46.77	46.77	46.77	46.77	46.77
15	45.92	31.46	31.46	31.46	31.46	31.46
20	39.97	23.38	23.38	23.38	23.38	23.38
25	39.12	20.41	18.71	18.71	18.71	18.71
30	41.67	22.53	15.73	15.73	15.73	15.73
35	46.34	27.21	13.61	13.61	13.61	13.61
40	37.84	20.41	11.90	11.90	11.90	11.90
45	48.04	29.76	14.46	10.63	10.63	10.63
50	59.10	40.39	25.09	9.35	9.35	9.35
55	71.43	52.30	36.56	21.26	8.50	8.50
60	85.03	65.48	49.74	34.01	18.28	7.65
65	99.91	79.93	63.78	48.04	31.89	16.58
70	112.24	91.84	75.26	59.10	43.37	27.21

Table F-38. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of -1 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	156.46	150.09	145.41	141.16	136.48	132.23
10	90.99	84.61	80.36	76.11	71.85	67.60
15	72.28	66.33	62.07	57.82	53.57	49.32
20	65.90	59.95	55.70	51.45	47.19	42.94
25	65.05	58.67	54.85	50.60	46.34	42.09
30	67.60	61.22	56.97	52.72	48.47	44.64
35	71.85	65.48	61.22	56.97	53.15	48.89
40	61.65	55.70	51.87	48.04	44.22	40.39
45	71.85	65.48	61.65	57.82	54.00	50.17
50	83.33	76.53	72.70	68.88	65.05	61.22
55	96.09	88.86	85.03	81.21	76.96	73.13
60	110.12	102.89	98.64	94.81	90.56	86.73
65	125.43	117.77	113.52	109.69	105.44	101.62
70	138.18	130.10	125.85	122.02	117.77	113.52

Table F-39. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	184.52	192.18	201.53	211.31	220.66	230.44
10	117.77	125.00	134.35	143.28	152.64	161.99
15	98.64	105.87	114.80	123.72	133.08	142.01
20	92.26	99.06	107.99	116.92	125.85	135.20
25	90.99	97.79	106.72	116.07	125.00	133.93
30	93.54	100.34	109.27	118.20	127.13	136.05
35	98.21	104.59	113.52	122.87	131.80	140.73
40	104.59	111.39	120.32	129.25	138.61	147.53
45	96.51	102.04	110.54	119.05	127.55	136.05
50	107.99	113.52	122.02	130.53	139.46	147.96
55	121.17	126.70	135.20	143.71	152.64	161.14
60	135.20	140.73	149.66	158.59	167.09	176.02
65	151.36	156.46	165.39	174.74	183.67	192.60
70	164.54	169.64	179.00	187.93	197.28	206.63

Table F-40. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of 1 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	212.59	234.27	258.08	282.31	306.12	330.36
10	144.98	165.82	188.78	212.16	235.12	258.93
15	125.43	145.83	168.79	191.33	214.29	237.67
20	118.62	139.03	161.56	184.10	207.06	230.44
25	117.35	137.76	160.29	183.25	206.21	229.17
30	119.90	139.88	162.84	185.37	208.76	232.14
35	124.57	144.98	167.52	190.48	213.86	237.24
40	131.38	151.36	174.32	197.70	221.09	245.32
45	121.17	139.46	160.71	182.40	230.44	254.68
50	133.08	151.79	173.04	195.15	217.26	239.80
55	146.26	164.97	187.07	209.18	231.72	254.68
60	161.14	179.85	202.38	225.34	248.30	271.68
65	177.72	196.85	219.39	242.77	-	-
70	191.75	210.46	233.84	-	-	-

Table F-41. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of 2 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	241.07	277.21	315.48	354.17	392.86	432.40
10	172.19	207.06	244.47	281.89	319.73	357.99
15	152.21	186.65	223.21	260.63	298.04	336.31
20	145.41	179.42	215.99	252.98	290.82	328.66
25	144.13	178.15	215.14	252.13	289.97	328.23
30	146.68	180.70	217.69	255.10	293.37	332.06
35	151.36	185.80	222.79	260.63	299.32	338.86
40	158.59	193.03	230.44	268.71	307.82	347.79
45	146.26	177.72	239.80	278.91	315.90	352.89
50	158.59	190.48	225.77	261.90	322.28	-
55	172.19	204.51	240.65	277.64	-	-
60	187.50	220.24	257.23	-	-	-
65	204.51	237.67	-	-	-	-
70	218.96	-	-	-	-	-

Table F-42. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of 3 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	269.56	320.15	373.30	426.87	481.29	536.14
10	199.83	248.72	300.60	352.89	406.04	460.03
15	179.42	227.89	278.91	331.21	383.93	437.50
20	172.19	220.66	271.68	323.98	376.70	430.70
25	171.34	219.39	270.83	323.13	376.70	431.12
30	173.89	221.94	273.81	326.96	380.95	436.22
35	179.00	227.47	279.76	333.33	388.18	443.45
40	185.80	235.12	287.84	342.69	394.56	-
45	171.77	244.47	297.19	348.21	-	-
50	184.52	230.02	280.19	-	-	-
55	198.55	245.32	-	-	-	-
60	214.71	261.90	-	-	-	-
65	232.14	-	-	-	-	-
70	-	-	-	-	-	-

Table F-43. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of 4 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	298.04	363.52	431.55	500.85	571.00	642.01
10	227.47	290.82	357.57	425.60	494.47	564.63
15	206.63	269.56	335.46	403.06	471.94	542.09
20	199.40	262.33	328.23	396.26	465.14	536.14
25	198.55	261.48	327.81	396.26	466.41	538.27
30	201.11	264.46	331.63	400.94	471.94	541.67
35	206.63	269.98	338.01	408.59	476.19	-
40	213.86	278.06	347.36	413.27	-	-
45	223.21	288.27	352.47	-	-	-
50	210.88	270.83	-	-	-	-
55	225.34	286.56	-	-	-	-
60	241.92	-	-	-	-	-
65	-	-	-	-	-	-
70	-	-	-	-	-	-

Table F-44. Fuel Consumption (gallons/1,000 miles) for Modern 4-Axle Trucks of Various Weights on Pavement with Grade of 8 Percent

Vehicle Weight (x 1,000 lbs.)						
	20	30	40	50	60	70
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	413.69	540.39	672.19	806.97	945.15	1086.31
10	340.14	464.29	594.39	728.32	866.50	1009.35
15	318.45	442.18	571.85	707.06	846.94	970.24
20	311.22	434.95	566.33	703.23	826.53	-
25	310.80	435.80	568.88	-	-	-
30	314.20	440.90	-	-	-	-
35	321.00	447.70	-	-	-	-
40	329.93	-	-	-	-	-
45	336.31	-	-	-	-	-
50	-	-	-	-	-	-
55	-	-	-	-	-	-
60	-	-	-	-	-	-
65	-	-	-	-	-	-
70	-	-	-	-	-	-

Table F-45. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of -8 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	93.96	93.96	93.96	93.96	93.96	93.96
10	46.77	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	18.71	18.71	18.71	18.71	18.71	18.71
30	15.73	15.73	15.73	15.73	15.73	15.73
35	13.61	13.61	13.61	13.61	13.61	13.61
40	11.90	11.90	11.90	11.90	11.90	11.90
45	10.63	10.63	10.63	10.63	10.63	10.63
50	9.35	9.35	9.35	9.35	9.35	9.35
55	8.50	8.50	8.50	8.50	8.50	8.50
60	7.65	7.65	7.65	7.65	7.65	7.65
65	7.23	7.23	7.23	7.23	7.23	7.23
70	6.80	6.80	6.80	6.80	6.80	6.80

Table F-46. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of -4 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	93.96	93.96	93.96	93.96	93.96	93.96
10	46.77	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	18.71	18.71	18.71	18.71	18.71	18.71
30	15.73	15.73	15.73	15.73	15.73	15.73
35	13.61	13.61	13.61	13.61	13.61	13.61
40	11.90	11.90	11.90	11.90	11.90	11.90
45	10.63	10.63	10.63	10.63	10.63	10.63
50	9.35	9.35	9.35	9.35	9.35	9.35
55	8.50	8.50	8.50	8.50	8.50	8.50
60	7.65	7.65	7.65	7.65	7.65	7.65
65	7.65	7.23	7.23	7.23	7.23	7.23
70	18.71	6.80	6.80	6.80	6.80	6.80

Table F-47. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of -3 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	93.96	93.96	93.96	93.96	93.96	93.96
10	46.77	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	18.71	18.71	18.71	18.71	18.71	18.71
30	15.73	15.73	15.73	15.73	15.73	15.73
35	13.61	13.61	13.61	13.61	13.61	13.61
40	11.90	11.90	11.90	11.90	11.90	11.90
45	10.63	10.63	10.63	10.63	10.63	10.63
50	9.35	9.35	9.35	9.35	9.35	9.35
55	17.43	8.50	8.50	8.50	8.50	8.50
60	29.34	7.65	7.65	7.65	7.65	7.65
65	42.52	15.31	7.23	7.23	7.23	7.23
70	54.42	26.79	6.80	6.80	6.80	6.80

Table F-48. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of -2 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	110.97	93.96	93.96	93.96	93.96	93.96
10	48.04	46.77	46.77	46.77	46.77	46.77
15	31.46	31.46	31.46	31.46	31.46	31.46
20	23.38	23.38	23.38	23.38	23.38	23.38
25	22.11	18.71	18.71	18.71	18.71	18.71
30	24.23	15.73	15.73	15.73	15.73	15.73
35	28.06	13.61	13.61	13.61	13.61	13.61
40	22.96	11.90	11.90	11.90	11.90	11.90
45	31.89	16.16	10.63	10.63	10.63	10.63
50	41.67	26.36	10.63	9.35	9.35	9.35
55	53.15	37.41	21.68	8.50	8.50	8.50
60	65.48	49.32	33.59	18.28	7.65	7.65
65	79.08	62.93	46.77	31.04	15.73	7.23
70	90.99	74.83	58.67	42.94	27.21	11.48

Table F-49. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of -1 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	150.94	146.68	142.43	138.18	133.93	129.68
10	86.73	82.48	78.23	74.40	70.15	65.90
15	68.03	63.78	59.95	55.70	51.45	47.62
20	61.22	56.97	53.15	48.89	45.07	40.82
25	59.95	55.70	51.87	47.62	43.79	39.54
30	61.65	57.40	53.57	49.32	45.49	41.24
35	65.48	61.65	57.40	53.57	49.32	45.49
40	71.43	54.42	50.60	46.77	42.94	39.12
45	67.60	63.78	59.52	55.70	51.87	48.04
50	77.81	73.98	70.15	65.90	62.07	58.25
55	89.29	85.46	81.21	77.38	73.55	69.73
60	102.04	98.21	93.96	90.14	86.31	82.06
65	116.07	112.24	107.99	104.17	99.91	96.09
70	128.83	125.00	120.75	116.50	112.67	108.42

Table F-50. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	191.33	200.68	209.61	218.96	227.89	237.24
10	125.85	134.78	143.71	152.64	161.56	170.49
15	106.29	115.22	124.15	132.65	141.58	150.51
20	99.49	107.99	116.92	125.43	134.35	143.28
25	97.79	106.72	115.22	124.15	132.65	141.58
30	99.49	108.42	116.92	125.85	134.35	143.28
35	103.74	112.24	121.17	130.10	138.61	147.53
40	109.69	118.62	127.13	136.05	144.98	153.91
45	103.74	112.24	120.32	128.83	137.33	145.83
50	114.37	122.87	131.38	139.88	148.38	156.89
55	126.70	135.20	143.71	152.21	161.14	169.64
60	139.88	148.38	157.31	165.82	174.74	183.67
65	154.76	163.27	172.19	181.12	190.05	199.40
70	167.94	176.87	186.22	195.15	204.51	213.44

Table F-51. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 1 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	232.14	254.68	277.64	300.60	323.55	346.51
10	165.39	187.50	209.61	232.14	254.68	277.21
15	145.41	167.09	189.20	211.31	233.84	255.95
20	138.18	159.86	181.97	204.08	226.19	248.72
25	136.48	158.16	180.27	202.38	224.91	247.45
30	138.18	160.29	182.40	204.51	227.04	249.57
35	142.43	164.54	186.65	209.18	231.72	254.68
40	148.81	170.92	193.45	215.99	238.95	261.90
45	140.73	161.99	201.53	224.49	247.87	271.26
50	152.21	173.47	195.15	216.84	239.37	261.48
55	164.54	186.22	208.33	230.87	253.40	275.94
60	178.57	200.68	223.21	245.75	268.71	292.09
65	193.88	216.41	239.37	262.76	-	-
70	208.33	231.29	254.68	-	-	-

Table F-52. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 2 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**					
5	272.96	309.52	346.09	383.08	420.49	457.48
10	204.93	240.65	276.79	312.93	349.49	386.05
15	184.52	219.81	255.53	291.67	327.81	364.80
20	177.30	212.59	248.30	284.01	320.58	357.57
25	175.60	210.88	247.02	283.16	319.73	356.72
30	177.72	213.01	249.15	285.71	322.70	360.54
35	181.97	217.69	254.25	291.24	328.66	366.92
40	188.78	224.91	261.48	298.89	337.16	375.00
45	196.85	233.42	270.83	307.40	343.96	380.95
50	190.48	225.34	261.05	315.05	352.04	-
55	203.66	239.37	275.51	312.50	-	-
60	218.54	254.68	291.67	-	-	-
65	234.69	271.68	-	-	-	-
70	249.57	-	-	-	-	-

Table F-53. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 3 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	313.78	364.37	415.39	466.84	518.28	570.15
10	244.90	294.22	344.39	394.98	446.00	497.45
15	224.49	273.38	323.13	373.30	424.32	475.77
20	216.84	265.73	315.90	366.50	417.52	469.39
25	215.14	264.46	315.05	365.65	417.52	470.24
30	217.69	267.01	318.03	369.47	422.19	475.34
35	222.36	272.53	323.98	376.28	429.42	480.87
40	229.17	279.76	332.06	383.93	434.52	-
45	238.10	289.54	339.29	389.88	-	-
50	230.02	278.91	346.94	-	-	-
55	243.62	293.79	-	-	-	-
60	258.93	-	-	-	-	-
65	276.36	-	-	-	-	-
70	-	-	-	-	-	-

Table F-54. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 4 Percent

	Vehicle Weight (x 1,000 lbs.)					
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	355.02	419.64	485.12	551.02	617.77	684.95
10	285.29	348.64	413.27	478.32	544.22	610.97
15	264.46	327.38	391.58	457.06	522.96	590.14
20	256.80	320.15	384.78	450.26	517.01	585.03
25	255.53	319.30	384.35	450.68	518.71	587.59
30	258.08	322.28	388.18	455.78	524.66	589.71
35	263.18	328.23	395.41	462.16	-	-
40	270.41	336.73	401.79	-	-	-
45	279.76	343.54	-	-	-	-
50	269.98	351.62	-	-	-	-
55	284.44	-	-	-	-	-
60	-	-	-	-	-	-
65	-	-	-	-	-	-
70	-	-	-	-	-	-

Table F-55. Fuel Consumption (gallons/1,000 miles) for Modern 5-Axle Trucks of Various Weights on Pavement with Grade of 8 Percent

Vehicle Weight (x 1,000 lbs.)						
	30	40	50	60	70	80
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)					
5	522.53	645.83	771.26	898.81	1028.06	1159.44
10	449.83	572.28	697.28	825.26	955.78	1089.29
15	428.57	551.02	677.30	806.55	934.52	1052.72
20	421.77	545.49	673.47	798.89	-	-
25	421.77	547.62	673.47	-	-	-
30	426.45	552.30	-	-	-	-
35	433.67	-	-	-	-	-
40	438.78	-	-	-	-	-
45	-	-	-	-	-	-
50	-	-	-	-	-	-
55	-	-	-	-	-	-
60	-	-	-	-	-	-
65	-	-	-	-	-	-
70	-	-	-	-	-	-

Table F-56. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of -8 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	195.15	195.15	195.15	195.15	195.15	195.15	195.15	195.15
10	97.36	97.36	97.36	97.36	97.36	97.36	97.36	97.36
15	65.05	65.05	65.05	65.05	65.05	65.05	65.05	65.05
20	48.89	48.89	48.89	48.89	48.89	48.89	48.89	48.89
25	39.12	39.12	39.12	39.12	39.12	39.12	39.12	39.12
30	32.31	32.31	32.31	32.31	32.31	32.31	32.31	32.31
35	28.06	28.06	28.06	28.06	28.06	28.06	28.06	28.06
40	24.23	24.23	24.23	24.23	24.23	24.23	24.23	24.23
45	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
50	19.56	19.56	19.56	19.56	19.56	19.56	19.56	19.56
55	17.86	17.86	17.86	17.86	17.86	17.86	17.86	17.86
60	16.16	16.16	16.16	16.16	16.16	16.16	16.16	16.16
65	14.88	14.88	14.88	14.88	14.88	14.88	14.88	14.88
70	14.03	14.03	14.03	14.03	14.03	14.03	14.03	14.03

Table F-57. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of -4 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	195.15	195.15	195.15	195.15	195.15	195.15	195.15	195.15
10	97.36	97.36	97.36	97.36	97.36	97.36	97.36	97.36
15	65.05	65.05	65.05	65.05	65.05	65.05	65.05	65.05
20	48.89	48.89	48.89	48.89	48.89	48.89	48.89	48.89
25	39.12	39.12	39.12	39.12	39.12	39.12	39.12	39.12
30	32.31	32.31	32.31	32.31	32.31	32.31	32.31	32.31
35	28.06	28.06	28.06	28.06	28.06	28.06	28.06	28.06
40	24.23	24.23	24.23	24.23	24.23	24.23	24.23	24.23
45	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
50	19.56	19.56	19.56	19.56	19.56	19.56	19.56	19.56
55	17.86	17.86	17.86	17.86	17.86	17.86	17.86	17.86
60	16.16	16.16	16.16	16.16	16.16	16.16	16.16	16.16
65	16.16	14.88	14.88	14.88	14.88	14.88	14.88	14.88
70	28.06	14.03	14.03	14.03	14.03	14.03	14.03	14.03

Table F-58. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of -3 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	195.15	195.15	195.15	195.15	195.15	195.15	195.15	195.15
10	97.36	97.36	97.36	97.36	97.36	97.36	97.36	97.36
15	65.05	65.05	65.05	65.05	65.05	65.05	65.05	65.05
20	48.89	48.89	48.89	48.89	48.89	48.89	48.89	48.89
25	39.12	39.12	39.12	39.12	39.12	39.12	39.12	39.12
30	32.31	32.31	32.31	32.31	32.31	32.31	32.31	32.31
35	28.06	28.06	28.06	28.06	28.06	28.06	28.06	28.06
40	24.23	24.23	24.23	24.23	24.23	24.23	24.23	24.23
45	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
50	19.56	19.56	19.56	19.56	19.56	19.56	19.56	19.56
55	24.66	17.86	17.86	17.86	17.86	17.86	17.86	17.86
60	37.41	16.16	16.16	16.16	16.16	16.16	16.16	16.16
65	51.02	23.81	14.88	14.88	14.88	14.88	14.88	14.88
70	63.78	36.14	14.03	14.03	14.03	14.03	14.03	14.03

Table F-59. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of -2 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	195.15	195.15	195.15	195.15	195.15	195.15	195.15	195.15
10	97.36	97.36	97.36	97.36	97.36	97.36	97.36	97.36
15	65.05	65.05	65.05	65.05	65.05	65.05	65.05	65.05
20	48.89	48.89	48.89	48.89	48.89	48.89	48.89	48.89
25	39.12	39.12	39.12	39.12	39.12	39.12	39.12	39.12
30	32.31	32.31	32.31	32.31	32.31	32.31	32.31	32.31
35	34.86	28.06	28.06	28.06	28.06	28.06	28.06	28.06
40	28.91	24.23	24.23	24.23	24.23	24.23	24.23	24.23
45	37.84	22.53	21.68	21.68	21.68	21.68	21.68	21.68
50	48.47	33.16	19.56	19.56	19.56	19.56	19.56	19.56
55	60.37	44.64	28.91	17.86	17.86	17.86	17.86	17.86
60	73.13	57.40	41.67	25.94	16.16	16.16	16.16	16.16
65	87.59	71.43	55.27	39.97	24.23	14.88	14.88	14.88
70	100.77	84.18	68.03	52.30	36.56	21.26	14.03	14.03

Table F-60. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of -1 Percent

	Vehicle Weight (x 1,000 lbs.)							
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	195.15	195.15	195.15	195.15	195.15	195.15	195.15	195.15
10	97.36	97.36	97.36	97.36	97.36	97.36	97.36	97.36
15	74.83	70.58	66.75	65.05	65.05	65.05	65.05	65.05
20	67.60	63.78	59.52	55.70	51.45	48.89	48.89	48.89
25	66.33	62.07	58.25	54.00	50.17	45.92	42.09	39.12
30	68.03	64.20	68.03	64.20	59.95	56.12	51.87	48.04
35	72.28	68.03	64.20	59.95	56.12	51.87	48.04	44.22
40	78.23	74.40	70.15	65.90	62.07	45.07	41.24	37.41
45	73.55	69.73	65.90	62.07	58.25	54.42	50.60	46.77
50	84.61	80.36	76.53	72.70	68.88	65.05	61.22	57.40
55	96.51	92.69	88.86	84.61	80.78	76.96	73.13	69.30
60	110.12	105.87	102.04	97.79	93.96	90.14	86.31	82.06
65	124.57	120.75	116.50	112.67	108.42	104.59	100.77	96.51
70	138.61	134.35	130.10	126.28	122.02	118.20	113.95	110.12

Table F-61. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	202.38	211.31	220.66	229.59	238.95	247.87	257.23	266.16
10	133.50	142.43	150.94	159.86	168.79	177.72	186.65	195.58
15	113.10	122.02	130.53	139.46	147.96	156.89	165.82	174.32
20	105.87	114.37	122.87	131.80	140.31	149.23	157.74	166.67
25	104.17	112.67	121.17	130.10	138.61	147.53	156.04	164.97
30	105.87	114.37	123.30	131.80	140.73	149.23	158.16	167.09
35	110.12	118.62	127.55	136.05	144.98	153.91	162.84	171.34
40	116.50	125.00	133.93	142.43	151.36	160.29	169.22	178.15
45	109.69	118.20	126.28	134.78	143.28	151.79	160.29	168.37
50	121.17	129.25	137.76	146.26	154.76	163.27	171.77	180.70
55	133.50	142.01	150.51	159.44	167.94	176.45	185.37	193.88
60	147.53	156.04	164.97	173.47	182.40	191.33	199.83	208.76
65	162.84	171.77	180.70	189.63	198.55	207.48	216.41	225.34
70	177.30	186.22	195.15	204.51	213.44	222.79	231.72	241.07

Table F-62. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of 1 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	242.77	265.31	287.84	310.80	333.76	356.29	379.25	402.64
10	172.62	194.73	216.84	238.95	261.48	283.59	306.12	328.66
15	151.79	173.47	195.58	217.26	239.37	261.90	284.01	306.55
20	144.13	165.82	187.50	209.61	231.72	253.83	276.36	298.89
25	142.43	164.12	186.22	207.91	230.02	252.55	275.09	297.62
30	144.56	166.24	187.93	210.03	232.57	254.68	277.64	300.17
35	148.81	170.49	192.60	215.14	237.67	260.20	283.16	306.12
40	155.19	177.30	199.40	221.94	244.90	267.43	290.82	314.20
45	146.68	167.94	208.33	230.87	253.83	277.21	300.60	323.13
50	158.59	179.85	201.11	222.79	244.90	267.01	307.82	330.78
55	171.77	193.03	215.14	237.24	259.35	281.89	304.85	328.23
60	186.22	207.91	230.44	252.98	275.51	298.89	-	-
65	202.38	224.49	247.45	270.41	293.79	-	-	-
70	217.26	240.22	263.18	-	-	-	-	-

Table F-63. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of 2 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	283.16	319.30	355.87	392.86	429.42	466.41	503.83	541.24
10	212.16	247.45	283.16	319.30	355.44	391.58	428.57	465.14
15	190.90	225.77	261.48	297.19	332.91	369.47	406.04	443.03
20	183.25	218.11	253.40	289.12	325.26	361.82	398.38	435.80
25	181.55	216.41	252.13	287.84	324.40	360.97	397.96	435.80
30	183.25	218.54	254.68	290.82	327.38	364.37	402.21	440.05
35	187.93	223.64	259.78	296.34	333.33	371.17	409.44	447.70
40	194.73	230.87	267.43	304.42	341.84	380.10	416.67	453.66
45	203.66	239.80	276.79	313.78	349.91	386.48	423.47	-
50	196.85	231.29	266.58	321.00	357.99	-	-	-
55	210.46	245.75	281.89	318.45	-	-	-	-
60	225.77	261.48	298.47	-	-	-	-	-
65	242.35	279.34	-	-	-	-	-	-
70	258.50	-	-	-	-	-	-	-

Table F-64. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of 3 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	323.98	374.15	424.74	475.34	526.79	578.23	630.10	682.40
10	251.70	301.02	350.77	400.51	451.11	502.13	553.57	605.02
15	230.44	278.91	328.23	377.98	428.57	479.59	531.04	583.33
20	222.36	271.26	320.58	370.75	421.34	472.79	524.66	577.38
25	220.66	269.56	319.30	369.90	421.34	473.21	525.94	579.51
30	223.21	272.11	322.70	373.30	425.60	478.32	531.89	584.18
35	227.89	277.64	328.66	380.10	432.82	485.12	536.14	-
40	235.12	285.29	336.73	389.03	439.20	-	-	-
45	244.05	295.07	344.81	395.41	-	-	-	-
50	235.54	284.44	352.89	-	-	-	-	-
55	250.00	299.74	-	-	-	-	-	-
60	266.16	-	-	-	-	-	-	-
65	283.59	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-

Table F-65. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of 4 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	364.80	429.00	494.05	559.10	625.00	691.33	758.50	825.68
10	292.09	355.02	418.79	482.99	548.47	614.37	681.12	748.30
15	269.98	332.48	396.26	460.88	526.36	592.26	659.44	727.89
20	261.90	324.83	388.61	453.66	519.56	586.73	654.76	724.06
25	260.63	323.98	388.18	454.08	520.83	588.86	658.59	723.21
30	263.18	326.96	392.01	458.76	526.79	593.11	-	-
35	268.71	332.91	399.23	466.84	531.46	-	-	-
40	275.94	341.41	406.89	471.51	-	-	-	-
45	285.71	349.06	413.69	-	-	-	-	-
50	275.51	357.14	-	-	-	-	-	-
55	290.39	-	-	-	-	-	-	-
60	307.40	-	-	-	-	-	-	-
65	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-

Table F-66. Fuel Consumption (gallons/1,000 miles) for Modern 7-Axle Trucks of Various Weights on Pavement with Grade of 8 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	531.04	653.06	777.21	902.64	1030.61	1160.29	1291.67	1425.17
10	455.36	576.11	699.83	825.68	954.51	1085.46	1219.81	1334.18
15	432.82	554.00	678.57	805.70	936.65	1055.27	1174.32	-
20	425.60	547.62	673.89	801.87	921.34	-	-	-
25	425.17	549.32	676.45	-	-	-	-	-
30	429.85	555.70	-	-	-	-	-	-
35	437.07	-	-	-	-	-	-	-
40	443.45	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-
65	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-

Table F-67. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of -8 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	204.51	204.51	204.51	204.51	204.51	204.51	204.51	204.51
10	102.04	102.04	102.04	102.04	102.04	102.04	102.04	102.04
15	68.03	68.03	68.03	68.03	68.03	68.03	68.03	68.03
20	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
25	40.82	40.82	40.82	40.82	40.82	40.82	40.82	40.82
30	34.01	34.01	34.01	34.01	34.01	34.01	34.01	34.01
35	29.34	29.34	29.34	29.34	29.34	29.34	29.34	29.34
40	25.51	25.51	25.51	25.51	25.51	25.51	25.51	25.51
45	22.53	22.53	22.53	22.53	22.53	22.53	22.53	22.53
50	20.41	20.41	20.41	20.41	20.41	20.41	20.41	20.41
55	18.71	18.71	18.71	18.71	18.71	18.71	18.71	18.71
60	17.01	17.01	17.01	17.01	17.01	17.01	17.01	17.01
65	15.73	15.73	15.73	15.73	15.73	15.73	15.73	15.73
70	14.46	14.46	14.46	14.46	14.46	14.46	14.46	14.46

Table F-68. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of -4 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	204.51	204.51	204.51	204.51	204.51	204.51	204.51	204.51
10	102.04	102.04	102.04	102.04	102.04	102.04	102.04	102.04
15	68.03	68.03	68.03	68.03	68.03	68.03	68.03	68.03
20	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
25	40.82	40.82	40.82	40.82	40.82	40.82	40.82	40.82
30	34.01	34.01	34.01	34.01	34.01	34.01	34.01	34.01
35	29.34	29.34	29.34	29.34	29.34	29.34	29.34	29.34
40	25.51	25.51	25.51	25.51	25.51	25.51	25.51	25.51
45	22.53	22.53	22.53	22.53	22.53	22.53	22.53	22.53
50	20.41	20.41	20.41	20.41	20.41	20.41	20.41	20.41
55	18.71	18.71	18.71	18.71	18.71	18.71	18.71	18.71
60	17.01	17.01	17.01	17.01	17.01	17.01	17.01	17.01
65	22.96	15.73	15.73	15.73	15.73	15.73	15.73	15.73
70	35.71	14.46	14.46	14.46	14.46	14.46	14.46	14.46

Table F-69. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of -3 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	204.51	204.51	204.51	204.51	204.51	204.51	204.51	204.51
10	102.04	102.04	102.04	102.04	102.04	102.04	102.04	102.04
15	68.03	68.03	68.03	68.03	68.03	68.03	68.03	68.03
20	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
25	40.82	40.82	40.82	40.82	40.82	40.82	40.82	40.82
30	34.01	34.01	34.01	34.01	34.01	34.01	34.01	34.01
35	29.34	29.34	29.34	29.34	29.34	29.34	29.34	29.34
40	25.51	25.51	25.51	25.51	25.51	25.51	25.51	25.51
45	22.53	22.53	22.53	22.53	22.53	22.53	22.53	22.53
50	20.41	20.41	20.41	20.41	20.41	20.41	20.41	20.41
55	31.04	18.71	18.71	18.71	18.71	18.71	18.71	18.71
60	43.79	17.01	17.01	17.01	17.01	17.01	17.01	17.01
65	58.25	31.04	15.73	15.73	15.73	15.73	15.73	15.73
70	71.43	43.79	16.58	14.46	14.46	14.46	14.46	14.46

Table F-70. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of -2 Percent

	Vehicle Weight (x 1,000 lbs.)							
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	204.51	204.51	204.51	204.51	204.51	204.51	204.51	204.51
10	102.04	102.04	102.04	102.04	102.04	102.04	102.04	102.04
15	68.03	68.03	68.03	68.03	68.03	68.03	68.03	68.03
20	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
25	40.82	40.82	40.82	40.82	40.82	40.82	40.82	40.82
30	36.99	34.01	34.01	34.01	34.01	34.01	34.01	34.01
35	41.24	29.34	29.34	29.34	29.34	29.34	29.34	29.34
40	34.01	25.51	25.51	25.51	25.51	25.51	25.51	25.51
45	43.79	28.06	22.53	22.53	22.53	22.53	22.53	22.53
50	54.42	38.69	23.38	20.41	20.41	20.41	20.41	20.41
55	66.33	50.60	35.29	19.98	18.71	18.71	18.71	18.71
60	79.93	63.78	48.04	32.74	17.43	17.01	17.01	17.01
65	94.39	78.23	62.50	46.77	31.04	15.73	15.73	15.73
70	107.99	91.84	75.68	59.95	44.22	28.49	14.46	14.46

Table F-71. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of -1 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	204.51	204.51	204.51	204.51	204.51	204.51	204.51	204.51
10	102.47	102.04	102.04	102.04	102.04	102.04	102.04	102.04
15	81.63	77.38	73.55	69.30	68.03	68.03	68.03	68.03
20	73.98	70.15	65.90	62.07	57.82	54.00	51.02	51.02
25	72.28	68.45	64.20	60.37	56.12	52.30	48.47	44.22
30	73.98	70.15	65.90	62.07	58.25	54.00	50.17	45.92
35	78.23	74.40	70.15	66.33	62.07	58.25	54.42	50.17
40	84.61	80.36	76.53	72.28	68.45	50.17	46.34	42.94
45	79.08	75.26	71.43	67.60	63.78	59.95	56.12	52.30
50	90.14	86.31	82.48	78.66	74.83	71.00	67.18	63.35
55	102.47	98.64	94.81	90.99	87.16	82.91	79.08	75.26
60	116.50	112.24	108.42	104.59	100.34	96.51	92.69	88.86
65	131.38	127.55	123.30	119.47	115.22	111.39	107.57	103.32
70	145.83	141.58	137.76	133.50	129.68	125.43	121.60	117.35

Table F-72. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of 0 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	213.01	222.36	231.29	240.22	249.57	258.50	267.43	276.79
10	141.16	150.09	158.59	167.52	176.45	184.95	193.88	202.81
15	119.90	128.40	137.33	145.83	154.34	163.27	172.19	180.70
20	111.82	120.75	129.25	137.76	146.68	155.19	164.12	172.62
25	110.12	118.62	127.55	136.05	144.56	153.49	161.99	170.92
30	111.82	120.32	129.25	137.76	146.26	155.19	163.69	172.62
35	116.07	125.00	133.50	142.01	150.94	159.44	168.37	177.30
40	122.45	130.95	139.88	148.81	157.31	166.24	175.17	184.10
45	115.22	123.30	131.80	139.88	148.38	156.89	165.39	173.47
50	126.70	135.20	143.28	151.79	160.29	168.79	177.30	185.80
55	139.46	147.96	156.46	164.97	173.47	182.40	190.90	199.40
60	153.91	162.41	170.92	179.42	188.35	197.28	205.78	214.71
65	169.64	178.15	187.07	196.00	204.51	213.44	222.79	231.72
70	184.52	193.45	202.38	211.31	220.24	229.17	238.52	247.87

Table F-73. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of 1 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	253.40	275.94	298.47	321.00	343.54	366.50	389.46	411.99
10	180.27	201.96	224.06	246.17	268.28	290.39	312.93	335.46
15	158.16	179.85	201.53	223.64	245.75	267.86	289.97	312.07
20	150.09	171.77	193.45	215.14	237.24	259.35	281.46	304.00
25	148.38	170.07	191.75	213.44	235.54	257.65	280.19	302.30
30	150.09	171.77	193.45	215.56	237.67	260.20	282.74	305.27
35	154.76	176.45	198.13	220.24	242.77	265.31	287.84	310.80
40	161.14	183.25	205.36	227.47	250.00	272.96	295.92	318.88
45	151.79	172.62	213.86	236.39	259.35	282.31	305.70	329.08
50	164.12	184.95	206.21	227.89	249.57	271.68	293.79	336.31
55	177.30	198.55	220.24	242.35	264.46	286.99	309.52	332.48
60	192.18	213.86	235.97	258.08	281.04	303.57	326.96	-
65	208.33	230.87	253.40	275.94	298.89	-	-	-
70	224.06	246.60	269.56	292.94	-	-	-	-

Table F-74. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of 2 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	293.79	329.51	366.07	402.64	439.20	475.77	512.76	550.17
10	219.39	254.68	289.97	325.68	361.82	397.96	434.52	471.09
15	197.28	232.14	267.43	302.72	338.44	374.57	410.71	447.28
20	188.78	223.64	258.93	294.64	330.36	366.50	403.06	439.63
25	187.07	221.94	257.23	292.94	329.08	365.22	402.21	439.20
30	189.20	224.06	259.78	295.49	332.06	368.62	406.04	443.45
35	193.88	229.17	264.88	301.02	338.01	375.00	412.84	451.11
40	200.68	235.97	272.53	309.10	346.51	384.35	421.77	458.33
45	209.18	245.32	281.89	319.30	355.44	391.58	428.15	-
50	201.96	236.39	271.26	326.53	363.10	400.09	-	-
55	215.99	250.85	286.56	322.70	359.69	-	-	-
60	231.29	267.01	303.15	-	-	-	-	-
65	248.30	284.86	-	-	-	-	-	-
70	264.88	-	-	-	-	-	-	-

Table F-75. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of 3 Percent

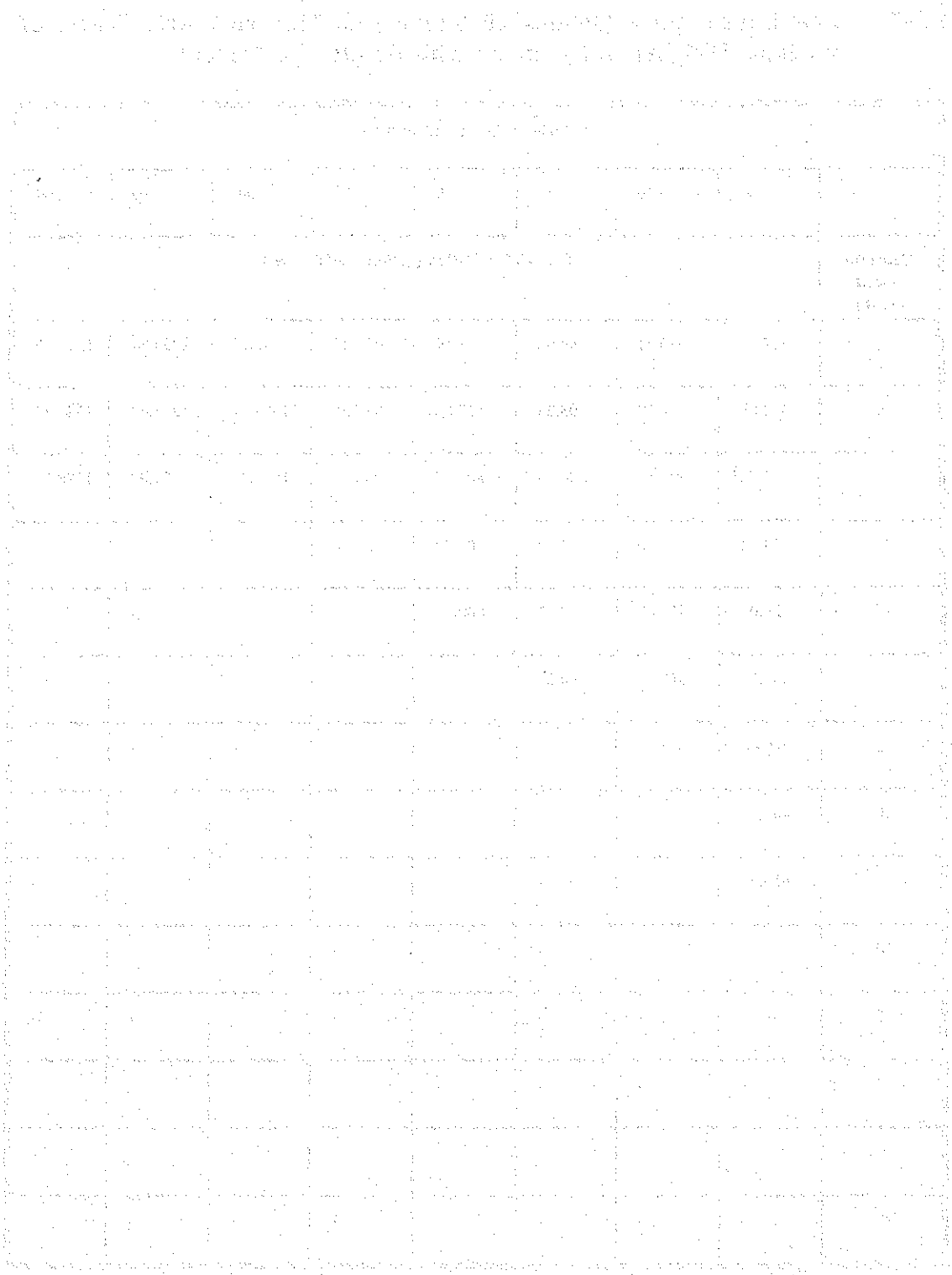
Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	Fuel Consumption (gallons/1,000 miles)							
5	334.18	383.93	434.10	484.69	535.71	586.73	638.18	690.05
10	258.93	307.82	357.14	406.89	457.06	507.23	558.25	609.69
15	236.39	284.86	333.76	383.08	433.25	483.84	534.86	586.31
20	227.89	276.36	325.68	375.00	425.60	476.19	528.06	579.93
25	226.19	274.66	324.40	374.15	425.17	476.62	528.91	581.63
30	228.32	277.21	326.96	377.55	429.00	481.29	534.44	588.01
35	233.42	282.74	332.91	384.35	436.22	489.37	540.39	-
40	240.65	290.39	341.41	393.28	444.30	494.90	-	-
45	249.57	300.17	350.77	400.09	451.11	-	-	-
50	240.65	288.69	358.42	409.01	-	-	-	-
55	255.10	304.42	354.59	-	-	-	-	-
60	271.26	321.43	-	-	-	-	-	-
65	289.12	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-

Table F-76. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of 4 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	375.00	438.78	502.98	568.03	633.50	698.98	765.73	832.48
10	298.89	361.39	424.74	488.52	553.57	618.62	684.95	751.70
15	275.94	338.01	401.36	465.14	530.19	595.66	661.99	729.59
20	267.43	329.93	393.28	457.48	522.96	589.29	656.89	724.91
25	265.73	328.66	392.43	457.48	523.81	590.99	659.44	727.47
30	268.28	331.63	396.26	461.73	529.34	597.79	662.41	-
35	273.38	337.59	403.06	469.81	535.71	-	-	-
40	281.04	346.09	412.41	476.19	-	-	-	-
45	290.82	355.02	418.37	-	-	-	-	-
50	279.76	362.67	-	-	-	-	-	-
55	295.07	359.27	-	-	-	-	-	-
60	312.07	-	-	-	-	-	-	-
65	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-

Table F-77. Fuel Consumption (gallons/1,000 miles) for Modern 9-Axle Trucks of Various Weights on Pavement with Grade of 8 Percent

Vehicle Weight (x 1,000 lbs.)								
	30	40	50	60	70	80	90	100
Constant Speed (mph)	**Fuel Consumption (gallons/1,000 miles)**							
5	539.97	660.71	784.01	908.59	1035.29	1163.27	1293.79	1425.17
10	460.88	580.78	703.23	827.81	955.36	1084.61	1216.84	1344.39
15	437.50	557.40	680.70	806.55	935.80	1061.22	1179.00	1298.04
20	429.42	550.60	675.60	803.57	925.60	-	-	-
25	429.00	551.87	678.57	800.60	-	-	-	-
30	433.25	557.82	680.27	-	-	-	-	-
35	440.48	562.93	-	-	-	-	-	-
40	448.13	-	-	-	-	-	-	-
45	455.36	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-
65	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-



Appendix G. ARFCOM Results for Modern Vehicles by Pavement Serviceability Index

Table G-1. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 1.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	71.43	44.64	36.56	34.01	33.16	33.59	25.94	27.64	30.19	32.74	35.71	39.12	43.37	47.19
Medium	112.67	56.12	43.37	39.97	38.69	39.12	29.34	31.04	33.59	36.56	39.54	43.37	47.62	51.87
Large	112.67	68.45	55.70	51.02	49.32	49.32	34.44	36.56	39.12	42.09	45.49	49.74	54.00	58.67
Pickup	151.36	75.68	50.60	45.07	44.64	45.49	38.27	42.09	45.92	50.60	56.12	62.07	68.88	76.53
2axle	239.37	119.90	89.29	83.76	82.91	85.03	85.88	94.39	104.17	115.22	127.55	142.01	156.46	164.97
3axle	173.47	125.85	112.24	107.57	107.14	108.84	112.67	117.77	111.82	121.17	131.38	142.86	155.19	163.27
3axle-comb	206.21	142.86	124.15	117.77	116.50	118.20	122.02	127.98	117.77	128.40	140.31	153.49	167.94	179.42
4axle	221.51	153.49	133.93	127.13	125.85	127.98	133.08	139.88	128.83	140.73	154.34	169.22	185.80	199.40
5axle	250.00	182.40	162.41	155.19	153.91	155.61	160.29	166.67	158.16	169.64	182.82	197.28	213.01	227.89
7axle-comb	284.01	213.01	191.75	184.10	182.40	184.52	189.20	196.43	204.93	198.55	212.59	227.89	245.32	261.48
9axle-comb	321.00	246.17	223.64	215.56	213.86	215.99	221.09	228.32	237.67	229.17	244.05	260.20	278.49	-

Table G-2. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 1.5

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	70.15	42.94	35.29	32.31	31.46	31.89	24.66	26.36	28.49	31.46	34.44	37.41	41.24	45.49
Medium	112.67	56.12	42.09	38.27	37.41	37.41	27.64	29.76	31.89	34.86	37.84	41.67	45.49	49.74
Large	112.67	66.75	54.00	49.32	47.62	47.62	33.16	34.86	37.41	40.39	43.79	47.62	51.87	56.55
Pickup	151.36	75.68	50.60	42.94	42.52	43.37	36.56	39.97	43.79	48.47	53.57	59.52	66.33	73.55
2axle	239.37	119.90	84.61	79.08	78.23	79.93	81.63	89.71	99.06	109.69	122.02	136.05	150.09	158.16
3axle	164.12	116.92	103.32	98.64	98.21	99.91	103.74	108.42	103.32	112.67	122.45	133.50	145.83	153.49
3axle-comb	197.28	133.93	115.65	109.27	107.99	109.69	113.52	119.05	109.69	120.32	131.80	144.98	159.01	170.07
4axle	212.16	144.13	124.57	117.77	116.92	119.05	123.72	130.53	119.90	131.80	144.98	159.86	176.02	189.63
5axle	235.97	169.22	149.23	142.01	140.31	142.43	146.68	153.06	144.98	156.46	169.22	183.25	198.98	213.44
7axle-comb	266.58	196.00	174.74	167.09	165.82	167.52	172.19	179.00	169.64	181.55	195.15	210.03	227.04	242.77
9axle-comb	299.74	225.34	203.23	195.15	193.03	195.15	199.83	207.06	215.99	208.33	222.36	238.10	255.95	272.53

Table G-3. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 2.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	69.30	42.52	34.44	31.89	31.04	31.04	23.81	25.94	28.06	30.61	33.59	36.56	40.39	44.22
Medium	112.67	56.12	41.24	37.41	36.56	36.56	27.21	28.91	31.46	34.01	36.99	40.39	44.64	48.89
Large	112.67	65.90	53.15	48.47	46.77	46.77	32.31	34.01	36.56	39.54	42.94	46.77	51.02	55.70
Pickup	151.36	75.68	50.60	41.67	41.24	42.52	35.71	38.69	42.94	47.19	52.30	58.25	64.63	71.85
2axle	239.37	119.90	82.06	76.53	75.26	77.38	79.08	87.16	96.51	107.14	119.05	133.08	147.11	154.76
3axle	159.44	112.24	98.64	94.39	93.54	95.24	99.06	103.74	99.06	107.99	118.20	128.83	141.16	148.81
3axle-comb	192.60	129.68	111.39	105.02	103.32	105.44	109.27	96.51	105.87	116.07	127.55	140.31	154.76	165.39
4axle	207.06	139.46	119.90	113.10	111.82	114.37	119.05	125.43	115.22	127.13	140.31	154.76	170.92	184.52
5axle	228.74	162.41	142.43	135.20	133.50	135.63	139.88	145.83	138.18	149.66	161.99	176.02	191.33	205.78
7axle-comb	257.65	187.07	166.24	158.59	156.89	159.01	163.27	170.07	160.71	172.62	186.22	201.11	217.69	232.99
9axle-comb	288.69	214.71	192.18	184.10	182.40	184.52	189.20	196.00	184.95	197.70	211.31	227.04	244.05	260.63

Table G-4. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 2.5

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	68.88	42.09	34.01	31.46	30.61	30.61	23.38	25.51	27.64	30.19	32.74	36.14	39.54	43.79
Medium	112.67	56.12	40.82	36.99	36.14	36.14	26.79	28.49	30.61	33.59	36.56	39.97	43.79	48.04
Large	112.67	65.48	52.72	47.62	46.34	46.34	31.89	33.59	36.14	39.12	42.09	45.92	50.17	54.85
Pickup	151.36	75.68	50.60	41.24	40.82	41.67	34.86	38.27	42.09	46.77	51.87	57.40	63.78	71.00
2axle	239.37	119.90	80.36	74.83	73.98	75.68	77.38	85.46	94.81	105.44	117.35	130.95	144.98	152.64
3axle	156.46	109.27	96.09	91.41	90.99	92.69	96.09	100.77	96.51	105.44	115.22	126.28	138.18	145.83
3axle-comb	189.63	126.70	108.84	102.04	100.77	102.47	106.29	93.96	103.32	113.52	125.00	137.76	151.79	162.84
4axle	204.08	136.48	116.92	110.12	109.27	111.39	116.07	122.45	112.67	124.15	137.33	151.79	167.94	181.12
5axle	224.49	157.74	138.18	130.95	129.25	131.38	135.20	141.58	133.93	145.41	157.74	171.34	187.07	201.11
7axle-comb	252.13	181.97	160.71	153.06	151.36	153.49	157.74	164.54	155.61	167.52	180.70	195.58	211.73	227.04
9axle-comb	281.89	207.91	185.80	177.72	175.60	177.72	182.40	189.20	178.57	190.90	204.51	219.81	236.82	253.40

Table G-5. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 3.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	68.45	41.67	34.01	31.04	30.19	30.61	23.38	25.09	27.21	29.76	32.74	35.71	39.12	43.37
Medium	112.67	56.12	40.39	36.56	35.71	35.71	26.36	28.06	30.61	33.16	36.14	39.54	43.37	47.62
Large	112.67	65.05	52.30	47.62	45.92	45.92	31.46	33.16	35.71	38.69	42.09	45.49	49.74	54.42
Pickup	151.36	75.68	50.60	40.82	40.39	41.24	34.44	37.84	41.67	46.34	51.45	56.97	63.35	70.58
2axle	239.37	119.90	79.93	73.55	72.70	74.40	76.53	84.61	93.54	104.17	116.07	129.68	143.71	151.36
3axle	154.34	107.14	93.96	89.29	88.86	90.56	93.96	86.73	94.39	103.32	113.10	124.15	136.05	143.71
3axle-comb	187.93	125.00	106.72	100.34	99.06	100.77	104.59	92.26	101.19	111.82	123.30	135.63	149.66	160.71
4axle	201.96	134.35	114.80	108.42	107.14	109.27	113.95	120.32	110.54	122.45	135.20	149.66	165.82	179.00
5axle	221.51	155.19	135.20	127.98	126.28	128.40	132.23	138.61	131.38	142.43	154.76	168.37	183.67	197.70
7axle-comb	248.30	178.15	157.31	149.66	147.96	149.66	154.34	160.71	151.79	163.69	176.87	191.33	207.91	222.79
9axle-comb	277.21	203.23	181.12	173.04	171.34	173.04	177.72	184.52	173.89	186.22	199.83	215.14	232.14	248.30

Table G-6. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 3.5

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	68.03	41.24	33.59	30.61	29.76	30.19	22.96	24.66	26.79	29.34	32.31	35.29	39.12	42.94
Medium	112.67	56.12	39.97	36.56	35.29	35.71	25.94	28.06	30.19	32.74	36.14	39.54	42.94	47.19
Large	112.67	65.05	52.30	47.19	45.49	45.49	31.04	33.16	35.29	38.27	41.67	45.49	49.32	54.00
Pickup	151.36	75.68	50.60	40.39	39.97	40.82	34.44	37.41	41.24	45.92	51.02	56.55	62.93	70.15
2axle	239.37	119.90	79.93	73.13	71.85	73.55	75.68	83.76	93.11	103.32	115.22	128.83	142.43	150.51
3axle	152.64	105.87	92.69	88.01	87.59	89.29	92.69	85.46	93.11	102.04	111.82	122.87	134.78	142.01
3axle-comb	186.22	123.72	105.44	99.06	97.79	99.49	103.32	90.99	100.34	110.54	122.02	134.35	148.38	159.44
4axle	200.26	133.08	113.52	106.72	105.87	107.99	112.67	119.05	109.27	121.17	133.93	148.38	164.12	177.72
5axle	219.39	153.06	133.08	125.85	124.57	126.28	130.53	136.48	129.25	140.31	152.64	166.24	181.55	195.58
7axle-comb	245.75	175.60	154.76	147.11	145.41	147.11	151.36	158.16	149.23	161.14	174.32	188.78	204.93	220.24
9axle-comb	273.81	200.26	178.15	170.07	167.94	170.07	174.32	181.12	170.92	183.25	196.85	211.73	228.74	244.47

Table G-7. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 4.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	68.03	41.24	33.59	30.61	29.76	30.19	22.96	24.66	26.79	29.34	31.89	35.29	38.69	42.52
Medium	112.67	56.12	39.97	36.56	35.29	35.29	25.94	27.64	30.19	32.74	35.71	39.12	42.94	47.19
Large	112.67	64.63	51.87	47.19	45.49	45.49	31.04	32.74	35.29	38.27	41.24	45.07	49.32	53.57
Pickup	151.36	75.68	50.60	39.97	39.54	40.39	34.01	37.41	41.24	45.49	50.60	56.12	62.50	69.73
2axle	239.37	119.90	79.93	72.28	71.43	73.13	75.26	83.33	92.26	102.89	114.80	127.98	142.01	149.66
3axle	151.79	105.02	91.41	87.16	86.31	88.01	91.84	84.61	92.26	101.19	110.97	121.60	133.50	141.16
3axle-comb	185.37	122.45	104.59	97.79	96.51	98.21	102.04	90.14	99.06	109.27	120.75	133.50	147.53	158.16
4axle	198.98	131.80	112.67	105.87	104.59	106.72	111.39	117.77	108.42	119.90	133.08	147.11	163.27	176.45
5axle	217.69	151.36	131.80	124.57	122.87	124.57	128.83	134.78	127.55	138.61	150.94	164.54	179.85	193.88
7axle-comb	243.62	173.47	152.64	144.98	143.28	144.98	149.66	156.04	147.53	159.01	172.19	186.65	202.81	218.11
9axle-comb	271.26	197.70	175.60	167.52	165.39	167.52	171.77	178.57	168.37	180.70	194.30	209.18	226.19	241.92

Table G-8. The Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 4.5

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	68.03	41.24	33.16	30.61	29.76	29.76	22.96	24.66	26.79	29.34	31.89	35.29	38.69	42.52
Medium	112.67	56.12	39.97	36.14	35.29	35.29	25.94	27.64	29.76	32.74	35.71	39.12	42.94	46.77
Large	112.67	64.63	51.87	46.77	45.07	45.07	30.61	32.74	35.29	37.84	41.24	45.07	48.89	53.57
Pickup	151.36	75.68	50.60	39.97	39.54	40.39	34.01	36.99	40.82	45.49	50.60	56.12	62.50	69.30
2axle	239.37	119.90	79.93	71.85	71.00	72.70	74.83	82.91	91.84	102.47	114.37	127.55	141.16	148.81
3axle	150.94	104.17	90.56	86.31	85.46	87.59	90.99	83.76	91.41	100.34	110.12	120.75	132.65	139.88
3axle-comb	184.52	121.60	103.74	97.36	95.66	97.36	101.19	89.29	98.64	108.84	120.32	132.65	146.68	157.31
4axle	198.13	130.95	111.82	105.02	103.74	105.87	110.54	116.92	107.57	119.05	132.23	146.26	162.41	175.60
5axle	216.41	150.09	130.53	123.30	121.60	123.30	127.55	133.50	126.70	137.33	149.66	163.27	178.57	192.60
7axle-comb	241.92	171.77	150.94	143.28	141.58	143.71	147.96	154.34	145.83	157.74	170.49	184.95	201.11	216.41
9axle-comb	269.13	195.58	173.47	165.39	163.69	165.39	170.07	176.45	166.67	178.57	192.18	207.06	224.06	239.80

Table G-9. Fuel Consumption (gallons/1,000 miles) for Modern Vehicles at Constant Speeds (mph) with a Pavement Serviceability Index of 5.0

	Constant Speed (mph)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Veh Type	**Fuel Consumption (gallons/1,000 miles)**													
Small	67.60	40.82	33.16	30.19	29.34	29.76	22.53	24.23	26.36	28.91	31.89	34.86	38.69	42.52
Medium	112.67	56.12	39.54	36.14	34.86	35.29	25.51	27.64	29.76	32.31	35.29	38.69	42.52	46.77
Large	112.67	64.63	51.87	46.77	45.07	45.07	30.61	32.74	34.86	37.84	41.24	44.64	48.89	53.57
Pickup	151.36	75.68	50.60	39.97	39.12	40.39	33.59	36.99	40.82	45.07	50.17	55.70	62.07	69.30
2axle	239.37	119.90	79.93	71.43	70.58	72.28	74.40	82.48	91.41	102.04	113.95	127.13	140.73	148.38
3axle	150.09	103.32	90.14	85.46	85.03	86.73	90.14	82.91	90.99	99.49	109.27	120.32	131.80	139.46
3axle-comb	183.67	121.17	102.89	96.51	95.24	96.94	100.77	88.86	97.79	107.99	119.47	132.23	145.83	156.89
4axle	197.70	130.10	110.97	104.17	102.89	105.44	109.69	116.07	106.72	118.62	131.38	145.83	161.56	174.74
5axle	215.56	149.23	129.25	122.02	120.75	122.45	126.70	132.65	125.43	136.48	148.81	162.41	177.30	191.33
7axle-comb	240.65	170.49	149.66	142.01	140.31	142.43	146.68	153.06	144.56	156.46	169.22	183.67	199.83	214.71
9axle-comb	267.86	193.88	172.19	164.12	161.99	163.69	168.37	174.74	164.97	177.30	190.48	205.78	222.36	238.10

Appendix H. Coefficients of Fuel Consumption Equations for TRDF Vehicles

Table H-1. Coefficients of Fuel Consumption Equations for TRDF Small Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Small	5	70	-8	Fuel	134.31743	1.49590	0.00000	-50.79023	0.00000	0.00000
Small	5	70	-4	Fuel	168.15972	1.87495	0.00000	-60.46021	0.00000	0.00000
Small	5	70	-3	Fuel	174.19197	1.88965	0.00000	-61.05491	0.00000	0.00000
Small	5	70	-2	Fuel	180.31475	1.90138	0.00000	-61.62588	0.00000	0.00000
Small	5	70	-1	Fuel	187.59589	1.92903	0.00000	-62.67653	0.00000	0.00000
Small	5	70	0	Fuel	193.84909	1.94530	0.00000	-63.28200	0.00000	0.00000
Small	5	70	1	Fuel	200.73828	1.96980	0.00000	-64.14712	0.00000	0.00000
Small	5	70	2	Fuel	206.56671	1.97605	0.00000	-64.50033	0.00000	0.00000
Small	5	70	3	Fuel	213.63824	2.00681	0.00000	-65.46145	0.00000	0.00000
Small	5	70	4	Fuel	213.13728	1.87655	0.00000	-62.07273	0.00000	0.00000
Small	5	65	8	Ln(Fuel)	5.96551	0.03013	-0.00006	-0.69730	0.00000	0.00000

Table H-2. Coefficients of Fuel Consumption Equations for TRDF Medium Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Medium	5	70	-8	Fuel	221.70058	1.79211	0.00000	-76.46708	0.00000	0.00000
Medium	5	70	-4	Fuel	233.36178	2.54267	0.00000	-85.35606	0.00000	0.00000
Medium	5	70	-3	Fuel	225.10082	2.46602	0.00000	-80.70019	0.00000	0.00000
Medium	5	70	-2	Fuel	218.61029	2.34500	0.00000	-75.84273	0.00000	0.00000
Medium	5	70	-1	Fuel	218.79369	2.27223	0.00000	-73.31469	0.00000	0.00000
Medium	5	70	0	Fuel	227.70554	2.29636	0.00000	-74.31424	0.00000	0.00000
Medium	5	70	1	Fuel	236.39701	2.31861	0.00000	-75.19316	0.00000	0.00000
Medium	5	70	2	Fuel	245.30108	2.35153	0.00000	-76.21676	0.00000	0.00000
Medium	5	70	3	Fuel	254.28961	2.38331	0.00000	-77.22550	0.00000	0.00000
Medium	5	70	4	Fuel	255.10614	2.23659	0.00000	-73.41848	0.00000	0.00000
Medium	5	70	8	Ln(Fuel)	6.12128	0.02915	-0.00005	-0.66428	0.00000	0.00000

Table H-3. Coefficients of Fuel Consumption Equations for TRDF Large Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Large	5	70	-8	Fuel	220.51693	1.74815	0.00000	-75.71676	0.00000	0.00000
Large	5	70	-4	Fuel	241.83055	2.57591	0.00000	-87.13702	0.00000	0.00000
Large	5	70	-3	Fuel	252.81952	2.59340	0.00000	-88.32569	0.00000	0.00000
Large	5	70	-2	Fuel	262.91650	2.61024	0.00000	-89.24597	0.00000	0.00000
Large	5	70	-1	Fuel	273.59426	2.62693	0.00000	-90.25449	0.00000	0.00000
Large	5	70	0	Fuel	284.18649	2.66070	0.00000	-91.42589	0.00000	0.00000
Large	5	70	1	Fuel	294.76580	2.67776	0.00000	-92.36537	0.00000	0.00000
Large	5	70	2	Fuel	305.49336	2.70652	0.00000	-93.43182	0.00000	0.00000
Large	5	70	3	Fuel	305.82385	2.52181	0.00000	-88.61918	0.00000	0.00000
Large	5	70	4	Fuel	306.86047	2.37308	0.00000	-84.27596	0.00000	0.00000
Large	5	70	8	Ln(Fuel)	6.35510	0.02898	-0.00006	-0.66979	0.00000	0.00000

Table H-4. Coefficients of Fuel Consumption Equations for TRDF Pickup Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Pickup	5	70	-8	Fuel	328.74365	4.92395	-0.02398	-127.26539	0.00000	0.00000
Pickup	5	70	-4	Fuel	315.15023	3.19648	0.00000	-114.43902	0.00000	0.00000
Pickup	5	70	-3	Fuel	335.59188	4.82166	-0.01183	-130.77613	0.00000	0.00000
Pickup	5	70	-2	Fuel	337.15713	5.50113	-0.01738	-134.11161	0.00000	0.00000
Pickup	5	70	-1	Ln(Fuel)	6.97722	0.04439	0.00000	-1.34760	0.00000	0.00000
Pickup	5	70	0	Ln(Fuel)	6.66883	0.03861	0.00000	-1.15517	0.00000	0.00000
Pickup	5	70	1	Fuel	278.11647	2.98431	0.00000	-91.87775	0.00000	0.00000
Pickup	5	70	2	Fuel	272.19238	2.83705	0.00000	-86.06996	0.00000	0.00000
Pickup	5	70	3	Fuel	262.93998	2.57665	0.00000	-77.59573	0.00000	0.00000
Pickup	5	70	4	Ln(Fuel)	5.68397	0.00000	0.00020	-0.40157	0.00000	0.00000
Pickup	5	70	8	Ln(Fuel)	6.14811	0.02865	-0.00006	-0.60699	0.00000	0.00000

Table H-5. Coefficients of Fuel Consumption Equations for TRDF 2-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
2axle	5	70	-8	Fuel	538.53567	8.58715	-0.04566	-208.64305	0.00000	-3.60998
2axle	5	70	-4	Fuel	559.02161	7.84341	-0.03347	-204.24893	0.00000	-12.52729
2axle	5	70	-3	Fuel	566.33273	7.64839	-0.02737	-204.10231	0.00000	-14.93269
2axle	5	70	-2	Fuel	568.47259	8.29289	-0.02516	-212.59678	0.00000	-11.49944
2axle	5	70	-1	Fuel	558.05792	11.07390	-0.04469	-233.62035	0.00000	0.00000
2axle	5	70	0	Ln(Fuel)	6.68878	0.05595	-0.00014	-1.26845	0.00000	0.20117
2axle	5	70	1	Ln(Fuel)	5.72088	0.03147	0.00000	-0.84427	0.0000	0.35577
2axle	5	70	2	Ln(Fuel)	5.26164	0.02678	0.00000	-0.69765	0.00000	0.48036
2axle	5	70	3	Ln(Fuel)	4.98695	0.02390	0.00000	-0.60538	0.00000	0.56946
2axle	5	70	4	Ln(Fuel)	4.83846	0.02123	0.00000	-0.53517	0.00000	0.62431
2axle	5	65	8	Ln(Fuel)	4.47761	0.00000	0.00019	-0.24537	0.00000	0.74149

Table H-6. Coefficients of Fuel Consumption Equations for TRDF 3-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
3axle	5	70	-8	Fuel	180.23942	2.80210	-0.01462	-68.87164	0.00000	-1.66356
3axle	5	70	-4	Fuel	216.20722	1.72415	0.00000	-60.64496	0.00000	-16.00199
3axle	5	70	-3	Fuel	257.12924	2.27432	0.00000	-69.20684	0.00000	-24.42590
3axle	5	70	-2	Fuel	271.97749	1.83343	0.01106	-67.84625	0.00000	-27.07929
3axle	5	70	-1	Fuel	247.26904	2.43924	0.00795	-76.22634	0.00000	-5.97176
3axle	5	70	0	Fuel	200.78204	3.30033	0.00000	-85.15110	0.00000	24.18716
3axle	5	70	1	Ln(Fuel)	4.73482	0.02322	0.00000	-0.58024	0.00000	0.42862
3axle	5	70	2	Ln(Fuel)	4.44431	0.02077	0.00000	-0.50513	0.00000	0.54254
3axle	5	65	3	Ln(Fuel)	4.26868	0.01860	0.00000	-0.44500	0.00000	0.61820
3axle	5	65	4	Ln(Fuel)	4.16691	0.01738	0.00000	-0.40776	0.00000	0.67567
3axle	5	50	8	Ln(Fuel)	3.90045	0.00000	0.00016	-0.19957	0.00000	0.80757

Table H-7. Coefficients of Fuel Consumption Equations for TRDF 4-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
4axle	5	70	-8	Ln(Fuel)	6.15057	0.00000	0.00000	0.99906	0.00000	0.00000
4axle	5	70	-4	Fuel	253.18465	1.87123	0.00000	-69.74912	0.00000	-15.87729
4axle	5	70	-3	Fuel	334.92244	2.63129	0.00000	-82.90695	0.00000	-31.51338
4axle	5	70	-2	Fuel	371.67515	0.00000	0.03515	-64.25041	0.00000	-43.44010
4axle	5	70	-1	Ln(Fuel)	6.83823	0.03167	0.00009	-0.94696	0.00000	-0.09159
4axle	5	70	0	Ln(Fuel)	5.38784	0.02762	0.00000	-0.69758	0.00000	0.28133
4axle	5	70	1	Ln(Fuel)	4.66906	0.02145	0.00000	-0.54023	0.00000	0.47745
4axle	5	65	2	Ln(Fuel)	4.25089	0.01809	0.00000	-0.44641	0.00000	0.60426
4axle	5	60	3	Ln(Fuel)	4.04919	0.01554	0.00000	-0.38045	0.00000	0.67636
4axle	5	60	4	Ln(Fuel)	3.95905	0.01474	0.00000	-0.35164	0.00000	0.72798
4axle	5	45	8	Ln(Fuel)	3.87088	0.01151	0.00000	-0.26772	0.00000	0.83629

Table H-8. Coefficients of Fuel Consumption Equations for TRDF 5-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
5axle	5	70	-8	Ln(Fuel)	6.15057	0.00000	0.00000	-0.99906	0.00000	0.00000
5axle	5	70	-4	Fuel	228.76247	2.62360	-0.00987	-75.44001	0.00000	-7.25787
5axle	5	70	-3	Fuel	289.54627	2.17205	0.00000	-75.10487	0.00000	-21.95306
5axle	5	70	-2	Fuel	377.69093	0.00000	0.03400	-63.23431	0.00000	-44.24155
5axle	5	70	-1	Ln(Fuel)	6.91936	0.04091	0.00000	-1.01318	0.00000	-0.08457
5axle	5	70	0	Ln(Fuel)	5.05496	0.02562	0.00000	-0.64433	0.00000	0.34808
5axle	5	65	1	Ln(Fuel)	4.20325	0.01879	0.00000	-0.46884	0.00000	0.56622
5axle	5	60	2	Ln(Fuel)	4.00513	0.02720	-0.00012	-0.48919	0.00000	0.67174
5axle	5	55	3	Ln(Fuel)	3.81813	0.02589	-0.00013	-0.43611	0.00000	0.74416
5axle	5	50	4	Ln(Fuel)	3.63337	0.01376	0.00000	-0.31356	0.00000	0.79294
5axle	5	30	8	Ln(Fuel)	3.27852	0.00684	0.00000	-0.11253	0.00000	0.89965

Appendix I. Coefficients of Pavement Roughness Factor Equations for TRDF Vehicles

Table I-1. Coefficients of Pavement Roughness Factor Equations* for TRDF Vehicles

Vehicle Type	Constant	PSI
Small	1.0926	-0.0241
Medium-Large	1.0913	-0.0237
Pickup	1.0934	-0.0243
2axle	1.1138	-0.0302
3axle	1.1758	-0.0459
4axle	1.1600	-0.0416
5axle	1.2008	-0.0523

* one independent variable and linear dependent variable

Table I-2. Coefficients of Pavement Roughness Factor Equations* for TRDF Vehicles

Vehicle Type	Constant	PSI	Ln(PSI)
Small	1.0705	0.0285	-0.1379
Medium-Large	1.0731	0.0196	-0.1134
Pickup	1.0735	0.0229	-0.1235
2axle	1.0879	0.0314	-0.1613
3axle	1.1371	0.0462	-0.2410
4axle	1.1251	0.0414	-0.2174
5axle	1.1565	0.0532	-0.2762

* two independent variables and linear dependent variable

Table I-3. Coefficients of Pavement Roughness Factor Equations* for TRDF Vehicles

Vehicle Type	Constant	PSI
Small	0.0894	-0.0233
Medium-Large	0.0884	-0.0230
Pickup	0.0903	-0.0235
2axle	0.1093	-0.0290
3axle	0.1653	-0.0432
4axle	0.1512	-0.0394
5axle	0.1872	-0.0489

* one independent variable and logarithmic dependent variable

Table I-4. Coefficients of Pavement Roughness Factor Equations* for TRDF Vehicles

Vehicle Type	Constant	PSI	Ln(PSI)
Small	0.0687	0.0259	-0.1290
Medium-Large	0.0715	0.0174	-0.1057
Pickup	0.0718	0.0204	-0.1150
2axle	0.0855	0.0275	-0.1480
3axle	0.1313	0.0377	-0.2118
4axle	0.1202	0.0343	-0.1931
5axle	0.1489	0.0423	-0.2387

* two independent variables and logarithmic dependent variable

Appendix J. Coefficients of Fuel Consumption Equations for Modern Vehicles

Table J-1. Coefficients of Fuel Consumption Equations for Modern Small Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Small	5	70	-8	Fuel	107.13038	0.88401	0.00000	-37.13442	0.00000	0.00000
Small	5	70	-4	Fuel	111.77917	1.28096	0.00000	-41.02061	0.00000	0.00000
Small	5	70	-3	Fuel	109.75674	1.22362	0.00000	-38.81647	0.00000	0.00000
Small	5	70	-2	Fuel	115.04036	1.24030	0.00000	-39.41889	0.00000	0.00000
Small	5	70	-1	Fuel	120.36422	1.25198	0.00000	-39.96826	0.00000	0.00000
Small	5	70	0	Fuel	125.77088	1.25958	0.00000	-40.44462	0.00000	0.00000
Small	5	70	1	Fuel	131.08277	1.28017	0.00000	-41.06200	0.00000	0.00000
Small	5	70	2	Fuel	136.64236	1.29354	0.00000	-41.62889	0.00000	0.00000
Small	5	70	3	Fuel	137.37791	1.20817	0.00000	-39.45343	0.00000	0.00000
Small	5	70	4	Fuel	137.86134	1.14512	0.00000	-37.43149	0.00000	0.00000
Small	5	65	8	Ln(Fuel)	5.50894	0.02768	-0.00005	-0.61949	0.00000	0.00000

Table J-2. Coefficients of Fuel Consumption Equations for Modern Medium Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Medium	5	70	-8	Fuel	246.86547	3.88038	-0.02005	-96.65235	0.00000	0.00000
Medium	5	70	-4	Fuel	244.23422	3.26400	-0.00988	-93.19708	0.00000	0.00000
Medium	5	70	-3	Fuel	248.08198	3.62995	-0.01208	-96.55073	0.00000	0.00000
Medium	5	70	-2	Fuel	249.27818	3.98039	-0.01486	-98.46641	0.00000	0.00000
Medium	5	70	-1	Fuel	245.84940	4.11862	-0.01647	-97.13812	0.00000	0.00000
Medium	5	70	0	Ln(Fuel)	5.98891	0.00000	0.00030	-0.83353	0.00000	0.00000
Medium	5	70	1	Ln(Fuel)	5.82541	0.00000	0.00027	-0.74003	0.00000	0.00000
Medium	5	70	2	Fuel	200.47458	1.86925	0.00000	-64.42508	0.00000	0.00000
Medium	5	70	3	Fuel	191.08166	1.65676	0.00000	-57.80806	0.00000	0.00000
Medium	5	70	4	Fuel	181.81286	1.46597	0.00000	-51.38672	0.00000	0.00000
Medium	5	70	8	Ln(Fuel)	5.70368	0.02853	-0.00006	-0.64186	0.00000	0.00000

Table J-3. Coefficients of Fuel Consumption Equations for Modern Large Passenger Vehicles

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Large	5	70	-8	Fuel	246.05196	3.80074	-0.01922	-95.95141	0.00000	0.00000
Large	5	70	-4	Fuel	226.37578	2.12357	0.00000	-80.16631	0.00000	0.00000
Large	5	70	-3	Fuel	221.11254	2.10563	0.00000	-77.38252	0.00000	0.00000
Large	5	70	-2	Fuel	213.90107	2.00536	0.00000	-72.94349	0.00000	0.00000
Large	5	70	-1	Fuel	208.82576	1.90032	0.00000	-68.94479	0.00000	0.00000
Large	5	70	0	Fuel	204.26346	1.77767	0.00000	-64.81411	0.00000	0.00000
Large	5	70	1	Fuel	204.59886	1.71853	0.00000	-62.78228	0.00000	0.00000
Large	5	70	2	Fuel	211.73276	1.73527	0.00000	-63.48284	0.00000	0.00000
Large	5	70	3	Fuel	209.75108	1.56076	0.00000	-58.96803	0.00000	0.00000
Large	5	70	4	Fuel	209.61664	1.44457	0.00000	-55.57456	0.00000	0.00000
Large	5	70	8	Ln(Fuel)	5.99296	0.02960	-0.00007	-0.67321	0.00000	0.00000

Table J-4. Coefficients of Fuel Consumption Equations for Modern Pickup Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
Pickup	5	70	-8	Ln(Fuel)	6.70713	0.00000	0.00003	-1.03603	0.00000	0.00000
Pickup	5	70	-4	Ln(Fuel)	6.05180	-0.07762	0.00101	-0.43145	0.00000	0.00000
Pickup	5	70	-3	Fuel	310.89085	3.02879	0.00000	-111.69225	0.00000	0.00000
Pickup	5	70	-2	Fuel	336.56695	4.91162	-0.01391	-131.54472	0.00000	0.00000
Pickup	5	70	-1	Fuel	341.22001	5.67403	-0.01974	-136.79966	0.00000	0.00000
Pickup	5	70	0	Fuel	339.21682	6.09423	-0.02346	-137.27761	0.00000	0.00000
Pickup	5	70	1	Ln(Fuel)	6.81840	0.04162	0.00000	-1.26002	0.00000	0.00000
Pickup	5	70	2	Ln(Fuel)	6.55873	0.03684	0.00000	-1.09775	0.00000	0.00000
Pickup	5	70	3	Ln(Fuel)	6.24654	0.03080	0.00000	-0.90496	0.00000	0.00000
Pickup	5	70	4	Ln(Fuel)	6.45116	0.05595	-0.00021	-1.07813	0.00000	0.00000
Pickup	5	70	8	Ln(Fuel)	5.76284	0.02667	-0.00005	-0.54057	0.00000	0.00000

Table J-5. Coefficients of Fuel Consumption Equations for Modern 2-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
2axle	5	70	-8	Fuel	528.23244	8.51909	-0.04480	-208.12932	0.00000	0.00000
2axle	5	70	-4	Fuel	558.42509	7.61936	-0.03108	-202.33964	0.00000	-13.10596
2axle	5	70	-3	Fuel	563.16474	7.25007	-0.02333	-200.77132	0.00000	-15.12860
2axle	5	70	-2	Fuel	563.83871	7.63705	-0.01875	-207.39938	0.00000	-11.81707
2axle	5	70	-1	Fuel	565.70786	10.58982	-0.03794	-233.58406	0.00000	-1.66380
2axle	5	70	0	Ln(Fuel)	7.07861	0.06989	-0.00020	-1.49540	0.00000	0.17155
2axle	5	70	1	Fuel	383.86131	9.05256	-0.03201	-181.57138	0.00000	36.30474
2axle	5	70	2	Ln(Fuel)	5.30080	0.03044	0.00000	-0.75243	0.00000	0.46503
2axle	5	70	3	Ln(Fuel)	4.98724	0.02701	0.00000	-0.64478	0.00000	0.55741
2axle	5	70	4	Ln(Fuel)	4.80668	0.02430	0.00000	-0.56946	0.00000	0.62013
2axle	5	70	8	Ln(Fuel)	4.33672	0.00000	0.00021	-0.23935	0.00000	0.76098

Table J-6. Coefficients of Fuel Consumption Equations for Modern 3-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
3axle	5	70	-8	Fuel	176.39558	2.94434	-0.01618	-70.07185	0.00000	0.00000
3axle	5	70	-4	Fuel	200.27826	1.54402	0.00000	-57.99234	0.00000	-12.16763
3axle	5	70	-3	Fuel	232.33089	1.97589	0.00000	-64.27300	0.00000	-19.35933
3axle	5	70	-2	Fuel	249.26651	1.57770	0.01042	-62.96842	0.00000	-23.77293
3axle	5	70	-1	Fuel	236.78234	2.56941	0.00486	-73.28397	0.00000	-8.78489
3axle	5	70	0	Fuel	190.52964	3.10889	0.00000	-79.75534	0.00000	20.40780
3axle	5	70	1	Ln(Fuel)	4.66300	0.02312	0.00000	-0.58425	0.00000	0.42829
3axle	5	70	2	Ln(Fuel)	4.33427	0.02026	0.00000	-0.49694	0.00000	0.55170
3axle	5	70	3	Ln(Fuel)	4.15053	0.01857	0.00000	-0.44428	0.00000	0.63661
3axle	5	70	4	Ln(Fuel)	4.04779	0.01675	0.00000	-0.39649	0.00000	0.69118
3axle	5	70	8	Ln(Fuel)	3.92445	0.01328	0.00000	-0.30004	0.00000	0.82110

Table J-7. Coefficients of Fuel Consumption Equations for Modern 3-Axle Combination Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
3axle-comb	5	70	-8	Ln(Fuel)	6.68707	0.00000	0.00000	-1.00045	0.00000	0.00000
3axle-comb	5	70	-4	Fuel	364.79991	5.65866	-0.02968	-138.86243	0.00000	-3.18188
3axle-comb	5	70	-3	Fuel	382.45083	5.13552	-0.02305	-134.91687	0.00000	-9.02545
3axle-comb	5	70	-2	Fuel	401.32009	3.11573	0.00000	-116.74160	0.00000	-19.98747
3axle-comb	5	70	-1	Fuel	401.80783	4.31629	0.00000	-125.15230	0.00000	-18.04480
3axle-comb	5	70	0	Fuel	223.97721	3.75196	0.00000	-102.57572	0.00000	29.49778
3axle-comb	5	70	1	Ln(Fuel)	4.50490	0.01981	0.00000	-0.53608	0.00000	0.47800
3axle-comb	5	70	2	Ln(Fuel)	4.02845	0.01609	0.00000	-0.42850	0.00000	0.62312
3axle-comb	5	70	3	Ln(Fuel)	3.77765	0.01354	0.00000	-0.35630	0.00000	0.71101
3axle-comb	5	70	4	Ln(Fuel)	3.67680	0.01152	0.00000	-0.30691	0.00000	0.76132
3axle-comb	5	70	8	Ln(Fuel)	3.59119	0.00000	0.00013	-0.16574	0.00000	0.86370

Table J-8. Coefficients of Fuel Consumption Equations for Modern 4-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
4axle	5	70	-8	Ln(Fuel)	6.15057	0.00000	0.00000	-0.99906	0.00000	0.00000
4axle	5	70	-4	Fuel	210.29679	1.46333	0.00000	-62.92824	0.00000	-7.23630
4axle	5	70	-3	Fuel	258.36495	1.91531	0.00000	-70.62784	0.00000	-16.74489
4axle	5	70	-2	Fuel	308.64570	0.00000	0.02478	-56.26509	0.00000	-33.04826
4axle	5	70	-1	Fuel	362.84928	4.14529	0.00000	-109.35185	0.00000	-17.91430
4axle	5	70	0	Ln(Fuel)	5.41223	0.02795	0.00000	-0.73444	0.00000	0.25481
4axle	5	70	1	Ln(Fuel)	4.58102	0.02063	0.00000	-0.54557	0.00000	0.47612
4axle	5	70	2	Ln(Fuel)	4.13187	0.01720	0.00000	-0.44616	0.00000	0.61404
4axle	5	70	3	Ln(Fuel)	3.89239	0.01454	0.00000	-0.37383	0.00000	0.69652
4axle	5	70	4	Ln(Fuel)	3.77077	0.01237	0.00000	-0.31806	0.00000	0.74727
4axle	5	70	8	Ln(Fuel)	3.73789	0.01064	0.00000	-0.25263	0.00000	0.85322

Table J-9. Coefficients of Fuel Consumption Equations for Modern 5-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
5axle	5	70	-8	Ln(Fuel)	6.15057	0.00000	0.00000	-0.99906	0.00000	0.00000
5axle	5	70	-4	Fuel	208.09774	3.46706	-0.01915	-82.55975	0.00000	0.00000
5axle	5	70	-3	Fuel	230.49141	2.67072	-0.01017	-75.96179	0.00000	-7.52228
5axle	5	70	-2	Fuel	317.29260	2.51115	0.00000	-80.84513	0.00000	-26.36783
5axle	5	70	-1	Fuel	373.19125	4.01757	0.00000	-106.96981	0.00000	-21.20348
5axle	5	70	0	Ln(Fuel)	5.08538	0.02623	0.00000	-0.69319	0.00000	0.31783
5axle	5	70	1	Ln(Fuel)	4.16493	0.01872	0.00000	-0.49297	0.00000	0.55198
5axle	5	70	2	Ln(Fuel)	3.74648	0.01525	0.00000	-0.39105	0.00000	0.67791
5axle	5	70	3	Ln(Fuel)	3.53279	0.01302	0.00000	-0.32683	0.00000	0.75580
5axle	5	70	4	Ln(Fuel)	3.53740	0.02078	-0.00011	-0.36042	0.00000	0.80101
5axle	5	70	8	Ln(Fuel)	3.46300	0.00834	0.00000	-0.19740	0.00000	0.88688

Table J-10. Coefficients of Fuel Consumption Equations for Modern 7-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
7axle	5	70	-8	Ln(Fuel)	6.88301	0.00000	0.00000	-1.00004	0.00000	0.00000
7axle	5	70	-4	Fuel	434.05486	7.35606	-0.04134	-172.94350	0.00000	0.00000
7axle	5	70	-3	Fuel	450.65382	6.72149	-0.03426	-167.64462	0.00000	-5.49125
7axle	5	70	-2	Fuel	496.41402	5.29172	-0.01562	-156.92297	0.00000	-19.36164
7axle	5	70	-1	Fuel	504.38038	7.12071	-0.01749	-169.64289	0.00000	-18.63022
7axle	5	70	0	Ln(Fuel)	5.03763	0.02497	0.00000	-0.66218	0.00000	0.32864
7axle	5	70	1	Ln(Fuel)	4.08933	0.01777	0.00000	-0.46559	0.00000	0.56602
7axle	5	70	2	Ln(Fuel)	3.69677	0.01471	0.00000	-0.37268	0.00000	0.68685
7axle	5	70	3	Ln(Fuel)	3.50731	0.01252	0.00000	-0.31147	0.00000	0.75882
7axle	5	70	4	Ln(Fuel)	3.42687	0.01081	0.00000	-0.26694	0.00000	0.80280
7axle	5	70	8	Ln(Fuel)	3.47134	0.00797	0.00000	-0.19083	0.00000	0.88349

Table J-11. Coefficients of Fuel Consumption Equations for Modern 9-Axle Trucks

Vehicle Type	Min. Speed Allowed	Max. Speed Allowed	Grade	Dep. Variable	Constant	Speed	(Speed)^2	Ln(Speed)	Grade	Ln(GVW)
9axle	5	70	-8	Ln(Fuel)	6.94225	0.00099	0.00000	-1.01025	0.00000	0.00000
9axle	5	70	-4	Fuel	454.57289	7.66109	-0.04271	-180.93003	0.00000	0.00000
9axle	5	70	-3	Fuel	476.29158	6.95472	-0.03472	-175.09701	0.00000	-6.87251
9axle	5	70	-2	Fuel	501.70948	3.67851	0.00000	-144.63273	0.00000	-22.17772
9axle	5	70	-1	Fuel	528.45346	7.56856	-0.01960	-177.48514	0.00000	-19.74577
9axle	5	70	0	Ln(Fuel)	5.13898	0.02460	0.00000	-0.65815	0.00000	0.31372
9axle	5	70	1	Ln(Fuel)	4.20619	0.01756	0.00000	-0.46639	0.00000	0.54579
9axle	5	70	2	Ln(Fuel)	3.80255	0.01455	0.00000	-0.37424	0.00000	0.66765
9axle	5	70	3	Ln(Fuel)	3.33111	0.01165	0.00000	-0.30486	0.00000	0.79948
9axle	5	70	4	Ln(Fuel)	3.49642	0.01060	0.00000	-0.26695	0.00000	0.78954
9axle	5	70	8	Ln(Fuel)	3.50207	0.00808	0.00000	-0.19321	0.00000	0.87837

Appendix K. Coefficients of Pavement Roughness Factor Equations for Modern Vehicles

Table K-1. Coefficients of Pavement Roughness Factor Equations (with One Independent Variable) for Modern Vehicles

Vehicle Type	Min. PSI	Max. PSI	Dep. Variable	Constant	PSI
Small	1.0	5.0	Ln(Fuel)	0.10111	-0.02671
Medium	1.0	5.0	Ln(Fuel)	0.08475	-0.02368
Large	1.0	5.0	Ln(Fuel)	0.08383	-0.02212
Pickup	1.0	5.0	Ln(Fuel)	0.08805	-0.02342
2axle	1.0	5.0	Ln(Fuel)	0.09533	-0.02455
3axle	1.0	5.0	Ln(Fuel)	0.15480	-0.04039
3axle-comb	1.0	5.0	Ln(Fuel)	0.13276	-0.03500
4axle	1.0	5.0	Ln(Fuel)	0.13445	-0.03505
5axle	1.0	5.0	Ln(Fuel)	0.17367	-0.04554
7axle-comb	1.0	5.0	Ln(Fuel)	0.19146	-0.05035
9axle-comb	1.0	5.0	Ln(Fuel)	0.20692	-0.05450

Table K-2. Coefficients of Pavement Roughness Factor Equations (with Two Independent Variables) for Modern Vehicles

Vehicle Type	Min. PSI	Max. PSI	Dep. Variable	Constant	PSI	Ln(PSI)
Small	1.0	5.0	Fuel	1.08388	0.02220	-0.13048
Medium	1.0	5.0	Ln(Fuel)	0.06640	0.01998	-0.11432
Large	1.0	5.0	Fuel	1.06707	0.02345	-0.12109
Pickup	1.0	5.0	Ln(Fuel)	0.06879	0.02239	-0.11997
2axle	1.0	5.0	Ln(Fuel)	0.07410	0.02595	-0.13225
3axle	1.0	5.0	Ln(Fuel)	0.12302	0.03521	-0.19796
3axle-comb	1.0	5.0	Ln(Fuel)	0.10473	0.03169	-0.17465
4axle	1.0	5.0	Ln(Fuel)	0.10565	0.03348	-0.17944
5axle	1.0	5.0	Ln(Fuel)	0.13784	0.03969	-0.22318
7axle-comb	1.0	5.0	Ln(Fuel)	0.15240	0.04258	-0.24335
9axle-comb	1.0	5.0	Ln(Fuel)	0.16444	0.04654	-0.26460

Appendix L. MicroBENCOST Analysis Results for Added Capacity Problem

The following are the results of MicroBENCOST analysis for the added capacity problem using current equations for TRDF vehicles.

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***** M i c r o B E N C O S T *****

BENEFIT-COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS
VERSION 1.0 REVISION A

National Cooperative Highway Research Program (NCHRP)

Developed by the Texas Transportation Institute,
Texas A&M University System

Problem 0A Demo Example #1 Added Capacity

Daily Through Traffic (Thous.)

	WITHOUT Improvement			WITH Improvement		
Year	Existing	Alternate	Proposed	Existing	Alternate	Proposed
1991	15.39	0.00	0.00	15.39	0.00	0.00
1992	15.79	0.00	0.00	0.00	0.00	15.79
1993	16.20	0.00	0.00	0.00	0.00	16.20
1994	16.62	0.00	0.00	0.00	0.00	16.62
1995	17.05	0.00	0.00	0.00	0.00	17.05
1996	17.50	0.00	0.00	0.00	0.00	17.50
1997	17.95	0.00	0.00	0.00	0.00	17.95
1998	18.42	0.00	0.00	0.00	0.00	18.42
1999	18.90	0.00	0.00	0.00	0.00	18.90
2000	19.39	0.00	0.00	0.00	0.00	19.39
2001	19.89	0.00	0.00	0.00	0.00	19.89
2002	20.41	0.00	0.00	0.00	0.00	20.41
2003	20.94	0.00	0.00	0.00	0.00	20.94
2004	21.49	0.00	0.00	0.00	0.00	21.49
2005	22.05	0.00	0.00	0.00	0.00	22.05
2006	22.62	0.00	0.00	0.00	0.00	22.62
2007	23.21	0.00	0.00	0.00	0.00	23.21
2008	23.81	0.00	0.00	0.00	0.00	23.81
2009	24.43	0.00	0.00	0.00	0.00	24.43
2010	25.06	0.00	0.00	0.00	0.00	25.06
2011	25.72	0.00	0.00	0.00	0.00	25.72

EXISTING Route Segment 1

Existing Route (2-Lane)
Existing Route Segment A
WITHOUT Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1991	53.03	15.39	0.00	8016.	1183.	31169.	24676.	7490.	63335.
1992	52.91	15.79	0.00	8224.	1132.	30527.	24111.	7319.	61957.
1993	52.79	16.20	0.00	8438.	1084.	29900.	23561.	7152.	60613.
1994	52.66	16.62	0.00	8657.	1037.	29286.	23023.	6988.	59297.
1995	52.54	17.05	0.00	8882.	993.	28686.	22497.	6828.	58012.
1996	52.41	17.50	0.00	9113.	950.	28100.	21984.	6672.	56755.
1997	52.28	17.95	0.00	9350.	909.	27527.	21483.	6520.	55529.
1998	52.15	18.42	0.00	9594.	870.	26967.	20994.	6371.	54331.
1999	52.02	18.90	0.00	9844.	833.	26419.	20516.	6225.	53160.
2000	51.89	19.39	0.00	10102.	797.	25882.	20049.	6083.	52014.
2001	51.76	19.89	0.00	10367.	763.	25358.	19595.	5944.	50897.
2002	51.62	20.41	0.00	10638.	731.	24845.	19150.	5808.	49803.
2003	51.48	20.94	0.00	10917.	699.	24343.	18715.	5675.	48733.
2004	51.34	21.49	0.00	11204.	670.	23854.	18292.	5545.	47691.
2005	51.20	22.05	0.00	11498.	641.	23377.	17877.	5419.	46673.
2006	51.05	22.62	0.00	11800.	614.	22911.	17472.	5295.	45678.
2007	50.90	23.21	0.00	12110.	588.	22455.	17077.	5174.	44706.
2008	50.75	23.81	0.00	12428.	563.	22010.	16690.	5056.	43756.
2009	50.59	24.43	0.00	12755.	539.	21577.	16313.	4940.	42830.
2010	50.43	25.06	0.00	13091.	516.	21155.	15943.	4827.	41925.
2011	50.26	25.72	0.00	13435.	495.	20744.	15583.	4717.	41043.
Total				220464.	16608.	537094.	415601.	126046.	1078741.

EXISTING Route Segment 1

Existing Route (2-Lane)
Existing Route Segment A
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1991	53.03	15.39	0.00	8016.	1183.	31169.	24676.	7490.	63335.

PROPOSED Route Segment 1

Proposed Route (4-Lane)
Proposed Route Segment A
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1992	57.61	15.79	0.00	8134.	1008.	26717.	23462.	5577.	55756.
1993	57.58	16.20	0.00	8348.	963.	26121.	22931.	5990.	55043.
1994	57.55	16.62	0.00	8568.	920.	25538.	22411.	5853.	53802.
1995	57.52	17.05	0.00	8794.	880.	24968.	21903.	5720.	52591.
1996	57.49	17.50	0.00	9026.	841.	24411.	21407.	5589.	51406.
1997	57.45	17.95	0.00	9264.	803.	23868.	20922.	5461.	50250.
1998	57.42	18.42	0.00	9509.	768.	23337.	20449.	5336.	49122.
1999	57.38	18.90	0.00	9760.	734.	22818.	19986.	5214.	48018.
2000	57.34	19.39	0.00	10018.	701.	22310.	19533.	5095.	46939.
2001	57.31	19.89	0.00	10283.	670.	21816.	19092.	4979.	45887.
2002	57.27	20.41	0.00	10555.	640.	21332.	18660.	4865.	44857.
2003	57.23	20.94	0.00	10834.	612.	20858.	18238.	4754.	43849.
2004	57.19	21.49	0.00	11121.	585.	20396.	17826.	4645.	42868.
2005	57.15	22.05	0.00	11415.	559.	19945.	17424.	4539.	41908.
2006	57.10	22.62	0.00	11716.	534.	19506.	17029.	4435.	40970.
2007	57.05	23.21	0.00	12025.	511.	19078.	16643.	4334.	40055.
2008	56.99	23.81	0.00	12342.	488.	18660.	16266.	4235.	39161.
2009	56.93	24.43	0.00	12666.	467.	18253.	15897.	4629.	38779.
2010	56.87	25.06	0.00	13000.	446.	17855.	15536.	4524.	37915.
2011	56.81	25.72	0.00	13342.	427.	17467.	15184.	4420.	37071.
Total				210722.	13558.	435255.	380799.	100193.	916246.

Summary of Discounted Benefits (Thous. $)

Year	Delay Savings	Red Veh Op Cost	Red Acc Cost	Total Benefits
1991	0.00	0.00	0.00	0.00
1992	3810.22	649.41	1741.95	6201.58
1993	3779.12	630.38	1161.28	5570.77
1994	3748.44	611.97	1134.72	5495.13
1995	3718.13	594.24	1108.77	5421.14
1996	3688.47	577.11	1083.41	5348.98
1997	3659.63	560.58	1058.65	5278.86
1998	3630.58	544.93	1034.46	5209.98
1999	3601.53	530.01	1010.83	5142.37
2000	3571.84	515.93	987.70	5075.47
2001	3542.42	502.61	965.17	5010.20
2002	3513.24	489.77	943.10	4946.10
2003	3484.71	477.39	921.51	4883.61
2004	3457.51	465.43	900.47	4823.41
2005	3431.98	453.62	879.90	4765.50
2006	3404.59	443.21	859.78	4707.58
2007	3377.43	433.42	840.13	4650.98
2008	3349.96	424.51	820.91	4595.38
2009	3324.03	415.80	310.59	4050.41
2010	3299.55	407.24	303.48	4010.27
2011	3276.54	398.90	296.55	3971.99
Total	70669.91	10126.46	18363.37	99159.73

Summary Problem Benefits, Costs, and Economic Measures

Total Discounted User Benefits (Mill. $) :	99.160
Discounted Construction Cost (Mill. $) :	52.381
Discounted Salvage Value (Mill. $) :	16.864
Discounted Increase in Maint. and Rehab. (Mill. $) :	2.148
Fuel Consumption Savings (Mill. Gal.) :	1.725
Carbon Monoxide Emission Reduction (Mill. Kg.) :	1.866
Net Present Value (Mill. $) :	61.495
Gross Benefit-Cost Ratio :	2.633
Netted Benefit-Cost Ratio :	2.174
Internal Rate of Return (Percent) :	14.900

The following are the results of MicroBENCOST analysis for the added capacity problem using the updated equations for TRDF vehicles.

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***** M i c r o B E N C O S T *****

BENEFIT-COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS
VERSION 1.0 REVISION A

National Cooperative Highway Research Program (NCHRP)

Developed by the Texas Transportation Institute,
Texas A&M University System

Problem 0A Demo Example #1 Added Capacity

Daily Through Traffic (Thous.)

	WITHOUT Improvement			WITH Improvement		
Year	Existing	Alternate	Proposed	Existing	Alternate	Proposed
1991	15.39	0.00	0.00	15.39	0.00	0.00
1992	15.79	0.00	0.00	0.00	0.00	15.79
1993	16.20	0.00	0.00	0.00	0.00	16.20
1994	16.62	0.00	0.00	0.00	0.00	16.62
1995	17.05	0.00	0.00	0.00	0.00	17.05
1996	17.50	0.00	0.00	0.00	0.00	17.50
1997	17.95	0.00	0.00	0.00	0.00	17.95
1998	18.42	0.00	0.00	0.00	0.00	18.42
1999	18.90	0.00	0.00	0.00	0.00	18.90
2000	19.39	0.00	0.00	0.00	0.00	19.39
2001	19.89	0.00	0.00	0.00	0.00	19.89
2002	20.41	0.00	0.00	0.00	0.00	20.41
2003	20.94	0.00	0.00	0.00	0.00	20.94
2004	21.49	0.00	0.00	0.00	0.00	21.49
2005	22.05	0.00	0.00	0.00	0.00	22.05
2006	22.62	0.00	0.00	0.00	0.00	22.62
2007	23.21	0.00	0.00	0.00	0.00	23.21
2008	23.81	0.00	0.00	0.00	0.00	23.81
2009	24.43	0.00	0.00	0.00	0.00	24.43
2010	25.06	0.00	0.00	0.00	0.00	25.06
2011	25.72	0.00	0.00	0.00	0.00	25.72

EXISTING Route Segment 1

Existing Route (2-Lane)
Existing Route Segment A
WITHOUT Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1991	53.03	15.39	0.00	584.	276.	31169.	16917.	7490.	55576.
1992	52.91	15.79	0.00	610.	275.	30527.	16543.	7319.	54389.
1993	52.79	16.20	0.00	638.	273.	29900.	16177.	7152.	53230.
1994	52.66	16.62	0.00	667.	271.	29286.	15820.	6988.	52095.
1995	52.54	17.05	0.00	697.	268.	28686.	15471.	6828.	50985.
1996	52.41	17.50	0.00	729.	265.	28100.	15130.	6672.	49901.
1997	52.28	17.95	0.00	762.	262.	27527.	14796.	6520.	48843.
1998	52.15	18.42	0.00	796.	259.	26967.	14471.	6371.	47809.
1999	52.02	18.90	0.00	833.	255.	26419.	14154.	6225.	46798.
2000	51.89	19.39	0.00	870.	251.	25882.	13843.	6083.	45808.
2001	51.76	19.89	0.00	910.	246.	25358.	13540.	5944.	44843.
2002	51.62	20.41	0.00	951.	241.	24845.	13244.	5808.	43897.
2003	51.48	20.94	0.00	994.	236.	24343.	12954.	5675.	42972.
2004	51.34	21.49	0.00	1039.	230.	23854.	12672.	5545.	42071.
2005	51.20	22.05	0.00	1087.	224.	23377.	12396.	5419.	41192.
2006	51.05	22.62	0.00	1136.	217.	22911.	12125.	5295.	40331.
2007	50.90	23.21	0.00	1187.	210.	22455.	11861.	5174.	39490.
2008	50.75	23.81	0.00	1240.	202.	22010.	11603.	5056.	38669.
2009	50.59	24.43	0.00	1296.	194.	21577.	11351.	4940.	37868.
2010	50.43	25.06	0.00	1354.	185.	21155.	11105.	4827.	37086.
2011	50.26	25.72	0.00	1415.	176.	20744.	10864.	4717.	36324.
Total				19797.	5017.	537094.	287037.	126046.	950177.

EXISTING Route Segment 1

Existing Route (2-Lane)
Existing Route Segment A
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1991	53.03	15.39	0.00	584.	276.	31169.	16917.	7490.	55576.

PROPOSED Route Segment 1

Proposed Route (4-Lane)
Proposed Route Segment A
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1992	57.61	15.79	0.00	362.	254.	26717.	15708.	5577.	48002.
1993	57.58	16.20	0.00	379.	252.	26121.	15358.	5990.	47469.
1994	57.55	16.62	0.00	396.	249.	25538.	15015.	5853.	46406.
1995	57.52	17.05	0.00	413.	246.	24968.	14680.	5720.	45368.
1996	57.49	17.50	0.00	432.	243.	24411.	14353.	5589.	44352.
1997	57.45	17.95	0.00	451.	240.	23868.	14033.	5461.	43362.
1998	57.42	18.42	0.00	472.	236.	23337.	13721.	5336.	42394.
1999	57.38	18.90	0.00	493.	232.	22818.	13416.	5214.	41448.
2000	57.34	19.39	0.00	516.	227.	22310.	13118.	5095.	40523.
2001	57.31	19.89	0.00	539.	222.	21816.	12827.	4979.	39622.
2002	57.27	20.41	0.00	564.	217.	21332.	12542.	4865.	38739.
2003	57.23	20.94	0.00	590.	211.	20858.	12264.	4754.	37875.
2004	57.19	21.49	0.00	617.	205.	20396.	11992.	4645.	37033.
2005	57.15	22.05	0.00	645.	199.	19945.	11727.	4539.	36211.
2006	57.10	22.62	0.00	674.	191.	19506.	11467.	4435.	35408.
2007	57.05	23.21	0.00	705.	184.	19078.	11213.	4334.	34624.
2008	56.99	23.81	0.00	738.	176.	18660.	10964.	4235.	33859.
2009	56.93	24.43	0.00	771.	167.	18253.	10721.	4629.	33604.
2010	56.87	25.06	0.00	807.	158.	17855.	10484.	4524.	32863.
2011	56.81	25.72	0.00	843.	148.	17467.	10252.	4420.	32140.
Total				11407.	4258.	435255.	255854.	100193.	791301.

Summary of Discounted Benefits (Thous. $)

Year	Delay Savings	Red Veh Op Cost	Red Acc Cost	Total Benefits
1991	0.00	0.00	0.00	0.00
1992	3810.22	834.87	1741.95	6387.04
1993	3779.12	819.85	1161.28	5760.25
1994	3748.44	805.17	1134.72	5688.33
1995	3718.13	790.89	1108.77	5617.79
1996	3688.47	776.95	1083.41	5548.82
1997	3659.63	763.37	1058.65	5481.65
1998	3630.58	750.27	1034.46	5415.31
1999	3601.53	737.56	1010.83	5349.92
2000	3571.84	725.30	987.70	5284.85
2001	3542.42	713.50	965.17	5221.09
2002	3513.24	701.94	943.10	5158.28
2003	3484.71	690.64	921.51	5096.86
2004	3457.51	679.62	900.47	5037.60
2005	3431.98	668.71	879.90	4980.59
2006	3404.59	658.46	859.78	4922.83
2007	3377.43	648.55	840.13	4866.12
2008	3349.96	639.08	820.91	4809.95
2009	3324.03	629.73	310.59	4264.34
2010	3299.55	620.50	303.48	4223.54
2011	3276.54	611.42	296.55	4184.51
Total	70669.91	14266.39	18363.37	103299.67

Summary Problem Benefits, Costs, and Economic Measures

Total Discounted User Benefits (Mill. $) :	103.300
Discounted Construction Cost (Mill. $) :	52.381
Discounted Salvage Value (Mill. $) :	16.864
Discounted Increase in Maint. and Rehab. (Mill. $) :	2.148
Fuel Consumption Savings (Mill. Gal.) :	7.806
Carbon Monoxide Emission Reduction (Mill. Kg.) :	0.482
Net Present Value (Mill. $) :	65.635
Gross Benefit-Cost Ratio :	2.743
Netted Benefit-Cost Ratio :	2.253
Internal Rate of Return (Percent) :	15.520

The following are the results of MicroBENCOST analysis for the added capacity problem using updated coefficients for modern vehicles.

06/23/94 13:30

***** M i c r o B E N C O S T *****

BENEFIT-COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS
VERSION 1.0 REVISION A

National Cooperative Highway Research Program (NCHRP)

Developed by the Texas Transportation Institute,
Texas A&M University System

Problem 0A Demo Example #1 Added Capacity

Daily Through Traffic (Thous.)

	WITHOUT Improvement			WITH Improvement		
Year	Existing	Alternate	Proposed	Existing	Alternate	Proposed
1991	15.39	0.00	0.00	15.39	0.00	0.00
1992	15.79	0.00	0.00	0.00	0.00	15.79
1993	16.20	0.00	0.00	0.00	0.00	16.20
1994	16.62	0.00	0.00	0.00	0.00	16.62
1995	17.05	0.00	0.00	0.00	0.00	17.05
1996	17.50	0.00	0.00	0.00	0.00	17.50
1997	17.95	0.00	0.00	0.00	0.00	17.95
1998	18.42	0.00	0.00	0.00	0.00	18.42
1999	18.90	0.00	0.00	0.00	0.00	18.90
2000	19.39	0.00	0.00	0.00	0.00	19.39
2001	19.89	0.00	0.00	0.00	0.00	19.89
2002	20.41	0.00	0.00	0.00	0.00	20.41
2003	20.94	0.00	0.00	0.00	0.00	20.94
2004	21.49	0.00	0.00	0.00	0.00	21.49
2005	22.05	0.00	0.00	0.00	0.00	22.05
2006	22.62	0.00	0.00	0.00	0.00	22.62
2007	23.21	0.00	0.00	0.00	0.00	23.21
2008	23.81	0.00	0.00	0.00	0.00	23.81
2009	24.43	0.00	0.00	0.00	0.00	24.43
2010	25.06	0.00	0.00	0.00	0.00	25.06
2011	25.72	0.00	0.00	0.00	0.00	25.72

EXISTING Route Segment 1

Existing Route (2-Lane)
Existing Route Segment A
WITHOUT Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1991	53.03	15.39	0.00	560.	276.	31169.	16892.	7490.	55551.
1992	52.91	15.79	0.00	586.	275.	30527.	16518.	7319.	54364.
1993	52.79	16.20	0.00	613.	273.	29900.	16154.	7152.	53206.
1994	52.66	16.62	0.00	641.	271.	29286.	15797.	6988.	52071.
1995	52.54	17.05	0.00	671.	268.	28686.	15448.	6828.	50963.
1996	52.41	17.50	0.00	702.	265.	28100.	15108.	6672.	49879.
1997	52.28	17.95	0.00	734.	262.	27527.	14775.	6520.	48822.
1998	52.15	18.42	0.00	768.	259.	26967.	14450.	6371.	47788.
1999	52.02	18.90	0.00	804.	255.	26419.	14133.	6225.	46778.
2000	51.89	19.39	0.00	841.	251.	25882.	13823.	6083.	45788.
2001	51.76	19.89	0.00	880.	246.	25358.	13521.	5944.	44823.
2002	51.62	20.41	0.00	920.	241.	24845.	13225.	5808.	43878.
2003	51.48	20.94	0.00	963.	236.	24343.	12936.	5675.	42953.
2004	51.34	21.49	0.00	1007.	230.	23854.	12654.	5545.	42053.
2005	51.20	22.05	0.00	1053.	224.	23377.	12378.	5419.	41174.
2006	51.05	22.62	0.00	1101.	217.	22911.	12108.	5295.	40314.
2007	50.90	23.21	0.00	1152.	210.	22455.	11845.	5174.	39474.
2008	50.75	23.81	0.00	1205.	202.	22010.	11587.	5056.	38653.
2009	50.59	24.43	0.00	1260.	194.	21577.	11335.	4940.	37852.
2010	50.43	25.06	0.00	1317.	185.	21155.	11089.	4827.	37071.
2011	50.26	25.72	0.00	1377.	176.	20744.	10849.	4717.	36309.
Total				19154.	5017.	537094.	286625.	126046.	949765.

EXISTING Route Segment 1

Existing Route (2-Lane)
Existing Route Segment A
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1991	53.03	15.39	0.00	560.	276.	31169.	16892.	7490.	55551.

PROPOSED Route Segment 1

Proposed Route (4-Lane)
Proposed Route Segment A
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1992	57.61	15.79	0.00	337.	254.	26717.	15683.	5577.	47977.
1993	57.58	16.20	0.00	353.	252.	26121.	15333.	5990.	47445.
1994	57.55	16.62	0.00	369.	249.	25538.	14991.	5853.	46383.
1995	57.52	17.05	0.00	386.	246.	24968.	14657.	5720.	45345.
1996	57.49	17.50	0.00	404.	243.	24411.	14330.	5589.	44330.
1997	57.45	17.95	0.00	423.	240.	23868.	14011.	5461.	43340.
1998	57.42	18.42	0.00	443.	236.	23337.	13700.	5336.	42372.
1999	57.38	18.90	0.00	464.	232.	22818.	13395.	5214.	41427.
2000	57.34	19.39	0.00	485.	227.	22310.	13097.	5095.	40502.
2001	57.31	19.89	0.00	508.	222.	21816.	12807.	4979.	39602.
2002	57.27	20.41	0.00	532.	217.	21332.	12523.	4865.	38719.
2003	57.23	20.94	0.00	557.	211.	20858.	12244.	4754.	37856.
2004	57.19	21.49	0.00	583.	205.	20396.	11973.	4645.	37015.
2005	57.15	22.05	0.00	610.	199.	19945.	11709.	4539.	36193.
2006	57.10	22.62	0.00	639.	191.	19506.	11449.	4435.	35390.
2007	57.05	23.21	0.00	669.	184.	19078.	11195.	4334.	34607.
2008	56.99	23.81	0.00	700.	176.	18660.	10947.	4235.	33842.
2009	56.93	24.43	0.00	733.	167.	18253.	10705.	4629.	33587.
2010	56.87	25.06	0.00	767.	158.	17855.	10468.	4524.	32847.
2011	56.81	25.72	0.00	803.	148.	17467.	10237.	4420.	32124.
Total				10767.	4258.	435255.	255454.	100193.	790902.

Summary of Discounted Benefits (Thous. $)

Year	Delay Savings	Red Veh Op Cost	Red Acc Cost	Total Benefits
1991	0.00	0.00	0.00	0.00
1992	3810.22	835.35	1741.95	6387.52
1993	3779.12	820.35	1161.28	5760.75
1994	3748.44	805.69	1134.72	5688.84
1995	3718.13	791.42	1108.77	5618.33
1996	3688.47	777.50	1083.41	5549.37
1997	3659.63	763.93	1058.65	5482.22
1998	3630.58	750.85	1034.46	5415.89
1999	3601.53	738.15	1010.83	5350.51
2000	3571.84	725.90	987.70	5285.44
2001	3542.42	714.10	965.17	5221.69
2002	3513.24	702.56	943.10	5158.89
2003	3484.71	691.26	921.51	5097.48
2004	3457.51	680.24	900.47	5038.22
2005	3431.98	669.35	879.90	4981.23
2006	3404.59	659.11	859.78	4923.47
2007	3377.43	649.20	840.13	4866.76
2008	3349.96	639.73	820.91	4810.60
2009	3324.03	630.39	310.59	4265.00
2010	3299.55	621.16	303.48	4224.19
2011	3276.54	612.07	296.55	4185.17
Total	70669.91	14278.29	18363.37	103311.57

Summary Problem Benefits, Costs, and Economic Measures

Total Discounted User Benefits (Mill. $) :	103.312
Discounted Construction Cost (Mill. $) :	52.381
Discounted Salvage Value (Mill. $) :	16.864
Discounted Increase in Maint. and Rehab. (Mill. $) :	2.148
Fuel Consumption Savings (Mill. Gal.) :	7.827
Carbon Monoxide Emission Reduction (Mill. Kg.) :	0.482
Net Present Value (Mill. $) :	65.647
Gross Benefit-Cost Ratio :	2.743
Netted Benefit-Cost Ratio :	2.253
Internal Rate of Return (Percent) :	15.522

Appendix M. MicroBENCOST Analysis Results for Pavement Overlay Problem

The following are the results of MicroBENCOST analysis for the pavement overlay problem using current equations for TRDF vehicles.

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***** M i c r o B E N C O S T *****

BENEFIT-COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS
VERSION 1.0 REVISION A

National Cooperative Highway Research Program (NCHRP)

Developed by the Texas Transportation Institute,
Texas A&M University System

Problem 0A Example Problem #8 Pavement

Daily Through Traffic (Thous.)

	WITHOUT Improvement			WITH Improvement		
Year	Existing	Alternate	Proposed	Existing	Alternate	Proposed
1994	4.21	0.00	0.00	4.21	0.00	0.00
1995	4.32	0.00	0.00	0.00	0.00	4.32
1996	4.43	0.00	0.00	0.00	0.00	4.43
1997	4.55	0.00	0.00	0.00	0.00	4.55
1998	4.67	0.00	0.00	0.00	0.00	4.67
1999	4.79	0.00	0.00	0.00	0.00	4.79
2000	4.91	0.00	0.00	0.00	0.00	4.91
2001	5.04	0.00	0.00	0.00	0.00	5.04
2002	5.17	0.00	0.00	0.00	0.00	5.17
2003	5.30	0.00	0.00	0.00	0.00	5.30
2004	5.44	0.00	0.00	0.00	0.00	5.44
2005	5.58	0.00	0.00	0.00	0.00	5.58
2006	5.73	0.00	0.00	0.00	0.00	5.73
2007	5.88	0.00	0.00	0.00	0.00	5.88
2008	6.03	0.00	0.00	0.00	0.00	6.03
2009	6.19	0.00	0.00	0.00	0.00	6.19
2010	6.35	0.00	0.00	0.00	0.00	6.35
2011	6.51	0.00	0.00	0.00	0.00	6.51
2012	6.68	0.00	0.00	0.00	0.00	6.68
2013	6.86	0.00	0.00	0.00	0.00	6.86
2014	7.04	0.00	0.00	0.00	0.00	7.03

EXISTING Route Segment 1

Existing Route
Existing Route Segment 1
WITHOUT Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1994	56.21	4.21	0.00	1046.	119.	3915.	3482.	1117.	8514.
1995	56.17	4.32	0.00	1073.	114.	3828.	3411.	1091.	8330.
1996	56.13	4.43	0.00	1101.	109.	3743.	3343.	1066.	8152.
1997	56.09	4.55	0.00	1129.	104.	3660.	3275.	1042.	7977.
1998	56.04	4.67	0.00	1158.	99.	3579.	3208.	1018.	7806.
1999	56.00	4.79	0.00	1188.	95.	3500.	3147.	995.	7642.
2000	55.95	4.91	0.00	1219.	91.	3424.	3088.	972.	7484.
2001	55.90	5.04	0.00	1250.	87.	3348.	3029.	950.	7327.
2002	55.85	5.17	0.00	1282.	83.	3275.	2973.	928.	7176.
2003	55.79	5.30	0.00	1315.	79.	3203.	2920.	907.	7030.
2004	55.74	5.44	0.00	1349.	76.	3133.	2869.	886.	6888.
2005	55.68	5.58	0.00	1384.	72.	3064.	2823.	866.	6753.
2006	55.62	5.73	0.00	1420.	69.	2998.	2778.	846.	6622.
2007	54.39	5.88	0.00	1431.	67.	3066.	2710.	827.	6603.
2008	54.33	6.03	0.00	1468.	64.	2999.	2670.	808.	6477.
2009	54.26	6.19	0.00	1506.	61.	2934.	2632.	789.	6355.
2010	54.19	6.35	0.00	1544.	59.	2871.	2605.	771.	6247.
2011	54.12	6.51	0.00	1584.	56.	2809.	2579.	754.	6141.
2012	54.04	6.68	0.00	1625.	54.	2748.	2558.	736.	6043.
2013	52.82	6.86	0.00	1640.	52.	2797.	2516.	720.	6033.
2014	52.74	7.04	0.00	1682.	50.	2737.	2516.	703.	5956.
Total				28394.	1659.	67630.	61134.	18790.	147554.

EXISTING Route Segment 1

Existing Route
Existing Route Segment 1
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1994	56.21	4.21	0.00	1046.	119.	3915.	3482.	1117.	8514.

PROPOSED Route Segment 1

Proposed Route
Proposed Route Segment
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1995	58.51	4.32	0.00	1114.	110.	3599.	2855.	1091.	7545.
1996	57.89	4.43	0.00	1131.	106.	3554.	2784.	1066.	7404.
1997	57.84	4.55	0.00	1161.	101.	3476.	2733.	1042.	7251.
1998	57.80	4.67	0.00	1191.	97.	3400.	2679.	1018.	7096.
1999	57.75	4.79	0.00	1221.	92.	3324.	2629.	995.	6948.
2000	57.70	4.91	0.00	1253.	88.	3252.	2577.	972.	6801.
2001	57.65	5.04	0.00	1285.	84.	3180.	2526.	950.	6655.
2002	57.59	5.17	0.00	1318.	81.	3110.	2482.	928.	6520.
2003	57.54	5.30	0.00	1352.	77.	3042.	2439.	907.	6388.
2004	57.48	5.44	0.00	1387.	74.	2976.	2396.	886.	6258.
2005	57.42	5.58	0.00	1422.	71.	2911.	2355.	866.	6131.
2006	57.35	5.73	0.00	1458.	67.	2847.	2316.	846.	6009.
2007	56.71	5.88	0.00	1482.	65.	2814.	2267.	827.	5908.
2008	56.64	6.03	0.00	1520.	62.	2753.	2236.	808.	5797.
2009	56.57	6.19	0.00	1559.	59.	2694.	2205.	789.	5688.
2010	56.49	6.35	0.00	1599.	57.	2636.	2175.	771.	5582.
2011	56.42	6.51	0.00	1640.	54.	2579.	2156.	754.	5489.
2012	56.34	6.68	0.00	1681.	52.	2523.	2135.	736.	5395.
2013	55.69	6.86	0.00	1709.	50.	2495.	2116.	720.	5330.
2014	55.61	7.04	0.00	1753.	48.	2441.	2110.	703.	5254.
Total				28234.	1497.	59607.	48171.	17673.	125450.

Summary of Discounted Benefits (Thous. $)

Year	Delay Savings	Red Veh Op Cost	Red Acc Cost	Total Benefits
1994	0.00	0.00	0.00	0.00
1995	228.79	556.03	0.00	784.82
1996	188.98	558.84	0.24	748.06
1997	183.92	542.31	0.00	726.23
1998	179.80	529.72	0.00	709.52
1999	175.76	518.84	0.00	694.60
2000	171.85	511.12	0.00	682.97
2001	167.99	503.38	0.00	671.37
2002	164.90	490.81	0.18	655.89
2003	160.60	481.51	0.00	642.11
2004	157.03	472.87	0.00	629.90
2005	153.52	468.32	0.00	621.85
2006	150.66	461.64	0.15	612.44
2007	251.70	443.02	0.14	694.86
2008	245.57	434.39	0.00	679.96
2009	240.11	426.29	0.00	666.40
2010	234.78	429.74	0.00	664.52
2011	229.56	422.62	0.00	652.17
2012	224.88	422.31	0.11	647.31
2013	301.99	400.73	0.00	702.71
2014	295.67	406.15	0.10	701.93
Total	4108.08	9480.63	0.92	13589.63

Summary Problem Benefits, Costs, and Economic Measures

Total Discounted User Benefits (Mill. $) :	13.590
Discounted Construction Cost (Mill. $) :	3.619
Discounted Salvage Value (Mill. $) :	0.719
Discounted Increase in Maint. and Rehab. (Mill. $) :	0.000
Fuel Consumption Savings (Mill. Gal.) :	-0.885
Carbon Monoxide Emission Reduction (Mill. Kg.) :	0.044
Net Present Value (Mill. $) :	10.690
Gross Benefit-Cost Ratio :	4.687
Netted Benefit-Cost Ratio :	3.954
Internal Rate of Return (Percent) :	30.543

The following are the results of MicroBENCOST analysis for the pavement overlay problem using updated equations for TRDF vehicles.

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***** M i c r o B E N C O S T *****

BENEFIT-COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS
VERSION 1.0 REVISION A

National Cooperative Highway Research Program (NCHRP)

Developed by the Texas Transportation Institute,
Texas A&M University System

Problem 0A Example Problem #8 Pavement

Daily Through Traffic (Thous.)

	WITHOUT Improvement			WITH Improvement		
Year	Existing	Alternate	Proposed	Existing	Alternate	Proposed
1994	4.21	0.00	0.00	4.21	0.00	0.00
1995	4.32	0.00	0.00	0.00	0.00	4.32
1996	4.43	0.00	0.00	0.00	0.00	4.43
1997	4.55	0.00	0.00	0.00	0.00	4.55
1998	4.67	0.00	0.00	0.00	0.00	4.67
1999	4.79	0.00	0.00	0.00	0.00	4.79
2000	4.91	0.00	0.00	0.00	0.00	4.91
2001	5.04	0.00	0.00	0.00	0.00	5.04
2002	5.17	0.00	0.00	0.00	0.00	5.17
2003	5.30	0.00	0.00	0.00	0.00	5.30
2004	5.44	0.00	0.00	0.00	0.00	5.44
2005	5.58	0.00	0.00	0.00	0.00	5.58
2006	5.73	0.00	0.00	0.00	0.00	5.73
2007	5.88	0.00	0.00	0.00	0.00	5.88
2008	6.03	0.00	0.00	0.00	0.00	6.03
2009	6.19	0.00	0.00	0.00	0.00	6.19
2010	6.35	0.00	0.00	0.00	0.00	6.35
2011	6.51	0.00	0.00	0.00	0.00	6.51
2012	6.68	0.00	0.00	0.00	0.00	6.68
2013	6.86	0.00	0.00	0.00	0.00	6.86
2014	7.04	0.00	0.00	0.00	0.00	7.03

EXISTING Route Segment 1

Existing Route
Existing Route Segment 1
WITHOUT Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1994	56.21	4.21	0.00	49.	32.	3915.	2439.	1117.	7470.
1995	56.17	4.32	0.00	52.	32.	3828.	2393.	1091.	7311.
1996	56.13	4.43	0.00	54.	31.	3743.	2349.	1066.	7158.
1997	56.09	4.55	0.00	57.	31.	3660.	2305.	1042.	7007.
1998	56.04	4.67	0.00	60.	30.	3579.	2262.	1018.	6859.
1999	56.00	4.79	0.00	63.	30.	3500.	2224.	995.	6719.
2000	55.95	4.91	0.00	66.	29.	3424.	2187.	972.	6583.
2001	55.90	5.04	0.00	70.	29.	3348.	2151.	950.	6448.
2002	55.85	5.17	0.00	73.	28.	3275.	2115.	928.	6318.
2003	55.79	5.30	0.00	77.	27.	3203.	2084.	907.	6194.
2004	55.74	5.44	0.00	82.	26.	3133.	2054.	886.	6073.
2005	55.68	5.58	0.00	87.	26.	3064.	2028.	866.	5958.
2006	55.62	5.73	0.00	92.	25.	2998.	2003.	846.	5848.
2007	54.39	5.88	0.00	96.	24.	3066.	1969.	827.	5861.
2008	54.33	6.03	0.00	102.	23.	2999.	1948.	808.	5754.
2009	54.26	6.19	0.00	108.	22.	2934.	1928.	789.	5651.
2010	54.19	6.35	0.00	116.	21.	2871.	1920.	771.	5562.
2011	54.12	6.51	0.00	124.	20.	2809.	1912.	754.	5474.
2012	54.04	6.68	0.00	133.	18.	2748.	1909.	736.	5394.
2013	52.82	6.86	0.00	140.	18.	2797.	1895.	720.	5412.
2014	52.74	7.04	0.00	152.	16.	2737.	1913.	703.	5353.
Total				1851.	537.	67630.	43988.	18790.	130408.

EXISTING Route Segment 1

Existing Route
Existing Route Segment 1
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1994	56.21	4.21	0.00	49.	32.	3915.	2439.	1117.	7470.

PROPOSED Route Segment 1

Proposed Route
Proposed Route Segment
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1995	58.51	4.32	0.00	33.	31.	3599.	1777.	1091.	6467.
1996	57.89	4.43	0.00	34.	31.	3554.	1742.	1066.	6362.
1997	57.84	4.55	0.00	36.	30.	3476.	1715.	1042.	6233.
1998	57.80	4.67	0.00	37.	30.	3400.	1685.	1018.	6102.
1999	57.75	4.79	0.00	39.	29.	3324.	1658.	995.	5977.
2000	57.70	4.91	0.00	41.	29.	3252.	1630.	972.	5853.
2001	57.65	5.04	0.00	42.	28.	3180.	1601.	950.	5731.
2002	57.59	5.17	0.00	44.	27.	3110.	1579.	928.	5617.
2003	57.54	5.30	0.00	46.	27.	3042.	1557.	907.	5506.
2004	57.48	5.44	0.00	48.	26.	2976.	1536.	886.	5398.
2005	57.42	5.58	0.00	50.	25.	2911.	1515.	866.	5291.
2006	57.35	5.73	0.00	52.	24.	2847.	1496.	846.	5190.
2007	56.71	5.88	0.00	54.	23.	2814.	1474.	827.	5115.
2008	56.64	6.03	0.00	56.	22.	2753.	1462.	808.	5023.
2009	56.57	6.19	0.00	59.	21.	2694.	1450.	789.	4933.
2010	56.49	6.35	0.00	61.	20.	2636.	1438.	771.	4845.
2011	56.42	6.51	0.00	64.	19.	2579.	1437.	754.	4770.
2012	56.34	6.68	0.00	68.	18.	2523.	1434.	736.	4694.
2013	55.69	6.86	0.00	75.	16.	2495.	1439.	720.	4653.
2014	55.61	7.04	0.00	86.	15.	2441.	1452.	703.	4597.
Total				1026.	492.	59607.	31078.	17673.	108358.

Summary of Discounted Benefits (Thous. $)

Year	Delay Savings	Red Veh Op Cost	Red Acc Cost	Total Benefits
1994	0.00	0.00	0.00	0.00
1995	228.79	615.70	0.00	844.49
1996	188.98	606.91	0.24	796.13
1997	183.92	590.01	0.00	773.93
1998	179.80	576.81	0.00	756.61
1999	175.76	565.60	0.00	741.37
2000	171.85	557.55	0.00	729.40
2001	167.99	549.45	0.00	717.44
2002	164.90	536.35	0.18	701.43
2003	160.60	527.10	0.00	687.71
2004	157.03	518.32	0.00	675.35
2005	153.52	513.85	0.00	667.37
2006	150.66	507.08	0.15	657.88
2007	251.70	494.33	0.14	746.18
2008	245.57	485.85	0.00	731.42
2009	240.11	477.74	0.00	717.85
2010	234.78	481.79	0.00	716.56
2011	229.56	475.17	0.00	704.73
2012	224.88	474.87	0.11	699.87
2013	301.99	456.61	0.00	758.59
2014	295.67	460.14	0.10	755.92
Total	4108.08	10471.23	0.92	14580.22

Summary Problem Benefits, Costs, and Economic Measures

Total Discounted User Benefits (Mill. $) :	14.580
Discounted Construction Cost (Mill. $) :	3.619
Discounted Salvage Value (Mill. $) :	0.719
Discounted Increase in Maint. and Rehab. (Mill. $) :	0.000
Fuel Consumption Savings (Mill. Gal.) :	0.776
Carbon Monoxide Emission Reduction (Mill. Kg.) :	0.013
Net Present Value (Mill. $) :	11.681
Gross Benefit-Cost Ratio :	5.028
Netted Benefit-Cost Ratio :	4.228
Internal Rate of Return (Percent) :	33.047

The following are the results of MicroBENCOST analysis for the pavement overlay problem using equations for modern vehicles.

06/27/94 14:53

***** M i c r o B E N C O S T *****

BENEFIT-COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS
VERSION 1.0 REVISION A

National Cooperative Highway Research Program (NCHRP)

Developed by the Texas Transportation Institute,
Texas A&M University System

Problem 0A Example Problem #8 Pavement

Daily Through Traffic (Thous.)

	WITHOUT Improvement			WITH Improvement		
Year	Existing	Alternate	Proposed	Existing	Alternate	Proposed
1994	4.21	0.00	0.00	4.21	0.00	0.00
1995	4.32	0.00	0.00	0.00	0.00	4.32
1996	4.43	0.00	0.00	0.00	0.00	4.43
1997	4.55	0.00	0.00	0.00	0.00	4.55
1998	4.67	0.00	0.00	0.00	0.00	4.67
1999	4.79	0.00	0.00	0.00	0.00	4.79
2000	4.91	0.00	0.00	0.00	0.00	4.91
2001	5.04	0.00	0.00	0.00	0.00	5.04
2002	5.17	0.00	0.00	0.00	0.00	5.17
2003	5.30	0.00	0.00	0.00	0.00	5.30
2004	5.44	0.00	0.00	0.00	0.00	5.44
2005	5.58	0.00	0.00	0.00	0.00	5.58
2006	5.73	0.00	0.00	0.00	0.00	5.73
2007	5.88	0.00	0.00	0.00	0.00	5.88
2008	6.03	0.00	0.00	0.00	0.00	6.03
2009	6.19	0.00	0.00	0.00	0.00	6.19
2010	6.35	0.00	0.00	0.00	0.00	6.35
2011	6.51	0.00	0.00	0.00	0.00	6.51
2012	6.68	0.00	0.00	0.00	0.00	6.68
2013	6.86	0.00	0.00	0.00	0.00	6.86
2014	7.04	0.00	0.00	0.00	0.00	7.03

EXISTING Route Segment 1

Existing Route
Existing Route Segment 1
WITHOUT Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1994	56.21	4.21	0.00	39.	32.	3915.	2428.	1117.	7460.
1995	56.17	4.32	0.00	41.	32.	3828.	2382.	1091.	7301.
1996	56.13	4.43	0.00	43.	31.	3743.	2338.	1066.	7148.
1997	56.09	4.55	0.00	45.	31.	3660.	2294.	1042.	6997.
1998	56.04	4.67	0.00	48.	30.	3579.	2251.	1018.	6849.
1999	56.00	4.79	0.00	50.	30.	3500.	2214.	995.	6709.
2000	55.95	4.91	0.00	53.	29.	3424.	2177.	972.	6573.
2001	55.90	5.04	0.00	56.	29.	3348.	2141.	950.	6438.
2002	55.85	5.17	0.00	59.	28.	3275.	2105.	928.	6308.
2003	55.79	5.30	0.00	62.	27.	3203.	2074.	907.	6184.
2004	55.74	5.44	0.00	66.	26.	3133.	2044.	886.	6063.
2005	55.68	5.58	0.00	70.	26.	3064.	2018.	866.	5948.
2006	55.62	5.73	0.00	74.	25.	2998.	1993.	846.	5837.
2007	54.39	5.88	0.00	77.	24.	3066.	1959.	827.	5851.
2008	54.33	6.03	0.00	82.	23.	2999.	1938.	808.	5744.
2009	54.26	6.19	0.00	87.	22.	2934.	1917.	789.	5641.
2010	54.19	6.35	0.00	93.	21.	2871.	1909.	771.	5551.
2011	54.12	6.51	0.00	99.	20.	2809.	1901.	754.	5463.
2012	54.04	6.68	0.00	107.	18.	2748.	1898.	736.	5382.
2013	52.82	6.86	0.00	112.	18.	2797.	1884.	720.	5400.
2014	52.74	7.04	0.00	121.	16.	2737.	1901.	703.	5341.
Total				1481.	537.	67630.	43768.	18790.	130188.

EXISTING Route Segment 1

Existing Route
Existing Route Segment 1
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1994	56.21	4.21	0.00	39.	32.	3915.	2428.	1117.	7460.

PROPOSED Route Segment 1

Proposed Route
Proposed Route Segment
WITH Improvement

Year	Major Route Aver. Speed (mph)	Major Route Num. Veh. (000)	Minor Route Num. Veh. (000)	Fuel Consp. (000) (gal)	Carbon Monox. (000) (kg)	Discounted Motorist Costs (Thous. $) Time Costs	Veh. Oper. Costs	Acc. Costs	Total Costs
1995	58.51	4.32	0.00	30.	31.	3599.	1774.	1091.	6464.
1996	57.89	4.43	0.00	31.	31.	3554.	1739.	1066.	6359.
1997	57.84	4.55	0.00	33.	30.	3476.	1712.	1042.	6230.
1998	57.80	4.67	0.00	34.	30.	3400.	1682.	1018.	6099.
1999	57.75	4.79	0.00	35.	29.	3324.	1655.	995.	5974.
2000	57.70	4.91	0.00	37.	29.	3252.	1627.	972.	5851.
2001	57.65	5.04	0.00	39.	28.	3180.	1598.	950.	5728.
2002	57.59	5.17	0.00	40.	27.	3110.	1576.	928.	5614.
2003	57.54	5.30	0.00	42.	27.	3042.	1555.	907.	5504.
2004	57.48	5.44	0.00	44.	26.	2976.	1533.	886.	5395.
2005	57.42	5.58	0.00	46.	25.	2911.	1512.	866.	5289.
2006	57.35	5.73	0.00	48.	24.	2847.	1494.	846.	5187.
2007	56.71	5.88	0.00	50.	23.	2814.	1472.	827.	5113.
2008	56.64	6.03	0.00	52.	22.	2753.	1460.	808.	5021.
2009	56.57	6.19	0.00	54.	21.	2694.	1448.	789.	4931.
2010	56.49	6.35	0.00	57.	20.	2636.	1436.	771.	4843.
2011	56.42	6.51	0.00	59.	19.	2579.	1435.	754.	4768.
2012	56.34	6.68	0.00	63.	18.	2523.	1432.	736.	4691.
2013	55.69	6.86	0.00	67.	16.	2495.	1436.	720.	4650.
2014	55.61	7.04	0.00	74.	15.	2441.	1448.	703.	4592.
Total				935.	492.	59607.	31023.	17673.	108302.

Summary of Discounted Benefits (Thous. $)

Year	Delay Savings	Red Veh Op Cost	Red Acc Cost	Total Benefits
1994	0.00	0.00	0.00	0.00
1995	228.79	608.55	0.00	837.34
1996	188.98	599.74	0.24	788.95
1997	183.92	582.84	0.00	766.77
1998	179.80	569.66	0.00	749.46
1999	175.76	558.40	0.00	734.16
2000	171.85	550.29	0.00	722.14
2001	167.99	542.15	0.00	710.14
2002	164.90	529.01	0.18	694.09
2003	160.60	519.66	0.00	680.27
2004	157.03	510.79	0.00	667.82
2005	153.52	506.17	0.00	659.70
2006	150.66	499.26	0.15	650.06
2007	251.70	486.49	0.14	738.33
2008	245.57	477.84	0.00	723.40
2009	240.11	469.56	0.00	709.67
2010	234.78	473.29	0.00	708.07
2011	229.56	466.40	0.00	695.96
2012	224.88	466.03	0.11	691.02
2013	301.99	448.41	0.00	750.39
2014	295.67	453.04	0.10	748.82
Total	4108.08	10317.57	0.92	14426.56

Summary Problem Benefits, Costs, and Economic Measures

Total Discounted User Benefits (Mill. $) :	14.427
Discounted Construction Cost (Mill. $) :	3.619
Discounted Salvage Value (Mill. $) :	0.719
Discounted Increase in Maint. and Rehab. (Mill. $) :	0.000
Fuel Consumption Savings (Mill. Gal.) :	0.507
Carbon Monoxide Emission Reduction (Mill. Kg.) :	0.013
Net Present Value (Mill. $) :	11.527
Gross Benefit-Cost Ratio :	4.975
Netted Benefit-Cost Ratio :	4.185
Internal Rate of Return (Percent) :	32.677