FUEL TAX DIFFERENTIALS OF TEXAS CARGO VEHICLES

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Research Report 131-1

Research Study Number 2-10-68-131
Studies of Truck Characteristics Relating
to Highway Use and Taxation in Texas

Sponsored by
the Texas Highway Department
in Cooperation With the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

May 23, 1968

Texas Transportation Institute
Texas A&M University
College Station, Texas

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ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable assistance that members of the Planning Survey Division, Texas Highway Department, gave in furnishing data necessary for this study. Mr. Joe E. Wright, the Director of this Division, and Mr. Robert S. Hamner, Assistant Fiscal Officer, should receive special recognition for their assistance. Mr. Charles R. Davis, Assistant Traffic Manager, and Mr. Bernard F. Barton, Computer Programmer also were helpful.

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SUMMARY OF FINDINGS

The findings of this report are a partial fulfillment of the first two objectives of the "Studies of Truck Characteristics Relating to Highway Use and Taxation in Texas," a research project sponsored by the Texas Highway Department in cooperation with the Bureau of Public Roads, U. S. Department of Transportation. The essential task was to relate the characteristics of cargo vehicles operating in Texas, as reflected by loadometer and registration data, to fuel consumption curves developed from secondary data and adapt these results to the highway user taxation.

The major findings from this research endeavor are as follows:

1. A review of the literature revealed that 10 formal research studies have been made to determine the fuel consumption differential between gasoline and diesel powered vehicles possessing the same characteristics and in similar service. Seven of the 10 studies reported information only on a combined axle group basis. Those reporting separate axle group data were plagued with erratic findings. It was also discovered that the Bureau of Public Roads used five of the 10 studies to develop composite curves to establish reasonable fuel consumption differentials for the Highway Cost Allocation Study.
2. Analysis of the fuel consumption studies, the Texas loadometer frequencies, and the Texas registration frequencies, by gross weight and fuel type, indicated that the composite fuel consumption curves could be reasonably adapted to Texas cargo

vehicles to determine a single gasoline to diesel fuel consumption differential.

3. After analysis on a combined and separate axle group basis, a single gasoline to diesel fuel consumption ratio of 1.34 was selected as an acceptable figure for determining a fuel tax differential. This ratio was developed using 99 percent of the diesel vehicles weighed on the highways in Texas during 1967.

4. Based on the fuel consumption composite ratio of 1.34 which represents a weighted average of 46,013 pounds for diesel vehicles in the 23,100 - 73,000 pound gross operating weight range and a gasoline tax of 5.00 cents per gallon, the supported (equalized) diesel tax is 6.70 cents per gallon.

5. Using a diesel fuel consumption rate of .188 gallons per mile for a vehicle operating weight of 46,013 pounds, a registered weight of 39,000 pounds and travel of 75,000 miles per year, the average Texas diesel vehicle pays an 11 percent "surcharge" of .30 cents per gallon. The diesel vehicle also pays a diesel fuel tax of 6.50 cents per gallon. With the two charges added together, the present diesel tax is 6.80 cents per gallon, or .10 cents per gallon over the supported diesel tax.

6. Stated in terms of a diesel tax differential, the supported diesel tax differential is 1.70 cents per gallon and the present diesel tax differential is 1.80 cents per gallon, or an apparent inequity of .10 cents per gallon.

INTRODUCTION

In September 1967, the Texas Transportation Institute, in co-operation with the Texas Highway Department and the Bureau of Public Roads, U. S. Department of Transportation, began a two-year study entitled "Studies of Truck Characteristics Relating to Highway Use and Taxation in Texas."

The major objective of the study is to determine whether Texas cargo vehicles of various types are being equitably taxed in relation to their highway use. The rationale of highway user taxation takes into account the differences in highway vehicles. It is known that variations in vehicles lead to differences in fuel efficiency and thus to greater or lesser burdens of taxes in relation to highway use. The concept of use is that of distance and weight in that for any given vehicle these are primary factors of fuel consumption. "Surcharges" on licenses and fees on cargo vehicles and among cargo vehicles are an additional attempt to base taxes on highway use.

To complicate the above problem, there are differences in fuel types, each of which has peculiar physical efficiency in relation to weights, miles, and ton-miles. The tax differential between various types of Texas vehicles directly related to the type of fuel used is of major concern at the present.

The overall objectives of the study have been broken into the following tasks:

1. To analyze the present system of motor fuel taxation in relation to highway use by weight classes of cargo vehicles.

2. To correlate total highway taxation (fuel imposts plus licenses and fees) with highway use by weight classes of cargo vehicles.

3. To investigate highway taxation relationships with other (alternative) highway use concepts such as ton-mile and 18-kip axle equivalents.

4. To determine the frequency distribution of axle weights by cargo vehicle classes on various highway systems, to compare these data with total loadometer data and to derive associated highway use and taxation inferences.

5. To derive methods for quick review and evaluation of highway use and highway taxation.

This interim report partially fulfills the first two tasks. The following sections relate the characteristics of cargo vehicles operating in Texas, as reflected by loadometer and registration data, to fuel consumption curves developed from secondary data.

MOTOR VEHICLE FUEL TAXATION IN TEXAS

The present fuel tax laws in Texas are summarized briefly here. Two levels of taxation are involved in the case of diesel powered vehicles, namely a fuel tax and a "surcharge" on the registration of diesel engines. These are discussed separately.

The present laws provide a tax differential between different fuels used in motor vehicles, and the differential varies according to the use of vehicle. The gasoline and liquefied gas (butane) taxes are five cents (5¢) per gallon for all such fuels consumed in vehicles using the public highways in the state. The distillate fuel (diesel) tax is six and one-half cents (6.5¢) per gallon. The above tax rates apply to all vehicles using public roads in the state except buses (owned by transit companies) which are used primarily to transport persons within cities and towns. For such buses, the tax rate is four cents (4¢) per gallon on gasoline and liquefied gas and six cents (6¢) per gallon on diesel fuel.

In addition to the tax differential levied on diesel fuel usage, all vehicles powered by a diesel motor are taxed an extra 11 percent over and above the annual registration fee which is based on the registered gross weight of the vehicle. The 11 percent differential does not involve the gross weight of the trailer or semi-trailer pulled by the truck or truck-tractor. The annual fee for the registration of the truck or truck-tractor is based on the following schedule:

Gross Weight in Pounds	Fee Per 100 Pounds or Fraction Thereof*	
	Equipped With Pneumatic Tires	Equipped With Solid Tires
1 - 6,000	$0.44	$0.55
6,001 - 8,000	.495	.66
8,001 - 10,000	.605	.77
10,001 - 17,000	.715	.88
17,001 - 24,000	.77	.99
24,001 - 31,000	.88	1.10
31,001 - and Up	.99	1.32

* Must add a 30 cent reflectorization fee. Also, the minimum fee is $5.30.

A comparison of the taxes paid by vehicles due to fuel type must take into account the gross weight and the 11 percent "surcharge." The quantity of fuel consumed in gallons per mile and the amount of the 11 percent "surcharge" are both dependent on the gross weight of the vehicle.

STUDIES OF CARGO VEHICLE FUEL CONSUMPTION RATES BY TYPE FUEL

It has been recognized for many years that vehicles powered with diesel motors consume less fuel per mile than do vehicles powered with gasoline motors carrying the same gross weight under similar circumstances. A number of studies have been made at the Federal and State levels to establish or determine precisely the difference due only to the type of fuel used. Such studies were necessary as a basis for tax levies on fuels used in motor vehicles on public roads.

All known significant studies of the last 30 years which investigate gasoline and diesel consumption ratios are reviewed in this section. Each of these studies is covered in greater detail in Appendix B where the specific gasoline and diesel fuel consumption curves of comparable vehicles for each study are shown and explained.

All of the studies were initiated by public governing bodies and in some instances conducted with the cooperation of private owners of trucks and buses. Table 1 lists these studies and reviews the time periods covered, study locations, research agencies, methods of data collection, types of vehicle ownership, highway systems used, weight ranges of test vehicles, and the typical diesel axle combinations studied.

These studies represent gasoline and diesel fuel consumption comparisons ranging from highly controlled experiments to those reflecting the actual daily operations of the aggregate group of vehicles in similar service. The studies which fall into the controlled category

TABLE 1

Fuel Consumption Studies Conducted to Determine the Gasoline and Diesel Fuel Consumption Rates for Vehicles in Similar Service

Name of Study[1]	Time Period Covered by Study	Study Location	Research Agency	Method of Data Collection	Type of Vehicle Ownership	Highway System Used	Compared Weight Range of Test Vehicles in 1,000 Pounds[2]	Typical Diesel Axle Combinations
North Dakota (1)	1951	North Dakota	State[3]	Interview	For-Hire	All	26-59	-
Line-Haul (4)	1955-56	National	Federal	Questionnaire	For-Hire and Private	All	23-106	2-S2
Montana (5)	1956	Montana	State[3]	Questionnaire	For-Hire	All	17-80	-
Motor Vehicle Classification (6)	1956-57	National	Federal	Questionnaire	For-Hire and Private	All	17-65	2-S2
Fuel and Time Consumption (3)	1957-58	Five States[4]	Federal	Controlled Tests	For-Hire, Private and Public	Federal	17-65	3-S2
Oregon (7)	1937	Oregon	State	Controlled Tests	-	-	30-50	-
Washington State (8)	1949	Washington	State[3]	Questionnaire	For-Hire	All	40-70	-
Kansas (9)	1961	Kansas	Federal and State	Questionnaire	For-Hire and Private	All	50-70	-
AASHO Road Test (10)	1958-60	Illinois	Federal	Controlled Tests	Public	Special Federal	65	2-S1 and 3-S2
University of Washington (11)	1959	Washington	Federal and State	Controlled Tests	Public	Federal	24-57	-

1 The numbers in parentheses correspond to the numbers on the List of References in Appendix C.

2 Only the comparable weight ranges between gasoline and diesel vehicles.

3 Private consultant to Legislative Fact Finding Committee.

4 Ohio, Michigan, Maryland, Virginia and Washington.

are the Fuel and Time Consumption Study, Oregon Study, AAS and the University of Washington Study. The first of thes includes actual day-to-day operations. Generally, a limited number of vehicles were used in the controlled experiments, whereas the experience studies observed a large number of vehicles.

Most of the studies report fuel consumption data only on an aggregative basis and not by individual axle types. Only three studies report data by axle type: the Fuel and Time Consumption Study, Line-Haul Trucking Cost Study, and University of Washington Study. The last of these reports a highly controlled experiment.

As can be noted from Table 1, the federal government has initiated several of these studies to help, among other things, make a policy decision on a diesel fuel tax rate. Researchers of the Bureau of Public Roads have combined the results of its studies with two state studies to arrive at a composite fuel consumption curve for each fuel. The Montana Study, Line-Haul Trucking Cost Study, Fuel and Time Consumption Study and North Dakota Study were used to determine the gasoline composite curve. All but the North Dakota Study were u to determine the diesel composite curve. Essentially, the latest studies were used in the above determination. However, the studies not used by the Bureau of Public Roads do not reflect greatly different fuel consumption rates. The studies that were used represented vehicles operated in several states and covered comparable weights reflecting a majority of the diesel powered vehicles in service. (The AASHO Road Test is an example of a study which did not have comparable weights of

vehicles for its measurements of differences between gasoline and diesel fuel comsumption.)

After an analysis of all the studies, it seems that the composite curves are applicable to Texas conditions and may be used to arrive at an aggregative gasoline to diesel fuel consumption ratio for cargo vehicles operating within the state. The use of the composite curves is preferred over individual axle type curves because of the limitations found in such data. The major axle type study, the Line-Haul Trucking Cost Study, shows data covering a limited gross weight range for several axle types. Also, some of the results of this study are not consistent. For instance, the axle type (3-S2) shows a lower gasoline to diesel fuel consumption ratio than that shown for lighter axle types. (For a description of each axle type and corresponding code, see Table 10 in Appendix A.) The results of the other two studies (University of Washington Study and Fuel and Time Consumption Study) reporting 3-S2 axle type data disagree widely with the results of the Line-Haul Trucking Cost Study. Yet, for other axle types the three studies generally agree with one another. Thus, the greatest disagreement found in tbe axle type data occurs with respect to the most commonly used diesel powered axle type (3-S2).

In most cases, the fuel consumption studies failed to report separate fuel consumption rates for empty vehicles. The two which did so report, the Line-Haul Trucking Cost and University of Washington Studies, indicated gasoline to diesel ratios little different from those reflected by all loaded and empty vehicles combined.

One study, the Fuel and Time Consumption Study, reported data comparisons of urban and rural vehicles. Most of the other studies are a reflection of rural vehicle usage. The above study indicates that in urban areas for the same gross weights gasoline to diesel fuel consumption ratios are significantly higher.

FUEL CONSUMPTION RATES APPLIED TO TEXAS CARGO VEHICLES

A determination of the fuel consumption rate differentials applicable to Texas cargo vehicles was made by weighting the appropriate fuel consumption rates with 1967 loadometer frequency distributions for each fuel type and gross operating weight class. This method assumes that fuel consumption rates found in other studies are proper for Texas and that loadometer observations obtain a cross-section of traffic on Texas roads. The loadometer frequency distributions were chosen in preference to registration frequencies because the registered gross weights fail to adequately reflect operating gross weights. This fact is indicated by Table 2, especially in the case of truck-tractor combinations. (Also, see Table 11 in Appendix A.) The operating gross weights were established by weighing trucks at the 21 loadometer stations. The registered gross weights were established from the 1967 truck registration receipts. The registered gross weight is defined by State law as the actual weight of the vehicle fully equipped with body and other equipment plus its net carrying capacity. The net carrying capacity is defined as the weight of the heaviest net load to be carried on the vehicle being registered, provided that the net carrying capacity is not less than the manufacturer's rated carrying capacity. It should be noted that the weight which is carried on trailer wheels may not be included as a part of the registered weight of the truck.

Since only 1.18 percent of all vehicles weighted in 1967 were butane powered vehicles, these vehicles were not used in the determination of the fuel consumption differentials. Some of the literature suggests that the butane fuel consumption rates are quite similar to those of gasoline, but separate fuel consumption rates for butane powered vehicles generally are

TABLE 2

Number of Registered and Weighed Single-Unit Trucks and Truck-Tractor Combinations, by Type of Fuel and Weight Class, 1967

Registered or Weighed Gross Weight in Pounds	Number of Vehicles Registered and Weighed By Body and Fuel Type							
	Single-Unit Trucks				Truck-Tractor Combinations			
	Gasoline		Diesel		Gasoline		Diesel	
	Registered	Weighed	Registered	Weighed	Registered	Weighed	Registered	Weighed
0-2,000	160	0	0	0	0			
2,100-4,000	57,580	408	0	1	7			
4,100-6,000	876,940	2,227	30	2	27			
6,100-8,000	33,650	1,090	30	10	151			
8,100-10,000	20,980	942	0	12	812	3		
10,100-12,000	32,540	691	0	24	1,405	11	23	1
12,100-14,000	19,400	561	30	38	1,366	39	35	
14,100-16,000	15,560	434	0	48	1,180	99	33	3
16,100-18,000	13,400	358	50	37	1,547	15	142	11
18,100-20,000	11,120	296	130	14	1,629	338	136	77
20,100-22,000	10,460	227	150	18	3,074	358	261	205
22,100-24,000	11,320	143	400	18	5,678	278	589	485
24,100-26,000	5,900	123	180	15	3,506	244	902	718
26,100-28,000	2,810	81	310	11	2,978	167	1,499	773
28,100-30,000	1,100	53	130	6	286	151	279	668
30,100-32,000	580	47	30	3	228	130	158	458
32,100-34,000	300	43	30	0	106	89	56	362
34,100-36,000	620	25	380	6	214	131	82	305
36,100-38,000	820	28	30	2	336	122	153	242
38,100-40,000	1,970	21	990	7	3,765	96	16,787	265
40,100-45,000	2,370	28	350	13	84	209	974	586
45,100-50,000	1,590	10	560	12	12	249	23	685
50,100-over	40	13	50	26	213	586	267	4,667
Total Number	1,131,210	7,849	3,860	332	28,604	3,515	22,399	10,511
Percent of Registered Vehicles		.7%		8.6%		12%		47%

not reported.

The ratios or differentials developed are generally a reflection of the weight ranges covered by the fuel consumption studies. In other words, only limited extrapolations of the fuel consumption data are involved here. Very little data on diesel fuel consumption rates were found for gross operating weights below 20,000 pounds. This fact presents no real problem because there is only a small number of diesel vehicles registered or weighed in Texas below the 20,000 pound weight.

Since this is a study of vehicles of the cargo type instead of those of the automobile type, four-tire vehicles were deleted from the loadometer frequency distributions used to determine the fuel consumption ratios. Also, due to the limitations of the fuel consumption data and the Texas legal weight limit of 72,000 pounds, all vehicles weighing less than 10,100 or more than 80,000 pounds were deleted from the frequency distributions. In all, 5,421 vehicles were deleted; the vast majority being gasoline powered vehicles weighing less than 10,000 pounds.

The gasoline to diesel fuel consumption ratios were determined first for all remaining vehicles regardless of axle type and then for various axle type groupings. Certain minor axle types had to be grouped together because of the way in which fuel consumption data were reported. Vehicles of similar axle combinations and average weights were put into the same grouping. The groupings used by the fuel consumption studies were generally followed.

Table 3 shows the total gasoline and diesel vehicle frequencies on a combined axle and separate axle group basis. Then, the above limitations were imposed on these frequencies in deriving the fuel consumption differentials discussed below.

Fuel Consumption Rates for Combined Axle Groups

The primary analysis used the combined axle group frequencies of both loaded and empty vehicles in connection with fuel consumption

TABLE 3

Number of Texas Cargo Vehicles Weighed at 21 Loadometer Stations by Axle Group and Fuel Type, 1967

Average Gross Operating Weight in Pounds	Number of Vehicles by Axle Group and Fuel Type[1]													
	Axle Groups Combined		2-S1		2-S2		3-S2		2-Axle 6 tires, 3, 2-1, 2-2 2-S3, 3-1, 3-S1		2-3 3-3, 3-2, 3-S3, 2-S1-2, 3-S1-2		2-Axle 4 Tire	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
0-10,000	4,670	25	3						1,534	18	2		3,131	7
10,100-11,000	355	11	3		1				342	11	1		8	
11,100-13,000	654	31	17		7	1	1		624	29			5	1
13,100-15,000	594	43	42		19		1		521	43	2		9	
15,100-17,000	504	56	71	4	69	1	3		360	51			1	
17,100-19,000	638	57	100	8	172	21	26	7	335	21	3		2	
19,100-21,000	600	152	115	29	180	44	55	66	248	13			2	
21,100-23,000	509	324	118	38	135	78	68	192	187	16	1			
23,100-25,000	383	636	76	61	86	95	92	457	127	19	2	4		
25,100-27,000	317	798	74	32	63	91	69	651	111	20		4		
27,100-29,000	215	735	59	24	51	67	43	626	62	11		7		
29,100-31,000	191	570	54	36	62	54	28	466	46	10	1	4		
31,100-33,000	152	410	49	37	38	51	20	312	43	2	2	8		
33,100-35,000	158	328	63	32	45	57	7	225	42	5	1	9		
35,100-37,000	145	286	57	33	48	51	13	181	23	9	4	12		
37,100-39,000	132	258	46	30	49	59	15	155	22	7		7		
39,100-41,000	108	253	42	14	40	50	8	174	17	6	1	9		
41,100-43,000	86	246	19	5	44	55	9	174	14	4		8		
43,100-45,000	96	227	18	1	55	55	14	161	8	6	1	4		
45,100-47,000	104	264	3	1	75	61	18	190	7	6	1	6		
47,100-49,000	104	287		1	85	58	14	215	4	6		7		
49,100-51,000	99	290		1	75	54	20	218	4	8		9		
51,100-53,000	77	309			62	39	13	261	2	2		7		
53,100-55,000	83	355		1	50	33	31	307	2	4		10		
55,100-57,000	68	365			24	19	43	333	1	2		11		

TABLE 3 continued

Average Gross Operating Weight in Pounds	Number of Vehicles by Axle Group and Fuel Type[1]													
	Axle Groups Combined		2-S1		2-S2		3-S2		2-Axle 6 tires, 3, 2-1, 2-2 2-S3, 3-1, 3-S1		2-3 3-3, 3-2, 3-S3, 2-S1-2, 3-S1-2		2-Axle 4 Tire	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
57,100-59,000	56	484			18	15	37	453	1	3		13		
59,100-61,000	57	494			8	10	47	472	1		1	12		
61,100-63,000	54	569			8	12	44	541			2	17		
63,100-65,000	41	572			4	4	37	551				17		
65,100-67,000	39	456			3	2	34	440			2	14		
67,100-69,000	28	358			2		25	337			1	21		
69,100-71,000	21	218				1	21	205				12		
71,100-73,000	10	146			1	2	9	136				8		
73,100-75,000	4	70					4	63				7		
75,100-77,000	4	56					4	49				7		
77,100-79,000	4	30					4	25				5		
79,100-80,000	0	12					0	10				2		
80,100-up	4	53					4	51				2		
Total Number Vehicles	11,364	10,834	1,030	388	1,579	1,140	881	8,704	4,688	331	28	263	3,158	8
Percent of Axle Group	51%	49%	73%	27%	58%	42%	9%	91%	93%	7%	10%	90%	99.7%	0.3%
Percent of Axle Groups Combined	100.0%	100.0%	9.1%	3.6%	13.9%	10.5%	7.7%	80.3%	41.3%	3.1%	0.2%	2.4%	27.8%	0.1%

1 The minor axle types were combined.

rates, in gallons per mile, for each 2,000 pound gross weight class to compute weighted average fuel consumption rates by fuel type. See Table 14 in Appendix A.

Table 4 summarizes the findings of the above analysis. As should be noted, the analysis reports findings for two different weight ranges. The 10,100 - 80,000 pound weight range reflects an extrapolation of the diesel fuel consumption curve on both ends. The 23,100 - 73,000 pound weight range reflects no such extrapolation of the above curve. Obviously, the latter weight range gives the most reliable answers. However, they both give the same gasoline to diesel fuel consumption ratio when weighting by diesel numbers is used. Such a weighting is the most logical of the two given in Table 4. Footnotes 3 and 4 state the formulas used to compute the appropriate ratios.

When weighting by gasoline numbers, it is assumed that the gasoline vehicles are diesel powered. In contrast, when weighting by diesel numbers, it is assumed that the diesel vehicles are gasoline powered. Since the central problem is to determine what kind of fuel consumption advantage, if any, diesel vehicles have over gasoline vehicles (identical in all respects to the diesel and in similar service), it seems imperative to use the diesel frequency for weighting. Thus, for the remainder of this report, the conclusions will be based on ratios developed from a weighting by diesel numbers.

The use of a single gasoline to diesel fuel consumption ratio for cargo vehicles operating in Texas is advisable from the standpoint of keeping the taxing procedures simple to administer. This criterion can easily be met by using the ratio of 1.34 which represents 99 percent

TABLE 4

Fuel Consumption Differentials of Combined Axle Groups of Texas Vehicles as Reflected by the Composite Fuel Consumption Rates[1]

Characteristic	Loaded and Empty Vehicles in 10,100-80,000 lb. Weight Range	23,100-73,000 lb. Weight Range
Total Number of Vehicles in Weight Range		
Gasoline	6,369	2,832
Diesel	10,706	9,854
Percent of All Gasoline Vehicles Weighed	56	25
Percent of All Diesel Vehicles Weighed	99	91
Average Vehicle Weight in Pounds[2]		
Gasoline	26,452	38,344
Diesel	44,813	46,013
Average Fuel Consumption in Gal. Per Mi.[2]		
Gasoline	.187	.230
Diesel	.186	.188
Gasoline to Diesel Fuel Consumption Ratio		
Weighted by Gasoline Numbers[3]	1.22	1.30
Weighted by Diesel Numbers[4]	1.34	1.34

1 The 10,000 - 80,000 pound weight range represents an extrapolation beyond the range of the fuel consumption studies, while the 23,100 - 73,000 weight range keeps within the range of the fuel consumption studies.

2 Weighted by the numbers of vehicles in each 2,000 pound weight class.

3 Assumes that the gasoline vehicles used diesel fuel for a weighting factor. The formula: Σ(GPM of Gasoline x Number of Gasoline Vehicles) $\div$ Σ(GPM of Diesel x Number of Gasoline Vehicles) where GPM = Gallons Per Mile.

4 Assumes that the diesel vehicle used gasoline fuel for a weighting factor. The formula: Σ(GPM of Gasoline x Number of Diesel Vehicles) $\div$ Σ(GPM of Diesel x Number of Diesel Vehicles).

of all diesel vehicles weighed in Texas during 1967. As will be seen in the next section, this ratio represents something of a compromise between the ratios developed for each axle group.

Table 15 in Appendix A presents the analysis of empty vehicles weighed at Texas loadometer stations in 1967. About 33 percent of all diesel vehicles and 36 percent of all gasoline vehicles weighed are empty vehicles operating within the 10,000 - 80,000 pound weight range. (Although not strictly comparable figures, the Line-Haul Trucking Cost Study reported that 25 percent of its diesel vehicles and 20 percent of the gasoline vehicles were completely empty on the return trip.)

Table 16 in Appendix A presents the analysis of urban fuel consumption rates on the Texas loadometer data which include urban weighings of five percent. Based on the fuel comsumption rates of the Fuel and Time Consumption Study, the ratio of gasoline to diesel fuel consumption is 1.70 for vehicles in the 23,100 - 71,000 weight range. This ratio is considerably above the ratio of 1.34 which was based on fuel consumption rates for vehicles operating on rural highways. Actually, the results should be based purely on urban frequencies, but it is questionable whether frequencies which could be developed from the 1967 loadometer data are representative of urban travel in Texas. Thus, the above findings for developing an urban versus rural differential are inconclusive. The analysis does indicate that the fuel differential between gasoline and diesel powered vehicles operating in urban areas is likely to be at least as great as that in rural areas.

Fuel Consumption Rates for Separate Axle Groups

This section summarizes the results of the analysis of cargo vehicle frequencies by axle group in relation to corresponding fuel consumption rates for the axle group in question. The results are summarized on a fuel consumption study basis, because this seems to be most logical in view of the differences between the studies. Tables 17 - 21 in Appendix A show all the fuel consumption data and individual frequencies for each axle group.

Table 5 gives the summarized results for separate axle groups as reflected by the Line-Haul Trucking Cost Study. The weight ranges for each axle group are very similar, except for Combined Group II. (See Footnote 1 of Table 5 for the axle types that are included in Combined Groups I and II.) The results are somewhat mixed considering the fact that the fuel consumption ratios range from 1.19 to 1.47. As can be seen, these ratios represent a low of 13.9 percent to a high of 53.5 percent of all diesel vehicles in each axle group.

It is significant that three of the five axle groups presented in Table 5 have ratios higher than the 1.34 ratio which was obtained by using the combined axle group frequencies and employing the fuel consumption rates of the composite curves. Thus, this ratio represents a compromise between the individual axle group ratios.

Table 6 shows the results of the separate axle group analyses using the University of Washington fuel consumption rates. Here again, the weight ranges are very similar for all axle groups. These broader weight ranges include a much higher percentage of all diesel vehicles weighed than those shown in Table 5. Three of the four axle groups

TABLE 5

Fuel Consumption Differentials of Separate Axle Groups of Texas Vehicles as Reflected by the Line-Haul Trucking Cost Study Fuel Consumption Rates

Characteristic	Loaded and Empty Vehicles by Axle Group[1]				
	2-S1's in 37,100-55,000 lb. Weight Range	2-S2's in 39,100-59,000 lb. Weight Range	3-S2's in 45,100-73,000 lb. Weight Range	Combined Group I in 37,100-57,000 lb. Weight Range	Combined Group II in 65,100-81,000 lb. Weight Range
Total Number of Vehicles in Weight Range					
Gasoline	129	528	393	82	3
Diesel	54	439	4,659	52	76
Percent of All Gasoline Vehicles in Axle Group	12.5	33.4	44.6	15.7	10.7
Percent of All Diesel Vehicles in Axle Group	13.9	38.5	53.5	15.4	28.9
Average Vehicle Weight in Pounds					
Gasoline	40,391	48,876	58,527	42,660	66,717
Diesel	39,902	47,348	59,779	46,012	70,682
Average Fuel Consumption in Gal. Per Mi.[2]					
Gasoline	.249	.258	.277	.223	.283
Diesel	.170	.173	.226	.198	.198
Gasoline to Diesel Fuel Consumption Ratio					
Weighted by Gasoline Numbers[3]	1.42	1.48	1.22	1.17	1.47
Weighted by Diesel Numbers[4]	1.45	1.47	1.22	1.19	1.46

1 Combined Group I represents 2 (six tires), 3, 2-1, 2-2, 2-S3, 3-1, and 3-S1 Texas loadometer axle combinations weighted with the fuel consumption rates of the 2-2, 2-3, 3-2 and 3-3 axle combinations. Combined Group II represents 2-S1-2, 3-S1-2, 3-2, 3-3 and 3-S3 Texas loadometer axle combinations weighted with the fuel consumption rates of the 2-S1-2, 2-S2-2, 3-S1-2 and 3-S2-2 axle combinations.

2-4 See the corresponding footnotes under Table 4.

TABLE 6

Fuel Consumption Differentials of Separate Axle Groups of Texas Vehicles
as Reflected by the University of Washington Study Fuel Consumption Rates

Characteristic	Loaded and Empty Vehicles by Axle Group[1]			
	2-S2's in 23,100-59,000 lb. Weight Range	3-S2's in 27,100-69,000 lb. Weight Range	Combined Group I in 25,100-57,000 lb. Weight Range	Combined Group II in 27,100-73,000 lb. Weight Range
Total Number of Vehicles in Weight Range				
Gasoline	970	520	411	17
Diesel	964	6,791	111	232
Percent of All Gasoline Vehicles in Axle Group	61.4	59.0	8.8	60.7
Percent of All Diesel Vehicles in Axle Group	84.6	78.0	33.5	88.2
Average Vehicle Weight in Pounds				
Gasoline	40,036	50,606	31,990	50,047
Diesel	37,469	49,669	37,476	53,132
Average Fuel Consumption in Gal. Per Mi.[2]				
Gasoline	.162	.197	.158	.168
Diesel	.119	.102	.130	.132
Gasoline to Diesel Fuel Consumption Ratio				
Weighted by Gasoline Numbers[3]	1.33	1.91	1.25	1.33
Weighted by Diesel Numbers[4]	1.32	1.92	1.31	1.33

1 Combined Group I represents 2 (six tires), 3, 2-1, 2-2, 2-S3, 3-1 and 3-S1 Texas loadometer axle combinations weighed with the fuel consumption rates of the 2-2 and 3-2 axle combinations. Combined Group II represents 2-S1-2, 3-S1-2, and 3-S3 Texas loadometer axle combinations weighted with the fuel consumption rates of the 2-S1-2 axle combination.

2-4 See corresponding footnotes under Table 4.

yield very similar fuel consumption ratios. These three ratios fall between extremes of those yielded by the Line-Haul Trucking Cost Study. No explanation can be given as to why the 3-S2 axle group has such a high ratio. By the same token, no reason can be found to explain why the ratio for this axle group reflected by the Line-Haul Trucking Cost Study is comparatively low.

Except for the 3-S2 axle group ratio, the ratios of Table 6 are very close to the 1.34 composite ratio. This result tends to support the conclusion to use a single ratio to represent all cargo vehicles operating in Texas.

Table 7 summarizes the results for the 3-S2 axle type reflecting the fuel consumption rates of three studies, two of which have been reported on in Tables 5 and 6. The additional findings for this axle group are based on the Fuel and Time Consumption Study. Using a 27,100 - 71,000 pound weight range, this study yielded a fuel consumption ratio of 1.52. When compared to the ratios of the other two studies, this ratio is nearly an average of the two. Such a ratio is much more like the ratios of several other axle groups and the composite ratio (1.34). Therefore, the middle ratio of the three studies seems to be most realistic for the 3-S2 axle group. It is important to note that 3-S2's represent 80 percent of all the diesels weighed in the 1967 Texas loadometer sample.

To further summarize, Table 8 shows what is considered to be the most logical fuel consumption differential for each axle group as developed from the three studies. The criterion followed here was to select the broadest weight range for each axle group used by any one of the

TABLE 7

Fuel Consumption Differentials of the 3-S2 Axle Group of Texas Vehicles as Reflected by the Fuel Consumption Rates of Three Separate Studies[1]

Characteristic	Loaded and Empty Vehicles of the 3-S2 Axle Group		
	L - H	F - T	U - W
	45,100-73,000 lb. Weight Range	27,100-71,000 lb. Weight Range	27,100-69,000 lb. Weight Range
Total Number of Vehicles in Weight Range			
Gasoline	393	541	520
Diesel	4,659	6,997	6,791
Percent of All Gasoline Vehicles in Axle Group	44.6	61.4	59.0
Percent of All Diesel Vehicles in Axle Group	53.5	80.3	78.0
Average Vehicle Weight in Pounds[2]			
Gasoline	58,527	51,621	50,606
Diesel	59,779	50,266	49,669
Average Fuel Consumption in Gal. Per Mi.[2]			
Gasoline	.277	.280	.197
Diesel	.226	.181	.102
Gasoline to Diesel Fuel Consumption Ratio			
Weighted by Gasoline Numbers[3]	1.22	1.52	1.91
Weighted by Diesel Numbers[4]	1.22	1.52	1.92

1 The three studies are represented by the following: L - H, Line-Haul Trucking Cost Study; F - T, Fuel and Time Consumption Study, and U - W, University of Washington Study.

2-4 See corresponding footnotes under Table 4.

TABLE 8

Selected Fuel Consumption Differentials
for Each Axle Group of Texas Vehicles
as Reflected by Three Studies[1]

Axle Group	Fuel Study	Weight Range in Pounds[2]	Gasoline to Diesel Ratio[3]
2-S1	L-H	37,100-55,000	1.45
2-S2	U-W	27,100-69,000	1.47
3-S2	F-T	27,100-71,000	1.52
Group I[4]	U-W	25,100-57,000	1.31
Group II[4]	U-W	27,100-73,000	1.33

1 See Footnote 1, Table 7.

2 Broadest weight range reflected by any one of the three studies.

3 Weighted by diesel numbers as explained in Footnote 4, Table 4.

4 Represents the axle combinations listed in Footnote 1, Table 6.

studies. As a result, all three studies are represented with ratios for at least one of the five axle groups. The selected ratios range from 1.31 to 1.52, or a spread of 21 ratio points.

The composite ratio of 1.34 is a conservative compromise between the above ratios. Two of the above ratios are slightly below the composite ratio, and three of the others are considerably above the composite ratio. Yet, the conclusion remains to favor using the composite ratio in determining the tax rate differential between gasoline and diesel fuel used to propel cargo vehicles on the public roads of the state.

The above conclusion seems applicable to intercity and intracity buses which have respective ratios of 1.53 and 1.45. The analysis of the bus data appears in Table 22 of Appendix A. Generally speaking, buses of both types have higher fuel consumption differentials than do trucks of the same gross operating weight.

DIESEL TAX DIFFERENTIALS OF TEXAS CARGO VEHICLES

In this section, the present diesel tax differential, based on state law, is compared with the supported (equalized) diesel tax differential, based on fuel consumption studies. To make such a comparison, the present diesel engine tax must be estimated, making certain assumptions, and added to the present 1.50 cents per gallon diesel fuel tax differential. The sum of the two is called the present diesel tax differential.

As indicated earlier, present state laws require the collection of an 11 percent diesel engine "surcharge" applied to the Texas annual registration fee. By assuming certain registered gross weights, diesel fuel consumption rates, and annual miles of travel, the amount of this "surcharge" can be estimated in cents per gallon for various gross weights. Table 23 in Appendix A contains the basic calculations for making this estimate.

As stated above, the supported diesel tax differential is based on fuel consumption studies and is determined by using the composite gasoline to diesel fuel consumption ratio for a certain gross operating weight and the present gasoline tax. For example, the gasoline to diesel fuel consumption ratio for vehicles having a gross weight of 46,013 is 1.34, and the present gasoline tax is 5.00 cents per gallon. If the 1.34 fuel consumption ratio is multiplied by 5.00 cents per gallon, the supported diesel tax should be 6.70 cents per gallon. By deducting the 5.00 cents per gallon gasoline tax from this figure, the supported diesel tax differential is 1.70 cents per gallon compared to the present

differential of 1.80 cents per gallon (1.80 cents equals 1.50 cents plus .30 cents per gallon equivalent of diesel engine tax, assuming 75,000 miles of annual travel.)

Table 9 gives the present and supported diesel tax differentials for cargo vehicles traveling selected annual mileages at various gross operating weights and assumed registered gross weights. As presented above, the last column gives the supported diesel tax differential established for Texas cargo vehicles by correlating loadometer frequencies with the composite fuel consumption rates. In estimating the present diesel tax differential for each gross operating weight, the assumed registered gross weights were determined by a study of the 1967 registered gross weight frequencies.

It is obvious from Table 9 that for the lower gross weights, the present diesel tax differentials are much more than the supported diesel tax differentials. For the higher gross weights, the reverse is true, suggesting a higher diesel fuel tax rate of diesel engine "surcharge". Figure 1a gives a vivid picture of the relationship between the present and supported diesel tax differentials as the gross weight and miles of travel change. With the average Texas cargo diesel vehicle weighing 46,013 pounds and traveling 75,000 miles annually, the supported diesel tax differential is 1.70 cents per gallon or .10 cents per gallon under the present diesel tax differential. The above annual mileage compares favorably with the 77,400 average annual miles logged by cargo vehicles covered in the Line-Haul Trucking Cost Study.[4]

It should be pointed out that the present diesel tax differentials are somewhat overstated in Table 9 and Figure 1a. This overstatement arises from the fact that the average diesel vehicle travels at least 10,000 more annual miles than its gasoline counter-part. Since the

TABLE 9

Present and Supported Diesel Tax Differentials for Various Gross Operating Weights Assuming Certain Registered Gross Weights and Miles of Travel, Texas

Gross Operating Weight in Pounds	Assumed Registered Gross Weight in Pounds[1]	Diesel Tax Differential in Cents Per Gal. by Miles of Travel					
		50,000		75,000		100,000	
		Present[2]	Supported[3]	Present[2]	Supported[3]	Present[2]	Supported[3]
20,000	20,000	1.74	.85	1.66	.85	1.62	.85
30,000	27,000	1.82	1.25	1.71	1.25	1.66	1.25
40,000	39,000	1.97	1.55	1.81	1.55	1.73	1.55
50,000	39,000	1.93	1.85	1.79	1.85	1.72	1.85
60,000	39,000	1.91	2.05	1.77	2.05	1.70	2.05
70,000	39,000	1.88	2.25	1.76	2.25	1.69	2.25
46,013[4]	39,000	1.95	1.70	1.80	1.70	1.73	1.70

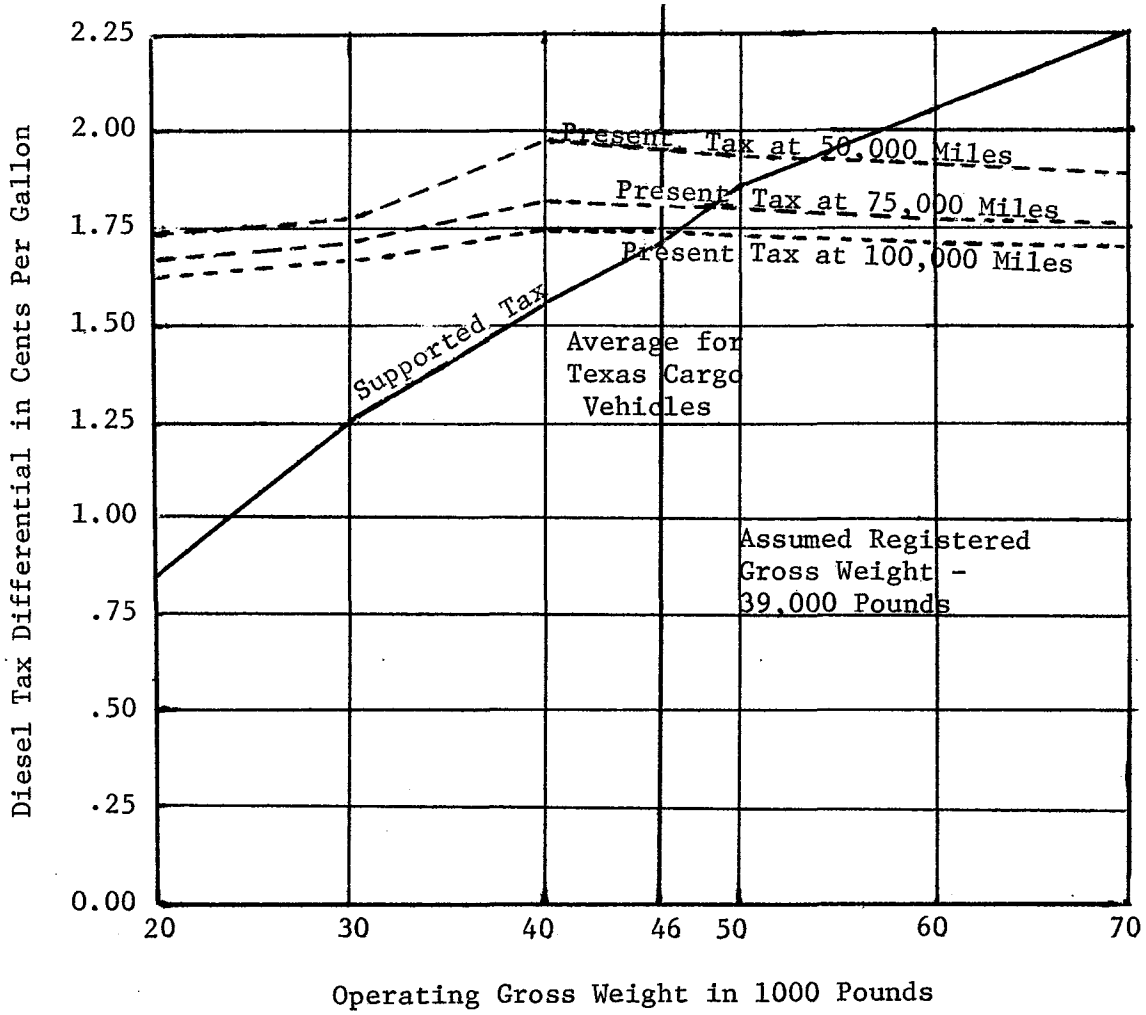
1 Based on a study of the registered gross weight frequencies. See Table 2.

2 Includes the actual 1.5 cents per gallon fuel tax differential and the 11 percent diesel engine tax differential in cents per gallon based on the assumed registered weight and miles of travel and using the composite curve diesel fuel consumption rates. See Table 23 in Appendix A.

3 The total diesel tax justified as indicated by the gasoline and diesel fuel consumption rates from the composite curves. See Table 34 in Appendix B.

4 The average weight of diesel vehicles in the 23,100 - 73,000 weight range. At this weight, the gasoline to diesel fuel consumption ratio is 1.34 which represents 91 percent of all diesels weighed.

FIGURE 1a.--Present and Supported Diesel Tax Differentials Reflecting Current Tax Rates by Gross Operating Weight and Miles of Travel, Texas.

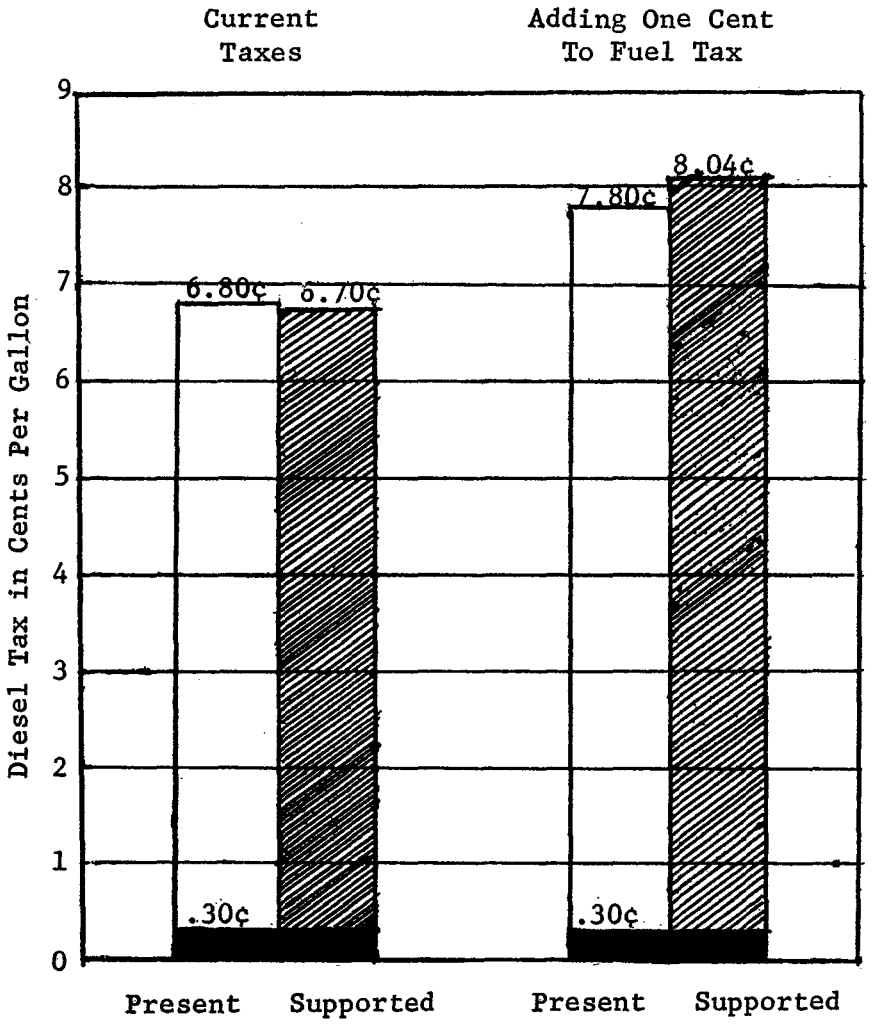


diesel "surcharge" becomes less sensitive for greater mileages, this tax would in effect be lower at the assumed mileages than previously calculated.

Figure 1b shows the present and supported diesel fuel tax reflecting current taxes and an increase in fuel taxes. The present diesel tax is 6.80 cents per gallon, obtained by adding the .30 cents per gallon diesel engine tax (based on a diesel vehicle registered at 39,000 pounds, traveling 75,000 miles, and using .188 gallons per mile) to be present diesel fuel tax of 6.50 cents per gallon. In contrast, the supported diesel tax for Texas cargo vehicles with a gross operating weight of 46,013 pounds is 6.70 cents per gallon, obtained by multiplying the 1.34 fuel consumption ratio by the current 5.00 cents per gallon gasoline tax. This supported tax of 6.70 cents per gallon could be divided into the current .30 cent per gallon diesel engine tax and a 6.40 cent per gallon diesel fuel tax. Yet, the fact is that the present diesel tax is .10 cents per gallon higher than the supported diesel tax.

If the current gasoline and diesel fuel taxes were increased by 1.00 cent per gallon, the present diesel tax would be increased to a total of 7.80 cents per gallon. On the other hand, the supported diesel tax would be 8.04 cents per gallon, a net increase of 1.34 cents per gallon. In other words, the spread between the present and supported diesel tax would change from a .10 cent per gallon over payment (apparent inequity) to a .24 cent per gallon under payment. Thus, if the gasoline tax is increased by 1.00 cent per gallon, the diesel fuel tax should be increased by 1.24 cents per gallon. Then, the present and supported diesel tax would be equated.

FIGURE 1b.--Present and Supported Diesel Tax Reflecting Current Tax Rates and an Increase in Fuel Taxes, Texas



Present Diesel Fuel Tax

Supported Diesel Fuel Tax
(At 46,013 Pounds Operating Weight)

Calculated 11 Percent Diesel Engine Tax
(At 39,000 Pounds Registered Weight and 75,000 Miles of Travel.)

The above analysis indicates that the present diesel tax differentials given a single fuel tax ratio are very insensitive to vehicle weight differences. Some sensitivity comes through the diesel engine "surcharge" but the amount of such a tax is a small percentage of the total diesel tax. The supported diesel tax differentials based on a series of fuel consumption differences are quite sensitive to vehicle weight differences and suggest that the taxing policies should be changed in some way to reflect the supported diesel tax differentials for the respective vehicle operating weights. Perhaps the diesel engine "surcharge" registration schedule should be changed to bring about the proper sensitivity in the present diesel tax differentials.

APPENDIX A

SUPPLEMENTAL TABLES

TABLE 10

Texas Cargo Vehicles Defined According to Axle Combination and Corresponding Code

Axle Combinations	Code for Axle Combination
Single Unit Trucks	
2-Axle, 4 Tires	2
2-Axle, 6 Tires	2
3-Axle	3
Combinations	
2-Axle Tractor, 1-Axle Semitrailer	2-S1
2-Axle Tractor, 2-Axle Semitrailer	2-S2
3-Axle Tractor, 1-Axle Semitrailer	3-S1
3-Axle Tractor, 2-Axle Semitrailer	3-S2
2-Axle Tractor, 3-Axle Semitrailer	2-S3
3-Axle Tractor, 3-Axle Semitrailer	3-S3
2-Axle Truck, 1-Axle Balance Trailer	2-1
2-Axle Truck, 2-Axle Full Trailer	2-2
2-Axle Truck, 3-Axle Full Trailer	2-3
3-Axle Truck, 2-Axle Full Trailer	3-2
3-Axle Truck, 3-Axle Full Trailer	3-3
3-Axle Truck, 1-Axle Balance Trailer	3-1
2-Axle Tractor, 1-Axle Semitrailer, 2-Axle Full Trailer	2-S1-2
3-Axle Tractor, 1-Axle Semitrailer, 2-Axle Full Trailer	3-S1-2

TABLE 11

Percentages of Trucks and Combinations Weighed and Registered in Texas and the United States for Respective Years

Vehicle Description	Percentage of Vehicles			
	Texas, 1967		United States 1957[1]	
	Weighed	Registered	Weighed	Registered
Single Unit Trucks				
2-Axle, 4-Tire	14.3	-	31.2	61.8
2-Axle, 6-Tire	18.4	-	27.8	28.6
3-Axle,	1.7	-	2.9	1.7
Total	34.4	95.2[2]	61.9	92.1
Tractor-Semitrailer Combinations				
3-Axle (2-S1)	6.4	-	9.9	2.1
4-Axle (2-S2)	12.3	-	19.3	2.3
5-Axle or more	43.4	-	4.7	.5
Total	62.1	4.6	33.9	4.9
Other Combinations[3]	3.5	.2	4.2	3.0
Total Percent	100.0	100.0	100.0	100.0

1 The year that a comprehensive study was made in 48 states and District of Columbia.

2 Includes light trailers pulled by passenger cars, truck-trailer combinations.

3 Includes all vehicles listed in Footnote 2 and also buses, except that Texas registration data show only buses.

Source: Texas data were furnished by the Texas Highway Department; United States data came from the "Third Progress Report of the Highway Cost Allocation Study," 86th Congress, 1st Session, House Document No. 91, March 1959.

TABLE 12

Percentage of Buses Registered in Texas and the United States for Selected Years

Type[1]	Percentage of Buses Registered	
	Texas, 1967	United States, 1957
City Buses (Transit)	55.69	75.12
Motor Buses (Intercity)	44.31	24.88
Total Percent	100.00	100.00

1 School buses and other nonrevenue buses are not included in the U. S. data.

Source: Texas data were furnished by the Texas Highway Department; United States data came from the "Third Progress Report of the Highway Cost Allocation Study," 86th Congress, 1st Session, House Document No. 91, March 1959.

TABLE 13

Number and Percent of Vehicles Counted and Weighed at 21 Loadometer Stations in Texas, by Vehicle Type[1]

Type of Vehicle	Number and Percent of Vehicles					
	Counted in 1966		Weighed in 1966		Weighed in 1967	
	Number	Percent	Number	Percent	Number	Percent
Commercial Buses	2,927	1.5	-	-	-	-
Single-Unit Trucks						
2-Axle, 4-Tire, Under One Ton	93,430	46.4	3,211	12.3	2,886	12.8
2-Axle, 4-Tire, One Ton and Over	3,660	1.8	400	1.5	335	1.5
2-Axle, 6-Tire	24,522	12.2	4,687	18.0	4,142	18.5
3-Axle	3,787	1.9	754	2.9	719	3.2
Subtotal	125,399	62.3	9,052	34.7	8,082	36.0
Truck-Tractor Semitrailers						
3-Axle	8,065	4.0	1,837	7.0	1,439	6.4
4-Axle	16,406	8.1	3,960	15.2	2,826	12.5
5-Axle or More	46,178	23.0	10,987	42.1	9,691	43.1
Subtotal	70,649	35.1	16,784	64.3	13,956	62.0
Semitrailer-Trailers						
4-Axle	-	-	-	-	-	-
5-Axle	431	.2	88	.3	126	.6
6-Axle or More	307	.1	87	.3	103	.4
Subtotal	738	.3	175	.6	229	1.0
Truck and Trailer						
3-Axle	459	.2	45	.2	100	.4
4-Axle	773	.4	25	.1	91	.4
5-Axle or More	414	.2	22	.1	38	.2
Subtotal	1,646	.8	92	.4	229	1.0
Totals	201,359	100.0	26,103	100.0	22,496	100.0

1 Includes butane vehicles.

TABLE 14

Frequency Distribution of All Texas Cargo Vehicles With More Than Four Tires and Weighing Over 10,000 Pounds Correlated With Composite Fuel Consumption Rates By Weight Class and Fuel Type[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.	
	Gasoline	Diesel	Gasoline	Diesel
10,100-11,000	347	14	.116	.112
11,100-13,000	344	32	.128	.120
13,100-15,000	585	43	.138	.126
15,100-17,000	503	56	.148	.132
17,100-19,000	636	57	.157	.137
19,100-21,000	599	153	.166	.142
21,100-23,000	509	325	.175	.147
23,100-25,000	385	638	.183	.152
25,100-27,000	317	733	.190	.156
27,100-29,000	216	735	.198	.160
29,100-31,000	191	570	.205	.164
31,100-33,000	152	410	.212	.168
33,100-35,000	158	328	.219	.171
35,100-37,000	145	286	.226	.175
37,100-39,000	133	259	.232	.178
39,100-41,000	108	253	.239	.182
41,100-43,000	87	246	.245	.185
43,100-45,000	96	227	.251	.188
45,100-47,000	104	264	.257	.191
47,100-49,000	105	287	.263	.194
49,100-51,000	99	290	.268	.196
51,100-53,000	78	310	.274	.199
53,100-55,000	84	355	.279	.202
55,100-57,000	68	365	.285	.204
57,100-59,000	56	484	.290	.207
59,100-61,000	57	494	.295	.209
61,100-63,000	54	570	.300	.212
63,100-65,000	41	572	.305	.214
65,100-67,000	39	456	.310	.216
67,100-69,000	28	358	.315	.219
69,100-71,000	21	218	.320	.221
71,100-73,000	10	146	.325	.223
73,100-75,000	4	70	.330	.225
75,100-77,000	5	56	.334	.227
77,100-79,000	4	30	.339	.229
79,100-80,000	1	16	.343	.231
Total Number of Vehicles[2]	6,369	10,706		
Average Vehicle Weight	26,452	44,813		
Average Fuel Consumption	.187	.186		

1 Composite fuel consumption rates based on several studies reported in Supplementary Report to Highway Cost Allocation Study (2).

2 This table represents 56.0 percent of all gasoline vehicles and 98.8 percent of all diesel vehicles weighed.

TABLE 15

Frequency Distribution of All Empty Texas Cargo Vehicles With More Than Four Tires and Weighing Over 10,000 Pounds Correlated With Composite Fuel Consumption Rates, By Weight Class and Fuel Type[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.	
	Gasoline	Diesel	Gasoline	Diesel
10,100-11,000	197	7	.116	.112
11,100-13,000	281	26	.128	.120
13,100-15,000	212	35	.138	.126
15,100-17,000	203	51	.148	.132
17,100-19,000	318	46	.157	.137
19,100-21,000	352	136	.166	.142
21,100-23,000	262	292	.175	.147
23,100-25,000	187	574	.183	.152
25,100-27,000	120	728	.190	.156
27,100-29,000	64	644	.198	.160
29,100-31,000	32	435	.205	.164
31,100-33,000	27	247	.212	.168
33,100-35,000	14	135	.219	.171
35,100-37,000	10	70	.226	.175
37,100-39,000	3	33	.232	.178
39,100-41,000	2	27	.239	.182
41,100-43,000	0	7	.245	.185
43,100-45,000	4	4	.251	.188
45,100-47,000	2	4	.257	.191
47,100-49,000	1	4	.263	.194
49,100-51,000	0	4	.268	.196
51,100-53,000	0	1	.274	.199
53,100-55,000	0	2	.279	.202
55,100-57,000	0	5	.285	.204
57,100-59,000	0	3	.290	.207
59,100-61,000	0	2	.295	.209
61,000-63,000	1	0	.300	.212
63,100-65,000	0	1	.305	.214
65,100-67,000	0	1	.310	.216
67,100-69,000	0	2	.315	.219
69,100-71,000	0	0	.320	.221
71,100-73,000	0	1	.325	.223
Total Number of Vehicles	2,292	3,527		
Average Vehicle Weight	18,731	26,961		
Average Fuel Consumption	.158	.157		
		Range of 10,100-80,000 lbs.		Range of 23,100-73,000 lbs.
Fuel Consumption Ratio For:				
Weighted by Gasoline Numbers[2]		1.15		1.23
Weighted by Diesel Numbers[2]		1.23		1.24

1 See Footnote 1, Table 14. This table represents 20.2 percent of all gasoline vehicles and 32.6 percent of all diesel vehicles weighed.

2 See Footnotes 3 and 4, Table 4.

TABLE 16

Frequency Distribution of Texas Cargo Vehicles of all Axle Groups with More than Four Tires Correlated with Fuel Consumption Rates of Urban Travel as Reported by the Fuel and Time Consumption Study[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.	
	Gasoline	Diesel	Gasoline	Diesel
23,100-25,000	385	638	.222	.116
25,100-27,000	317	733	.230	.121
27,100-29,000	216	735	.238	.128
29,100-31,000	191	570	.246	.134
31,100-33,000	152	410	.254	.140
33,100-35,000	158	328	.262	.146
35,100-37,000	145	286	.271	.152
37,100-39,000	133	259	.279	.158
39,100-41,000	108	253	.287	.165
41,100-43,000	87	246	.295	.171
43,100-45,000	96	227	.303	.177
45,100-47,000	104	264	.312	.183
47,100-49,000	105	287	.320	.189
49,100-51,000	99	290	.328	.195
51,100-53,000	78	310	.336	.201
53,100-55,000	84	355	.344	.207
55,100-57,000	68	365	.352	.213
57,100-59,000	56	484	.361	.220
59,100-61,000	57	494	.369	.226
61,100-63,000	54	570	.377	.232
63,100-65,000	41	572	.385	.238
65,100-67,000	39	456	.393	.244
67,100-69,000	28	358	.402	.250
69,100-71,000	21	218	.410	.256
71,100-73,000	10	146	.418	.262
Total Number of Vehicles	2,832	9,854		
Average Vehicle Weight	38,344	46,013		
Average Fuel Consumption	.280	.183		
Fuel Consumption Ratio[2]				
Weighted by Gasoline Numbers	1.76			
Weighted by Diesel Numbers		1.70		

1 This table represents 24.9 percent of all gasoline vehicles and 90.8 percent of all diesel vehicles weighed in 1967. Only five percent of all vehicles weighed were at urban loadometer stations.

2 See Footnotes 3 and 4, Table 4.

TABLE 17

Frequency Distribution of Texas Cargo Vehicles of the 2-S1 Axle Group Correlated with the Fuel Consumption Rates of the Same Axle Group as Reported by the Line-Haul Trucking Cost Study

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.	
	Gasoline	Diesel	Gasoline	Diesel
37,100-39,000	46	30	.243	.170
39,100-41,000	42	14	.249	.170
41,100-43,000	19	5	.252	.171
43,100-45,000	18	1	.258	.172
45,100-47,000	3	1	.261	.172
47,100-49,000	1	1	.266	.173
49,100-51,000		1	.270	.173
51,100-53,000			.272	.174
53,100-55,000		1	.276	.175
Total Number of Vehicles[1]	129	54		
Average Vehicle Weight	40,391	39,902		
Average Fuel Consumption	.249	.170		
Fuel Consumption Ratio Weighted by Gasoline Numbers[2]	1.42	-		
Fuel Consumption Ratio Weighted by Diesel Numbers[2]	-	1.45		

1 This table represents 12.5 percent of the gasoline vehicles and 13.9 percent of the diesel vehicles weighed of the 2-S1 axle group.

2 See Footnotes 3 and 4, Table 4.

TABLE 18

Frequency Distribution of Texas Cargo Vehicles of the 2-S2 Axle Group Correlated with the Fuel Consumption Rates of the Same Axle Group as Reported by the Following Studies[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per. Mi.			
			U-W		L-H	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
23,100-25,000	86	95	.135	.104		
25,100-27,000	63	91	.138	.106		
27,100-29,000	51	67	.141	.108		
29,100-31,000	62	54	.145	.110		
31,100-33,000	38	51	.148	.112		
33,100-35,000	45	57	.152	.114		
35,100-37,000	48	51	.155	.116		
37,100-39,000	49	59	.159	.119		
39,100-41,000	40	50	.162	.122	.234	.166
41,100-43,000	44	55	.166	.124	.238	.168
43,100-45,000	55	55	.169	.127	.247	.170
45,100-47,000	75	61	.173	.129	.252	.172
47,100-49,000	85	58	.176	.132	.258	.174
49,100-51,000	75	54	.180	.134	.263	.176
51,100-53,000	62	39	.183	.137	.268	.178
53,100-55,000	50	33	.187	.139	.273	.180
55,100-57,000	24	19	.190	.142	.279	.182
57,100-59,000	18	15	.194	.145	.285	.184
Total Number Vehicles[2]	970	964	970	964	528	439
Average Vehicle Weight	40,036	37,969	40,036	37,969	48,876	47,348
Average Fuel Consumption	-	-	.162	.119	.258	.173
Fuel Consumption Ratio						
Weighted by Gasoline Numbers[3]	-	-	1.33	-	1.48	-
Weighted by Diesel Numbers[3]	-	-	-	1.32	-	1.47

1 U-W represents the University of Washington Study, and L-H represents the Line-Haul Trucking Cost Study. The U-W data are based on 40 mile per hour constant speed.

2 This table represents 61.4 percent of the gasoline vehicles and 84.6 percent of the diesel vehicles weighed of the 2-S2 axle group. The L-H Study represents 33.4 percent gasoline and 38.5 percent diesel of this axle group.

3 See Footnotes 3 and 4, Table 4.

Frequency Distribution of Texas Cargo Vehicles of the 3-S2 Axle Group Correlated with the Fuel Consumption Rates of the Same Axle Group as Reported by the Following Studies[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gallons Per Mile					
			L-H		F-T		U-W	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
27,100-29,000	43	626	-	-	.240	.154	.174	.086
29,100-31,000	28	466	-	-	.243	.156	.176	.087
31,100-33,000	20	312	-	-	.246	.159	.178	.089
33,100-35,000	7	225	-	-	.250	.162	.180	.090
35,100-37,000	13	181	-	-	.253	.164	.182	.092
37,100-39,000	15	155	-	-	.256	.166	.184	.093
39,100-41,000	8	174	-	-	.260	.169	.186	.095
41,100-43,000	9	174	-	-	.263	.172	.188	.096
43,100-45,000	14	161	-	-	.266	.174	.190	.097
45,100-47,000	18	190	.245	.200	.270	.176	.192	.099
47,100-49,000	14	215	.253	.208	.273	.179	.194	.100
49,100-51,000	20	218	.256	.212	.276	.182	.196	.102
51,100-53,000	13	261	.260	.215	.280	.184	.198	.103
53,100-55,000	31	307	.268	.219	.283	.186	.200	.104
55,100-57,000	43	333	.271	.222	.286	.189	.202	.106
57,100-59,000	37	453	.276	.227	.290	.192	.204	.108
59,100-61,000	47	472	.280	.229	.293	.195	.206	.110
61,100-63,000	44	541	.282	.230	.296	.197	.208	.112
63,100-65,000	37	551	.285	.233	.300	.200	.210	.114
65,100-67,000	34	440	.288	.235	.304	.202	.212	.115
67,100-69,000	25	337	.292	.237	.308	.204	.214	.117
69,100-71,000	21	205	.294	.238	.312	.206	-	-
71,100-73,000	9	136	.295	.239	-	-	-	-
Total Number of Vehicles[2]	550	7,133	393	4,659	541	6,997	520	6,792
Average Vehicle Weight	52,152	50,682	58,527	59,779	51,621	50,266	50,606	49,669
Average Fuel Consumption	-	-	.277	.226	.280	.181	.197	.102
Fuel Consumption Ratio								
Weighted by Gasoline Numbers[3]			1.22	-	1.52	-	1.91	-
Weighted by Diesel Numbers[3]			-	1.22	-	1.52	-	1.92

1 See Footnote 1, Table 18, except F-T stands for Fuel and Time Consumption Study.

2 This represents 62.4 percent of gasoline vehicles and 81.9 percent of diesel vehicles weighed of the 3-S2 axle group. For percentages for each study, see Table 7.

3 See Footnotes 3 and 4, Table 4.

TABLE 20

Frequency Distribution of Texas Cargo Vehicles of the Combined Axle Group I Correlated with the Fuel Consumption Rates of the Same Axle Groups as Reported by the Following Studies[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.			
			L-H		U-W	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
25,100-27,000	111	20			.146	.124
27,100-29,000	62	11			.150	.125
29,100-31,000	46	10			.154	.126
31,100-33,000	44	2			.158	.127
33,100-35,000	42	5			.162	.128
35,100-37,000	23	9			.167	.129
37,100-39,000	22	7	.210	.173	.171	.130
39,100-41,000	17	6	.217	.179	.175	.131
41,100-43,000	14	4	.223	.186	.179	.132
43,100-45,000	8	6	.228	.194	.184	.133
45,100-47,000	7	6	.233	.199	.188	.135
47,100-49,000	4	6	.243	.206	.192	.136
49,100-51,000	4	8	.248	.210	.196	.137
51,100-53,000	2	2	.252	.214	.200	.138
53,100-55,000	2	4	.257	.219	.205	.139
55,100-57,000	2	2	.261	.223	.209	.140
57,100-59,000		3			.214	.141
59,100-61,000	1				.218	.142
Total Number of Vehicles[2]	411	111	82	52	411	111
Average Vehicle Weight	32,162	37,834	42,660	46,012	32,162	37,834
Average Fuel Consumption			.223	.198	.158	.130
Fuel Consumption Ratio						
Weighted by Gasoline Numbers[3]			1.17		1.25	
Weighted by Diesel Numbers[3]				1.19		1.31

1 U-W represents the University of Washington Study, and the data are based on 40 miles per hour constant speed. L-H represents the Line-Haul Trucking Cost Study. For combined axle group content see Footnote 1, Tables 5 and 6.

2 This table represents 8.8 percent of the gasoline vehicles and 33.5 percent of the diesel vehicles weighed of this combined axle group. The Line-Haul Study represents 1.7 percent gasoline and 15.7 percent diesel of this axle group.

3 See Footnotes 3 and 4, Table 4.

TABLE 21

Frequency Distribution of Texas Cargo Vehicles of the Combined Axle Group II Correlated With the Fuel Consumption Rates of the Same Axle Group as Reported by the Following Studies[1]

Gross Operating Weight in Pounds	Number of Vehicles by Fuel Type		Fuel Consmp. in Gal. Per Mi. L-H		Fuel Consmp. in Gal. Per Mi. U-W	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
27,100-29,000		7			.146	.110
29,100-31,000	1	4			.148	.112
31,100-33,000	2	8			.150	.114
33,100-35,000	1	9			.153	.115
35,100-37,000	4	12			.155	.117
37,100-39,000		7			.157	.119
39,100-41,000	1	9			.160	.120
41,100-43,000		8			.162	.122
43,100-45,000	1	4			.164	.124
45,100-47,000	1	6			.167	.125
47,100-49,000		7			.170	.127
49,100-51,000		9			.172	.129
51,100-53,000		7			.175	.130
53,100-55,000		10			.177	.132
55,100-57,000		11			.180	.134
57,100-59,000		13			.182	.136
59,100-61,000	1	11			.185	.138
61,100-63,000	2	18			.187	.140
63,100-65,000		17			.190	.142
65,100-67,000	2	14	.281	.191	.192	.144
67,100-69,000	1	21	.286	.195	.195	.146
69,100-71,000		12	.289	.198	.197	.148
71,100-73,000		8	.291	.201	.200	.150
73,100-75,000		7	.293	.203		
75,100-77,000		7	.295	.205		
77,100-79,000		5	.296	.207		
79,100-81,000		2	.298	.208		
Total Number of Vehicles[2]	17	253	3	76	17	232
Average Vehicle Weight	50,047	55,449	66,717	70,682	50,047	53,132
Average Fuel Consumption			.283	.198	.168	.132
Fuel Consumption Ratio Weighted by Gasoline Numbers[3]			1.47		1.33	
Weighted by Diesel Numbers[3]				1.46		1.33

1 See Footnote 1, Table 18

2 This table represents 60.7 percent of gasoline vehicles and 96.2 percent of diesel vehicles weighed of this combined axle group. For percentages by study see Tables 5 and 6.

3 See Footnotes 3 and 4, Table 4.

TABLE 22

Frequency Distribution of Texas Intercity and Intracity Bus Registrations Correlated with the Fuel Consumption Rates of the Same Bus Type as Reported in Research Studies[1]

Registered Gross Weight in Pounds	Intercity Buses				Intracity Buses			
	Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.		Number of Vehicles by Fuel Type		Fuel Consumption in Gal. Per Mi.	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
10,001-12,000	1		.131	.087	133	28	.142	.146
12,001-14,000	3		.147	.098	60	23	.178	.158
14,001-16,000	10		.164	.108	24	65	.214	.170
16,001-18,000	4	7	.180	.118	24	134	.250	.182
18,001-20,000	16	14	.196	.129	2	176	.286	.194
20,001-22,000	19	9	.212	.139	1	248	.322	.206
22,001-24,000	29	12	.228	.159				
24,001-26,000	6	33	.245	.160				
26,001-28,000	7	264	.261	.170				
28,001-30,000		27	.285	.181				
Total Number of Vehicles[2]	95	366			244	674		
Average Vehicle Weight	20,810	26,191			12,582	18,415		
Average Fuel Consumption			.255	.166			.275	.190
Fuel Consumption Ratio[3]								
Weighted by Gasoline Numbers			1.49				1.10	
Weighted by Diesel Numbers				1.53				1.45

1 Based on the Washington State Study and Motor Vehicle Classification Study results combined. School buses are excluded from the fuel consumption data and the registration frequencies.

2 This table represents 54.6 percent of gasoline buses and 58.4 percent of diesel buses registered of the Intercity type. This table represents 58.0 percent of gasoline buses and 99.1 percent of diesel buses registered of the Intracity type.

3 See Footnotes 3 and 4, Table 4.

TABLE 23

Estimated 11 Percent Diesel Engine Registration Tax for Specific Miles of Travel and Operating Gross Weights, Texas

Operating Gross Weight (Pounds)	Indicated Fuel Consumption of Diesel Vehicles[1] (Gal. Per Mi.)	Diesel Fuel Consumed For Specific Miles of Travel 50,000 (Gallons)	75,000 (Gallons)	100,000 (Gallons)	Assumed Registered Gross Weight of Diesel Vehicle[2] (Pounds)	11 Percent Diesel Engine Tax at Registered Weight[3] (Dollars)	Proration of Diesel Engine Tax Over Specific Miles of Travel 50,000 (Cts. Per Gal.)	75,000 (Cts. Per Gal.)	100,000 (Cts. Per Gal.)
20,000	.142	7,100	10,630	14,200	20,000	16.94	.238	.159	.119
30,000	.164	8,200	12,300	16,400	27,000	26.14	.319	.212	.159
40,000	.182	9,100	13,650	18,200	39,000	42.47	.467	.311	.233
50,000	.196	9,800	14,700	19,600	39,000	42.47	.433	.289	.217
60,000	.209	10,450	15,675	20,900	39,000	42.47	.406	.271	.203
70,000	.221	11,050	16,575	22,100	39,000	42.47	.384	.256	.192
46,013[4]	.188	9,400	14,100	18,800	39,000	42.47	.452	.301	.226

1 Based on the composite diesel fuel consumption curve found in Figure 11 of Appendix B.

2 As indicated by the diesel vehicle registration frequencies of Table 2.

3 See schedule of commercial truck registration fees by registered gross weight in Appendix C.

4 The average weight of diesel vehicles in the 23,100-73,000 weight range. At this weight, the gasoline to diesel fuel consumption ratio is 1.34 which represents 91 percent of all diesels weighed.

APPENDIX B

A REVIEW OF FUEL CONSUMPTION STUDIES

INTERCITY TRUCK STUDIES

North Dakota Study

In 1951, the North Dakota Legislative Research Committee employed James C. Nelson, Economic Consultant and Professor of Economics, Washington State University, to study the problem of financing North Dakota's highways, roads and streets.[1] The fuel consumption data used in the study are based on a 1951 North Dakota Road Use Survey where a sample of principally for-hire truck owners were interviewed.

The above findings indicated that diesel powered trucks experienced considerably lower gallons per mile as compared to gasoline powered trucks of the same gross weights. Although the survey reported gasoline fuel consumption data on trucks weighing from 4,000 to 60,000 pounds, only limited diesel fuel consumption data span this weight range. However, fairly reliable diesel fuel consumption rates were reported for the licensed gross weights between 24,000 to 60,000 pounds. In particular, six companies operating both gasoline and diesel trucks of similar licensed gross weights and performing substantially the same services reported gallons per mile averages for diesel powered trucks which ranged from up to 50 percent lower than that of gasoline powered trucks.

Only specific data points for the six companies described above are shown in Figure 2. The gasoline fuel consumption curve is a reflection of data from all firms reporting on the survey. This curve was taken from a supplementary report to the Highway Cost Allocation Study.[2]

FIGURE 2.--Fuel Consumption Rates by Registered Gross Weight, North Dakota Study

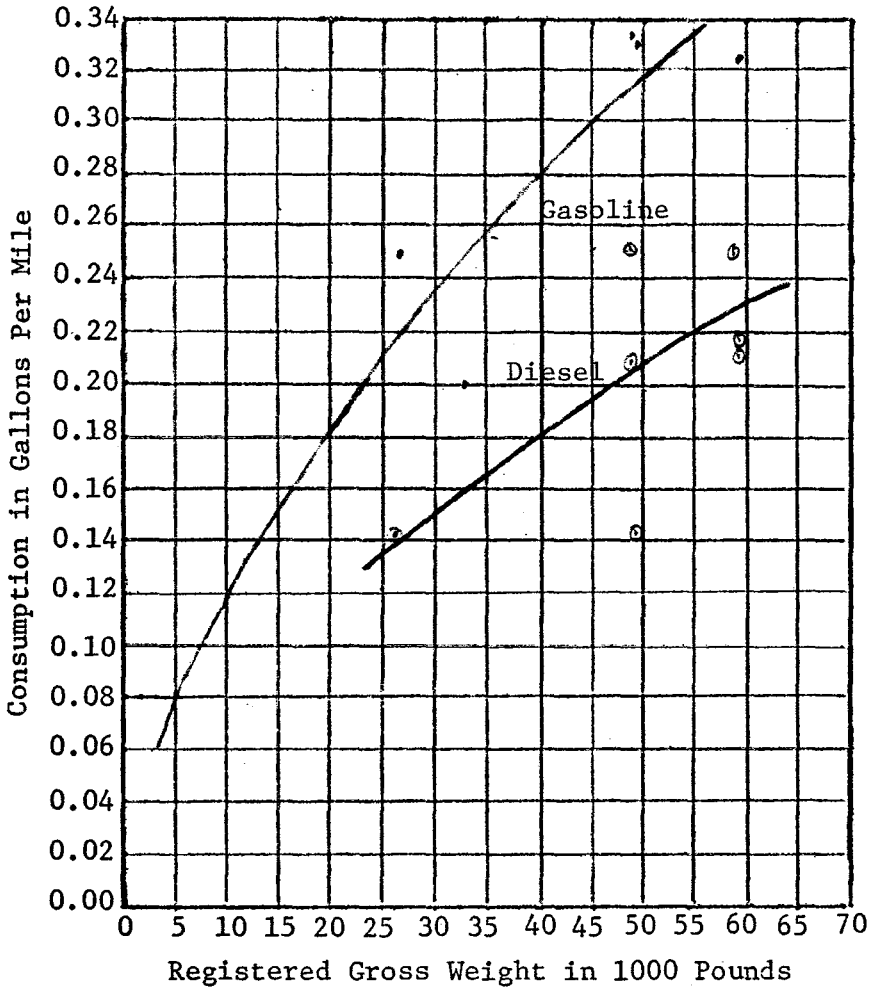


TABLE 24.--Fuel Consumption Rates by Registered Gross Weight, North Dakota Study

Registered Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
25,000	.212	.136	1.56
30,000	.237	.151	1.57
35,000	.258	.167	1.54
40,000	.280	.182	1.54
45,000	.300	.196	1.53
50,000	.319	.210	1.52
55,000	.339	.220	1.54
60,000	.354	.230	1.54

1 These rates were derived from the curves in Figure 2.

The diesel fuel consumption curve is freehanded and is based only on the data points reported by the six companies.

Table 24 shows the derived values from the two fuel consumption curves and corresponding gasoline to diesel ratios for various licensed gross weights. The actual data were not used because, in some cases, these were grouped in a manner such that more than one data point was given for the same weight group.

Based on the data from the six companies, the diesel vehicles averaged 66,583 miles driven compared to 55,093 miles for the gasoline vehicles. This is a difference of 11,490 miles. Actually, the difference was greater for trucks of higher gross weights than for those of lower gross weights. It should be emphasized that the fuel consumption data collected in the above study were not the results of a controlled experiment. However, they do not differ widely from the results of another study which was a controlled experiment.[3]

Line-Haul Trucking Cost Study

In the late 1950's the U. S. Bureau of Public Roads conducted a Line-Haul Trucking Cost Study[4] which delved into fuel costs, gasoline versus diesel, and related them to vehicle gross weights. This study was under the direction of Mr. Hoy Stevens. Data were obtained from the 1955-56 records of 611 motor carriers, which included common carriers, contract carriers, exempt-for-hire carriers and private carriers. The cost data cover only the line-haul operation of trailer combinations and do not cover such items as terminal costs and city pickup or delivery

costs. Those who conducted the study believe that the results are reasonably representative of trailer combinations used in line-haul service with trip lengths of at least 150 miles.

The study covered fuel consumption and fuel costs for vehicles using public and private roads, most of which were hard surfaced. The private roads were surfaced with gravel or rock but were not necessarily the all-weather type. Vehicles using the private roads were those of the extremely heavy axle and gross weight type, operated principally in the western states hauling logs to lumber mills. For all practical purposes, the extreme weights found on private gravel roads are not applicable to this present study.

Power plants using gasoline or liquefied petroleum were considered together for comparison with the diesel power plants. The study covered 14 different truck or truck-tractor semitrailer and trailer combinations. Also, there were 10 body types considered with the different vehicle types. However, due to the smallness of the sample in several body types, separate cost data were not developed.

The Line-Haul Study reports two separate sets of data which can be used to indicate the extent of a fuel consumption differential between diesel and gasoline powered vehicles. The two sets of data resulted from the fact that 40 percent of the line-haul respondents kept separate fuel consumption records by individual or by groups of similar power units, which could be related to trailer combinations and their respective loaded gross weights. All other respondents in the study kept only fuel cost records.

Figure 3 shows the gasoline and diesel fuel consumption curves derived from the basic reports of the Line-Haul Study, as reported in the 1965 supplementary report of the Highway Cost Allocation Study.[2] Table 25 shows the derived fuel consumption rates and ratios, based on the curves of Figure 3, at various gross weights.

As in the North Dakota Study, this study shows a significant and almost constant differential between diesel and gasoline fuel consumption throughout the 25,000 - 65,000 pound weight range. However, the differential or ratio is not as large as in the former study which showed higher fuel consumption rates for all gross weights for both types of fuel as compared to the Line-Haul Study. Perhaps one reason for this difference between the two studies is that the Line-Haul Study was more broadly based, geographically, than the other study.

Montana Study

In 1956, W. L. Hall, a Transportation Economist, conducted a study of problems concerned with financing modern highways in Montana for a Fact Finding Committee on Highways which was established by the 1955 Legislative Assembly.[5] The data for the study were gathered through the aid of several public and private organizations. The fuel consumption data were obtained from a study of commercial truck operations conducted and financed by the Montana Motor Transport Association at the request of the Fact Finding Committee.

A sample of about 1,500 trucks was obtained from member and non-member firms cooperating with the Association on this study. This sample included trucks owned by large and small firms. The reports

FIGURE 3.--Fuel Consumption Rates by Operating Gross Weight, Line-Haul Trucking Cost Study

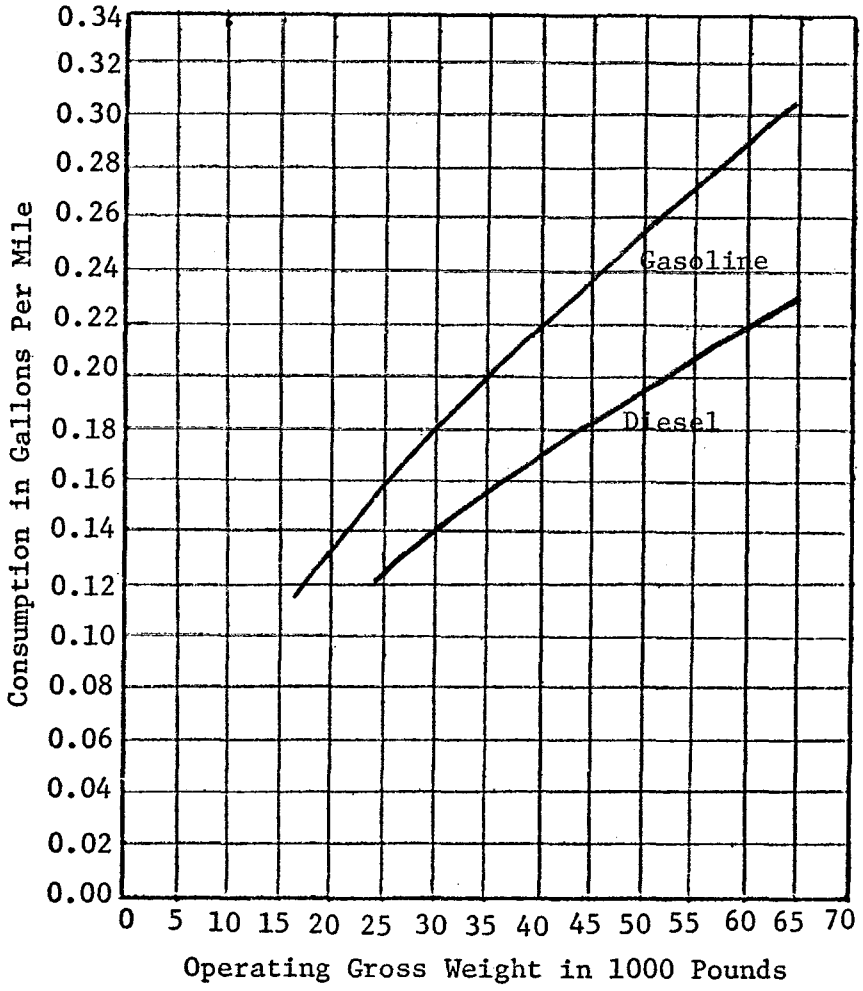


TABLE 25.--Fuel Consumption Rates by Operating Gross Weight, Line-Haul Trucking Cost Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
25,000	.160	.127	1.26
30,000	.180	.141	1.28
35,000	.201	.153	1.31
40,000	.220	.170	1.29
45,000	.239	.182	1.31
50,000	.255	.195	1.31
55,000	.272	.208	1.31
60,000	.290	.211	1.37
65,000	.306	.230	1.33

1 Derived from the curves in Figure 3.

from these respondents were designed to obtain average annual characteristics of each firm's operation, such as the registered gross weight and corresponding average operating weights, annual mileage, type and amount of fuel consumed annually. Another part of this study was a controlled investigation of the operating characteristics of a selected range of vehicles to obtain the amount of weight transported on selected trips, the type of vehicle and registered gross vehicle weight, the length of trip, the amount and type of fuel consumed. Mr. Hall stated that the findings of this commercial truck study qualify for broad application in that they can be applied to trucks not operated commercially.

Figure 4 represents the findings of the commercial truck study and shows a considerable differential between the fuel consumption of gasoline powered vehicles and that of diesel powered vehicles. Table 26 gives derived fuel consumption rates and ratios for various gross weights as represented by the curves in Figure 4. They are not observed values.

Compared to the other two studies already covered, the differentials or ratios of the Montana Study compare quite closely with those of the Line-Haul Study. Both of these studies generally show a smaller differential between gasoline and diesel consumption than does the North Dakota Study.

Motor Vehicle Classification Study

In 1956, the Bureau of Public Roads cooperated with State Highway Departments to draw a sample of the 1956 and 1957 truck registrants over the country in conducting a Motor Vehicle Classification Study

FIGURE 4.--Fuel Consumption Rates by Operating Gross Weight, Montana Study

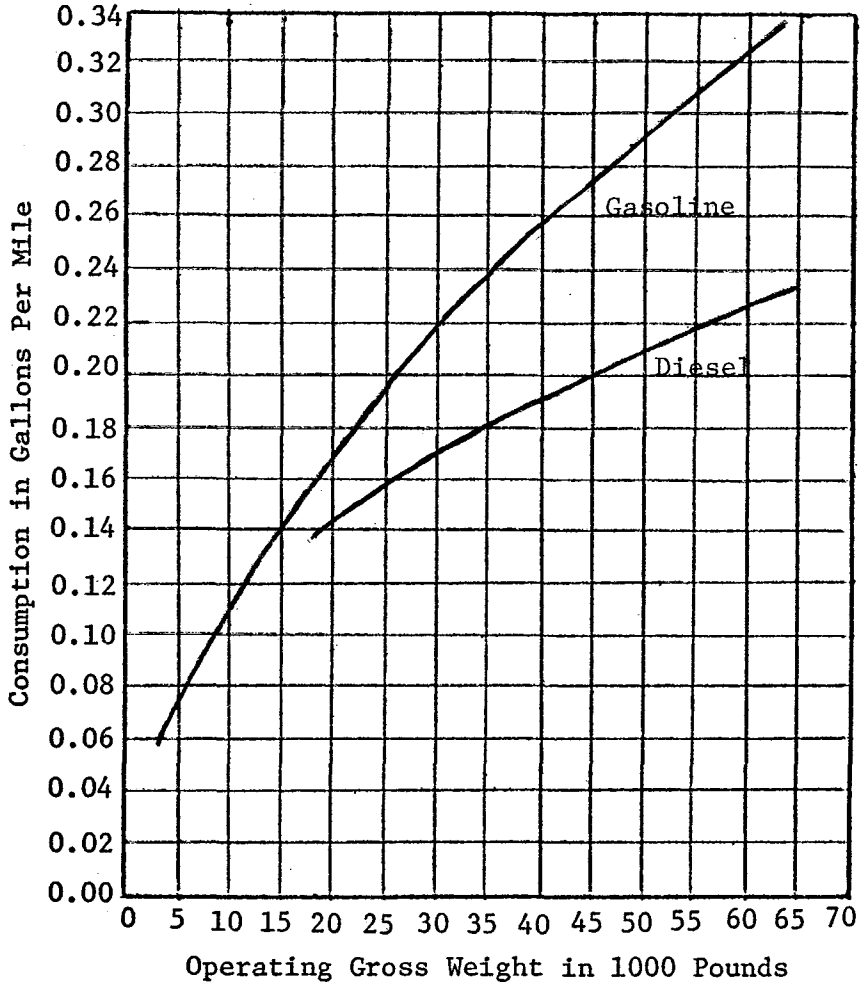


TABLE 26.--Fuel Consumption Rates by Operating Gross Weight, Montana Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
30,000	.216	.169	1.28
40,000	.253	.190	1.33
50,000	.284	.209	1.36
60,000	.313	.225	1.39
70,000	.340	.240	1.42
80,000	.366	.254	1.44

1 These data are derived from the following formulas: Gasoline, MPG = $32.9\ (GVW \times 10^{-3})^{-.577}$, in a sample of 38 and having a Standard Error of Estimate of .9470 MPG; Diesel, MPG = $9.31\ (GVW \times 10^{-4})^{-.413}$, in a sample of 136 and having a Standard Error of Estimate of .8432 MPG. The corresponding curves are shown in Figure 4.

that was published in 1959.[6] In this study, a census of single unit trucks, truck-tractor semitrailers and truck-trailer combinations and buses, according to visual types, registered gross weight groups, and type of operation was made. Also, since the registration records did not provide information regarding travel or fuel consumption a supplemental study (first reported in the Third Annual Progress Report of the Highway Cost Allocation Study[6]) was made of a sample of motor vehicle registrants in 37 states. Questionnaires were mailed to many of the 1957 registrants, but later the sample was expanded to the 1956 calendar year registrations. Then the 1956 information was used to obtain the desired classification of 1957 registrations by vehicle type and weight.

Estimated annual rates of fuel consumption (obtained from the sample of truck registrants) in gallons per mile by registered gross weight groups are reported in Table 27. This table also contains data on buses which will be discussed in a later section of this report. Since the fuel consumption rate depends on the actual weight at which a vehicle is operated and not on the maximum weight for which it was registered, the data in the table are not a completely true reflection of the former situation. Such may account for some of the irregularities in the progression of gallons per mile with vehicle weight that show up in the table. These data show that diesel powered vehicles have a rather marked advantage over gasoline powered vehicles as far as fuel consumption is concerned for comparable registered gross weights above 40,000 pounds. This study found that 82 percent of the diesel powered trucks and combinations were registered at 50,000 pounds of gross weight or more.

TABLE 27

Estimated Average Rates of Motor-Fuel Consumption of Trucks and Buses by Registered Gross Weight Group
(In Gallons Per Mile)

Vehicle Type	Registered Gross Weights in Pounds											
	Up to 3,999	4,000 to 7,999	8,000 to 11,999	12,000 to 15,999	16,000 to 19,999	20,000 to 25,999	26,000 to 31,999	32,000 to 39,999	40,000 to 49,999	50,000 to 59,999	60,000 and Over	All Vehicles
Trucks and Combinations												
Single-Unit Trucks												
Gasoline[1]	.079	.085	.103	.122	.128	.139	.167	.192	.213	.227	.244	.102
Diesel	.076	.093	.119	.149	.139	.161	.179	.204	.204	.192	.217	.185
Combinations												
Gasoline[1]	.137	.086	.101	.143	.156	.164	.175	.182	.192	.213	.244	.204
Diesel	-	-	.149	.182	.137	.172	.179	.200	.189	.175	.217	.196
Total Trucks and Combinations												
Gasoline[1]	.079	.085	.103	.122	.128	.139	.169	.185	.196	.213	.244	.119
Diesel	.076	.093	.119	.154	.139	.164	.179	.204	.192	.175	.217	.196
Buses												
Intercity												
Gasoline[1]	.172	.093	.122	.152	.182	.217	.250	-	-	-	-	.192
Diesel	-	-	-	-	.135	.159	.164	.204	-	-	-	.169
Transit												
Gasoline[1]	-	.094	.128	.182	.250	.333	.417	-	-	-	-	.270
Diesel	-	-	-	.164	.182	.213	.233	-	-	-	-	.217
School, Other Nonrevenue, Etc.												
Gasoline[1]	.086	.112	.132	.141	.152	.172	.204	-	-	-	-	.137
Diesel	-	-	.100	-	.200	-	-	-	-	-	-	.185

1 Includes liquefied petroleum gas.

Source: "Third Progress Report of the Highway Cost Allocation Study," 86th Congress, 1st Session, House Document 91, Washington, D. C., 1959.[6]

Figure 5 presents the fuel consumption curves for gasoline and diesel powered vehicles as related to average operating gross weights of vehicles reported by the truck registrants. These curves were reproduced from the before mentioned supplementary report to the Highway Cost Allocation Study of 1956. Unlike the registered gross weight group presentation in Table 27, these curves show that diesel powered vehicles possess a fuel consumption advantage over gasoline powered vehicles at average gross weights as low as 13 or 14 thousand pounds. The fuel consumption differentials or ratios presented in Table 28 are derived from curves in Figure 5. These are the most modest ratios presented thus far.

Fuel and Time Consumption Study

In 1957, the Bureau of Public Roads cooperated with the Universities of Ohio State, Michigan, and Washington, and a Transportation Consultant from the University of Maryland to conduct a study to measure the fuel consumption and overall travel time of selected trucks in rural and urban line-haul service and city pickup and delivery service under traffic conditions ranging from restricted to free flowing.[3] The study group, under direction of Malcolm F. Kent, obtained the cooperation of private, government-owned, and for-hire highway freight carriers. However, the only axle group tested among diesel powered vehicles was the 3-S2, whereas, the gasoline powered vehicles tested were 3-2's, 2-S1's, 3-S1's, 2-S2's, 3-S2's, and 3-S2-2's. A total of five diesel powered and 40 gasoline powered vehicles was used in the test.

FIGURE 5.--Fuel Consumption Rates by Operating Gross Weight, Motor Vehicle Classification Study

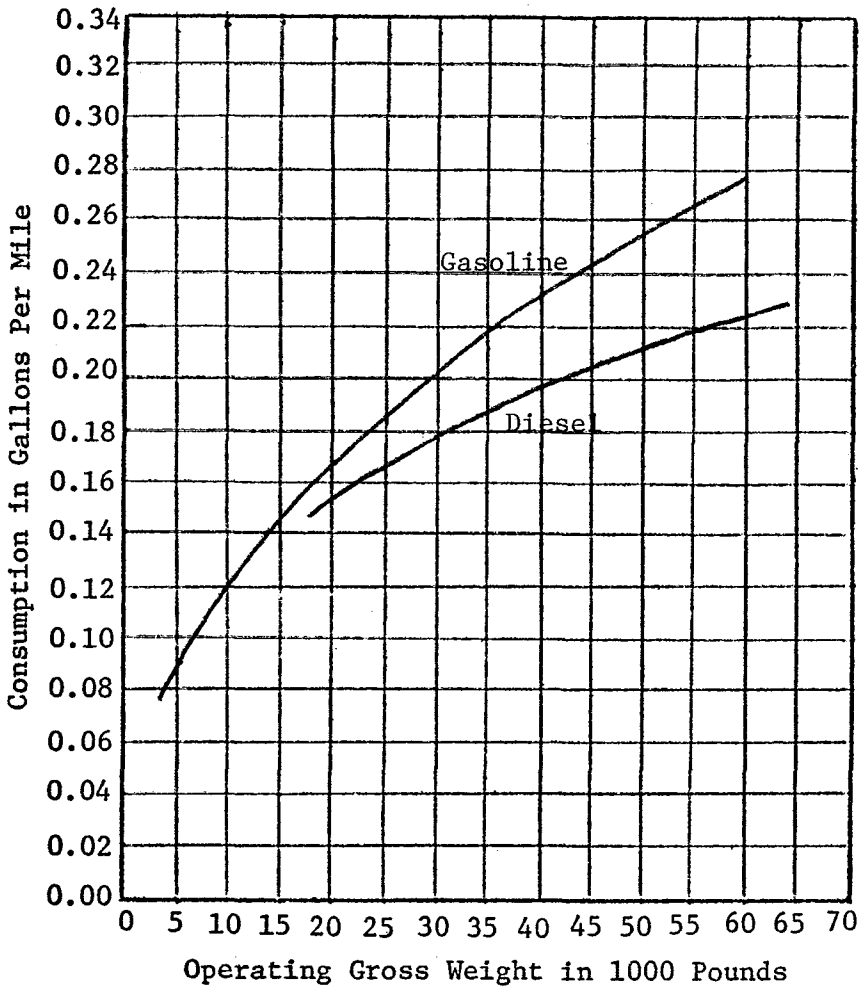


TABLE 28.--Fuel Consumption Rates by Operating Gross Weight, Motor Vehicle Classification Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
20,000	.168	.155	1.08
25,000	.185	.167	1.11
30,000	.202	.178	1.13
35,000	.217	.188	1.15
40,000	.230	.197	1.17
45,000	.242	.204	1.19
50,000	.254	.213	1.19
55,000	.266	.219	1.21
60,000	.278	.224	1.24
65,000	.285	.230	1.24

1 Derived from curves in Figure 5.

Figure 6 shows the fuel consumption curves represented by gasoline and diesel powered vehicles in rural line-haul service over the same routes for gross vehicle weights ranging from about 30 to 70 thousand pounds. Table 29 presents the derived rates and ratios at various gross weights corresponding to Figure 6. The average rise and fall encountered on the test trips was 1.17 feet per 100 feet. The average net horse power for the vehicles involved was 199 for gasoline engines and 200 for diesel engines. For an overall average, the diesel powered vehicles consumed 51 percent less gallons of fuel per mile than did by the gasoline powered vehicles.

Compared to the other studies covered above, the fuel consumption differential represented by this study closely approximates those in the higher weight range of the North Dakota Study. Actually, it seems to extend the curves of the North Dakota Study.

Other aspects of the Fuel and Time Consumption Study will be reviewed later in this report.

Oregon Study

One of the oldest formal research efforts to determine the actual differential between gasoline and diesel fuel consumption of trucks on rural highways was directed by the Oregon State Highway Commission and published in 1937.[7] Although the study occurred some 20 years prior to the last of the major studies of this type, the findings are not wholly unlike the others. Figure 7 and Table 30 show the results of this study. These findings are presented in and compared to those findings published in the Fuel and Time Consumption Study report.

FIGURE 6.--Fuel Consumption Rates by Operating Gross Weight, Fuel and Time Consumption Study

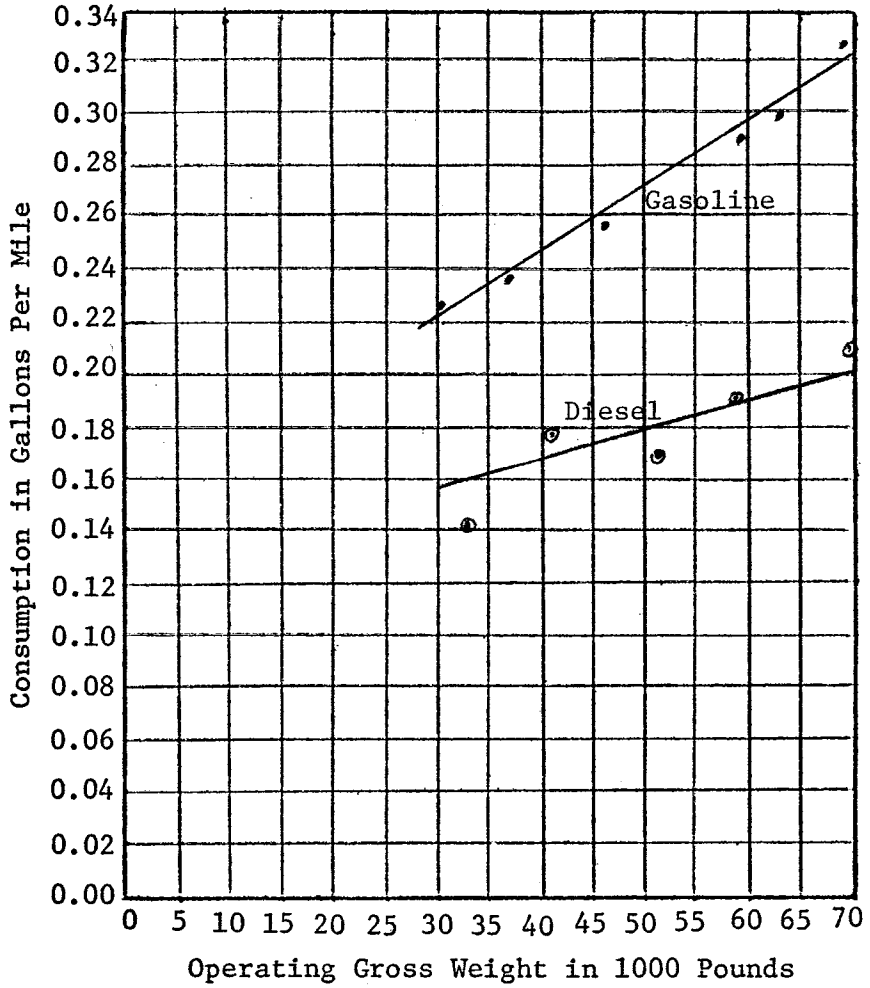


TABLE 29.--Fuel Consumption Rates by Operating Gross Weight, Fuel and Time Consumption Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
30,000	.220	.155	1.42
35,000	.233	.161	1.45
40,000	.245	.166	1.48
45,000	.258	.172	1.50
50,000	.271	.178	1.52
55,000	.284	.183	1.55
60,000	.297	.189	1.57
65,000	.310	.195	1.59
70,000	.323	.200	1.62
Overall Average	.283	.188	1.51

1 Derived from the curves in Figure 6 using the following formulas: Gasoline, 0.14217 + 0.00258W; Diesel, 0.12106 + 0.00113W. (W = GVW in thousands of pounds.) The overall average is not based on the formulas.

FIGURE 7.--Fuel Consumption Rates by Operating Gross Weight, Oregon Study

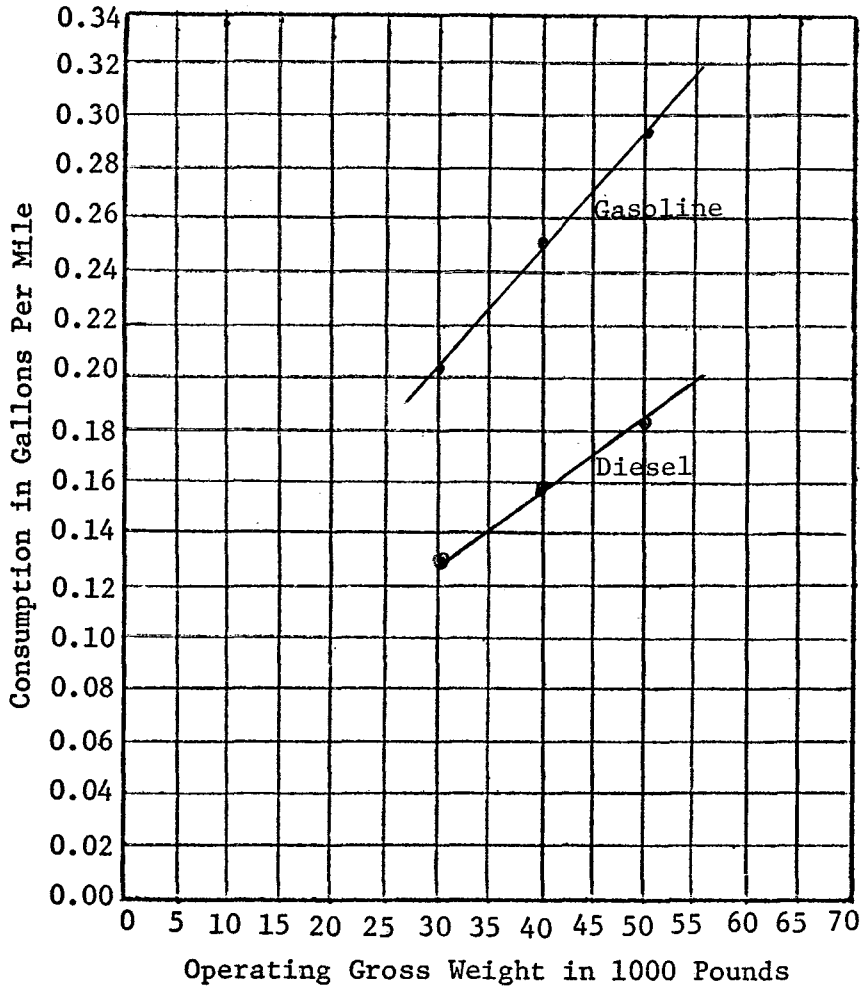


TABLE 30.--Fuel Consumption Rates by Operating Gross Weight, Oregon Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
30,000	.203	.128	1.59
40,000	.251	.157	1.60
50,000	.295	.183	1.61

1 Rate of rise and fall was one foot per 100 feet.

Although the rate of consumption for a particular vehicle weight and the rate of increase in consumption as the vehicle's weight increases are different, this study's differential or ratios at various weights are somewhat similar to those of the Fuel and Time Consumption Study. But more importantly, these results are strikingly similar to those of the North Dakota Study. In this case, not only is the differential or ratios between the curves about the same, but also the rate of increase in consumption for both gasoline and diesel fuel is about the same.

Thus, it seems that with the passage of time, the differential between gasoline and diesel fuel consumption has not changed significantly.

Washington State Study

James C. Nelson, an Economic Consultant from the State College of Washington, conducted a study in 1949 on how to tax Washington State's motor vehicles equitably for highway services rendered.[8] In the course of this study, he tried to determine the differential in fuel consumption between gasoline and diesel powered vehicles.

To collect the necessary information for measuring the above differential, a questionnaire was devised and sent out to Class I Motor Carriers of Property known to operate both diesel and gasoline powered units. These carriers were asked to complete the questionnaire from their 1949 records. Seventeen responded to the request and reported the mileage and gallons of fuel consumed from operation in and out of Washington, by licensed gross weight groups.

Figure 8 and Table 31 present a modified version of the findings incorporated in the above report. The modification resulting from combining of the licensed gross weight of the truck or truck-tractor with that of the trailer or semitrailer usually pulled to build up an operating gross weight from the data. The number of trucks and tractors, by fuel type, hauling trailers or semitrailers were: diesel, 148; and gasoline, 79. The number of diesel units reported represents the vast majority of all such vehicles registered in Washington, especially those in the heavier weights.

The curves, freehanded in Figure 8, lean heavily toward data points having the largest number of vehicles. For instance, the data points above the gasoline curve represent only a few vehicles in each case. The gasoline to diesel ratios indicated here more or less represent a compromise between the two extremes thus far presented. The diesel curve is very similar to those of the Montana and Motor Vehicle Classification Studies. The gasoline curve is similar to the Line-Haul, Motor Vehicle Classification, and Fuel Consumption and Time Studies. The ratios are quite similar to those of the Montana Study.

Kansas Study

In 1961, the State Highway Commission of Kansas, in cooperation with the U. S. Bureau of Public Roads, made a survey to obtain information on the number of vehicles registered for operation. Enough information was obtained to classify these vehicles according to vehicle type, number of axles, number of tires, type of body, and registered gross weight. Additional information on type of fuel used license fees

FIGURE 8.--Fuel Consumption Rates by Registered Gross Weight, Washington State Study

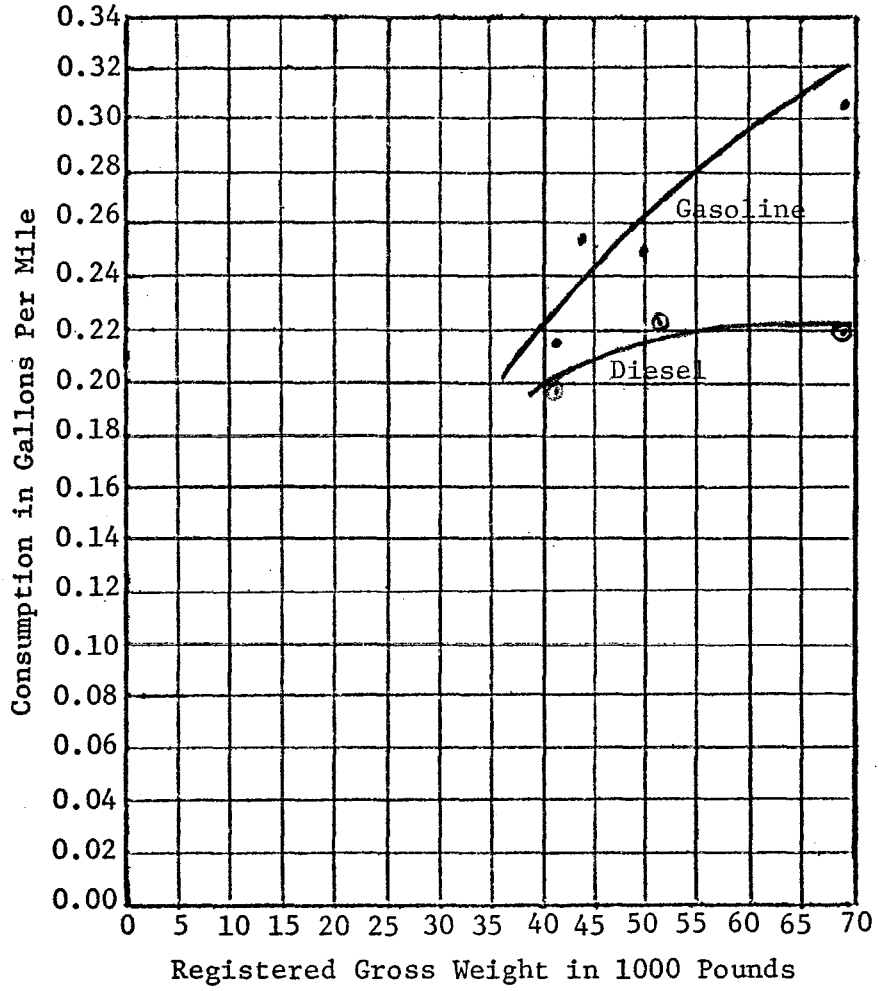


TABLE 31.--Fuel Consumption Rates by Registered Gross Weight, Washington State Study

Registered Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
40,000	.221	.200	1.11
45,000	.244	.210	1.16
50,000	.263	.215	1.22
55,000	.281	.219	1.28
60,000	.297	.221	1.34
65,000	.310	.222	1.40
70,000	.322	.222	1.45

1 Derived from the curves in Figure 8.

paid, annual mileage driven, miles per gallon, and ownership characteristics was obtained from questionnaires returned from the owners of 8,000 trucks systematically selected throughout the state.

The resulting information on fuel consumption was published in 1961.[9] The fuel consumption data are reported by fuel type, type of ownership, visual classification and registered gross vehicle weight class. However, no overall fuel consumption figures were reported. Data were received through correspondence with the State Highway Commission of Kansas. These data are reported in Figure 9 and Table 32. All types of operators, private as well as for-hire, are reflected in these figures.

The above results compare fairly well with other data collected in a similar manner. The differential is not greatly different from that of the Line-Haul, Motor Vehicle Classification, and Washington State Studies, especially in weight ranges above 55,000 pounds. Also, the diesel curve is much like that of the Fuel and Time Consumption Study, and confirms the lower end of the diesel curve developed in the Association of State Highway Officials (AASHO) Road Test to be presented next. However, on a whole, the rate of fuel consumption for a particular weight is much lower than that presented in most of the other studies.

FIGURE 9.--Fuel Consumption Rates by Registered Gross Weight, Kansas Study

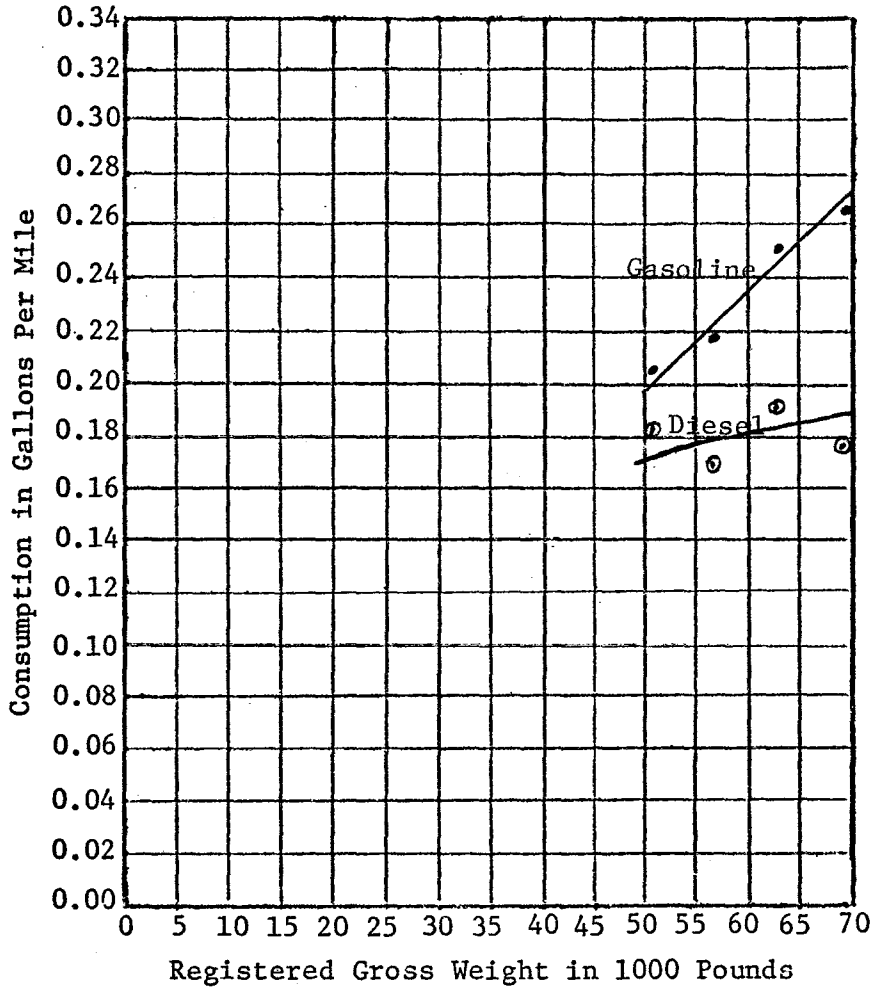


TABLE 32.--Fuel Consumption Rates by Registered Gross Weight, Kansas Study

Registered Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
50,000	.193	.171	1.13
55,000	.217	.177	1.23
60,000	.236	.181	1.30
65,000	.254	.184	1.38
70,000	.274	.188	1.46

1 These data are estimated from the fuel consumption curves in Figure 9.

AASHO Road Test

One of the by-products of the AASHO Road Test, conducted at Ottawa, Illinois, between 1958 and 1960, was a record of the gasoline and diesel fuel consumption rates for all vehicles used in the test. A total of 75 gasoline and 52 diesel vehicles were used making up 10 different axle combinations and gross weight groups. However, none of these weight groups had both gasoline and diesel powered vehicles, thus preventing a direct comparison of fuel consumption. Consequently, it is obvious that the AASHO Road Test was not planned in such a way as to determine the fuel consumption differential between the gasoline and diesel powered vehicles.

However, the results, published in 1962,[10] tend to confirm those obtained by other studies presented here. Figure 10 and Table 33 show the fuel consumption curves and actual data points developed from the Road Test. The gasoline curve is much like that of the Line-Haul and Motor Vehicle Classification Studies, and the diesel curve seems to be an extension of those of the Fuel and Time Consumption and Kansas Studies.

About the only point where a differential between gasoline and diesel consumption rates is indicated by the Road Test data is at about the 65,000 pound gross weight. Here a differential of .10 gallons per mile, or a gasoline to diesel ratio of 1.60, is shown. This is almost the same ratio for that weight as found by the Fuel and Time Consumption Study.

FIGURE 10.--Fuel Consumption Rates by Operating Gross Weight, AASHO Road Test

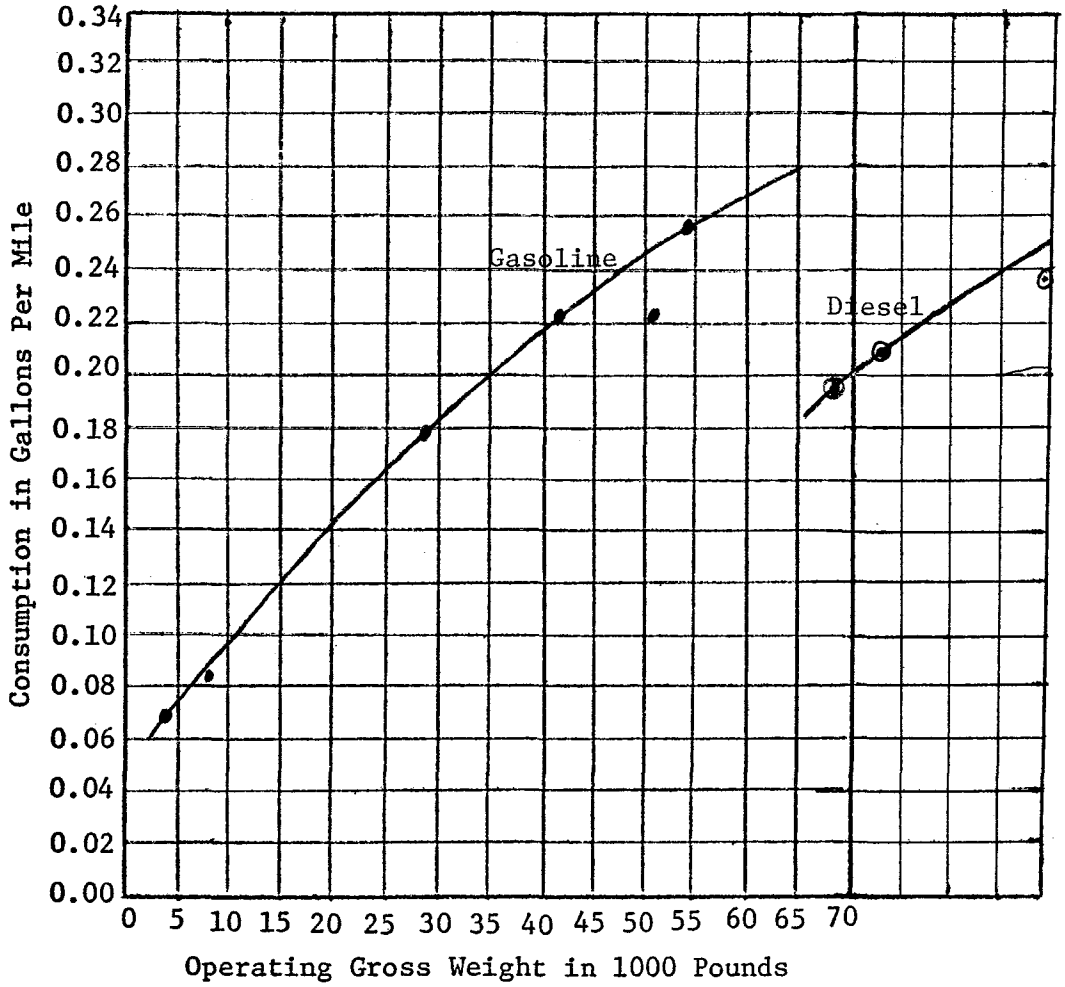


TABLE 33.--Fuel Consumption Rates by Operating Gross Weight, AASHO Road Test

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]	
	Gasoline	Diesel
4,000	.070	--
8,000	.083	--
28,500	.179	--
42,000	.222	--
51,000	.222	--
54,500	.256	--
69,000	--	.196
73,500	--	.208
89,000	--	.238
108,000	--	.294

1 Actual data points shown in Figure 10.

Composite of Several Studies

As has been shown the fuel consumption rates for both gasoline and diesel powered trucks and combinations at the same gross weight vary from study to study. As a result, an effort has been made to develop composite (average) curves by combining the results of several of the most recent studies. Such a set of composite curves has been developed and published by the U.S. Bureau of Public Roads in 1965.[2] These data were used for highway cost allocation purposes on a national level.

The composite gasoline curve is based on the Montana, Line-Haul Cost, Fuel and Time Consumption, Motor Vehicle Classification, and the North Dakota Studies. The composite diesel curve is based on the same studies used in the case of gasoline, except for the North Dakota Study. This study was left out because it had relatively few diesel vehicles in the sample.

It is significant to point out that the studies used to develop these composite curves are somewhat related in time, method of study and sample. Figure 11 presents the two composite or average curves which are further translated into gallons per mile amounts in Table 34 for selected vehicle operating gross weights.

Table 34 also shows the ratios of gasoline to diesel fuel consumption for the selected gross operating weights. It reveals that this ratio ranges from 1.17 at 20,000 pounds and 1.45 at 70,000 pounds. The ratio means that, for the respective gross weights, gasoline powered trucks or combinations consume 17 and 45 percent more fuel than diesel powered trucks and combinations on a per mile basis. Table 35

FIGURE 11.--Fuel Consumption Rates by Operating Gross Weight, Composite of Studies

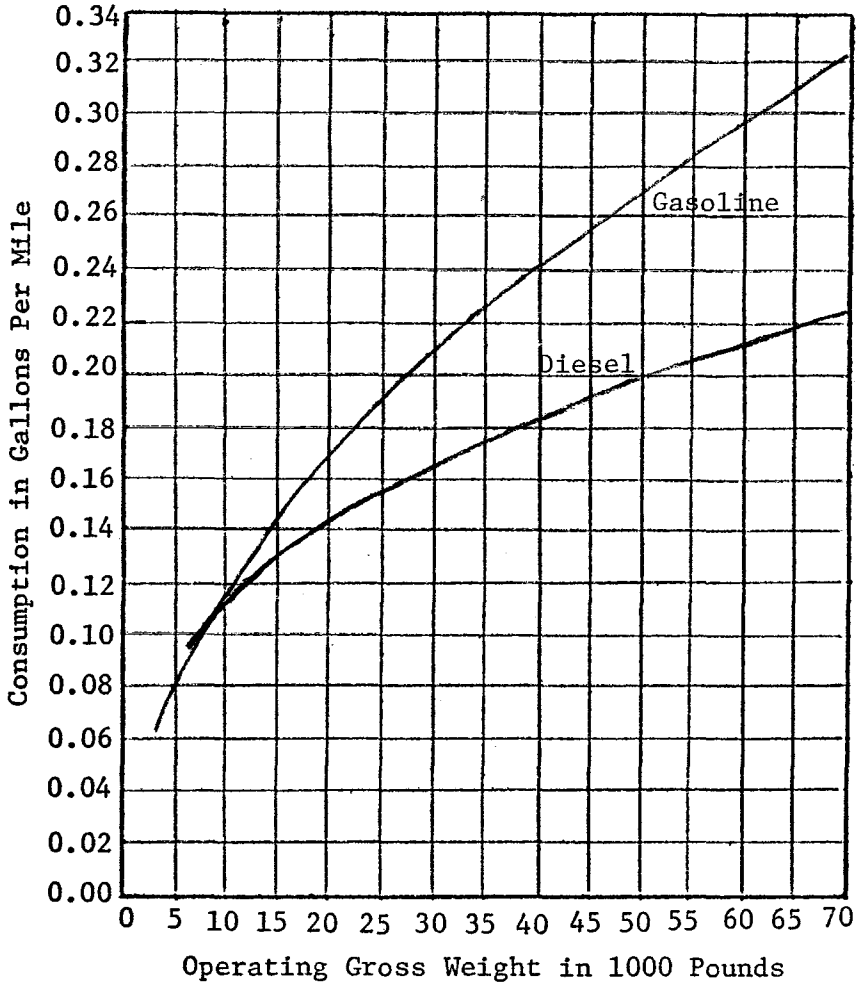


TABLE 34.--Fuel Consumption Rates by Operating Gross Weight, Composite of Studies

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
20,000	.166	.142	1.17
25,000	.186	.154	1.21
30,000	.205	.164	1.25
35,000	.222	.173	1.28
40,000	.238	.181	1.31
45,000	.253	.189	1.34
50,000	.268	.196	1.37
55,000	.282	.203	1.39
60,000	.295	.209	1.41
65,000	.307	.215	1.43
70,000	.320	.221	1.45

TABLE 35

Fuel Consumption Ratios Calculated From Various Studies By Gross Vehicle Weight

Gross Vehicle Weight in Pounds	Gasoline to Diesel Fuel Consumption Ratios by Study[1]								
	North Dakota	Line-Haul Trucking Cost	Montana	Motor Vehicle Classification	Fuel and Time Consumption	Oregon	Washington State	Kansas	Composite of First Five Studies
20,000				1.08					1.17
25,000	1.56	1.26		1.11					1.21
30,000	1.57	1.28	1.28	1.13	1.42	1.59			1.25
35,000	1.54	1.31		1.15	1.45				1.28
40,000	1.54	1.29	1.33	1.17	1.48	1.60	1.11		1.31
45,000	1.53	1.31		1.19	1.50		1.16		1.34
50,000	1.52	1.31	1.36	1.19	1.52	1.61	1.22	1.13	1.37
55,000	1.54	1.31		1.21	1.55		1.28	1.23	1.39
60,000	1.54	1.37	1.39	1.24	1.57		1.34	1.30	1.41
65,000		1.33		1.24	1.59		1.40	1.38	1.43
70,000			1.42		1.62		1.45	1.46	1.45

1 The indicated ratio for the AASHO Road Test at 65,000 pounds is 1.60.

gives a comparison of these composite ratios with all of the studies reviewed in this report. A study of the ranges of the ratios of each given gross weight reveals that on the low side of the ranges the ratios run from 1.08 to 1.42. On the high side of the ranges, the ratios run from 1.17 to 1.62 through the weight groups.

The above differentials in fuel consumption between gasoline and diesel vehicles of the same weight seem conservative compared to those of some of the above studies as well as those advertised by leading diesel truck manufacturers. One company distributed written material indicating that gasoline vehicles use 67 percent more fuel than comparable diesel vehicles. Another has claimed fuel savings of 50 percent for diesels. The records of a well known trucking company indicate that the diesel vehicles operated by that firm averaged 39 percent more miles per gallon than the almost identical gasoline vehicles in similar service.

Thus, it seems that the gasoline to diesel fuel consumption ratio, at the various gross weights, may have increased since the above studies were conducted.

INTRACITY TRUCK STUDIES

Few gasoline versus diesel fuel consumption studies have been made that reflect the differences between primarily intercity services and primarily intracity services. In fact, only one of the above cited studies made a formal comparison between rural and urban fuel consumption rates. Data from that study are presented here.

The Fuel and Time Consumption Study[3] gives gasoline and diesel

fuel consumption data for line-haul truck-tractor combinations operating in rural and urban areas. These data are reported in Figure 12 and Table 36. The fuel consumption rate for gasoline powered vehicles in urban travel is about 30 percent higher than in rural travel regardless of gross vehicle weight. On the other hand, the fuel consumption rate of diesel powered vehicles in urban travel is about the same as that in rural travel at the 42,000 gross vehicle weight, but it becomes higher as the gross weight increases. At 70,000 pounds, diesel fuel consumption is 27 percent higher for urban travel than for rural travel.

The above data also shows that gasoline powered vehicles weighing 30,000 pounds consume 12 percent more fuel in rural travel than do comparable diesel powered vehicles. In urban travel, the same gasoline powered vehicles consume 81 percent more fuel than do comparable diesel powered vehicles. At the 70,000 weights, gasoline powered vehicles consume 55 percent more fuel than comparable diesel powered vehicles in rural travel. In urban travel, the same gasoline vehicles consume 58 percent more fuel than do the diesel vehicles. The gasoline to diesel ratios, urban versus rural, presented in Table 36 shows about the same pattern.

The same study researched multi-stop pickup and delivery vehicle gasoline consumption rates. The type of vehicles tested ranged from two-axle panel trucks to 2-S2 tank truck-tractor semitrailers. The weight range was from 4,400 to 70,000 pounds. It was reported that the consumption rates closely approximated those values for gasoline powered vehicles in urban line-haul service.

FIGURE 12.--Fuel Consumption Rates, Urban Versus Rural Usage, by Operating Gross Weight, Fuel and Time Consumption Study

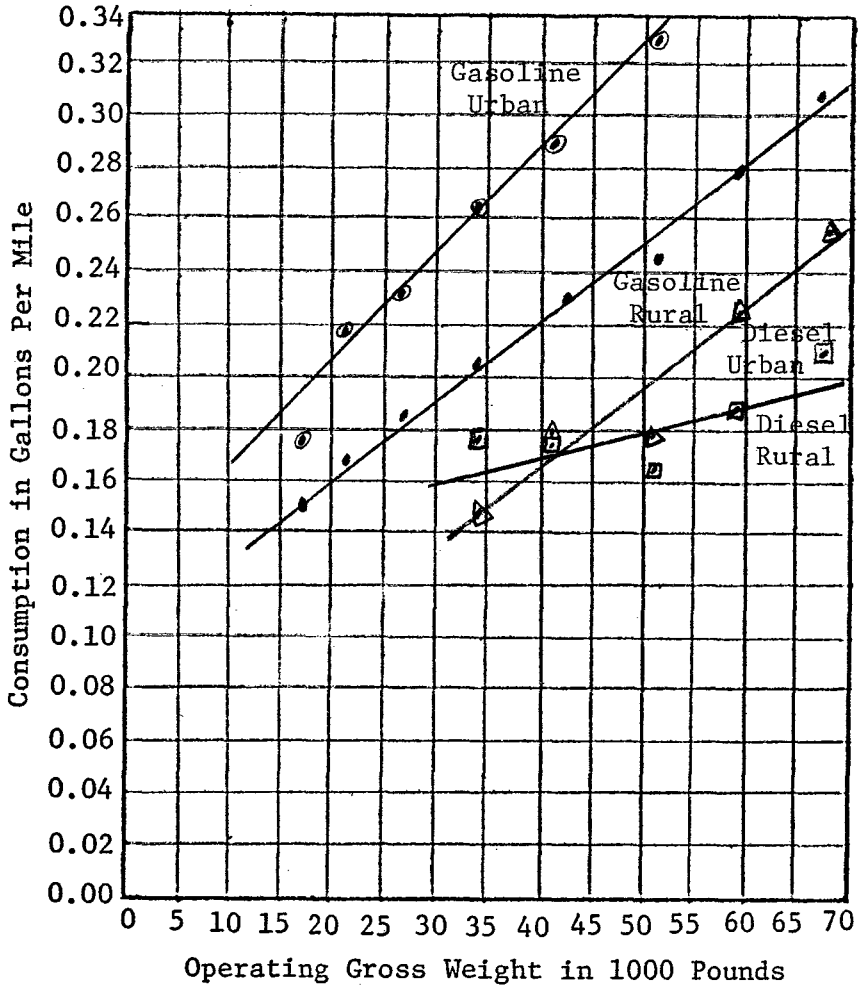


TABLE 36.--Fuel Consumption Rates, Urban Versus Rural Usage, by Operating Gross Weight, Fuel and Time Consumption Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]					
	Urban			Rural		
	Gasoline	Diesel	Ratio of Gasoline to Diesel	Gasoline	Diesel	Ratio of Gasoline to Diesel
17,000	.175	--	--	.150	--	--
21,300	.218	--	--	.166	--	--
27,000	.232	--	--	.184	--	--
34,500	.263	.147	1.79	.206	.176	1.17
42,000	.291	.179	1.63	.229	.176	1.30
51,200	.332	.180	1.84	.243	.164	1.48
59,500	.365	.225	1.62	.280	.189	1.48
67,900	.395	.255	1.55	.308	.212	1.45

1 The equations expressing the curves in Figure 12 are as follows: Gasoline Urban, GPM = 0.11865 + 0.00413W; Diesel Urban, GPM = 0.03924 + 0.00310W; Gasoline Rural, GPM = 0.10115 + 0.00299W; Diesel Rural, GPM = 0.13180 + 0.00101W. Where GPM = gallons per mile and W = gross vehicle weight in thousands of pounds. However, the data in this table reflect the actual data points in Figure 12.

INTERCITY BUS STUDIES

Two of the above studies give some fuel consumption data on intercity buses. One was the Motor Vehicle Classification Study of 1956-57. In this study, the necessary information was obtained through the aid of the American Transit Association and the National Association of Motor Bus Operators. Questionnaires were sent out to intracity (transit) and intercity commercial operators in an effort to obtain the number of buses of various seating capacity, registered gross vehicle weight groups, type of fuel, total miles operated during the year, the rate of fuel consumption, and the total fuel used. The resulting data were published in the previously mentioned report.[6]

The other fuel consumption study of buses was the 1949 Washington State Study, published in 1950.[8] Data were obtained by questionnaire from eight intercity and three intracity bus companies which used both gasoline and diesel powered buses having about the same seating capacity and empty weight and used in the same services.

For the intercity gasoline and diesel fuel consumption, the combined findings of both studies are presented in Figure 13 and further translated into Table 37. The consumption rates for both fuels are fairly similar to those of intercity trucks and combinations at the corresponding gross weights. However, the ratios of gasoline to diesel fuel consumption are somewhat larger. For instance, at the 25,000 pound gross weight, buses have a 1.53 ratio and trucks have 1.21 (Table 34).

Data reported by a bus manufacturer and presented in Table 38 indicate a 1.42 gasoline to diesel fuel consumption ratio. It is not known what gross weight this ratio represents.

FIGURE 13.--Fuel Consumption Rates for Intercity Buses by Registered Gross Weight, Washington State and Motor Vehicle Classification Studies

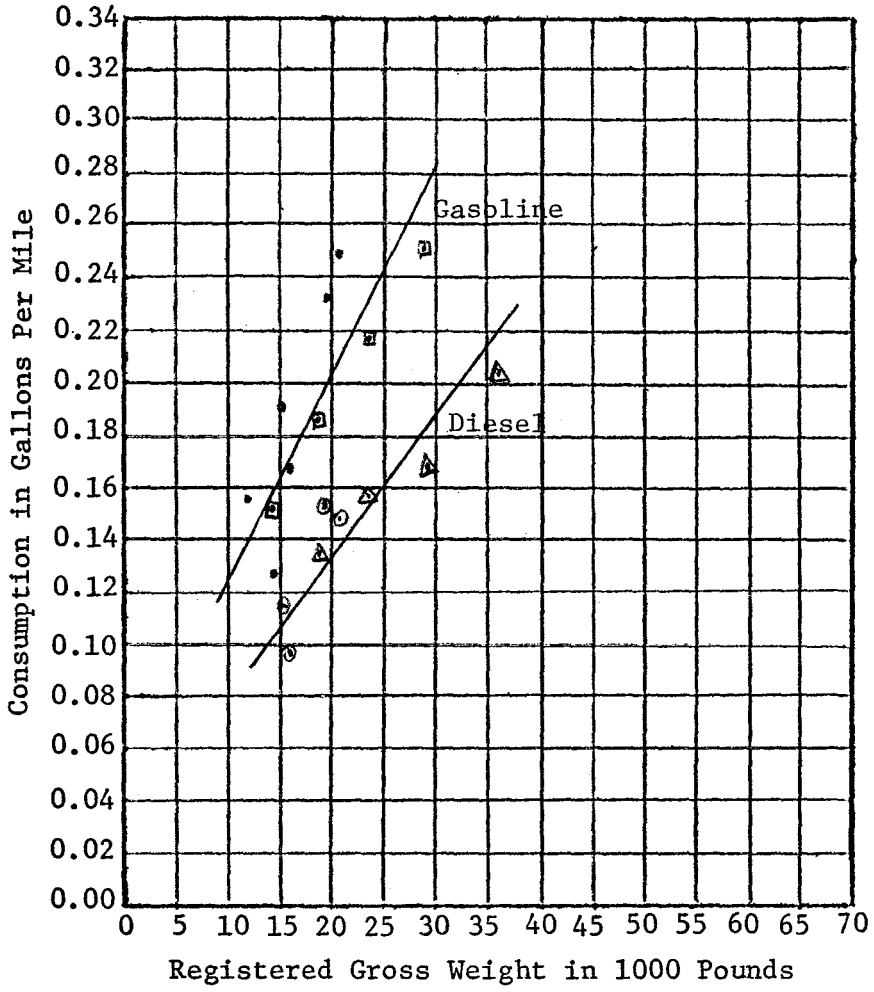


TABLE 37.--Fuel Consumption Rates for Intercity Buses by Registered Gross Weight, Washington State and Motor Vehicle Classification Studies

Registered Gross Weight in Pounds[1]	Fuel Consumption in Gallons Per Mile[2]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
15,000	.164	.108	1.52
20,000	.204	.134	1.52
25,000	.245	.160	1.53
30,000	.285	.186	1.53

1 The Motor Vehicle Classification Study used registered gross weight groups. The data points in Figure 13 are at the midpoints of each group. The Washington State Study reported the weights as empty vehicle weights.

2 Derived from the curves in Figure 13.

INTRACITY BUS STUDIES

Figure 14 presents the findings of the above two studies in regard to fuel consumption patterns of intracity buses. Table 39 further translates the data into tabular form and presents the gasoline to diesel fuel consumption ratios at various gross weights.

The fuel consumption rates for both fuels are much higher than those found in the case of intercity buses weighing over 20,000 pounds. However, the gasoline to diesel consumption ratios were much smaller in the weights below 20,000 pounds. In other words, the intracity ratios range from 1.29 to 1.88 and the intercity ratios varied only one point, and after the 20,000 gross weight, the ratios are approximately the same.

The findings of a refining company and a bus manufacturer, as shown in Table 38, indicate that the gasoline to diesel fuel consumption ratios for intracity buses are quite similar to those found for intercity buses. But, again, it is not known what gross weight these ratios represent.

TABLE 38

Fuel Consumption Rates for Buses According to Type of Use as Reported by the Truck and Fuel Manufacturing Industries

Type of Vehicle Use	Fuel Consumption in Gallons Per Mile		
	Gasoline	Diesel	Ratio of Gasoline To Diesel
Intercity [1]	.190	.134	1.42
Intracity [1]	.294	.201	1.46
Intracity [2]	.249	.179	1.39

1 Data appeared in an advertisement published in Bus Transportation, May, 1952. The results are based on a bus manufacturer's study of 100 operators for a one year period.

2 From an article published in the National Petroleum News, May, 1957 issue, which reported the results of a two year study of 20 new buses operated in Harrisburg, Pennsylvania. The test was sponsored by a refining company. The diesel fuel consumption rate is almost the same as that reported in an advertisement by a bus manufacturer which appeared in the Bus Transportation June, 1952 issue. There were 27 transit 36 passenger buses in the test.

FIGURE 14.--Fuel Consumption Rates for Intracity Buses by Registered Gross Weight, Washington State and Motor Vehicle Classification Studies

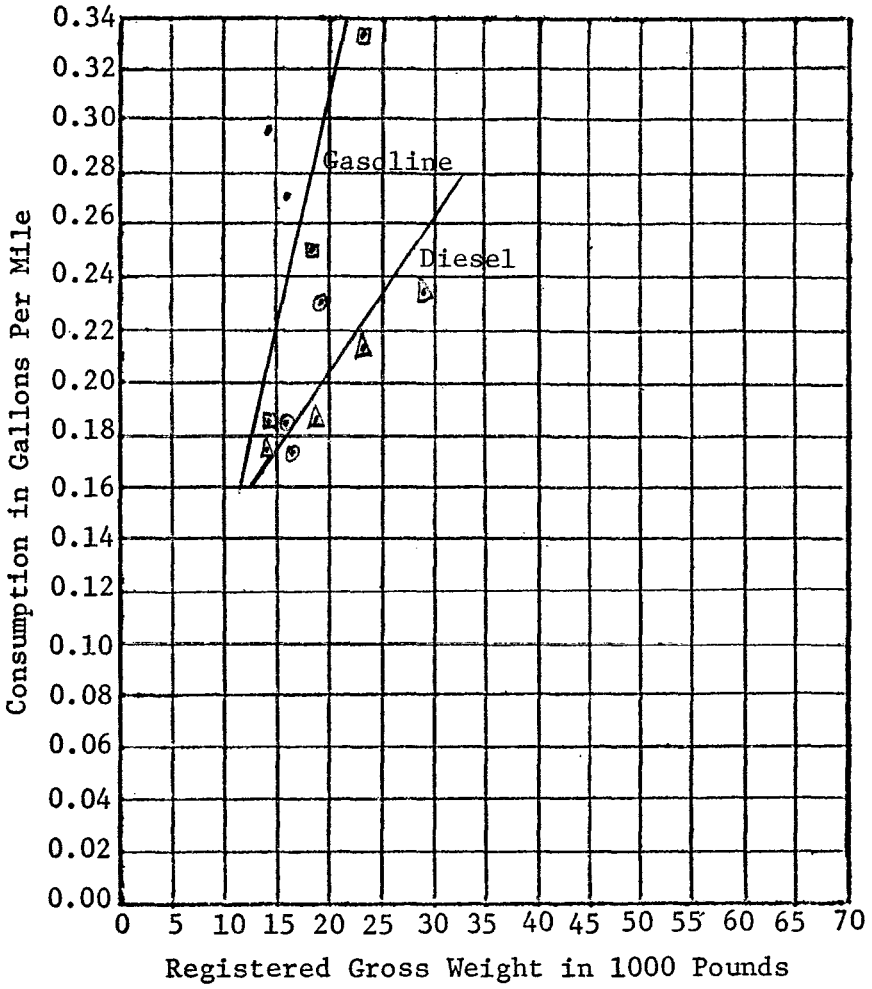


TABLE 39.--Fuel Consumption Rates for Intracity Buses by Registered Gross Weight, Washington State and Motor Vehicle Classification Studies

Registered Gross Weight in Pounds[1]	Fuel Consumption in Gallons Per Mile[2]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
15,000	.222	.172	1.29
20,000	.315	.202	1.56
25,000	.408	.233	1.75
30,000	.491	.261	1.88

1 The Motor Vehicle Classification Study used registered gross weight groups. The data points in Figure 14 are at the midpoints of each group. The Washington State Study reported the weights as empty vehicle weights.

2 Derived from the curves in Figure 14.

TRUCK AXLE GROUP STUDIES

Two of the above studies, the Line-Haul Trucking and the Fuel and Time Consumption, as well as another study, cast some light on the differences in gasoline and diesel fuel consumption by trucks of certain axle groups used in intercity service. The other study was conducted by the University of Washington in cooperation with the U.S. Bureau of Public Roads in the summer of 1959.[11]

From the above studies separate information was obtained on the following axle groups: 2-S1, 2-S2, 3-S2, and 2-S1-2. Additional data on several axle groups of lesser importance were collected and analyzed in two groupings as follows: Group 1 has 2-S1-2, 2-S2-2, 3-S2-3, and 3-S1-2 axle groups; and Group 2 has 2-2, 3-2, 2-3, and 3-3 axle groups.

Two Axle Tractor-One Axle Semitrailer

The Line-Haul Trucking Cost Study is alone in reporting fuel costs on the 2-S1 axle group, and even it presents data for a limited weight range. Figure 15 shows the freehand fuel consumption curves and Table 40 shows the derived fuel consumptions and resulting ratios. Extreme data points were ignored.

When comparing the 2-S1's fuel consumption rates and ratios with those developed from the composite curve (Figure 11) as given in Table 34, one sees a fairly close resemblance between the two sets of data. The gasoline fuel consumption rates are almost the same, but the diesel fuel consumption rates are somewhat lower than those of Table 34.

FIGURE 15.--Fuel Consumption Rates for 2-S1 Axle Group by Operating Gross Weight, Line-Haul Trucking Costs Study

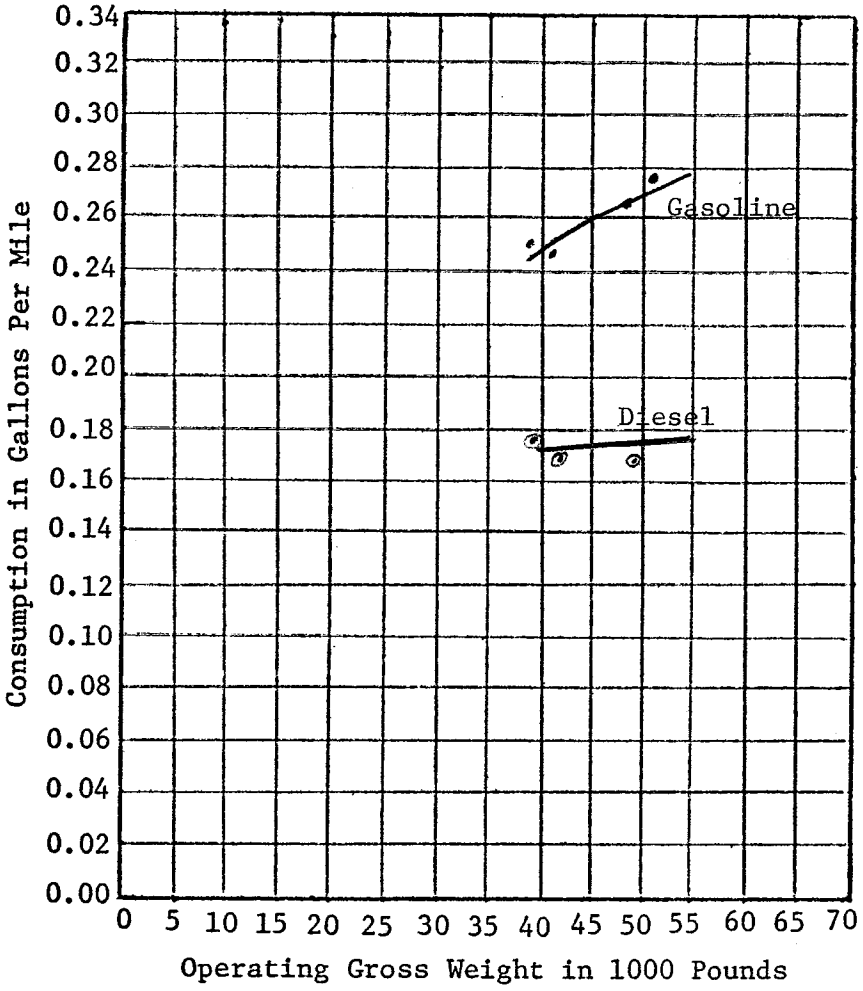


TABLE 40.--Fuel Consumption Rates for 2-S1 Axle Group by Operating Gross Weight, Line-Haul Trucking Costs Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
40,000	.249	.170	1.46
45,000	.259	.172	1.51
50,000	.270	.173	1.56
55,000	.277	.176	1.57

1 Derived from the curves in Figure 15.

Two Axle Tractor-Two Axle Semitrailer

The University of Washington study[11] tested the 2-S2 axle group, as well as others, in its measurements of fuel consumption and travel time of commercial vehicles tested under varying conditions of grade, surface, speed, weight, stopping and slowing. Data were reported separately for each vehicle type involved in the test.

For purposes of this report, the data presented here are based on constant speeds of 20 and 40 miles per hour, a level (zero) grade and paved highway. The former seems to be more representative of the average urban line-haul speeds and the latter the rural line-haul speeds. The gross weights represent empty, part loaded and fully loaded vehicles, and these vary according to the axle group. The loaded weights are at or near the maximum legal weights allowed by Texas laws. Although these data are given for only three weights for each axle group, they are spread out over a wide range to give a good indication of the gasoline to diesel fuel consumption ratios that can be expected.

The findings on the 2-S2 axle group are presented in Figure 16 and Table 41. The gasoline to diesel ratios at 20 miles per hour are from 16 to 25 ratio points greater than those at 40 miles per hour. The ratios of the latter correspond fairly close to those found in Table 34. In fact, at the 42,500 pound weight, the ratios are the same.

The Line-Haul Trucking Cost Study also gives data on the 2-S2 axle group. Figure 17 shows the freehanded fuel consumption curves, and Table 42 shows the derived fuel consumption rates and resulting ratios.

FIGURE 16.--Fuel Consumption Rates for 2-S2 Axle Group by Operating Gross Weight, University of Washington Study

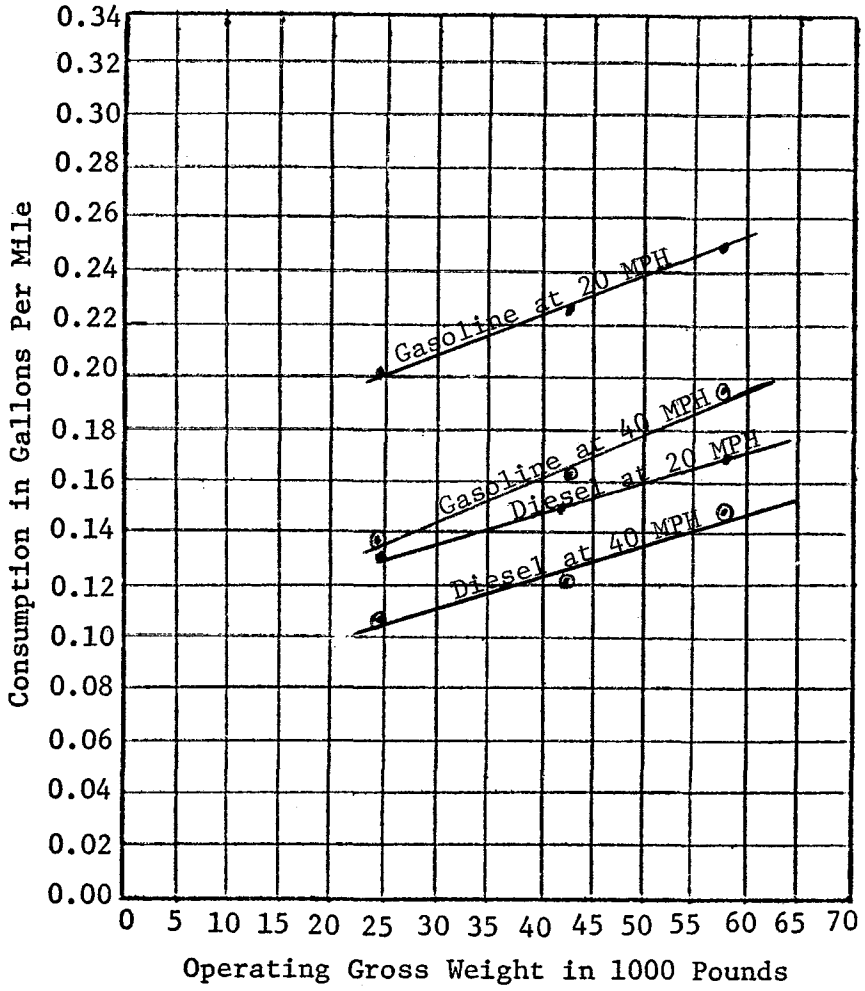


TABLE 41.--Fuel Consumption Rates for 2-S2 Axle Group by Operating Gross Weight, University of Washington Study

Operating Gross Weight in Pounds[1]	Fuel Consumption in Gallons Per Mile[2]					
	At 20 Miles Per Hour			At 40 Miles Per Hour		
	Gasoline	Diesel	Ratio of Gasoline to Diesel	Gasoline	Diesel	Ratio of Gasoline to Diesel
24,500	.200	.132	1.52	.136	.107	1.27
42,500	.225	.148	1.52	.160	.120	1.33
57,500	.250	.169	1.48	.196	.149	1.32

1 Rounded off to within 500 pounds for each vehicle involved in test. The data points in Figure 16 are at the actual vehicle weights.

2 Test at constant speed and at zero grade.

FIGURE 17.--Fuel Consumption Rates for 2-S2 Axle Group by Operating Gross Weight, Line-Haul Trucking Costs Study

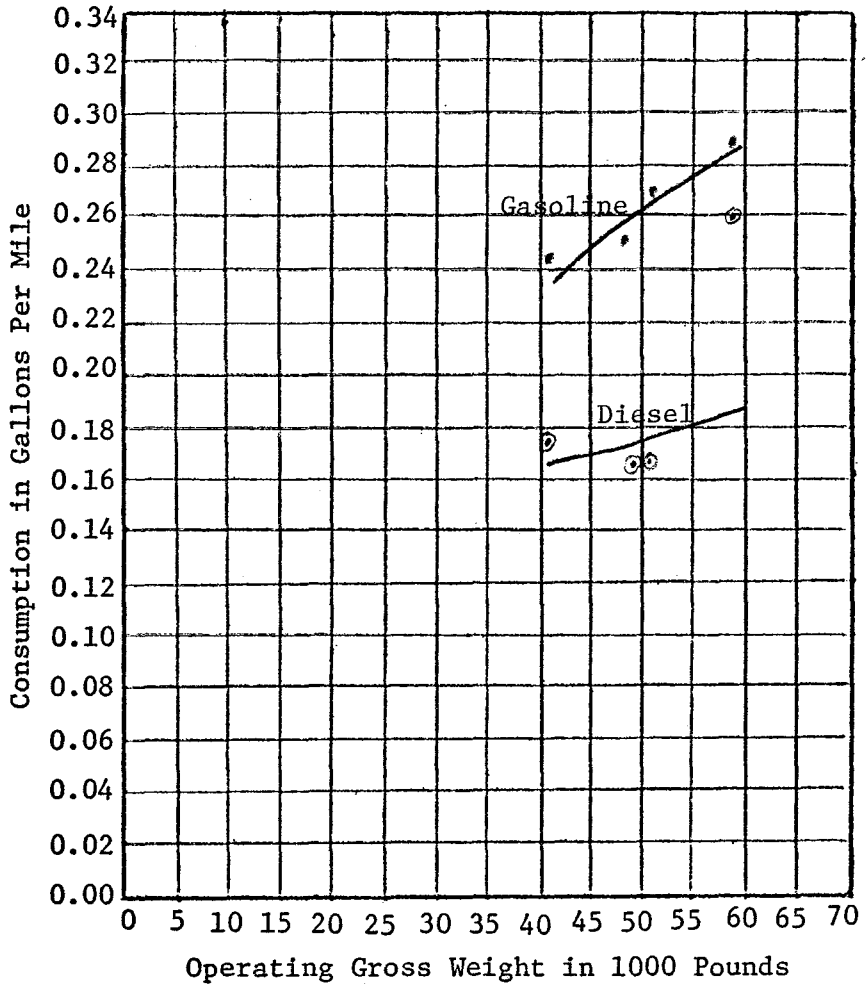


TABLE 42.--Fuel Consumption Rates for 2-S2 Axle Group by Operating Gross Weight, Line-Haul Trucking Costs Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
40,000	.234	.166	1.41
45,000	.249	.171	1.46
50,000	.263	.176	1.49
55,000	.277	.181	1.53
60,000	.289	.187	1.55

1 Derived from curves in Figure 17.

The extreme data points are ignored. For corresponding operating weights, the gasoline consumption rate is practically the same as that represented by Table 34 of the composite studies. Such a fact would support the proposition that the composite gasoline consumption rates be used to represent those experienced by the 2-S2 vehicles. This axle group was represented with a greater number of gasoline and diesel units than any axle group reported in the Line-Haul Study.

Three Axle Tractor-Two Axle Semitrailer

Another tractor semitrailer combination extensively used within the United States is the 3-S2. Consequently, diesel and gasoline fuel consumption data on this axle group were collected by three different studies.

Starting with the University of Washington Study which was discussed in the last section, the fuel consumption data are presented in Figure 18 and Table 43. As in the previous case, the weights used in the 3-S2 study varied widely, ranging from approximately 27,500 to 65,500 pounds.

The gasoline to diesel fuel consumption ratios for 20 or for 40 miles per hour, tell about the same story. In fact, the ratios for the part loaded weight of 47,500 pounds are identical at both speeds. At this same weight, the ratio developed from the composite curves, as presented in Table 34, is 1.34, or 52 percentage points lower.

The Fuel and Time Consumption Study gives more modest ratios than the University of Washington Study. In a study of rural line-haul

FIGURE 18.--Fuel Consumption Rates for 3-S2 Axle Group by Operating Gross Weight, University of Washington Study

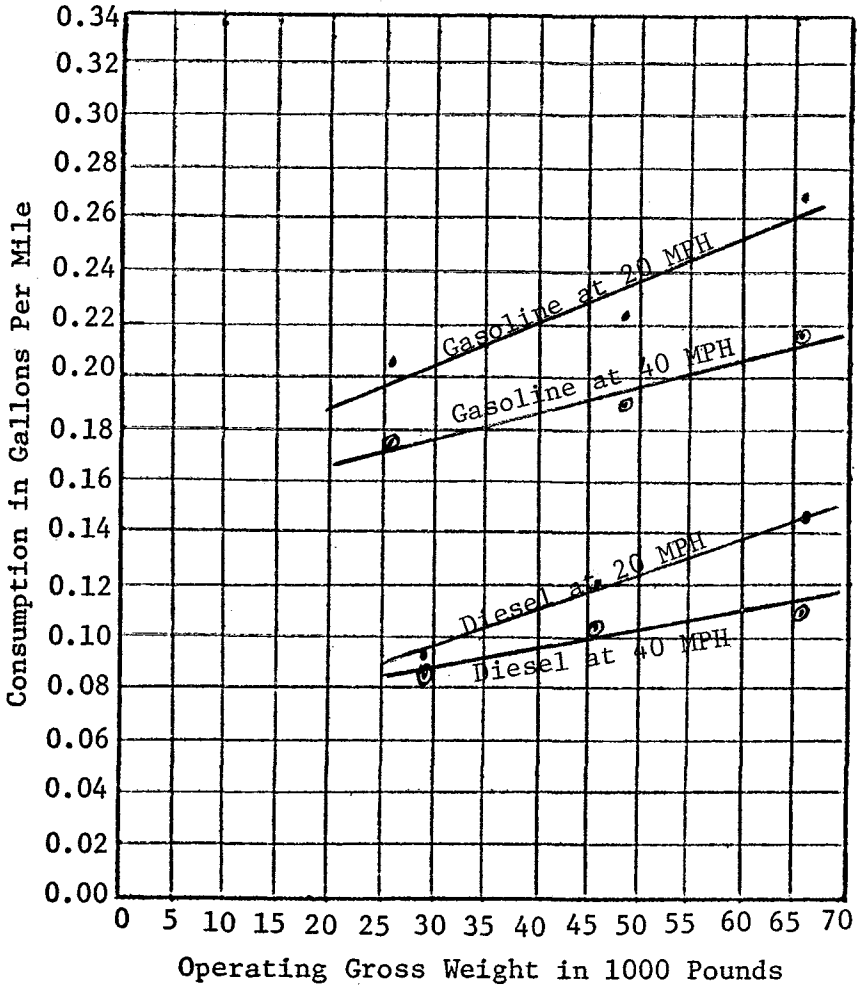


TABLE 43.--Fuel Consumption Rates for 3-S2 Axle Group by Operating Gross Weight, University of Washington Study

Operating Gross Weight in Pounds[1]	Fuel Consumption in Gallons Per Mile[2]					
	At 20 Miles Per Hour			At 40 Miles Per Hour		
	Gasoline	Diesel	Ratio of Gasoline to Diesel	Gasoline	Diesel	Ratio of Gasoline to Diesel
27,500	.205	.095	2.16	.175	.085	2.06
47,500	.223	.120	1.86	.190	.102	1.86
65,500	.270	.145	1.86	.214	.110	1.95

1 Rounded off to within 1,000 pounds of actual weight of vehicle in test. The data points in Figure 18 are at the actual vehicle weights.

2 Test at constant speed and at zero grade.

operations, the former established the fuel consumption results for the 3-S2 axle group as presented in Figure 19 and Table 44. These fuel consumption rates and ratios are based on 3-S2's which had engines with at least 200 horsepower and 590 cubic inches of displacement. As can be seen, the derived ratios are about the same for all three gross weights.

The Line-Haul Study gives the most conservative fuel consumption ratios of the three studies. The data presented in Figure 20 and Table 45 were derived from fuel cost information and not fuel consumption data. The indicated fuel consumption rates are quite variable, especially in the case of diesel fuel. The curves in Figure 20 are freehand and ignore the most extreme data points.

Tractor Semitrailer and Full Trailer

Some vehicle axle groups of lesser importance than those covered thus far are the truck tractor semitrailer and full trailer combinations. Those which have been studied singularly or together are as follows: Gasoline, 2-S1-2, 2-S2-2, and 3-S2-3 combinations; Diesel, 2-S1-2, 2-S2-2, 3-S2-3, and 3-S1-2 combinations.

The Line-Haul and University of Washington Studies give limited fuel consumption data on the above vehicle combinations. The former compares the combined groups of gasoline combinations with the combined group of diesel combinations. However, the study revealed that none of the diesel combinations reporting data were below the 70,000 pound gross weight; whereas, there were gasoline combinations weighing as low as 42,000 pounds. Thus, it is only in the 70,000 pounds and above range that the gasoline versus diesel fuel consumption rates and ratios can be compared.

FIGURE 19.--Fuel Consumption Rates for 3-S2 Axle Group by Operating Gross Weight, Fuel and Time Consumption Study

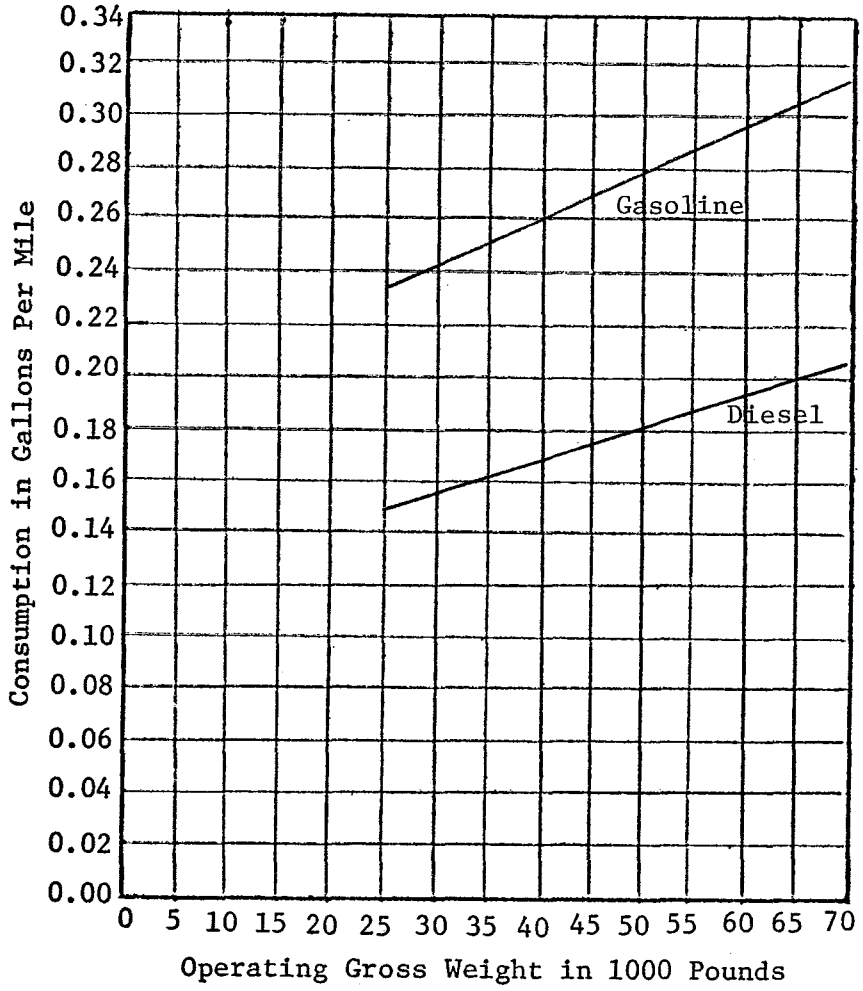


TABLE 44.--Fuel Consumption Rates for 3-S2 Axle Group by Operating Gross Weight, Fuel and Time Consumption Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
27,500	.242	.153	1.58
47,500	.275	.178	1.57
65,500	.304	.200	1.52

1 Derived from the curves in Figure 19 by using the following formulas: Gasoline, GPM = 0.1975 + 0.00162W; Diesel, GPM = 0.1194 + 0.001229W. GPM is gallons per mile and W is gross vehicle weight in thousands of pounds.

FIGURE 20.--Fuel Consumption Rates for 3-S2 Axle Group by Operating Gross Weight, Line-Haul Trucking Costs Study

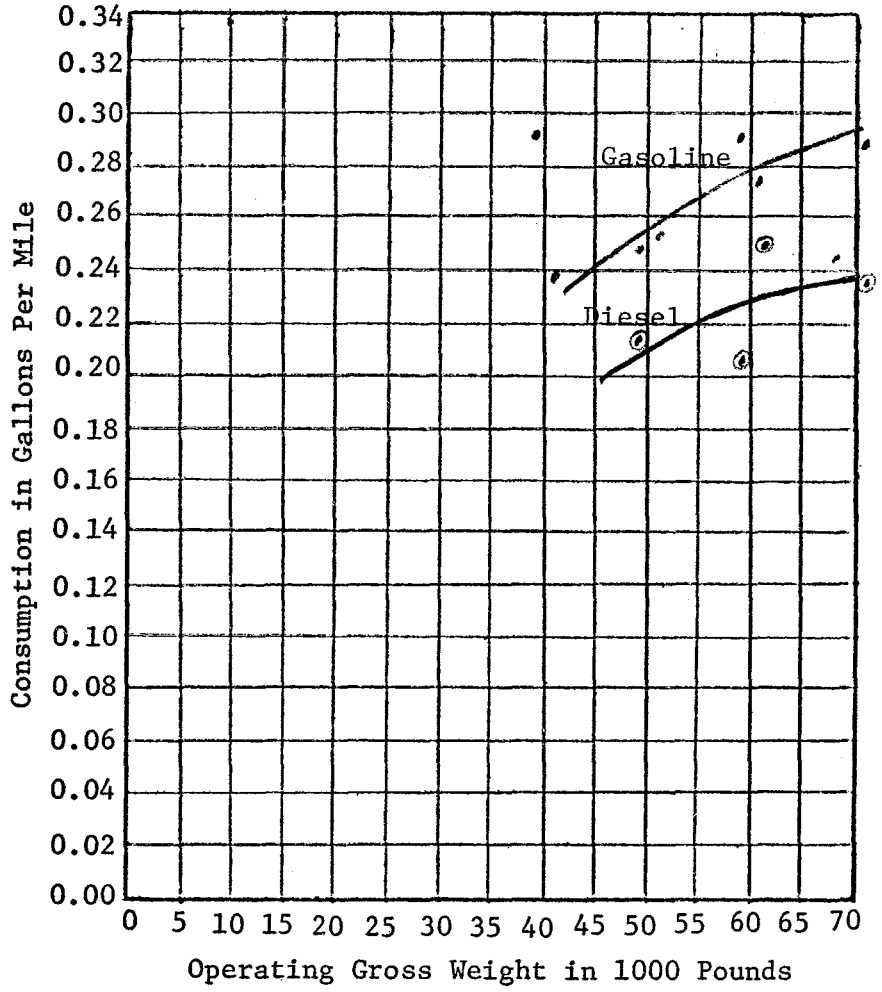


TABLE 45.--Fuel Consumption Rates for 3-S2 Axle Group by Operating Gross Weight, Line-Haul Trucking Costs Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
47,500	.251	.206	1.22
55,500	.271	.222	1.22
65,500	.288	.234	1.23

1 Data derived from curves in Figure 20.

Figure 21 and Table 46 present the data from the Line-Haul Study. Incidentally, the only other study yet covered that gives fuel consumption data above 75,000 pounds of gross weight is the AASHO Road Test, and it gave diesel fuel consumption only. The gasoline curve of the Line-Haul Study is practically identical to that of the AASHO Road Test. Also, the diesel curve is quite similar but a little flatter. They meet at the 70,000 pound gross weight, indicating practically the same gasoline to diesel fuel consumption ratio. In like manner, the composite curve gives almost the same ratio at that weight.

The University of Washington Study reported gasoline versus diesel fuel consumption data for only one axle group of the above combinations, that being the 2-S1-2. These data are presented in Figure 22 and Table 47. At the 72,000 pound weight, the gasoline to diesel ratios for the two speeds are from 12 to 14 percentage points below those of the compromise curve and the Line-Haul Study. But regardless of the speed or weight, the ratios remain much the same.

Truck and Full Trailer

There are various truck and full trailer combinations on the road at the present time. Although they are relatively few in number, their importance is increasing.

The Line-Haul Study gives data comparisons on gasoline and diesel truck and full trailer combinations. The axle combinations represented by the data are as follows: Gasoline, 2-2 and 3-2; and Diesel, 2-2 3-2, 2-3, and 3-3.

FIGURE 21.--Fuel Consumption Rates for 2-S1-2, 2-S2-2, 3-S1-2, and 3-S2-3 Axle Groups by Operating Gross Weight, Line-Haul Trucking Costs Study

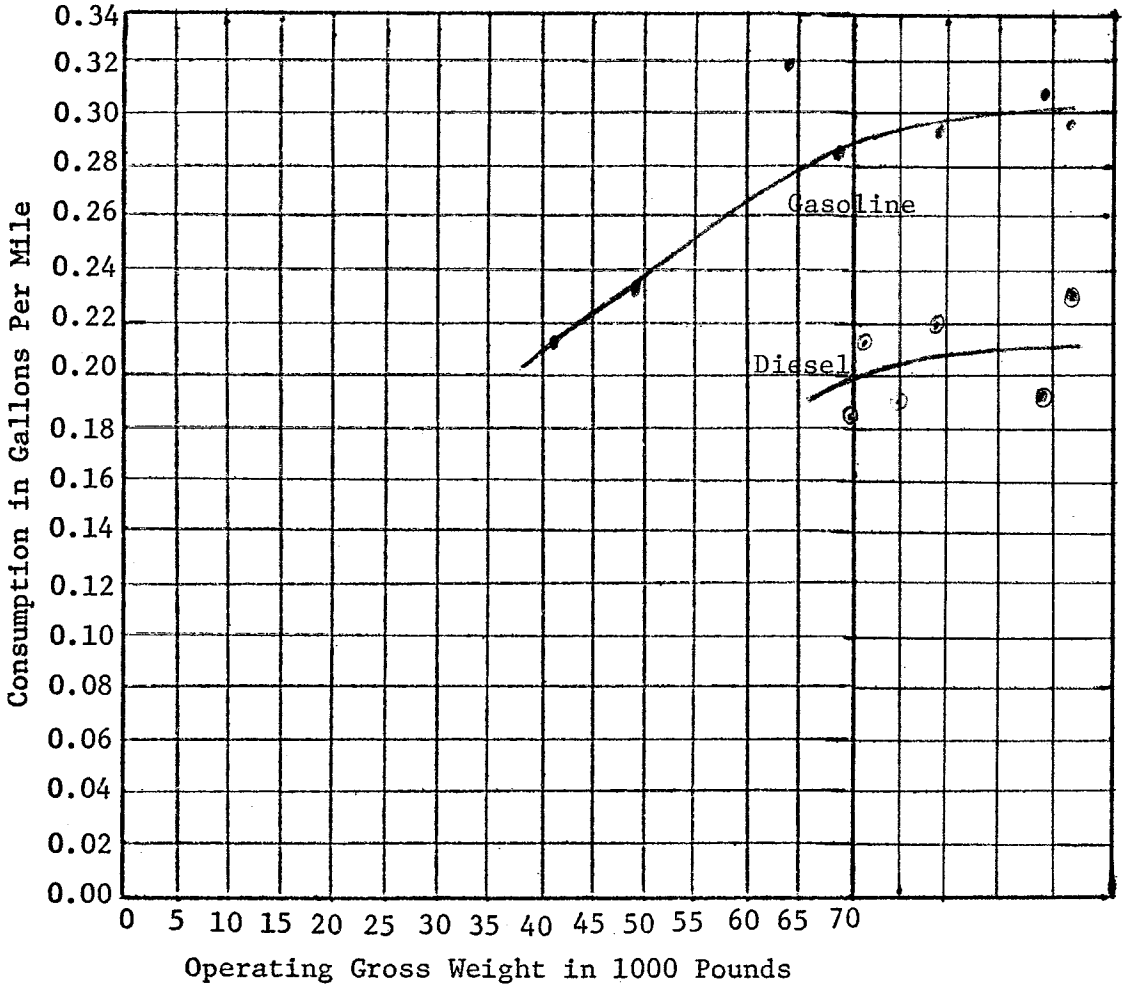


TABLE 46.--Fuel Consumption Rates for 2-S1-2, 2-S2-2, 3-S1-2, and 3-S2-3 Axle Groups by Operating Gross Weight, Line-Haul Trucking Costs Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
65,000	.280	.189	1.49
72,000	.290	.200	1.45
80,000	.297	.209	1.43
90,000	.301	.210	1.43

1 Derived from the curves shown in Figure 21.

FIGURE 22.--Fuel Consumption Rates for 2-S1-2 Axle Group by Operating Gross Weight, University of Washington Study

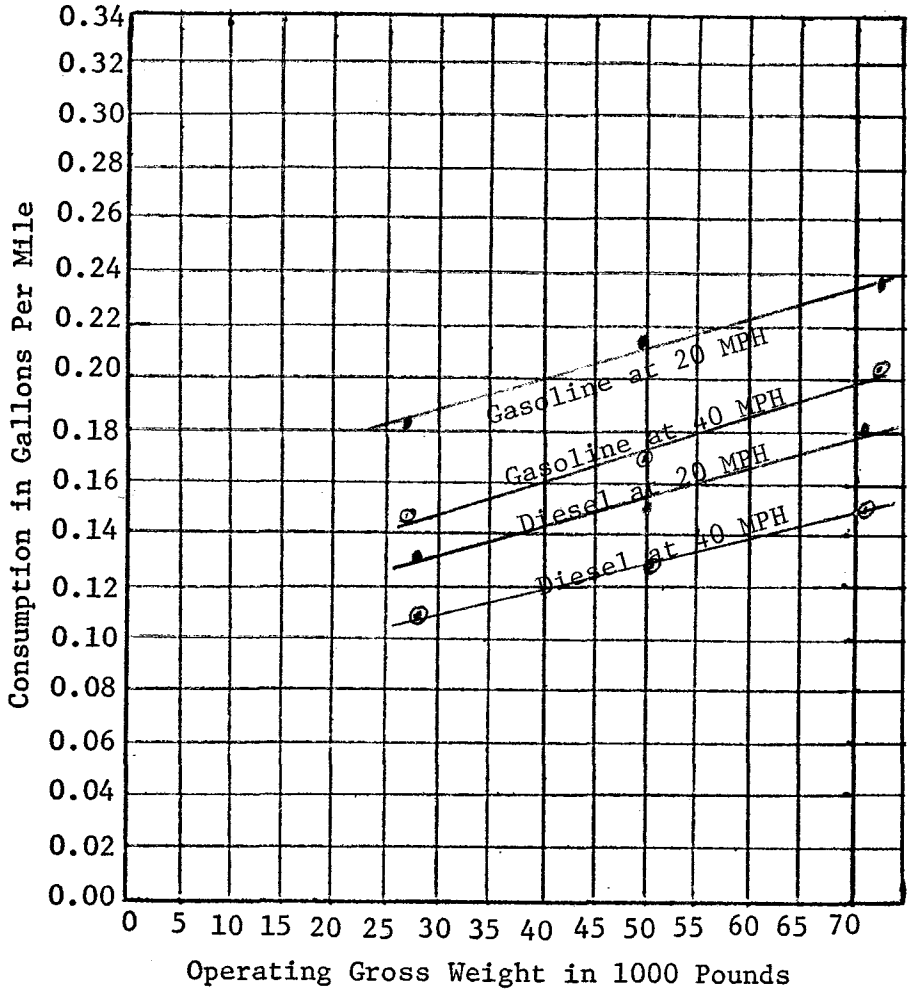


TABLE 47.--Fuel Consumption Rates for 2-S1-2 Axle Group by Operating Gross Weight, University of Washington Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile					
	At 20 Miles Per Hour			At 40 Miles Per Hour		
	Gasoline	Diesel	Ratio of Gasoline to Diesel	Gasoline	Diesel	Ratio of Gasoline to Diesel
27,000	.182	.133	1.37	.147	.110	1.34
50,000	.213	.152	1.40	.172	.129	1.33
72,000	.238	.181	1.31	.200	.150	1.33

Figure 23 and Table 48 present the findings on the above axle combinations. The freehand gasoline and diesel fuel consumption curves are much like that of the 3-S2's, as reported in Figure 20, from the same study. But both are in between the composite curves presented in Figure 11. The ratios are very similar to those found by the Motor Vechicle Classification Study for all axle groups combined. This was the study which showed the lowest ratios of all studies covered in this report.

The University of Washington Study gave some indication of the fuel consumption rates of the 2-2 and 3-2 axle groups. Tests were made on a 2-2 gasoline powered vehicle and a 3-2 diesel powered vehicle. As in the case of the other University of Washington test vehicles, these two vehicles were tested under empty, part loaded and fully loaded conditions.

A comparison was made of the fuel consumption rates of the two vehicles. The freehand fuel consumption curves are presented in Figure 24, and the derived fuel consumption rates and ratios are presented in Table 49. The 40 miles per hour rates and ratios are used for comparison purposes. It should be pointed out that such ratios are considerably greater than those reported in the Line-Haul Study.

Comparison of All Axle Groups

Table 50 presents a comparison of the gasoline to diesel fuel consumption ratios by axle group and study and relates them to the ratios derived from the composite curves of Figure 11. Although data gaps are evident, there are data for the weight groups that represent a majority of the vehicles of each axle group.

FIGURE 23.--Fuel Consumption Rates for 2-2, 2-3, 3-2, and 3-3 Axle Groups by Operating Gross Weight, Line-Haul Trucking Costs Study

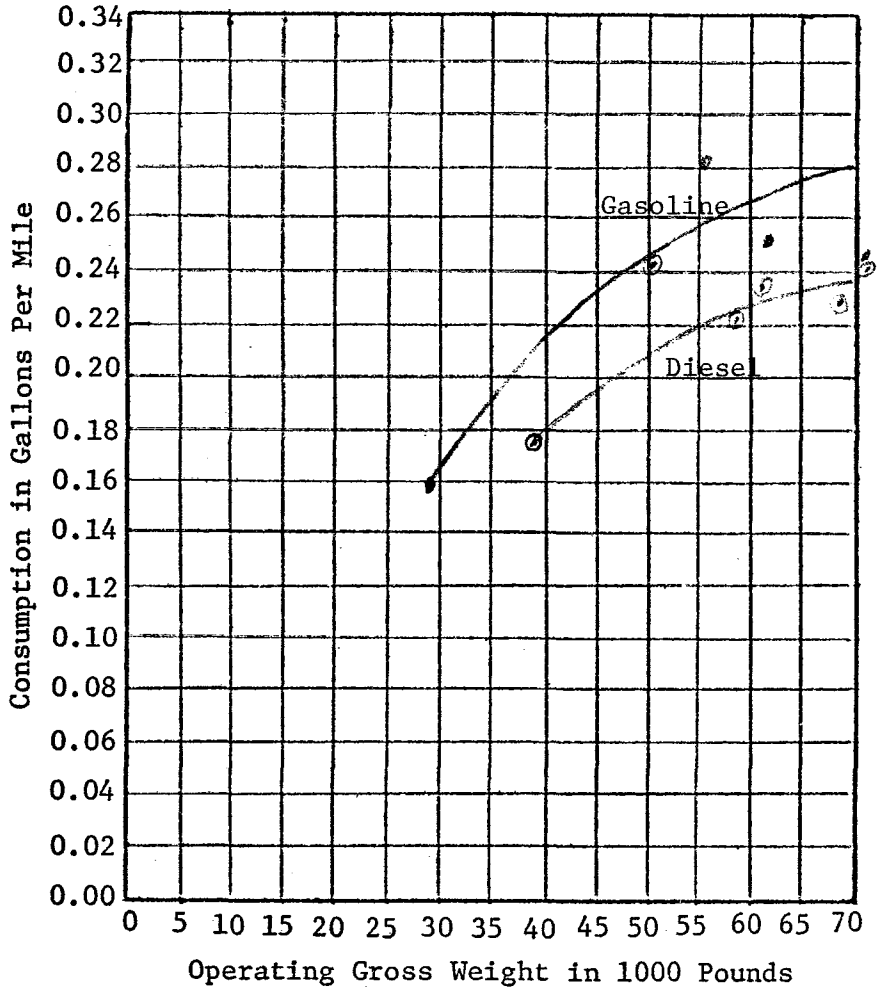


TABLE 48.--Fuel Consumption Rates for 2-2, 2-3, 3-2, and 3-3 Axle Groups by Operating Gross Weight, Line-Haul Trucking Costs Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]		
	Gasoline	Diesel	Ratio of Gasoline to Diesel
40,000	.217	.179	1.21
50,000	.247	.210	1.18
60,000	.269	.229	1.17
70,000	.287	.237	1.21

1 Derived from the curves reported in Figure 23.

FIGURE 24.--Fuel Consumption Rates for 2-2 and 3-2 Axle Groups by Operating Gross Weight, University of Washington Study

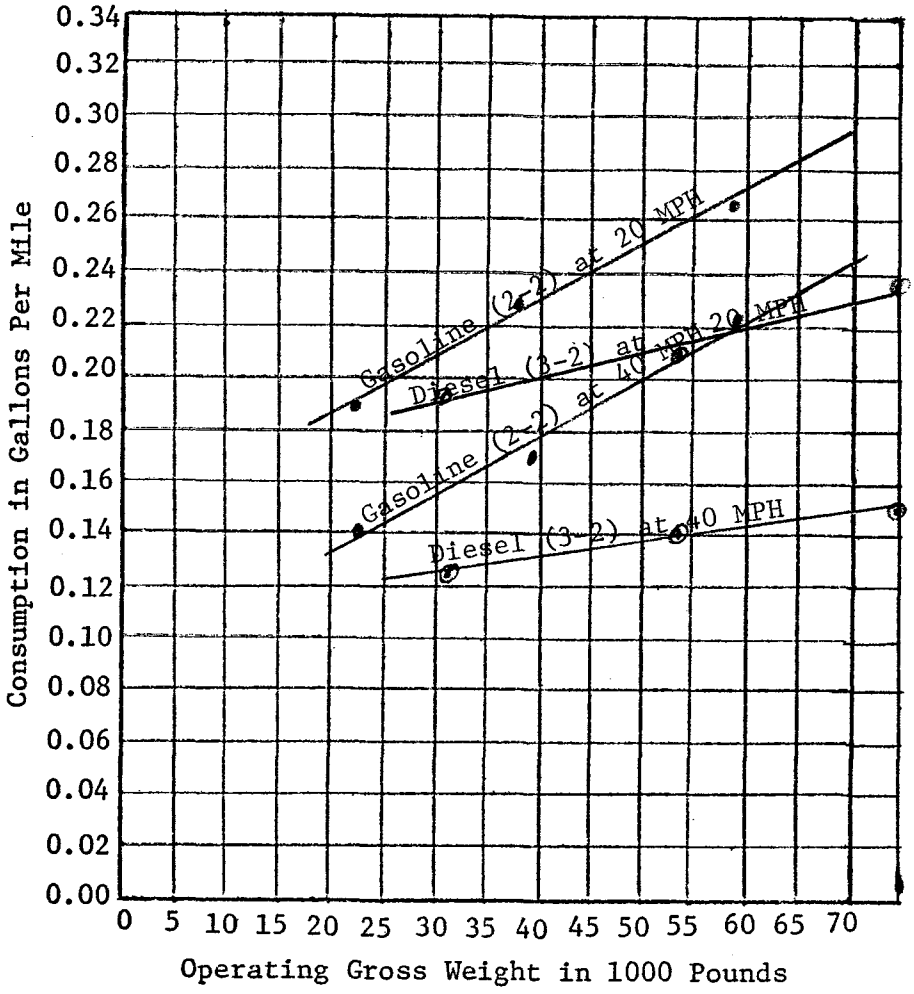


TABLE 49.--Fuel Consumption Rates for 2-2 and 3-2 Axle Groups by Operating Gross Weight, University of Washington Study

Operating Gross Weight in Pounds	Fuel Consumption in Gallons Per Mile[1]					
	At 20 Miles Per Hour			At 40 Miles Per Hour		
	Gasoline	Diesel	Ratio of Gasoline to Diesel	Gasoline	Diesel	Ratio of Gasoline to Diesel
30,000	.209	.181	1.15	.155	.125	1.29
40,000	.230	.200	1.15	.177	.132	1.34
50,000	.251	.210	1.20	.199	.137	1.45
60,000	.273	.218	1.25	.221	.143	1.55
70,000	.295	.228	1.29	.242	.149	1.62

1 Derived from the curves shown in Figure 24.

TABLE 50

Fuel Consumption Ratios for Axle Groups Calculated From Various Studies By Gross Operating Weight

Operating Gross Weight in Pounds	Ratio of Gasoline to Diesel Fuel Consumption by Axle Group and Study[1]										
	2-S1	2-S2		3-S2			2-S1-2, 2-S2-2, 3-S2-3, 3-S1-2		2-2, 2-3, 3-2, 3-3		Composite of Five Studies[4]
	L-H	L-H	U-W	L-H	F-T	U-W	L-H	U-W[2]	L-H	U-W[3]	
25,000	-	-	1.30	-	-	2.01	-	1.33	-	-	1.21
30,000	-	-	1.32	-	1.56	1.99	-	1.33	-	1.29	1.25
35,000	-	-	1.32	-	1.54	1.97	-	1.33	-	1.31	1.28
40,000	1.46	1.41	1.33	-	1.54	1.95	-	1.33	1.21	1.34	1.31
45,000	1.51	1.46	1.34	-	1.53	1.92	-	1.33	1.18	1.39	1.34
50,000	1.56	1.49	1.34	1.21	1.52	1.88	-	1.33	1.18	1.45	1.37
55,000	1.57	1.53	1.35	1.22	1.51	1.87	-	1.33	1.17	1.50	1.39
60,000	-	-	-	1.22	1.50	1.87	-	1.33	-	1.55	1.41
65,000	-	-	-	1.23	1.50	1.87	-	1.33	-	1.59	1.43
70,000	-	-	-	1.23	-	1.85	1.46	1.33	-	1.62	1.45

1 Derived from studies giving axle group data as follows: Line-Haul Trucking Cost Study (L-H), University of Washington Study (U-W), and Fuel and Time Consumption Study (F-T). The ratios of the University of Washington Study are those representing a constant speed of 40 miles per hour on level pavement.

2 Represents only the 2-S1-2 axle group.

3 Represents a 2-2 gasoline and 3-2 diesel vehicle.

4 Represents all the above axle types and is based on five studies, including two of the above studies.

APPENDIX C

LIST OF REFERENCES

LIST OF REFERENCES

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