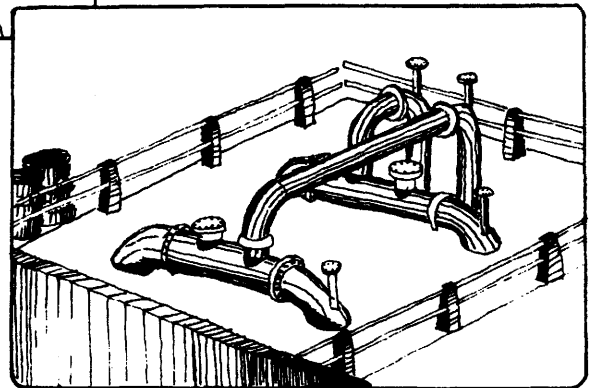
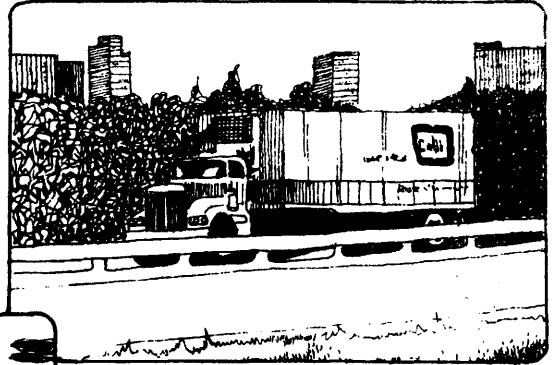
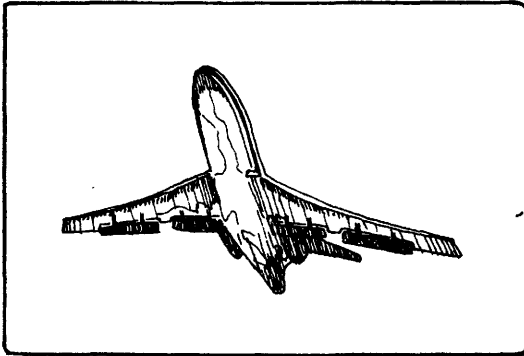


TRENDS IN TEXAS TRANSPORTATION FUEL CONSUMPTION

TECHNICAL REPORT 1059-1
STUDY 2-10-79-1059



TEXAS
TRANSPORTATION
INSTITUTE
TEXAS A&M UNIVERSITY

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

In Cooperation with
the Department of Transportation
Urban Mass Transportation Administration

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TRENDS IN TEXAS TRANSPORTATION
FUEL CONSUMPTION

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Research Study Number 2-10-79-1059

Sponsored by
State Department of Highways and Public Transportation

In Cooperation with the
Department of Transportation
Urban Mass Transportation Administration

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

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DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Urban Mass Transportation Administration or the State Department of Highways and Public Transportation. The report does not constitute a standard, a specification, or a regulation.

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ABSTRACT

As a result of the shortages experienced after the 1973 Arab Oil Embargo and again in the summer of 1979, considerable attention has been focused on energy availability and the relationship between transportation and energy. The energy policies developed in the next few months may change the manner in which the transportation system is allowed to function in the near future. In order for decision makers and appropriate officials to fully understand the possible effect of energy-related actions on the operation of the transportation system, a reliable data base must exist.

Considerable data have been published in recent years concerning transportation energy consumption. This report documents the more relevant data as those data relate to transportation in Texas. In addition, estimates of past, present, and future transportation energy consumption, by mode, in the state are presented. These data will form the basis of analyses to be documented in subsequent project reports.

Key words: Energy, Transportation Fuel Consumption, Fuel Efficiency, Transportation Energy

SUMMARY

As a major user of energy, the transportation sector accounts for approximately 25 percent of the total energy consumed in the United States, and about 18 percent of the energy consumed in Texas. In 1970, over 7.3 billion gallons (27.6 billion liters) of fuel were consumed by the transportation sector in Texas. This figure increased to 10.9 billion (41.3 billion liters) in 1978, and it is expected to reach 11.6 billion (43.9 billion liters) by 1990. Highway modes of transportation accounted for 86 percent of the 7.3 billion gallons (27.6 billion liters) consumed in 1970. This percentage should decrease to 80 percent by 1990 due to increased vehicle fuel efficiency.

Estimates of 1970, 1978, and 1990 transportation fuel consumption by mode indicate that, even without a severe shortage of fuel, future increases in fuel consumption can be expected to be relatively small. In fact, highway consumption of gasoline will actually decrease slightly. Nevertheless, any attempts to bring about large-scale reductions in transportation fuel consumption will need to be directed toward the highway modes of transportation since these modes will continue to consume the majority of transportation fuel.

IMPLEMENTATION STATEMENT

Since the 1973 Arab Oil Embargo, considerable attention has been focused on energy issues with particular attention directed to those users of energy that depend heavily on petroleum products. The transportation sector, which uses 18 percent of total energy consumed in Texas, also uses 60 percent of total petroleum consumed nationwide. With the recent petroleum shortage and the rising cost of petroleum products across the nation, many governmental programs have been proposed at the federal level that would significantly impact energy availability in the transportation sector.

As such programs are developed, certain factors must be considered. For example, the transportation sector is the largest user of petroleum products; however, unlike several other sectors of the economy, only limited opportunities for using alternative energy sources are available to serve the demands of transportation in the near future.

Also, transportation programs implemented at the federal level will influence different states in different manners. The transportation system in Texas is not necessarily similar to the "average" U.S. system; Texas is more auto oriented for both intracity and intercity travel. Vehicle miles of travel per capita are higher in Texas than is the national average. The state is also large; urban areas have developed at low densities, and considerable travel distances exist between these urban areas. Modal alternatives such as the train service available in the northeastern states do not exist in Texas.

As a consequence, decision-makers in Texas need to be aware of the potential impacts on the state's transportation system that would result from various federal legislative actions concerning energy availability and cost.

The background information presented in this initial report should provide officials and decision makers at the state level with a factual basis for deciding which course of action should be pursued in the near future. This type of information should prove valuable in formulating the policy of the state concerning possible federal legislative actions which may influence transportation energy availability and cost in Texas.

INTRODUCTION

The transportation system in Texas is a major user of energy. In many respects, the excellent transportation system in the state is responsible for the vibrant economy of the state. As a consequence, any conservation efforts that will impact the functioning of the transportation system in Texas require careful evaluation.

As such conservation programs are developed, certain factors must be considered. For example, the transportation sector is the largest user of petroleum products; however, unlike several other sectors of the economy, only limited opportunities for using alternative energy sources are available to serve the demands of transportation in the near future.

Also, transportation programs implemented at the federal level will influence different states in different manners. The transportation system in Texas is not necessarily similar to the "average" U. S. system; Texas is more auto oriented for both intracity and intercity travel. Vehicle miles of travel per capita are higher in Texas than is the national average. The state is also spread out; urban areas have developed at low densities, and considerable travel distances exist between these urban areas. Modal alternatives such as the frequent train service available in the northeastern states do not exist in Texas.

This report, which presents a data base relating transportation and energy in Texas, is the first in a series that will address energy and transportation in Texas. It is divided into four major sections. The first section documents data which relate transportation energy consumption to total energy consumption. The second section describes historical and current trends in highway motor fuel consumption in Texas, and the third section presents estimates of 1970,

1978 and 1990 transportation energy consumption by mode in Texas. The final section documents certain conclusions.

Subsequent reports will identify the policies being considered at the federal level that may affect transportation energy availability and will define the magnitude of that impact. In addition, estimates of the effect on the Texas transportation system that would result from implementation of the various federal actions will be presented. Finally, a general assessment of the effect on the Texas economy which would result from the adverse impacts on the transportation system will be developed.

TRANSPORTATION ENERGY CONSUMPTION

Having developed during a period of time when energy was readily available and relatively inexpensive, the State of Texas presently has an excellent transportation system that is essential to the economic prosperity of the state. The ability of this system to serve the transportation needs of the state depends on an adequate supply of energy being available.

However, the development of energy legislation at the federal level creates uncertainties regarding future energy availability in the state. For example, suggested rationing or fuel allocation programs could greatly reduce the energy supply available in Texas. Because the transportation system cannot change rapidly (e.g., all urban areas cannot immediately purchase, obtain, and begin operating extensive new bus service), the impact on, and the capabilities of, the existing system to function effectively under a condition of reduced energy supply are unknown.

The transportation system of Texas and the energy consumed by that system are not necessarily representative of the "average" U.S. system; as a consequence, federal legislation which is based on average data may have a disproportionately large impact on Texas. This has been a significant issue in recent Congressional debates over "standby" gasoline rationing authority.

For example, a comparison of data relating the transportation system of Texas to the "average" transportation system in the U.S. reveals that:

- Population densities within the urban areas of Texas are lower. Seventy-five percent of the population of Texas resides in urban areas. Population densities within these urban areas are in the range of 2,000 to 4,000 persons per square mile (772 to 1,544 persons per square kilometer). Nationally, however, many major

cities have densities in excess of 10,000 persons per square mile (3,861 persons per square kilometer).

- Travel distances between urban areas in Texas are greater. Although Texas has the population centers to generate large volumes of intercity travel, the intercity travel distances are greater than the national average. In Texas there is one standard metropolitan statistical area (SMSA) every 38,000 square miles (98,420 square kilometers); nationwide, there is one SMSA every 28,000 square miles (72,520 square kilometers).
- The development of Texas has been more auto oriented. Texas has developed as an auto oriented state. Consequently, alternate modes of transportation are not readily available to serve large volumes of trips. For example, in intracity travel, existing transit systems scarcely serve 2 percent of the total urban trips.
- Per capita consumption of transportation energy in Texas is higher. The transportation sector accounts for only 18 percent of the total energy consumed in Texas. However, due to the dispersed nature of development in Texas, the high dependence on the automobile to serve travel demands, and a variety of other reasons, per capita consumption of transportation energy in Texas is somewhat higher than the national average. For example, in 1970, 653 gallons (2,472 liters) of transportation fuel per capita were consumed in Texas, whereas 606 gallons (2,294 liters) per capita were consumed in the U.S.

In addition, the private automobile continues to represent the major mode of transportation in the State of Texas. Several factors influencing and/or describing auto travel patterns and fuel consumption in Texas and the United States are shown in Table 1. Travel descriptors, such as registered vehicles per person and vehicle-miles of travel per person, for Texas exceed the corresponding U.S. values by approximately 10 percent.

Table 1: Estimates of Travel Indicators for 1978

Travel Indicator	Texas	U.S.
Population (millions)	13.0	217.9
Licensed Drivers (millions)	8.4	141.5
Registered Vehicles (millions)	9.6	148.8
Vehicles Per Person	0.74	0.68
Vehicles Per Licensed Driver	1.14	1.05
Gallons of Highway Gasoline Consumed/Year (billions)	8.4	110.5
Highway Gasoline Consumed Per Vehicle/Week (gallons)	16.8	14.3
Highway Gasoline Consumed Per Capita Per Year (gallons)	646.0	507.0
Vehicle-Miles of Travel Per Year (billions)	100.0	1508.3
Percent Urban	57.0	56.0
Vehicle-Miles Per Person Per Year	7700.0	6900.0

Note: 1 gallon = 3.785 liters; 1 mile = 1.609 kilometers

Source: References 1 and 2

TRENDS IN HIGHWAY MOTOR FUEL CONSUMPTION

In 1970, it was estimated that over 86 percent of the total transportation fuel consumption in Texas was by highway modes of transportation; the great majority of this was by the automobile (Table 2). This percentage is expected to decrease by 5 percent by the year 1990. As a result, any attempts to bring about large-scale reductions in transportation fuel consumption will need to be directed toward the highway modes of transportation.

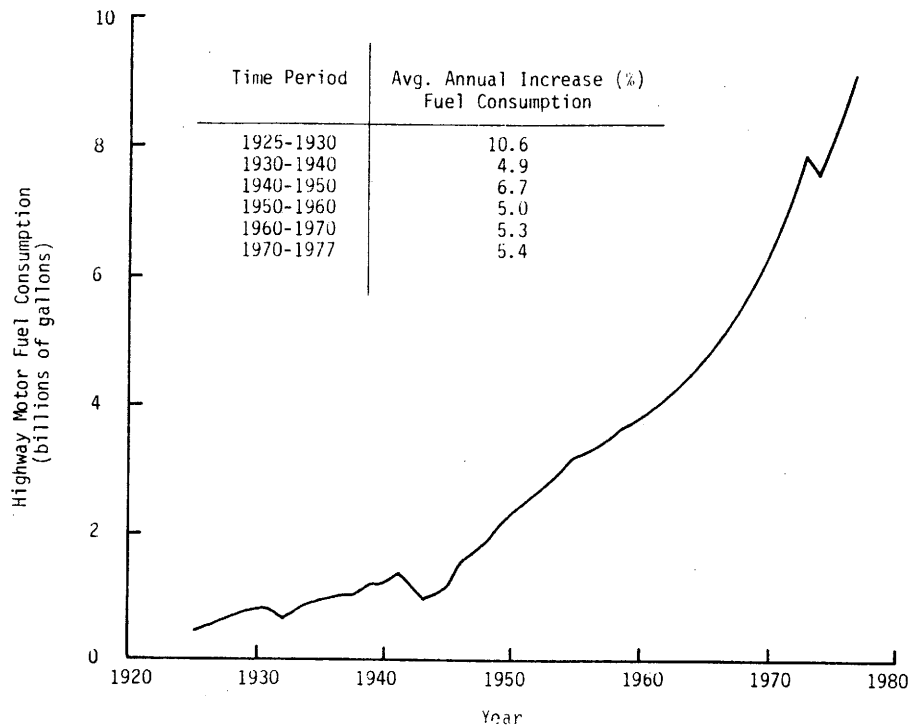
Table 2: Estimated Highway and Non-Highway Use of Transportation Fuel in Texas for 1970, 1978, and 1990

Mode	Percentage of Total Transportation Fuel Consumption		
	1970	1978	1990
Highway	86.5	84.7	80.2
Automobile	73.1	72.4	62.6
Truck	13.0	12.1	17.2
Bus	0.4	0.2	0.4
Non-Highway	13.5	15.3	19.8
Railroad	3.3	2.9	3.5
Air	7.1	9.6	12.5
Water	0.4	0.4	0.5
Oil Pipeline	2.7	2.4	3.3
Total	100.0	100.0	100.0

Source: Assumptions and analyses documented in the Appendices.

Highway Motor Fuel Consumption 1925-1977

A review of historical data reveals that, in spite of recent conservation efforts, highway motor fuel consumption in Texas from 1925 to 1977 continued to increase (Figure 1).



Note: 1 gallon = 3.785 liters

Source: Reference 3

Figure 1: Texas Highway Motor Fuel Consumption, 1925-1977

Specific figures associated with the historical consumption of gasoline and special fuels (diesel and liquified petroleum gas) for Texas and the annual percentage increase (decrease) in consumption are presented in Table 3. In 1925, approximately 442 million gallons (1.7 billion liters) of motor fuel was consumed in Texas. With the exception of four years (1932, 1942, 1943 and 1974), fuel consumption has steadily increased to the point that in 1977, over 9 billion gallons (34 billion liters) of motor fuel were consumed in travel on Texas highways. Of that figure, gasoline consumption accounted for 8.2 billion gallons (31 billion liters), while special fuel consumption represented 953 million gallons (3.6 billion liters).

Table 3: Highway Motor Fuel Consumption in Texas, 1925 to 1977

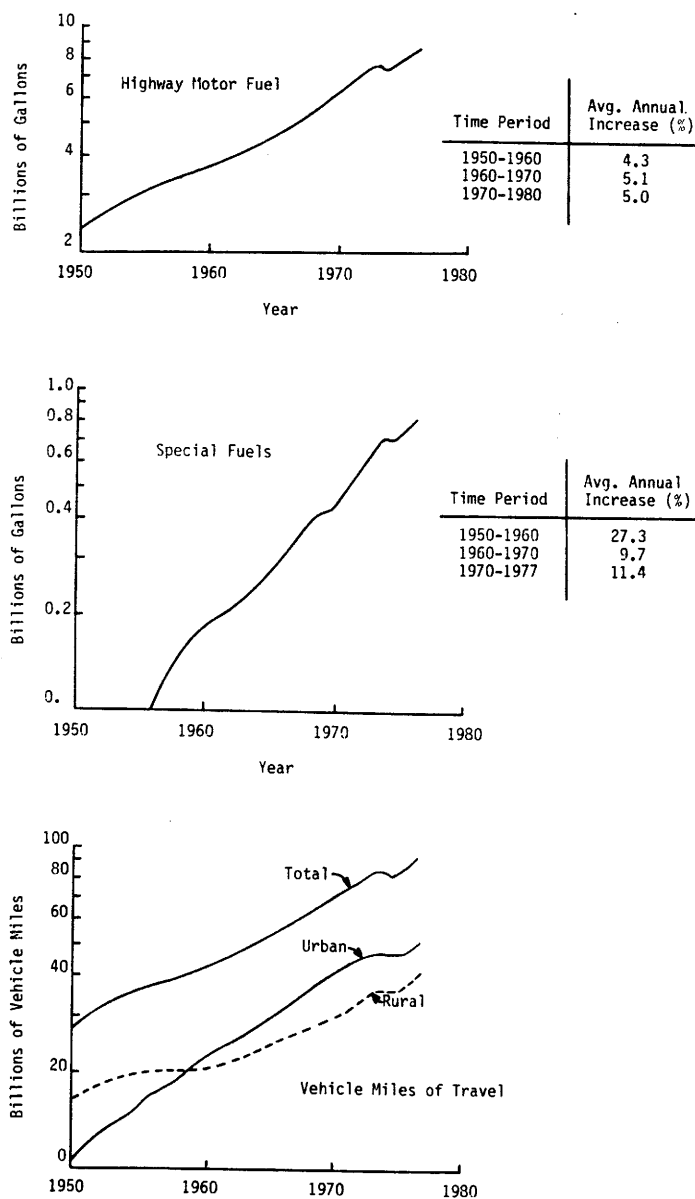
Year	Total Motor Fuel Consumption		Gasoline		Special Fuel	
	Millions of Gallons	Percent Inc.	Millions of Gallons	Percent Inc.	Millions of Gallons	Percent Inc.
1925	442	-				
1926	496	12.2				
1927	563	13.5				
1928	644	14.4				
1929	741	15.1				
1930	749	1.1				
1931	773	3.2				
1932	687	(11.1)				
1933	724	5.4				
1934	804	11.0				
1935	851	5.8				
1936	974	14.5				
1937	1057	8.5				
1938	1090	3.1				
1939	1145	5.0				
1940	1204	5.2				
1941	1348	12.0				
1942	1153	(14.5)				
1943	967	(16.1)				
1944	1013	4.8				
1945	1173	15.8				
1946	1531	30.5				
1947	1692	10.5				
1948	1868	10.4				
1949	2065	10.5	2053	-	12.4	-
1950	2357	14.1	2339	13.9	18.1	46.0
1951	2496	5.9	2465	5.4	30.9	70.7
1952	2703	8.3	2653	7.6	49.6	60.5
1953	2810	4.0	2753	3.8	56.8	14.5
1954	2924	4.1	2858	3.8	65.6	15.5
1955	3161	8.1	3080	7.8	80.8	23.2
1956	3271	3.5	3165	2.8	105.6	30.7
1957	3364	2.8	3238	2.3	125.8	19.1
1958	3500	4.0	3357	3.7	143.3	13.9
1959	3691	5.5	3524	5.0	167.0	16.5
1960	3729	1.0	3547	0.7	181.2	8.5
1961	3868	3.7	3673	3.6	195.1	7.7
1962	4019	3.9	3817	3.9	201.8	3.4
1963	4212	4.8	3996	4.7	216.1	7.1
1964	4484	6.5	4235	6.0	249.0	15.2
1965	4677	4.3	4396	3.8	280.6	12.7
1966	4928	5.4	4607	4.8	320.4	14.2
1967	5169	4.9	4817	4.6	351.7	9.8
1968	5581	8.0	5186	7.7	395.4	12.4
1969	5952	6.6	5534	6.7	417.8	5.7
1970	6294	5.7	5841	5.5	453.0	8.4
1971	6715	6.7	6192	6.0	522.8	15.4
1972	7290	8.6	6694	8.1	596.4	14.1
1973	7821	7.3	7112	6.2	709.1	18.9
1974	7593	(2.9)	6885	(3.2)	707.4	(0.2)
1975	8006	5.4	7261	5.5	745.3	5.4
1976	8564	7.0	7735	6.5	829.1	11.2
1977	9129	6.6	8175	5.7	953.4	15.0

Note: 1 gallon = 3.785 liters

Source: Highway Statistics, Federal Highway Administration

Fuel Consumption and Vehicle-Miles of Travel 1950-1977

Trends in gasoline consumption, special fuel consumption and vehicle-miles of travel in Texas from 1950 to 1977 are presented in Figure 2.



Note: 1 gallon = 3.785 liters; 1 mile = 1.609 kilometers

Source: Reference 3

Figure 2: Trends in Gasoline Consumption, Special Fuel Consumption, and Vehicle-Miles of Travel in Texas, 1950-1977

As indicated in this figure, vehicle-miles of travel, both urban and rural, continued to increase between 1950 and 1977 with the most noticeable increase being in the category of urban vehicle-miles. Special fuel and total highway motor fuel consumption also showed significant increases, particularly special fuel consumption which experienced average annual increases of 27.3 percent from 1950 to 1960, 9.7 percent from 1960 to 1970, and 11.4 percent from 1970 to 1977.

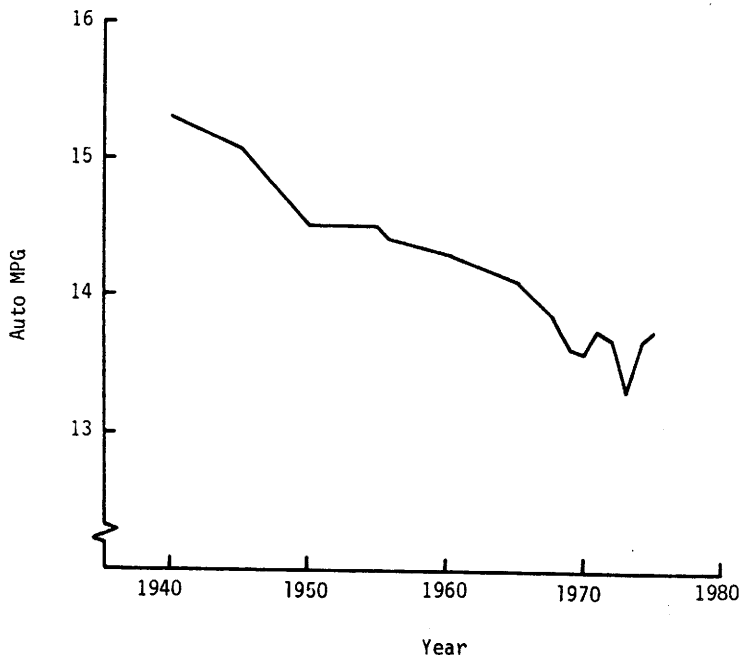
Two factors, however, are occurring that will result in a decline in the rate of increase in fuel consumption. First, new mandatory fuel efficiency standards (Table 4) will reduce the fuel demand per vehicle-mile of travel as new model years are introduced. The average fuel economy will increase from 18 miles per gallon (mpg) (7.6 km/liter) in 1978 to 27.5 miles per gallon (11.6 km/liter) by 1985. This will reduce the downward trend in average auto fuel efficiency (Figure 3). Second, vehicle availability per capita has historically been increasing; however, this component of increased travel has nearly reached a saturation point (Figure 4). Virtually all eligible drivers are licensed, and the ratio of registered vehicles per licensed driver in Texas is approximately 1.2.

Table 4: Auto Fuel Efficiency Standards

Model Year	Avg. Fuel Economy (mpg)
1978	18.0
1979	19.0
1980	20.0
1981	22.0
1982	24.0
1983	25.0
1984	27.0
1985	27.5

Note: 1 mpg = .42 km/liter

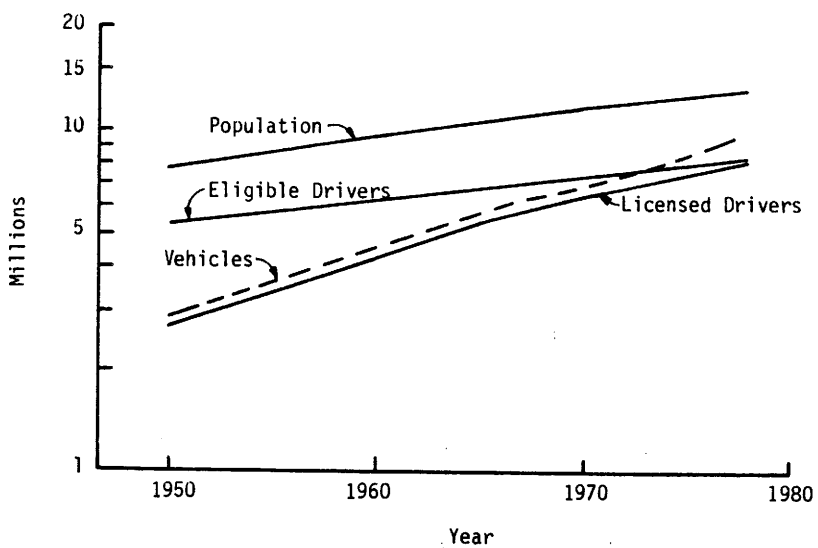
Source: References 4 and 5



Note: 1 mile per gallon = .42 km/liter

Source: Reference 3

Figure 3: Trends in Average Auto Fuel Efficiency, 1940-1975



Source: References 1 and 3

Figure 4: Trends in Vehicle Availability in Texas, 1950-1977

TRENDS IN MODAL FUEL CONSUMPTION

Estimates of 1970, 1978 and 1990 transportation fuel consumption by mode, for both person movement and goods movement, are presented in this section. Estimates of passenger-miles (or ton-miles) and fuel efficiencies for each mode are also presented. The analyses and assumptions used in developing these estimates are documented in the Appendices of this report.

Estimated 1970 Transportation Fuel Consumption by Mode

In 1970, over 7.3 billion gallons (27.6 billion liters) of fuel were consumed by the transportation sector in Texas (Table 5). Person movement by various modes represented 80.3 percent of this total while goods movement accounted for 19.7 percent.

Table 5: Estimated 1970 Transportation Fuel Consumption by Mode, Texas

Type of Transport	Passenger-Miles or Ton-Miles		Fuel Efficiency (passenger-miles or ton-miles per gallon)	Fuel Consumption	
	Miles (millions)	Percent of Total		Gallons (millions)	Percent of Total
<u>Person Movement, Total</u>	<u>122,053</u>	<u>100.0</u>	<u>21</u>	<u>5,875</u>	<u>80.3</u>
Urban, Total	55,394	45.4	16	3,381	46.2
Automobile	54,850	45.0	16	3,355	45.8
Bus	420	0.3	35	12	0.2
Taxi	124	0.1	9	14	0.2
Intercity, Total	66,659	54.6	27	2,494	34.1
Automobile	58,000	47.5	29	1,986	27.1
Air	6,900	5.7	14	493	6.7
Bus	1,400	1.1	125	11	0.2
Rail	359	0.3	80	4	0.1
<u>Goods Movement, Total</u>	<u>178,687</u>	<u>100.0</u>	<u>125</u>	<u>1,434</u>	<u>19.7</u>
Urban (truck), Total	1,732	1.0	4	433	5.9
Intercity, Total	176,955	99.0	177	1,001	13.8
Truck	27,200	15.2	52	520	7.1
Rail	47,180	26.4	200	236	3.2
Oil Pipelines	96,150	53.8	500	192	2.7
Intracoastal Waterway	6,210	3.5	220	28	0.4
Air	215	0.1	10	25	0.4
TOTAL	--	--	--	7,309	100.0

Note: 1 mile = 1.609 km; 1 gallon = 3.785 liters; 1 mile per gallon = .42 km/liter; 1 ton = 900 kg; 1 ton-mile = 1,448 kg-km; 1 ton-mile per gallon = 383 kg-km/liter

This fuel consumption resulted in over 122 billion passenger-miles (196 billion passenger-km) of travel and over 178 billion ton-miles (257×10^{12} kg-km) of goods movement.

Estimated 1978 Transportation Fuel Consumption by Mode

The amount of fuel consumed by the transportation sector in Texas increased to approximately 10.8 billion gallons (41 billion liters) in 1978 (Table 6). This represents a 49 percent increase over 1970 consumption levels. Of this total, person movement accounted for 8.9 billion gallons (33.7 billion liters). The private automobile alone, in both urban and intercity travel, consumed over 7.8 billion gallons (29.5 billion liters) of fuel. As a result, passenger-miles of travel for 1978 totaled 186 billion (299 billion passenger-km), and ton-miles of goods transport reached 240 billion (347×10^{12} kg-km).

Table 6: Estimated 1978 Transportation Fuel Consumption by Mode, Texas

Type of Transport	Passenger-Miles or Ton-Miles		Fuel Efficiency (passenger-miles or ton-miles per gallon)	Fuel Consumption	
	Miles (millions)	Percent of Total		Gallons (millions)	Percent of Total
<u>Person Movement, Total</u>	<u>186,576</u>	<u>100.0</u>	<u>21</u>	<u>8,924</u>	<u>81.9</u>
Urban, Total	81,861	43.9	17	4,910	45.1
Automobile	81,200	43.5	17	4,878	44.9
Bus	509	0.3	35	15	0.1
Taxi	152	0.1	9	17	0.2
Intercity, Total	104,715	56.1	26	4,014	36.8
Automobile	89,000	47.7	30	2,988	27.4
Air	14,200	7.6	14	1,014	9.3
Bus	1,410	0.7	125	11	0.1
Rail	105	0.1	80	1	-
<u>Goods Movement, Total</u>	<u>240,077</u>	<u>100.0</u>	<u>125</u>	<u>1,970</u>	<u>18.1</u>
Urban (truck), Total	2,520	1.1	4	630	5.8
Intercity, Total	237,557	98.9	177	1,340	12.3
Truck	36,000	15.0	52	692	6.3
Rail	63,000	26.2	200	315	2.9
Oil Pipelines	129,400	53.9	500	259	2.4
Intracoastal Waterway	8,820	3.7	220	40	0.4
Air	337	0.1	10	34	0.3
TOTAL	--	--	--	10,894	100.0

Note: 1 mile = 1.609 km; 1 gallon = 3.785 liters; 1 mile per gallon = .42 km/liter; 1 ton = 900 kg; 1 ton-mile = 1,448 kg-km; 1 ton-mile per gallon = 383 kg-km/liter

Estimated 1990 Transportation Fuel Consumption by Mode

In 1990, it is estimated that over 11.6 billion gallons (43.9 billion liters) of fuel will be consumed by the transportation sector in Texas (Table 7). This represents only a 7 percent increase in fuel consumption in spite of the fact that total passenger-miles are estimated to increase by 47 percent and ton-miles by 43 percent. Person movement is expected to represent 8.7 billion gallons (32.9 billion liters) while goods movement will account for approximately 2.9 billion gallons (11 billion liters).

Table 7: Estimated 1990 Transportation Fuel Consumption by Mode, Texas

Type of Transport	Passenger-Miles or Ton-Miles		Fuel Efficiency (passenger-miles or ton-miles per gallon)	Fuel Consumption	
	Miles (millions)	Percent of Total		Gallons (millions)	Percent of Total
<u>Person Movement, Total</u>	<u>273,129</u>	<u>100.0</u>	<u>31</u>	<u>8,722</u>	<u>75.1</u>
Urban, Total	119,899	43.9	26	4,542	39.1
Automobile	118,950	43.5	26	4,506	38.8
Bus	726	0.3	35	21	0.2
Taxi	223	0.1	15	15	0.1
Intercity, Total	153,230	56.1	37	4,180	36.0
Automobile	130,410	47.7	47	2,752	23.7
Air	19,610	7.2	14	1,401	12.1
Bus	3,060	1.1	125	25	0.2
Rail	150	0.1	80	2	-
<u>Goods Movement, Total</u>	<u>342,526</u>	<u>100.0</u>	<u>119</u>	<u>2,887</u>	<u>24.9</u>
Urban (truck), Total	3,456	1.0	4	864	7.4
Intercity, Total	339,070	99.0	168	2,023	17.5
Truck	59,000	17.2	52	1,135	9.8
Rail	81,000	23.7	200	405	3.5
Oil Pipelines	185,200	54.1	500	370	3.2
Intracoastal Waterway	13,350	3.9	220	61	0.5
Air	520	0.1	10	52	0.5
TOTAL	--	--	--	11,609	100.0

Note: 1 mile = 1.609 km; 1 gallon = 3.785 liters; 1 mile per gallon = .42 km/liter; 1 ton = 900 kg; 1 ton-mile = 1,448 kg-km; 1 ton-mile per gallon = 383 kg-km/liter

By 1990, passenger-miles of travel by various modes are expected to total 273 billion (439 billion passenger-km) and ton-miles of freight movement should reach 342 billion (495 x 10¹² kg-km).

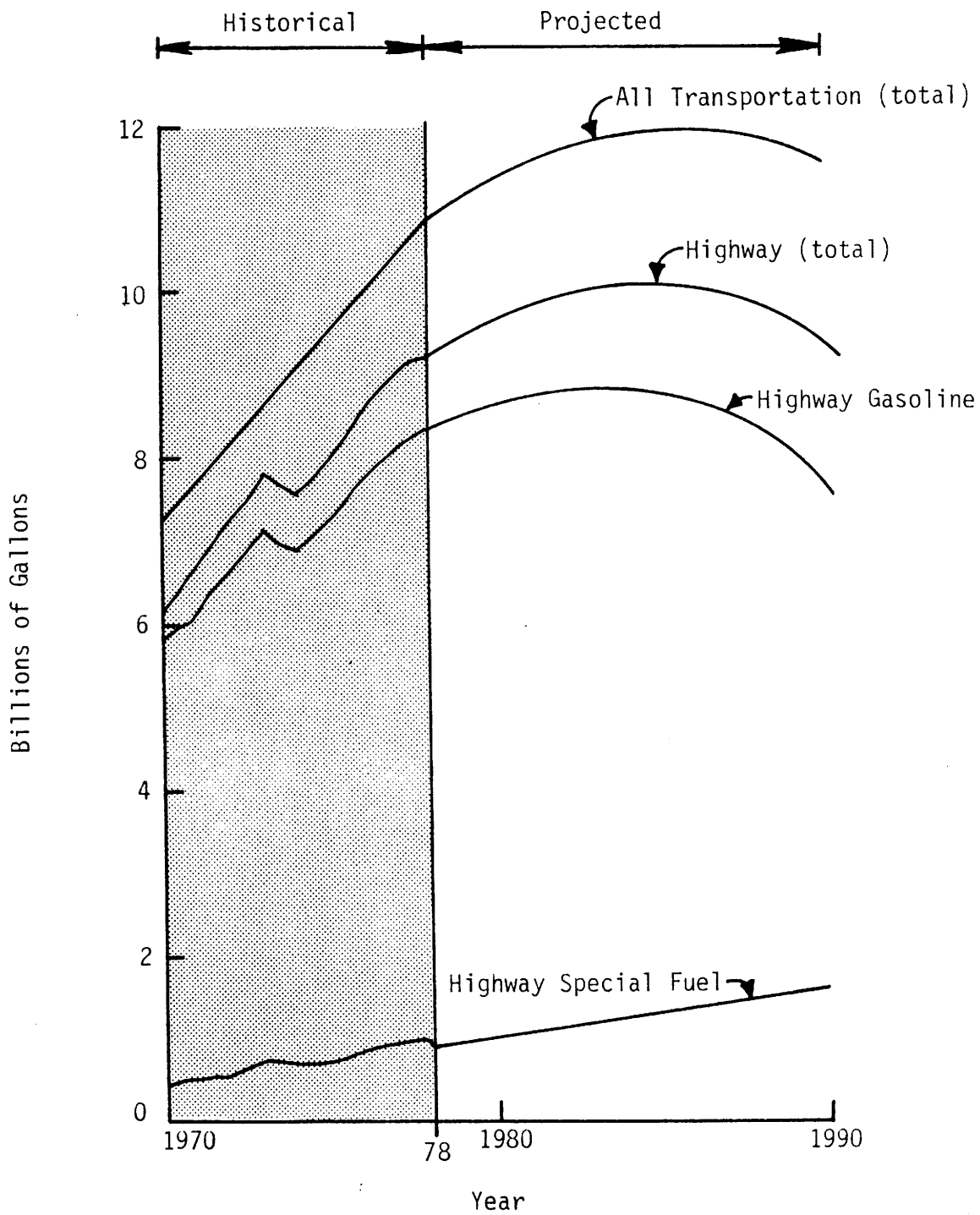
Comparison of 1970, 1978 and 1990 Estimates

A summary of the 1970, 1978 and 1990 estimates of transportation fuel consumption by mode is presented in Table 8. A comparison of that data reveals that, even without a severe shortage of fuel, future increases in transportation fuel can be expected to be relatively small. In fact, highway consumption of gasoline will actually decrease (Figure 5). These decreases in consumption are the result of increased fuel efficiency for automobile travel and a saturation level of licensed drivers and vehicles (as discussed in the previous section). Significant increases in the price of fuel or limitation in supply through allocation or rationing programs should result in an even greater reduction in total fuel consumption by the transportation sector.

Table 8: Summary of 1970, 1978 and 1990 Estimates of Transportation Fuel Consumption by Mode in Texas

Type of Transport	Fuel Consumption 1970		Fuel Consumption 1978		Fuel Consumption 1990	
	Gallons (millions)	Percent of Total	Gallons (millions)	Percent of Total	Gallons (millions)	Percent of Total
<u>Person Movement, Total</u>	<u>5,875</u>	<u>80.3</u>	<u>8,925</u>	<u>81.9</u>	<u>8,722</u>	<u>75.1</u>
Urban, Total	3,381	46.2	4,910	45.1	4,542	39.1
Automobile	3,355	45.8	4,878	44.8	4,506	38.8
Bus	12	0.2	15	0.1	21	0.2
Taxi	14	0.2	17	0.2	15	0.1
Intercity, Total	2,494	34.1	4,014	36.8	4,180	36.0
Automobile	1,986	27.1	2,988	27.4	2,752	23.7
Air	493	6.7	1,014	9.3	1,401	12.1
Bus	11	0.2	11	0.1	25	0.2
Rail	4	0.1	1	-	2	-
<u>Goods Movement, Total</u>	<u>1,434</u>	<u>19.7</u>	<u>1,970</u>	<u>18.1</u>	<u>2,887</u>	<u>24.9</u>
Urban (truck), Total	433	5.9	630	5.8	864	7.4
Intercity, Total	1,001	13.8	1,340	12.3	2,023	17.5
Truck	520	7.1	692	6.3	1,135	9.8
Rail	236	3.2	315	2.9	405	3.5
Oil Pipelines	192	2.7	259	2.4	370	3.2
Intracoastal Waterway	28	0.4	40	0.4	61	0.5
Air	25	0.4	34	0.3	52	0.5
TOTAL	7,309	100.0	10,894	100.0	11,609	100.0

Note: 1 mile = 1.609 km; 1 gallon = 3.785 liters; 1 mile per gallon = .42 km/liter; 1 ton = 900 kg;
1 ton-mile = 1,488 kg-km; 1 ton-mile per gallon = 383 kg-km/liter



Note: 1 gallon = 3.785 liters

Figure 5: Estimated Transportation Fuel Consumption in Texas, 1970-1990

CONCLUSIONS

The transportation system in Texas requires an adequate supply of energy in order to function satisfactorily. In reviewing various federal legislation relating to energy availability, it needs to be realized that, in terms of factors such as auto orientation and density of development, Texas is not necessarily an "average" state; both travel demand and transportation energy consumption per capita in Texas exceed nationwide averages.

Of total transportation energy consumed in Texas, over 80% is used by highway modes of transportation. With the exception of 4 years, highway fuel consumption has increased every year since 1925.

Estimates developed in this report suggests that all Texas transportation consumed 7.3 billion gallons (27.6 billion liters) of fuel in 1970 and 10.8 billion gallons (40.9 billion liters) in 1978. It is projected that some 11.6 billion gallons (43.9 billion liters) of fuel will be consumed by transportation in Texas in 1990.

Thus, relative to historical increases in transportation fuel consumption, future increases can be expected to be relatively small. In fact, highway consumption of motor fuels will actually peak in the mid 1980's, and 1990 consumption will be less than 1978 consumption. This is the combined result of new auto fuel efficiency standards plus a saturation level that will occur in a major travel indicator (registered vehicles per licensed driver).

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APPENDICES

APPENDICES

Appendices A, B, and C document the analyses and assumptions used in developing estimates of fuel consumption by mode of transportation for 1970, 1978 and 1990. Fuel consumption estimates are presented for both urban and intercity travel in Texas. In addition, fuel efficiencies and passenger-miles (or ton-miles) of travel are also calculated. These estimates of fuel consumption, fuel efficiency and passenger-miles (ton-miles) were used in the development of Tables 3, 6, 7, 8 and 9 of this report.

The Appendices are divided into the following nine sections:

- Appendix A-1: 1970 Estimates of Fuel Consumption for Intercity Person Movement by Mode of Transportation in Texas
- Appendix A-2: 1970 Estimates of Fuel Consumption for Urban Person Movement by Mode of Transportation in Texas
- Appendix A-3: 1970 Estimates of Fuel Consumption for Goods Movement by Mode of Transportation in Texas
- Appendix B-1: 1978 Estimates of Fuel Consumption for Intercity Person Movement by Mode of Transportation in Texas
- Appendix B-2: 1978 Estimates of Fuel Consumption for Urban Person Movement by Mode of Transportation in Texas
- Appendix B-3: 1978 Estimates of Fuel Consumption for Goods Movement by Mode of Transportation in Texas
- Appendix C-1: 1990 Estimates of Fuel Consumption for Intercity Person Movement by Mode of Transportation in Texas
- Appendix C-2: 1990 Estimates of Fuel Consumption for Urban Person Movement by Mode of Transportation in Texas
- Appendix C-3: 1990 Estimates of Fuel Consumption for Goods Movement by Mode of Transportation in Texas

APPENDIX A-1

1970 Estimates of Fuel Consumption for Intercity Person Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing the values for intercity person movement shown in Table 6. Data for 1970 were utilized, and at least two independent estimations of passenger-miles of intercity travel were made for each mode of transportation. These estimates were then averaged to acquire a final estimate for each mode. In addition, the fuel consumption and fuel efficiency were also calculated for each mode.

Population data are the basis of several computations in this Appendix. In 1970, the population of Texas was 11.2 million while the U.S. population was 200.3 million. The population of Texas was 5.5 percent of the U.S. population (1).*

AUTOMOBILE

Passenger-Miles

Estimate 1 -- U.S. Intercity Passenger-Miles

- The population of Texas was 5.5 percent of U.S. population (1).
- U.S. intercity passenger-miles by private auto totalled 1,026 billion (1,651 billion passenger-km) (2).
- $1,026 \text{ billion} \times 5.5\% = 56.4 \text{ billion intercity passenger-miles}$ (90.8 billion intercity passenger-km) by private auto in Texas.
- This method assumes that intercity passenger-miles by private auto in Texas were the same percentage of intercity passenger-miles by private auto in the U.S. as Texas population was of U.S. population.

Estimate 2 -- Daily Texas Intercity Miles

- State Department of Highways and Public Transportation manual count data reveal that approximately 90 percent of daily intercity vehicle-miles of travel are intercity miles of travel by private auto (includes pick-up trucks) (3).

* Refer to reference number listed at end of Appendices.

- Intercity vehicular travel totaled 28.8 billion vehicle-miles (46.3 billion vehicle-km) (4).
- 28.8 billion x 90% = 25.9 billion auto-miles (41.7 billion auto-km).
- The average occupancy of passenger vehicles in intercity travel is 2.3 persons (5).
- 25.9 billion x 2.3 = 59.6 billion passenger-miles (95.8 billion passenger-km) of intercity travel by private auto in Texas.
- This estimate is based on the total intercity vehicle-miles of travel in Texas. However, only 90 percent of this sum is intercity travel by private auto (3). After deriving intercity vehicle-miles of travel by private auto, the annual intercity passenger-miles are found by expanding vehicle-miles by the average number of passengers per private auto to get total annual passenger-miles of intercity travel by private auto in Texas.

Final Estimate -- Average

- By averaging the two preliminary estimates, a final estimate was acquired.

<u>Estimate</u>	<u>Method</u>
56.4 billion miles	Estimate 1 -- U.S. Intercity Passenger-Miles
<u>59.6 billion miles</u>	Estimate 2 -- Texas Intercity Vehicle-Miles
116.0 billion miles (186.6 billion km)	Total ÷ 2 = Average

- The final estimate of intercity passenger-miles of travel by private auto in Texas is 58 billion (93.3 billion km).

Fuel Efficiency

- A total of 5.84 billion gallons (22.1 billion liters) of gasoline was consumed in Texas (6). Total vehicular traffic equaled 68 billion miles (109 billion km) (4).
- 68 billion ÷ 5.84 billion = 11.64 miles per gallon (4.9 km per liter).
- The average fuel consumption of private autos in Texas was 11.64 miles per gallon (mpg). The fuel consumption for rural and urban travel can be found by using vehicle-miles traveled and a weighting factor (7).

Urban vehicle-miles = 39.2 billion (4)
 Rural vehicle-miles = 28.8 billion (4)
 x = urban fuel efficiency (mpg)
 14x/12 = rural fuel efficiency (mpg)

$$11.64 = \frac{39.2 (x) + 28.8 (14x/12)}{68.0}$$

$$x = 10.9 \text{ urban mpg}$$

Urban fuel consumption = 10.9 mpg (4.6 km/liter)

Rural fuel consumption = 12.7 mpg (5.3 km/liter)

- The fuel efficiency of the intercity auto can be found by multiplying the number of persons per vehicle-mile times the average miles per gallon.
- $2.3 \times 12.7 = 29.2$ passenger-miles per gallon (12.3 passenger-km per liter).

Fuel Consumption

- The amount of fuel consumed by intercity autos was calculated by dividing the total passenger-miles of intercity auto travel by the average number of miles per gallon.
- $58.0 \text{ billion} \div 29.2 = 1.986 \text{ billion gallons}$ (75.18 billion liters) of fuel consumed by intercity autos.

AIR

Passenger-Miles

Estimate 1 -- Ratio of Enplanements

- 10,039,886 Civil Aeronautics Board (CAB), Texas enplanements (8)
 + 234,910 Texas Aeronautical Commission (TAC) enplanements (9)
 10,274,796 Texas annual enplanements
- 169,668,000 Total U.S. enplanements (10)
 - 11,132 International enplanements (8)
 169,656,868 Annual domestic U.S. enplanements
- Total U.S. domestic intercity air passenger-miles of travel in 1970 were 119 billion (191 billion air passenger-km) (2).

- | | | | | | | |
|----------------------|---|-------------------|---|-----------------------------------|---|--|
| ● Texas enplanements | ÷ | U.S. enplanements | x | Domestic U.S. air passenger-miles | = | Air passenger-miles in Texas |
| (10,274,776 | ÷ | 169,656,868) | x | 119,000,000,000 | = | |
| 0.06 | | | x | 119,000,000,000 | = | 7.1 billion air passenger-miles
(11.9 billion air passenger-km)
in Texas |
- Estimate 1 -- Ratio of Enplanement is based on the assumption that the percentage of domestic U.S. enplanements represented by Texas enplanements can be applied to U.S. air passenger-miles to obtain an estimate of the total air passenger-miles for Texas.

Estimate 2 -- Population

- The population of Texas was 5.5 percent of U.S. population (1).
- Domestic U.S. air passenger-miles x 5.5% = air passenger-miles in Texas.
- 119 billion (2) x 5.5% = 6.5 billion air passenger-miles (10.5 billion air passenger-km) in Texas.
- The basis for this estimate is the assumption that air passenger-miles in Texas are equivalent to the same percent of domestic air passenger-miles in the U.S. as the population of Texas is to the U.S. population.

Estimate 3 -- Vehicle-Miles

- The final estimate for passenger-miles of intercity travel by private auto in Texas was 58.0 billion (93.3 billion passenger-km).
- | | | | | | | |
|--|---|--|---|--|---|--|
| ● Passenger-miles of intercity travel by private auto in Texas | x | Percent of total U.S. intercity travel by air (2). | ÷ | Percent of total U.S. intercity travel by private auto (2) | = | Number of intercity air passenger-miles in Texas |
| 58.0 | x | (10% ÷ 86%) | | | = | |
| 58.0 | x | .12 | | | = | 7.0 billion passenger-miles
(11.3 billion passenger-km) of intercity travel by air in Texas |
- The premise for Estimate 3 -- Vehicle-Miles is that the ratio of total U.S. passenger-miles of intercity travel by air to total U.S.

passenger-miles of intercity travel by private auto is the same as passenger-miles of intercity travel by air for Texas to passenger-miles of intercity travel by private auto for Texas.

Final Estimate -- Average

- The final estimate for air passenger-miles of intercity travel in Texas was obtained by averaging the estimates computed by the three methods.

<u>Estimate</u>	<u>Method</u>
7.1 billion miles	Estimate 1 -- Ratio of Enplanements
6.5 billion miles	Estimate 2 -- Population
<u>7.0 billion miles</u>	Estimate 3 -- Vehicle-Miles
20.6 billion miles (33.1 billion km)	Total ÷ 3 = Average

- Final estimate is 6.9 billion passenger-miles (11 billion passenger-km) of intercity air travel in Texas.

Fuel Efficiency

- The fuel efficiency of intercity air travel is 14 passenger-miles per gallon (5.9 passenger-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity air travel was determined by dividing the total passenger-miles of air travel in Texas by the average number of miles per gallon.
- 6.9 billion ÷ 14 = 493 million gallons (1.866 billion liters) of fuel consumed in intercity air travel in Texas.

BUS

Passenger-Miles

Estimate 1 -- Population

- 25 billion passenger-miles of intercity travel by bus in U.S. (2)
x 5.5% Texas population is 5.5% of U.S. population (1)
1.375 billion passenger-miles (2.2 billion passenger-km) of intercity travel by bus in Texas

- It is assumed that passenger-miles of intercity travel by bus in Texas and passenger-miles of intercity travel by bus in U.S. existed in the same ratio as Texas population and U.S. population.

Estimate 2 -- Share of the Market

- The final estimate for passenger-miles of intercity travel by private auto in Texas was 58.0 billion (93.3 billion passenger-km).

● Passenger-miles of intercity travel by private auto in Texas	x	Percent of total U.S. intercity travel by bus (2)	÷	Percent of total U.S. intercity travel by private auto (2)	=	Bus passenger-miles of intercity travel in Texas
58.0	x	(2.14%	÷	86%)	=	
58.0	x	.024			=	1.4 billion bus passenger-miles (2.3 billion bus passenger-km) of intercity travel in Texas

- The basis for this estimate is the ratio of total U.S. intercity travel by bus to total U.S. intercity travel by private auto.
- It was assumed that intercity bus passenger-miles in Texas were the same percentage of intercity auto passenger-miles in Texas as total intercity bus passenger-miles in the U.S. were to the total intercity auto passenger-miles in the U.S.

Estimate 3 -- Commercial Buses

- 3031 total commercial and transit buses in Texas (6)
-1175 total transit buses in Texas (8)
 1856 commercial buses in Texas

- 88,823 total commercial and transit buses in U.S. (6)
-49,700 total transit buses in U.S. (14)
 39,123 commercial buses in U.S.

- Texas/U.S. Ratio

1856 ÷ 39,123 = 4.7% of total U.S. commercial buses are in Texas

- Total U.S. Bus passenger-miles of intercity travel (2) x Ratio = Bus passenger-miles of intercity travel in Texas
 25 billion x 4.7% = 1.2 billion bus passenger-miles (1.9 billion bus passenger-km) of intercity travel in Texas

- This estimate is based on the assumption that bus passenger-miles of intercity travel in Texas is equivalent to the same percentage of total bus passenger-miles of intercity travel in the U.S. as the total number of commercial buses in Texas is to the total number of commercial buses in U.S.

Final Estimate -- Average

- The three preliminary estimates were averaged to obtain the final estimate.

<u>Estimate</u>	<u>Method</u>
1.4 billion miles	Estimate 1 -- Population
1.5 billion miles	Estimate 2 -- Share of the Market
<u>1.2 billion miles</u>	Estimate 3 -- Commercial Buses
4.1 billion miles (6.6 billion km)	Total ÷ 3 = Average

- The final estimate is 1.4 billion passenger-miles (2.3 billion passenger-km) of intercity travel by bus in Texas.

Fuel Efficiency

- The efficiency of intercity bus travel is 125 passenger-miles per gallon (52.5 passenger-km per liter) (13).

Fuel Consumption

- The amount of fuel consumed by intercity buses was found by dividing the passenger-miles of intercity bus travel by the average number of miles per gallon of fuel.
- 1.4 billion ÷ 125 = 11.2 million gallons (42.4 million liters) of fuel consumed in intercity travel by bus in Texas.

RAIL

Passenger-Miles

Estimate 1 -- Population

- Intercity travel (excluding commuter travel) in Texas was assumed to be the same percentage of U.S. travel as the population of Texas was to the population of the U.S.
- 11.0 billion intercity rail passenger-miles in U.S. (17.7 km) (2)
 -4.6 billion miles of commuter travel (7.4 billion km) (12)
 6.4 billion intercity rail-miles (10.3 billion intercity rail-km)
 x 5.5% Texas population is 5.5% of U.S. population (1)
 352 million rail passenger-miles (566 million rail passenger-km)
 in Texas

Estimate 2 -- Share of the Market

- Rail passenger service accounts for 0.54 percent of total U.S. intercity travel (2).
- The final estimate for passenger-miles of intercity travel by private auto in Texas was 58.0 billion (93.3 billion passenger-km).
- | Passenger-miles of intercity travel by private auto in Texas | x | Percent of total U.S. intercity travel by rail (2) | ÷ | Percent of total U.S. intercity travel by private auto (2) | = | Rail Passenger-miles of intercity travel in Texas |
|--|---|--|---|--|---|---|
| 58.0 | | | | (0.54% ÷ 86%) | = | |
| 58.0 | | | | 0.0063 | = | 365 million rail passenger-miles (587 million rail passenger-km) of intercity travel in Texas |
- The basis for this estimate is the ratio of total U.S. intercity travel by rail to total U.S. intercity travel by private auto. It is assumed that rail passenger-miles of intercity travel in Texas are the same percentage of auto passenger-miles of intercity travel in Texas as rail passenger-miles of intercity travel in the U.S. are of auto passenger-miles of intercity travel in the U.S.

Final Estimate

- By averaging the two preliminary estimates, the final estimate was acquired.

<u>Estimate</u>	<u>Method</u>
352 million miles	Estimate 1 -- Population
<u>365 million miles</u>	Estimate 2 -- Share of the Market
717 million miles (1.153 billion km)	Total ÷ 2 = Average

- Average = 359 million rail passenger-miles (577 million rail passenger-km) of intercity travel in Texas.

Fuel Efficiency

- Passenger rail efficiency is approximately 80 passenger-miles per gallon (33.6 passenger-km per liter) (13).

Fuel Consumption

- The amount of fuel consumed in intercity rail travel in Texas was calculated by dividing the passenger-miles of intercity rail travel by the average number of miles per gallon of fuel.
- $359 \text{ million} \div 80 = 4.4 \text{ million gallons}$ (16.6 million liters of fuel consumed in intercity rail travel in Texas).

INTRACOASTAL WATERWAY

- In 1970, intercity passenger travel via water was only 0.34% of total U.S. intercity travel (2). Since there is no large scale passenger intercity water travel available in Texas, no estimates were made for passenger-miles, fuel consumption or fuel efficiency for intercity person movement in 1970, 1978 or 1990.

APPENDIX A-2

1970 Estimates of Fuel Consumption for Urban Person Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing various values shown in Table 6. Data for 1970 were utilized and estimations of passenger-miles, fuel efficiency and fuel consumption were made for the urban person movement process by automobile, bus and taxi.

AUTOMOBILE

Fuel Consumption

- Intercity auto fuel consumption was estimated in Appendix A-1 to be 1.986 billion gallons (7.52 billion liters).
- The total highway consumption of motor fuel was 6,294,098,000 gallons (23.85 billion liters) (6).
- The consumption of special fuels amounted to 453,027,000 gallons (1.71 billion liters) (6).
- $6,294,098,000 - 453,027,000 = 5,841,071,000$ gallons (22.10 billion liters) of gasoline used by autos and trucks.
- Truck travel accounted for 67 million gallons (254 million liters) of gasoline (6).
- $5,841,071,000 - 67,000,000 = 5,774,071,000$ gallons (21.85 billion liters) of gasoline used by autos, both urban and intercity.
- $5,774,071,000 - 1,986,000,000 = 3,788,071,000$ gallons (14.34 billion liters) of gasoline used in urban auto travel.
- It was assumed that 7.5 percent of the total gasoline was used in urban goods movement by auto (15).
- $5,774,071,000 \times 7.5\% = 433$ million gallons (1.64 billion liters) of gasoline used in urban goods movement by auto.
- $3,788,071,000 - 433,000,000 = 3.355$ billion gallons (12.7 billion liters) of gasoline used in urban person movement by auto.

Fuel Efficiency

- The fuel efficiency of urban travel by private auto (found in Appendix A-1) was 10.9 vehicle-miles per gallon (4.58 vehicle-km per liter).

- The average occupancy of passenger vehicles in urban travel is 1.5 persons per vehicle (13).
- $10.9 \times 1.5 = 16.35$ passenger-miles per gallon (6.87 passenger-km per liter).

Passenger-Miles

- The number of passenger-miles of travel by urban auto was determined by multiplying the gallons of fuel consumed times the average number of passenger-miles per gallon.
- $3.355 \text{ billion} \times 16.35 = 54.85 \text{ billion}$ passenger-miles (88.3 billion passenger-km) by urban auto in Texas.

BUS

Fuel Consumption

- In 1970, there were 1720 transit buses in Texas (8). These buses averaged 28,000 miles (45,052 km) per year per bus at 3.88 miles per gallon (1.63 km per liter) (6).
- $28,000 \text{ miles/year/bus} \times 1720 \text{ buses} = 48.16 \text{ million vehicle-miles}$ (77.5 million vehicle-km).
- $48.16 \text{ million} \div 3.88 \text{ miles per gallon} = 12.4 \text{ million gallons}$ (46.9 million liters) of fuel consumed in intercity passenger travel by bus.

Fuel Efficiency

- Transit buses have a fuel efficiency of 35 passenger-miles per gallon (14.7 passenger-km per liter) (13).

Passenger-Miles

- The number of passenger-miles of urban travel by bus can be calculated by multiplying the gallons of fuel consumed times the average number of passenger-miles per gallon of fuel.
- $12 \text{ million} \times 35 = 420 \text{ million}$ passenger-miles (676 million passenger-km) of urban travel by bus.

TAXI

Passenger-Miles

- It was assumed that Texas cities which have populations of 50,000 or more have taxi service available.
- An analysis of Houston, Dallas and San Antonio data revealed that there was an average of 0.59 licenses per 1,000 people. This factor was applied to the remaining cities, with a total of 3,098 licenses being computed.
- An average of 40,000 miles per license (64,360 km per license) was used to calculate the total vehicle-miles traveled by taxis.
- $3098 \times 40,000 = 123.9$ million passenger-miles (199.4 million passenger-km).

Fuel Efficiency

- Taxis were found to have a fuel efficiency of 9 passenger-miles per gallon (3.8 km per liter) of gasoline (13).

Fuel Consumption

- The amount of fuel consumed by urban taxis can be determined by dividing the passenger-miles traveled via urban taxi by the average number of miles per gallon of fuel.
- $123,920,000 \div 9 = 13.8$ million gallons (52.2 million liters) of fuel consumed by taxis in urban travel.

APPENDIX A-3

1970 Estimates of Fuel Consumption for Goods Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing various values shown in Table 6. Data for 1970 were utilized and estimations of ton-miles, fuel efficiency and fuel consumption were made for both the urban and intercity goods movement processes by mode of transportation.

INTERCITY TRUCK

Ton-Miles

- The number of intercity ton-miles traveled by motor trucks in Texas totaled 27.2 billion (39.4×10^4 kg-km) (11).

Fuel Efficiency

- Intercity truck freight travel has a fuel efficiency of 52 ton-miles per gallon (19.9×10^3 km-kg per liter) (11).

Fuel Consumption

- The amount of fuel consumed by trucks in the intercity goods movement process can be found by dividing the number of ton-miles of intercity truck travel by the average number of miles per gallon.
- $27.2 \text{ billion} \div 52 = 520 \text{ million gallons}$ (1.97 billion liters) of fuel consumed by trucks in intercity travel.

RAIL

Ton-Miles

- The number of intercity rail ton-miles traveled in Texas totaled 47.18 billion (68.32×10^{12} kg-km) (11).

Fuel Efficiency

- The fuel efficiency for intercity rail freight was found to be 200 ton-miles per gallon (76.6×10^3 kg-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in the intercity rail transport of goods was found by dividing the ton-miles of intercity rail travel by the average number of miles per gallon of fuel.
- $47.18 \text{ billion} \div 200 = 236 \text{ million gallons (893 million liters)}$ of fuel consumed in intercity travel by rail.

OIL PIPELINES

Ton-Miles

- In order to estimate the volume of cargo handled by oil pipelines, it was necessary to estimate Texas' percentage of the total U.S. capacity (17).
- The volume of crude, gathering and product lines for Texas = 25.33 million barrels.
- The volume of crude, gathering and product lines for the U.S. = 113.55 million barrels.
- Texas' capacity = $\frac{25.33 \text{ million}}{113.55 \text{ million}}$ or 22.3% of the nation's capacity.
- This figure was applied to the total volume handled by oil pipelines in the U.S.
- $431.16 \text{ billion ton-miles} \times 22.3\% = 96.15 \text{ billion ton-miles (} 139.2 \times 10^{12} \text{ kg-km)}$ of freight movement through oil pipelines in Texas.

Fuel Efficiency

- The fuel efficiency of freight movement through oil pipelines is 500 ton-miles per gallon ($191.5 \times 10^3 \text{ kg-km per liter}$) (11).

Fuel Consumption

- The amount of fuel consumed by the movement of freight through oil pipelines can be found by dividing the ton-miles of freight movement by the average number of miles per gallon.
- $96.15 \text{ billion} \div 500 = 192 \text{ million gallons (727 million liters)}$ of fuel consumed by freight movement through oil pipelines in Texas.

INTRACOASTAL WATERWAY

Ton-Miles

- An examination of the freight traffic volume on the Gulf Intracoastal Waterway yielded an estimate of 6.21 billion ton-miles (9.0×10^{12} kg-km) (16).

Fuel Efficiency

- The fuel efficiency of freight movement by water is 220 ton-miles per gallon (84.3×10^3 kg-km) (16).

Fuel Consumption

- The amount of fuel consumed in the transportation of freight by water can be calculated by dividing the ton-miles of freight movement via waterway by the average number of miles per gallon.
- $6.21 \text{ billion} \div 220 = 28 \text{ million gallons}$ (106 million liters) of fuel consumed in freight transportation by waterway.

AIR

Ton-Miles

- Volumes of freight traffic by air, rail, and truck in the U.S. will be used to arrive at two ratios. These ratios will then be applied to volumes of Texas freight traffic to arrive at a final estimate.
- Based on U.S. data for ton-miles by mode:

$$\frac{\text{air}}{\text{truck}} = \frac{3.3 \text{ billion}}{412.0 \text{ billion}} = .0080$$

$$\frac{\text{air}}{\text{rail}} = \frac{3.3 \text{ billion}}{771.0 \text{ billion}} = .00428$$

- These ratios are then applied to Texas freight mileage, which has already been computed.

$$\text{Truck: } 27.2 \text{ billion} \times .0080 = 218 \text{ million ton-miles} (316 \times 10^9 \text{ kg-km})$$

$$\text{Rail: } 47.18 \text{ billion} \times .00428 = 202 \text{ million ton-miles} (293 \times 10^9 \text{ kg-km})$$

- 215 million ton-miles will be used in Table 6.

Fuel Efficiency

- The fuel efficiency of freight movement by air is approximately 10 ton-miles per gallon (3.83×10^3 km-kg per liter) (11).

Fuel Consumption

- The amount of fuel consumed in the movement of air freight was determined by dividing the ton-miles of air freight movement by the average number of miles per gallon of fuel.
- $215 \div 10 = 21.5$ million gallons (81.4 million liters) of fuel consumed in freight movement by air.

URBAN TRUCK

Fuel Consumption

- Fuel consumption by urban truck is estimated to be 7.5% of the total gasoline as seen in the urban auto estimate in Appendix A-1 (15).
- $5,774,071,000$ gallons $\times 7.5\% = 433$ million gallons (1.64 billion liters) of fuel consumed in urban freight movement by truck.

Fuel Efficiency

- Urban truck fuel efficiency is estimated at 4 ton-miles per gallon (1532 kg-km per liter) (11).

Ton-Miles

- The number of ton-miles traveled by urban trucks can be found by multiplying the number of gallons times the ton-miles per gallon.
- 433 million $\times 4 = 1.732$ billion ton-miles (2.51×10^9 kg-km).

APPENDIX B-1

1978 Estimates of Fuel Consumption for Intercity Person Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing the values for intercity person movement shown in Table 7. Projections for 1978 were utilized and estimations of passenger-miles fuel efficiency and fuel consumption were made for intercity person movement process by automobile, bus and taxi.

Population data were the basis of several computations in this Appendix. The population of Texas was estimated to be 13.0 million as of June 1, 1978 (2). The population of the U.S. for the same time period was estimated to be 217.9 million (1). The population of Texas represented 5.9 percent of the U.S. population.

AUTOMOBILE

Passenger-Miles

- State Department of Highways and Public Transportation manual count data reveal that approximately 90 percent of the daily intercity vehicle-miles of travel are by auto (includes pick-up trucks) (3).
- The volume of intercity vehicular travel was estimated at 43.0 billion vehicle-miles (69.2 billion vehicle-km) (4).
- $43.0 \text{ billion} \times 90\% = 38.7 \text{ billion intercity auto-miles (62.3 billion intercity auto-km)}$.
- The average occupancy of passenger vehicles in intercity travel is 2.3 persons (5).
- $38.7 \text{ billion} \times 2.3 = 89.0 \text{ billion intercity passenger-miles (143.2 billion intercity passenger-km) by auto in Texas}$.

Fuel Efficiency

- The fuel efficiency of intercity auto travel was obtained using an estimate of gasoline consumption and the estimate for total vehicle-miles. A weighted average for urban and rural efficiencies was obtained (7).

Total vehicle miles	÷	Highway gas consumption	=	Average mileage for all autos
100 billion	÷	8.40 billion	=	11.90 miles per gallon (5.0 km per liter)

Urban vehicle-miles = 57 billion

Rural vehicle-miles = 43 billion

x = urban fuel efficiency (mpg)

14x/12 = rural fuel efficiency (mpg)

$$11.9 = \frac{57x + 43(14x/12)}{100}$$

Urban fuel consumption = 11.1 mpg (4.66 km/liter)

Rural fuel consumption = 12.95 mpg (5.44 km/liter)

- The fuel efficiency of the intercity auto can be found by multiplying the number of persons per vehicle-mile times the average miles per gallon.
- $2.3 \times 12.95 = 30$ passenger-miles per gallon (12.6 passenger-km per liter).

Fuel Consumption

- The amount of fuel consumed by intercity autos can be calculated by dividing the auto passenger-miles of intercity travel by the average number of miles per gallon.
- $38.7 \text{ billion} \div 12.95 = 2.988 \text{ billion gallons}$ (11.3 billion liters) of fuel consumed by autos in intercity travel.

AIR

Passenger-Miles

Estimate 1 -- Ratio of Enplanements

- 16,400,000 CAB, Texas enplanements (8)
+4,100,000 TAC enplanements (9)
 20,500,000 Texas annual enplanements
- The total domestic U.S. enplanements in 1978 were estimated to be 221 million.

Final Estimate -- Average

- The final estimate for air passenger-miles of intercity travel in Texas was obtained by averaging the estimates computed by the three methods.

<u>Estimate</u>	<u>Method</u>
17.8 billion miles	Estimate 1 -- Ratio of Enplanements
11.3 billion miles	Estimate 2 -- Population
<u>13.4 billion miles</u>	Estimate 3 -- Vehicle-Miles
42.5 billion miles (68.4 billion km)	Total ÷ 3 = Average

- Final estimate is 14.2 billion air passenger-miles (22.8 air passenger-km) of intercity travel in Texas.

Fuel Efficiency

- The fuel efficiency of intercity air travel is 14 passenger-miles per gallon (5.9 passenger-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity air travel can be calculated by dividing passenger-miles of intercity air travel by the average number of miles per gallon.
- 14.2 billion ÷ 14 = 1.014 billion gallons (3.838 billion liters) of fuel consumed in intercity travel by air.

BUS

Passenger-Miles

Estimate 1 -- Population

- 27.2 billion passenger-miles of intercity travel by bus in U.S. (1)
x 5.9% Texas population is 5.9% of U.S. population (2)
1.60 billion passenger-miles (2.57 billion passenger-km) of intercity travel by bus in Texas
- It is assumed that passenger-miles of intercity travel by bus in Texas and passenger-miles of intercity travel by bus in U.S. existed in the same ratio as Texas population and U.S. population.

Estimate 2 -- Share of the Market

- Final estimate for passenger-miles of intercity travel by auto in Texas was 89.0 billion (143.2 billion passenger-km).
- Passenger-miles of intercity travel by private auto in Texas \times Percent of total U.S. intercity travel by bus (1) \div Percent of total U.S. intercity travel by auto (1) = Bus passenger-miles of intercity travel in Texas

89.0 billion	\times	(1.70%	\div	84.2%)	=	
89.0 billion	\times			0.02	=	1.78 billion bus passenger-miles (2.86 billion bus passenger-km) of intercity travel in Texas
- The basis for this estimate is the ratio of total U.S. intercity travel by bus to total U.S. intercity travel by auto.
- It was assumed that intercity bus passenger-miles in Texas were the same percentage of intercity auto passenger-miles in Texas as total intercity bus passenger-miles in the U.S. were to the total intercity auto passenger-miles in the U.S.

Estimate 3 -- Commercial Buses

- The total number of commercial buses in Texas was found to be 1381 (18).
- 98,800 total commercial and transit buses in U.S. (6)
 -54,250 total transit buses in U.S. (14)
 44,550 total commercial buses in U.S.
- Texas/U.S. Ratio
 $1381 \div 44,550 = 3.1\%$ of total U.S. commercial buses are in Texas
- Total U.S. Bus passenger-miles of intercity travel (1) \times Ratio = Bus passenger-miles of intercity travel in Texas

27.2 billion	\times	3.1%	=	843 million bus passenger-miles (1.356 billion bus passenger-km) of intercity travel in Texas
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- This estimate is based on the assumption that bus passenger-miles of intercity travel in Texas is equivalent to the same percentage of total bus passenger-miles of intercity travel in the U.S. as the total number of commercial buses in Texas is to total number of commercial buses in the U.S.

Final Estimate -- Average

- The three preliminary estimates were averaged to obtain a final estimate.

<u>Estimate</u>	<u>Methods</u>
1.60 billion miles	Estimate 1 -- Population
1.78 billion miles	Estimate 2 -- Share of the Market
<u>.84 billion miles</u>	Estimate 3 -- Commercial Buses
4.22 billion miles (6.79 billion km)	Total ÷ 3 = Average

- The final estimate is 1.41 billion passenger-miles (2.3 billion passenger-km) of intercity travel by bus in Texas.

Fuel Efficiency

- The efficiency of intercity bus travel is 125 passenger-miles per gallon (52.5 passenger-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed by intercity buses can be calculated by dividing passenger-miles of intercity bus travel by the average number of miles per gallon.
- 1.41 billion ÷ 125 = 11 million gallons (41.6 million liters) of fuel consumed in intercity travel by bus in Texas.

RAIL

Passenger-Miles

- Rail passenger travel was estimated as 0.1% of total intercity travel (11). Texas does not have as extensive a rail network as the eastern states, therefore the percentage of rail travel in Texas is very small.

- | | | | | | | |
|---|---|--|---|--|---|---|
| ● Intercity
passenger-
miles by
auto | + | Intercity
passenger-
miles by
air | + | Intercity
passenger-
miles by
bus | = | Total passenger-miles
of intercity travel
(excluding travel by
rail) |
|---|---|--|---|--|---|---|
- | | | | | | | |
|--------------|---|--------------|---|--------------|---|---|
| 89.0 billion | + | 14.2 billion | + | 1.41 billion | = | 104.61 billion passenger-
miles (168.32 billion
passenger-km) of intercity
travel in Texas |
|--------------|---|--------------|---|--------------|---|---|
- | | | | | |
|------------------|---|------|---|--|
| ● 104.61 billion | x | 0.1% | = | 105 million passenger-miles (168 million passenger-
km) of intercity travel by rail in Texas. |
|------------------|---|------|---|--|

Fuel Efficiency

- Passenger rail efficiency is approximately 80 passenger-miles per gallon (33.6 passenger-km per liter) (13).

Fuel Consumption

- The amount of fuel consumed in intercity rail travel can be calculated by dividing the passenger-miles of intercity rail travel by the average number of miles per gallon.
- 104.61 million ÷ 80 = 1.3 million gallons (4.9 million liters) of fuel consumed in intercity travel by rail.

APPENDIX B-2

1978 Estimates of Fuel Consumption for Urban Person Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing various values in Table 7. Projections for 1978 were utilized and estimations of passenger-miles, fuel efficiency and fuel consumption were made for the urban person movement process by automobile, bus and taxi in Texas.

AUTOMOBILE

Fuel Consumption

- This estimate is based on a projection of the amount of urban vehicle-miles traveled.
- Urban vehicle-miles totaled 57.0 billion (91.7 billion vehicle-km) (4).
- It was assumed that 95% of the total urban vehicular travel was travel by auto (3).
- $57 \text{ billion} \times 95\% = 54.15 \text{ billion urban auto-miles (87.13 billion urban auto-km)}$.
- The fuel efficiency of urban travel by auto (found in Appendix B-1) was 11.1 vehicle-miles per gallon (4.66 vehicle-km per liter).
- $54.15 \text{ billion} \div 11.1 = 4.878 \text{ billion gallons (18.5 billion liters) of fuel consumed in urban travel by auto.}$

Fuel Efficiency

- The average occupancy of passenger vehicles in urban travel is 1.5 persons per vehicle (5).
- $11.1 \text{ vehicle-miles per gallon} \times 1.5 \text{ persons per vehicle} = 16.65 \text{ passenger-miles per gallon (7.0 passenger-km per liter)}$.

Passenger-Miles

- $54.15 \text{ billion urban auto-miles} \times 1.5 \text{ persons per vehicle} = 81.2 \text{ billion passenger-miles (130.7 billion passenger-km) of urban travel by auto.}$

BUS

Fuel Consumption

- In 1978, there were approximately 1869 transit buses in Texas (11). These buses averaged 30,200 miles (48,600 km) per year per bus at 3.88 miles per gallon (1.63 km per liter) (17).
- 30,200 miles/year/bus x 1869 buses = 56.44 million vehicle-miles (90.81 vehicle-km).
- 56.44 million ÷ 3.88 = 14.55 million gallons (55.1 million liters) of fuel consumed in intercity travel by bus.

Fuel Efficiency

- Transit buses have a fuel efficiency of 35 passenger-miles per gallon (14.7 passenger-km per liter) (13).

Passenger-Miles

- 14.55 million x 35 = 509 million (819 million passenger-km) of urban travel by bus.

TAXI

Passenger-Miles

- This estimate is based on the assumption that the ratio of passenger-miles by taxi to population in taxi-served areas remains constant.
- In 1970, the number of persons living in urban areas assumed to have taxi service totaled 5,478,933 (1).
- From 1970 to 1978, the population of Texas increased by 1,714,000 (1).
- Assume that 90% of this increase occurred in areas having taxi service (11).
- 1,714,000 x 90% = 1,543,000 additional persons living in urban areas of Texas where taxi service is available.
- This increased the number of Texans having taxi service by a value of:

$$\frac{5,478,933 + 1,543,000}{5,478,933} = 1.3$$

- Assuming that this value of 1.3 can be applied directly to passenger-miles:

117 million passenger-miles \times 1.3 = 152 passenger-miles (245 million passenger-km).

Fuel Efficiency

- Because taxis are basically urban autos, they will have an increase in fuel efficiency approximately equal to that of urban autos.
- The 1970 fuel efficiency for taxis was 9 passenger-miles per gallon (3.78 passenger-km per liter).
- The change in urban auto efficiency from 1970 to 1978 went from 10.9 mpg (4.58 km/liter) to 11.1 mpg (4.66 km/liter).
- $9 \times (11.1 \div 10.9) =$ a fuel efficiency of 9.2 passenger-miles per gallon (3.86 passenger-km per liter).

Fuel Consumption

- The amount of fuel consumed by urban taxis was calculated by dividing the passenger-miles of intercity travel via taxi by the average number of miles per gallon.
- $152 \text{ million} \div 9.2 = 16.5 \text{ million gallons}$ (62.5 million liters of fuel consumed in intercity travel by taxis).

APPENDIX B-3

1978 Estimates of Fuel Consumption for Goods Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumption used in developing various values shown in Table 7. Projections for 1978 were utilized and estimation of ton-miles, fuel efficiency and fuel consumption were made for both the urban and intercity goods movement processes by mode of transportation.

INTERCITY TRUCK

Ton-Miles

- Based on historical trends, it was projected that 36 billion ton-miles (52×10^{12} kg-km) of freight was hauled by intercity truck.

Fuel Efficiency

- The fuel efficiency of intercity freight movement was estimated at 52 ton-miles per gallon (9.9×10^3 kg-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed by trucks in the intercity goods movement process was determined by dividing the ton-miles of intercity truck travel by the average number of miles per gallon.
- $36 \text{ billion} \div 52 = 692$ million gallons (2.61 billion liters) of fuel consumed in intercity goods transport by truck.

RAIL

Ton-Miles

- Based on historical trends, it was projected that 63 billion ton-miles (91×10^{12} kg-km) of freight was transported by intercity rail (11).

Fuel Efficiency

- The fuel efficiency of intercity rail transport was found to be 200 ton-miles per gallon (77.6×10^3 kg-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity rail travel can be calculated by dividing the passenger-miles of rail travel by the average number of miles per gallon.
- $63 \text{ billion} \div 200 = 315 \text{ million gallons}$ (1.19 billion liters) of fuel consumed in intercity passenger travel by rail.

OIL PIPELINES

Ton-Miles

- This estimate assumed that the ratio of pipeline ton-miles in Texas to those of the U.S. in 1978 was the same as that in 1970.
- It was estimated that in 1978, pipelines in the U.S. carried 580 billion ton-miles (840×10^{12} kg-km) of cargo (2).
- In 1970, 431 billion ton-miles (624×10^{12} kg-km) of cargo were handled by oil pipelines in the U.S. 96.15 billion ton-miles (139×10^{12} kg-km) of cargo were handled by oil pipelines in Texas.
- Texas' capacity = $\frac{96.15 \text{ billion}}{431 \text{ billion}}$ or 22.3% of the nation's capacity.
- This figure was applied to the total volume handled by oil pipelines in the U.S.
- $580 \text{ billion} \times 22.3\% = 129.4 \text{ billion ton-miles}$ of freight movement through oil pipelines in Texas.

Fuel Efficiency

- The approximate fuel efficiency of freight movement through oil pipelines is 500 ton-miles per gallon (192×10^3 kg-km per liter).

Fuel Consumption

- The amount of fuel consumed by freight movement through oil pipelines was calculated by dividing the ton-miles of freight movement through oil pipelines by the average number of miles per gallon.
- $129.4 \text{ billion} \div 500 = 259 \text{ million gallons}$ (980 million liters) of fuel consumed by freight movement through oil pipelines.

INTRACOASTAL WATERWAY

Ton-Miles

- An analysis of historical data was used to arrive at an estimate of 8.82 billion ton-miles (12×10^{12} kg-km) of freight carried along the Gulf Intracoastal Waterway (16).

Fuel Efficiency

- The fuel efficiency of freight movement by water is 220 ton-miles per gallon (84.3×10^3 kg-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in the transportation of freight by waterway was calculated by dividing the ton-miles of freight movement via waterway by the average number of miles per gallon.
- $8.82 \text{ billion} \div 220 = 40.1 \text{ million gallons}$ (152 million liters) of fuel consumed in freight movement via waterway.

AIR

Ton-Miles

- Volumes of freight traffic by air, rail, and truck in the U.S. will be used to arrive at two ratios. These ratios will then be applied to volumes of Texas freight traffic to arrive at a final estimate.
- U.S. air freight traffic was estimated as 4.59 billion ton-miles (6.65×10^{12} kg-km) (2).
- Truck freight traffic accounted for 542 billion ton-miles (785×10^{12} kg-km) (1) in the U.S. and 36 billion ton-miles (52.0×10^{12} kg-km) in Texas.
- Rail freight traffic totaled 783 billion ton-miles (1.13×10^{15} kg-km) (2) in the U.S. and 63 billion ton-miles (91×10^{12} kg-km) in Texas.
- Based on U.S. data for ton-miles by mode:

$$\frac{\text{air}}{\text{truck}} = \frac{4.59 \text{ billion}}{542 \text{ billion}} = .00847$$

$$\frac{\text{air}}{\text{rail}} = \frac{4.59 \text{ billion}}{783 \text{ billion}} = .00586$$

- These ratios are then applied to Texas freight mileage, which has already been computed:
 Truck: 36 billion x .00847 = 305 million ton-miles (442×10^9 kg-km)
 Rail: 63 billion x .00586 = 369 million ton-miles (534×10^9 kg-km)
- (305 million + 369 million) ÷ 2 = 337 million ton-miles (488×10^9 kg-km).

Fuel Efficiency

- The fuel efficiency of freight movement by air is approximately 10 ton-miles per gallon (3.83×10^3 kg-km) (11).

Fuel Consumption

- The amount of fuel consumed in the movement of air freight was determined by dividing the ton-miles of air freight movement ÷ the average number of miles per gallon.
- 337 million ÷ 10 = 33.7 million gallons (128 million liters) of fuel consumed in the movement of air freight by air in Texas.

URBAN TRUCK

Fuel Consumption

- Fuel consumption by urban truck is estimated to be 7.5% of the total gasoline as seen in the urban auto estimate in Appendix A-1 (15).
- 8.40 billion gallons x 7.5% = 630 million gallons (2.38 billion liters) of fuel consumed in urban freight movement by truck in Texas.

Fuel Efficiency

- Urban truck fuel efficiency is estimated at 4 ton-miles per gallon (1584 kg-km per liter) (11).

Ton-Miles

- The number of ton-miles traveled by urban trucks was found by multiplying the gallons of fuel consumed times the ton-miles per gallon.
- 630 million x 4 = 2.52 billion ton-miles (3.65×10^{12} kg-km).

APPENDIX C-1

1990 Estimates of Fuel Consumption for Intercity Person Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing the values for intercity person movement shown in Table 8. Projections for 1990 were utilized and estimations of passenger-miles fuel efficiency and fuel consumption were made for intercity person movement process by automobile, bus and taxi.

AUTOMOBILE

Fuel Efficiency

- An analysis of historical trends revealed that in Texas, vehicle-miles per capita increased at a rate of 3.05 percent per year between 1970 and 1980. One-half of this increase per year was used for the years between 1980 and 1990. An estimate of 9545 vehicle-miles (15,360 vehicle-km) per capita was derived for 1990. A population estimate of 15,342,000 was obtained (1).
- 9545 vehicle-miles per capita x 15,342,000 persons = 146.4 billion miles (235.6 billion km) of travel in Texas.
- Rural travel has been estimated as constituting 43 percent of the vehicle-miles traveled in the State of Texas (4).
- 146.4 billion miles x 43% = 62.95 billion vehicle-miles.
- It has been estimated that autos will represent 90 percent of the vehicle-miles traveled in Texas in 1990 (3).
- 62.95 billion vehicle-miles x 90% autos = 56.7 billion vehicle-miles (91.2 billion vehicle-km) by auto in Texas.
- The proposed EPA gasoline mileage standards were found to be 20 percent in excess of actual mileage achieved. This reduction was made and an estimate of 18.9 miles per gallon (7.94 km per liter) was obtained assuming an auto turnover rate of 10 percent. Weighting factors used in Appendix B-1. Intercity auto were then used to calculate an average.
- $x = \text{urban fuel efficiency (mpg)}$
 $14x/12 = \text{rural fuel efficiency (mpg)}$

$$18.9 = \frac{83.45x + 62.95 (14x/12)}{146.4}$$

Urban fuel consumption = 17.64 mpg (7.41 km/liter)
Rural fuel consumption = 20.58 mpg (8.64 km/liter)

- The fuel efficiency of the intercity auto can be found by multiplying the number of persons per vehicle-miles times the average mile per gallon. The average occupancy of passenger vehicles in intercity travel for the year 1990 is predicted to remain at 2.3 as in 1970 (5).
- 2.3 persons per vehicle-miles x 20.58 mpg = 47 passenger-miles per gallon (19.74 passenger-km per liter).

Fuel Consumption

- Intercity fuel consumption was found using an estimated efficiency of 20.6 mpg (8.64 km/liter).
- 56.7 billion vehicle-miles ÷ 20.6 = 2.75 billion gallons (10.4 billion liters) of fuel consumed by intercity auto.

Passenger-Miles

- The total volume of intercity travel by auto was found to be 56.7 billion vehicle-miles.
- 56.7 billion intercity vehicle-miles x 2.3 persons per vehicle = 130.41 billion passenger-miles (209.83 billion passenger-km) of intercity travel by auto.

AIR

Passenger-Miles

- Based on historical trends, it is predicted that intercity passenger traffic by auto will represent 85.1 percent of the total intercity passenger traffic (2).
- 130.41 billion passenger-miles by auto ÷ 85% autos = 153.4 billion passenger-miles of total intercity passenger travel.
- Intercity passenger travel by air is predicted to represent 12.8 percent of the total intercity passenger travel (2).
- 153.4 billion x 12.8% = 19.6 billion passenger-miles (31.6 passenger-km) of travel by air.

Fuel Efficiency

- The fuel efficiency of intercity air travel is 14 passenger-miles per gallon (5.9 passenger-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity air travel was calculated by dividing the passenger-miles of intercity air travel by the average number of miles per gallon.
- $19.6 \text{ billion} \div 14 = 1.4 \text{ billion gallons}$ (5.3 billion liters) of fuel consumed in intercity passenger travel by air.

BUS

Passenger-Miles

- Intercity passenger travel by bus is predicted to represent 2.0 percent of the total intercity passenger travel (2).
- $153.4 \text{ billion} \times 2.0\% = 3.1 \text{ billion passenger-miles}$ (5.0 billion passenger-km) of travel by bus.

Fuel Efficiency

- The efficiency of intercity bus travel is 125 passenger-miles per gallon (52.5 passenger-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed by intercity buses was calculated by dividing the passenger-miles of intercity bus travel by the average number of miles per gallon.
- $3.1 \text{ billion} \div 125 = 25 \text{ million gallons}$ (95 million liters) of fuel consumed in intercity travel by bus.

RAIL

Passenger-Miles

- Intercity passenger travel by rail is predicted to represent 0.1 percent of the total intercity passenger travel (2).

- $153.4 \text{ billion} \times 0.1\% = 153 \text{ million passenger-miles}$ (246.2 million passenger-km) of travel by rail.

Fuel Efficiency

- Passenger rail efficiency is approximately 80 passenger-miles per gallon (33.6 passenger-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity rail travel was calculated by dividing the passenger-miles of rail travel by the average number of miles per gallon.
- $153 \text{ million} \div 80 = 1.9 \text{ million gallons}$ (7.3 million liters) of fuel consumed in intercity passenger travel by rail.

APPENDIX C-2

1990 Estimates of Fuel Consumption for Urban Person Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing various values in Table 8. Projections for 1990 were utilized and estimations of passenger-miles, fuel efficiency and fuel consumption were made for the urban person movement process by automobile, bus and taxi.

AUTOMOBILE

Fuel Efficiency

- The efficiency of the automobile in urban travel, as found in Appendix C-1, was estimated to be 17.6 miles per gallon (7.4 km per liter).

Fuel Consumption

- It was estimated in Appendix C-1, that vehicle-miles of travel in Texas will total 146.4 billion (235.6 billion vehicle-km) by 1990.
- Urban travel has been estimated as constituting 57 percent of the vehicle-miles traveled in the state of Texas.
- $146.4 \text{ billion vehicle-miles} \times 57\% = 83.45 \text{ billion urban vehicle-miles.}$
- It was assumed that autos will represent 95 percent of the vehicle-miles traveled in urban areas in Texas (3).
- $83.45 \text{ billion urban vehicle-miles} \times 95\% = 79.3 \text{ billion auto-miles}$ (127.6 billion auto-km).
- $79.3 \text{ billion auto-miles} \div 17.6 \text{ mpg} = 4.506 \text{ billion gallons}$ (17.1 billion liters) of fuel consumed in urban auto travel in 1990.

Passenger-Miles

- In 1990, the average occupancy of an automobile in urban travel is estimated to remain at the 1970 level 1.5 persons per vehicle.
- $79.3 \text{ billion auto-miles} \times 1.5 \text{ persons per vehicle} = 118.95 \text{ billion passenger-miles}$ (191.4 billion passenger-km).

BUS

Passenger-Miles

- The increase in urban travel by bus can be related to the increase in total vehicle-miles. An increase of 3.0 percent per year was observed for vehicle-miles during the period from 1970 to 1978, and this trend is expected to continue.
- The estimate for urban travel by bus in 1990 is therefore expected to reach 726 million passenger-miles (1.17 billion passenger-km).

Fuel Efficiency

- The fuel efficiency of transit buses in 1990 is expected to remain at the 1970 level 35 passenger-miles per gallon (14.7 passenger-km per liter) (13).

Fuel Consumption

- The amount of fuel consumed by urban buses was calculated by dividing the passenger-miles of urban bus travel by the average number of miles per gallon.
- $726 \text{ million} \div 35 = 20.7 \text{ million gallons}$ (78.4 million liters) of fuel consumed in urban passenger travel by bus.

TAXI

Passenger-Miles

- It is estimated that passenger-miles by taxi will represent the same percentage of urban passenger-miles by auto in 1990 as they did in 1978.
- The passenger-miles traveled by taxi in 1978 = 152 million (245 million passenger-km).
- The passenger-miles traveled by urban auto in 1978 = 81.2 billion (131 billion passenger-km).
- $\frac{152}{81,200} = .001872$
- 118.95 billion passenger-miles by urban auto in 1990 x .001872 = 223 million passenger-miles by taxi in 1990.

Fuel Efficiency

- The fuel efficiency of taxis will increase as the fuel efficiency of urban autos increases.
- The fuel efficiency for taxis in 1970 was 9 passenger-miles per gallon (3.78 passenger-km per liter).
- The change in urban auto fuel efficiency from 1970 to 1990 is estimated to be from 10.9 mpg to 17.6 mpg.
- $9 \times (17.6 \div 10.9) = 15$ passenger-miles per gallon (6.3 passenger-km per liter) in 1990.

Fuel Consumption

- The amount of fuel consumed by urban taxis was determined by dividing the passenger-miles of urban travel via taxi by the average number of miles per gallon.
- $223 \text{ million} \div 15 = 14.9$ million gallons (56.4 million liters) of fuel consumed in urban passenger travel by taxi.

APPENDIX C-3

1990 Estimates of Fuel Consumption for Goods Movement by Mode of Transportation in Texas

This Appendix documents the analyses and assumptions used in developing various values shown in Table 8. Projections for 1990 were utilized and estimations of ton-miles, fuel efficiency and fuel consumption were made for both urban and intercity goods movement processes by mode of transportation.

URBAN TRUCK

Fuel Consumption

- This estimate is based on the assumption that the fuel efficiency for autos will not change between 1978 and 1990. The fuel consumption of urban and rural autos will be estimated using the number of auto-miles calculated in Appendix C-2, Urban Automobile. The fuel consumption for urban goods movement by truck will be calculated as 7½ percent of this figure as the fuel efficiency for urban trucks is not expected to increase at the same rate as the fuel efficiency for autos.
- Urban auto fuel consumption + 79.3 billion auto-miles ÷ 11.10 mpg = 7.144 billion gallons (27.0 billion liters).
- Rural auto fuel consumption = 56.7 billion auto-miles ÷ 12.95 mpg = 4.378 billion gallons (16.6 billion liters).
- 7.144 billion gallons + 4.378 billion gallons = 11.522 billion gallons (43.62 billion liters) total.
- Fuel consumed by urban trucks is 7.5 percent of the fuel consumed by autos, assuming that no increase in efficiency occurs (7).
- 11.522 billion gallons x 7.5% = 864 million gallons (3.27 x 10⁹ liters) of fuel consumed in goods movement by urban truck.

Fuel Efficiency

- The fuel efficiency of urban goods movement by truck is estimated to remain at 4 ton-miles per gallon (1532 kg-km per liter) (11).

Ton-Miles

- The ton-miles of freight hauled by urban trucks in 1990 was estimated by multiplying the expected consumption times the fuel efficiency.

- 864 million gallons of fuel x 4 ton-miles per gallon = 3.456 billion ton-miles (5.00×10^{12} kg-km) of freight will be hauled by urban trucks in 1990.

INTRACOASTAL WATERWAY

Ton-Miles

- Based on historical trends, it is estimated that the waterway freight traffic in 1990 will be 13.35 billion ton-miles (16).

Fuel Efficiency

- The fuel efficiency for water borne freight carriers is expected to remain at approximately the same level of 220 ton-miles/gallon (84.3×10^3 kg-km/liter) for 1970 (11).

Fuel Consumption

- The amount of fuel consumed in goods transport via waterway was estimated by dividing the ton-miles of freight transported via waterway by the average number of miles per gallon.
- $13.35 \text{ billion} \div 220 = 61 \text{ million gallons}$ (231 million liters) of fuel consumed.

OIL PIPELINES

Ton-Miles

- It is anticipated that oil pipelines in Texas will carry the same percentage of U.S. freight traffic in 1990 as it did in 1970. This ratio can then be applied to the U.S. estimate for 1990.
- U.S. estimate for 1970 = 431 billion ton-miles (624×10^{12} kg-km).
- Texas estimate for 1970 = 96.15 billion ton-miles (139×10^{12} kg-km).
- U.S. estimate for 1990 = 830 billion ton-miles (1.2×10^{15} kg-km).
- $(96.15 \text{ billion} \div 431 \text{ billion}) \times 830 \text{ billion} = 185.2 \text{ billion ton-miles}$ (268×10^{12} kg-km) of freight carried by oil pipelines in 1990.

Fuel Efficiency

- The 1970 oil pipeline efficiency of 500 ton-miles/gallon (192×10^3 kg-km/liter) is expected to remain constant in 1990 (11).

Fuel Consumption

- The amount of fuel consumed in goods transport through oil pipelines was estimated by dividing the ton-miles of freight transported through oil pipelines by the average number of miles per gallon.

RAIL

Ton-Miles

- Three projections of rail freight traffic were made. The second of these was used and an estimate of 81 billion ton-miles was achieved.

Fuel Efficiency

- The fuel efficiency of the rail mode is expected to remain constant at 200 ton-miles per gallon (76.6×10^3 kg-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity goods movement by rail was determined by dividing the ton-miles of goods transported via rail by the average number of miles per gallon.
- $81 \text{ billion} \div 200 = 405 \text{ million gallons}$ (1.5×10^{12} liters) of fuel consumed in the intercity transportation of freight by rail.

INTERCITY TRUCK

Ton-Miles

- By averaging two projections, the movement of freight by trucks was projected as being 59 billion ton-miles (85×10^{12} kg-km).

Fuel Efficiency

- It is estimated that the fuel efficiency of the movement of goods by truck will remain at 52 ton-miles per gallon (19.9×10^3 kg-km/liter) (9).

Fuel Consumption

- The amount of fuel consumed in intercity goods movement by truck was estimated by dividing the ton-miles of goods transported via truck by average number of miles per gallon.
- 59 billion ton-miles \div 52 ton-miles/gallon = 1.135 billion gallons (4.30 billion liters) of fuel consumed in intercity goods movement by truck.

AIR

Ton-Miles

- The magnitude of freight movement by air is estimated to remain at 0.15 percent of the remaining goods movement modes (2).
- - 3.46 billion urban truck ton-miles
 - 13.35 billion waterway ton-miles
 - 189.50 billion oil pipeline ton-miles
 - 81.00 billion rail ton-miles
 - +59.00 billion intercity truck ton-miles
 - 346.31 billion total ton-miles of freight movement
- 346 billion ton-miles \times 0.0015 = 520 million ton-miles (753×10^{12} kg-km) of freight movement by air.

Fuel Efficiency

- The fuel efficiency of freight movement by air is estimated to remain at the 1970 level of 10 ton-miles per gallon (3.83×10^3 kg-km per liter) (11).

Fuel Consumption

- The amount of fuel consumed in intercity air freight movement was determined by dividing the ton-miles of air freight movement by the average number of miles per gallon.
- 520 million \div 10 = 52 million gallons (197 million liters) of fuel consumed in the intercity movement of goods by air.

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