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# THE STATE OF TEXAS
# GOVERNOR'S ENERGY ADVISORY COUNCIL





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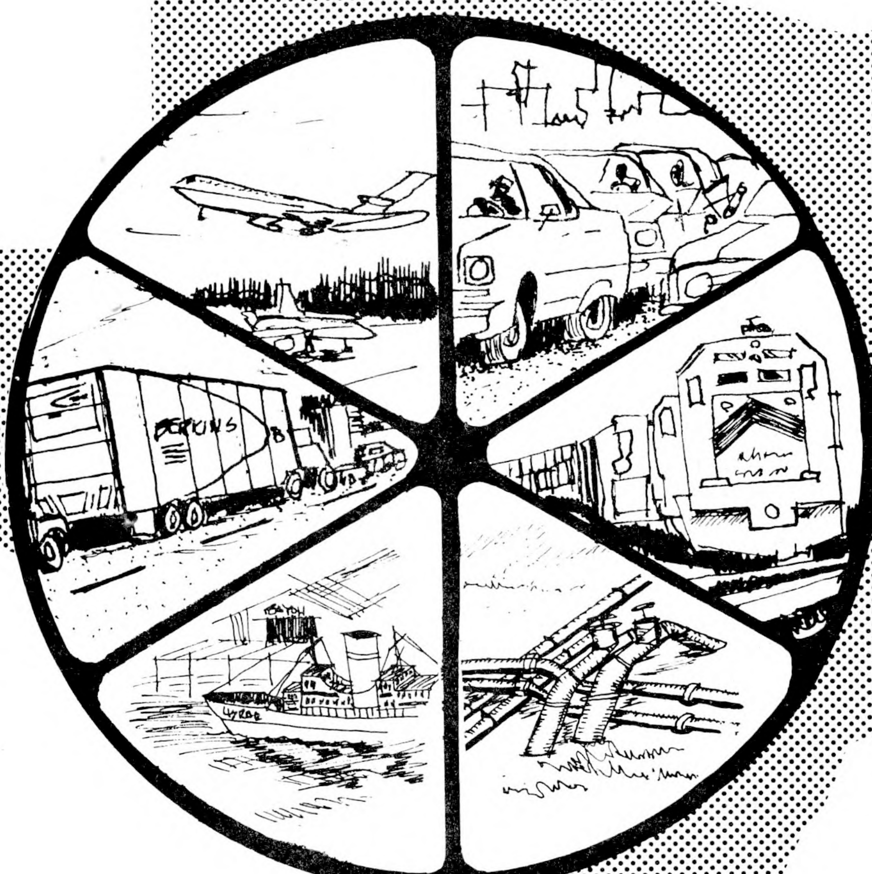
# FINAL REPORT
# VOLUME II

# FUEL CONSERVATION MEASURES: THE TRANSPORTATION SECTOR





THE STATE OF TEXAS
GOVERNOR'S ENERGY ADVISORY COUNCIL

TTI
TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

# FUEL CONSERVATION MEASURES: THE TRANSPORTATION SECTOR

PROJECT S/D-9

FINAL REPORT, VOLUME II

*MODAL SHIFT OPPORTUNITIES*

*URBAN FORM CONSIDERATIONS*

*AUTOMOTIVE FUEL EFFICIENCY*

Prepared For
Governor's Energy Advisory Council

by

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

January 1975

## PREFACE
### Final Report, Volume II

Final Report, Volume II, documents the final findings of a study conducted for the Governor's Energy Advisory Council. It complements Final Report, Volume I, which primarily analyzed the short range effectiveness of alternative voluntary and mandatory transportation fuel conservation measures. Volume II, investigates potential transportation fuel savings associated with both increased fuel efficiency and variations in urban form. In those instances where similar material is presented, Volume II supersedes Volume I.

This volume is divided into three independent chapters. Chapter I documents the magnitude of transportation fuel consumption in Texas. Projections of fuel use for intercity travel are presented and the possible effects of modal shifts are estimated. Chapter II evaluates the relationship between urban development and transportation fuel consumption. The third chapter investigates the effects of auto fuel efficiency on total transportation fuel consumption.

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Executive Summary

## FUEL CONSERVATION MEASURES: THE TRANSPORTATION SECTOR

The transportation sector accounts for 25 percent of the energy consumed in the United States and 18 percent of the energy consumed in Texas. Energy consumption in Texas represents 8.9 percent of national consumption. Of the energy used by transportation in the United States, 6.2 percent is consumed in Texas.

Over 7.3 billion gallons of fuel were consumed by the Texas transportation sector in 1970 (Table S-1). Person movement consumed 82.3 percent of this total. The private auto alone, operated in both urban and intercity travel, consumed 75.3 percent of total statewide transportation fuel.

Table S-1: Estimated 1970 Transportation Fuel Consumption By Mode, Texas

| Type of Transport | Passenger Miles or Ton Miles: Miles (Millions) | | Passenger Miles or Ton Miles: Percent of Total* | | Fuel Efficiency (Passenger Mi. or Ton Mi./Gallon) | Fuel Consumed: Gallons (millions) | | Fuel Consumed: Percent of Total** | |
|---|---|---|---|---|---|---|---|---|---|
| Person Movement, Total | 131,633 | | 100.0 | | 22 | 6,023 | | 82.3 | |
| Urban, Total | 69,387 | | 52.7 | | 18 | 3,850 | | 52.6 | |
| Automobile | | 68,850 | | 52.3 | 18 | | 3,825 | | 52.2 |
| Bus | | 420 | | 0.3 | 35 | | 12 | | 0.2 |
| Taxi | | 117 | | 0.1 | 9 | | 13 | | 0.2 |
| Intercity | 62,246 | | 47.3 | | 29 | 2,173 | | 29.7 | |
| Automobile | | 54,000 | | 41.0 | 32 | | 1,688 | | 23.1 |
| Air | | 6,600 | | 5.0 | 14 | | 471 | | 6.4 |
| Bus | | 1,300 | | 1.0 | 125 | | 10 | | 0.1 |
| Rail | | 346 | | 0.3 | 80 | | 4 | | 0.1 |
| Goods Movement, Total | 180,353 | | 100.0 | | 139 | 1,293 | | 17.7 | |
| Urban (Truck), Total | 1,161 | | 0.6 | | 4 | 287 | | 3.9 | |
| Intercity, Total | 179,192 | | 99.4 | | 178 | 1,006 | | 13.8 | |
| Truck | | 27,200 | | 15.2 | 52 | | 520 | | 7.1 |
| Rail | | 47,180 | | 26.2 | 200 | | 236 | | 3.2 |
| Oil Pipelines | | 98,387 | | 54.5 | 500 | | 197 | | 2.7 |
| Intracoastal Water | | 6,210 | | 3.4 | 220 | | 28 | | 0.4 |
| Air | | 215 | | 0.1 | 10 | | 25 | | 0.4 |
| TOTAL | --- | | --- | | --- | 7,316 | | 100.0 | |

* Two separate percentages are presented. The first represents percent of passenger miles served by the different modes; the second represents percent of ton miles served by the different modes.

** One percentage is presented. The percent of total transportation fuel consumed by the different modes is identified.

Because of the large volume of energy consumed by the transportation sector, it is appropriate to evaluate the feasibility of improving transportation fuel efficiency to reduce fuel demand. Fuel efficiency is commonly expressed as passenger-miles per gallon for person movement and ton-miles per gallon for goods movement.

Improving the fuel efficiency of transportation requires reversing the existing trend toward less fuel efficient transportation. Over the past decade, use of heavier autos with more power options, lower auto occupancies (persons per auto), declining transit availability, and increased use of the air mode have contributed to a lower overall fuel efficiency.

Several approaches can be pursued to reduce transportation fuel consumption. A brief description of the more pertinent approaches is presented below.

*Urban Person Movement*

1. Improved Vehicle Efficiency - Increase the average miles per gallon associated with auto travel.

2. Mass Transit Improvements - Increase mass transit availability.

3. Other Conservation Measures - Provide incentives for car pooling, walking, and bicycling. Improve traffic flow.

*Intercity Person Movement*

1. Improved Vehicle Efficiency - Increase the average miles per gallon associated with auto travel.

2. Increased Airline Load Factors - Provide incentives to increase the percent of occupied seats per flight.

3. Modal Shifts - Encourage shifts in travel to the more efficient travel modes.

*Urban Goods Movement*

1. Incentives To Increase Load Factors - Provide incentives to increase the average size of load per delivery vehicle.

*Intercity Goods Movement*

1. Improved Diesel Efficiency - Increase the average miles per gallon associated with motor truck transportation.

2. Alterations in Regulation - Alter regulation to reduce empty backhauls and increase weight limits.

3. Modal Shifts - Encourage the use of the more energy efficient modes for goods movement.

Table S-2 presents an estimate of reductions in transportation fuel consumption that could result from implementation of these actions.

Table S-2: Summary, Effectiveness of Policies Designed to Reduce Transportation Fuel Consumption

| Type of Travel and Policy | Maximum Percent Reduction In Total Transportation Fuel Consumption | Dates Associated With Policies | | Governmental Unit Primarily Responsible For Policy Promotion |
|---|---|---|---|---|
| | | Implementation | Maximum Effectiveness Attained | |
| Person Movement | | | | |
| Urban | | | | |
| Improved Vehicle Efficiency | 17.4 | 1975 | 1992 | Federal |
| Mass Transit Improvements | 1.7 | 1975 | 1985 | Federal, State, Local |
| Other Conservation Measures | 4.0 | 1975 | 1980 | Local |
| Combined Impact* | 20.2 | 1975 | 1992 | --- |
| Intercity | | | | |
| Improved Vehicle Efficiency | 7.7 | 1975 | 1992 | Federal |
| Increased Airline Load Factors | 1.1 | 1975 | 1980 | Federal, State |
| Modal Shifts | 0.6 | 1975 | 1980 | Federal |
| Combined Impact* | 9 | 1975 | 1992 | --- |
| Total Potential Savings | 29.2 | 1975 | 1992 | --- |
| Goods Movement | | | | |
| Urban | | | | |
| Incentives to Increase Load Factors | 0.8 | 1975 | 1980 | Local |
| Intercity | | | | |
| Improved Diesel Efficiency | 1.0 | 1975 | 1980 | Federal |
| Alterations in Regulation | 2.0 | 1975 | 1980 | Federal, State |
| Modal Shift | 0.2 | 1975 | 1980 | Federal, State |
| Combined Impact* | 3 | 1975 | 1980 | --- |
| Total Potential Savings | 3.8 | 1975 | 1980 | --- |
| All Transportation | 33.0 | 1975 | 1992 | --- |

* All conservation measures are not compatible. Thus, the potential savings associated with the individual measures are not additive in determining total savings.

Actions directed toward improving the fuel efficiency of person movement could reduce transportation fuel consumption by as much as 29.2 percent. Improved fuel efficiency for goods movement could curtail fuel consumption by an additional 3.8 percent.

While these savings appear impressive, it should be noted that over 75 percent of the estimated reduction in fuel consumption results from improved auto fuel efficiency. This is based on the assumption that auto fuel efficiency can be increased 50 percent by the 1980 model year. Because of the impressive fuel savings that can be realized from improved auto efficiency, it is an action that warrants considerable study in policy development.

A certain lead time will exist between the time at which a policy is initiated and the time at which the maximum benefits of that policy are realized (Table S-2). The policy with the greatest potential fuel savings (i.e., improved auto fuel efficiency) also has the greatest lead time. If all the possible actions listed in Table S-2 were initiated in 1975, maximum possible savings could be realized by 1992.

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# I. Fuel Savings Associated With Modal Shifts

# I. Fuel Savings Associated With Modal Shifts

Twenty-five percent of all energy consumed in the United States is used in transportation (1).* In Texas, slightly less than half of transportation energy is utilized in the intercity movement of persons and goods. Certain modes of intercity transportation are more energy efficient than others; if travel could be shifted to more energy efficient modes, overall transportation fuel efficiency would be increased.

This chapter is divided into three sections. The first section determines the magnitude of total transportation fuel consumption in Texas. That portion of total transportation fuel used for intercity travel is identified. The second section addresses intercity person movement while the third section considers intercity goods movement. The fuel efficiency of the intercity travel modes is identified. An estimate is provided of existing and future passenger-miles and ton-miles of intercity travel in Texas. From these data, estimates of fuel consumption are formulated. Indications of the magnitude of fuel savings that might result from modal shifts are also presented.

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* Denotes reference number listed at end of chapter.

## IA. Magnitude of Transportation Fuel Consumption In Texas

In 1970, over 7.3 billion gallons of transportation fuel were consumed in Texas (Table I-1). This fuel provided in excess of 130 billion passenger-miles of travel and in excess of 180 billion ton-miles of goods movement. The percentage values presented in Table I-1, although based on 1970 data, should be representative of current travel.

Table I-1: Estimated 1970 Transportation Fuel Consumption by Mode, Texas

| Type of Transport | Passenger Miles or Ton Miles | | Fuel Efficiency (Passenger Mi. or Ton Mi./Gallon) | Fuel Consumed | |
|---|---|---|---|---|---|
| | Miles (Millions) | Percent of Total* | | Gallons (millions) | Percent of Total** |
| Person Movement, Total | 131,633 | 100.0 | 22 | 6,023 | 82.3 |
| Urban, Total | 69,387 | 52.7 | 18 | 3,850 | 52.6 |
| Automobile | 68,850 | 52.3 | 18 | 3,825 | 52.2 |
| Bus | 420 | 0.3 | 35 | 12 | 0.2 |
| Taxi | 117 | 0.1 | 9 | 13 | 0.2 |
| Intercity | 62,246 | 47.3 | 29 | 2,173 | 29.7 |
| Automobile | 54,000 | 41.0 | 32 | 1,688 | 23.1 |
| Air | 6,600 | 5.0 | 14 | 471 | 6.4 |
| Bus | 1,300 | 1.0 | 125 | 10 | 0.1 |
| Rail | 346 | 0.3 | 80 | 4 | 0.1 |
| Goods Movement, Total | 180,353 | 100.0 | 139 | 1,293 | 17.7 |
| Urban (Truck), Total | 1,161 | 0.6 | 4 | 287 | 3.9 |
| Intercity, Total | 179,192 | 99.4 | 178 | 1,006 | 13.8 |
| Truck | 27,200 | 15.2 | 52 | 520 | 7.1 |
| Rail | 47,180 | 26.2 | 200 | 236 | 3.2 |
| Oil Pipelines | 98,387 | 54.5 | 500 | 197 | 2.7 |
| Intracoastal Water | 6,210 | 3.4 | 220 | 28 | 0.4 |
| Air | 215 | 0.1 | 10 | 25 | 0.4 |
| TOTAL | --- | --- | --- | 7,316 | 100.0 |

* Two separate percentages are presented. The first represents percent of passenger miles served by the different modes; the second represents percent of ton miles served by the different modes.

** One percentage is presented. The percent of total transportation fuel consumed by the different modes is identified.

Over 80 percent of transportation fuel is consumed in the movement of persons. Less than 20 percent is used in goods movement.

Also, the majority of fuel is used to provide urban transportation. The urban movement of both persons and goods consumes 56.5 percent of total transportation fuel. Thus, intercity travel, which is evaluated in this chapter, consumes only 43.5 percent of total transportation fuel; intercity person movement utilizes 29.7 percent of transportation fuel and intercity goods movement consumes 13.8 percent of Texas transportation fuel. Highway transportation modes consumed 86.8 percent and non-highway modes consumed 13.2 percent of Texas transportation fuel in 1970 (Table I-2).

Table I-2: Estimated 1970 Highway and Non-Highway Use of Transportation Fuel, Texas

| Mode of Travel | Percent of Total Transportation Fuel Consumed | |
|---|---|---|
| Highway Use | 86.8 | |
| Passenger Cars | | 75.3 |
| Trucks (Non-personal use) | | 11.0 |
| Buses | | 0.3 |
| Taxis | | 0.2 |
| Non-Highway Use | 13.2 | |
| Railroad | | 3.3 |
| Air | | 6.8 |
| Oil Pipelines | | 2.7 |
| Intracoastal Water | | 0.4 |
| Total | 100 | 100.0 |

On a national basis, transportation consumes 25 percent of total energy (1) which, in 1970, was equivalent to $16.4 \times 10^{15}$ Btu. Based on the total fuel use shown in Table I-1, transporation in Texas consumes approximately $1.03 \times 10^{15}$ Btu, or approximately 6.2 percent of U.S. transportation fuel. In that Texas' population is 5.5 percent of U.S. population and that vehicle miles per person in Texas exceeds the U.S. average by 9 percent, this value appears reasonable.

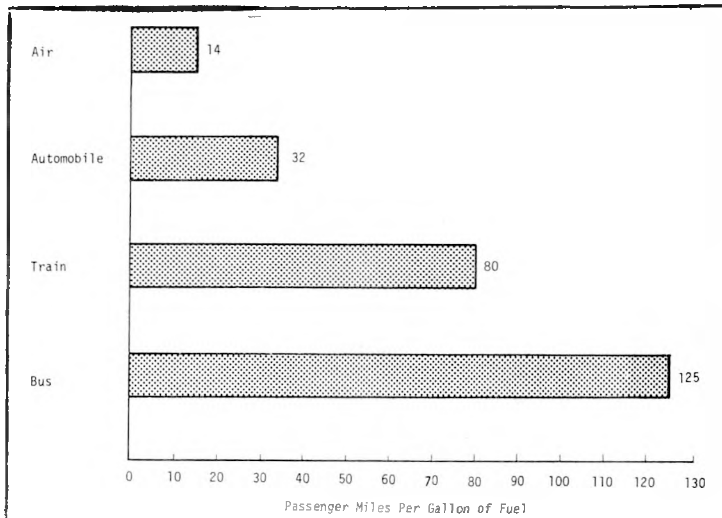
Analysis of data developed by others (2) indicates that total 1970 energy consumption in Texas was $5.76 \times 10^{15}$ Btu. Assuming this value to be accurate, transportation fuel consumption in Texas represents only 17.8 percent of statewide energy usage. This value suggests that although Texas contains only 5.5 percent of U.S. population, it consumes 8.9 percent of U.S. energy. This implies that per capita energy consumption in Texas exceeds the national average by 60 percent.

In summary, over 7.3 billion gallons of fuel were consumed in statewide transportation in 1970. Approximately 44 percent of this fuel was used in the intercity movement of persons and goods. Since transportation accounts for 18 percent of total Texas energy consumption, the fuel used in the intercity movement of persons and goods represents 8 percent of total energy consumption.

## IB. Intercity Passenger Transportation

### Fuel Efficiency of Intercity Passenger Modes

Intercity passenger travel in Texas is primarily served by the automobile, rail, air, and bus. The fuel efficiencies of these modes (expressed in passenger miles per gallon), based on existing operations, are quite different (Figure I-1). The bus and the train are the more energy efficient modes of transportation, while air and the auto are considerably less efficient. These fuel efficiencies are highly dependent on the number of passengers per vehicle. Fuel efficiency can be improved by either increasing vehicle occupancy or by shifting travel to the more fuel efficient modes.




Source: References 1, 3, 4

Figure I-1: Energy Efficiencies of Intercity Passenger Transportation Modes

### Historical Travel Trends, United States Data

A review of historical travel data (Figure I-2) provides both an indication of the increase in total travel as well as a description of trends in modal use. Between 1943 and 1971, intercity passenger miles of travel increased at an annual compound rate slightly in excess of 5.5 percent. Total U.S. intercity passenger miles of travel exceeded 1200 billion in 1971 (3,4).

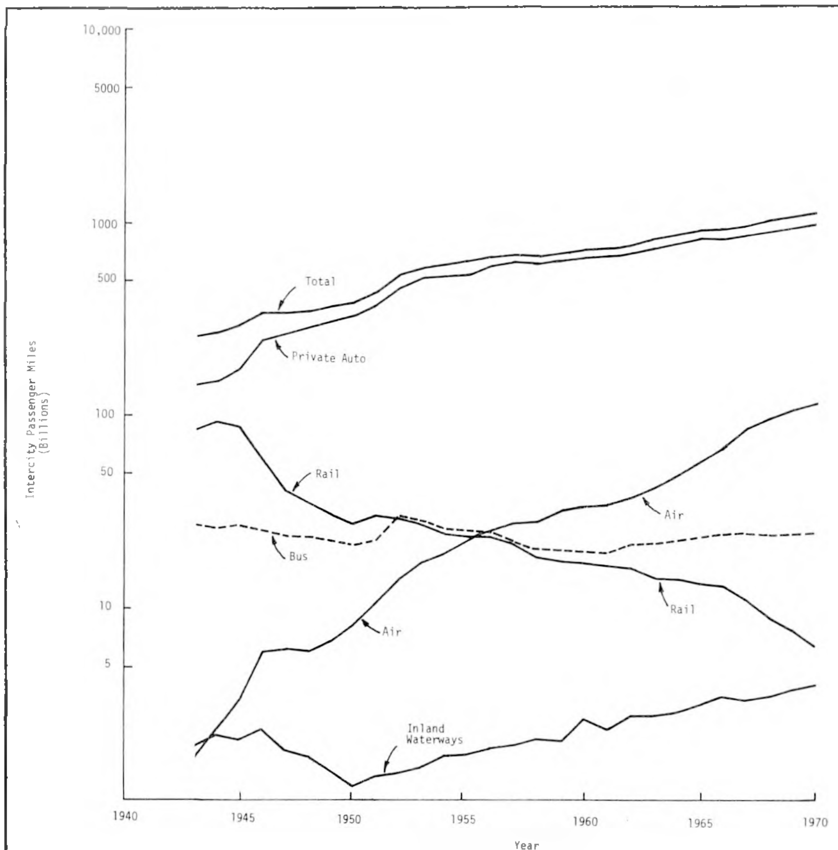


Figure 1-2: U.S. Intercity Passenger Miles of Travel By Mode of Transportation

Between 1943 and 1949, the private auto increased its share of the intercity passenger market from 56 to 84 percent. Since that time, the auto has consistently served 85 to 90 percent of intercity passenger travel.

Intercity air travel has also experienced significant growth. While this mode served less than one percent of travel in 1943, it served in excess of ten percent in 1970. The rate of growth between 1943 and 1970 was reasonably constant; however, the percent of total intercity travel served by the air mode decreased between 1970 and 1971.

Rail served nearly 30 percent of the intercity travel market in 1943. This had declined to approximately 0.5 percent of intercity travel by 1970.

The volume of traffic served by the bus has remained relatively constant since 1950. However, since total intercity travel increased during this same period, the percentage of intercity travel served by bus declined.

On a national basis, a limited amount of intercity passenger travel is accommodated on inland waterways. Approximately 0.7 percent of intercity passenger travel moved by water in 1943; the percentage of the intercity travel market served by water declined to 0.3 percent in 1970.

## 1970 Travel By Mode, U.S. and Texas

Available data compiled by the Interstate Commerce Commission (4) document the magnitude of total travel and the travel by mode in the United States. Explicit data are not available for Texas travel.

Consequently, an estimate of intercity passenger travel in Texas was formulated. The analyses and assumptions used in developing this estimate are documented in Appendix A of this report.

Table I-3 presents 1970 intercity travel data for Texas and the United States. Texas intercity travel represents 5.3 percent of total U.S. intercity travel. The percent of total travel served by the different modes in Texas and the nation is quite similar.

Table I-3: Estimated 1970 Intercity Passenger Miles of Travel By Mode, Texas and the United States

| Mode | Texas* | | United States** | |
|---|---|---|---|---|
| | Passenger Miles (millions) | Percent of Total | Passenger Miles (millions) | Percent of Total |
| Automobile | 54,000 | 86.7 | 1,026,000 | 86.9 |
| Air | 6,600 | 10.6 | 119,000 | 10.2 |
| Rail | 346 | 0.6 | 6,409 | 0.5 |
| Bus | 1,300 | 2.1 | 25,000 | 2.1 |
| Waterways | 0 | 0.0 | 4,000 | 0.3 |
| Total | 62,246 | 100.0 | 1,180,409 | 100.0 |

* Source: Appendix A

** Source: References 3,4

## Projected Travel By Mode, Texas

Nationwide, intercity passenger travel has been increasing at an annual compound rate of 5.5 percent. Expansion by this historical rate may overestimate future travel; decreases in both expendable income and birth rate should cause some decrease in the rate of increase in intercity travel. Thus, it is assumed that in the absence of any occurrences significantly affecting intercity travel, intercity passenger miles of travel will increase at an annual compound rate of 5.0 percent.

To obtain total future intercity travel in Texas, the total 1970 travel presented in Table I-3 was increased by the assumed growth rate. At this rate of increase, total intercity passenger miles of travel in Texas in the year 2000 will exceed 260 billion.

Unless strong actions are taken, it is reasonable to assume that existing travel patterns and modal choice will not change significantly. Based on U.S. data (4), historical trends and projections of the percent of the market served by the different modes are presented in Figure I-3. By extrapolating these data, future intercity passenger travel in Texas is estimated to be as shown in Table I-4. Figure I-4 graphically presents this information.

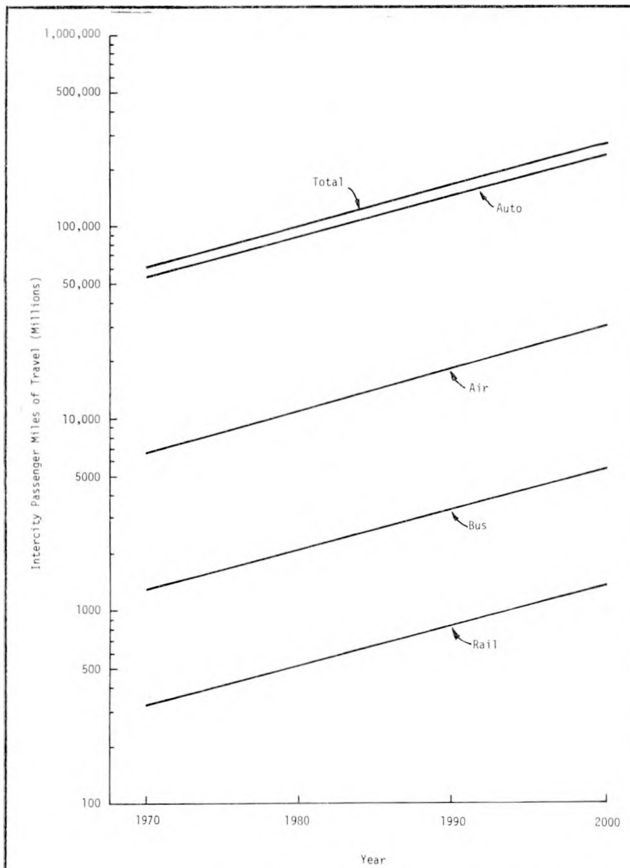



Figure I-4: Projected Intercity Passenger Miles of Travel in Texas By Mode, 1970 - 2000.

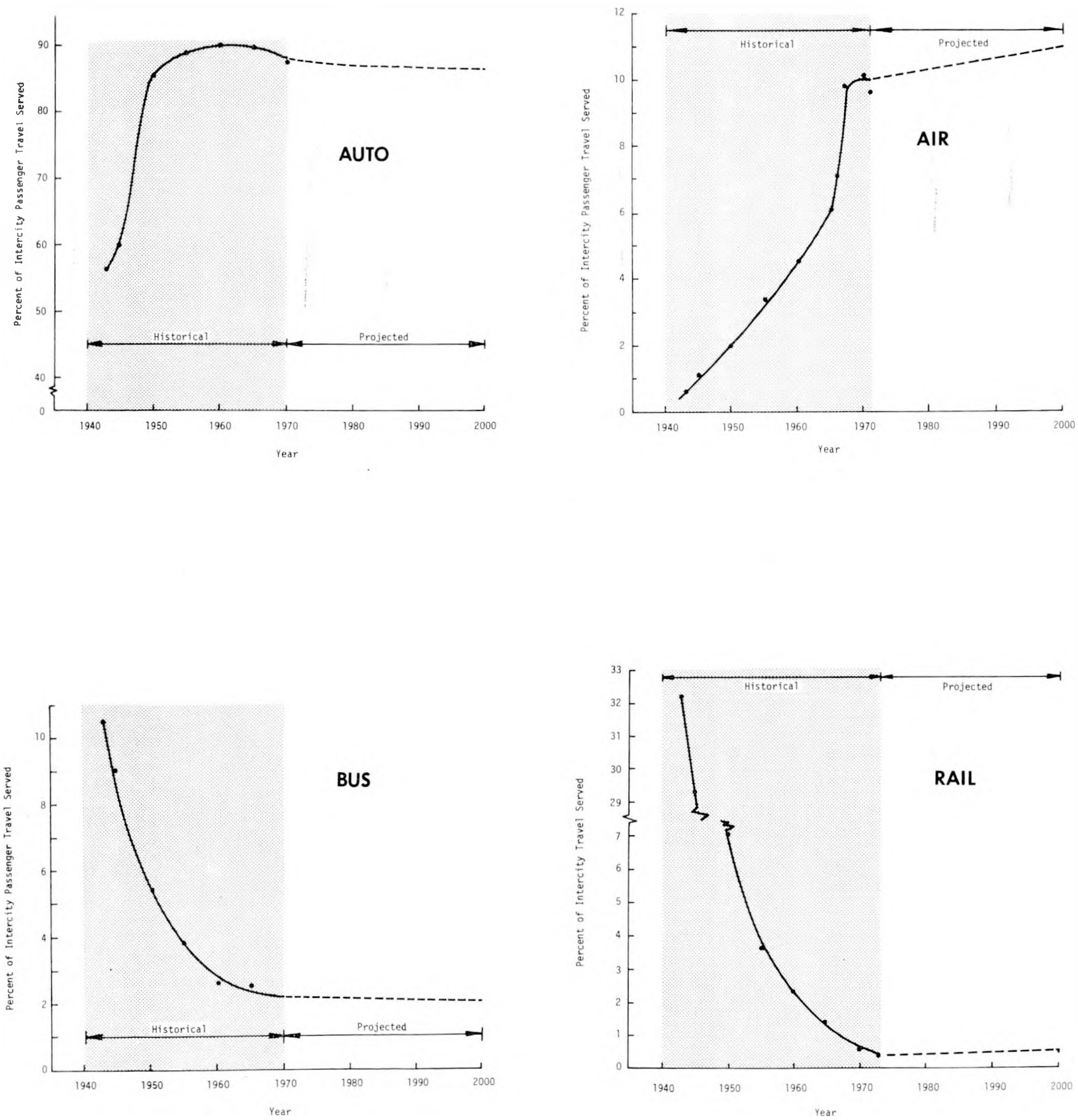



Figure I-3: Historical and Future Trends In Modal Use, U.S. Data

Table I-4: Estimated Intercity Passenger Miles of Travel in Texas By Mode, 1970 and 2000

| Mode | 1970 | | 2000 | |
|---|---|---|---|---|
| | Passenger Miles (millions) | Percent of Total | Passenger Miles (millions) | Percent of Total |
| Automobile | 54,000 | 86.7 | 232,703 | 86.5 |
| Air | 6,600 | 10.6 | 29,592 | 11.0 |
| Rail | 346 | 0.6 | 1,345 | 0.5 |
| Bus | 1,300 | 2.1 | 5,380 | 2.0 |
| Total | 62,246 | 100.0 | 269,020 | 100.0 |

If the estimated travel demand in the year 2000 actually occurs, the capacity of the existing transportation system will be greatly exceeded. New facilities will be required to serve this demand. If energy conservation is the primary consideration, facilities can be provided to encourage the use of the more energy efficient modes of travel.

## 1970 Intercity Passenger Transportation Fuel Consumption

By applying the modal fuel efficiencies (Figure I-1) to the 1970 travel data (Table I-3), an indication of 1970 transportation fuel consumption in both Texas and the United States is formulated. This information is presented in Table I-5.

The overwhelming majority of intercity passenger transportation fuel is consumed by the fuel inefficient transportation modes. Whereas air serves only 10.6 percent of Texas intercity passenger miles, it consumes 21.7 percent of the transportation fuel used in intercity passenger transport. Air and auto, the least fuel efficient modes of transportation,

Table I-5: Estimated 1970 Transportation Fuel Used in Intercity Passenger Transport, By Mode, Texas and United States

| Mode | Texas | | United States | |
|---|---|---|---|---|
| | Gallons of Fuel (millions) | Percent of Total | Gallons of Fuel (millions) | Percent of Total |
| Automobile | 1,688 | 77.7 | 32,062 | 78.5 |
| Air | 471 | 21.7 | 8,500 | 20.8 |
| Rail | 4 | 0.2 | 80 | 0.2 |
| Bus | 10 | 0.4 | 200 | 0.5 |
| Waterways | 0 | 0.0 | N.A. | N.A. |
| Total | 2,173 | 100.0 | 40,842 | 100.0 |

N.A. = Not Available

serve 97.3 percent of all passenger miles of intercity travel and consume 99.4 percent of all fuel used in intercity passenger movement. Recent trends have been toward more dependence on the less fuel efficient air mode.

These data should not be interpreted to imply that auto and air travel should necessarily be strongly discouraged for energy reasons. The fuel efficiency of these modes can be improved significantly by increasing the average occupancy per vehicle and/or by improving vehicle engine fuel efficiency. These approaches certainly warrant additional consideration.

Projected Intercity Passenger Transportation Fuel Consumption

The data concerning modal fuel efficiencies (Figure I-1) and the information pertaining to projected intercity passenger travel demand are combined to develop an estimate of future fuel demand in Texas.

This information is summarized in Table I-6 and in Figure I-5.

Table I-6: Projected Transportation Fuel Used in Intercity Passenger Transport in Texas, 1970-2000

| Mode | Gallons of Fuel Consumed (millions) | |
|---|---|---|
| | 1970 | 2000 |
| Automobile | 1,688 | 7,271 |
| Air | 471 | 2,113 |
| Rail | 4 | 17 |
| Bus | 10 | 43 |
| Total | 2,173 | 9,444 |

The values shown in Table I-6 and Figure I-5 are based on the following assumptions:

- intercity travel will continue to increase at an annual compound rate of 5.0 percent;
- no drastic changes will occur in modal use; and
- the fuel efficiencies of the various modes will not be changed significantly.

The estimate of future travel and fuel consumption presented is a realistic estimate of what can be expected to occur unless actions are taken in the future that will

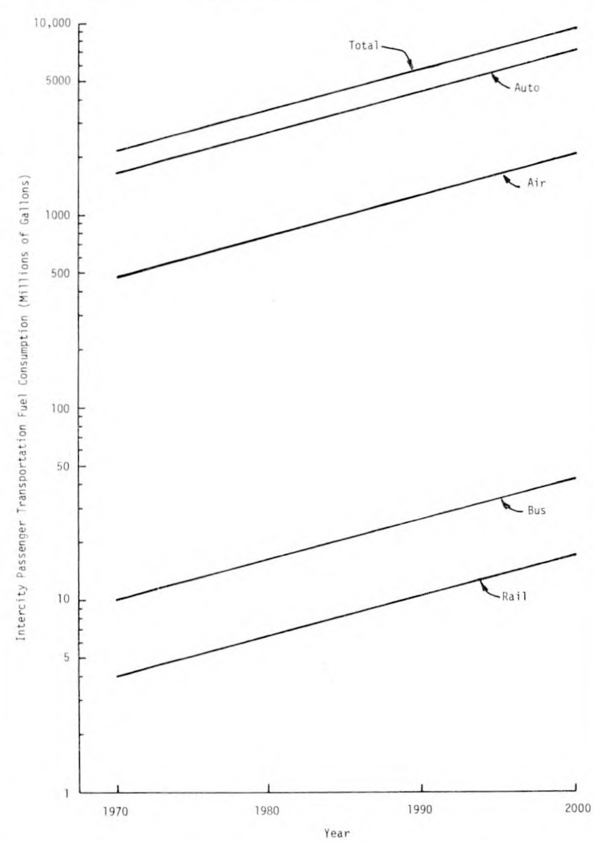


Figure I-5: Projected Intercity Passenger Transportation Fuel Consumption in Texas, 1970 - 2000.

invalidate these assumptions. Unless events occur (changes in regulatory policy, increased fuel cost, continued decreases in personal income, etc.) that will stimulate changes in current travel habits, there is no reason to expect that significant modal shifts will occur.

## Effect of Modal Shifts

At present, nearly all intercity passenger movement is served by the two least fuel efficient modes -- the auto and the airplane. If some of this travel could be shifted to more fuel efficient modes, total fuel consumption could be reduced. Table I-7 presents the estimated fuel savings that can be accrued from each one percent of traffic served by a relatively fuel inefficient mode that is shifted to a more fuel efficient mode.

Table I-7: Estimated Effect of Modal Shifts on Intercity Passenger Transportation Fuel Consumption In Texas

| Modal Shift* | Percent Increase In Intercity Passenger Transportation Fuel Efficiency | Gallons of Fuel Saved (millions) | |
|---|---|---|---|
| | | 1970 | 2000 |
| 1% of Air Travel Shifted To: | | | |
| Auto | 0.11 | 2.4 | 10.4 |
| Rail | 0.13 | 2.9 | 12.3 |
| Bus | 0.14 | 3.1 | 13.2 |
| 1% of Auto Travel Shifted To: | | | |
| Rail | 0.47 | 10.3 | 44.4 |
| Bus | 0.58 | 12.7 | 54.8 |

*In 1970, air served 6.6 billion passenger-miles; auto served 54 billion passenger-miles. Thus, a one percent shift of air travel involves 66 million passenger-miles; a one percent shift of auto travel involves 540 million passenger-miles.

At present, the overall fuel efficiency associated with intercity passenger movement is 28.65 passenger-miles per gallon. Shifts to more efficient modes will increase this efficiency. For example, for each one percent of existing air travel shifted to auto travel, overall fuel efficiency will increase by 0.11 percent. Similarly, for each one percent of existing auto travel shifted to busses, overall fuel efficiency will increase by 0.58 percent.

Shifts to more energy efficient modes will result in a reduction in total fuel consumed. For example, in the year 2000, a shift of one percent of auto travel to bus travel could conserve in excess of 50 million gallons of fuel.

## Considerations Concerning Modal Shifts

Shifting travel to more energy efficient modes initially appears to represent an attractive means of conserving transportation energy. However, it should be noted that people prefer the inefficient modes because of the advantages and disadvantages associated with the different intercity passenger modes. Unless actions are taken or occur to alter the competitive positions of the different modes, it is unrealistic to expect that significant modal shifts will occur.

This section is divided into two parts. The first briefly describes the characteristics of the various intercity passenger modes. It identifies the reasons individuals choose different modes. The second part identifies the types of travel that are served largely by the fuel inefficient modes. This information should be useful in identifying actions that will induce modal shifts.

*Characteristics of Intercity Passenger Transporation Modes* (5)

Since the advent of the automobile and the development of extensive highway systems, people in the United States have depended heavily upon the automobile for intercity travel (86.6% of the total U.S. intercity travel in 1970 (4)). The private automobile will continue to be an attractive mode of travel since it offers a level of convenience and flexibility unmatched by other modes of transportation.

The automobile is especially attractive for short intercity trips and recreational travel. The driver can depart his own home and arrive directly at his destination. While at his destination, the automobile provides the traveler a means of transportation in the local area. However, the private automobile is not as desirable on longer trips because of the additional travel time as well as cost of food and lodging.

Air travel is generally considered to be attractive for the following reasons:

- speed of travel;
- status, prestige, and comfort; and
- dependability of service.

Since air travel does not require a fixed facility cost between terminals, it can be economically feasible despite relatively low passenger demand. Air can successfully serve levels of intercity passenger demand that are not sufficient to justify rail service. Nevertheless, air is an expensive means of intercity travel.

High speed rail service has shown that it can compete successfully with short-haul air service between areas of extremely dense passenger demand. Trains operating at speeds of 100 to 150 miles per hour can provide a comparable level of service to air. However, the cost of rail facilities does require a substantial volume of intercity travel demand.

The level-of-service (travel time and cost) provided by conventional intercity rail lies between that provided by the bus and that provided by air. Travel time is slower than air and comparable to bus. Cost of travel, however, exceeds that of the bus. Rail does, however, provide a different travel experience. The traveller can get up, walk around, eat meals, etc., as a part of his travel experience.

Intercity travel by bus is dependable but slow. It is less expensive and commonly selected by people who do not own automobiles and cannot afford air fares. Non-stop bus service between cities less than 200 miles apart can provide a competitive alternative to intercity travel by high-speed rail or air.

*Travel Characteristics by Mode*

In terms of fuel consumed per passenger mile, air and auto are relatively inefficient modes of intercity passenger transportation. Thus, modal shifts designed to increase overall fuel efficiency (based on existing operating efficiencies) should discourage travel by these modes. Tables I-8 and I-9 identify the type of travel being served by the different modes (6). Due to data discrepencies, the numbers shown in these tables do not correspond to those presented previously; only intercity trips of 100 miles

Table I-8: Volume of U.S. Intercity Travel, By Mode*

| Characteristic | Mode of Intercity Passenger Travel | | | | |
|---|---|---|---|---|---|
| | Auto | Air | Bus | Rail | Other |
| Passenger Miles (Millions) | 256,545 | 101,904 | 5,392 | 1,882 | 3,874 |
| Percent of Total Travel | 69.4 | 27.5 | 1.5 | 0.5 | 1.1 |

Table I-9: Intercity Travel by Trip Purpose*

| Trip Characteristic | Percent of Intercity Passenger Travel Served By Each Mode | | | |
|---|---|---|---|---|
| | Auto | Air | Bus | Rail |
| Trip Purpose | | | | |
| Visit Friends, Relatives | 29.9 | 7.6 | 0.5 | 0.30 |
| Business, Conventions | 9.5 | 12.0 | 0.2 | 0.10 |
| Outdoor Recreation | 19.2 | 4.4 | 0.5 | 0.10 |
| Other | 10.8 | 3.5 | 0.3 | 0.05 |
| Family Income | | | | |
| Under $10,000 | 27.2 | 6.1 | 0.9 | 0.18 |
| Over $10,000 | 39.4 | 20.1 | 0.5 | 0.30 |
| No Answer | 2.8 | 1.3 | 0.1 | 0.02 |
| Occupation, Head of Household | | | | |
| Professional | 24.9 | 15.0 | 0.32 | 0.24 |
| Craftsman, Laborer | 19.8 | 3.8 | 0.32 | 0.07 |
| Clerical | 10.0 | 4.2 | 0.13 | 0.06 |
| Other | 14.7 | 4.5 | 0.73 | 0.13 |
| Round Trip Distance (Miles) | | | | |
| Under 1,000 | 31.3 | 2.6 | 0.8 | 0.1 |
| Over 1,000 | 38.1 | 24.9 | 0.7 | 0.4 |
| Day of Week | | | | |
| Weekend | 29.4 | 4.9 | 0.50 | 0.13 |
| Weekday | 35.4 | 20.6 | 0.83 | 0.34 |
| No Answer | 4.6 | 2.0 | 0.13 | 0.03 |
| Number of Persons on Trip | | | | |
| One | 12.6 | 15.3 | 0.79 | 0.17 |
| Two | 20.8 | 8.3 | 0.44 | 0.15 |
| Three to Five | 29.9 | 3.7 | 0.21 | 0.16 |
| Six or More | 6.1 | 0.2 | 0.02 | 0.02 |

* Only intercity trips of more than 100 miles (one-way distance) are included in these data.

or more (one-way distance) are included in these data. As a result, air travel is disproportionately represented.

According to the 1972 Census of Transportation (6), nearly 370 billion annual intercity passenger-miles occurred on trips of 100 miles (one-way distance) or more in the United States. Nearly 97 percent of these trips were made by either air or auto.

Air travel, in terms of passenger-miles per gallon, is the least efficient of the modes. Table I-9 shows that the air mode primarily serves the following types of trips:

- business trips;
- trips by persons with annual incomes in excess of $10,000;
- trips by professional persons;
- round trip distance in excess of 1000 miles;
- weekday trips; and
- trips with only one person in the traveling party.

If efforts are to be made to divert air travel to more fuel efficient modes, it appears that these efforts should be directed primarily at the types of trips identified above.

## Conclusions

Based on existing operations in the United States, the fuel efficiencies of the intercity passenger transportation modes differ. Bus and rail are the more efficient modes. Air and auto are the least fuel efficient modes.

Intercity passenger-miles of travel have been increasing; between 1973 and 1971 this travel increased at an annual compound rate of 5.5

percent. The trend has been toward a greater percentage of intercity passenger travel being served by the inefficient modes of transport, namely air and auto.

In 1970, it is estimated that over 62 billion passenger-miles of intercity travel occurred in Texas; nearly 1,200 billion passenger-miles of travel occurred in the United States during this same year. The percent of total travel served by the different modes in Texas and the nation is quite similar.

In the absence of significant changes in current conditions, intercity passenger travel should increase in the future at an annual compound rate of approximately 5 percent. At this rate, total intercity passenger-miles of travel in Texas will exceed 260 billion by the year 2000.

Intercity passenger transportation fuel consumption in Texas in 1970 was nearly 2.2 billion gallons. The overwhelming majority of this fuel is consumed by the inefficient modes of transportation. Whereas air serves only 10.6 percent of intercity passenger-miles in Texas, it consumed 21.7 percent of intercity passenger transportation fuel. Based on the projected increases in intercity travel, intercity transportation fuel demand in Texas in the year 2000 will exceed 9 billion gallons.

A shift of travel from fuel inefficient to more fuel efficient modes of transportation will increase overall fuel efficiency. For example, each one percent of existing air travel that is shifted to auto travel will increase the overall fuel efficiency of intercity passenger movement by 0.11 percent. However, it must be emphasized the existing modal choice is made for rational reasons. Unless external forces are applied to the existing transportation system, there is no reason to expect that any modal shift will actually occur.

## IC. Intercity Goods Movement

The intercity movement of freight is a vital factor to a diversified economy. The importance of this activity to the entire State cannot be underestimated. During this period of shortages and increasing prices for motor fuel, it is imperative that intercity movement of freight is accommodated in the most efficient and economical manner. Policy makers must be aware of the magnitude of this activity as well as the alternatives and consequences associated with specific actions. The ton-miles of intercity goods movement will continue to increase. Efforts can, however, be directed toward actions that hold the greatest promise for improved fuel efficiency.

Certain types of intercity freight are currently being transported by an inefficient mode when efficiency is evaluated only on the basis of ton-miles carried per energy unit. However, the introduction of others factors into the decision making process may indicate that the current traffic allocation is both efficient and economical. Changes in transportation policy and relative prices, for instance, may cause the user to reassess available alternatives.

As presented previously (Table I-1, page 5), intercity goods movement consumes approximately 14 percent of total statewide transportation fuel consumption. Over half of the fuel consumed in intercity goods movement is used by the motor truck. As a result, the primary attention in the analyses presented in this section will be focused on opportunities and alternatives for modal shift and traffic reallocation between motor trucks and rail.

Pipeline is a highly efficient specialized mode; however, it is not currently adaptable to a wide range of uses. Air transport is designed primarily for certain transport requirements and represents a very small percentage of intercity freight tonnage. Barge transport is another area of relatively specialized movement. However, due to the impact of this mode on the economy of Texas, the fuel efficiencies of waterborne commerce are also examined in this section.

## Fuel Efficiency of Intercity Goods Movement Modes

Intercity goods movement in Texas is served by motor trucks, railways, pipelines, waterways, and airways. Certain modes use fuel more efficiently in producing their ton-mile output. Ton-miles of freight transported per gallon of fuel consumed is the common descriptor of modal energy efficiencies.

Studies (1,7) have identified the various modal efficiencies. A review of these data indicate that the fuel efficiencies presented in Figure I-6 are representative of existing operations. Pipeline, water and rail are all relatively fuel efficient modes of intercity goods transport. The truck is considerably less fuel efficient and air is the least fuel efficient mode.

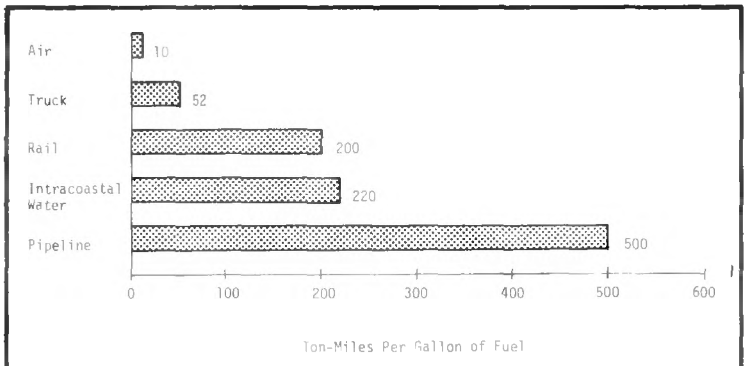



Figure I-6: Energy Efficiencies of Intercity Goods Movement Modes

Based on the data presented in Figure I-6, it is readily apparent that certain modes produce a higher level of ton-mile output than other modes. If the modes were perfect substitutes and users indifferent to the mode selected, traffic allocation could be easily assigned. This, however, is not the situation. The modes are not perfect substitutes and users have valid selection criteria other than fuel efficiency measures.

The estimates presented in Figure I-6 are generalized for the entire nation. Although Texas may have certain freight transportation characteristics which are unique to the State, there is no basis to assume any significant difference in modal fuel efficiencies.

Historical Transport Trends, United States Data

Total intercity ton-miles of goods movement in the United States have been increasing at a relatively constant rate (3). Between 1940 and 1971, ton-miles of travel increased at an annual compound rate of approximately 3.7 percent. Ton-miles transported in the United States in 1971 exceeded 1,930 billion (Figure I-7).

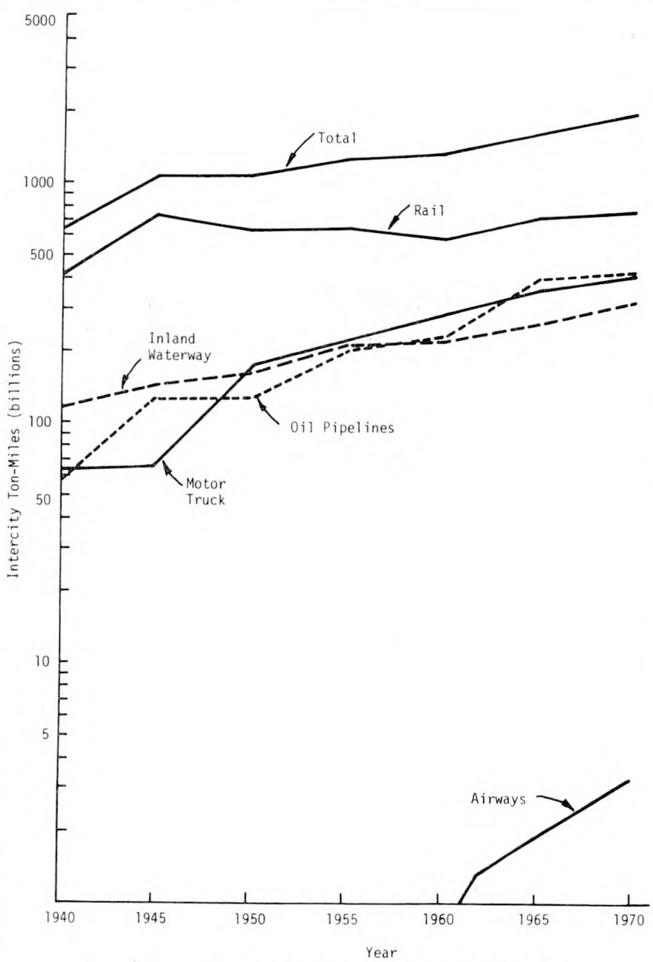



Figure I-7: Intercity Ton Miles Transported, By Mode

Railroads transport the bulk of the ton-miles; however, the percentage of total ton-miles served by rail has been declining. Rail served 63 percent of U.S. ton-miles in 1940 and served less than 40 percent of the total in 1970.

Between 1940 and 1960, motor trucks increased their share of the market from 9 to 21 percent. Since then, truck has continued to serve approximately 20 percent of total ton-miles.

The share of ton-miles moved by inland waterways has declined slightly. Inland waterways accounted for 18.1 percent of total ton-miles in 1940 and 16.5 percent in 1970. During this same period, oil pipelines have increased their share of the market from 9 to 22 percent.

Air is experiencing the most rapid rate of increase in ton-miles. However, in 1970 it served less than 0.2 percent of the market.

## Historical and Projected Intercity Goods Movement, Texas

Table I-10 presents the estimated 1970 movement of intercity goods in Texas. Oil pipelines served the majority of this movement.

Table I-10: Estimated 1970 Intercity Ton-Miles of Travel By Mode, Texas

| Mode | Ton-Miles (Millions) | Percent of Total |
|---|---|---|
| Motor Truck | 27,200 | 15.2 |
| Rail | 47,180 | 26.3 |
| Oil Pipelines | 98,387 | 54.9 |
| Intracoastal Water | 6,210 | 3.5 |
| Air | 215 | 0.1 |
| Total | 179,192 | 100.0 |

Information concerning the ton-miles of intercity freight moved in Texas by both railroad and motor truck is presented in Figure I-8. Data on ton-miles generated by railroads in the State are available from Railroad Commission statistics. Similar data regarding the ton-miles produced by motor trucks on Texas highways are not available. Two estimates of motor truck ton-miles for the period 1960-1973 are presented in Figure I-8. The procedures used in development of these estimates are presented in Appendix B. Projections of both rail and motor truck ton-miles are also shown in Figure I-8. The projection procedures are also discussed in Appendix B.

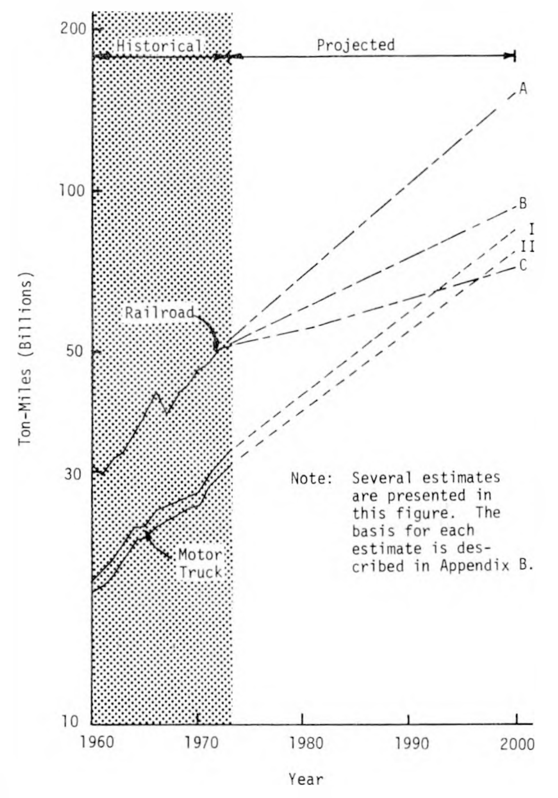


Figure I-8: Intercity Freight Movements By Railroads and Motor Trucks in Texas, 1960-2000

Intercity goods movement by railroads has grown from 31.6 billion ton-miles in 1960 to 51.6 billion in 1972 (8). This represents an increase of over 63.0 percent during the thirteen year period. During this same period, the intercity movement of freight by motor truck has increased by approximately 65.0 percent. It is estimated that between 30.7 and 36.4 billion ton-miles of freight were transported over Texas highways by motor truck in 1973. Railroads produced 51.6 billion ton-miles in 1972.

Using estimating procedures and data presented in Appendix B, projections were developed for intercity ton-miles of freight transported by both truck and rail to the year 2000. By 2000, between 77 and 85 billion ton-miles of intercity freight will move over Texas highways. At that time, railroads will be generating between 70 and 150 billion ton-miles of freight annually.

## Intercity Goods Movement Fuel Consumption, Historical and Present

Table I-11 presents the estimated 1970 consumption of fuel in Texas by the intercity goods movement modes. The trucking sector, although accounting for only 15.2 percent of total intercity ton-miles, consumed over 50 percent of the fuel used in intercity goods transportation.

Table I-11: Estimated 1970 Intercity Goods Movement Fuel Consumption By Mode, Texas

| Mode | Gallons of Fuel (Millions) | Percent of Total |
|---|---|---|
| Motor Truck | 520* | 51.7 |
| Rail | 236 | 23.4 |
| Oil Pipelines | 197 | 19.6 |
| Intracoastal Water | 28 | 2.8 |
| Air | 25 | 2.5 |
| Total | 1,006 | 100.0 |

* Special Fuels and Gasoline

Historical data on fuel used by railroads in Texas is presented in Table I-12. In 1972, more than 266 million gallons of fuel were consumed in producing 51.6 billion ton-miles. The fuel efficiency for that specific year was 194 ton-miles per gallon.

Table I-12: Total Ton-Miles and Fuel Consumption Of Railroad Companies Operating in Texas

| Year | Ton-Miles (thousands) | Gallons of Fuel Consumed | Ton-Miles Per Gallon |
|---|---|---|---|
| 1960 | 31,604,335 | 193,682,289 | 163.18 |
| 1961 | 30,514,827 | 237,931,640 | 128.3 |
| 1962 | 32,633,584 | 190,363,223 | 171.43 |
| 1963 | 33,686,847 | 189,425,170 | 177.84 |
| 1964 | 36,485,042 | 204,176,512 | 178.69 |
| 1965 | 39,569,549 | 203,564,861 | 194.33 |
| 1966 | 43,270,917 | 215,561,690 | 200.74 |
| 1967 | 39,429,613 | 217,366,673 | 181.40 |
| 1968 | 42,677,355 | 209,502,291 | 203.71 |
| 1969 | 44,333,599 | 231,341,611 | 191.64 |
| 1970 | 47,180,534 | 236,068,706 | 199.86 |
| 1971 | 48,539,908 | 239,800,878 | 202.42 |
| 1972 | 51,568,514 | 266,031,475 | 193.85 |

Source: Reference 8

Consumption of fuel by motor truck in Texas is presented in Table I-13. Recent trends have been toward more use of diesel vehicles; thus, gasoline consumption by trucks has been declining. Overall fuel efficiency has not changed significantly.

Table I-13: Intercity Ton-Miles Transported and Fuel Consumed by Motor Trucks in Texas

| Year | Ton-Miles (billions) | Gallons of Fuel (Thousands) | | | Ton-Miles Per Gallon |
|---|---|---|---|---|---|
| | | Special | Gasoline | Total | |
| 1963 | 22.2 | 216,090 | 190,000 | 406,090 | 54.7 |
| 1964 | 23.5 | 249,024 | 170,000 | 419,024 | 56.1 |
| 1965 | 23.7 | 280,622 | 160,000 | 440,622 | 53.8 |
| 1966 | 25.1 | 320,411 | 130,000 | 450,411 | 55.7 |
| 1967 | 25.7 | 351,698 | 110,000 | 451,698 | 56.9 |
| 1968 | 26.1 | 395,419 | 100,000 | 495,419 | 52.7 |
| 1969 | 26.7 | 417,000 | 100,000 | 517,000 | 51.6 |
| 1970 | 27.2 | 453,027 | 67,000 | 520,027 | 52.3 |
| 1971 | 29.4 | 522,833 | 65,000 | 587,833 | 50.0 |

Source: References 9,10

Motor trucks consumed nearly 600 million gallons of fuel in 1971 while railroads consumed 239 million gallons. Trends in fuel consumption are presented in Figure I-9.

## Projected Intercity Goods Movement Fuel Consumption

The data concerning modal fuel efficiencies (Figure I-6) and the projected ton-miles of travel by truck and rail (Figure I-8) are combined to develop an estimate of future fuel demand in Texas. This information is summarized in Table I-14.

In 1970, trucks consumed 2.2 times as much fuel as rail. It is estimated that, by the year 2000, trucks will use 2.8 times as much fuel as railroads.

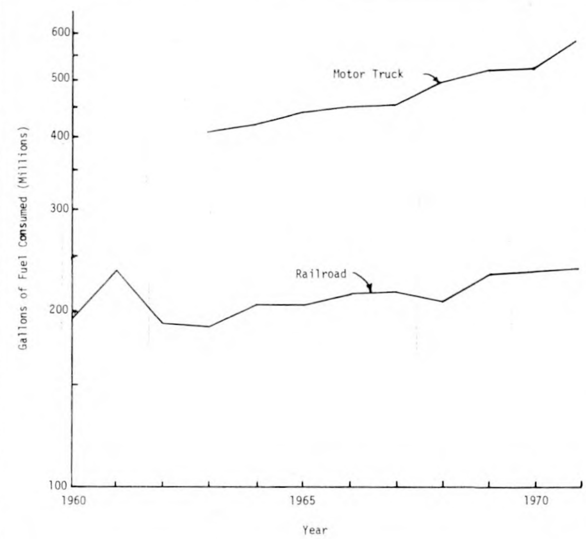



Figure I-9: Fuel Consumption By Railroads and Motor Trucks In Texas

Table I-14: Projected Ton-Miles and Transportation Fuel Used By Truck and Rail in Intercity Goods Movement, Texas

| Mode | Year | | | |
|---|---|---|---|---|
| | 1970 | | 2000 | |
| | Ton-Miles (billions) | Gallons of Fuel (millions) | Ton-Miles (billions) | Gallons of Fuel (millions) |
| Rail | 47.2 | 236 | 110 | 550 |
| Truck | 27.2 | 520 | 81 | 1560 |

## Effect of Modal Shifts

Most of the modes serving intercity goods movement are relatively fuel efficient. The air mode, although highly fuel inefficient, serves only a limited quantity of goods. Trucking, however, serves 15 percent of intercity ton-miles but consumes 52 percent of the fuel used for this purpose. This is a logical sector to consider for possible fuel savings. Traffic diverted from truck would tend to be served primarily by rail.

Under existing operation, motor trucks operate at a fuel efficiency of 52 ton-miles per gallon while railways produce 200 ton-miles per gallon. If some truck traffic could be shifted to rail, total fuel consumption could be reduced. Assuming that this modal shift will not greatly alter the modal fuel efficiencies, each one percent of truck traffic diverted to rail will reduce the consumption of fuel for intercity goods movement by 0.1 percent.

## Considerations Concerning Modal Shifts

Initially, the idea of shifting traffic to more energy efficient modes appears attractive. However, the existing modal split exists for definite economic reasons. Shippers and receivers select modes based on the characteristics of the modes. Unless actions are taken to alter the competitive positions of the different modes, it is unrealistic to expect that significant modal shifts will occur.

This section is divided into three parts. The first part discusses the inherent advantages of the various modes of intercity transport. The second section describes the characteristics of shipments transported by the different modes. The final section evaluates opportunities for modal shifts.

*Characteristics of Trucking and Rail (5)*

Trucks, operating on an extensive network of streets and highways, provide the most flexible form of goods movement. Trucks can normally pick up shipments at their point of origin and deliver them directly to their destination. This high degree of flexibility combined with relatively short delivery time yield a high level of service that make trucking an extremely attractive mode for the shipment of high-value goods over relatively short distances despite its apparently higher cost.

Railroads provide a reasonably rapid means of transporting bulk goods and have the capability of moving many different commodities. The extensive network of rail tracks makes this the most flexible mode of bulk transportation. However, unless the origin and destination of the shipment are both located at a rail siding, goods shipped by rail must also be transported by another mode.

*Characteristics of Intercity Freight*

The distance a shipment travels is a criterion used in selecting the mode of transportation. Table I-15 presents the ton-mile distribution by distance shipped for both the State and the nation. Two distributions are presented, one with and the other without petroleum and coal products. A comparison of U.S. and Texas (all commodities) shows some striking differences, primarily the large percent of Texas ton-miles that are generated on long distance shipments. More than 80.0 percent of the total Texas ton-miles are generated by movement of 1000 miles and over. Only 51.4 percent of U.S. ton-miles are generated through shipments in this mileage category.

Table I-15: Percent Distribution of Intercity Ton-Miles Goods Movement by Mileage Block - 1967

| Distance (miles) | United States | | Texas | |
|---|---|---|---|---|
| | All Commodities | Excluding Petroleum and Coal Products | All Commodities | Excluding Petroleum and Coal Products |
| Less Than 100 | 2.6 | 3.6 | 0.5 | 2.9 |
| 100-199 | 4.5 | 6.6 | 1.3 | 6.0 |
| 200-299 | 5.7 | 7.9 | 1.8 | 8.9 |
| 300-499 | 9.6 | 13.7 | 2.0 | 9.8 |
| 500-999 | 26.2 | 28.6 | 12.5 | 27.4 |
| 1000-1499 | 27.6 | 13.0 | 54.6 | 31.8 |
| 1500 & Over | 23.8 | 26.6 | 27.3 | 13.2 |
| TOTAL | 100.0 | 100.0 | 100.0 | 100.0 |

Note: Total Ton-Miles Texas: All commodities = 198,678 (million); excluding petroleum and coal products = 22,478 (million).

Total Ton-Miles U.S. : All commodities 678,992 (million) excluding petroleum and coal products = 390,636.

Pipeline shipments are not included in these data.

Source: Reference 11

The removal of petroleum and coal products ton-miles results in distributions for the U.S. and Texas which are similar in most mileage categories. For example, 39.6 percent of the U.S. ton-miles are generated in freight movement of 1000 miles and over, while 45.0 percent of the Texas ton-miles are produced in this mileage category. Petroleum and coal products were removed from the distribution because their movement is predominately by water or pipeline, both highly energy efficient modes.

The distribution of intercity ton-miles by mode is presented in Table I-16. Again, two distributions for both the U.S. and Texas are shown. Water transport is the primary mode when all commodities are considered. Almost 90.0 percent of the Texas intercity ton-miles are generated in waterborne commerce.* The removal of petroleum and coal products

Table I-16: Percent Distribution of Intercity Ton-Miles Goods Movement by Mode of Shipment, 1967 Data

| Mode | United States | | Texas | |
|---|---|---|---|---|
| | All Commodities | Excluding Petroleum & Coal Products | All Commodities | Excluding Petroleum & Coal Products |
| Rail | 36.8 | 61.4 | 6.6 | 49.0 |
| Truck | 19.0 | 31.2 | 3.7 | 27.2 |
| Air | 0.1 | 0.2 | --- | --- |
| Water | 43.7 | 6.5 | 89.7 | 23.8 |
| Other & Unknown | 0.4 | 0.7 | --- | --- |
| TOTAL | 100.0 | 100.0 | 100.0 | 100.0 |

Source: Reference 11

Note: Pipeline shipments are not included in these data.

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* This value is substantially highly than the value presented in Table I-10. The value in Table I-10 includes only those ton-miles that occur within Texas. The value shown on this page is based on shipment length; i.e. tons that originate in Texas multiplied by shipment length.

result in some significant changes in both the U.S. and Texas distributions. Rail is the predominate means of transportation of intercity ton-miles in both the U.S. and Texas, although the percent of ton-miles generated by rail in Texas is considerably less than the rest of the nation. Also, even with petroleum and coal removed from consideration, 23.8 percent of the Texas ton-miles are generated in waterborne commerce. Rail generated 49.0 percent of the Texas ton-miles and over 61.0 percent of total U.S. ton-miles.

Table I-17 presents the modal distribution of Texas and U.S. ton-miles by commodity group. A larger percent of U.S. ton-miles were generated by rail for almost all commodity groups as compared to Texas ton-miles. Also, there is an indication that more reliance is placed on private trucking in Texas than in the rest of the nation. For several commodity groups, the role of the motor carrier in both Texas and the U.S. is similar. Some commodity groups are orientated towards a specific mode of transportation -- petroleum, for example, moves primarily by water.

Table I-18 presents the percent distribution of Texas ton-miles by length of haul and commodity group. The majority of ton-miles for all commodity groups, except "Food and Kindred Products" and "Stone, Clay and Glass Products," are generated in movements of 500 miles and more. These two commodity groups have the largest percent of ton-miles in the less than 300 miles category. No commodity group has more than 50 percent of ton-miles in the less than 300 miles category.

The distribution of ton-mile by weight of shipment for the U.S. is presented in Table I-19. Shipment size is one of the variables which

Table I-17: Percent of Distribution of Intercity Ton-Miles, 1967 Data*

| Commodity Group | Location | Mode of Travel | | | | | |
|---|---|---|---|---|---|---|---|
| | | Rail | Motor Carrier | Private Truck | Air | Water | All Others |
| ALL COMMODITIES | Texas | 6.6 | 2.4 | 1.3 | | 89.7 | |
| | U.S. | 36.8 | 14.7 | 4.3 | 0.1 | 43.7 | 0.3 |
| FOOD AND KINDRED PRODUCTS | Texas | 51.7 | 22.5 | 22.6 | | 2.5 | 0.7 |
| | U.S. | 66.1 | 21.1 | 9.9 | | 2.6 | 0.3 |
| APPAREL & OTHER FINISHED TEXTILE PRODUCTS | Texas | 0.3 | 65.4 | 19.7 | 0.1 | 0.3 | 14.2 |
| | U.S. | 12.2 | 67.7 | 8.3 | 1.9 | 0.5 | 9.4 |
| FURNITURE & FIXTURES | Texas | 3.2 | 24.3 | 72.4 | | | 0.1 |
| | U.S. | 33.4 | 48.9 | 13.4 | 0.1 | 3.4 | 0.8 |
| PULP, PAPER, AND ALLIED PRODUCTS | Texas | 63.8 | 22.4 | 13.8 | | | |
| | U.S. | 77.4 | 15.2 | 3.9 | | 2.9 | 0.6 |
| CHEMICALS AND ALLIED PRODUCTS | Texas | 48.9 | 9.6 | 1.8 | | 39.6 | 0.1 |
| | U.S. | 60.2 | 20.3 | 4.5 | 0.1 | 14.6 | 0.3 |
| PETROLEUM AND COAL PRODUCTS | Texas | 1.2 | 0.5 | 0.2 | | 98.1 | |
| | U.S. | 3.4 | 1.8 | 0.7 | | 94.1 | |
| RUBBER AND MISCELLANEOUS PLASTIC PRODUCTS | Texas | 34.4 | 52.8 | 12.7 | 0.1 | | |
| | U.S. | 34.2 | 56.8 | 6.0 | 0.5 | 0.4 | 2.1 |
| STONE, CLAY, AND GLASS PRODUCTS | Texas | 43.3 | 36.6 | 18.8 | | 1.3 | |
| | U.S. | 50.8 | 31.9 | 9.8 | | 7.3 | 0.2 |
| PRIMARY METAL PRODUCTS | Texas | 62.1 | 12.7 | 14.5 | | 10.3 | 0.4 |
| | U.S. | 60.2 | 25.5 | 3.9 | | 10.3 | 0.2 |
| FABRICATED METAL PRODUCTS | Texas | 28.4 | 28.5 | 36.2 | 0.3 | 6.5 | 0.1 |
| | U.S. | 39.7 | 46.0 | 10.1 | 0.5 | 2.9 | 0.8 |
| MACHINERY, EXCEPT ELECTRICAL | Texas | 22.5 | 58.0 | 17.6 | 0.4 | 0.2 | 1.3 |
| | U.S. | 39.1 | 48.2 | 8.3 | 0.9 | 0.9 | 2.6 |
| TRANSPORTATION EQUIPMENT | Texas | 38.8 | 46.7 | 13.7 | 0.7 | | 0.1 |
| | U.S. | 72.6 | 21.9 | 3.9 | 0.4 | 0.8 | 0.4 |

* Data do not include pipeline transportation.
Source: Reference 11

Table I-18: Percent Distribution of Intercity Ton-Miles By Commodity Group and Distance Shipped, 1967 Data*

| Commodity Group | Location | Distance of Travel: Less Than 300 Miles | 300-499 Miles | Over 500 |
|---|---|---|---|---|
| ALL COMMODITIES | Texas | 3.6 | 2.0 | 94.4 |
| | U.S. | 12.8 | 9.6 | 77.6 |
| FOOD AND KINDRED PRODUCTS | Texas | 42.0 | 19.8 | 38.2 |
| | U.S. | 18.8 | 14.0 | 67.2 |
| APPAREL & OTHER FINISHED TEXTILE PRODUCTS | Texas | 8.4 | 3.4 | 88.2 |
| | U.S. | 9.6 | 11.8 | 78.6 |
| FURNITURE & FIXTURES | Texas | 12.0 | 14.3 | 73.8 |
| | U.S. | 10.3 | 15.3 | 74.4 |
| PULP, PAPER, AND ALLIED PRODUCTS | Texas | 26.4 | 16.3 | 57.3 |
| | U.S. | 12.5 | 11.4 | 76.1 |
| CHEMICALS AND ALLIED PRODUCTS | Texas | 8.2 | 4.6 | 87.2 |
| | U.S. | 17.3 | 14.8 | 67.9 |
| PETROLEUM AND COAL PRODUCTS | Texas | 1.8 | 1.0 | 97.2 |
| | U.S. | 5.6 | 4.0 | 90.4 |
| RUBBER AND MISCELLANEOUS PLASTIC PRODUCTS | Texas | 2.0 | 5.1 | 92.9 |
| | U.S. | 10.5 | 12.7 | 76.8 |
| STONE, CLAY, AND GLASS PRODUCTS | Texas | 47.2 | 22.6 | 30.2 |
| | U.S. | 42.8 | 19.5 | 37.7 |
| PRIMARY METAL PRODUCTS | Texas | 15.8 | 9.9 | 74.3 |
| | U.S. | 24.2 | 17.3 | 58.5 |
| FABRICATED METAL PRODUCTS | Texas | 20.9 | 16.8 | 62.3 |
| | U.S. | 19.8 | 17.0 | 63.2 |
| MACHINERY, EXCEPT ELECTRICAL | Texas | 11.6 | 11.7 | 76.7 |
| | U.S. | 10.0 | 12.0 | 78.0 |
| TRANSPORTATION EQUIPMENT | Texas | 30.8 | 22.4 | 46.8 |
| | U.S. | 15.5 | 18.4 | 66.1 |

* Data do not include pipeline transportation.
Source: Reference 11

Table I-19: Percent Distribution of Intercity Ton-Miles By Commodity Group and Shipment Size, 1967 Data

| Commodity Group | Shipment Size (pounds) | |
|---|---|---|
| | Less Than 60,000 | 60,000 and Greater |
| All Commodities | 28.4 | 71.6 |
| Food and Kindred Products | 42.7 | 57.3 |
| Apparel and Other Finished Textile Products | 94.1 | 5.9 |
| Furniture and Fixtures | 96.1 | 3.9 |
| Pulp, Paper and Allied Products | 37.8 | 62.2 |
| Chemicals and Allied Products | 48.7 | 51.3 |
| Petroleum and Coal Products | 2.8 | 97.2 |
| Rubber and Miscellaneous Plastic Products | 90.9 | 9.1 |
| Stone, Clay, and Glass Products | 46.0 | 54.0 |
| Primary Metal Products | 32.2 | 67.8 |
| Fabricated Metal Products | 74.3 | 25.7 |
| Machinery | 77.9 | 22.1 |
| Transportation Equipment | 73.3 | 26.2 |

Source: Reference 11

shippers evaluate when considering alternative modes. Larger size shipments tend to be more adaptable to rail or water movements. Neither shipment size nor distance of shipment directly affect the fuel economy. Both these factors are allocative devices. However, changes in relative price of fuel between the modes will affect the economics of transport and influence the decision making process.

Table I-20 shows the distribution of intercity ton-miles by mode and weight category. Of the total rail shipments, 77.6 percent were more than 60,000 pounds while 22.4 percent were less than this weight. Shipments by motor trucks, however, were predominately less than 60,000 pounds. Water shipments were almost all in the larger category while the reverse was true for air shipments.

Table I-20: Percent Distribution of Intercity Ton-Miles By Mode and Weight Category, 1967 Data

| Mode | Shipment Size (pounds) | | |
|---|---|---|---|
| | Less Than 60,000 | 60,000 And Greater | Total |
| Rail | 22.4 | 77.6 | 100.0 |
| Motor Carrier | 86.1 | 13.9 | 100.0 |
| Private Truck | 88.8 | 11.2 | 100.0 |
| Water | 1.4 | 98.6 | 100.0 |
| Air | 95.7 | 4.3 | 100.0 |

Figure I-10 shows the average miles a ton of freight is transported, by mode, for both the U.S. and Texas. The estimates are based on a 1967 publication (11). Texas and total U.S. average haul are approximately identical for two of the three categories. There is a difference in the average haul per ton by private truck, however.

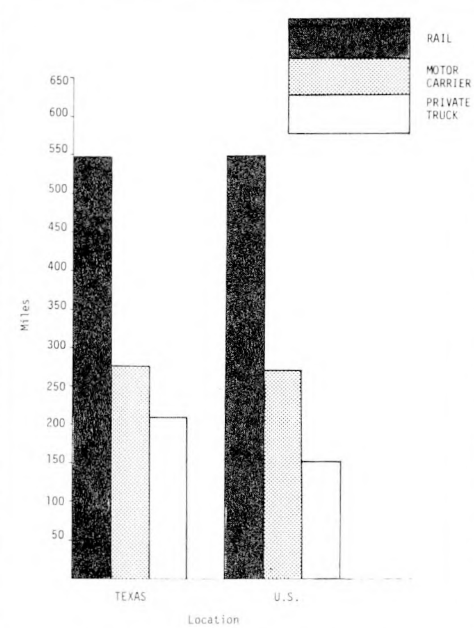


Figure I-10: Average Haul Per Ton of Intercity Freight Movement for all Commodities, by Mode, 1967

Table I-21 presents the average length of haul by commodity group and mode for Texas and the U.S. Only commodity groups for which there were U.S. and Texas comparisons are presented in Table I-21. In eight categories the average rail movement for Texas exceeds that for the U.S. In all the categories the average miles a ton of freight is hauled by motor carriers in Texas is greater than the U.S. average. Private trucks in Texas exhibit this same characteristic. A comparison of the average haul per ton for all commodities, however, indicates differences only in the area of private trucking.

It is apparent that some commodity groups moving by rail have a longer average haul than the average of all commodities transported by rail. This is also true for some commodity groups moving by other modes. While rail is usually considered the more efficient mode for long hauls (over 200-300 miles) and is certainly more energy fuel efficient when measured by the ton-mile fuel ratio, long distance movement by truck may be efficient when other variables are considered.

A comparison of the average length of haul by the various commodity groups by mode reveals only small variations. For example, the average length of haul for a ton of "Rubber and Miscellaneous Plastic Products" is approximately the same regardless of mode. Conversely, "Petroleum and Coal Products" have a longer average haul when transported by rail.

Traffic shifts cannot be predicted, nor tonnage allocations made, on the basis of distance hauled; there are other variables and factors which users consider in the decision making process. Marketing requirements

Table I-21: Average Length of Haul by Commodity Groups, 1967 Data, In Miles*

| Commodity Group | Location | Mode of Travel | | | | | |
|---|---|---|---|---|---|---|---|
| | | Rail | Motor Carrier | Private Truck | Air | Water | All Others |
| ALL COMMODITIES | Texas | 544 | 276 | 209 | | 1172 | |
| | U.S. | 549 | 270 | 152 | | 815 | 654 |
| FOOD AND KINDRED PRODUCTS | Texas | 286 | 572 | 177 | | 1424 | 399 |
| | U.S. | 559 | 360 | 144 | | 517 | 199 |
| APPAREL & OTHER FINISHED TEXTILE PRODUCTS | Texas | 948 | 624 | 523 | | | 916 |
| | U.S. | 631 | 543 | 265 | 1275 | 2750 | 735 |
| FURNITURE & FIXTURES | Texas | 521 | 570 | 464 | | | |
| | U.S. | 780 | 498 | 273 | | 2220 | 596 |
| PULP, PAPER, AND ALLIED PRODUCTS | Texas | 449 | 386 | 172 | | | |
| | U.S. | 695 | 281 | 132 | | 913 | 125 |
| CHEMICALS AND ALLIED PRODUCTS | Texas | 723 | 325 | 185 | | 714 | 103 |
| | U.S. | 506 | 271 | 135 | | 529 | 293 |
| PETROLEUM AND COAL PRODUCTS | Texas | 522 | 166 | 151 | | 1200 | |
| | U.S. | 462 | 117 | 99 | | 832 | |
| RUBBER AND MISCELLANEOUS PLASTIC PRODUCTS | Texas | 894 | 849 | 718 | 842 | | |
| | U.S. | 766 | 476 | 279 | 879 | 2300 | 923 |
| STONE, CLAY, AND GLASS PRODUCTS | Texas | 344 | 166 | 182 | 286 | | |
| | U.S. | 288 | 137 | 107 | | 750 | 130 |
| PRIMARY METAL PRODUCTS | Texas | 813 | 326 | 395 | | 350 | 1100 |
| | U.S. | 429 | 232 | 203 | | 613 | 351 |
| FABRICATED METAL PRODUCTS | Texas | 622 | 368 | 313 | 1156 | 317 | 385 |
| | U.S. | 567 | 341 | 177 | 934 | 635 | 425 |
| MACHINERY, EXCEPT ELECTRICAL | Texas | 1142 | 593 | 431 | 1239 | 1231 | 503 |
| | U.S. | 833 | 513 | 355 | 1067 | 5550 | 667 |
| TRANSPORTATION EQUIPMENT | Texas | 495 | 266 | 351 | 1192 | | 341 |
| | U.S. | 609 | 259 | 282 | 607 | 3743 | 454 |

Source: Computed for 1967 Census of Transportation, Commodity Transportation Survey, Reference 11.

* Data do not include pipeline transportation.

and nonquantifiable aspects of transportation such as service, dependability, and availability are part of the decision making process. In addition, governmental regulations and the pricing policies of the various modes influence the traffic allocation process.

*Opportunities for Modal Shifts*

Data presented in the previous section indicated certain characteristics of the freight movement on a commodity basis. Information was developed which defined the current shipping patterns by manufacturing commodity groups. These patterns have evolved on the basis of user requirements and comparative total costs. It must be assumed that the current patterns are indicative of rational behavior on the part of the user.

Two major assumptions are involved in identifying that part of the freight traffic flow which may be adaptable to movement by an alternative mode. They are:

- large size shipments tend to move by the more energy efficient modes, either rail or water; and
- as the shipment distance increases, so does the tendancy to use either rail or water.

These assumptions are based on physical and economic constraints associated with the competing modes. The percent of the various commodities moving by truck and rail has been defined. Assuming that long distance shipments (over 500 miles) and bulk shipments (over 60,000 pounds) are susceptible to service by rail, an estimate of potential modal shifts is developed. It should be stressed that these are only estimates of potential shifts which might be expected or encouraged under the existing set of policy constraints. Change in policy, as well as economic adjustment in fuel prices or fuel availability, will result in a reevaluation of available alternatives by the users.

Assuming that air and truck are relatively fuel inefficient while water and rail are relatively fuel efficient, commodity areas that may be adaptable to shipment by a more fuel efficient mode, based on the weight and distance assumptions discussed previously, are presented in Table I-22. This table presents, by commodity group, the percentage of shipments presently moving by fuel efficient modes (column 1) and, based on the weight and distance assumptions, the percentage of shipments that are adaptable to shipment by the more fuel efficient modes (column 2). Thus, by subtracting the values in column 2 from those in column 1, an indication of possible modal shift is determined (column 3). If the percentage in column 3 is positive, it is assumed that no shifts are possible; more traffic is presently moving by the fuel efficient modes that would be expected. Conversely, if the percentage in column 3 is negative, some potential for modal shift may exist; less traffic is moving by the fuel efficient modes than might be expected. Only two commodity groups have negative percentages that may be interpreted as opportunities for modal shifts. It is important, however, to recognize that traffic allocation to the modes may be subject to several variable factors. Marketing requirements may exert as much if not more influence on modal selection than either shipment weight or distance. The two commodity groups with a negative percent may, in fact, be subject to marketing considerations which would make changes in the modal split inappropriate.

Table I-22: Estimates of Potential Modal Shifts By Commodity Group, 1967 Data*

| Commodity Group | Column 1<br>Percent Presently Moving By Fuel Efficient Mode (Rail or Water) | Column 2<br>Percent Available For Movement By An Energy Efficient Mode* | Column 3<br>Potential Shifts (Column 1-Column 2) |
|---|---|---|---|
| All Commodities | 96.3 | 71.6 | +24.7 |
| Food and Kindred Products | 54.2 | 38.2 | +16.0 |
| Apparel and Other Finished Textile Products | 0.6 | 5.9 | - 5.3 |
| Furniture and Fixtures | 3.2 | 3.9 | - 0.7 |
| Pulp, Paper, and Allied Products | 63.8 | 57.3 | + 6.5 |
| Chemicals and Allied Products | 88.5 | 51.3 | +37.2 |
| Petroleum and Coal Products | 99.3 | 97.2 | + 2.1 |
| Rubber and Miscellaneous Plastic Products | 34.4 | 9.1 | +25.3 |
| Stone, Clay, and Glass Products | 44.6 | 30.2 | +14.4 |
| Primary Metal Products | 72.4 | 67.8 | + 4.6 |
| Fabricated Metal Products | 34.9 | 25.7 | + 9.2 |
| Machinery, Except Electrical | 22.7 | 22.1 | + 0.6 |
| Transport Equipment | 38.8 | 26.2 | +12.6 |

* Smaller percent of weight or distance criteria (U.S. totals)

* Data for pipeline transportation not included.

The data presented in Table I-22 were developed from Table I-17 and I-18 or I-19. Using the actual modal distribution as presented in Table I-17 and the smaller of the corresponding percentage estimates in Table I-18 and I-19, opportunities for modal shifts were identified.

It appears that given the existing modal characteristics, efforts directed toward voluntary shifts in the traffic pattern will be of little benefit. This however, does not imply that shifts would not occur given the application of some external force resulting in a reordering of the array of alternatives. Indeed, under present pricing and policy, the current modal split represents the combined decisions of users and is assumed to be a rational decision. As previously stated, factors such as service, dependability and availability influence shipper decision and interact with prices in determining traffic allocation.

## Conclusions

Intercity goods movement presently consumes 14 percent of the transportation fuel used in Texas. Over half of this fuel is used by motor trucks.

Based on existing operations, the fuel efficiencies of the various modes of intercity goods movement differ. Pipeline, water, and rail are relatively fuel efficient modes. Trucking is less fuel efficient while air is highly fuel inefficient.

Intercity ton-miles of transport have been increasing; between 1940 and 1971, U.S. intercity ton-miles of travel increased at an annual compound rate of 3.7 percent. On a national basis, rail has, during this time period, been the primary mode of intercity goods movement.

It is estimated that in 1970, nearly 180 million ton-miles of transport occurred in Texas. Over 50 percent of these ton-miles were served by pipelines. Motor trucks served 15 percent and railroads 26 percent.

In the future, intercity ton-miles of transport will continue to increase. By the year 2000, it is estimated that in Texas, rail will transport 110 billion ton-miles and truck will serve 81 billion ton-miles.

In Texas in 1970, over one billion gallons of fuel were used in intercity goods transportation. Motor trucks and railroads consumed over 750 million gallons. In the year 2000, rail and truck will, based on existing fuel efficiencies, consume over two billion gallons. The percent of intercity goods movement fuel being consumed by trucks is increasing.

Intercity goods movement consumes only 13.8 percent of all transportation fuel used in Texas. The results of these analyses indicate that rather drastic policy changes would be required to stimulate a significant modal shift. It will be quite difficult to effect more than a one percent savings in total transportation fuel consumption through modal shifts in intercity goods movement.

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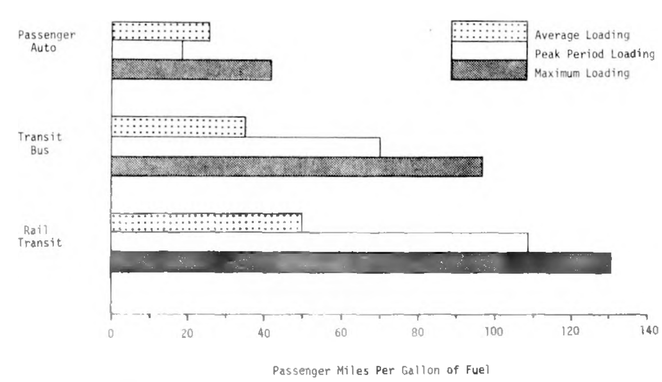
# II. URBAN FORM AND TRANSPORTATION FUEL EFFICIENCY

# II. Urban Form and Transportation Fuel Efficiency

Fuel Efficiency of Urban Transportation Modes (1,2)*

Vehicular transportation in urban areas is provided primarily by the auto and the bus. In a few urban areas, rail transit is also a significant means of transportation. The fuel efficiency, expressed in passenger miles per gallon of gasoline or its equivalent, of each mode is highly dependent on the number of persons using the mode at any given time. There is a difference between the average daily fuel efficiency, the fuel efficiency during peak periods, and the maximum potential fuel efficiency of each mode. The efficiencies shown in Figure II-1 (2) reflect the number of persons occupying each modal vehicle at different times of day.

In the United States, rail transit provides the most energy efficient means of urban travel; however, it operates in only a few major, densely populated cities. The bus is the next most fuel efficient mode of travel, and the auto is the least fuel efficient mode of urban transportation. It should be emphasized that the data presented in Figure II-1 are based on the operations of existing systems, which operate within compatible urban forms. These are not the fuel efficiencies that would be achieved if transit were operated along less compatible routes or in an urban form less conducive to transit ridership.




Source: Reference 2

Figure II-1. Energy Efficiencies of Urban Passenger Transport Modes

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*denotes reference number listed at end of section

In general, if transportation energy savings are the primary consideration, shifts in urban development that would result in more transit usage should be encouraged. This will require increases in the intensity of urban development.

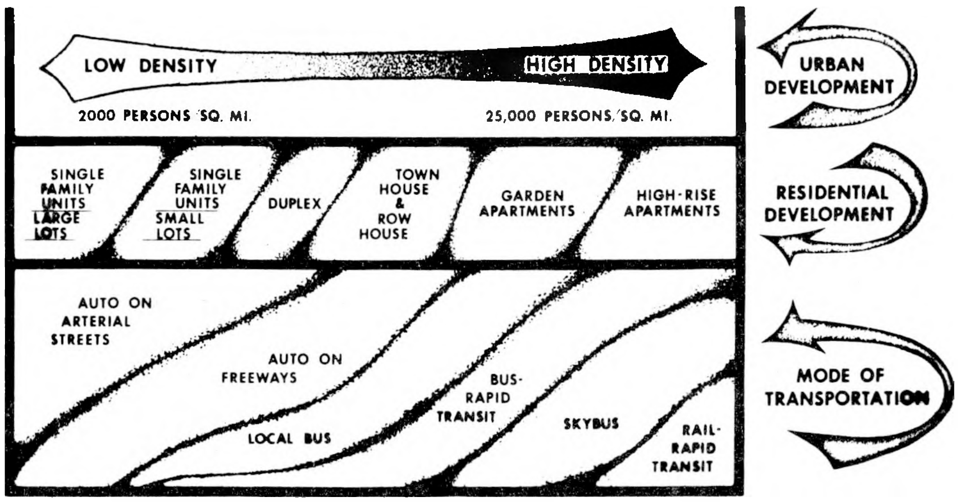
Transportation/Land Use Relationship (3)

Urban development and transportation are integrally related. Recognition of this relationship is essential to the planning of both urban development and transportation systems. A decision with respect to one of these factors carries with it a limitation on the rational decisions that may be made with respect to the other. Thus, if transit usage is to be encouraged for energy reasons, basic changes in urban development must also be encouraged.

A dispersed urban development similar to that of Houston and Dallas (consisting primarily of single family homes) cannot be economically or efficiently served by a major rail transit system. Conversely, intensely developed urban areas such as New York City (a heavy dependence on multi-family dwelling units), cannot be served solely by an automobile oriented transportation system. The relationship between types of urban development and compatible modes of transportation is presented in Figure II-2. Although this relationship is oversimplified, a realization of this concept is essential in relating urban development and transportation.

Urban Development/Population Density Relationships (3)

The residential development in different urban areas in the United States has resulted in different intensities of urban development.




Source: Reference 3

Figure II-2: Transportation/Land Use Relationship

Population density is, perhaps, the most commonly used descriptor of the intensity of urban development. It is usually expressed in persons per square mile (ppsm) and represents total urban population divided by total urban land area.

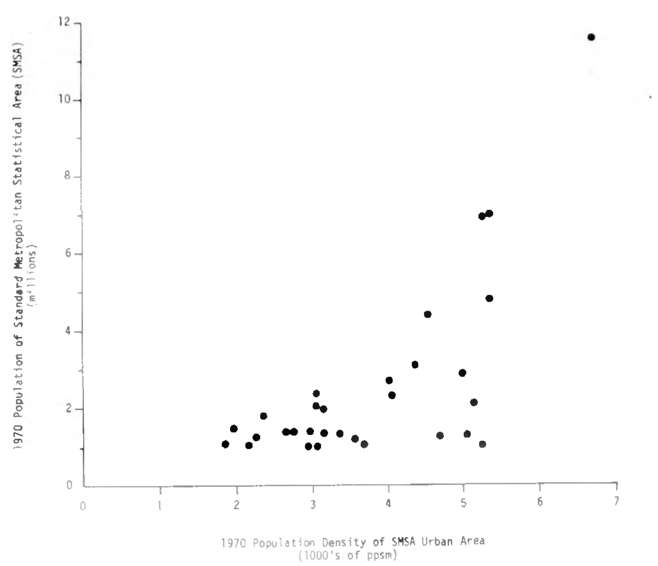
Different types of residential development result in different urban area population densities (Table II-1). Development in Texas is centered around the single family housing unit; correspondingly, the population density of Texas cities lies between 2500 and 3500 ppsm.

The population density of an urban area is not a function of the population of the urban area (Figure II-3). It is more properly a function of the age of the city and the type of transportation that was available when the city experienced significant growth (4).

## Table II-1: Examples of Population Densities Associated With Various Residential Developments

| Type Of Residential Development | Description Of Development | Assumed Ave. Sq. Ft. Of Lot Per Dwelling Unit | Dwelling Units Per Acre | Net Population Density Within The Residential Development (ppsm) | Corresponding Population Density Of The Urban Area (ppsm) |
|---|---|---|---|---|---|
| Single Family | Large house in well-to-do neighborhood | 32,000 | 1 | 2,200 | 880 |
| Single Family | Relatively large house in middle class neighborhood | 16,000 | 2 | 4,400 | 1,750 |
| Single Family | Average new sub-division development | 9,000 | 3.67 | 8,000 | 3,200 |
| Townhouse | Relatively large individual units | 3,000 | 10 | 16,000 | 6,400 |
| Townhouse | Relatively small individual units | 2,000 | 14 | 22,400 | 9,000 |
| Garden Apartment | Typical 2-Story development | - | 15 | 19,000 | 7,600 |
| Garden Apartment | Typical 3-Story development | - | 25 | 32,000 | 13,000 |
| Multi-Story Apartment | 12 Story high rise apartment development | - | 85 | 92,500 | 37,000 |

Source: Reference 3



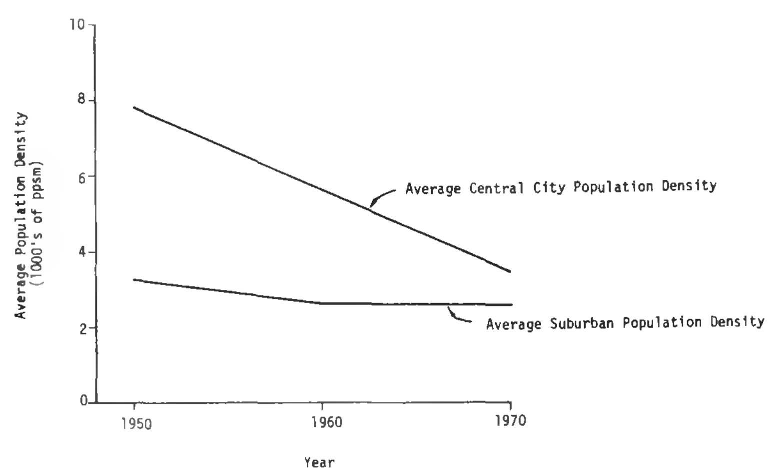

Source. Reference 6

Figure II-3: Population Versus Population Density for Major U.S. Urban Areas, 1970

Trends in Population Densities (5,6,7)

Cities in the United States have been trending toward lower population densities. The average decline in population density for suburban regions and central cities in the nation is depicted in Figure II-4.

Transportation has permitted these decreased densities to occur. In the early development of many cities, walking was the prime means of transportation. As a result, people crowded into a relatively small land area. Transit routes allowed development to spread out along corridors. Still, however, people lived within walking distance of a transit line. The automobile allowed urban development to become highly dispersed. The suburban development trends shown in Figure II-4 represent the densities characteristic of auto development.




Source: References 6 and 7

Figure II-4: Historical Trends In Urban Population Densities

The automobile has received much criticism due to the dispersed development associated with it. However, the auto did not cause the lower density development but merely provided a means for people to pursue their individual desires -- living in single family dwelling units. Thus, if higher density living is to be encouraged as a means to increase transit use and decrease auto use, the existing development trend to lower densities will need to be arrested and reversed.

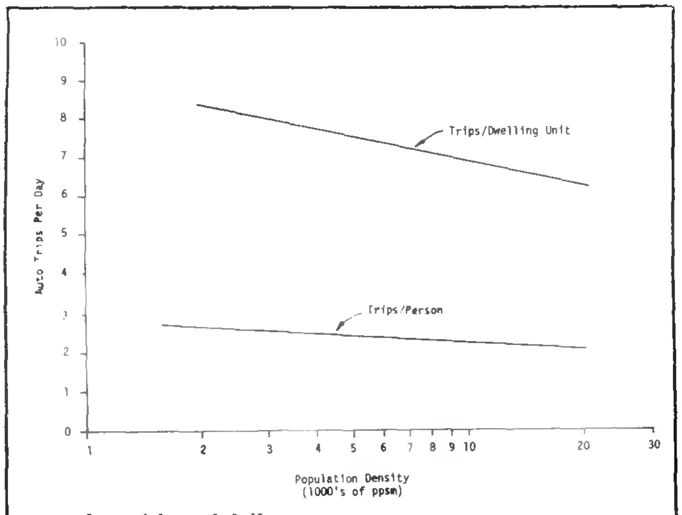
## Fuel Consumption As Related to Urban Density

The effect of alternative urban developments on fuel consumption per person is evaluated in this section. Population density, expressed in person per square mile (ppsm), is used as the descriptor of the intensity of urban development.

### *Auto Fuel Consumption Per Person*

Urban transportation studies (8,9) conducted in United States cities have determined that as population density increases, auto trips per dwelling unit and per person decrease. The apparent reason for this occurrence is that as density increases more trips are made by walking and transit.

Trip making rates, as determined in previous transportation studies, can be updated to reflect temporal changes (10), thus approximating current trip making rates. Using this information, an estimate was formulated relating the number of auto trips per person and per dwelling unit per average weekday to urban population density (Figure II-5). Trips per person were obtained by dividing trips per dwelling unit by 3.2 (8). Traffic counts compiled by the Texas Highway Department (11) indicate that the volume of weekend travel does




Source: References 8, 9, 10

Figure II-5: Relationship Between Number of Auto Trips and Urban Population Density not differ appreciably from weekday travel in urban areas; thus, the values in Figure II-5 can be multiplied by 365 to approximate annual trips per person.

From Texas data (8), the average auto trip length in larger urban areas (developed at densities of about 3000 ppsm) is known to be approximately 5 miles. For a given urban population, urban land area will decrease as population density increases. Assuming that trip length will decrease accordingly, the effect of population density on trip length is estimated in Figure II-6. An estimate of auto vehicle-miles of travel per year per person is developed by multiplying annual auto trips per person times average trip length. Assuming urban auto fuel efficiency to be 10 mpg, this is converted to gallons of auto fuel consumed per urban resident at various population densities (Table II-2).

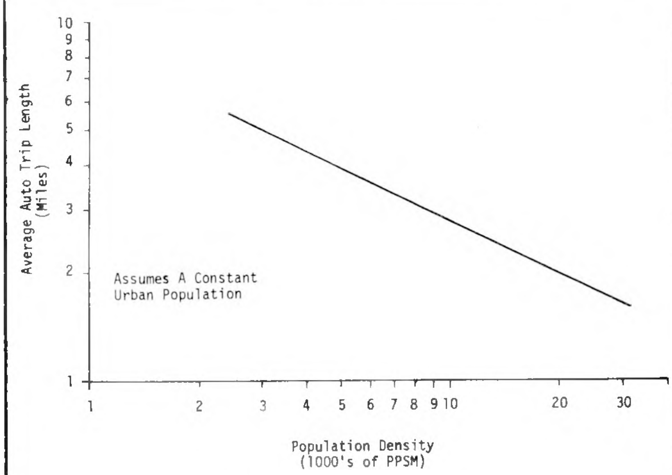


Figure II-6: Relationship Between Average Auto Trip Length and Urban Population Density

*Transit Fuel Consumption Per Person*

Studies have shown that as population density increases, auto ownership decreases and transit usage increases. This results in a corresponding increase in transit fuel consumption per person per year.

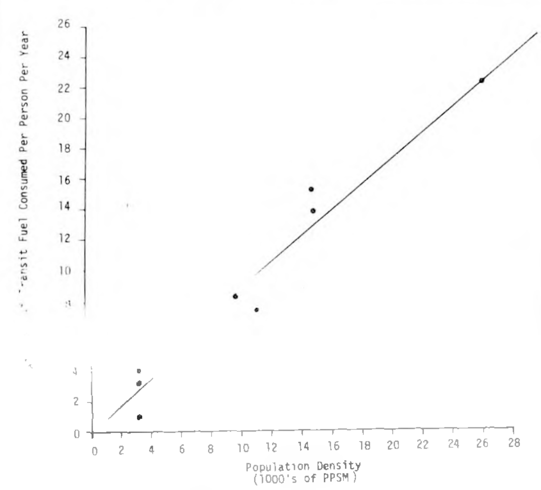
To determine this relationship, data for individual cities were evaluated. Population densities and total transit fuel consumption for each city were

Table II-2: Estimated Annual Urban Auto Fuel Consumption Per Urban Resident By Urban Population Density

| Population Density (ppsm) | Annual Urban Auto Trips/ Person | Average Trip Length (miles) | Annual Urban Auto Miles/ Person | Annual Urban Auto Fuel Consumption Per Person (gallons) |
|---|---|---|---|---|
| 2500 | 950 | 5.4 | 5130 | 513 |
| 5000 | 875 | 3.9 | 3410 | 341 |
| 10000 | 800 | 2.8 | 2240 | 224 |
| 15000 | 770 | 2.3 | 1770 | 177 |
| 20000 | 750 | 2.0 | 1500 | 150 |
| 25000 | 730 | 1.8 | 1310 | 131 |

determined (6,12). In those cities that use rail transit, kilowatt-hours of energy were converted to equivalent gallons of gasoline (2).

The relationship between annual transit fuel consumption per person and population density is presented in Figure II-7. The relationship is linear; as population density doubles so does transit fuel consumption per person.




Source: References 6,11

Figure II-7: Per Capita Transit Fuel Consumption As Related To Urban Population Density

*Total Fuel Consumption Per Person*

By totalling transit fuel and auto fuel consumed per person per year, the relationship between total per capita fuel consumption and population density is developed (Table II-3). These data are presented graphically in Figure II-8.

Table II-3: Estimated Total Annual Fuel Consumption Per Urban Resident By Population Density

| Population Density (ppsm) | Annual Auto Fuel Consumed Per Person (gallons) | Annual Transit Fuel Consumed Per Person (gallons) | Total Annual Transportation Fuel Consumed Per Person (gallons) |
|---|---|---|---|
| 2500 | 513 | 2 | 515 |
| 5000 | 341 | 4 | 345 |
| 10000 | 224 | 9 | 234 |
| 15000 | 177 | 13 | 190 |
| 20000 | 150 | 17 | 167 |
| 25000 | 131 | 22 | 153 |

*Maximum Fuel Savings Related to Urban Development*

As indicated by the previous discussion, as urban development increases in density and becomes more transit oriented, the demand for transportation related fuel decreases. The magnitude of transportation fuel savings that could be realized by altering urban form from being entirely auto oriented (the least fuel efficient mode) to being entirely rail transit oriented (the most fuel efficient mode) is determined in this section.

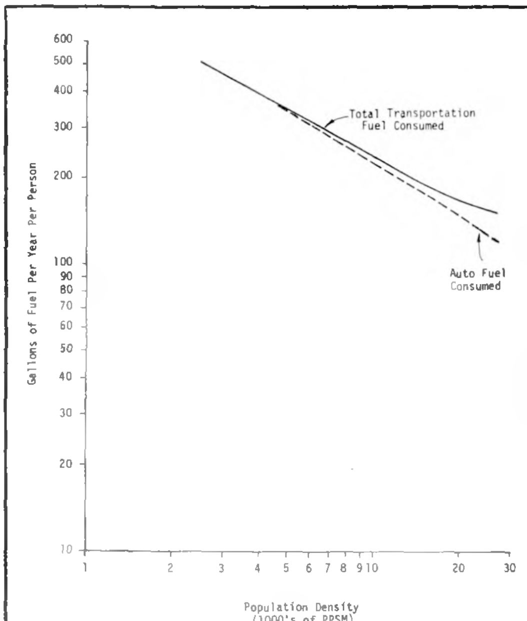
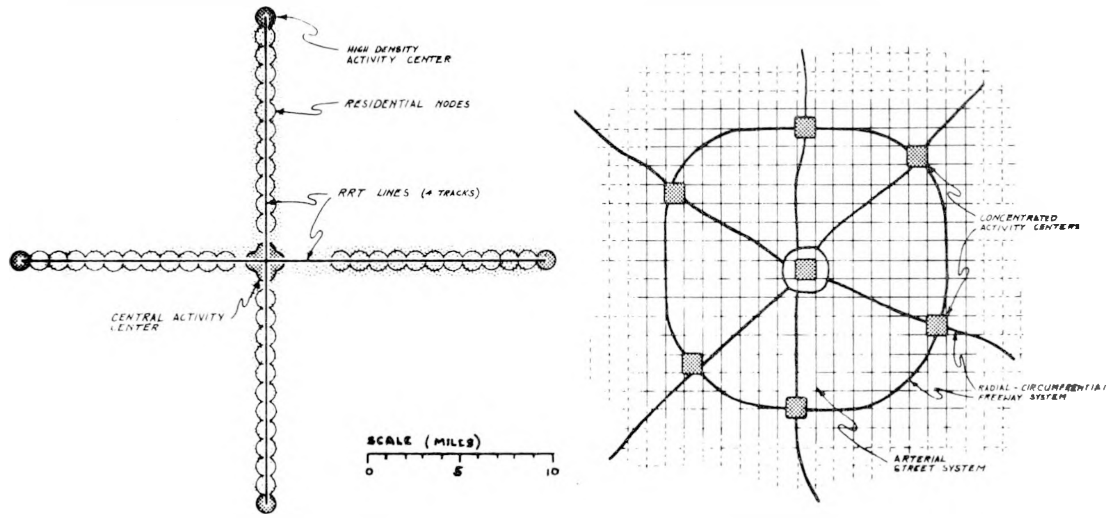



Figure II-8: Annual Transportation Fuel Consumption Per Person As Related to Population Density

A previous Texas Transportation Institute report (3) developed the characteristics of both types of cities. Cities could be designed to be served adequately by either mode, but they would require totally different urban forms. City form for a city of one million persons might resemble that shown in Figure II-9. The auto city would be similar to existing Texas urban areas. There are no entirely rail transit oriented cities. A summary of some of the major urban characteristics of the two types of cities is provided in Table II-4.




Rail Transit City

Auto City

Source: Reference 3

Figure II-9: Comparisons of Urban Form for a City of One Million Persons

The auto city would consist of single family residential areas. All transportation would be provided by the private auto; arterial streets and freeways would accommodate the travel demand.

Table II-4: Characteristics of Auto and Rail City
for One Million Population

| Characteristic | Auto City | Rail Transit City |
|---|---|---|
| Type of Residential Structure | Single Family Houses | 10 Story Apartments |
| Land Area, Sq. Mi. | 330 | 46 |
| Population Density, ppsm | 3000 | 22,000 |

Source: Reference 3

In the rail transit city, people would live in residential nodes containing about 25,000 persons and occupying about one square mile. These nodes would cluster around transit stations. Many trips would be served by walking or bicycling; the remaining trips would all be served by rail transit.

The two different cities would require different energy levels to provide the needed mechanical transportation. Required fuel for the auto city is calculated as follows.

- A city of one million would have approximately 500,000 autos (3). Each auto might travel 10,000 urban miles per year.
- This would result in 5.0 billion vehicle miles. Assuming a fuel efficiency of 10 mpg, 500 million gallons of fuel per year would be needed.
- This results in an annual requirement of 500 gallons of transportation fuel per urban resident.

Required fuel for the rail transit city is calculated as shown below.

- The rail transit city would require 4000 transit cars to provide the needed service (3).
- Each vehicle would travel 20,000 miles per year (3). Annually, 80 million vehicle miles would be operated.

- 5.5 kilowatt-hours of energy are required per vehicle mile (13). This converts to 0.45 equivalent gallons of gasoline per vehicle mile (2).

- 80 million vehicle miles @ 2.2 mpg equals an annual fuel consumption of 36 million gallons of gasoline, or approximately 36 gallons per person.

Thus, in an entirely auto oriented city, the average resident consumes 500 gallons of transportation fuel per year. In the entirely rail transit city, the average resident consumes only 36 gallons of fuel per year, although he also does much less mechanical travel. Thus, in shifting from an all auto to an all rail transit city, transportation fuel use can be reduced by over 90 percent.

Although these potential transportation fuel savings are impressive, it should be emphasized that they are associated with a form of urban development unlike any that currently exist. Such an urban development could be created only with absolute governmental land use controls.

Even in New York City, which has the most extensive rail transit system in the Western Hemisphere, per capita fuel consumption is well above that previously estimated for the rail transit city. In this relatively densely developed urban area, transportation fuel consumption is still heavily auto oriented. Estimated per capita transportation fuel consumption in New York City is presented in Table II-5 (6,14).

It appears that large scale fuel savings will not result merely by superimposing a rail transit line over an existing urban form. Such savings accrue only when the urban area is oriented toward massive service by a rail transit system. For example, by making the assumptions listed below, it is estimated that, by constructing a rail transit line through the Houston

Table II-5: Estimated Annual Per Capita Transportation Fuel Consumption in New York City

| Mode of Travel | Annual Per Capita Transportation Fuel Consumption | |
|---|---|---|
| | Equivalent Gallons of Fuel | Percent of Total |
| Auto | 125 | 84 |
| Transit | 23 | 16 |

central business district operating primarily within Loop 610, total transportation fuel consumption in Houston would be reduced by less than 0.1 percent.

- The transit line might resemble the Lindenwold Line, a rail transit line operating in the metropolitan Philadelphia area.
- This route serves about 9 million passengers per year (15). Assuming that 50 percent of these trips would be diverted auto traffic (16), some 4.5 million auto trips per year would be eliminated.
- Assuming an average trip length of 5 miles, 22.5 million vehicle miles of auto travel would be eliminated. At 10 mpg, auto fuel consumption would be reduced by 2.25 million gallons.
- Approximately 3 million vehicle miles of rail transit service would be required to provide the needed service (15). At 0.45 equivalent gallons of gasoline per vehicle mile (2), about 1.35 million gallons of transit fuel would be utilized.
- A total annual transportation fuel savings of 0.9 million gallons (2.25-1.35) would be realized.
- Using Table II-3, total annual transportation fuel consumption for Houston is estimated (population ~ 2,000,000; population density

~3100 ppsm) to be 944 million gallons per year. (470 auto gallons per capita per year, 2 transit gallons per person per year; 472 gallons per capita per year x 2,000,000 people = 944 million gallons per year).

- Thus, provision of the rail transit line would reduce total transportation fuel consumption in an area similar to Houston by less than 0.1 percent (0.9 ÷ 944).

Conclusions

The fuel efficiencies of urban travel modes differ. Rail transit is the most efficient mode, bus transit is the next most efficient means of urban travel, and the auto is the least efficient mode of transportation.

Transportation and land-use development are integrally related. Changes in urban development that will encourage increased transit ridership will reduce the demand for urban transportation fuels.

If increased transit usage is to be fostered, actions should be undertaken to increase the population density of urban areas. These actions would need to be quite strong, as the recent trends in urban development have been toward lower population densities.

Merely increasing transit availability without providing corresponding alterations in urban form may have little or no effect on transportation fuel consumption. For example, superimposing a rail transit line through metropolitan Houston would reduce total transportation fuel consumption in that area by less than 0.1 percent.

Transportation fuel consumption per capita does decrease significantly as population density increases. As population density increases from 2500 to 25,000 persons per square mile, annual per capita urban transportation fuel consumption decreases from 513 to 153 gallons.

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# III. Automotive Fuel Efficiency

## III. Automotive Fuel Efficiency

One fourth of the U.S. energy consumption is fuel consumed by transportation (1)*. The private automobile consumes 75 percent of transportation fuel. In evaluating alternative programs to reduce transportation fuel consumption, it is appropriate that the feasibility of improving auto fuel efficiency be investigated. One means of increasing this efficiency is by altering vehicle design. This chapter discusses vehicle design and its effect on auto fuel efficiency.

Due to the large percentage of transportation fuel used by the private auto, improved auto fuel efficiency can significantly reduce the volume of fuel consumed by transportation (Figure III-1). For example, a 20 percent increase in auto fuel efficiency would reduce total transportation fuel consumption by 13 percent.

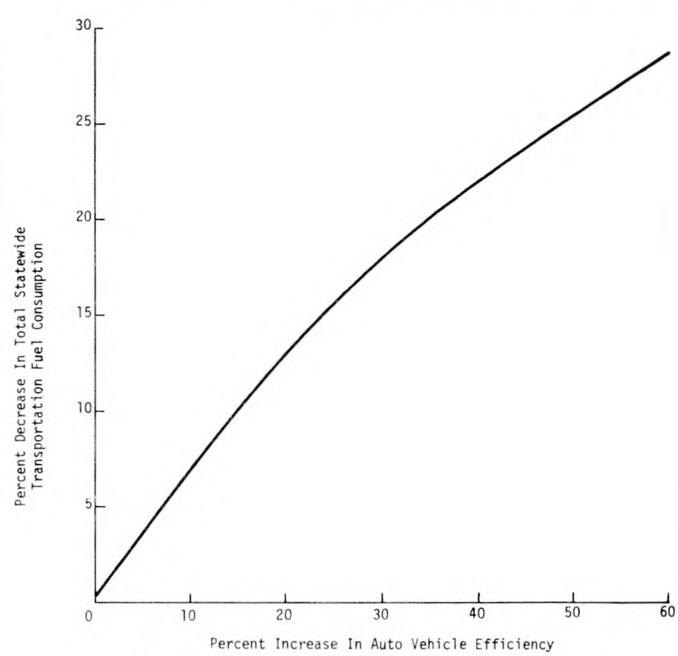


Figure III-1: Effect of Increases In Auto Fuel Efficiency On Total Statewide Transportation Fuel Consumption

### Trends In Auto Weight

The primary factor influencing fuel economy is vehicle weight (2). Buyer's demands for greater comfort and improved "ride" have led to an increase in average

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* Denotes number of reference listed at end of chapter.

weight. Recently, the imposition of required safety devices has further influenced this trend (3). The recent trend toward heavier vehicles for three different types of autos is shown in Figure III-2.

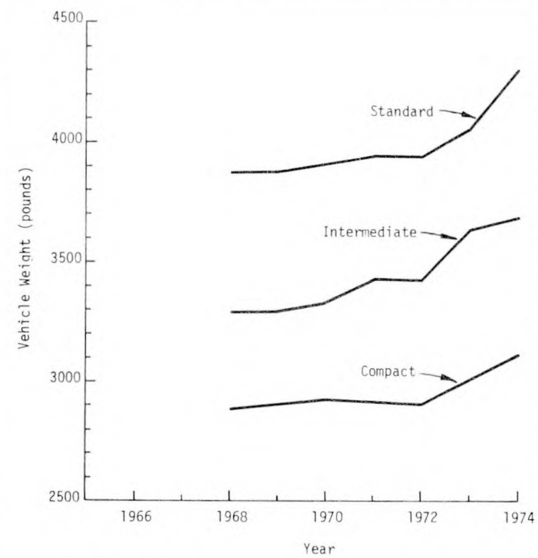

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Figure III-2: Trends In Vehicle Weight for Three Specific Vehicles, 1968-1974

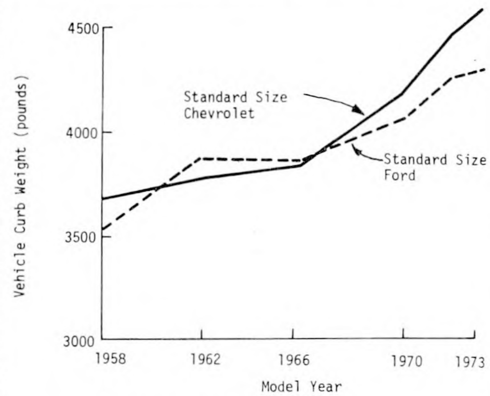

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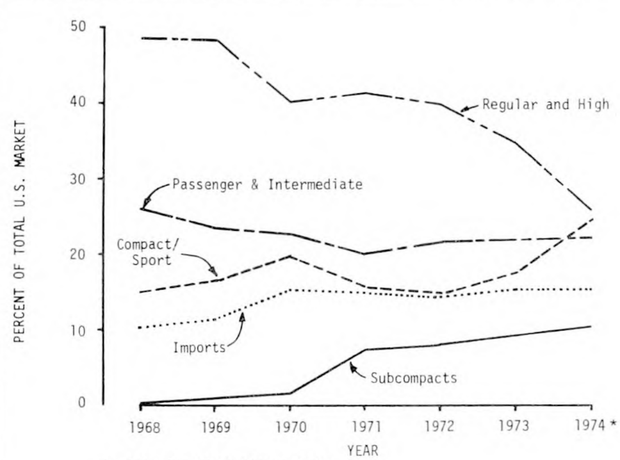
Figure III-3: Vehicle Weight By Model Year, Standard Size Cars

From available data, vehicle weight trends since 1958 are identified. The most popular standard size cars in America have gained approximately 1000 pounds since 1958 (Figure III-3).

Although the trend has been toward increasing weight of specific models, there has also been an increase in sales of smaller models (Figure III-4). In 1973, 40 percent of all new passenger cars weighed between 2000 and 3000 pounds (5). Sales

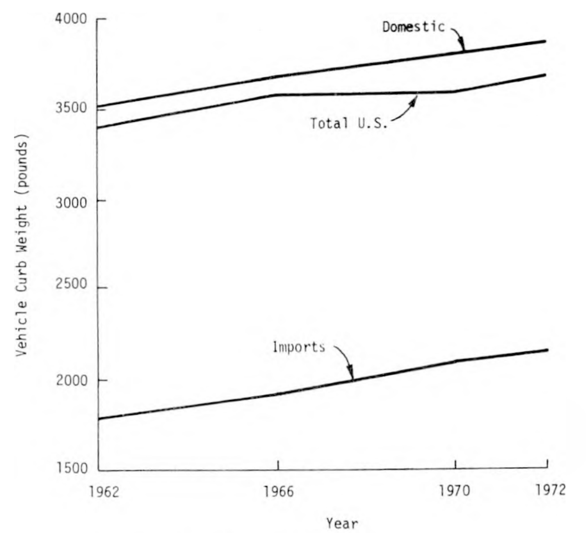


* data for first five months

Source: Motor Vehicle Manufacturers Association

Figure III-4: Trends In New Car Deliveries By Price-Product Groups, 1968-1974 of standard and medium cars, as a percent of total cars sold, fell approximately 20 percent during the first half of 1974 (6).

The trend of increased weight per model, however, has more than offset the trend toward smaller vehicles (Figure III-5). As a result, average weight per vehicle has increased.



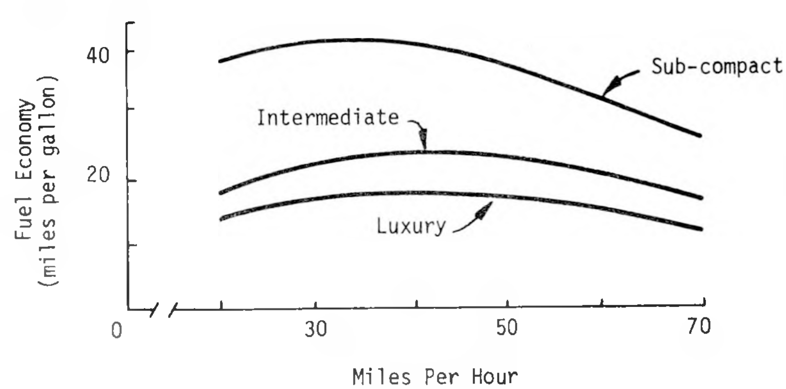

Reproduced from Reference 4

Figure III-5: Average Vehicle Weight By Model Year, Domestic, Imports, and Total Passenger Cars

Increased vehicle weight results in decreased auto fuel efficiency. In general, sub-compacts are relatively fuel efficient while large, luxury sedans are relatively fuel inefficient (Figure III-6).

## Effect of Emission Controls (4)

Since emission control requirements were established, the difference in fuel economy between heavy and light vehicles has increased significantly. Table III-1 indicates the change in fuel economy




Reproduced from Reference 2

Figure III-6: Vehicle Fuel Economy, Steady Speed Operation on Level Road between 1973 vehicles with emission controls and uncontrolled vehicles of similar size and weight.

Table III-1: Change In Fuel Economy Due To Emission Controls

| Inertia Weight Class (pounds) | Percent Change In Fuel Economy |
|---|---|
| 2000 | +2.6 |
| 2250 | +0.9 |
| 2500 | +3.1 |
| 2750 | +2.3 |
| 3000 | +1.3 |
| 3500 | +3.0 |
| 4000 | -14.3 |
| 4500 | -13.7 |
| 5000 | -14.7 |
| 5500 | -18.1 |

Source: Reference 4

Vehicles with emission controls, weighing 3500 pounds or less, averaged a 2.2 percent (non-weighted average) improved fuel economy. There was an average decrease in fuel economy of 15.2 percent for all vehicles over 3500 pounds.

## Other Factors Affecting Fuel Economy

Although weight is the primary factor adversely affecting fuel economy, other factors also have a negative effect. The effect of those other factors is, however, substantially less than the weight effect. A partial list of other factors that adversely affect auto fuel efficiency is presented below (4):

- automatic transmission;
- air conditioning;
- power steering;
- power brakes;
- power seats;
- power windows; and
- power sunroof.

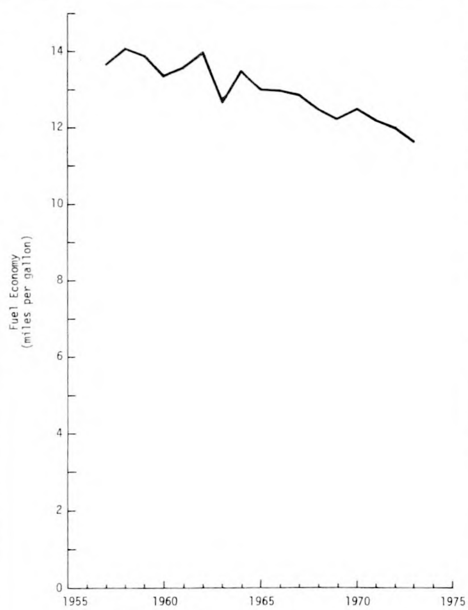
Trends in recent years have been toward increased use of these options (7).

## Trends In Fuel Economy

Increased vehicle weight and increased use of power options have resulted in a decrease in fuel economy. The average fuel economy of all 1957 vehicles was 13.7 miles per gallon (4); fuel economy had declined to 11.7 miles per gallon for 1973 vehicles (Figure III-7).

## Effect of Vehicle Type of Fuel Consumption

At present, the average auto achieves a fuel economy of approximately 14 miles per gallon (8). Urban driving consumes more fuel and reduces fuel economy to about 12 mpg (9) while rural driving improves fuel economy to approximately 16 mpg. Table III-2 presents characteristics of selected 1975 model cars.




Source: Reference 4

Figure III-7: Sales Weighted Fuel Economy By Model Year, 1957-1973

Table III-2: Characteristics of Selected 1975 Model Automobiles

| 1975 Model | Fuel Economy (mi./gallon) | | Fuel Efficiency* (pass. mi./gallon) | | Engine Size | No. of Cylinders | Curb** Weight | Horse-Power | Weight/ Horsepower |
|---|---|---|---|---|---|---|---|---|---|
| | Urban | Rural | Urban | Rural | (cubic in.) | | (lb.) | | Ratio |
| Chevrolet Vega | 22 | 29 | 33 | 58 | 140 | 4 | 2404 | 75 | 32.1 |
| Volkswagon Dasher | 23 | 35 | 35 | 70 | 109 | 4 | 2158 | 72 | 29.9 |
| Ford Pinto | 18 | 26 | 27 | 52 | 140 | 4 | 2466 | 88 | 28.0 |
| Dodge Dart | 17 | 23 | 26 | 46 | 225 | 6 | 3400 | 95 | 35.8 |
| Ford Maverick | 16 | 21 | 24 | 42 | 250 | 6 | 2915 | 91 | 32.0 |
| Oldsmobile Delta 88 | 14 | 18 | 21 | 36 | 350 | 8 | 4452 | 170 | 26.2 |
| Chevrolet Monte Carlo | 13 | 18 | 19 | 36 | 350 | 8 | 3777 | 145 | 26.0 |
| Mercury Montego | 10 | 14 | 15 | 28 | 400 | 8 | 4003 | 170 | 23.5 |
| Chevrolet Chevelle | 13 | 17 | 19 | 34 | 400 | 8 | 3877 | 150 | 25.8 |
| Lincoln Continental | 10 | 15 | 15 | 30 | 460 | 8 | 5219 | 220 | 23.7 |
| Ford Torino Elite | 10 | 16 | 15 | 32 | 460 | 8 | 3975 | 195 | 20.4 |

* assumes 1.5 persons per vehicle for urban driving and 2.0 persons per vehicle for rural driving
** equipped with automatic transmission and air conditioning

Source: Reference 10, 11, 12

Thus, a 1975 Chevrolet Chevelle (8 cylinder) is representative in terms of fuel economy, of the average vehicle presently on the road; if all autos on the road were 1975 Chevrolet Chevelles, transportation fuel consumption would not change significantly.

Shifts to more fuel efficient vehicles would reduce the consumption of transportation fuel. Figure III-8 illustrates the effect of alternative vehicle fleets on statewide fuel consumption.

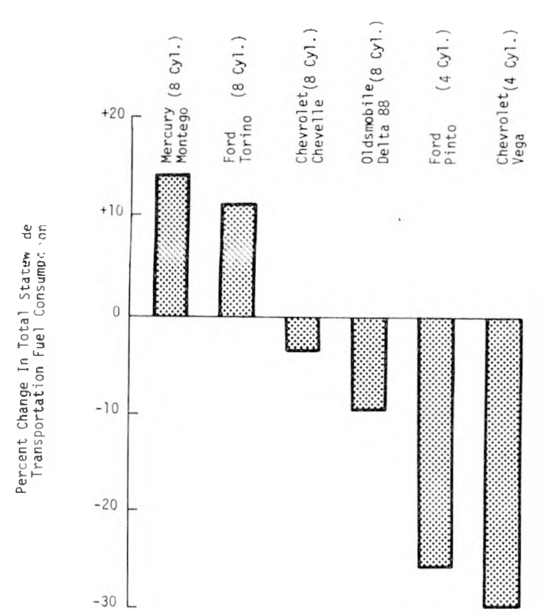



Figure III-8: Percent Change in Total Statewide Transportation Fuel Consumption That Would Result if Specific 1975 Models Were Representative of the Entire Auto Fleet.

## Conclusions

Seventy-five percent of transportation fuel used in Texas is consumed by the private automobile. Therefore, improved auto efficiency can significantly reduce transportation fuel consumption.

Auto weight is the primary factor influencing fuel economy. The trend has been toward heavier vehicles. Correspondingly, the trend has also been toward poorer fuel economy.

Emission controls have not adversely affected the fuel economy of all vehicles. For vehicles weighing 3500 pounds or less, fuel economy has actually been improved by emission control devices.

At present, the fuel economy experienced by a 1975 Chevrolet Chevelle (8 cylinder engine) is representative of the "average" vehicle on the road. Shifts to more fuel efficient vehicles can greatly increase fuel efficiency. For example, if a 1975 Ford Pinto (4 cylinder engine) were representative of the "average" vehicle, statewide fuel consumption would be reduced over 25 percent.

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# Appendices

## APPENDIX A

### Estimates of Intercity Passenger Miles of Travel By Mode of Transportation

This appendix documents the analyses and assumptions used in developing the values shown in Table I-1. 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 averaged to acquire a final estimate 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).*

### Private Automobiles

#### *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 (2).
- 1,026,000,000,000 X 5.5% = 56.4 billion intercity passenger miles by private auto in Texas.
- This method assumes that intercity passenger miles by private auto in Texas were the same percent of U.S. intercity passenger miles by private auto as Texas population was of U.S. population.

#### *Estimate 2 -- Daily Texas Intercity Miles*

- As the data available were for 1972, it was assumed that 90% of the 1972 total would be representative of 1970 vehicle miles of travel on Texas highways (3).
- Texas Highway Department manual count data reveal that approximately 90% of daily intercity vehicle miles of travel are intercity miles of travel by private auto (includes pick-up trucks) (4).

---

* Refer to reference number listed at end of APPENDIX A.

- The following vehicle miles were assumed to represent intercity vehicular travel.

| | |
|---|---|
| 19,705,596 | Daily vehicle miles on interstate highways in Texas (3) |
| 44,075,855 | Daily vehicle miles on state highways (3) |
| 11,978,322 | Daily FAS vehicle miles on farm or ranch to market roads (3) |
| 75,759,773 | Total daily intercity vehicle miles of travel in Texas in 1972 |

- 

| | |
|---|---|
| 75,759,773 | Total daily 1972 intercity vehicle miles |
| x 90% | |
| 68,183,795 | Daily intercity vehicle miles of travel in Texas for 1970 |

- 

| | |
|---|---|
| 68,183,795 | |
| x 90% | (4) |
| 61,365,415 | Daily intercity vehicle miles of travel by private auto in Texas for 1970 |

- Average occupancy of passenger vehicles in intercity travel is 2.3 persons (5).

- 

| | |
|---|---|
| 61,365,415 | Daily intercity vehicle miles of travel by private auto |
| x 2.3 | Average occupancy |
| 141,140,454 | Daily passenger miles of intercity travel in Texas |
| x 365 | Days/Year |
| 51.5 | Billion annual passenger miles of intercity travel in Texas |

- The basis for this estimate is total daily intercity vehicle miles of travel in Texas. However, only 90 percent of this sum is intercity travel by private auto (5). After deriving daily intercity vehicle miles of travel by private auto on Texas highways, the annual intercity passenger miles of travel are found by expanding daily vehicle miles by the average number of passengers per private auto to get daily passenger miles and by the number of days per year to arrive at the total annual passenger miles of intercity travel by private auto in Texas.

*Final Estimate -- Average*

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

| Estimate | Method |
|---|---|
| 56.4 billion | Estimate 1 -- U.S. intercity passenger miles |
| 51.5 billion | Estimate 2 -- Daily Texas intercity vehicle miles |
| 10719 billion | Total ÷ 2 = Average |

- Final estimate of intercity passenger miles by private auto in Texas is 54.0 billion.

Air

*Estimate 1 -- Ratio of Enplanements*

- 10,039,886 CAB, Texas Enplanements (6)
  + 234,910 Texas Aeronautical Commission (TAC) enplanements (7)

  10,274,796 Texas Annual Enplanements

- 169,668,000 Total U.S. enplanements (8)
  \- 11,132 International enplanements (6)

  169,656,868 Annual Domestic U.S. enplanements

- Total U.S. domestic intercity air passenger miles of travel in 1970 were 119 billion (2).

- 

| | | | | | | |
|---|---|---|---|---|---|---|
| Texas Enplanements | ÷ | U. S. Enplanements | X | Domestic U.S. Passenger Air Miles | = | Passenger Air Miles in Texas |
| (10,274,776 | ÷ | 169,656,868) | X | 119,000,000,000 | | |
| | 0.06 | | X | 119,000,000,000 | = | 7.1 Billion Passenger Air Miles in Texas |

- Estimate 1 -- Ratio of enplanements is based upon the assumption that the percent of domestic U.S. enplanements represented by Texas enplanements can be applied to U.S. passenger air miles to obtain an estimate of the total passenger air miles for Texas.

*Estimate 2 -- Population*

- The population of Texas is 5.5 percent of U.S. population (1).

- Domestic U.S. Passenger Air Miles X 5.5% = Passenger Air Miles in Texas
  119,000,000,000 (2) X .055 = 6.5 billion Passenger Air Miles in Texas

- The basis for this estimate is the assumption that passenger air miles in Texas are equivalent to the same percent of domestic U.S. passenger air miles as the population of Texas is to U.S. population.

## Railroads

Between 1970 and 1973, significant decreases occurred in the volume of intercity rail travel. The 1970 estimates of travel are used in forecasting future travel for the various modes. However, this approach would be somewhat misleading for rail. As a result, both a 1970 and a 1973 estimate of rail ridership in Texas are provided.

*Estimate 1 -- Population*

*1970*

| | |
|---|---|
| 11.0 | Billion rail intercity passenger miles in U.S. (2) |
| -4.6 | Billion miles of commuter travel (9) |
| 6.4 | Billion intercity rail miles |
| x 0.055 | Texas population is 5.5% of U.S. population (1) |
| 352 | Million rail passenger miles in Texas |

*1973*

| | |
|---|---|
| 2.99 | Billion intercity AMTRAK miles (10) |
| + 0.13 | Billion long distance intercity, non-AMTRAK (9) |
| 3.12 | Billion intercity rail passenger miles. |
| x 0.055 | Texas population if 5.5% of U.S. population |
| 172 | Million rail passenger miles of intercity travel in Texas |

*Estimate 2 -- Share of the Market*

*1970*

- Rail passenger service accounts for 0.54 percent of total U.S. intercity travel (2).
- Final estimate for passenger miles of intercity travel by private auto in Texas was 54.0 billion.

*Estimate 3 -- Vehicle Miles*

- Final estimate for passenger miles of intercity travel by private auto in Texas was 54.0 billion.

- 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)

| | | | | |
|---|---|---|---|---|
| 54.0 | X | 10% ÷ 86% | | |
| 54.0 | X | .12 | = | 6.2 Billion Passenger Air Miles in Texas |

- The premise for Estimate 3 -- Vehicle Miles is that the ratio of total U.S. passenger air miles of intercity travel to total U.S. passenger miles of intercity travel by private auto is the same as passenger air miles of intercity travel for Texas to passenger miles of intercity travel by private auto for Texas.

*Final Estimate -- Average*

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

| Estimate | Methods |
|---|---|
| 7.1 Billion | Estimate 1 -- Ratio of enplanements |
| 6.5 Billion | Estimate 2 -- Population |
| 6.2 Billion | Estimate 3 -- Vehicle miles |
| 19.8 Billion | Total ÷ 3 = Average |

- Final estimate is 6.6 billion passenger air miles of intercity travel in Texas.

- 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

| | | | | | | |
|---|---|---|---|---|---|---|
| 54.0 | X | 0.54 | ÷ | 86% | = | |
| 54.0 | X | 0.0063 | | | = | 340 Million Rail Passenger Miles of Inter-City Travel In Texas |

*1973*

- Assuming a 5½% annual growth rate, compounded annually, the passenger miles of intercity travel by private auto in Texas for 1973 should total 63.1 billion.

- Passenger Miles of Intercity Travel by Private Auto In Texas X Percent of Total U.S. Intercity Travel by Rail ÷ Percent of Total U.S. Intercity Travel By Private Auto = Rail Passenger Miles of Intercity Travel in Texas

| | | | | | | |
|---|---|---|---|---|---|---|
| 63.1 | X | 0.26% | ÷ | 86% | = | |
| 63.1 | X | .00292 | | | = | 184 Million Rail Passenger Miles of Travel in Texas |

- The basis for these estimates 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 in Texas are the same percent of passenger miles of intercity travel by private auto in Texas as rail miles are of total U.S. passenger miles of intercity travel by private auto.

*Final Estimate*

*1970*

| Estimate | Method |
|---|---|
| 352 Million | Estimate 1 -- Population |
| 340 Million | Estimate 2 -- Share of the Market |
| 692 Million | Total ÷ 2 = Average |

- Average - 346 million rail passenger miles of intercity travel in Texas.

*1973*

| Estimate | Method |
|---|---|
| 172 Million | Estimate 1 -- Population |
| 184 Million | Estimate 2 -- Share of the Market |
| 356 Million | Total ÷ 2 = Average |

- Average - 178 million rail passenger miles of intercity travel in Texas.

Buses

*Estimate 1 -- Population*

- | | |
  |---|---|
  | 25 | Billion passenger miles of intercity travel by bus in U.S. (2) |
  | .055 | Texas population is 5.5% of U.S. population (1). |
  | 1.4 | Billion passenger miles 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. exist in the same ratio as Texas population and U.S. population.

*Estimate 2 -- U.S. Bus Miles*

- Final estimate for passenger miles of intercity travel by private auto in Texas was 54.0 billion.

| | | | | | | |
|---|---|---|---|---|---|---|
| • 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 Inter-City Travel In Texas |
| 54.0 | X | 2.14% | ÷ | 86% | = | |
| 54.0 | X | .025 | | | = | 1.3 Billion Bus Passenger Miles of Intercity Travel in Texas |

*Estimate 3 -- Commercial Buses*

- 3031 Total commercial and transit buses in Texas (11).
  -1175 Total transit buses in Texas (6).

  1856 Commercial buses in Texas

- 88,823 Total commercial and transit buses in U.S. (11)
  -49,700 Total commercial and transit buses in U.S. (12)

  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 |
  | 25,000,000,000 | X | 4.7% | = | 1.2 Billion Bus Passenger Miles of Intercity Travel in Texas |

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

*Final Estimate -- Average*

- The preliminary estimates are averaged to obtain the final estimate.

| Estimate | Method |
|---|---|
| 1.4 billion | Estimate 1 -- Population |
| 1.3 billion | Estimate 2 -- U.S. Bus Miles |
| 1.2 billion | Estimate 3 -- Commercial Buses |
| 3.9 billion | Total ÷ 3 = Average |

- The final estimate is 1.3 billion bus passenger miles of intercity travel in Texas.

## *Waterways*

No estimates were made for passenger miles of intercity travel by waterways. In 1970, intercity 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, passenger miles of intercity travel by waterways is assumed to be zero in this report.

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# APPENDIX B

## Estimates of Intercity Ton-Miles of Travel By Rail and Motor Truck

This appendix documents the analyses and assumptions used in developing the values presented in Figure I-8. Historical and projected data relative to ton-miles transported by rail and motor truck in Texas are presented.

### Railroads

Historical (1960 to 1972) data are based upon data developed by the Railroad Commission of Texas (1).* Three separate projections of future transport are developed.

Projection A is based on an extrapolation of the historical growth rate that occurred between 1960 and 1972; an annual compound growth rate of slightly less than 4.5 percent characterized this time period. Using this procedure, in the year 2000, approximately 175 billion ton-miles will be transported by rail in Texas. This estimate should establish an upper bound on rail projections.

Projections B and C are computed from estimates of total U.S. intercity freight traffic presented in Energy Consumption for Transportation in the U.S. (2). In using these data, it was assumed that the Texas share of U.S. rail tonnage was 6.2 percent (based on historical data).

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* denotes reference number listed at end of Appendix B.

## Motor Trucks

### *Historical*

Two historical trends are presented. The higher trend is based on the data in Table B-1.

Table B-1: Total Motor Truck Ton-Miles, U.S. and Estimate for Texas

| Year | Billions of Ton-Miles | |
|---|---|---|
| | U.S. | Texas* |
| 1960 | 285 | 18.8 |
| 1961 | 296 | 19.5 |
| 1962 | 309 | 20.4 |
| 1963 | 336 | 22.2 |
| 1964 | 356 | 23.5 |
| 1965 | 359 | 23.7 |
| 1966 | 381 | 25.1 |
| 1967 | 389 | 25.7 |
| 1968 | 396 | 26.1 |
| 1969 | 404 | 26.7 |
| 1970 | 412 | 27.2 |
| 1971 | 445 | 29.4 |

* Estimated that Texas serves 6.6 percent of U.S. ton-miles, as developed in reference 3.

The lower historical trend is based on data presented in Table B-2. This estimate is based on the percent of rural road mileage that is in Texas. The implied assumption is that each mile of rural road generates approximately the same number of motor truck ton-miles.

Table B-2: Estimated Motor Truck Ton-Miles, U.S. and Texas

| Year | Miles of Rural Roads | | | Billions of Ton-Miles | |
|---|---|---|---|---|---|
| | U.S. | Texas | Texas As A Percent of U.S. | U.S. | Texas |
| 1960 | 3,109,460 | 194,176 | 6.2 | 285 | 17.8 |
| 1961 | 3,127,225 | --- | 6.2 | 296 | 18.4 |
| 1962 | 3,144,377 | 194,983 | 6.2 | 309 | 19.2 |
| 1963 | 3,145,505 | --- | 6.2 | 336 | 20.8 |
| 1964 | 3,152,577 | --- | 6.2 | 356 | 22.1 |
| 1965 | 3,183,220 | 197,078 | 6.2 | 359 | 22.2 |
| 1966 | 3,187,715 | 197,166 | 6.2 | 381 | 23.5 |
| 1967 | 3,183,711 | 196,994 | 6.2 | 389 | 24.0 |
| 1968 | 3,152,047 | 196,779 | 6.2 | 396 | 24.7 |
| 1969 | --- | --- | 6.2 | 404 | 25.1 |
| 1970 | 3,169,412 | 198,325 | 6.2 | 412 | 25.8 |
| 1971 | 3,165,895 | 198,864 | 6.3 | 445 | 27.9 |

One other approach, not presented herein, was used as a further check of accuracy. It considered the percent of U.S. special fuel consumed in Texas.

*Projections*

Two projections are presented. Projection I applies the Wilbur Smith estimate (3) of 1990 ton-miles to the higher of the two historical trends. Straight line extrapolation is used beyond 1990.

The second estimate applies the same growth rate developed by Wilbur Smith (3) to the lower of the two historical trends.

## REFERENCES - APPENDIX B


1. Railroad Commission of Texas. Railroad Statistics (for specified years).

2. Hirst, Eric. Energy Consumption for Transportation in the U.S. Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 1972.

3. Wilbur Smith and Associates. Economic Effects of Changes in Legal Vehicle Weights and Dimensions on Highways. National Cooperative Highway Research Program, Final Report, Project No. 19-3, June 1972.