RAIL VS. TRUCK FUEL EFFICIENCY:

The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in a Range of Corridors

MAY 1991

Summary of Findings

for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

by

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16. Abstract

This report summarizes the findings of a study to evaluate the fuel efficiency of rail freight operations relative to competing truckload service. The objective of the study was to identify the circumstances in which rail freight service offers a fuel efficiency advantage over alternative truckload options, and to estimate the fuel savings associated with using rail service. The findings are based on computer simulations of rail and truck freight movements between the same origins and destinations. The simulation input assumptions and data are based on actual rail and truck operations. Input data was provided by U.S. regional and Class I railroads and by large truck fleet operators.

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PREFACE

The U.S. Department of Transportation, Federal Railroad Administration has undertaken a study of the fuel efficiency of rail freight operations relative to truck freight operations. This report summarizes the study findings and conclusions. The findings are based on computer simulations of rail and truck freight movements between the same origin and destination locations. The simulation input assumptions and data are based on actual rail and truck operations. Input data was provided by U.S. regional and Class I railroads and by large truck fleet operators. Contributors to the study are listed in the appendix.

SUMMARY OF FINDINGS

A fuel efficiency study was performed by Abacus Technology for the U.S. Department of Transportation, Federal Railroad Administration (FRA). Rather than attempting to make broad judgments about the relative fuel efficiency of all rail freight versus all truck freight as other studies have done, this study compares the fuel efficiency of rail service with competing truckload service in the same corridors, taking account of the circuity of the routing. Only major rail-truck competitive commodities were compared, and the study anticipated that results would vary according to differing conditions.

The rail fuel efficiency findings are based on simulations using a train performance simulator (TPS). Truck fuel efficiency findings are based on simulations performed with the Cummins Engine Company vehicle mission simulation (VMS) model. Both models are respected for their accuracy and are used extensively by industry. Characteristics of the routes and operating scenarios are defined to reflect real world operating conditions and are simulated separately for rail and truck. The rail scenarios include calculations of fuel used in local rail switching, terminal operations, and truck drayage, as relevant to the move. Parametric analysis is not used in this study.

Additional findings are based on reviews of relevant literature, discussions with equipment operators and manufacturers, and consultations with railroad and motor carrier industry representatives. The study findings are consistent with previous studies reporting the superiority of rail fuel efficiency over truckload service.

FINDINGS

This study analyzes the fuel efficiency of truck and rail freight movement; it does not consider transportation cost, speed of delivery or quality of service. The key findings are:

1. **TON-MILES PER GALLON WAS DETERMINED TO BEST MEET THE STUDY REQUIREMENTS FOR A FUEL EFFICIENCY MEASUREMENT.**

Ton-miles per gallon is the unit selected to express relative fuel efficiency. To support this selection, 21 previous studies of rail and truck fuel efficiency were examined. From those studies, five candidate units of measure were identified, including:

- Ton-miles per gallon
- Miles per gallon
- BTUs per ton-mile
- Gallons per 40 foot container
- Price per ton-mile.

Ton-miles per gallon was selected because i) it measures the size of the freight as well as the distance moved, ii) it has been used in several previous studies of modal fuel efficiency and iii) it best meets the objectives of this study. The weight of the commodity was used to express the ton-miles per gallon measure. The fuel consumed by the railcar and its contents were used in the ton-mile per gallon calculation. Similarly, the fuel used by the truck with its commodity was used to calculate the commodity ton-miles per gallon for truck.

2. <u>WHERE RAIL IS MORE CIRCUITOUS, THE RELATIVE ADVANTAGE OF HIGHER RAIL TON-MILES PER GALLON IS SOMEWHAT OFFSET</u>.

Circuity was taken into account in each corridor by comparing the amount of fuel consumed in comparable rail and truck runs. For the model runs where rail is more circuitous than truck, the percentage advantage of rail fuel consumed was not as great as the percentage advantage of rail ton-miles per gallon.

3. <u>THE COMPETITIVE FREIGHT MARKET FOR RAILROADS AND TRUCKS INCLUDES 13 MANUFACTURED COMMODITY GROUPS</u>.

A 1989 study by the Association of American Railroads identified 13 commodity groups which represent an important component of the traffic base of both rail and truck. The commodities range from small items, such as canned fruit, to motor vehicles, as shown in Exhibit S-1. These commodities formed the initial basis for definition of the truck competitive rail scenarios.

EXHIBIT S-1
COMMON AND COMPETITIVE COMMODITIES

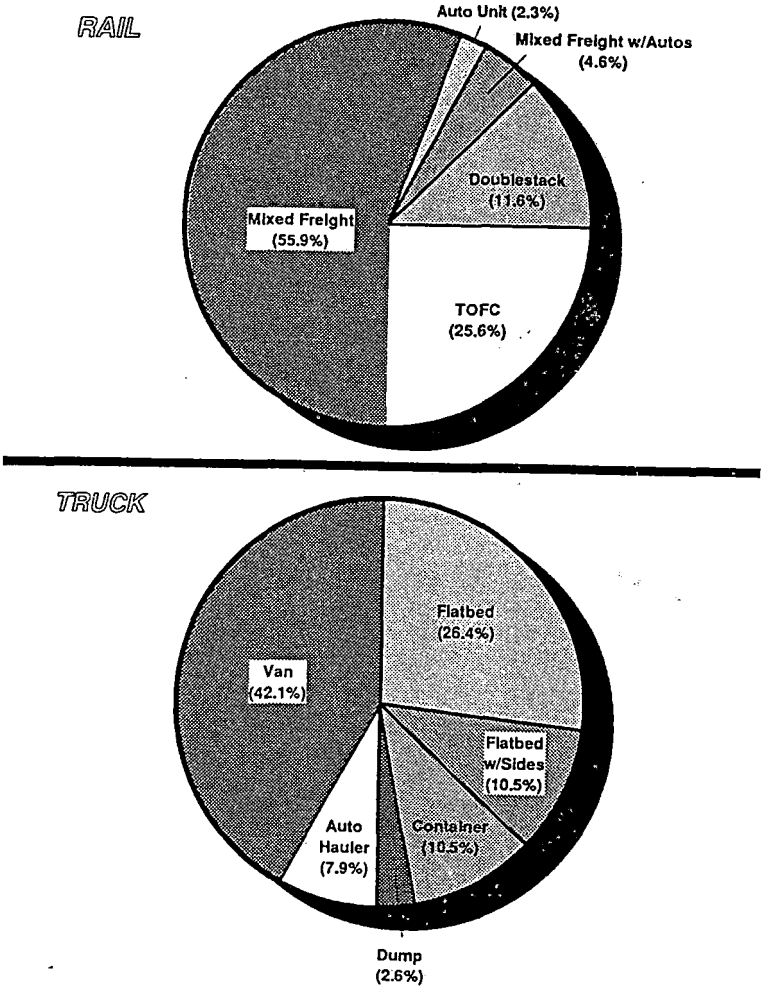
STCC NUMBER	COMMODITY	RANK IN RAIL TON-MILES
203	Canned/Preserved Fruits, Vegetables	12
204	Grain Mill Products	5
208	Beverages or Flavoring Extracts	10
209	Miscellaneous Food Preparations	9
242	Sawmill Products	2
243	Millwork or Prefabricated Wood Products	11
262	Paper	8
281	Industrial Chemicals	3
282	Plastic Materials, Synthetic Fibers	7
289	Miscellaneous Chemical Products	13
331	Steel Works, Rolling Mill Products	6
371	Motor Vehicles or Equipment	4
41-47	Intermodal Traffic	1

Source: Association of American Railroads, 1989. STCC is the Standard Transportation Commodity Code.

4. MIXED FREIGHT TRAINS AND TRUCK VAN TRAILERS ARE THE PREDOMINANT EQUIPMENT TYPES IN THE STUDY.

Mixed freight trains and truck van trailers are the predominant equipment types in use. As shown in Exhibit S-2, these two equipment types also dominate the scenarios selected for this study. The most prevalent advanced equipment in current use was selected for the scenarios. For trucks, this included the frequent use of 48-foot truck trailers with a large carrying capacity, aerodynamic aids to lessen truck fuel consumption and an advanced, commonly used truck engine. Rail double-stacked containers and, in some scenarios, updated locomotives are among the rail innovations used.

EXHIBIT S-2
EQUIPMENT TYPES AS A PERCENT OF ALL STUDY SCENARIOS



5. **RAIL ACHIEVED HIGHER TON-MILES PER GALLON THAN TRUCKS IN ALL SCENARIOS.**

Although the scenarios in this study represent examples of a range of types of comparable freight services and cannot be averaged, all rail equipment achieved higher ton-miles per gallon than truck equipment, as shown in Exhibit S-3. Rail achieved from 1.4 to 9 times more ton-miles per gallon than competing truckload service. Rail fuel efficiency ranged from 196 to 1,179 ton-miles per gallon while truck fuel efficiency ranged from 84 to 167 ton-miles per gallon.

The extent of track grade and curvature and train resistance (including such factors as rolling and flange resistance) are major contributors to rail fuel efficiency. Lading weight, horsepower per trailing ton and train speed also influence fuel efficiency. Generally, higher speeds adversely affect fuel efficiency.

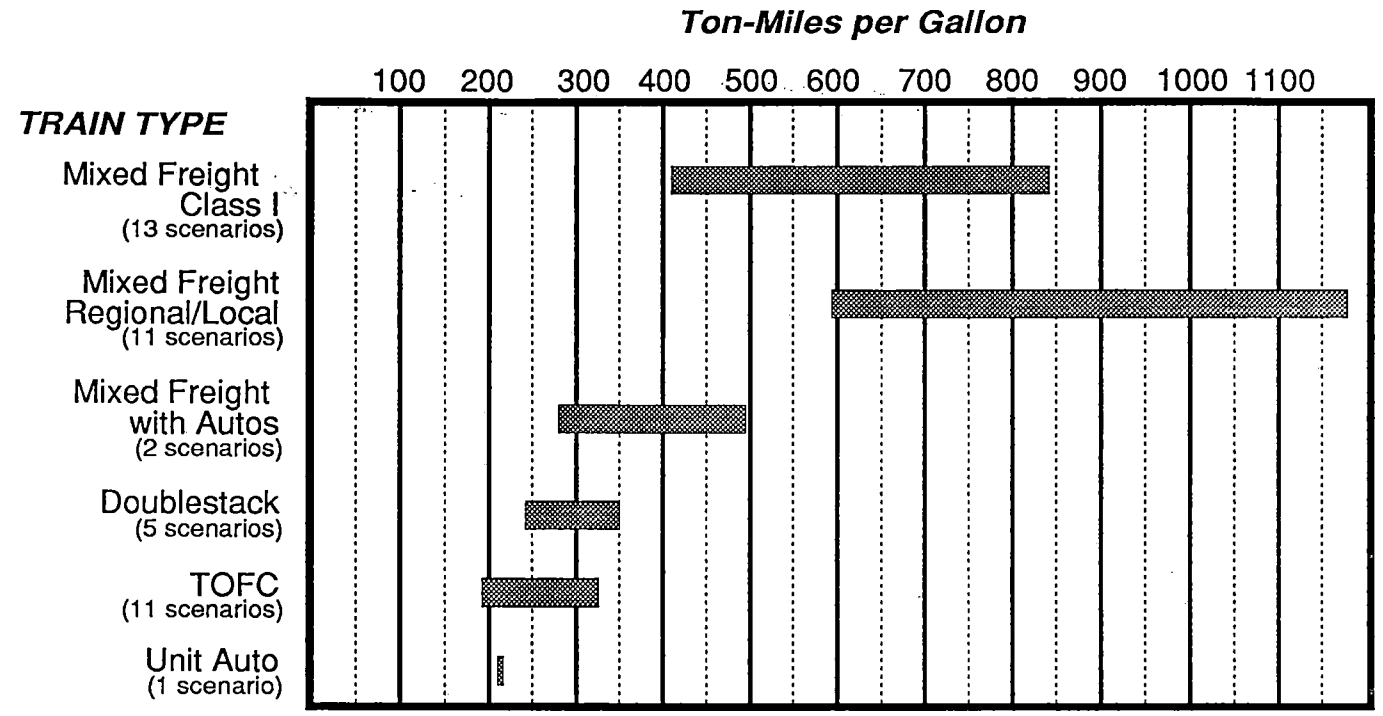
6. **RAIL TON-MILE RANGES ARE CONSIDERABLY LARGER THAN THE TRUCK RANGES.**

As shown in Exhibit S-3, there is a wide range of values for most train types while the truck ton-mile ranges are comparatively narrow. Compared to truck scenarios, the rail scenarios use varying horsepower per trailing ton and varying speeds and a variety of locomotives, while only one truck engine, the Cummins 350, was selected for all truck simulations. These factors contribute to the range differences. Three Class I railroads provided energy consumption data for various scenarios to Abacus Technology for analysis and compilation. Although the TPS models they used are basically the same, they may possess some minor variations. However, strong efforts were made to assure that consistent variable values were assumed in all cases. For example, the same railcar and locomotive frontal areas were assumed for each model execution. Thus, differences attributable to the models were minimized as much as possible. The Cummins VMS simulates Cummins truck engines only, and the 350 was selected as best meeting the requirements of all the study scenarios.

7. **RAIL ACHIEVED HIGHER TON-MILES PER GALLON THAN TRUCK IN EVERY EQUIPMENT CATEGORY FOR CLASS I/OVER-THE-ROAD SERVICE.**

Exhibit S-4 summarizes train and truck equipment types and ton-miles per gallon for the Class I/over-the-road scenarios with routes over 100 miles long. The findings for different equipment are:

EXHIBIT S-3
RANGE IN TON-MILES PER GALLON BY EQUIPMENT TYPE
(All Scenarios)



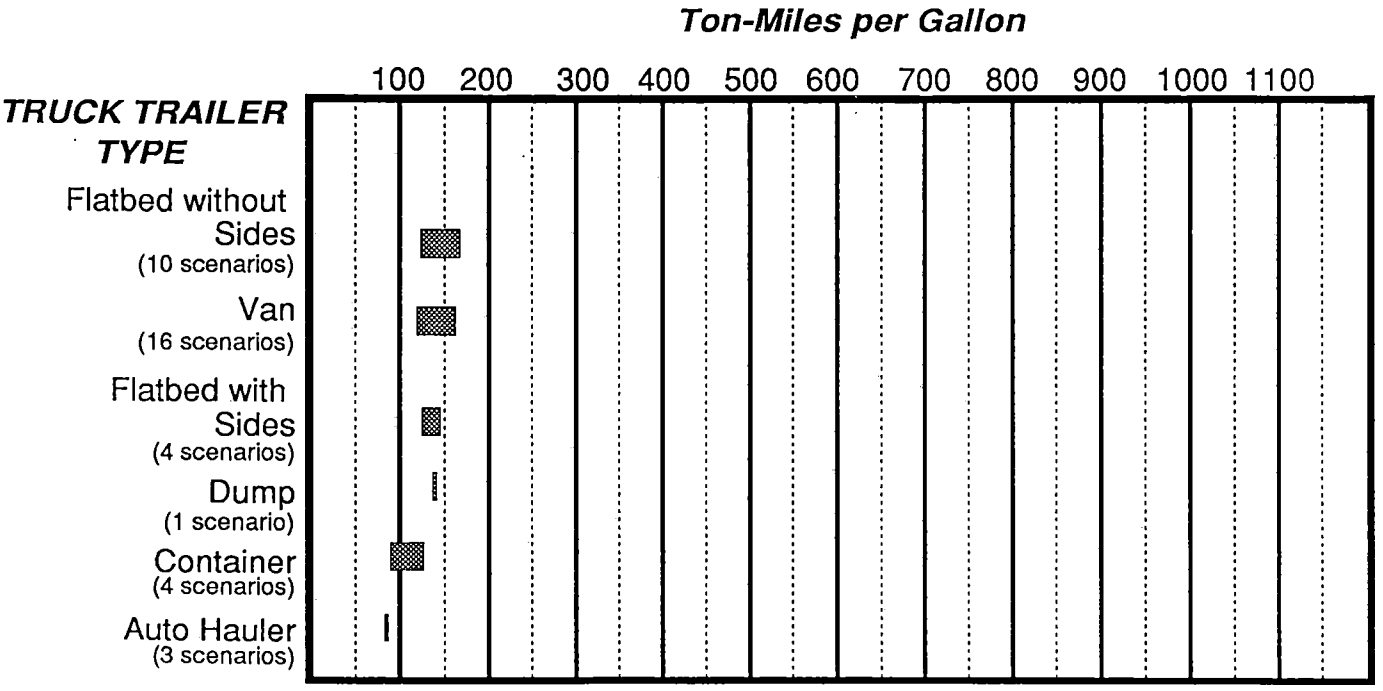


EXHIBIT S-4
FUEL EFFICIENCY BY EQUIPMENT TYPE
FOR CLASS I/OVER-THE-ROAD SCENARIOS (OVER 100 MILES)

TRAIN TYPE	FUEL EFFICIENCY (FE) RANGE (TMI/G)	TRUCK TYPE	FUEL EFFICIENCY (FE) RANGE (TMI/G)	RAIL/TRUCK FE RATIO RANGE
Mixed Freight	471 - 843	Flatbed Trailer - Without Sides	141 - 167	2.82 - 5.51
	414 - 688	Van Trailer	131 - 163	2.96 - 5.25
Mixed Freight with Autos	279 - 499	Auto Hauler	84 - 89	3.32 - 5.61
Double-stack	243 - 350	Container Trlr.	97 - 132	2.51 - 3.43
TOFC	229	Flatbed Trailer - Without Sides	133	1.72
	240	- With Sides	147	1.63
	196 - 327	Van Trailer	134 - 153	1.40 - 2.14
Unit Auto	206	Auto Hauler	86	2.40

Rail: TOFC - Trailer-on-Flatcar

- Rail Mixed Freight Achieved the Highest Level of Ton-Miles per Gallon. The rail mixed freight trains achieved both the highest level and the widest range in ton-miles per gallon. The highest ton-mile per gallon values were obtained using trains with lower average speeds. In addition, lower horsepower per trailing ton and favorable aerodynamics are also factors in rail mixed freight fuel efficiency.

- Rail double-stack and TOFC achieve the third and fourth highest ton-miles per gallon on the Class I routes. The lower aerodynamic drag of rail double-stack, set in a well, compared to rail TOFC contributes to the double-stack's better fuel efficiency. As shown in Exhibit S-4, rail TOFC achieves the lowest rail to truck fuel efficiency ratio of 1.40. Double-stack competes directly with truck container trailers and is 2.51 to 3.43 times more energy-efficient than comparable truck moves.

8. **RAIL MIXED FREIGHT ACHIEVED HIGHER TON-MILES PER GALLON THAN ALL TRUCK EQUIPMENT CATEGORIES IN THE REGIONAL/LOCAL SCENARIOS.**

Exhibit S-5 summarizes the fuel efficiency of different equipment types simulated on regional/local routes under 100 miles long. Only rail mixed freight trains were assumed on these routes. The range of rail mixed freight ton-miles per gallon and the rail/truck fuel efficiency ratios show better ton-miles per gallon than the competing truckload service. Including all the truck equipment types in Exhibit S-5, the rail mixed freight achieved ton-miles per gallon from 4.03 to 9.00 times greater than truck. The lower average speed of the rail mixed freight contributed to the higher fuel efficiency performance.

EXHIBIT S-5
FUEL EFFICIENCY BY TRAIN TYPE
FOR REGIONAL/LOCAL SCENARIOS (UNDER 100 MILES)

TRAIN TYPE	FUEL EFFICIENCY (FE) RANGE (TMI/G)	TRUCK TYPE	FUEL EFFICIENCY (FE) RANGE (TMI/G)	RAIL/TRUCK FE RATIO RANGE
Mixed Freight		Flatbed Trailer		
	596 - 890	- Without Sides	148 - 150	4.03 - 5.93
	641 - 1,104	- With Sides	135 - 148	4.51 - 7.77
	625 - 1,179	Van Trailer	131 - 140	4.46 - 9.00
	619	Dump Trailer	144	4.30

9. **THE TRUCK FLATBED WITHOUT SIDES TRAILER ACHIEVED THE HIGHEST TON-MILES PER GALLON OF THE TRUCK TRAILERS.**

The truck flatbed without sides trailer achieved a high of 167 ton-miles per gallon. The truck van trailer achieved the next highest truck fuel efficiency of 163 ton-miles per gallon.

10. **TRUCKS WITH THE HIGHEST PAYLOAD ACHIEVED THE HIGHEST TRUCK TON-MILES PER GALLON.**

All trucks were assumed to operate with the Cummins 350 engine. Trucks hauling high payload weights exhibited a higher average level of ton-miles per gallon than trucks with low payload weights. As shown in Exhibit S-6, the average ton-miles per gallon for trucks carrying 24 tons is 4 percent greater than for trucks carrying 23 tons. Similar improvements in ton-miles per gallon are noted for all the truck payload weight categories.

EXHIBIT S-6
TRUCK PAYLOAD WEIGHT IN RELATION TO TON-MILES PER GALLON

PAYLOAD WEIGHT (TONS)	NUMBER OF SCENARIOS	AVERAGE FUEL EFFICIENCY (TMi/G)
24	11	154
23	2	148
22	13	141
21	5	132
20	1	131
15	6	93
	38	

11. <u>THE MOST GALLONS OF FUEL ARE SAVED ON THE LONGEST ROUTES</u>.

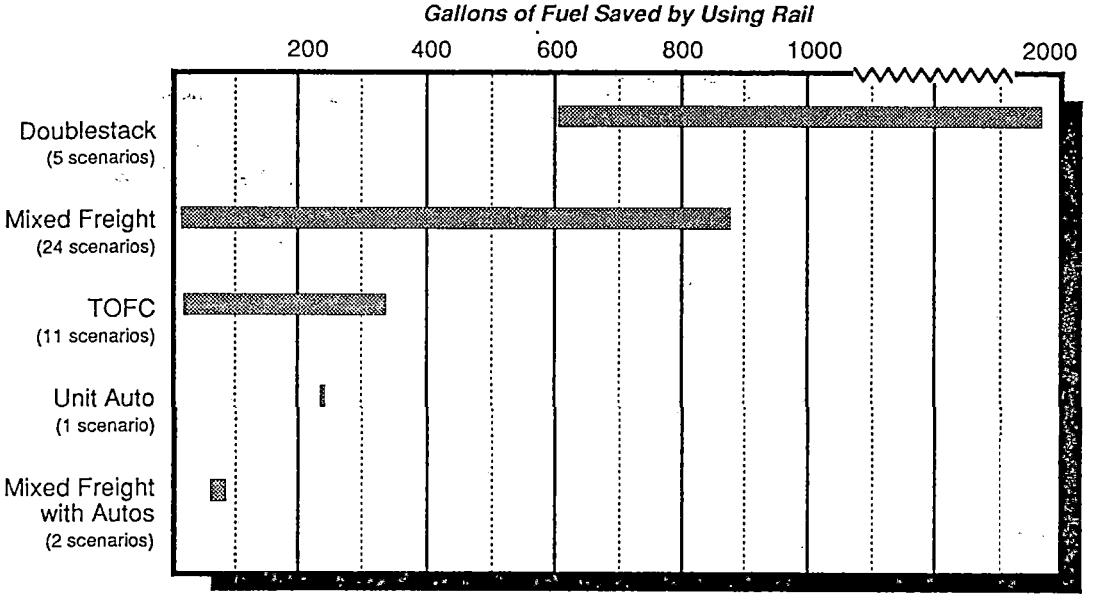
The most fuel efficient train in terms of ton-miles per gallon does not necessarily contribute the highest fuel savings in comparison with truck service. Obviously, the longer the route distance the greater the rail gallons of fuel saved. As the route extends, the difference between rail and truck fuel consumption is greater because of rail's fuel efficiency. The amount of fuel saved per carload using rail ranged from 7 gallons on a small local route of 22 rail miles to 1,965 gallons on a 1,891-mile rail route.

The long distance moved, combined with heavy lading of the double-stack cars which carry 10 containers on each car, results in considerable fuel savings--ranging from 602 to 1,965 gallons. To move the equivalent lading requires 10 trucks. As shown in Exhibit S-7, the next highest levels of fuel savings were with the rail mixed freight and the rail trailer-on-flatcar (TOFC). Exhibit S-8 presents a graphic comparison of fuel saved using rail by equipment type.

EXHIBIT S-7
RANGE OF FUEL SAVED BY RAILCAR TYPE FOR ALL STUDY SCENARIOS

RAILCAR TYPE	FUEL EFFICIENCY RANGE (TON-MILES/GALLON)	RANGE OF FUEL SAVED PER RAILCAR (GALLONS)	DISTANCE RANGE (MILES)
Double-stack	243 - 350	602 - 1,965	778 - 2,162
Mixed Freight	414 - 1,179	7 - 875	261 - 2,162
Trailer-On-Flatcar	196 - 327	11 - 338	251 - 2,162
Auto Unit Train	206	234	1,799
Mixed Freight/Auto	279 - 499	51 - 86	343 - 579

EXHIBIT S-8
RANGE OF GALLONS SAVED BY USING RAIL
FOR ALL STUDY SCENARIOS



12. <u>COMPARING A FULL TRAIN TO A COMPARABLE NUMBER OF TRUCKS, FUEL SAVINGS WITH RAIL WOULD BE SUBSTANTIAL</u>.

Although this study did not focus on fuel savings of a trainload of freight versus the same commodities carried by truck, such a comparison is useful. For example, a 34 car TOFC unit train carrying 1,360 tons of commodity over a 1,007-mile rail route saves 3,555 gallons of fuel. A 26 car double-stack unit train carrying 3,900 tons of commodity over a 778-mile distance saves 15,652 gallons of fuel.

13. <u>THE USE OF MORE ADVANCED EQUIPMENT AND CHANGES IN CARRYING CAPACITY REGULATIONS HAS RESULTED IN BETTER FUEL EFFICIENCY FOR BOTH RAIL AND TRUCK</u>.

Greater allowable payload weight, more efficient engines and improved aerodynamic aids and features has contributed to better truck fuel efficiency compared with previous decades. Rail has realized improvements through more efficient locomotives, more aerodynamic and lighter car design and even better lubricants for the track itself to decrease the effects of friction.

* * * * *

In summary, Class I/over-the-road and regional/local rail and truck service scenarios were analyzed. Rail fuel efficiency (ton-miles per gallon) for the scenarios studied ranged from 196 to 1,179 ton-miles per gallon. Truck fuel efficiency ranged from 84 to 167 ton-miles per gallon. Where rail is more circuitous, the relative advantage of higher rail ton-miles per gallon is somewhat offset. However, there are some scenarios where rail circuity does not explain the difference between the fuel efficiency ratio and the fuel consumption ratio. In these scenarios, factors such as average speed, terrain, equipment types and aerodynamics may influence the relationship between these ratios. The next chapter describes the objectives, scope and methodology of this investigation.