Comprehensive Truck Size and Weight (TS&W) Study

Phase 1-Synthesis

Energy Conservation

and

Truck Size and Weight Regulations

Working Paper 12

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1.0 Technical Relationships of Policy Consequence Concerning Energy Conservation

The research on various truck size and weight (TS&W) considerations and energy conservation is limited. Following the energy crisis in the mid 1970s, there was significant interest and research on energy conservation. Most of the references cited in this working paper are from this period. With the stabilization of fuel supplies and the decline in fuel prices, interest and research in energy conservation was greatly reduced. However, there has been renewed interest in energy conservation in the 1990s, and it appears that some recent research has been conducted which addresses some of the weaknesses of the older research.

1.1 Vehicle Weight

Most research shows that payload weights can be increased with a less than proportional (1:1) increase in fuel consumption. For example, the Society of Automotive Engineers estimated that a 50 percent increase in gross vehicle weight resulted in only a 10 percent increase in fuel consumption (ATA, 1981). An earlier study conducted by the U.S. Department of Transportation (DOT) found a similar relationship. The DOT's study found a 50 percent increase in payload weight caused less than a 7 percent increase in fuel consumption (DOT, 1975). The American Trucking Associations published several reports in 1981 which concluded that increasing truck weight limitations would significantly reduce diesel fuel consumption.

While there would seem to be a compelling argument for increased weight limits, there are several weaknesses with the research on energy savings from increased truck weight limits. First, the studies are old, relying on data from the 1970s, and substantial changes have occurred in truck technology. Second, the analyses assume the same trip length (i.e., all additional payload is picked up and delivered to the same destination) and ignore any additional travel that may be required. Third, the research has not addressed performance penalties that may result from greater weights. For example, in order to maintain speeds, truckers may use larger engines to pull heavier loads, which could partially offset fuel savings. Finally, only a few specific scenarios have been included in the research and therefore do not reflect the range of potential TS&W issues.

Despite the weaknesses in vehicle weight research, liberalizing vehicle weight limits would seem to have a significant positive impact on energy savings. Updated research on a variety of scenarios is needed to corroborate common assumptions.

1.2 Vehicle Dimension

As with vehicle weight, it is often assumed that increased vehicle lengths will allow more freight to be shipped by fewer tractors pulling longer or multiple trailers. This assumption is valid for low density cargos which fill the volume capacity (i.e., cube out) before reaching the gross vehicle or axle weight limits. However, higher density freight will not benefit from increased vehicle dimension limits unless truck weight limits are also increased (DOT, 1981). From the limited data available, it would appear that dimension limits would have a relatively minor impact on energy conservation objectives.

Another factor contributing to fuel consumption is the aerodynamic drag from longer or multiple trailers that might be used under increased TS&W limits. No studies have attempted to quantify what effect, if any, increased truck lengths would have on energy consumption. The Transportation Research Board's (TRB) analysis of Twin Trailer Trucks (TRB, 1986) indicated twin trailer combinations encounter greater air resistance than tractor-semitrailers and are less able to sustain high speeds. Numerous improvements to truck design have been implemented to improve aerodynamic properties and these would seem to lessen the impacts of air resistance.

1.3 Intermodalism

While many would agree that increased TS&W limits allow fewer trucks to move the same amount of freight with fewer trucks for an energy savings, more controversy surrounds the intermodal impacts of TS&W limits. The general argument is that rail transport is less energy intensive than truck transport. While increased TS&W limits would promote energy conservation by moving more freight with fewer trucks, this could result in diversion of freight traffic from rail to trucks. (For additional discussion on possible diversion, see Working Paper No. 9, Truck Travel and Mode Share.) If such diversion occurred, it would tend to diminish or reverse the energy savings gained within the truck mode.

Many organizations have looked at potential modal share changes as a result of TS&W limit changes. The DOT conducted a detailed analysis of TS&W issues in 1981. Although the study approach was reasonable at the time and provides lessons to guide future research, it is now nearly 14 years old and is not valid for application to current national freight movements. Other more recent studies have looked at the energy conservation impacts of intermodal freight transport. These studies all tend to support the position that direct comparisons should be made between truck and rail energy consumption, looking at specific commodity types and routes, rather than more generic application of industry wide energy efficiencies. Ton-miles of freight is probably the best measure for energy comparisons, provided that ton-miles are applied to specific commodities that travel by both modes. A commodity and route-specific application of a ton-mile measure recognizes differences between the modes. The remainder of this section examines each of the intermodal studies in greater detail.

(a) U.S. DOT, <u>An Investigation of TS&W Limits: Final Report</u>, August 1981

DOT published several reports on TS&W, many of which discussed energy conservation issues (DOT, 1981). The energy conservation impacts described in this report can be summarized as follows:

> "Increasing the size and weight limits will permit trucks to transport more freight with only a slight increase in fuel consumption [varies by scenario]. Total freight transported per gallon of fuel will thus rise. This improvement in fuel efficiency, however, will be offset somewhat by diversion of traffic to trucks from rail, since rail is more fuel-efficient in carrying the freight traffic which would be diverted. Higher weight limits may also result in increases in energy consumed in paving and maintaining the highway system and in increased bridge rehabilitation work." (DOT, 1981, pp III-45).

For truck related data, the effects of alternative scenarios on aggregate fuel consumption used changes in VMT, effects on ton-miles transported and data on truck fuel requirements to determine the relative impacts of the scenarios. The basic fuel-requirements data used for this analysis was obtained from the truck simulation model developed by the Cummins Engine Company. These data related fuel consumption on Interstate-quality roads to gross vehicle weight (GVW) and were obtained for: 22 combinations of vehicle configuration and body type, two levels of fuel-efficiency technology, three types of terrain (level, hilly and mountainous), and two speed limits (55 mph and 65 mph - only 55 mph was used).

The scenarios evaluated were grouped into five categories: elimination of the "Grandfather Clause," elimination of "barrier limits," establishment of uniform national TS&W limits by elimination of both the grandfather and barrier limits, reduction of Federal limits to those which existed prior to the increases enacted in 1974, and increase in Federal TS&W limits, along with the elimination of barrier limits.

For rail, the study used modal diversion estimates and data on rail fuel requirements and distinguished among carload and trailer-on-flatcar (TOFC) trailers as well as line-haul and local service rail routes. The results also looked at the fuel consumed in drayage.

The analysis concluded that increasing GVW limits would allow trucks shipping loads of higher densities or weights to reduce their average gallon per ton-mile consumption rate. There would be no effect on trucks that have partial loads unless the higher weight limit encourages higher tare weight trucks, in which case fuel consumption will increase for the partial load trucks. Increasing vehicle length limits would not effect higher density load trucks unless higher GVW limits were approved. Without increased GVW limits, increased size limits will only improve fuel efficiency for low density load trucks.

Regarding the energy tradeoffs between truck and rail services, DOT concluded that rail transport is more energy efficient than truck transport, except in a small percentage of freight shipments when the payload is very light, and rail circuity is high (defined as 100 percent extra miles).

The 1981 DOT studies accounted for changes in: vehicle utilization (VMT based), and fuel consumption from modal diversion of freight added to or taken from railroads. Based on the review of other studies, these seem to be the major areas of impact and the analysis methodology appears to be sound. The studies are also well documented and generally support the conclusions at the time they were conducted.

Unfortunately, the DOT studies are nearly 15 years old at this time. This leads to a number of current issues that the studies do not address.
First, the freight transportation industry has undergone substantial regulatory and technological changes since the late 1970s when the data for these studies were available. For example, the DOT studies discuss TOFC but do not address containerized traffic, which has increased tremendously over the last 15 years. Second, the direct truck/rail energy comparisons assessed single and double 45 foot trailers with TOFC and boxcar rail services. This is of limited usefulness and is not valid today when considering single trailer lengths greatly exceed 45 feet and a variety of vehicle configurations other than twin 45 foot trailers are in use.

(b) Fred P. Nix, <u>Trucks and Energy Use: A Review of the Literature and the Data in Canada</u>, August 1991

Nix summarized TS&W literature for the Ontario, Quebec, and Canada Trucking Associations. The literature reviewed includes eight U.S. studies (including a 1981 review of nine other studies from the 1960s and 1970s), as well as ten Canadian studies of truck and rail fuel efficiencies. These studies are included in Exhibits 1 and 2.

Four general conclusions are drawn by Nix in his report:

- Railways can move a given mass over a specified distance with less fuel consumed for propulsion than trucks in most intercity routes. The difference decreases when factors such as urban pickup and delivery, circuity, specific routes, and characteristics of the commodities carried are taken into account. The debate becomes academic because ton-miles is only a partial measure of service. "The exception would be on a specific haul where all other aspects of service such as transit time are relatively similar...In this case, direct comparisons of energy per ton-kilometer may have meaning" (Canadian Trucking Association, 1991).

- There are large differences in estimates of energy efficiency for trucking between the studies measuring industry-wide averages and those actually monitoring heavy duty trucks in use. Much of the difference can be attributed to the fact that industry-wide averages include a variety of trucking services - from pickup and delivery to linehaul.

- The preceding two decades have witnessed large gains in fuel efficiency. Nix estimates a doubling of efficiency while allowable GVW limits have increased since the mid 1970s. This increase in GVW magnifies the doubling of fuel efficiency.

- Energy efficiency is not accurately described if ton-miles is used as the measure of efficiency (it only measures mass over distance).

Nix offers four reasons why ton-miles (kilometers) is a poor or incomplete measure of transportation output for comparing rail and truck. First, transportation also involves moving cubic volume, not just mass. Second, ton-miles ignores circuity -- the distance beyond the direct air distance that must be traveled to deliver goods from shipper to receiver. Third, rail only provides linehaul service while trucking provides point to point transport including urban delivery and off-road services. Fourth, ton-miles does not address other attributes such as: shipment size, speed, the measure of frequency, and loss/damage experience.

Exhibit 1
U.S. Truck/Rail Energy Efficiency Studies (included in Nix 1991 Report)

Study	Detail	Trucks kJ/tne-km[1]	Rail kJ/tne-km[1]
P.J. Martin, 1981 Summarized US studies from 1960s & 1970s	Rice Mooz Hirst DOT - NASA TSC Mitre Battelle Carnegie-Mellon DOT-TEP	1,603 - 1,700 1,659 - 1,760 1,930 - 2,047 769 - 1,497 1,855 - 1,966 2,307 - 2,446 1,182 - 1,355 1,892 - 2,006 3,153 - 3,343	466 - 494 514 - 545 459 - 487 226 - 400 464 - 492 464 - 492 324 - 344 225 - 1,034 498 - 528
M.S. Bronzini, 1979 US DOT, using 1972 data	Intercity freight transportation	1,693	496
A.B. Rose, 1979 U.S. 1977 data	- route miles - effective miles	1,785 2,045	484 636
R.B. Capelle, 1984 LCV study using 1983-84 data	- 5-axle tractor-semi - Western double - Rocky Mtn double - Turnpike double - Triple	1,256 - 1,332 1,085 - 1,150 651 - 690 813 - 862 714 - 758	
FHWA, 1985 LCV Study	- Turnpike doubles - Triples	853 - 904 1,087 - 1,150	
L.R. Batts, 1991 ATA, "futuristic vehicle"	- average over 5,445 km - best 1,133 km segment	427 - 453 389 - 412	
D.S. Smith, 1985 Double-stack train, based on computer model	Los Angeles - Chicago prediction		185 - 196
Progressive Railroader, November 1990. US double-stack train	Los Angeles - Chicago "average"		398 - 422

Source: Fred P. Nix, Trucks and Energy Use: A Review of the Literature and the Data in Canada, prepared for the Ontario, Quebec, and Canadian Trucking Associations, August 23, 1991.

[1]Kilojoule (kJ) per ton-kilometer. Kilojoule is a measure of the energy content of fuels. There are 1.054615 kJ per British Thermal Unit (BTU).

Exhibit 2
Canadian Truck/Rail Energy Efficiency Studies (included in Nix 1991 Report)

Study	Detail	Trucks kJ/tne-km[2]	Rail kJ/tne-km[1]
Transport Canada, 1977	1970 intercity 1970 urban	3,251	470
Transport Canada, 1978	1976 total industry	1,631	396
F.R. Wilson, 1977 Day & Ross 1975/76 data	summer driving winter driving	982 - 1,308 1,268 - 1,521	
P. Detmold, CP Rail	1978 freight service		334 - 354
A. Clayton, 1984 Data from 13 carriers	summer driving fall/spring driving winter driving	568 - 892 591 - 951 636 - 1,040	
A. Cubukgil, 1985 fuel consumption model	base case (36.3 tne at 96.5 kph) Fruehauf's special base case at 45.4 tne	709 - 796 518 - 602 574 - 639	
Ontario MTO, 1989 "DriveSave/TruckSave"	overall winner	277 - 294	
Manitoba Pro-Trucker Challenge, 1990	overall winner	516 - 548	
CN Rail, 1990	Toronto-Montreal - Laser service - competing trucks	 764 - 811	 278 - 295
A. Kahn, 1991	total industry for hire, Class 1 & 2	2,385 1,357	313

Source: Fred P. Nix, Trucks and Energy Use: A Review of the Literature and the Data in Canada, prepared for the Ontario, Quebec, and Canadian Trucking Associations, August 23, 1991.

[2]Kilojoule (KJ) per ton-kilometer. Kilojoule is a measure of the energy content of fuels. There are 1.054615 KJ per British Thermal Unit (BTU).

Nix offers several alternatives to ton-miles for energy use comparisons: (1) energy consumption per dollars of revenue, (2) for Canadian estimates, using Statistics Canada's Input-Output tables, and (3) industry energy used divided by industry Gross Domestic Product.

Dollars of revenue are suggested as an alternative measure of transportation output. Nix suggests this measure because "the price that customers are willing to pay for a particular service represents the perception they have of the total value of that service". Nix recalculated two studies he cited earlier on the energy per dollar of revenue basis. (These studies had the appropriate data available.) The recalculations result in trucking being more efficient or equal to rail on this basis. The results indicate that the trucking industry generates a dollar of revenue with less energy than the rail industry, 34 percent less energy.

However, this approach has some weaknesses. First, obtaining consistent data for both truck and rail output is difficult, because different sources cover different members of industry. Second, this approach makes industry wide comparisons, which was an argument used against ton-miles. Third, the results of the dollar of revenue approach may really be demonstrating that high value goods, typically shipped by truck, are heavily weighted in the trucking revenues and lead to the final result that trucking is more efficient.

Statistics Canada's Input-Output Tables. Using Canadian statistics the author again looks at the industry wide energy input and revenues from a consistent source. However, energy is measured in monetary, not physical, units. The comparison can be distorted if one mode uses a more expensive form of energy. Also, energy used here is total energy, not just propulsive energy. Finally, railways include passenger service as well as freight. The results show rail as producing more net revenues than trucking, ranging from almost the same level up to twice the level of net revenues. This data source is not available for U.S. comparisons.

Energy Use Divided by GDP. One final method for comparing energy use between truck and rail is using energy use as a ratio of dollars of gross domestic product (GDP). Nix calculated these ratios for the 1962-1986 time period. The results indicate lower energy use per dollar of GDP for trucking every year, but both trucking and rail have significant variances over time. This approach uses energy as a monetary unit like Statistics Canada. Also, this approach compares industry-wide statistics, ignoring important differences between the modes.

Although it is worth considering alternative measures for energy uses, ton-miles carried of specific commodities on specific routes is the best measure.

Nix points out that because rail and trucks carry different cargos, specific direct comparisons of commodities and routes should be examined. By performing direct comparisons and including all services from origin to destination (e.g., drayage), reasonable comparisons can be made between the modes.

(c) U.S. DOT Federal Railway Administration (FRA), <u>Rail versus Truck Fuel Efficiency, April 1991</u>

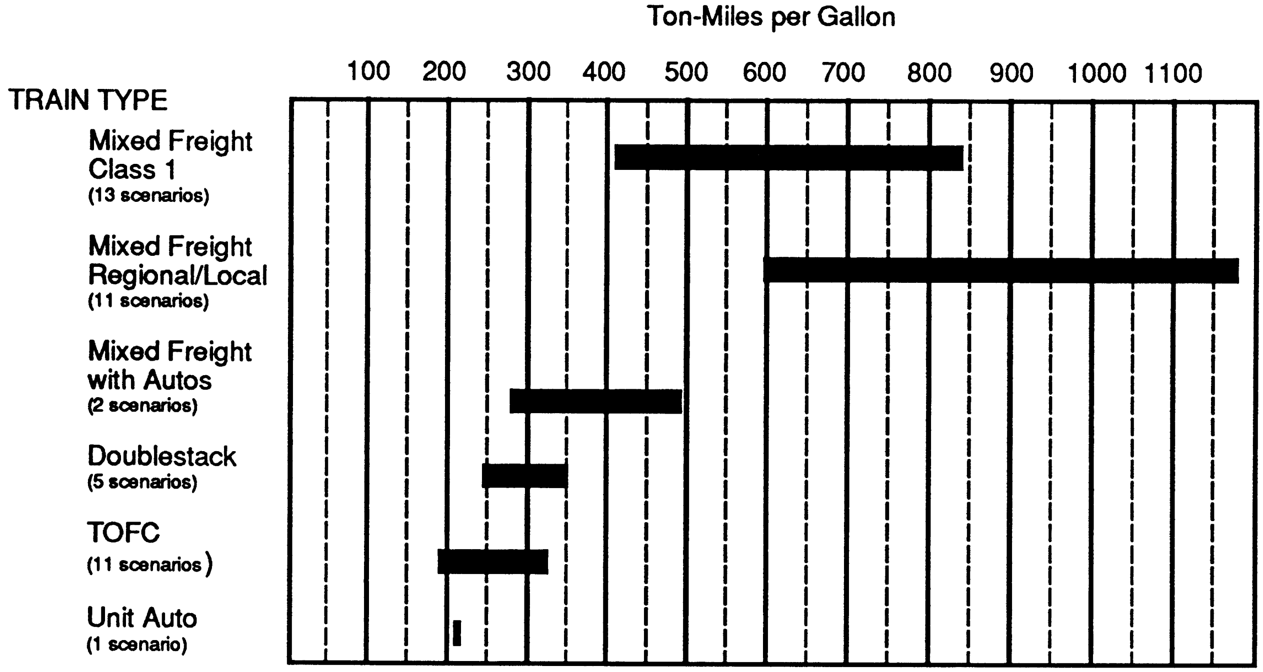
Abacus Technology Corporation produced a study for FRA that used computer simulations for both truck and rail results based on respected industry models that consider the specific route characteristics. This study is unique in that it considers specific routes, loads, and equipment. The results were determined along real transportation corridors that are used today. The operating scenarios used considered various commodities that are shipped on these routes and that are transported by both rail and truck in these corridors. The results include calculations for fuel used in local rail switching, terminal operations, and truck drayage. Rail demonstrates better fuel efficiency for all combinations from 1.4 to 9 times better than trucking as shown in Exhibit 3. Underlying factors for this fuel efficiency difference include equipment type, average speed, terrain, lading or payload weight, and horsepower.

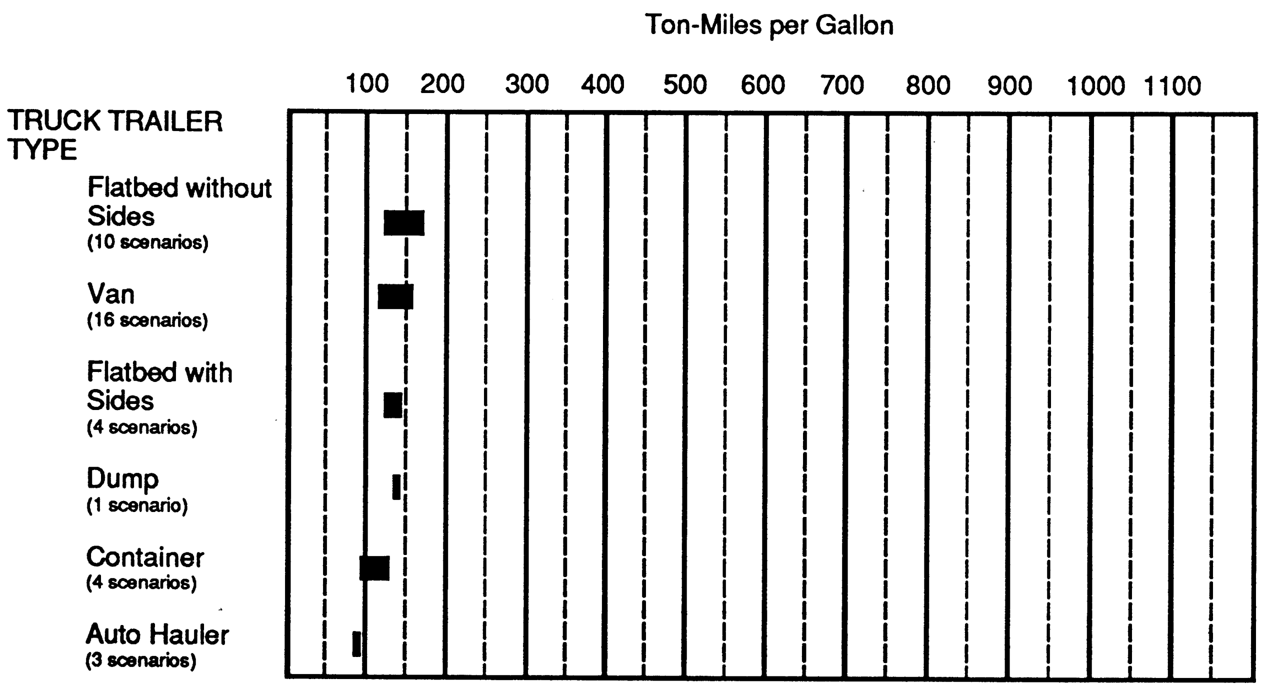
Rail circuity decreases the relative advantage of rail versus truck fuel efficiency measured in ton-miles/gallon, but rail has better efficiency in all cases analyzed. The report describes changes in the design and operations of both rail and truck transport and attempts to quantify the impact on fuel efficiency of each. Operating fleets' level of participation in adopting the new technologies and operations is addressed.

Ton-miles per gallon is used as a measure for fuel efficiency because: 1) it measures the size of the freight as well as the distance moved, 2) it has been used in several previous studies of modal fuel efficiency, and 3) it best met the overall needs of the study (direct commodity/route comparisons). Other measures were considered and dismissed for reasons detailed in the report.

This report has a number of strengths. As mentioned earlier, specific commodities and routes were selected for simulation where rail and truck directly competed. This addresses many of the concerns of inequity that have been raised in other studies. Numerous scenarios for different types of rail and truck transport were included which provide a range of options

Exhibit 3
Range in Ton-Miles Per Gallon By Equipment Type (FRA, 1991 Report)
(All Scenarios)





Source: US DOT/FRA, Rail versus Truck Fuel Efficiency: The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in a Range of Corridors, April 1991.

for TS&W considerations. The study prorated energy consumption for fractions of trucks in calculating energy consumption. For example, if it required 1.8 trucks to carry the equivalent payload of 1 rail car, the truck mode was not charged the full energy consumption of two tractors. Finally, the study takes into account many technological changes in both trucking and rail shipments that occurred during the 1980s.

There are some weaknesses with this study: first, longer combination vehicles (LCVs) are excluded from all scenarios. The study acknowledges that an option trucks may use to improve efficiency is multiple trailer configurations, but they were not included in the analysis. There is no clear method of determining how many trucks use multiple trailers or even what percentage of trips or VMT are accomplished with multiple trailers. If more than one trailer is pulled by a single tractor, then the truck energy consumption estimates presented in the report are significantly overstated.

Second, empty or back-haul miles are not mentioned in this study for rail and are assumed to be zero for trucks. It may be that on the specific routes examined there is limited or no occurrence of this phenomenon, but the complete absence of the topic raises concern. Other studies have indicated that empty back haul miles are an important section of the route structure and negatively impact fuel efficiency, especially for rail. As a result, the fuel efficiency for rail may be overstated.

Third, the trucking model in the study used the same engine for all truck types. This may be reasonable if all of the trucks (on the commodity/routes selected) required the same performance in this study, but this is not likely to be true in all situations. More research on this is needed. As noted earlier when discussing vehicle weight, engine horsepower requirements could significantly impact fuel consumption.

(d) American Association of State Highway and Transportation Officials (AASHTO), 1993 Reports

In 1993, the American Association of State Highway and Transportation Officials (AASHTO) issued two freight policy reports: <u>Synthesis of the Impacts of TS&W on the Transportation System and the Economy</u>, from the Subcommittee on TS&W of the AASHTO Joint Committee on Domestic Freight Policy (AASHTO Joint Committee, 1993), and <u>Review of National Domestic Freight Policy</u> (AASHTO, 1993). These reports do not provide any new research but they raise at least one important policy question. Increased TS&W limits will certainly impact rail traffic, but the real question is how much and at what impact? Rail transport is generally better than trucking for congestion and fuel conservation purposes. Trucking can be more energy efficient than rail when rail freight delivery is extremely circuitous (e.g., possibly for short-hauls) and when rail is not a realistic option (e.g., drayage operations).

The AASHTO reports note that changes in truck pricing can be made in conjunction with changes to TS&W limits. Pricing changes could limit the savings that can be passed on to trucking consumers, thus limiting modal diversion of freight traffic from rail. Additional policy factors which complicate the TS&W analysis include international freight movements, particularly with NAFTA, and greater cooperation that has been occurring between rail/trucking/intermodal companies over the last decade, which have not been adequately explored in the research to date.

1.4 Tires

It has been estimated that improved tire technologies can improve current truck fuel economy by 2-10 percent. Over the years, there has been increased utilization of improved tire technology. For example, considerable fuel savings resulted in the early 1980s when virtually all trucks converted from bias-ply to radial tires. Low-profile radial tires, which have less resistance than traditional radial tires, offer the most promise for further improvements in truck fuel efficiency. Initial research also indicates that super single tires contribute to improved fuel economy. However, the amount of contribution, particularly given possible TS&W changes, has not been quantified and requires additional research (AASHTO Joint Committee, 1993).

On the other hand, increased use of double and triple trailer configurations can contribute to increased irregular tire wear. This can occur due to excessive movement on dolly axles (Heavy Duty Trucking, Feb. 1992, pp 68). Irregularly worn tires can increase friction and resistance, creating more load on the engine. The impact of worn tires has not been discussed in the literature, but it may be as significant as the improvements new tire technologies provide. Similarly, the effects of tire and axle loads on energy conservation have not been researched. To the extent these increase resistance and exacerbate load on the engine, fuel efficiency will be reduced.

1.5 Environmental Laws

Diesel is the primary fuel technology for heavy trucks currently and in the foreseeable future. However, the Clean Air Act Amendments (CAAA) of 1990 have required since October 1993 that low sulfur diesel fuel be available in all States except Alaska and Hawaii (CRS, 1991). Clean diesel and emissions control technologies may have a negative impact on heavy duty vehicles' fuel efficiency. (For a more complete discussion of these issues, refer to Working Paper No. 11, Environment.) In addition, the CAAA, the Energy Policy Act of 1992 (EPACT), and other legislation will provide pressure in the future for more alternative fuel vehicles. No alternative fuel has as much energy (british thermal units) per gallon as diesel fuel. Therefore, for trucks to have the same range as current vehicles, alternatively fueled trucks would require larger fuel tanks. This results in greater tare weights which could negatively impact fuel economy and could potentially limit payload weights for some fuel technologies. More research is needed to evaluate these issues.

Alternative fuel vehicles are not likely to be a factor on long-haul routes. They could, however, be an important factor in drayage or pick up and delivery operations. If intercity and interstate truck loads increase due to increases in TS&W limits, these larger loads will have to be broken into smaller loads for local pick up and delivery. Trucks performing these drayage operations will be more likely to be powered by alternative fuels as a result of the CAAA and EPACT. Since the fuel storage may displace some of the payload capacity for these alternative fuel trucks, more trips may be necessary by the alternative fuel trucks relative to a conventional truck in order to perform all of the drayage for a given load size. This may result in increased energy use because more trips are necessary, and, each trip uses more fuel energy because the tare weight has increased. Again, this area requires more research.

1.6 Equipment Specifications and Technology

As was discussed earlier in this paper, technological improvements, particularly in the area of aerodynamic enhancements of trucks have contributed significantly to energy conservation. These technological trends are likely to continue into the future, particularly if new truck designs are brought into common usage. However, increased use of double and triple trailer configurations could partially offset these improvements because of the interrupted airflow between the trailer combinations. No data was identified in the research literature on these issues, but technologies could significantly improve fuel efficiency and energy conservation.

1.7 Vehicle Performance

One major factor in determining fuel economy is vehicle speed. A DOT study cited earlier (DOT, 1975) found a significant relationship between speed and fuel economy. For example, a fuel savings of 10 percent was found from operating a vehicle at 55 miles per hour instead of 60 mph. That particular DOT study is quite old (1975) and had several weaknesses in its methodological approach. However, given the numerous improvements that have occurred and the potential significance on the effect of energy consumption, more research is needed.

Several other potential vehicle performance factors could impact energy conservation. A major factor affecting fuel consumption is vehicle condition and proper maintenance. It is widely assumed that a lack of routine maintenance can significantly worsen fuel economy, but specific research quantifying this relationship was not identified. Other vehicle performance factors that can impact energy conservation include fuel consumption versus volume to capacity ratio or speed. No data was found in the research to indicate the potential significance of any of these factors.

1.8 Indirect Energy Consumption

Energy consumed directly in the form of fuel used for propulsion is the most obvious and most important component of transportation energy required, as well as the most easily and accurately estimated. However, there are a number of additional indirect requirements for energy. These include the energy embodied in the transport vehicles and facilities; energy required to extract, refine and transport propulsion fuel; and "overhead energy" associated with maintenance and administration of the system. In the case of freight transported by truck or rail, these indirect requirements account for nearly half of total energy requirements (DOT, 1981). Estimates of the magnitude of indirect energy consumption for truck transport varies, but DOT has estimated it to be about 70 percent of direct energy costs (DOT Technical Supplement, 1981).

2.0 Knowledge Gaps and Research Needs

2.1 Vehicle Weight

A gap in existing research is the power requirements that might be needed if TS&W limits change. For example, if gross vehicle weight limits are increased, motor carriers may utilize more powerful tractors (engines with increased horsepower) to pull the heavier loads and maintain current vehicle performance characteristics. Generally, it is assumed that increased horsepower results in increased fuel consumption. However, the existing research dates back to the 1970s. Given the significance of recent technological improvements, new research is needed to analyze both horsepower requirements and the related fuel efficiency impacts. New research should also analyze a variety of engines and vehicle weights, because most studies have considered only one engine type.

2.2 Vehicle Dimension

Research is needed to determine if changes in vehicle dimension limits would increase or decrease energy consumption. While longer or multiple trailers would allow more freight to be transported in fewer trips, additional stops or miles of travel might be needed to fill up the additional cubic capacity. Additionally, longer vehicle limits without a corresponding increase in weight limits serves no benefit except with light-weight cargo. It may actually raise fuel costs/consumption with no increase in efficiency. Travel to and from staging areas to couple/decouple multiple trailers may be necessary if vehicle dimension limits are increased. Research is also needed to determine if longer or multiple trailers would add drag to the vehicle and penalize fuel economy. No data was found in the research to address this issues, but the potential impacts of vehicle dimension changes are likely to be smaller than vehicle weight issues.

2.3 Intermodal Tradeoffs Between Trucks, Rail, Mixed Modes (e.g., Containers)

Given the vast changes that occurred over the last 15 years, more research is needed on modal diversion models, including examination of containerized cargo shipments. None of the studies has examined domestic or international container shipments, which is a fast growing segment of freight transport. Additional investigation into intermodal highway connectors with ports, implications for the national highway system (as an expansion from the Interstate system) is needed. This need increases if increased vehicle lengths and widths are contemplated, since locating staging areas on or near major road networks is important in order to maximize energy efficiency under a scenario of increased LCVs. This is a critical research need, especially in light of emerging issues such as the North American Free Trade Agreement, and increased cooperation between rail, trucking, and intermodal freight shipping companies.

Attention needs to be given to charging mechanisms for TS&W changes. It has been suggested that TS&W changes could be made in conjunction with charging mechanisms to achieve energy conservation goals without affecting the mode share split between truck and rail.

2.4 Tires

A relatively minor research need is the impact of tires. If changes in TS&W limits promoted more tires or axles, this could increase the drag and resistance and potentially lower emissions. Significant changes in tire technologies or widespread adoption of super single tires could impact energy conservation objectives and changes to TS&W limits. These impacts are expected to be low, but should be investigated.

2.5 Actual Vehicle Energy Consumption Characteristics

As discussed in section 1.7, many things impact the vehicle energy performance including the age and types of vehicles in operation, condition of the equipment and standards for maintenance and repair, technologies used, terrain traveled, and the driver's skill (which is potentially the largest determinant of actual vehicle fuel efficiency). Research into actual conditions for these factors is needed, particularly given the changes that the industry is undergoing. Changes in TS&W may encourage motor carriers to purchase newer engines, which are generally more fuel efficient and could promote energy conservation. This type of information will allow for theoretical analysis to be directly applied to current situations. An important area not to overlook is fuel economies associated with various LCV combinations that may become increasingly used given contemplated changes in the TS&W limits.

2.6 Environmental Laws

With EPACT, CAAA, ISTEA, and other requirements, the acceptability of clean diesel technologies and their energy performance penalties need to be addressed. Although there are many demonstrations of alternatively fueled vehicles underway, many of these demonstrations are transit bus fleets, and their results need to be assessed to provide insight into how alternative fuels may serve heavy duty truck fleets. As noted in the environmental working paper, a research gap currently exists in terms of what operational restrictions may be applied against diesel fueled vehicles, most notably in the Los Angeles Air Basin. The impact of any changes to TS&W on the FIP must also be addressed.

2.7 Indirect Energy Consumption

Given that existing research suggested that indirect energy costs at least approach direct energy consumption (70 percent) and that the supporting research for that estimate is nearly 15 years old, a real knowledge gap exists in the accuracy, availability, and ability of models to estimate the indirect energy consumption in truck and rail transport. Given the potential infrastructure investment that would be required in TS&W limit changes, indirect energy consumption could significantly impact energy conservation goals.

3.0 References for Energy Conservation Working Paper

1994

Longer Combination Trucks - Potential Infrastructure Impacts, Productivity Benefits, and Safety Concerns, GAO, August 1994.

Infrastructure Decisions in Relationship to Energy Consideration, (1994), R. Strammer, presented at the Third Engineering Foundation Conference on Vehicle-Road and Vehicle-Bridge Interaction, Third Engineering Foundation Conference, June 1994.

Economic Impact of the U.S. Environmental Protection Agency's Federal Implementation Plan on the South Coast Air Basin, prepared for the Los Angeles Area Chamber of Commerce, First Interstate Economics, Appendix I, Comments on the California Federal Implementation Plan, (Docket A-94-09), August 29, 1994.

American Trucking Associations, Inc., Comments on: Approval and Promulgation of Federal Implementation Plans, California--Sacramento and Ventura Ozone; South Coast Ozone and Carbon Monoxide; Sacramento Ozone Area Reclassification, 40 CFR Parts 52 and 81; 59 Federal Register 23,264 EPA Docket No. A-94-09, August 31, 1994.

California Federal Implementation Plan (FIP) - Excerpts of Proposed Rule, Part II Environmental Protection Agency, 40 CFR Parts 52 and 81, Approval and Promulgation of State and Federal Implementation Plans; Proposed Rule, May 5, 1994.

1993

Report of the Subcommittee on Truck Size and Weight of the AASHTO Joint Committee on Domestic Freight Policy: Synthesis of the Impacts of Truck Size and Weight on the Transportation System and the Economy, AASHTO, July 2, 1993.

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