Modal Shift Analysis

Final Draft Desk Scan

Comprehensive Truck Size and Weight Limits Study

November 2013

U.S. Department of Transportation
Federal Highway Administration

FINAL DRAFT DESK SCAN

Section 1 – INTRODUCTION

The purpose of this task *(Modal Shift Analysis, USDOT Comprehensive Truck Size and Weight (CTSW) Limits Study)* is to estimate the extent to which changes in Federal truck size and weight limits might cause shifts in how freight is shipped including shifts between modes (*e.g.*, some traffic shifting from rail to truck) and shifts from one truck configuration to another (*e.g.*, shifts from configurations that were legal under current truck size and weight limits to configurations that would become legal under new size and weight limits). These shifts could affect the volume of truck traffic that would be required to carry a given amount of freight and the weights of trucks traveling on different parts of the highway system. These changes in turn will affect safety, infrastructure preservation costs, productivity, energy consumption, environmental emissions and other factors. Detailed estimates of changes in the characteristics of freight transportation associated with changes in truck size and weight limits will be required to assess the various potential impacts of those changes.

This report provides a scan of the literature on data and methods used in previous studies of freight modal diversion and assesses how the data and methods used in previous studies meet requirements for nationwide modal diversion estimates in the current CTSW Study.

1.1 Study Requirements Related to Modal Diversion:

Several different vehicle configurations will be examined in the CTSW Study, each with unique operating characteristics that will influence the types of highways that could be suitable for their use. Characteristics that would affect the suitability of different vehicle configurations to operate on different parts of the highway network include the vehicle's ability to negotiate curves of various widths; the ability to maintain speeds on grades; the rearward amplification of turning maneuvers in multi-trailer combinations; and the vehicle's overall dimensions. Potential impacts of allowing these different vehicle configurations to operate on different highway networks throughout the U.S. will be assessed including the potential diversion of freight from vehicles that are legal under existing federal truck size and weight limits to trucks that would become legal under higher federal weight limits. The modal shift analysis will also estimate potential diversion from other modes of transportation to vehicle configurations that could be allowed under higher federal truck size and weight limits. Limitations on the highway networks suitable for different vehicle configurations will affect the extent to which each configuration might be an economical alternative for transporting different types of commodities between different origins and destinations.

A highly disaggregated set of commodity flows will be required to assess feasibility and costs of moving different types of cargo between different origins and destinations by various vehicle configurations on different parts of the highway network. The USDOT, Comprehensive Truck

Size and Weight Study, 2000 (2000 CTSW Study), used county-to-county flows, which allowed a detailed analysis of the effects of limiting certain Longer Combination Vehicles (LCV) to the Interstate System. Larger aggregations of origin-destination data, at the US Bureau of Economic Analysis (BEA) or FHWA's Freight Analysis Framework (FAF) region level for instance, would make this type of analysis much more difficult since Interstate System Highways likely would pass through most if not all of those larger regions. The 2000 CTSW Study found that limiting networks on which certain vehicle configurations were allowed to operate could significantly affect the costs and utilization rates of using different vehicle configurations, particularly between origins and destinations not directly served by highways available to all truck configurations. When LCVs were not allowed to travel off networks designated for their use, they had to be assembled and disassembled at staging areas to travel to destinations that were not immediately adjacent to the designated network, just as they currently have to do on certain eastern turnpikes. Depending on the shipment distance and commodity value, this requirement that LCVs be broken down to travel off the designated network made the difference between whether the LCV was used or whether the commodity was shipped by vehicles that did not have to be broken down to travel from origin to destination. Such impacts of having restricted networks available to certain vehicle configurations cannot be adequately assessed with highly aggregated commodity flow data.

1.2 Freight Trends

Between 2002 and 2007 the railroads' share of total freight ton-miles increased from 45 to 48 percent while trucking's share of ton-miles remained at about 42 percent over this period. The share of freight ton-miles shipped on navigable waterways (including shallow and deep draft and Great Lakes) fell from 13 to 10 percent (**Figure 1**). Trucking's share of vehicle-miles of freight transportation increased from 86 to 89 percent over this period while rail car-miles decreased from 14 to 11 percent.

Rail is efficient at moving heavy freight over long distances, as are water and pipeline freight services. Railroads also are important for intermodal moves of long-haul containerized freight, and in certain markets, short-line railroads successfully compete with trucks to haul large volumes of dense commodities relatively short distances. Trucks excel in providing time-sensitive delivery services for high-value goods being transported over medium and short-haul distances. Raw materials and heavy freight going long distances are likely to continue their journey by rail, or some combination of truck, rail, and water. With the future growth in freight, it is anticipated that freight rail will continue to make investments in the capacity required to move heavy and long-distance shipments. Railroads also are making investments to allow them to compete more vigorously with trucks for medium-distance freight traffic. It is in this area where potential impacts of changes in truck size and weight limits could have the greatest impact on the railroads. The US Department of Transportation's (USDOT) Federal Railroad

Administration (FRA). **Table 1** shows the modal comparative advantage by market (USDOT FRA 2010, p. 17).

Figure 1. Shipment Characteristics by Total Modal Activity (Ton-Miles) for the United States: 2007 and 2002 (2007 Commodity Flow Survey)

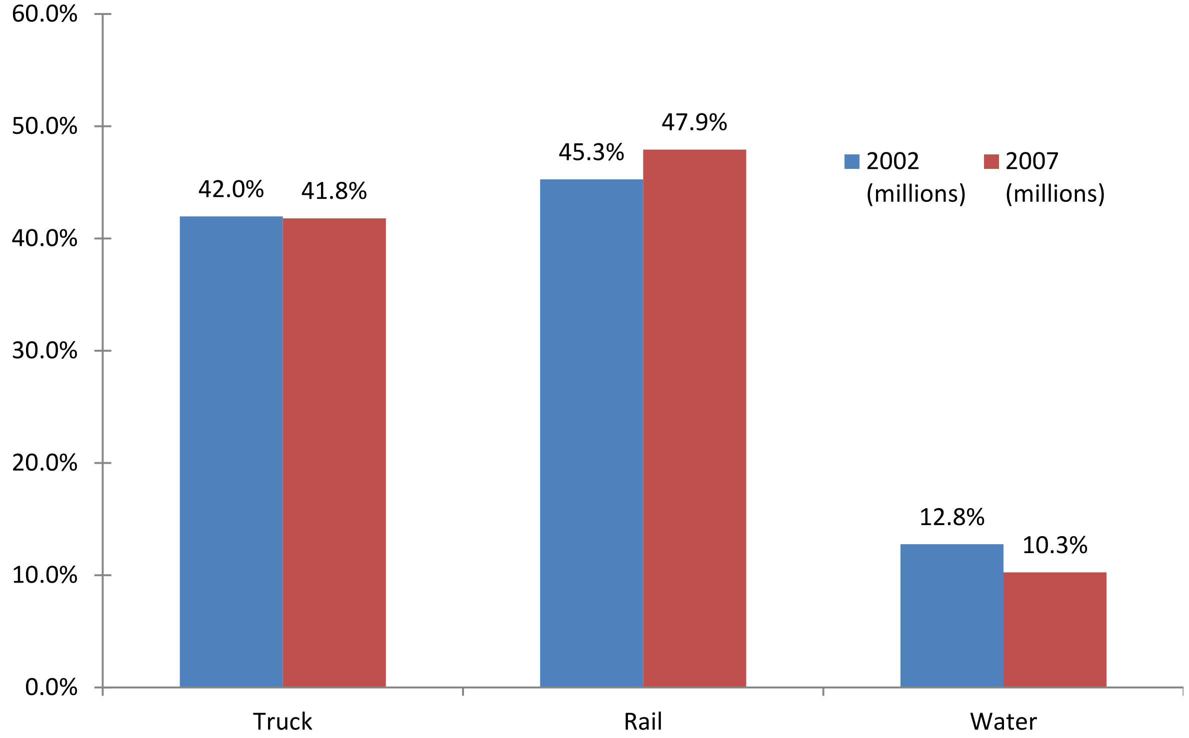


Table 1. Modal Comparative Advantage by Market (USDOT FRA 2010, p. 17)

WEIGHT	Intercity Distance in Miles					
		0-250	250-500	500-1,000	1,000-2,000	>2,000
	Retail Goods/Light	Truck	Truck	Truck Rail Intermodal	Truck Rail Intermodal	Truck Rail Intermodal
	Consumer Durables and Other Manufactured Goods/Moderate	Truck Rail	Truck Rail Rail Intermodal	Truck Rail Rail Intermodal	Truck Rail Rail Intermodal	Truck Rail Rail Intermodal
	Bulk Goods/Heavy	Truck Rail Water	Rail Water Truck	Rail Water	Rail Water	Rail Water

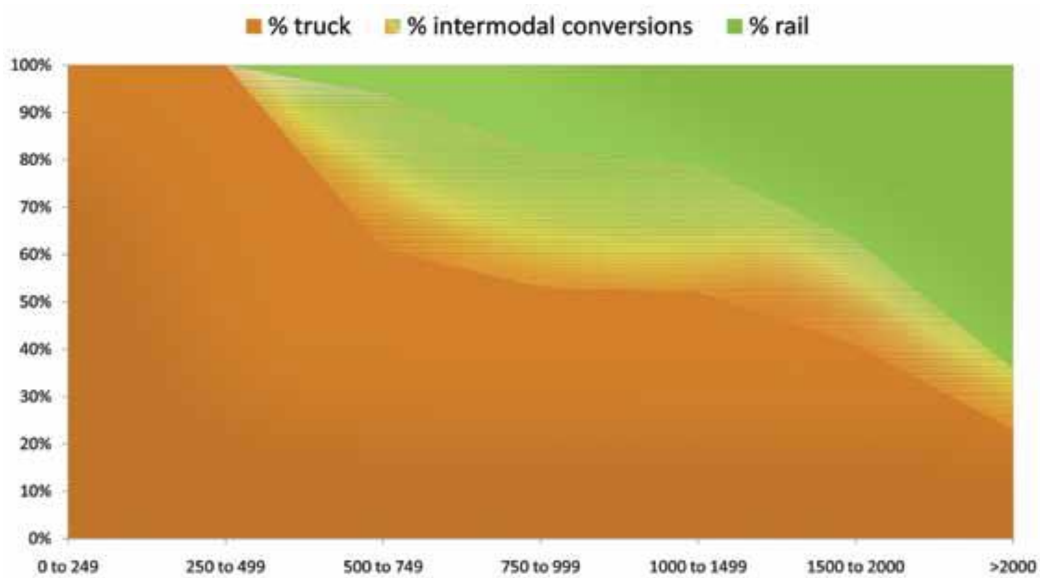
The Federal Railroad Administration, in its 2010 draft National Rail Plan, identifies a future need for more freight capacity. Particularly in the next 25 years it estimates there will be 2.8 billion more tons of freight and in the next 40 years – 4 billion more tons of freight. Two goals identified in the draft National Rail Plan are to support the current freight rail market share and growth and to develop strategies to attract 50 percent of all shipments 500 miles or greater to intermodal rail. As is identified in the study, some diversion to rail is a National goal.

The draft National Rail Plan notes that the U.S. leads the world in terms of freight rail tonnage. Passengers and freight often travel along the same rail corridors making both reliability and safety a challenge. Two goals for freight rail identified in the report are as follows:

- Support the current freight rail market share and growth.
- Develop strategies to attract 50 percent of all shipments 500 miles or greater to intermodal rail.

The Plan notes that improving freight rail's intermodal market share and connections to ports will improve international trade opportunities and supports the President's National Export Initiative. In relation to rail intermodal, the report mentions that replacing 300 trucks with one long-distance, double stack train between Chicago and Los Angeles has the potential to save 75,000 gallons of fuel. Benefits of freight rail as compared to truck include enhanced safety, fuel efficiency, congestion mitigation, reduction of logistics cost, and reduction of greenhouse gases. **Figure 2** shows the additional market share needed for rail to move 50 percent of the 500-mile or greater market by 2035, one of the goals identified in the study.

Figure 2. Modal Shift Projection (USDOT Federal Rail Administration, National Rail Plan Progress Report 2010, p. 20



% Market Share

Miles

SUMMARY OF KEY MODAL SHIFT STUDIES AND RELATED DATABASES

A recent report summarized major truck size and weight studies that have been conducted since 1941.[1] The summaries are mainly provided from two sources – executive summaries from the study documents and a working paper summary of various studies done over the years by the Federal Highway Administration (FHWA). The following are the truck size and weight studies identified and summarized in that report:

U. S. Department of Transportation Studies

a. The Western Uniformity Scenario Analysis 2004
b. The Comprehensive Truck Size and Weight Study 2000 (2000 CTSW Study)
c. Longer Combination Vehicle Operations in Western States 1986
d. The Feasibility of a Nationwide Network of LCVs 1985
e. Maximum Desirable Dimensions and Weights of Vehicles Operated on the Federal-Aid System 1964
f. Federal Regulation of the Sizes and Weight of Motor Vehicles 1941

Transportation Research Board Studies

a. Special Report 267: Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles 2002
b. Special Report 227: New Trucks for Greater Productivity and Less Road Wear, An Evaluation of the Turner Proposal 1990
c. Special Report 225: Truck Weight Limits: Issues and Options 1990

The Government Accountability Office Studies

a. Longer Combination Trucks: Potential Infrastructure Impacts, Productivity Benefits, and Safety Concerns 1994
b. Longer Combination Trucks: Driver Controls and Equipment Inspection Should be Improved
c. Truck Safety: The Safety of Longer Combination Vehicles is Unknown

While not a comprehensive list of all studies related to truck size and weight limits during this period, this list contains major national policy studies relevant for examining modal diversion related to truck size and weight. The most recent studies are summarized in this desk scan while summaries of the other studies can be found in the original report.

To complete the picture of relevant studies, the team scanned the literature for other freight modal diversion studies have been conducted that are not cited in afore mentioned summary reports. These include studies conducted by individual States and studies commissioned by the railroad industry. Major studies uncovered in the desk scan are included in this report.

In the context of truck size and weight studies, modal diversion includes not just diversion of freight traffic from rail to truck as the result of changes in truck size and weight limits, but also shifts of traffic from truck configurations that are legal under existing truck size and weight limits to configurations that would become legal if size and weight limits were increased. Freight traffic is generally characterized as either “weigh out” or “cube out.” Weigh out traffic reaches the gross vehicle weight (GVW) limit at or before the cubic capacity of the cargo-carrying unit is filled. Weigh out traffic can benefit from increasing the maximum GVW of trucks. Some benefit would be realized by increasing the GVW limit of trucks that are the same length as existing configurations, but even greater more cargo could be hauled in each trip if both the cubic capacity and GVW of the vehicle were increased. Cube out traffic on the other hand fills the cargo-carrying unit before reaching the gross vehicle weight limit. Additional cubic capacity is required to carry more cube-out traffic, and this usually requires adding one or more trailers to the vehicle.

Mode choice involves consideration of more than just the relative cost of transporting cargo by various modes and vehicle configurations. Total logistics costs associated with each transport alternative must also be considered. The principal logistics costs related to alternative transportation modes are transit time, warehousing and inventory costs, and safety stock requirements. In general the higher the value of the good the more important are non-transportation logistics costs to the choice of mode. While differences between non-transportation logistics costs typically are greater between truck and rail, there are differences between truck configurations as well that must be considered in mode choice analyses.

SUMMARY OF PREVIOUS MODAL SHIFT STUDIES

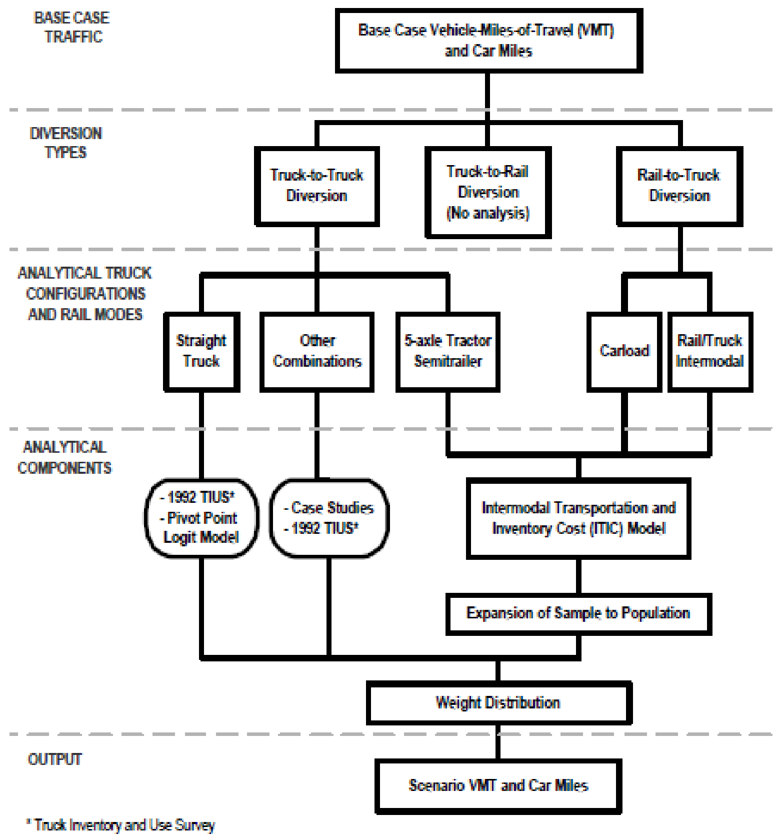
Comprehensive Truck Size and Weight Study

The USDOT's Comprehensive Truck Size and Weight Study, 2000[2] (2000 CTSW Study) used a total logistics cost model and highly disaggregated commodity flow data to estimate mode choice decisions for shipments of different commodities to different origins and destinations. County-to-county flows of different types of commodities were evaluated to determine the lowest total logistics cost for each mode, taking into consideration among other things route restrictions that were assumed to be placed on various longer combination vehicle (LCV) configurations. County-level origins and destinations were necessary to reflect differences in the highway networks assumed to be available to different LCVs.

The 2000 CTSW Study estimated both diversion from one truck configuration to another and rail-to-truck diversion. The logistics cost model used in the 2000 CTSW Study was called the Truck-Rail/Rail-Truck Diversion Model and was based on the Association of American Railroads' (AAR) Intermodal Competition Model that had been used in the Transportation Research Board's Special Report 225, Truck Weight Limits[3] Study. No public commodity flow data by truck were available for the 2000 CTSW Study so the study relied on an AAR database of long-haul truck movements. Rail flows came from the rail waybill database and rail rate data came from proprietary Surface Transportation Board (STB) data. This proprietary rate data was essential to the study since no other source of actual rail rates for different types of shipments in different corridors was available to compare to costs of moving the same commodities between the same origins and destinations by various truck configurations. Truck rate data was purchased from a private vendor because no comparable data that reflected differential rates in various markets were available in the public domain.

Figure 3 shows the analysis of the scenario vehicle miles of travel (VMT) and car miles. Diversion of freight from one truck configuration to another accounted for a substantial share of the total change in truck VMT associated with Truck Size and Weight (TS&W) policy options.

Figure 3. Analysis of Scenario VMT and Car Miles (USDOT FHWA 2000, vol. 3, p. IV-2)



The analysis of truck-to-truck diversion was divided into short-haul shipments and longer-haul. Several policy scenarios were analyzed to isolate potential impacts of different vehicle configurations that might be allowed under different TS&W policy options. Both rail intermodal—containers or trailers going by rail for part of their journey—and rail carload moves were analyzed. Impacts of changes in TS&W limits examined in the study included safety, pavement and bridge deterioration, traffic operations, productivity, energy consumption, and environmental impacts.

Networks for Scenario Analysis The 2000 CTSW Study assumed the following networks for the purposes of scenario analysis.

National Network for Large Trucks: The Surface Transportation Assistance Act (STAA) of 1982 required States to allow 48-foot semitrailers and 28-foot double trailer combinations (often referred to as "STAA doubles") on specified highways. The National Network includes virtually all Interstate Highways as well as other highways. States are required to allow reasonable access for the STAA vehicles to and from the National Network.

National Highway System: With the National Highway System (NHS) Designation Act of 1995, Congress established the NHS. Until recently, this system consisted of the highways of greatest national interest and in

+cludes the Interstate System, a large portion of the other principal arterial highways, and a small portion of mileage on other functional systems.

Analytical Networks for Longer Combination Vehicles: Two illustrative networks were specified to analyze expanded LCV operations under the various scenarios. The USDOT emphasized that these networks, like the scenarios themselves, were purely for illustrative purposes and did not reflect the USDOT's position on where various vehicle classes should be allowed to operate. The network developed to test the operation of long double trailer combinations -- Rocky Mountain Doubles (RMDs) and Turnpike Doubles (TPDs) -- consisted of access-controlled, interconnecting segments of the Interstate System and other highways of comparable design and traffic capacity. The routes connected major markets and distribution centers. The network designed to evaluate the impact of allowing triple-trailer combinations to operate nationwide includes 65,000 miles of rural Interstate and other highways. Some urban Interstate highway segments were included for connectivity. This network included many low traffic highways in the U.S.-West and some four lane highways in the U.S.-East. The network designed for the operation of triple-trailer combinations is larger than the network used to analyze long double combination operations because triple trailer combination vehicles have better offtracking performance than long twin trailer combinations.

Scenario Analysis Of the policy scenarios examined in the 2000 CTSW Study, three involved increased TS&W limits. These scenarios are described below.

The North American Trade Scenario This scenario would allow heavier tridem axles, up to either 44,000 or 51,000 pounds, to facilitate trade between the U.S. and its NAFTA partners. Such changes would allow the eight-axle B-train combinations used in Canada to operate on U.S. highways. It would also increase the use on U.S. highways of six-axle tractor-semitrailer combinations, which are currently much more common in Canada and particularly Mexico. The network would comprise 42,000 miles for Rocky Mountain Doubles and Turnpike Doubles, 60,000 miles for triples, and the existing National Network for eight-axle B-train doubles. The study noted that only 21 states allow LCVs, and that some eastern states only allow those vehicles on their turnpikes.

Longer Combination Vehicles Nationwide Scenario This scenario assumed that a national network over which these vehicles could operate. The network would comprise 42,000 miles for Rocky Mountain Doubles (RMD) and Turnpike Doubles (TPD), 60,000 miles for triples, and the existing National Network for eight-axle B-train doubles. Due to their poor offtracking, the scenario did not allow long double-trailer combinations (TPDs and RMDs) off the designated network. It is assumed that drivers of these vehicles would use staging areas—large parking lots—to disconnect the extra trailer and attach that trailer to another tractor for delivery to its final destination. Drayage is assumed to be along the most direct route off the network between the shipper or receiver and the network. The staging area costs are not included in the truck operating costs because it is unclear whether charges would be levied for use of the staging areas.

Triples Nationwide Scenario The Triples Nationwide Scenario would establish a national 65,000-mile network for seven-axle triple combinations weighing up to 132,000 pounds. Little diversion from rail intermodal was expected, however, because this scenario assumed that each triple-trailer combination can only handle containers up to 28 feet in length and the majority of rail intermodal traffic is transported in containers or trailers 40 feet or longer.

Western Uniformity Scenario Analysis[4]

As the USDOT's 2000 CTSW Study was nearing completion, the Western Governors' Association (WGA) asked the USDOT to analyze another illustrative truck size and weight scenario in addition to the scenarios already included in the study. The "Western Uniformity Scenario" requested by WGA would assess impacts of lifting the LCV freeze and allowing harmonized LCV weights, dimensions, and routes among only those western states that currently allow LCVs. Specifically the WGA requested that USDOT analyze impacts of expanded LCV operations assuming that weights would be limited only by federal axle load limits and the federal bridge formula, with a maximum gross vehicle weight of 129,000 pounds.

LCVs have operated in western states for many years. Grandfather rights in effect since 1956 have allowed those vehicles to exceed the 80,000-pound federal weight limit on Interstate Highways. Until 1991 States could determine the weights and dimensions allowed under their grandfather rights, but the LCV freeze instituted in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) prohibits States from increasing allowable LCV weights on the Interstate System or allowing longer LCVs on the National Network established in the Surface Transportation Assistance Act of 1982. Because grandfather rights in each of the western states differ, allowable weights and dimensions for LCVs in most western states vary.

Both the logistics cost model and the commodity flow data used for the 2000 CTSW Study were significantly improved for the Western Uniformity Scenario Analysis. The logistics cost model, which was renamed the Intermodal Transportation and Inventory Cost (ITIC) model, was made easier to use and logistics costs were updated and refined. The major improvement, however, in the Western Uniformity Scenario Analysis was in the commodity flow database. The Federal Highway Administration (FHWA) developed its Freight Analysis Framework (FAF) in 2002 and that database was used for the Western Uniformity Scenario Study. The FAF, which is discussed in more detail later in this technical memorandum, was based on the Census Bureau's Commodity Flow Survey (CFS) with additional data sources to fill in commodity flows that were not collected in the CFS. For the Western LCV Uniformity Scenario, a version of FAF having county-to-county flows was developed that allowed detailed assessments of the potential shift to LCVs based on the networks that would be available to those vehicles and the extent to which those networks served various origins and destinations at the county level. Without county level origins and destinations it would have been impossible to directly reflect network limitations for some LCVs when estimating potential diversion of traffic to those configurations since virtually all FAF regions are served by all highway systems. The limited networks assumed to be available to various types of LCVs, and the requirement that they assemble and disassemble for travel off those networks, significantly affected estimates of overall diversion and the configurations to which shipments were diverted.

TRB Special Report 225, Truck Weight Limits

The Transportation Research Board's 1990 Special Report 225, Truck Weight Limits was one of the most comprehensive analyses of truck size and weight policy options that had been done to date. The study analyzed impacts of 10 specific truck size and weight policy options including several that are similar to scenarios being analyzed in the current CTSW Study.

Base case forecasts of VMT and payload ton-miles for a future year (1995) were developed for 10 vehicle types, seven regions of the country, nine gross vehicle weight ranges, and four highway systems (rural and urban Interstate, other rural and other urban).

Interviews with 32 firms representing all segments of the trucking industry were a key input to developing forecasts of scenario VMT. No mathematical model was used to estimate shifts from one truck configuration to another, but the authors note that many perspectives were provided in the interviews that would be difficult to capture in a mathematical model. On the other hand findings depend to a great degree on the firms interviewed for the study and there is uncertainty about whether actual responses to truck size and weight changes would correspond to anticipated responses noted in the interviews.

It was assumed that State length limits and access policies for multi-trailer combinations would remain unchanged. Thus in regions where length limits would not allow longer combination vehicles, such vehicles would not be allowed in that region even under a scenario in which that vehicle otherwise would be allowed. Likewise in regions with restrictive access limits, multi-trailer vehicles might be restricted to the Interstate System whereas in the U.S.-West where LCVs have much broader access, scenario vehicles would retain that same degree of access.

Transportation costs were calculated for each vehicle, but those costs were not used to estimate modal shifts. Rather they were used in combination with estimated changes in miles traveled by each configuration to estimate changes in total transportation costs associated with each scenario. Costs considered in the study were driver costs, vehicle costs, fuel costs, tires, maintenance, and overhead costs. Cost estimates were developed from The Truck Blue Book, interviews with operators and dealers, and a review of estimates from previous studies. Costs were expressed in terms of cost per mile, cost per loaded mile, and cost per ton-mile. No non-transportation logistics costs were considered in the analysis. The Association of American Railroads'(AAR) Intermodal Competition Model, which no longer is used by AAR, was used to forecast potential truck/rail diversion.

Carl Martland conducted a study for the railroads in 2007 to estimate potential competitive impacts of larger trucks on rail freight traffic.[5] The study creates a base case of synthetic O-D movements intended to represent the traffic that is handled or could be handled by a railroad or group of railroads. For each O-D movement, the study identifies the cost, capacity, and service characteristics offered by each transportation mode and estimates the total logistics costs that would result from using each available mode for each O-D. The method then allocates the traffic to each mode based upon a comparison of the total logistics costs using a statistical logit model. If the costs are equal, all modes share the traffic equally; if one mode dominates, then that mode captures all the traffic. The resulting traffic is summed over all O-D pairs to get the mode share for the base case. For scenario evaluation new cases are structured based on changes to the performance characteristics of one or more modes, unit costs, and operating parameters and the results are subsequently compared to the base case for changes in market share by mode, changes in traffic volumes, and performance.

This approach cannot provide exact estimates of market changes, since actual conditions will often be more complex than what is covered by this methodology. However, this methodology does include the major factors known to influence mode choice, and it is broad enough to provide insight into the probable effects of new technologies or other changes in the competitive transportation environment. Technological or operating changes that result in significantly higher or lower logistics costs for one mode can be expected to cause significant changes in mode choice; technologies that afford only minor changes in total logistics costs will be unlikely to cause significant changes in mode choice. However, one drawback of the method is the allocation of all traffic to the dominant mode. The logit model determines the probability of choosing each mode, so allocating all traffic to the mode with highest probability likely over-allocates to that mode and under-allocates to other modes.

The data relies on values of trip distances, values/pound, density, and annual use rates from studies sponsored by the International Railroad Congress, and the American Short Line and Regional Railroad Association for short line rail traffic.

The study was conducted in coordination with the Association of American Railroads (AAR). The study uses a methodology developed at MIT and applied previously in various studies, including a similar study of the competitive effects of larger trucks on short line railroads. The methodology was applied in two analyses, each of which examines rail mode share for a set of generic origins and destinations under various assumptions concerning trucking capabilities.

Babcock has examined the impacts of railroad abandonment on communities. [6] [7] His research measured quantifiable impacts of shortline railroad abandonment in Kansas through four research tasks. First, an assessment of Kansas county road conditions and financing was conducted to determine the ability of counties to absorb the resulting incremental heavy truck traffic. Second, the changes in wheat handling and transportation costs were computed. Third, the increase in truck-attributable road damage costs to Kansas county and state roads was computed. Fourth, the additional highway accident benefits and costs attributable to the resulting incremental truck traffic were calculated. He concluded that "losses of shortline railroads would have negative effects on rural Kansas communities, including increased road damage costs and reduction in farm income." Furthermore, energy consumption and emissions required to move freight would increase if shortline railroads were abandoned.

RECENT STATE MODAL DIVERSION STUDIES

Minnesota Truck Size and Weight Study[8]

The Minnesota Department of Transportation conducted an extensive analysis of TS&W alternatives in cooperation with an advisory committee representing a variety of industries, all levels of government, and other interested organizations. The methodology for the project was based on nationally accepted methods utilized by the National Academy of Sciences and the USDOT.

"To guide estimates of the amount of freight that might shift to heavier trucks under each Scenario, tables were created to show the current distribution of truck traffic by truck type, operating weight, and highway system (Interstates, other trunk highways, and local)...With these distributions, estimates were made regarding the amount of Base Case freight (measured in payload ton-miles) moving in trucks that are at or close to Base Case weight limits. This weight-limited freight is a good candidate for shifting to heavier trucks if weight limits are increased."

"The principal shipper and carrier responses considered were changes in operating weights and the types of trucks used, in order to reduce the amount of truck VMT (and hence cost) to carry a given amount of freight. The following possibilities also were considered: 1) changes in limits might cause shifts from rail to truck, 2) changes in the total amount of freight shipped, 3) shifts in highway systems used by trucks and 4) shifts in the time of year for shipments (due to seasonal differences in limits). Sensitivity analysis was performed to investigate how different assumptions about the size of shifts might affect the overall evaluation of a scenario."

The impact areas covered in the study are:

- Truck traffic effects (including modal or system diversion);
- Transport costs;
- Pavement costs;
- Bridge posting and replacement;

- Bridge fatigue;
- Bridge decks;
- Bridge design;
- Crash costs; and
- Congestion costs.

"To guide estimates of the amount of freight that might shift to heavier trucks under each Scenario, tables were created to show the current distribution of truck traffic by truck type, operating weight, and highway system (Interstates, other trunk highways, and local). Data on truck miles by state, highway functional class, truck type, and operating weight from the USDOT's 2000 CTSW Study was used as the starting point in preparing these truck traffic distributions. The USDOT distributions were updated and adjusted to be consistent with more recent data on truck miles compiled by Mn/DOT."

"With these distributions, estimates were made regarding the amount of Base Case freight (measured in payload ton-miles) moving in trucks that are at or close to Base Case weight limits. This weight-limited freight is a good candidate for shifting to heavier trucks if weight limits are increased." The primary basis for estimating shifts among vehicle configurations was expert opinion based on characteristics of freight traffic in the State and viewpoints of shippers and carriers. No quantitative modeling was used to estimate potential shifts among vehicle configurations or between modes.

Wisconsin Truck Size and Weight Study[9]

"The purpose of the project is to assess potential changes in Wisconsin's TS&W laws that would benefit the Wisconsin economy while protecting roadway and bridge infrastructure and maintaining safety...The broad challenge of this evaluation is the ability of the TS&W changes to balance economic gains resulting from increased truck productivity with the potential costs to safety and infrastructure.

The methodology draws heavily upon past studies of truck size and weight limit changes by the Minnesota DOT, the USDOT, and the Transportation Research Board. Estimates of diversion from Base Case to Scenario configurations were developed for two cases:
1. Non-Interstates Only. Scenario configurations are not allowed on Interstate highways; and
2. All Highways. Scenario configurations are allowed on Interstate highways (this case would require a change in Federal truck size and weight regulations)."

New truck configurations examined in the study included 6-axle 90,000 pound tractor-semitrailer; 7-axle 97,000 tractor-semitrailer; 7-axle 80,000 pound single unit; 8-axle 108,000 pound twin trailer; 6-axle 98,000 pound tractor-semitrailer; and 6-axle truck-trailer combination.

Impacts were estimated in the following areas:

- Truck usage
- Goods movement costs
- Pavement and bridge impacts
- Bridge reconstruction, rehabilitation and posting costs
- Safety
- Congestion, and
- Energy and the environment

As with the Minnesota Truck Size and Weight Study, shifts among vehicle configurations were estimated using expert opinion based on characteristics of freight traffic in the State and viewpoints of shippers and carriers. No quantitative modeling was used to estimate potential shifts among vehicle configurations or between modes.

Montana

Jerry Stephens and colleagues at Montana State University conducted a study in 1996 of the Impact of Adopting Canadian Interprovincial and Canamax Limits on Vehicle Size and Weight on the Montana State Highway System.[10] As in the Minnesota and Wisconsin studies, it was assumed that only weight limited vehicles would consider shifting to new configurations and operating weights. Data on existing vehicle weights operating on Montana highways were used. Between 33 and 66 percent of total freight carried on vehicles within 10 % of their weight limits was assumed to divert to alternative configurations. The authors note that, "In reality, the availability of proper shipping/receiving facilities, cost of new equipment, maneuverability requirements, type of haul, etc. will influence decisions of this kind, and some weight limited operators will choose to continue to use their existing configurations."

Estimates of diversion of traffic from rail to truck was based on findings of the TRB 225 study which estimated that ton-miles on highway system would increase by 3 3/4 % under Canadian Interprovincial Limits. Diversion estimates did not consider limiting the networks available to longer combination vehicles.

Texas

Bienkowski and Walton at the Southwest Region University Transportation Center prepared a paper analyzing The Economic Efficiency of Allowing Longer Combination Vehicles in Texas.[11] "An LCV scenario for Texas was chosen, with specific routes and vehicle types. Operational costs for these vehicles were calculated on a cost per mile and cost per ton (or cubic yard) mile. The LCV scenario and the current truck base case were analyzed to find the number of truck trips, the number of miles, and the cost per mile for the chosen routes. These are then compared to estimate the change if LCVs were allowed in Texas."

To decide which types of LCVs would be safe and appropriate for Texas, the research team contacted companies interested in using LCVs. The first vehicle chosen was a 97,000 pound tridem semi-trailer, which is not an LCV. The next configuration coupled two standard 53-foot semitrailers and was assumed to travel at a maximum gross weight of 138,000 pounds. Finally, that same double combination was studied at a gross vehicle weight of 90,000 pounds to serve cube-out traffic.

Based on operator surveys and input from industry contacts, the researchers decided that the following LCV scenario would be realistic for this study:

- LCV approval would affect primarily standard 5-axle tractor-semitrailers;
- 15% of current truck cargo currently hauled by 5-axle tractor-semitrailers would remain in this vehicle class;
- 35% would be transferred to the 97,000 pound tridem axle tractor-semitrailers;
- 20% would be transferred to the light doubles; and,
- The remaining 30% would become the 138,000 double 53s.

These shifts among configurations were based solely on expert opinion and not on a detailed analysis of the costs of using alternative configurations for hauling different commodities over different distances.

Virginia

Virginia has conducted several studies of freight movement along the I-81 corridor. A major focus of those studies is to estimate the potential for diverting truck traffic to rail in the corridor. A 2009 study evaluated several strategies for diverting traffic from truck to rail, one of which involved the use of cross-elasticities to estimate the change in traffic for one mode when prices for the other mode change.[12]

An important finding of that study that has implications for the current study is that “the literature on freight elasticities does not tell a clear story. One recent study[13] cited compiled results from prior studies. The widest range cited suggests that price elasticities for trucking range from -0.04 to -2.97 and price elasticities for rail range from -0.08 to -2.68, depending on commodity. The narrowest range cited suggests that elasticities for both trucking and rail range from -0.25 to -0.35. The average value of -0.30 is suggested for the present analysis, mostly because it yields the most plausible results.”

“For trucking, this means a 1 percent increase in price results in a 0.3 percent loss of traffic. Looking at the choice between truck and rail costs, it might be expected that for each 1 percent cost savings offered by rail, 0.3 percent of trucks might divert to rail when offered the choice.”

The study notes, “The diversion estimates are very sensitive to price assumptions. Even relatively small changes in price can produce significant changes in the estimates. This analysis is based on average rates, but in practice, trucking and rail costs vary widely depending on the commodity, travel lane and distance, competitive market conditions, and other factors. Further analysis would be needed to accurately reflect these important differences.…We have relied on a general estimate of price elasticity. The best diversion models are based on corridor and commodity-specific elasticities not only for price, but also for changes in speed, reliability, and other factors."

This conclusion has significant implications for the use of cross-elasticities based on econometric analysis for the current CTSW Study. Detailed cross-elasticities for different commodities moving in different markets are not available, nor are elasticities that reflect changes in non-transportation logistics costs.

Another study of potential diversion of truck traffic to rail along the I-81 corridor in Virginia used the ITIC model in combination with the Transearch database.[14] "The purpose of the freight diversion analysis was to evaluate the potential for truck traffic currently using I-81 to divert to rail intermodal service, and to confirm assumptions from previous studies. Several steps were taken to develop a method for the modal diversion analysis:

- A literature review was conducted to evaluate previous studies that examined diversion potential in the corridor, and identify existing data sources for inputs to the model.;
- Identified existing truck-to-rail diversion models and selected the FHWA's Intermodal Transportation and Inventory Cost Model (ITIC) for the analysis.
- Translated a set of assumptions provided by Norfolk Southern and others about rail capacity improvements into values which could be modeled in ITIC; and
- Developed a set of criteria to select certain commodity movements in the 1998 Virginia Transearch™ database which are considered modally competitive.

The ITIC model was selected for use in the mode diversion analysis after a review of existing truck-to-rail diversion models. An advantage of this model is that it was developed and is maintained by the FHWA Office of Transportation Policy Studies in cooperation with the Federal Railroad Administration. Most of the data required for the model (except for rail variable costs and drayage distances) are readily attainable, and the model is well documented by the USDOT. The model is currently being refined and upgraded by a steering group of rail and truck experts under the FHWA.

ITIC, which is described in more detail later in this desk scan, is non-proprietary and can be modified to fit various truck size and weight, rail and transportation cost scenarios. It was also used to evaluate route diversions based on tolling scenarios in the I-81 study area. ITIC predicts modal diversion by calculating and comparing the total logistics costs for different modes of freight transportation.

The Transearch™ database provides the base data for this analysis. Transearch™ provides commodity detail to the four digit level as well as the annual tonnage for a particular commodity flow between an origin and destination. Only records that have been assigned to I-81 were analyzed. It is also important to note that only movements greater than 500 miles were assumed to be divertible to rail. County to county movements in Virginia, and shorter interstate movements were not included in the analysis. Movements that meet the following criteria were selected for analysis:

- Lane Density — Over 12.5 tons moved annually; and
- Distance — The distance between the origin and destination of the movement will be greater than 500 miles."

International Studies

A recent NCHRP report summarized the experience in Canada operating under their revised framework for regulating the size and weight of commercial motor vehicles.[15] This was an ex post assessment of changes associated with changes in truck size and weight policy in Canada.

The study concluded that the "Memorandum of Understanding among Canadian Provinces regarding vehicle weights an dimensions limits had a significant effect on the composition of the trucking fleet in Canada. There were significant differences in fleets in various regions of Canada reflecting differences in the types of commodities hauled. The 8-axle B-train is clearly the vehicle of choice for heavy haul in the four western provinces and in the four eastern provinces, where it did not exist prior to the Memorandum of Understanding (M.o.U)." "The M.o.U. introduced the tridem semitrailer and the 8-axle B-train, and these are now the third and fifth most common configurations across Canada." "The tractor-tandem semitrailer (T12-2) was the most common configuration, by a wide margin, in all provinces, and made almost two-thirds of all cross-border truck trips, a proportion more than 60% higher than for all trips in Canada."

The study highlights the fact that, "A formal body, including federal and provincial government representation, was established to develop and oversee the process of rationalizing size and weight policy based on scientific analysis. The basis for technical input was the Canadian Vehicle Weights and Dimensions Study, which was specifically conducted to provide scientific input. The size and weight study provided an understanding of vehicle infrastructure interaction and produced a set of vehicle performance metrics that were used to specify vehicle configurations that had desirable vehicle dynamic characteristics and could operate within the load capability and geometric constraints of the road network."

The study concluded that "Size and weight regulation needs to be thorough and comprehensive so that the desired outcomes are achieved and undesirable outcomes are prevented. There is a need for monitoring of the fleet as it evolves to ensure that undesirable vehicles are kept in check and that the objectives of the policy can be fully achieved."

"The Canadian experience points to the simultaneous achievements of productivity, safety and environmental effects—aspects that are sometimes viewed as trade-offs."

Studies Using Aggregate Data and Econometric Models

In a literature search conducted for the 2000 CTSW Study, the most relevant modal-diversion study using aggregate data that was identified was performed by Jones, Nix and Schwier (1990).[16] "This study developed two sets of estimates of modal diversion resulting from changes in truck costs per ton-mile for three different potential changes in tax policy. Both sets of results were derived using estimates of the cross-elasticities of railroad revenue and railroad ton-miles relative to changes in truck costs. One set of results was obtained by deriving implicit cross-elasticities from high and low estimates of modal diversion previously provided to the Roads and Transport Association of Canada (RTAC) by the Canadian National (CN) and Canadian Pacific (CP) railways. In that case one set of cross-elasticities was applied to all traffic carried by the CN without regard to commodity, and a second set was applied to all traffic carried by the CP. The second set of results was obtained using elasticities developed by commodity, for 18 commodity groups, by the Association of American Railroads (AAR). The AAR elasticities vary with the size of the change in costs as well as with commodity group. The AAR elasticities produced estimates of revenue diversion that were up to 40 percent higher than did the CN/CP elasticities, and estimates of ton-mile diversion that were about twice as large as those produced by the CN/CP elasticities. The most likely reason for these differences is differences in the original estimates of modal diversion from which the cross-elasticities were derived. Other possible reasons are differences in the character of the road system in the United States and Canada, and differences in the character (commodity value, length of haul, etc.) of the movements in the individual commodity groups in the two countries.

The differences in the two sets of results illustrate an important limitation in the use of this type of analysis — the results are only as good as the cross-elasticities used. A related issue is the degree to which the scenario to be analyzed is similar to the one used in developing the cross-elasticities. In particular, if the cross-elasticities are expressed relative to transport costs (rather than relative to total logistics costs), do both scenarios generate similar changes in non-transport logistics costs for truck transport? (Many size and weight policy changes affect inventory costs, but changes in transport tax policy generally do not.) Also, do both scenarios apply uniformly to all types of hauls, or does one apply primarily to relatively divertible traffic (*e.g.,* medium and long-haul traffic) and the other primarily to less divertible traffic?"

Since the 2000 CTSW Study several studies have used aggregate data to estimate the cross-elasticity of rail traffic with respect to trucking costs. Gerard McCullough of the University of Minnesota updated a study of the intercity freight markets that Ann Friedlaender and Richard Spady (FS) published in the Review of Economics and Statistics in 1980.[17] "The FS Study provided a macro-level perspective on the freight markets by focusing on transportation decisions in key industrial sectors—food, wood products, paper, chemicals, automobiles, and so on. The FS analysis and the current update of that analysis complement the short-run estimates of rail-truck competition levels. The FS analysis is based on a more generalized economic framework in which shippers have the flexibility to choose a range of productive inputs that includes truck and rail freight transportation along with labor, materials and capital. The FS framework thus provides a broader and longer term perspective on the potential effect that changes in TS&W regulations would have on the freight markets.

The diversion effects analyzed in the current study are based on a hypothetical ten percent decrease in trucking costs. This assumption is based in turn on the TS&W cost effects projected by the USDOT in its 2000 CTSW Study. The underlying assumption of the FS analysis is that freight shippers are business firms whose decisions can be modeled using statistical cost analysis. The elements of the cost analysis are industry output levels, freight movements and expenditures, firm levels of capital and materials, labor prices, truck prices, and rail prices. From their cost analysis, FS derive equations which specify how the shares of freight carried by each mode will respond to changes in truck and rail prices and other producer prices as well. The focus of both the FS analysis and the current analysis is on industry sectors where railroads and trucks compete for freight traffic."

The own-price and cross-price elasticities estimated in the study all had the proper sign and all were statistically significant. The report concludes that with a generalized 10 percent reduction in truck rates "the TS&W-related diversion effects ... would be consequential for railroads, shippers and general highway users."

Naleszkiewicz and Tejeda[18] estimate truck to rail diversion using a freight mode choice model and the FAF database. The mode choice model is specified using a binomial logit functional form. The paper discusses the estimation of diversion in a risk adjusted framework which allows the capture of uncertainty associated not only with the diversion estimate but also forecasts of future freight traffic.

The proposition of the study is that rail capital improvement projects have the potential to divert trucks from highways by offering a lower-cost shipping alternative. The method uses a set of diversion filters first based on O-D pairs, followed by commodity filters, and finally distance. The mode choice model uses shipping costs as the primary variable and considers the price/mile and value of time/hour by truck and rail. The risk analysis is performed on the estimates of the logit regression over a range of possible values for the coefficients of the regression, using a distribution that is centered at the mean estimate and whose dispersion is proportional to the standard error of each estimator. This provides a risk-adjusted diversion function that assigns likelihoods to different possible market shares resulting from a given change in cost differentials. In addition, sensitivity analysis to estimate the market shares over a range of dependent and independent variables is useful to evaluate the accuracy and significance of the model estimates and permit the identification of critical variables affecting the market shares of each mode.

Induced Demand

A key issue that has been raised in connection with potential increases in truck size and weight limits is the extent to which such changes might induce additional truck traffic because of lower costs associated with the use of larger, heavier trucks. A working paper was commissioned as part of USDOT's 2000 CTSW Study to examine this issue.[19] Pickrell and Lee of USDOT's Volpe Center stated the issue as follows: "To the extent that truck operators are constrained by regulations to operate differently from what they would choose to do without restrictions, the relaxation of truck size and weight regulations would allow truckers to carry more cargo at less cost. If it is assumed that trucking is a competitive industry, these savings will be passed on to shippers. Lower prices to shippers will induce some additional amount of freight movement, with more impact in the long run as producers and consumers respond directly and indirectly to the relatively lower prices. The question addressed here is how much additional truck freight?"

Pickrell and Lee distinguish two ways in which a reduction in truck freight costs could stimulate an increase in total freight shipments: (1) Changes in the composition of national output. "Prices for goods whose production and distribution costs include a significant trucking cost component would decline, and demand for these goods would increase in response. Producing and distributing the larger volumes of these goods demanded at their reduced prices would require an increase in the use of trucking services." (2) Substitution of trucking for other inputs to production. "Suppliers of goods would attempt to substitute trucking services for non-transportation inputs in their production and distribution processes, further increasing the number of ton-miles carried by truck. This could occur, for example, as suppliers relocate production or warehousing facilities to take advantage of lower shipping rates by distribution networks or even reorganize production processes to substitute transportation for other inputs in response to reduced costs for truck shipping."

For a hypothetical 10 percent reduction in trucking costs, the authors estimated the increase in truck shipping that would result through each of these two channels. The choice of 10 percent was for comparability with the reductions in trucking costs of between 5 and 12 percent that the 2000 CTSW Study estimated for its truck size and weight scenarios. The authors concluded that output compositional effects (the first of the channels identified above) would cause only a slight increase in truck freight, less than 0.3 percent. Although uncertainties about the parameter values underlying this estimate make it rather illustrative, the authors' conclusion appears sound. As the authors explain, trucking costs account for only a small share of production costs for most commodities; among the 48 commodity groups in their calculations, that share is less than 5 percent in all cases, and typically less than 2 percent. Therefore, a 10 percent reduction in trucking costs would produce only very small changes in the relative output prices of these commodities. Regarding the effects of input substitution (the second of the above-identified channels), the authors estimated that they would cause about a 2.5 percent increase in truck freight. However, this estimate is based on a highly conjectural value (0.25) for the elasticity of substitution between trucking and other inputs (a parameter that measures the extent to which these inputs are substitutable).

ITIC Model

The ITIC model is used to evaluate truck-to-truck, rail carload-to-truck, and rail intermodal-to-truck diversion. The model has two modules – one for transportation costs, and one for inventory costs. While the inventory costs are calculated in the same manner for both rail and truck, the costs vary by mode. The transportation cost module is different for truck and rail as the two modes are represented by different datasets.

The ITIC model has been used with the Transearch commodity flow database as well as with county-level FAF data. When used with FAF data, the model takes as its inputs commodity flows by tonnage. Routes by different vehicle classes are determined for each O/D pair by commodity based on routes assumed to be available to each vehicle configuration. Commodity attributes (density, value, handling requirements (dry, temp controlled, bulk, etc.)), equipment type (van, reefer, bulk, etc.), highway network mileages, commodity/equipment-type/configuration load factors and O/D specific truckload volume freight rates by equipment-type/configuration are appended to the FAF flow data. For rail intermodal traffic being tested for diversion, rail line-haul and rail dray distance for costing freight rate of rail move is appended and the transportation costs for base and scenario cases are calculated.

The results of this analysis is fed into ITIC including annual commodity volume, handling requirements, shipment weight, base and scenario line-haul charges, dray charge (for rail intermodal), and line-haul and dray (for rail intermodal) miles.

The documentation of the ITIC model acknowledges that the model captures service quality considerations only in a "general way" and this is an artifact of the underlying data. Since detailed data is not available or is very difficult to get at the national scale, it is necessary to categorize the commodities more broadly. For example, "food and kindred products" would have included both canned goods and highly perishable goods. Service quality considerations present similar challenges for modeling choices of transportation mode. Choices between trucking and rail freight services (or rail combined with road) generally present a tradeoff between price and service quality. Rail freight is generally cheaper, but trucking has advantages in flexibility and speed, and often in reliability. It is difficult to quantify the service levels provided by each mode and the values that shippers assign to each service attribute.

Analysis of long-haul shipments The assumption in the ITIC model is that the shipper chooses the transportation alternative that minimizes the sum of transportation and non-transportation logistics costs. The model adopts the conventional categorization of inventory costs as safety stock, cycle costs, and in-transit costs. For the calculation of safety stock, the model includes parameter values that measure the reliability of lead time for delivery. These values indicate lower reliability for rail carload than for other shipment options.

The ITIC model specifies that the amount of cycle inventory increases proportionally with the payload of the freight-moving unit. This means, for example, when a shipper switches to a truck with 20 percent more payload than a truck used previously, the amount of cycle inventory increases by 20 percent.

The scenario analyses assume that the total volume of freight that is shipped is fixed and does not attempt to estimate whether reductions in transportation costs would affect the total volume of freight shipped. As noted above, a brief study conducted by the Volpe Center for the 2000 CTSW Study concluded that any induced increase in truck freight traffic caused by reductions in shipping costs would be small enough to ignore without much loss of realism.

Analysis of short-haul shipments For short-haul shipments, the study notes that rail generally is not competitive with truck and considers only truck-to-truck substitution. For single unit trucks, substitution between three and four-axle trucks is a function of the change in their relative operating costs (induced by changes in TS&W limits). Short-haul combination trucks are assumed to have diversion that mirrors the diversion of long-haul combination trucks.

GAO Analysis of ITIC Model

The Government Accountability Office (GAO) evaluated the ITIC-IM model developed by the Federal Railroad Administration (FRA) as part of their evaluation of intercity passenger and freight rail. To determine whether the available data and model assumptions were reliable for the purposes of the study, the GAO evaluated the ITIC-IM model input data for their relevance, completeness, accuracy, validity, and consistency. The GAO found that of the 26 variables used as input into the ITIC-IM model, empirical data were available for nine of the inputs.

SUMMARY OF MODE CHOICE METHODS AND PAST STUDIES

This section summarizes findings of the literature review of modal shift models and databases that might be applicable to the current CTSW Study. Many studies have examined the issue of freight mode choice using a variety of data and methods. The choice of data and methods in various studies typically is guided by the resources available for the study, the study scope and objectives, and other factors unique to each study. Thus in evaluating potential data and methods for the current CTSW Study, it is important to consider the unique requirements of this CTSW Study. Resources available for this study are greater than for most academic studies and State or regional studies. Along with the significant resources available for this CTSW Study comes an expectation that key issues will be examined rigorously and that the best, most reliable data will be used to analyze potential impacts of allowing various types of new configurations to use different parts of the highway system. **Table 2** compares different general approaches to conducting modal shift studies that have been used in past studies. Study methods can be broken down into three general methodologies – (1) those that estimate modal choice for individual shipments based on characteristics of those shipments, and costs associated with moving shipments by the various modes between various origins and destinations; (2) studies that rely on expert opinions of shippers and carriers concerning the likelihood of shipments of various commodities traveling different distances under a variety of operating conditions and restrictions shifting to alternative modes; and (3) aggregate methods that estimate cross-elasticities of demand for one made based on changes in price and other characteristics of shipments by another mode.

Most recent large scale studies have used disaggregate analyses of individual shipments, although several recent State studies have relied primarily on expert opinions of shippers and carriers. Most studies using disaggregate methods have used actual data, but some like the study by Martland used synthetic data in lieu of actual data. Actual data is preferred when resources permit since they are less likely to be challenged as being representative. This is especially true for studies such as the current CTSW Study when complex relationships involving different vehicle classes operating on different highway networks in different parts of the country are being analyzed.

Table 3 summarizes key freight mode choice studies in terms of their geographic scope, the modes considered in the study, the data used in the mode choice analysis, and the general methodology used to estimate mode choice. The methodologies correspond to those included in **Table 2**. Most national studies have used disaggregate total logistics cost models for at least part of the study, the exception being the academic study by McCullough which used econometric methods to estimate cross-elasticities of demand for one rail based on an assumed change in trucking rates. Recent State truck size and weight studies have tended to rely on expert opinion supplemented by sensitivity analysis.

Table 2. Assessment of Alternative Modal Shift Methodologies and Data		
	Advantages	**Disadvantages**
Disaggregate data and model	•Easier to understand than econometric models	•Very data intensive, especially if disaggregate universe data is used
Actual data	•Better representation of actual freight movements than synthetic data	•Since studies using actual data generally use more observations than those using synthetic data, data requirements are greater. •Actual data may not be available for all variables, especially if data must be publicly available
Disaggregate data	•Provides best representation of movements by all modes between all O-Ds •Allows differences between regions and vehicle configurations to be more accurately represented than with aggregate data that cannot capture important differences among networks, vehicle configurations, and geographic areas.	•Most data intensive •Highly disaggregated data not always publicly available •Use of data that is not publicly available may be criticized if source of those data is questionable or potentially biased •May require estimation if source data are not collected or reported at desired level of disaggregation
Aggregate data	•More likely to be publicly available than highly disaggregate data •Not as data intensive as disaggregate data •Still reflects all movements by all modes	•May not allow all scenarios to be adequately analyzed since it may not reflect real cost differences of using different modes and vehicle configurations •May not allow impacts on different networks to be adequately assessed •Requires more assumptions about which configurations can be used and what the cost of using those configurations will be. This may lead to criticisms by those unhappy with results
Estimated data	•Substitute for data that is not publicly	•Estimates may be subject to criticism

Table 2. Assessment of Alternative Modal Shift Methodologies and Data		
	Advantages	**Disadvantages**
	available. •Reduces cost of collecting some data items •Sensitivity analysis can indicate degree to which results may vary if estimates do not reflect reality	•Some basis is required to make estimates. In some cases there may not be a good basis for estimates.
Synthetic data	•Least data intensive than other methods •May be used to quickly assess general directions of impacts and perhaps relative order of magnitude	•As with estimated data, some basis is required for developing synthetic data •Results likely subject to greater criticism than other methods because they are not based on actual data •Difficult to capture all factors that affect modal choice
Expert opinion	• Captures factors affecting shipper/carrier decision making that are difficult to reflect in a quantitative model •Does not require as much data as more quantitative methods •May be less costly and quicker method than quantitative model development •Opinions good for identifying most important factors affecting decisions	•Opinions may vary depending on who is interviewed •Actual responses to policy change may be different from ex ante anticipated responses •Opinions may be biased by local conditions and may not reflect responses in other markets •Opinions generally do not provide good evidence of the magnitude of responses to various options
Aggregate econometric model	•Allows relationships revealed in one area to be estimated in other areas without extensive data collection	•Mathematical models not as easily understood by general public as other methods •Subject to statistical issues such as multicollinearity making it difficult to isolate impact of individual factors affecting mode choice

Table 2. Assessment of Alternative Modal Shift Methodologies and Data		
	Advantages	**Disadvantages**
		•Difficult to reflect impacts of allowing different vehicles on different highway systems •Difficult to reflect complexity of mode choice decisions for individual commodities and markets •More amenable to analyzing binary choice between truck and rail than to estimating choice among multiple truck configurations •Difficult to use elasticities from other studies because elasticities vary by commodity, corridor, and by costs upon which they are estimated.

Table 3. Selected Freight Modal Shift Studies

Study	Scope		Principal Data Sources	Modal Shift Analysis Method
	Geographic	Modes		
2000 CTSW Study	National	Truck, Heavy Truck, Rail	AAR truck data, rail weighbill	T-R/R-T disaggregate total logistics cost model
Oak Ridge National Laboratory, 1994	National	Truck, Heavy Truck, Rail	Survey of firms in different industries; Truck Inventory and Use Survey	Freight Transportation Analyzer disaggregate total logistics cost model
TRB 225, 1990	National	Truck, Heavy Truck, Rail	Forecasts of truck traffic, AAR	Expert opinion, disaggregate total logistics cost
McCullough, 2013	National	Truck, Rail	Aggregate industry costs	Econometric estimation of cross-elasticities
Western Uniformity Scenario, 2004	Regional	Truck, Heavy Truck, Rail	FAF, rail weighbill	ITIC disaggregate total logistics cost
Minnesota TSW Study, 2006	State	Truck, Heavy Truck	State VMT, weight distributions	Expert opinion, sensitivity analysis
Wisconsin TSW Study, 2009	State	Truck, Heavy Truck	State VMT, weight distributions	Expert opinion, sensitivity analysis
Montana	State	Truck, Heavy Truck, Rail	State VMT, weight distributions	Expert opinion, results from previous studies
Virginia	Corridor	Truck, Rail	State VMT data	Cross-elasticities from past studies
Virginia	Corridor	Truck, Rail	Transearch	ITIC disaggregate total logistics cost model
Texas LCV Study, 2011	Corridor	Truck, Heavy Truck	State VMT, weight distributions	Expert opinion

Several critical decisions must be made regarding the modal shift analysis for the current truck size and weight study. These include:

- the method (and specific model if applicable) to be used to estimate shifts among vehicle configurations and different modes as the result of the truck size and weight scenarios
- the source and level of disaggregation of data that will be needed to support analyses using the selected analytical tool
- the extent to which all data must be publicly available

Each of these factors is discussed below including tradeoffs associated with certain decisions.

Modal shift methodology

As shown in **Table 2**, there are three basic methods that have been used in recent studies examining potential modal shifts associated with changes in truck size and weight policy

- Disaggregate total logistics cost models
- Expert opinion, often accompanied by sensitivity analysis
- Aggregate econometric methods based on estimates of the cross-elasticity of demand for one mode based on changes in price or service characteristics of another mode.

Recent large-scale Federal studies have all used disaggregate total logistics cost models for at least part of the analysis. Several recent State studies have used expert opinion coupled with sensitivity analysis. Only a very few studies have based their estimates of mode choice on estimates of cross-elasticities of demand between two modes.

A review of the literature indicates that there is no single cross-elasticity that can be used to reflect competitive relationships across modes for the movement of different commodities in different markets. The primary use of cross-elasticities has been to estimate potential truck to rail or rail to truck shifts resulting from some price or service change. In general, those studies that have used cross-elasticities have been interested only in general estimates of the overall impact on one mode associated with changes in another mode. They have not been interested in mechanisms by which those changes occur or differentiating impacts on different parts of the industry. No examples were found where cross-elasticities were used to estimate potential shifts among different truck configurations as the result of size and weight policy changes. Nor is there data upon which to adequately estimate cross-elasticities between modes based on different network availabilities. Based on these findings, it does not appear feasible to use cross-elasticities derived from aggregate econometric analysis to satisfy the requirements of the CTSW Study.

Recent State studies that have relied upon expert opinions of shippers and carriers to estimate changes in mode choice associated with truck size and weight policy changes have generally been focused on a narrower range of issues than the current truck size and weight study. Expert opinion is valuable when opinions are based on a clear understanding of the factors that will affect mode choice decisions, but the more complex the decisions, the harder it is for experts to reliably anticipate the overall response to policy changes. Most recent State studies have been primarily concerned about potential impacts of allowing heavier tractor-semitrailers to operate. Network limitations have been easily defined and it has been relatively easy to identify the universe of shipments that might divert to vehicles with higher gross vehicle weight limits. A nationwide study that includes both larger, heavier trucks as well as rail and potentially water modes is more complex than the State studies that have relied on expert opinion. The impact of network limitations on certain vehicle configurations would be difficult for many experts to estimate and tradeoffs between rail and longer combination vehicles are not always clear. Perhaps the greatest drawback to the use of expert opinion for the current study, however, is the lack of objective criteria upon which modal shift estimates are made. Not everyone will agree who is an expert and even experts could be expected to disagree on the potential use of different configurations based on different individual assumptions about how they would operate. The lack of objective criteria for modal shift decisions could adversely affect the credibility of the study.

While there certainly are known weaknesses with existing disaggregate total logistics cost models, they do offer an objective basis upon which to estimate the changes in transportation and non-transportation logistics costs to move different commodities between different origins and destinations resulting from changes in truck size and weight limits. Existing models such as ITIC are transparent and have been used in enough different types of application to have some confidence in their use.

Conclusion: There are several reasons for using the ITIC model for the current CTSW Study. First, it is a model that was developed by the Department and it has been used by both FHWA and FRA. Second, the ITIC model has undergone recent updates that should reduce the time it takes to get the model up and running. There are several versions of ITIC and some time will be required to compare the various versions to identify/develop a version that meets the specific requirements of the study, but this should not take long. On the other hand, developing an entirely new logistics model or trying to modify an existing model with which the team is unfamiliar would appear to be infeasible given the short time for completing the CTSW Study. Based on these factors, it is recommended that the ITIC model be used as the basis for estimating modal shifts for long haul freight traffic. While it has not been used in previous studies to estimate modal shifts of short haul and LTL traffic, the structure of ITIC is flexible enough to analyze those types of traffic as well.

DATA SOURCES

The analysis of potential modal shifts associated with truck size and weight policy changes is only as good as the data upon which it is based. As noted above, having good data on both the commodities being moved and the origins and destinations of commodity movements by different modes is essential to assessing which moves might shift to alternative modes and truck configurations. A review of commodity flow databases was conducted as part of the National Cooperative Freight Research Program (NCFRP) 20 Study, Developing Subnational Commodity Flow Data[20].

For the purpose of this study, two data products are of primary interest: A multi-dimensional commodity flow matrix, the principal dimensions of which are the volumes of freight moving between various origins and destinations by mode and type of commodity; and a series of network routings showing how freight vehicles move over the nation's freight transportation network (highways, railways, waterways,)

Several commodity flow databases potentially could be used for the CTSW Study. The two principal databases that have been used in national, state, and regional freight studies are the Freight Analysis Framework (FAF3) developed by FHWA and Transearch developed by IHS Global Insight. An earlier version of the FAF was used in the USDOT's USDOT's Western Uniformity Scenario analysis, and FAF has been used in numerous other freight planning and analysis studies as well. The Transearch database can be obtained at finer levels of geography than the FAF which to date has been made available only at a regional level. An important consideration for the use of the Transearch database for the CTSW Study would be the high cost of obtaining the nationwide Transearch database for others who might wish to replicate results of the study. Other national commodity flow databases include the Commodity Flow Survey (CFS) and the Surface Transportation Board's (STB) Waybill sample, both of which are used in developing the FAF and the Transearch databases.

Freight Analysis Framework (FAF) Data The FAF, available from FHWA, integrates data from a variety of sources to estimate commodity flows and related freight transportation activity among states, regions, and major international gateways. The original version, FAF1, provides estimates for 1998 and forecasts for 2010 and 2020. FAF2, provided estimates for 2002 plus forecasts through 2035. The latest version of the FAF, FAF3, is based on the 2007 Commodity Flow Survey (CFS) and provides estimates for 2007, plus forecasts through 2040. FAF3 has a number of improvements to the commodity flow matrix over previous versions including:

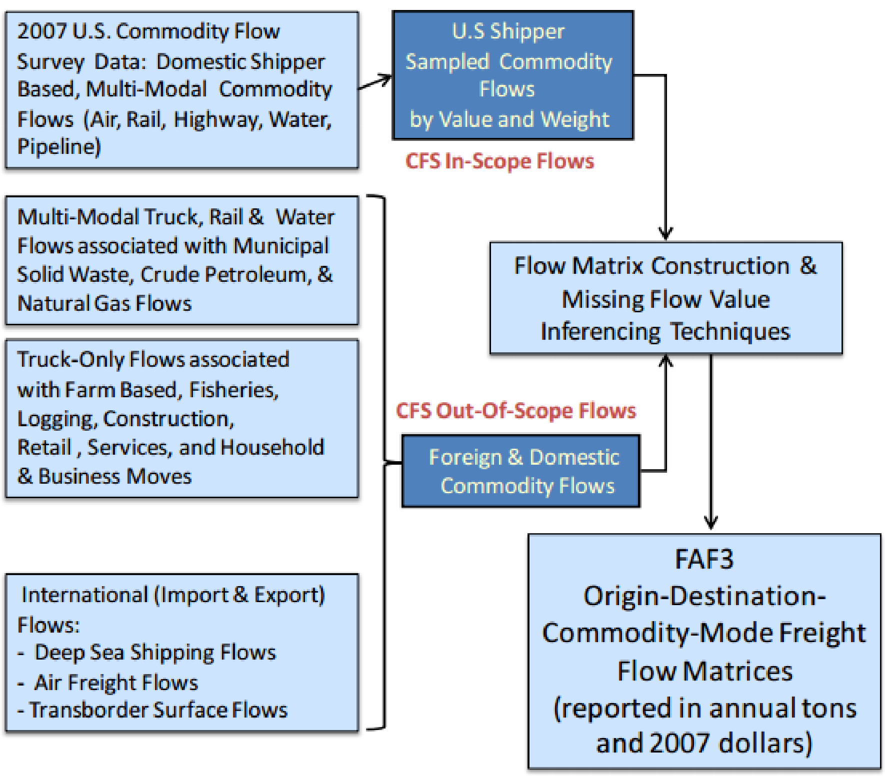
- A roughly doubling of the number of U.S. shipping establishments sampled as part of the 2007 U.S. Commodity Flow Survey (from some 50,000 establishments in 2002, to approximately 100,000 establishments surveyed in 2007);
- The use of PIERS data to support improved allocations of imports and exports to FAF domestic zones of freight origination (for U.S. exports) and destinations (for U.S. imports);
- Incorporation of additional federal datasets within an improved FAF3 log-linear modeling/iterative proportional fitting algorithm, as well as the development of estimates of flows for commodities that were out-of-scope for the CFS;

- Greater use of U.S. inter-industry input-output coefficients in estimating commodity flows that were out-of-scope for the 2007 CFS; and
- FAF3 provides an O-D specific treatment of natural gas products, which were evaluated only at the level of national or broad regional activity totals in FAF2 (USDOT FHWA 2010, p. 3).

Figure 4 shows the FAF3 freight flow matrix construction process. The process for developing FAF3, including how estimates were made where data on particular types of shipments were not available, is described in detail by Oak Ridge National Laboratory.[21] This provides an understanding of strengths and potential weaknesses of the FAF3.

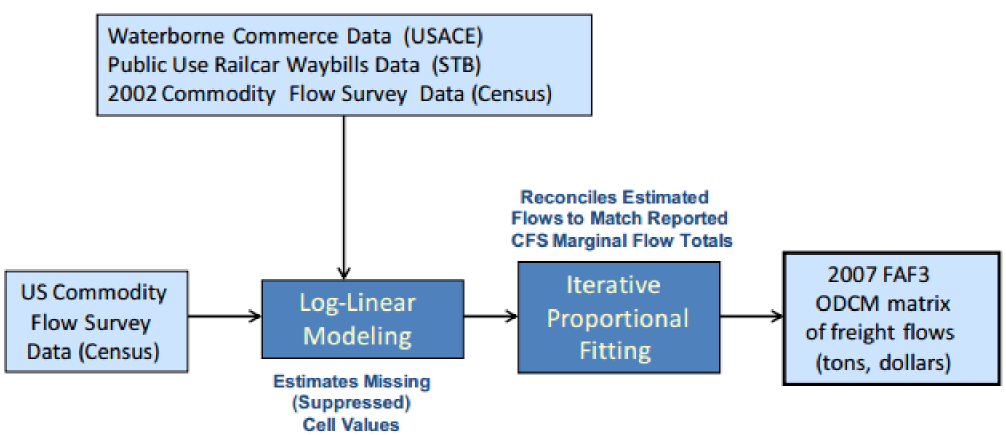
The matrix construction begins with the data from the 2007 CFS, and uses the same geographic (123 domestic U.S. FAF zones) and commodity (43 Standard Classification of Transported Goods (SCTG) definitions as the CFS but uses a modified version of the CFS modal definitions (USDOT FHWA 2010, p. 7).

Figure 4. Overview of the FAF3 Freight Flow Matrix Construction Process (USDOT FHWA 2010, p. 7)



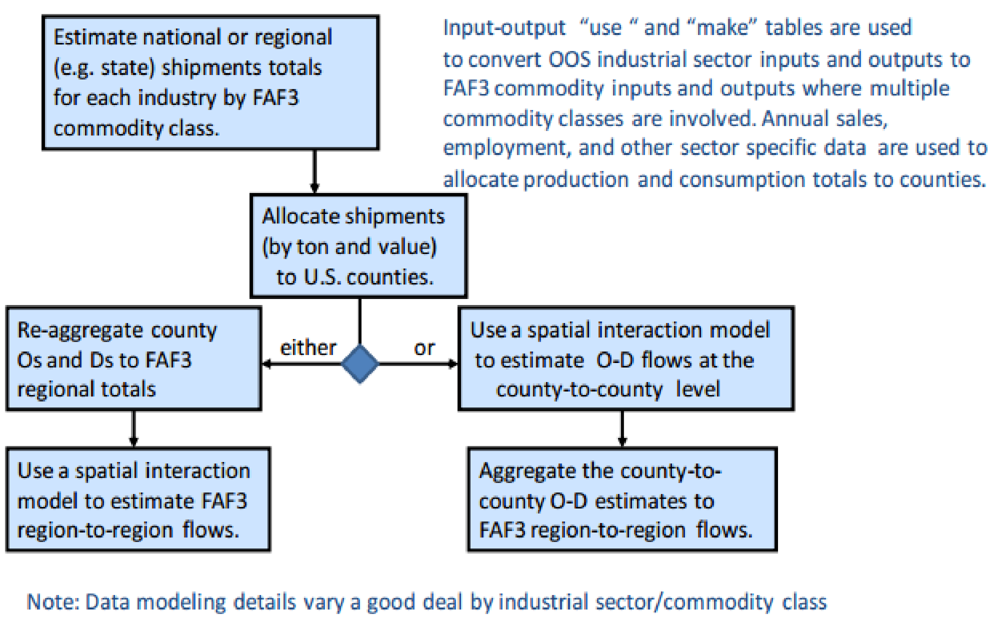
The CFS represents the best basis for FAF construction because it provides shipper sampled, and subsequently expanded estimates of both tons shipped and dollar value trades within and between all US regions for all modes of freight transportation. However, the CFS has a number of well researched weaknesses that require considerable additional effort in order to construct a complete accounting of freight movements within the United States (see TRB, 2006). First, the CFS does not collect secondary moves, *e.g.*, public warehousing where public means a for-hire service and not an auxiliary establishment of a manufacturer. Second, the CFS does not report imports, and CFS reporting of export flows is also subject to data quality issues resulting from limited sample size. Finally, the CFS either does not collect data from the following freight generating and receiving industries, or collects insufficient data to cover the industries in a comprehensive manner: Truck, rail and pipeline flows of crude petroleum, and natural gas; Truck shipments associated with farm-based, fishery, logging, construction, retail, services, municipal solid waste, and household and business moves; and Imported and exported goods transported by ship, air, and trans-border land (truck, rail) modes. In FAF3 these industries produce what are referred to in **Figure 4** as Non-CFS or Out-Of-Scope (OOS) to the CFS freight flows. Their estimation requires a good deal of data collection and integration into the larger flow matrix generation process. These OOS flows represent some 32% of all U.S. freight movements measured on an annual tonnage basis. In addition to the OOS movements noted above, suppression of some in-scope flows is also an issue if there are insufficient CFS observations across mode, commodity, or origin and destination to protect confidentiality. The FHWA used a combination of log-linear modeling and Iterative Proportional Fitting (IPF) techniques to fill missing cell values, supplementing the CFS with data from the Surface Transportation Board (STB) Public Use Railcar Waybill data and US Army Corp of Engineers (USACE) Waterborne Commerce Data. **Figure 5** gives an overview of the process to estimate the missing cell values in the 2007 CFS.

Figure 5. Estimation of Missing Cell Values in the 2007 CFS (USDOT FHWA 2010, p. 10)



OOS flows were estimated using commodity specific datasets and different computational methods for each industrial class. Methods varied depending on whether flows were domestic or import/export. Where an industrial sector produces O-D flows in more than one commodity class, data from national inter-industry input-output tables were used to estimate how much freight each sector contributes to a specific set of SCTG 2-digit commodity flows. State and county level data on volume of production, industrial or commodity specific sector sales, or industrial sector employment is then used to allocate flows between origins and destinations. Spatial allocation formulas are then used to produce O-D flow volumes. Where truck movements were concerned this occurred in one of two ways. One way was to determine county level origin and destination activity totals and then apply a spatial interaction model to these county productions and attractions, with subsequent aggregation of inter-county flows back up to FAF3 region-to-region flow totals. The second way was to estimate origins and destinations of commodities at the FAF3 regional level and then estimate flow between each of the FAF3 regions. The specific form of spatial interaction model used also varied by commodity class. Either a distance decay coefficient was calibrated against an empirically derived average shipping distance, or a simple allocation was made based on market potentials (*i.e.*, on the relative size of a county's or region's demand for a specific commodity). County-level spatial interaction modeling here allows for cross-county flows to be captured that are also cross-FAF3 adjacent regional flows. Use of regional O and D shipment totals prior to spatial interaction modeling occurred where data sources proved more reliable at this less detailed level or geography. **Figure 6** shows the process for generating the OOS truck freight flows.

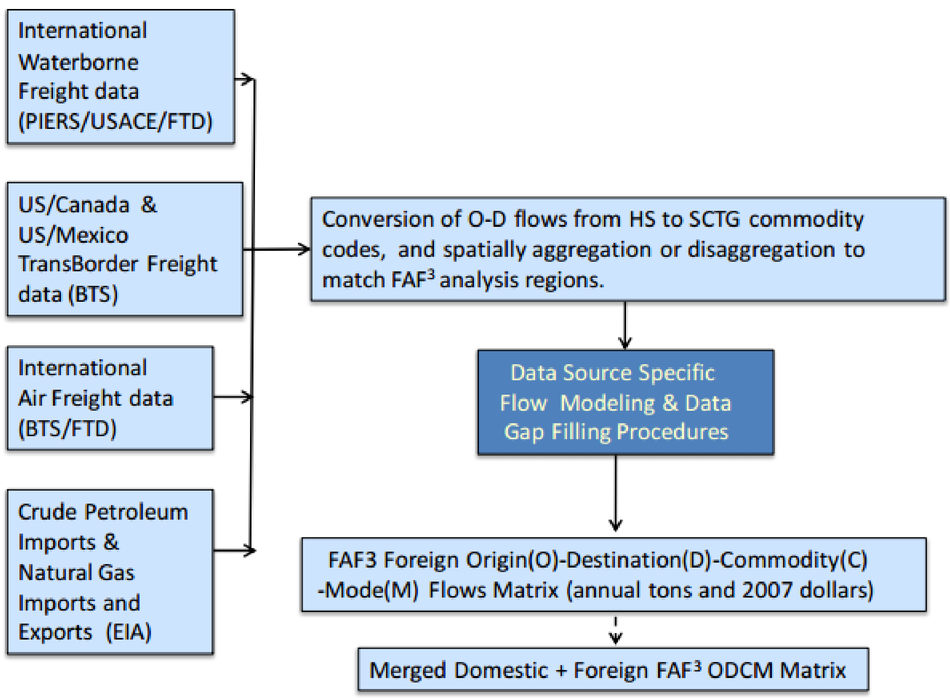
Figure 6. Process for Generating OOS Truck Freight Flows (USDOT FHWA 2010, p. 14)



Import and export freight flows in FAF3 are constructed from a variety of data sources, each of which has their own unique coding system and needs to be converted into FAF3's 2-digit SCTG codes, as well as have its flows either spatially aggregated or disaggregated to FAF3 analysis zones. **Figure 7** provides an overview of the FAF3 international data modeling. As shown in the figure, datasets from multiple private and public agencies such as the Bureau of Transportation

Statistics (BTS), USACE, Energy Information Administration (EIA), US Census Bureau's Foreign Trade Division (FTD), Port Import Export Reporting Service (PIERS), etc., are used to construct FAF3's import-export freight flows.

Figure 7. FAF3 International Data Modeling ((USDOT FHWA 2010, p. 22)



Use of FAF in the Western LCV Uniformity Scenario. For FHWA's Western LCV Uniformity Scenario, a version of FAF having county-to-county flows was developed that allowed detailed assessments of the potential shift to LCVs based on the networks that would be available to those vehicles and the extent to which those networks served various shipment origins and destinations at the county level. The current release of FAF (version 3) has data available only at the FAF region level. If the modal diversion analysis were performed at this level of detail, it would be impossible to directly consider network limitations for some LCVs when estimating potential diversion of traffic to those configurations since virtually all FAF regions are served by all highway systems. In the Western LCV Uniformity Scenario analysis, the limited networks assumed to be available to various types of LCVs significantly affected estimates of overall diversion and the configurations to which shipments were diverted. To understand the effects of network limitations on some vehicle configurations, greater geographic disaggregation of freight flows is required than the current version of FAF provides.

While disaggregating the FAF to a county level enhances the analysis of potential truck size and weight policy options by allowing impacts of limiting certain vehicle configurations to particular highway networks to be assessed, it is important to recognize that uncertainties exist in the disaggregation process. The greatest uncertainty is in the exact quantity of particular commodities shipped into or out of individual counties within each FAF region. Various measures of industrial activity are available at the county level, but associating exact quantities of commodities demanded or supplied with different levels of industrial activity is imprecise. That is one reason why FHWA does not provide county level data to State and local governments – while the data may be good enough for national level policy analysis, they may not be good enough by themselves for more detailed freight planning studies at the State or regional level. Depending on the purpose and scope of such freight planning studies, State and local agencies may purchase more detailed data from third-party suppliers or they may do special studies themselves to produce more accurate estimates of the commodity flows than could be produced simply by allocating regional totals on the basis of general measures of economic activity. Much greater precision is required for State and local planning studies that could lead to investment decisions than for national-level policy analyses.

IHS Global Insight Transearch

Transearch is a privately maintained comprehensive market research database for intercity freight traffic flows compiled by IHS Global Insight. The development of the Transearch database involves the fusion of various freight traffic data sources into a common framework for planning and analysis. The database provides detailed U.S. and cross-border origin-destination freight shipment data at the state, Bureau of Economic Analysis (BEA), county, metropolitan area, and zip-code level detail by commodity type (by Standard Transportation Commodity Classification (STCC) code) and major modes of transportation. Forecasts of commodity flows up to 30 years in the future are available for the following four modes – air, truck, water, and rail.

The data is compiled from the following sources: Commodity Flow Survey (CFS); Carload Waybill Sample; USACE Waterborne Commerce Statistics; Federal Aviation Authority (FAA) Airport Activity Statistics; Bureau of Census FTD; American Association of Railroads (AAR) Freight Commodity Statistics; and Inter-industry trade patterns. Transearch uses CFS data for the following: (TRB 2006, p.131)

- To calculate commodity $/ton values. The $/ton values maintained for Transearch production are updated annually for the intervening non-CFS years using inflation-based factors derived from sources such as the Producer Price Index;
- To calculate for-hire/private trucking mode share splits; To develop OD truck flows;
- To develop truck length-of-haul profiles;
- Identification of commodities moving via air mode; and
- Quality control.

Transearch has some limitations on how this data should be used and interpreted:
Mode Limitations – The Rail Waybill data used in Transearch is based on data collected by rail carriers terminating 4,500 cars or more annually. The waybill data contains some information for regional and short-line railroads, but only in regards to interline service associated with a Class I railroad. The rail tonnage movements provided by the Transearch database, therefore, represent only a portion of total rail shipments. Another issue with the rail waybill interlined shipments is that participating carriers may be billed for only their portion of the move, distorting the actual freight movements in the database.

Use of Multiple Data Sources – Transearch consists of a national database built from company-specific data and other available databases. To customize the dataset for a given region and project, local and regional data sources are often incorporated.

Data Collection and Reporting – The level of detail provided from some specific companies when reporting their freight shipment activities limits the accuracy of Transearch. If a shipper moves a shipment intermodally, for example, one mode must be identified as the primary method of movement. Suppose three companies make shipments from the Midwest U.S. to Europe using rail to New York then water to Europe. One company may report the shipment as simply a rail move from the Midwest to New York; another may report it as a water move from New York to Europe; the third may report the shipment as an intermodal move from the Midwest to Europe with rail as the primary mode. The various ways in which companies report their freight shipments can limit the accuracy of Transearch due to the reporting of unlinked trips

Limitations of International Movements – Transearch does not report international air shipments through the regional gateways. Additionally, specific origin and destination information is not available for overseas waterborne traffic through marine ports. Overseas ports are not identified and Transearch estimates the domestic distribution of maritime imports and exports. Transearch data also does not completely report international petroleum and oil imports through marine ports.

Transearch's county-to-county market detail is developed through the use of Global Insights' Motor Carrier Data Exchange inputs and Global Insights' Freight Locator database of shipping establishments. Freight Locator provides information about the specific location of manufacturing facilities, along with measures of facility size (both in terms of employment and annual sales) and a description of the products produced. This information is aggregated to the county level and used in allocating production among counties. Much of the Motor Carrier Data Exchange inputs from the trucking industry are provided by zip code. The zip code information is translated to counties and used to further refine production patterns. A compilation of county-to-county flows and a summary of terminating freight activity are used to develop destination assignments.

Transearch is widely used for State and local freight planning purposes. It also can be used in conjunction with the TREDIS modeling system developed by EDGR to assess economic impacts of various changes in freight transportation service and performance. TREDIS, however, is not a logistics-based model and would not be able to estimate mode choice decisions based on changes in truck size and weight limits.

2.3 Commodity Flow Survey The Commodity Flow Survey (CFS) produces data on the movement of goods in the United States and provides information on commodities shipped, their value, weight, and mode of transportation as well as the origin and destination of shipments of commodities from manufacturing, mining, wholesale, and select retail and service establishments. The CFS covers business establishments with paid employees that are located in the United States and are classified by the North American Industry Classification System (NAICS) in mining, manufacturing, wholesale trade, and selected retail and service trade industries. The survey does not cover establishments classified in transportation, construction, and most retail and service industries. Farms, fisheries, foreign establishments, and most government-owned establishments are also excluded. The CFS captures shipments originating from select types of business establishments located in the U.S., except for Puerto Rico and other U.S. possessions and territories. Shipments traversing the United States from a foreign location to another foreign location are not included, nor are shipments from a foreign location to a U.S. location. However, imported products are included in the CFS at the point that they leave the importer's initial domestic location for shipment to another location. Shipments that are shipped through a foreign territory with both the origin and destination in the U.S. are included in the CFS data. The CFS data is one of the main building blocks of both FAF and Transearch, but by itself is not suitable for modal diversion analysis.

2.4 STB Public Use Waybill Data The Public Use Waybill Sample (PUWS) is a non-proprietary version of the STB Carload Waybill Sample. The STB requires that all U.S. railroads that terminate more than 4,500 revenue carloads submit a yearly sample of terminated waybills. The waybills are sampled under two different plans, depending on the number of carloads on the waybill and weighted using appropriate multipliers for each sampling level, which are not disclosed, to represent total U.S. rail movements in that year. Use of the waybill data is subject to some qualifications. As with any sample, some portions of the total population are better represented than others. Since the full Carload Waybill Sample contains specific waybill information such as origin and termination freight station, junction points, and rail carrier identification, it is not suitable for public release. As an alternative, the Public Use Waybill Sample has been created from the original full sample by eliminating station and carrier information. Origin and termination points are reported by BEA area and junction points are reported by state or province, rather than by freight station or city name. Additionally, some waybill records are excluded from the PUWS. The PUWS only contains rail freight movements for commodities handled by at least three freight stations in the U.S. If a 5-digit commodity was not handled by at least three Freight Station Accounting Codes (FSACs) nationwide, the record is rejected for the PUWS. Commodities (with the exception of munitions data) are identified at the 5-digit STCC level. Because of the sensitive nature of the munitions data, this information is reported at the 2-digit STCC level (STCC 19) and no geographic coding for these records is included. The use of BEA economic areas in the PUWS is subject to the "three-FSAC rule". This rule was adopted to protect against any disclosure of competitively sensitive waybill data in the Public Use file. Under this approach, a BEA economic area is only reported if there is activity for at least three FSACs on one railroad for a given commodity within that BEA, or if there are at least two more FSACs with activity than there are railroads in that BEA economic area for a given commodity. Records that do not pass the three FSAC rule are still included, but without any geographic coding. Intermediate junction data is shown only when both the originating and the terminating BEAs pass these criteria. Only about 45 to 50% of the total waybill records have full geographic data.

Networks

The FAF2 geospatial network coverage was used as the basis for updating the FAF3 network. It represents more than 447,400 miles of the nation's highways comprised of Rural Arterials, Urban Principal Arterials, and all National Highway System (NHS) routes. The following roadways are included:

- Interstate highways;
- Other FHWA designated NHS routes;
- National Network (NN) routes that are not part of NHS;
- Other rural and urban principal arterials;
- Intermodal connectors;
- Rural minor arterials for those counties that are not served by either NN or NHS routes; and
- Urban bypass and streets as appropriate for network connectivity.

Updates from the FAF2 to the FAF3 network include:

- Updates to NHS designation and intermodal revisions current to version 2009.11 releases;
- Additions or updates to urban bypass or other state specific highway alignment; and
- Integration and updating of NN and LCV designations, state link specific truck restrictions, clearances, and hazmat route restrictions.

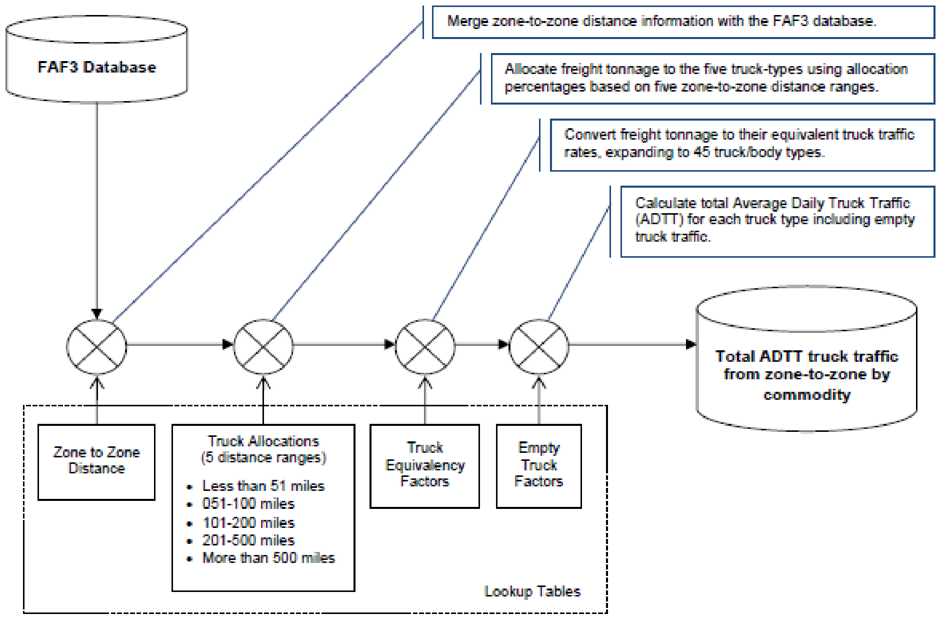
FAF3 Network and HPMS 2008 Data Integration Process

The 2008 HPMS database was selected for the 2007 network update to ensure base year information consistency. Typically each HPMS current year release (*e.g.*, 2008) is based on the last year (*e.g.*, 2007) state reported roadway inventory database. The link specific information was then further processed to minimize the attribute discrepancy at the state/or urban boundary and at other locations where link specific data gaps exist. For missing and non-sampled links, truck traffic percentages were updated using a combination of state specific functional class averages and/or correlations with adjacent link truck percentages. The 2040 values for average traffic volume and truck traffic were estimated using the state growth factor reported in the HPMS 2008 database and projected to 2040 using a linear growth algorithm.

The HPMS and NHS data sources both provide Linear Referencing System (LRS) information. However, due to changes in the submittal criteria, the two data sources have not maintained a common format that would allow direct relating of their respective data. To overcome this issue, HPMS and NHS data are related using algorithms, as necessary, for primary and secondary signage, mileposts, and translated LRS identifiers.

The FAF3 network has information on each link's truck restrictions, and the types of trucks and LCVs that are allowed on the network. The FAF3 data do not provide an estimation of the Average Daily Truck Traffic (ADTT) used to move freight between the shipping zones. The work flow diagram shown in **Figure 8** illustrates a general overview of the process of estimating the AADT. The primary source of information for developing the procedures for converting commodity flows in tons to truck trips was the 2002 Vehicle Inventory and Use Survey (VIUS) database. The VIUS provides national and state-level estimates of the total number of trucks by truck type.

Figure 8. Truck Conversion Flow Diagram (ORNL, FAF3 Freight Traffic Analysis, p. 3-2)



There are five groups of truck configurations, ranging from single unit trucks to tractor plus triple trailer combinations, nine types of truck body types, such as Dry Van, Flat Bed, and Tank. The allocation of FAF3 O-D tonnage for each truck configuration and body type was carried out for each commodity the truck carried. The conversion of commodity flows from tons to trucks is done in the following steps. The first step involves identifying the primary truck configurations (Single Unit Trucks, Truck plus Trailer Combinations, Tractor plus Semitrailer Combinations, Tractor plus Double Trailer Combinations, and Tractor plus Triple Trailer Combinations) and major truck body types (Dry Van, Flat Bed, Bulk, Reefer, Tank, Logging, Livestock, Automobile, and Other). This is followed by allocation of commodities to truck configurations used to transport these commodities. Following this, the average payload by vehicle group and body type is estimated and converted into the equivalent number of trucks. Finally, the percent of empty truck trips is calculated.

Impacts of Modal Diversion

The CTSW Study will analyze a number of potential impacts associated with modal shifts of freight traffic resulting from changes in truck size and weight limits. Critical safety, pavement, and bridge impacts are analyzed in separate parts of the CTSW Study; impacts on energy consumption, environment, and traffic operations are analyzed in this this section.

Energy and Environment

In 2007, heavy duty trucks (defined by EPA as on-highway vehicles with a GVW greater than 8,500 lb. and which are not Medium-Duty Passenger Vehicles) carried 71 percent of all freight moved in the U.S. by tonnage and 87 percent by value. Heavy-duty trucks are the largest source of Greenhouse Gases (GHG) in the transportation sector after light-duty vehicles and the total GHG emissions from this sector increased over 72 percent from 1990 to 2008. Current diesel engines are 35-38 percent efficient over a range of operating conditions with peak efficiency levels between 40 and 45 percent depending on engine sizes and applications, while gasoline engines are approximately 30 percent efficient overall. This means that approximately one-third of the fuel's chemical energy is converted to useful work and two-thirds is lost to friction, gas exchange, and waste heat in the coolant and exhaust. Trucks use this work delivered by the engine to overcome overall vehicle-related losses such as aerodynamic drag, tire rolling resistance, friction in the vehicle driveline, and to provide auxiliary power for components such as air conditioning and lights. Lastly, the vehicle's operation, such as vehicle speed and idle time, affects the amount of total energy required to complete its activity.

An important aspect of estimating the relative fuel consumption and environmental emissions of different modes is to determine the fuel consumption and environmental benefits of heavy-duty truck technologies through testing and analysis. Several methods are available to assess fuel consumption and greenhouse gas emissions from trucks. Truck fleets today often use SAE J1321 test procedures to evaluate criteria pollutant emissions changes based on paired truck testing. Light-duty trucks are assessed using chassis dynamometer test procedures. Heavy-duty engines are evaluated with engine dynamometer test procedures. Most large truck manufacturers employ various computer simulation methods to estimate truck efficiency. Each method has advantages and disadvantages. The Greenhouse Gas Emissions Model (GEM) was developed by the U.S. Environmental Protection Agency (US EPA) as a means for determining compliance with the proposed GHG emissions and fuel consumption vehicle standards for Class 7 and 8 combination tractors and Class 2b-8 vocational vehicles developed by US EPA and NHTSA respectively.[22] As both agencies' proposed compliance tool, GEM was designed with the following modeling attributes:

- capable of modeling a wide array of medium- and heavy-duty vehicles over different drive cycles;
- contains open source code, providing transparency in the model's operation;
- freely available and easy to use by any user with minimal or no prior experience;
- contains both optional and preset elements; and
- managed by the Agencies for compliance purposes.

The design of GEM focuses on the application of technologies having the largest impact on reducing vehicle GHG emission reductions or fuel consumption in the 2014-2017 timeframe. For the given timeframe, the model would allow various inputs to characterize a vehicle's properties (*e.g.*, weight, aerodynamics, and rolling resistance) and predict how the vehicle would behave when it to be operated over a particular driving cycle.

US EPA has validated GEM based on the chassis test results from “SmartWay”-certified tractors tested at the Southwest Research Institute. Since many aspects of one tractor configuration (such as the engine, transmission, axle configuration, tire sizes, and control systems) are similar to those used on a manufacturer’s sister models, the validation work conducted on these vehicles is representative of the other Class 8 tractors.

The input values needed for the simulation model (*e.g.*, drag coefficient, tire rolling resistance coefficients, tire/wheel weight reduction, vehicle speed limiter, aerodynamic drag, tire rolling, resistance coefficient inputs, and extended idle reduction technologies) are obtained as manufacturer testing or model default values. The tool also has a range for vehicle speed limiter and default extended idle reduction technology benefit variables.

After parameters are input to the graphical user interface, GEM predicts the individual and cycle weighted fuel consumption and CO2 emissions for three proposed test cycles – a Transient cycle, a 55 mph steady-state cruise cycle, and a 65 mph steady-state cruise cycle. The model can also be used to determine a level of technology necessary for a vehicle to meet a specified GHG standard and allows a manufacturer to estimate the benefits and costs of those changes to a particular vehicle for that level of GHG reductions.

While the GEM model can estimate fuel consumption based on detailed characteristics of a truck tractor, it does not estimate the effects on fuel consumption of trailer characteristics such as weight, aerodynamic drag, and the rolling resistance of tires. Bachman et.al.[23] cite a U.S. Department of Energy (DOE) report[24] that indicates, “At a steady speed of 65 miles per hour on a flat road, aerodynamic drag and rolling resistance account for 21 percent and 13 percent, respectively, of the total energy used by a class 8 heavy-duty tractor.” They note that “measurements of whole-vehicle emissions from class 8 tractor-trailers are not readily available because historically such measurements involve dynamometer testing in the laboratory, and dynamometers suitable for class 8 tractor trailers are rare.” Bachman reports on a study of the emission benefits of improving trailer aerodynamics and reducing tire rolling resistance that was conducted in connection with EPA’s SmartWay Transport Partnership. This partnership between shippers, transportation providers, such as truck fleets, and the US EPA is designed to encourage shippers and fleets to reduce air pollution and greenhouse gas emissions through lower fuel consumption. Installation of devices to reduce aerodynamic drag and use of super single tires to reduce rolling resistance were found to improve fuel economy of tractor-semitrailers by 18 percent at highway speeds and offered even greater improvements in a suburban driving cycle. A similar study in Austria found reductions in fuel consumption of 12 percent when vehicle aerodynamics were improved and low rolling resistant tires were used.[25]

A National Academy of Sciences (NAS) (NAS, 2010) study[26] found that the relationship between the percent improvement in fuel economy (FE) and the percent reduction in fuel consumption (FC) is nonlinear; *e.g.*, a 10 percent increase in FE (miles per gallon) corresponds to a 9.1 percent decrease in FC, whereas a 100 percent increase in FE corresponds to a 50 percent decrease in FC. The study also found that Medium and Heavy Duty Vehicles (MHDVs) are designed as load-carrying vehicles, and consequently their most meaningful metric of fuel efficiency will be in relation to the work performed, such as fuel consumption per unit payload carried, which is load-specific fuel consumption (LSFC). Methods to increase payload may be combined with technology to reduce fuel consumption to improve LSFC. Therefore, the study recommended that regulators need to use a common procedure to develop baseline LSFC data for various applications, to determine if separate standards are required for different vehicles that have a common function.

An FRA study completed by ICF International in 2009 compares rail and truck fuel efficiency and concludes that rail is more fuel efficient.[27] The study evaluates and compares rail and truck fuel efficiency on corridors and for services in which both modes compete. An analysis of past and future trends is also provided in the study. Competitive movements are defined as those of the same commodity having the same (or proximate) origin and destination. The study does not compare economic efficiency of the modes, nor does it evaluate any individual criteria that influence mode choice.

This study is an update to a similar 1991 study to address the technological and operational improvements that have been realized between 1991 and 2009 for both rail and truck. The methodology used was the same as in the 1991 study so that the studies are comparable.

Between 1990 and 2006 overall rail fuel efficiency had improved by about 21.5%, or about 1.2% per year. There have also been key developments in locomotive technology during the timeframe which include: adoption of electronic controls in all locomotive subsystems; continuing development of the diesel engine, including low-emissions models to meet US EPA Tier 2 requirements for emission standards; development of AC traction systems; locomotive truck and brake improvements; operator’s cab improvements; development of 6,000 hp engines; and hybrid and Genset locomotives. In addition, there have been improvements to non-locomotive technology that can impact fuel efficiency including 286,000 lb gross weight cars; lightweight car construction; electronically controlled pneumatic brakes; specialized car types; use of distributed power; reduction of rolling resistance through rail lubrication; steerable or radial trucks; and low friction bearings. Some of these developments result in benefits to fuel economy of rail.

Similarly, there have been improvements in the trucking industry that have resulted in increased fuel efficiency. These include tractor and trailer aerodynamic improvements, tare weight reduction, improvements in transmissions and lubricants, and idle reduction technology. Other factors that have improved fuel efficiency for trucks include operational changes such as speed reductions, fuel cost increase, and anti-idling policies.

Twenty three movements were selected and analyzed for the study. Of the 23 movements studied, double-stack trains accounted for 48% rail movements, dry van trailers accounted for 47% of the truck movements. A summary of the findings indicates that rail is more fuel efficient than truck on all 23 movements in terms of ton-miles per gallon. The rail fuel efficiency ranges from 156 to 412 ton-miles per gallon in the study. The truck fuel efficiency ranges from 68 to 133 ton-miles per gallon.

Ratios comparing the fuel efficiency by rail and by truck were calculated for the movements. The analysis shows that the rail-truck fuel efficiency ratio varied by rail equipment type with tank cars resulting in the highest ratio (5.3) and auto rack representing the lowest ratio (1.9). The study also found that truck drayage and intermodal terminal operations account for 7% to 27% of total fuel consumed by intermodal trains. Empty mileage was also taken into consideration in this study. The study concludes that when empty miles are considered, all intermodal movements (double-stack and TOFC) and gondola movements are even more fuel efficient than comparable truck movements. For box cars and covered hoppers, rail is still more fuel efficient than trucks, but the gap between the two modes narrows when including empty miles.

In comparison with the results from the 1991 study, overall, double-stack trains appear to have become more fuel efficient. On the other hand, dry vans and container on chassis are somewhat less fuel efficient now than in the 1991 study, which may be explained by the more realistic representation of truck movements in the 2009 study. These factors can explain the increase in rail-truck fuel efficiency ratios for commodities moved in double-stack trains.

The following criteria were used to identify the competitive movements used in the study analysis:

- Movements that had comparable rail and truck mode shares
- Movements that were representative in terms of freight activity (measured in ton-miles)
- A mix of short, medium and long distance movements
- A mix of different commodities (and thus different equipment types)
- A mix of geographic regions.

The evaluation measures and compares fuel efficiency in ton-miles per gallon and also uses a rail-truck efficiency ratio, which is a ratio between rail and truck fuel efficiency as measured in ton-miles per gallon. The calculation of line-haul fuel consumption considers factors including distance, circuitry, grade profile, speed profile, vehicle characteristics, vehicle weight, and vehicle aerodynamic profile. Rail fuel efficiency also considers short branchline movements. Truck idling was factored into the truck fuel efficiency calculations.

Rail fuel consumption was calculated by two participating railroads using in-house train simulators. Fuel consumption from other movements such as drayage, were added separately. Truck fuel consumption was estimated using the MOVES/PERE model designed by the US EPA and fuel consumption from idling was added in separately.

As noted above, the US EPA is part of a SmartWay Transport Partnership whose goal is to encourage shippers and fleets to reduce air pollution and greenhouse gas emissions through lower fuel consumption. One strategy that is part of the SmartWay program is the use of longer combination vehicles. The US EPA says that, "LCVs are more fuel-efficient, on a ton-mile basis, than typical combination trucks. For example, a Rocky Mountain Double consumes 13 percent less fuel per ton-mile of freight, compared to a typical combination truck. This saves over $8,000 in fuel costs per year. Turnpike Doubles and Triples reduce fuel use per ton-mile by 21 percent, saving over $13,000 in annual fuel costs."[28]

Traffic Flow and Operations

Because of the characteristics including size and weight, heavy vehicles including trucks, impact the flow and safety of traffic differently than passenger vehicles. A report prepared in conjunction with the USDOT 2000 CTSW Study identified the following issues as of particular interest to Federal policy considerations: passenger car equivalencies, capacity, level of service, and traffic stream costs.[29]

The report notes that traffic engineers use the concept of passenger car equivalencies (PCE) of trucks for analysis and design relating to highway capacity and level of service. PCEs represent the number of passenger cars that would consume the same percentage of a highway's capacity as the truck(s) under consideration.

The Highway Capacity Manual (HCM) has long been an important reference for factors affecting highway capacity, level of service, and traffic operations. The latest version of that TRB report was published in 2010. Heavy vehicles are defined in the HCM as those having "more than four tires touching the pavement". Trucks, buses and recreational vehicles make up the three groups of heavy vehicles. Trucks vary and the operational characteristics depend on the weight of its load and the engine performance. Heavy vehicles adversely impact traffic in two ways as explained in the HCM:

1. They are larger than passenger cars and occupy more roadway space; and
2. They have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.

According to the HCM, the second impact is more critical as the inability to keep pace with passenger vehicles can create large gaps that are not easily filled by passing maneuvers. Queues may also develop behind the heavy vehicle resulting in roadway inefficiencies that are not easily overcome. Particularly when downgrades are steep enough to require operation in a low gear, heavy vehicles can impact downgrade movements as well, which also causes gaps and queues.

The HCM presents PCE values that vary as a function of road class, geometry, types of trucks, and percent trucks in the traffic stream. However, the values are not explicitly sensitive to parameters considered in TS&W investigations such as truck weight, length, and configuration. The HCM identifies the methods for calculating traffic flow quality and accounts for heavy vehicles within the methodology for identifying Levels of Service (LOS). Other studies have addressed the issue of traffic flow and operation with respect to trucks including other truck size and weight studies.

The USDOT 2000 CTSW Study analyzed the "passenger-car equivalents" for different truck lengths and weight-horsepower ratios. **Table 4 and 5** illustrate the findings of this study separated by rural and urban highways.

Table 4. Vehicle Passenger Car Equivalents -- Rural Highways (USDOT, Comprehensive Truck Size and Weight Study, 2000.)

Roadway Type	Grade		Vehicle Weight to Horsepower Ratio (pounds/horsepower)	Truck Length		
	Percent	Length (miles)		40	80	120
Four-Lane Interstate	0	0.50	150	2.2	2.6	3.0
			200	2.5	3.3	3.6
			250	3.1	3.4	4.0
	3	0.75	150	9.0	9.6	10.5
			200	11.3	11.8	12.4
			250	13.2	14.1	14.7
Two-Lane Highway	0	0.50	150	1.5	1.7	Not Simulated
			200	1.7	1.8	Not Simulated
			250	2.4	2.7	Not Simulated
	4	0.75	150	5.0	5.4	Not Simulated
			200	8.2	8.9	Not Simulated

Table 5. Vehicle Passenger Car Equivalents -- Urban Highways (USDOT, Comprehensive Truck Size and Weight Study, 2000).

Roadway Type	Traffic Flow Condition	Grade	Vehicle to Horsepower Ratio (pounds/horsepower)	Truck Length		
				40	80	120
Interstate	Congested	0	150	2.0	2.5	2.5
			200	2.5	3.0	3.0
			250	3.0	3.0	3.0
	Uncongested	0	150	2.5	2.5	3.0
			200	3.0	3.5	3.5
			250	3.0	3.5	4.0
Freeway and Expressway	Congested	0	150	1.5	2.5	2.5
			200	2.0	2.5	2.5
			250	2.0	3.0	3.0
	Uncongested	0	150	2.0	2.0	2.0
			200	2.5	2.5	2.5
			250	3.0	3.0	3.0
Other Principal Arterial	Congested	0	150	2.0	2.0	2.5
			200	2.0	2.0	3.0
			250	3.0	3.0	4.0
	Uncongested	0	150	3.0	3.0	3.5
			200	3.5	3.5	3.5
			250	3.5	4.0	4.0

In both rural and urban areas, vehicle length has only minor effects on PCEs. Steep grades have a dramatic impact on PCEs especially for vehicles with high weight to horsepower ratios that cannot maintain their speed on upgrades. Weight to horsepower ratios also affect operations in urban areas since vehicles that cannot accelerate quickly adversely affect traffic operations.

Table 6 summarizes the effects of large truck characteristics on traffic flow and operations.

Table 6. Summary of Effects of Truck Size and Weight Characteristics on Highway and Traffic Operations (USDOT, Comprehensive Truck Size and Weight Study, 2000).

Vehicle Features		Traffic Congestion	Vehicle Offtracking		Traffic Operations			
			Low Speed	High Speed	Passing	Acceleration (merging and hill climbing)	Lane Changing	Intersection Requirements
Size	Length	- e	- E	+ e	- E	—	- E	- E
	Width	—	- e	+ e	- e	—	- e	—
	Height	—	—	- e	—	—	—	—
Design	Number of units	—	+ E	- E	—	—	- e	—
	Type of hitching	—	+ e	+ E	—	—	+ E	—
	Number of Axles	—	+ e	+ e	—	—	+ e	—
Loading	Gross vehicle weight	- e	—	- E	- E	- E	- e	- E
	Center of gravity height	—	—	- e	—	—	- e	—
Operation	Speed	+ E	+ E	- E	- E	—	+ e	+ E
	Steering input	—	- E	- E	—	—	- E	—

+/- As parameter increases, the effect is positive or negative.
E = Relatively large effect. e = relatively small effect. -- = no effect.

This table shows that in regards to traffic congestion, the speed of large trucks has a large effect compared with length and weight. Issues related to the length of the vehicle include low speed offtracking, passing, lane changing and intersection requirements.

In a study, sponsored by the Association of American Railroads, Roger Mingo used the FRESIM model to estimate PCEs for different types of truck configurations.[30] Large numbers of FRESIM runs were made varying the traffic composition and percent trucks in the traffic stream. Regression analysis was used to estimate the relative effect of each vehicle type on traffic speeds simulated in FRESIM compared to the passenger vehicle. Results of the analysis are shown in **Table 7**. The PCEs for doubles and LCVs are higher than estimates developed for the 1997

Federal Highway Cost Allocation Study, but there is insufficient documentation to determine potential reasons for the differences.

Table 7. Passenger Car Equivalents for Different Truck Classes Based on Speeds on Rolling Freeway Sections with Different Percent Trucks in the Traffic Stream

Truck Type	PCE (18%)	PCE (14%)	PCE (10%)
Single-Unit	1.263	1.486	1.526
Medium Load	2.030	2.507	3.666
Full Load	3.254	3.363	4.260
Double-Bottom	5.399	6.143	7.097
Long Combination	10.272	12.368	

The **Western Uniformity Scenario Analysis** was conducted as a follow-on to the USDOT's 2000 CTSW Study to analyze the impacts of lifting the LCV freeze and allowing consistent LCV weights, dimensions and routes among Western States that already allowed LCVs. Various impacts were considered as part of the study, including traffic flow and operations related to LCVs.

The study states that large trucks affect traffic flow due to their size, acceleration, and braking characteristics which can negatively affect the LOS. The study analyzed potential traffic operation impacts in the 13 western States included in the scenario analysis. Much of the same methodology used in the USDOT 2000 CTSW Study was used for the analysis in this report. Substantial improvements in data and some analytical methods had been realized between 2000 and 2004, so the improved information was used. The vehicles analyzed were a twin-trailer configuration with two 48-foot semitrailers and one with 45-foot trailer lengths. In the summary, however, only the impacts of the 48-foot configuration are reported. For the traffic operations analysis, the variables analyzed include traffic delay in million vehicle-hours, congestion costs, low-speed off-tracking, passing, acceleration, lane changing and intersection requirements.

Study assumptions affecting estimates of the impacts on traffic operations include limited networks for LCVs, no LCV operations in congested urban areas, and the use of more powerful tractors on LCVs to maintain typical weight/horsepower ratios. Another factor affecting estimates of traffic operations impacts is the fact that the western States included in the analysis are rural in character – neither California nor Texas which have large metro areas and heavy traffic volumes were included in the study. Taking into account the assumption that some freight will move to the more productive scenario trucks, the traffic operations will not degrade or for some variables may even improve with the Western Uniformity Scenario. It is important to note that the assumption that increased engine power is available for those configurations with increased gross vehicle rates was used. **Table 8** below shows the traffic operation impact and the resulting change using the Western Uniformity Scenario.

Table 8. Western Uniformity Scenario Traffic Impacts (USDOT, Western Uniformity Scenario Analysis, 2004, p. VIII-8).

Impact	2000 (base case)	2010 (scenario)
Traffic Delay (million vehicle-hours)	National Total 3,599*	Small decrease
Congestion Costs ($ million)	National Total $67 billion***	Small decrease
Low-Speed Off-tracking		Degradation (28-30 feet** for turnpike double versus 16 feet for semitrailer)
Passing		Requires operating restrictions.
Acceleration (merging and hill climbing)		Requires sufficient engine power.
Lane Changing		Some degradation due to additional length. (This is counterbalanced by decrease in heavy truck VMT.)
Intersection Requirements		Some degradation due to additional length. (This is counterbalanced by decrease in heavy truck VMT.)

*Computed by Texas Transportation Institute as the aggregate for 68 urban areas (not comparable with USDOT Comprehensive Truck Size and Weight 2000, Volume III).
**28 feet off-tracking for twin 45-foot TPDs and 30 feet off-tracking for twin 48-foot TPDs.
***Estimated for 75 largest urban areas.

Al-Kaisy examined factors that contribute to the effect of heavy vehicles on traffic operations and level of service.[31] He notes that two factors are primarily responsible for the effects of heavy vehicles on traffic operations -- their dimensions and their performance. The influence of these factors differs depending on three conditions: terrain, saturated versus unsaturated traffic, and traffic levels for unsaturated conditions. On level terrain the influence of heavy trucks is mainly attributed to their dimensions, but in rolling and especially mountainous terrain the vehicle's performance becomes important. As traffic volumes rise, heavy vehicle performance becomes an increasingly important influence on traffic operations.

Al-Kaisy notes that there has been a long-standing debate about the definition of passenger car equivalency due in part to the loose treatment of the subject in different editions of the Highway Capacity Manual (HCM). The 1965 HCM defined equivalency as "the number of passenger cars displaced in the traffic flow by a truck or a bus, under the prevailing roadway and traffic conditions." Average speed was used as the criterion to derive PCE factors for freeways and multilane highways. The 2000 HCM defines PCE as "the number of passenger cars displaced by a single heavy vehicle of a particular type under specified roadway, traffic and control conditions."

Recent work has noted that PCEs may vary depending on the type of traffic impact being studied. Van Aerde and Yagar note that "passenger car equivalents have generally been assumed to be similar for capacity, speed, platooning, and other types of analysis. This notion appears to be incorrect and is perhaps one of the main sources of discrepancies among the various PCE studies."[32]

The synthesis of previous truck size and weight studies and issues conducted for the 2000 CTSW Study identified other issues related to traffic operations. Heavy trucks can affect traffic operations when merging, weaving and changing lanes. "TS&W considerations can have important effects on these maneuvers because of their effects on gap size requirements and acceleration performance. Little is known about the effects of different percentages of trucks with variable size and weight on the ability to merge and change lanes in traffic streams of varying speed and density." The report noted that "ramp junctions and weaving areas are so site-specific as to their geometric design and operating speeds that simulation of those specific intersections is probably the only analytical method that will give reasonable precision."

Truck operations can also affect traffic operations at intersections. Larger and/or heavier vehicles can affect traffic operations at intersections in many ways including: (1) requiring extra time to accelerate up to the posted speed limit; (2) altering sight lines; (3) increasing sight distance requirements; (4) altering signal timing requirements. Many of these traffic disruption effects can be mitigated with the use of powertrains that ensure acceleration performance equivalent to or better than current vehicles.

Highway Cost Recovery

An important consideration related to truck size and weight policy is the extent to which highway agencies can recover any additional infrastructure costs associated with the operation of longer, heavier commercial motor vehicles. A number of factors must be considered related to cost recovery including:

- How to measure cost responsibility

- What cost recovery mechanism to use
- What costs to recover
- Whether an agency wishes to fully recover costs or to promote equitable cost recovery whereby different vehicle classes pay fees proportionate to their cost responsibility
- Whether to recover marginal costs or average costs

Many previous truck size and weight policy studies have estimated changes in pavement and bridge costs associated with truck size and weight policy options. Typically those studies have focused on measuring incremental costs associated with operations of vehicles under alternative truck size and weight limits, but not on the specific issue of how (or whether) to recover those costs. Methods for estimating these costs are discussed in the pavement and bridge desk scans.

Fewer studies have attempted to attribute those cost changes to the different vehicle classes operating at different weights under alternative truck size and weight limits. The 2000 CTWS Study did not test any cost recovery mechanisms for the bridge, geometric, or increased enforcement costs.[33]

There are two basic ways to recover added costs that may result from changes in truck size and weight limits – permit fees and changes in truck-related user fees. Permit fees would apply only to those vehicles that were required to operate under special permit while general truck-related user fees would pertain to all vehicles unless special exemptions were provided. Permit fees are discussed in more detail in the compliance desk scan, but in general States have not attempted to use permit fees to cover infrastructure costs associated with oversize/overweight vehicle operations.

States and the Federal Government conduct highway cost allocation studies to assess whether different vehicle classes pay fees that are proportionate to the highway costs each class occasions. Most studies have found that existing user fee structures do not reflect the relative infrastructure costs occasioned by the heaviest of the commercial motor vehicles. Oregon is the only State that explicitly attempts to link its user fee structure to the cost responsibility of different vehicle classes operating at different weights. It does this through a weight-distance tax.[34] The Federal user fee structure only generally reflects differences in highway cost responsibility for different vehicles operating at different weights. The result is that some vehicle classes pay more than their proportionate share of highway cost responsibility while other vehicle classes pay substantially less than their proportionate share of cost responsibility.[35]

There has been little if any direct cost recovery from any of the changes in vehicle size and weight made in Canada.[36] One key reason is that all provincial governments in Canada, and the federal government deposit revenues from all sources in their general treasuries where they may be spent on any purpose. Thus there would be no link between fees imposed on commercial motor vehicles to recover infrastructure costs and expenditures on highway infrastructure.

The terms highway cost allocation and highway cost responsibility tend to be used somewhat interchangeably, but some studies such as Oregon's highway cost allocation study have distinguished between the two. Past Federal and State highway cost allocation studies have focused primarily on allocating past or anticipated highway program expenditures for different functions (e.g., pavement preservation, bridge reconstruction, added capacity, etc.) to various vehicle classes based on the relative contribution of each vehicle class to the need for each type of program expenditure. Highway program expenditures and the aggregate costs that different vehicle classes impose on the infrastructure may not be the same, however, if highway agency budgets do not provide sufficient funds to offset infrastructure wear and tear attributable to vehicle operations.

The 2013-2015 Oregon highway cost allocation study notes, "Some past Oregon studies, including a special analysis in the 2001 Study, attempted to estimate and allocate a full-cost budget in addition to a base-level (actual expenditure) budget. The intent was to approximate costs by estimating the level of expenditures required to preserve service levels and pavement conditions at existing levels. In these studies heavy vehicles were found to be responsible for a greater share of the preservation level budget than of the base-level budget. This was because the majority of unmet needs at that time involved pavement rehabilitation and maintenance, items for which heavy vehicles have the predominant responsibility. Oregon notes that there are strong arguments for moving toward a full cost-based approach in highway cost allocation studies. Recognizing the benefit of moving toward a financing system based on efficient fees, a full 2011 Efficient Fee Highway Cost Allocation Study was performed in addition to the traditional study. "True" costs are still more difficult to quantify and incorporate in the analysis than are direct highway expenditures. Some of these problems are theoretical in nature or are limited by our knowledge of such costs, and data limitations also plague the calculation of many of these costs. As a practical matter, therefore, highway cost allocation studies, including this study, continue to focus on the allocation of expenditures rather than costs."

In referring to a "full-cost" highway cost allocation approach, the Oregon study was considering only those infrastructure and related costs for which the Oregon Department of Transportation is responsible. Many economists and others advocate that highway users should pay the full social costs of their highway use including not only infrastructure wear and tear, but also energy, environmental, congestion, safety, and other economic costs associated with highway use. While these factors are taken into consideration in planning and design decisions, transportation agencies have limited responsibilities and authority to fully account for (and charge for) these non-agency costs. The 2000 Addendum to the 1997 Federal Highway Cost Allocation Study noted, "The 1997 HCAS discussed four main costs of highway use not borne directly by transportation agencies -- crash costs, air pollution, congestion, and noise. Based on mid-range estimates, crash costs are the largest of those costs, accounting for about 75 percent of total costs for those four impacts. Congestion costs represent the next highest cost (14%), followed by air pollution (9%) and finally noise (1%). Most crash and congestion costs are borne directly by motorists, but impacts of air pollution and noise are not directly tied to an individual's use of the highway."

Forkenbrock analyzed external costs of the trucking industry and concluded, "from a societal perspective, it is desirable for all transportation users to pay their full social (private and external) costs[37]. We estimate four general types of external costs for intercity freight trucking and compare them with the private costs incurred by carriers. Estimated external costs include: accidents (fatalities, injuries, and property damage); emissions (air pollution and greenhouse gases); noise; and unrecovered costs associated with the provision, operation, and maintenance of public facilities. The analysis reveals that external costs are equal to 13.2% of private costs and user fees would need to be increased about threefold to internalize these external costs."

Morris notes that while "the domestic surface freight transportation system is privately operated, but government strongly influences its performance[38]. Government builds and operates roads and waterways; regulates pollutant emissions, truck size and weight, safety, and other aspects of the industry; and collects fees and taxes from freight firms. Government actions in these areas may subsidize some freight movements and penalize others; affect competition among the modes; influence the distribution of costs and benefits of freight activities; and ultimately affect the efficiency of the freight industries."

In 1996 the TRB published Special Report 246, Paying Our Way, Estimating Marginal Social Costs of Surface Freight Transportation that examined the extent to which subsidies in surface transportation adversely affect economic efficiency.[39] The report notes, "If some users pay their costs while others do not, the subsidized users will be unfairly advantaged and shippers and carriers will lack incentive to operate and use freight transportation efficiently. Traditionally, the focus of this debate has been whether users pay for the services and facilities that government provides…" In recent decades the subsidy debate has broadened to include the external costs of transportation services. External costs are those that freight carriers or shippers impose on others by, for example, adding to air pollution, increasing accident risks, or contributing to traffic congestion and delays. Government has tried to reduce external costs by regulating pollutant emissions and mandating safety procedures for freight carriers, among other measures. Some external costs remain, nevertheless, in part because it is seldom practical or efficient to eliminate such costs completely.

"The debate over whether some shippers or carriers are subsidized has bearing on nearly all areas of government policy affecting freight transportation, including highway and waterway user taxes, truck size and weight limits, railroad labor laws, emission controls, urban truck use restrictions, and public infrastructure investment. Ideally, decisions about government policies in these areas should be made using knowledge about the extent to which current policies foster efficient use of the freight system and the extent to which the performance of the freight industries differs from that which would be expected if no subsidies were provided. Such knowledge does not exist, and providing it would be a formidable undertaking given the conceptual and practical difficulties involved."

The TRB study committee recommended that, "when DOT, the state transportation departments, and the U.S. Army Corps of Engineers conduct cost allocation studies, studies of alternative user fee systems, and evaluations of investment proposals, they should routinely consider the effects of the structure of road and waterway user fees on freight transportation efficiency and consumer welfare and search for user fee schedules that improve economic efficiency." Further they noted, "The committee does not endorse any particular policy to impose new charges on freight operators in an effort to capture external costs. This study did not evaluate the costs and benefits of possible alternative user fees and taxes. Simplistic approaches to attempting to recover external costs by increasing freight carriers' fuel taxes or registration fees so as to generate revenue equal to an estimate of external costs almost certainly would harm efficiency."

Conclusion: A disaggregated (county-to-county) version of the FAF commodity flow database would be the best freight flow data to use in the CTSW Study. The methods used to develop the FAF are well documented and it is the most comprehensive national freight database available. Transearch would be an alternative, but the proprietary methods for constructing Transearch and the high cost for others to obtain the data make it less attractive than the FAF for the CTSW Study.

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