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ASSESSING THE POTENTIAL FOR RAIL-TRUCK INTERMODAL TRANSPORTATION TO REDUCE TRACTOR-TRAILER ACCIDENTS ON TENNESSEE HIGHWAYS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gregory Thad Gaides

May 1994

DEDICATION

In memory of "The Chop."

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ABSTRACT

In recent years, the movement of long-haul domestic freight by rail-truck intermodal has received considerable attention. One of the perceived societal advantages of rail-truck intermodal transportation relative to over-the-road truck service is improved highway safety. The argument is that when the line-haul portion of an over-the-road truck movement is replaced by rail transportation, tractor-trailer exposure levels on the highway system will be lessened. The decrease in exposure should then result in a reduction in the number of tractor-trailer accidents occurring on the highway system.

This study focuses on the highway safety aspects of intermodal. In particular, the study attempts to measure how many tractor-trailer accidents occur in Tennessee for which rail-truck intermodal transportation could have been used to haul the freight instead. By assigning dollar values to these accidents according to their injury outcome, some estimate of the accident savings can be achieved. Also of interest is measuring the effect that various changes in the rail and/or truck industry might have on the number of tractor-trailer accidents in Tennessee. For example, new intermodal technology aimed at capturing shorter-haul markets would likely reduce the number of trucks operating in such markets, and also reduce accident occurrence. Finally, the safety benefits are assessed to determine whether the Tennessee state government should encourage, within their limits, a shift toward intermodal, and if so, what specific actions can be taken.

A decision model was developed for determining whether a shipment in truck carriage is suitable for intermodal transport. The model included such factors as type

of commodity to be transported, shipment origin and destination, line-haul characteristics, and total length of haul. The data used to apply the model were information recorded on the shipping papers carried by each tractor-trailer driver who became involved in an accident in Tennessee. These papers document the type of cargo being transported as well as its origin and destination. The percentage of truck movements that were determined to have a potential for intermodal transport, based on the information provided on the shipping papers, represented the accident reduction.

The results of this study indicated that approximately one out of every four tractor-trailer accidents occurring on Tennessee highways involved movement of a commodity over a distance that was suitable for intermodal. The annual cost of these accidents was estimated at $21 million to $29 million.

There is significant potential for advancements in intermodal technology and other factors to further reduce tractor-trailer accident occurrences. Currently, intermodal is cost competitive with over-the-road trucks at trip distances of about 750 miles. The analysis indicated that for every 100 mile reduction in this distance threshold, roughly, about a 5 percent decrease in the number of tractor-trailer accidents is possible (assuming that smaller markets do not grow appreciably).

Even though intermodal transportation represents interstate commerce, the state government still can and should play a role in bringing about these safety benefits. The first step identified is for the State to commission a study that analyzes the utility of intermodal facilities and services available within Tennessee. Specific measures to foster intermodal activity would become apparent from this study. Some of the measures

envisaged include encouraging development of additional intermodal terminal facilities in Tennessee, improving access roads to existing terminals, and financing research to develop new technology and also to introduce new technology into the intermodal industry.

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I. INTRODUCTION AND PURPOSE

In recent years, the movement of domestic freight by rail-truck intermodal transportation[1] has received considerable attention on many fronts. To the shippers and receivers, intermodal represents another transportation alternative while both the railroad and motor carrier industries view it as a way to improve their operating performance. To the general public, intermodal offers many advantages relative to over-the-road truck transportation. These advantages include less adverse impact on the environment, reduced energy consumption, and a decrease in highway deterioration and congestion while improving highway safety.

This study focuses on the highway safety aspects of intermodal. The primary safety benefit offered by intermodal is its ability to remove from operation a certain portion of over-the-road tractor-trailers on the nation's highways. The freight is instead transported by rail over the line-haul (long haul) part of the trip and is transferred to/from trucks for the drayage (pick-up and delivery) portion. With less highway mileage traveled by tractor-trailers, the number of accidents involving these trucks should be reduced. At the same time, the new pattern of drayage movements to and from intermodal terminals may have a negative safety implication. Also, an increase in train traffic would be expected and it too may result in additional grade-crossing or trespassing-related accidents. While measurement of the net safety benefit of intermodal

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[1]For simplicity, rail-truck intermodal transportation will be referred to as intermodal, unless otherwise stated.

would necessarily involve the quantification of each of these aspects of transportation, this study examines only the reduction in tractor-trailer activity on the highways.

The safety concerns of tractor-trailers operating on the highway system are well documented. Over 200,000 combination trucks (tractor-trailers and bobtails) are involved in crashes each year, about 3,900 of which are fatal. In part because of their size and mass, accidents involving combination trucks are one and one-half times as likely to result in fatalities when compared to passenger car crashes [1]. In Tennessee, approximately 4,400 tractor-trailer accidents occur annually, of which about 75 are fatal. While these 4,400 accidents represent only about 3 percent of all motor vehicle accidents occurring in Tennessee, fatal tractor-trailers accidents account for nearly 7 percent of the state's fatal crashes [2,3].

In order for the highway safety benefits to accrue, intermodal services must represent a viable alternative to over-the-road tractor-trailer transportation. Following the construction of the Interstate highway system, commodities that had been transported by rail started moving by truck. In 1960, rail captured 47 percent of all intercity freight traffic and 31 percent of intercity freight revenue. By 1992, those figures had plummeted to 37.5 percent and 15 percent, respectively [4]. Manufactured commodities represent the largest area in terms of both tonnage and revenue where rail has lost market share to the trucking industry. In 1964, manufactured goods (exclusive of chemicals and petroleum products) commanded 30.6 percent of railroad tonnage and 51.3 percent of railroad revenue. By 1989, those figures had dropped to 20.1 percent and 36.8 percent,

respectively. During that time period, transport of bulk commodities and chemical and petroleum products by rail grew marginally [5].

Can railroads effectively compete with the trucking industry and win back lost market share? There appears to be several market segments within the railroad industry that offer promise. These segments include: rail carload, trailer on flat car (TOFC), double-stack container,[2] and new intermodal technology [6]. If for any of these segments the railroads' market share can be increased at the expense of the trucking industry, a reduction in vehicle-miles of travel among long-haul tractor-trailer trips and an associated reduction in the number of accidents involving these vehicles may be possible.

Can the State of Tennessee capture these benefits? In order to answer this question, information is needed about the characteristics of the tractor-trailer trips made in Tennessee (e.g. how long are the trips, what are the shipment origins and destinations, what types of cargos are being transported). Short truck trips and cargo that is not conducive to rail transport represent impenetrable markets for the railroads. Perhaps most importantly, there is a need to understand both the criteria and decision-making process that shippers and receivers use to determine which mode of transport best suits their needs. Therefore, any attempt by rail to more effectively compete against trucks for freight will require the railroads to better appeal to the needs of the shipper or receiver.

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[2]Two containers stacked one on top of the other on a rail car.

The purpose of this study is to estimate the number of over-the-road tractor-trailer accidents occurring in Tennessee that could be avoided through the greater use of intermodal to haul freight. By assigning dollar values to these accidents according to their injury outcome, some estimate of the accident savings can be made. The number of avoidable tractor-trailer accidents can be measured by determining how many truck accidents occur in situations where the shipment in transport was conducive to movement by an intermodal service. Of additional interest is assessing the potential for new intermodal technologies to improve its market share and, in effect, further reduce vehicle-miles of travel by long-haul tractor-trailers (thereby limiting accident potential). Several specific study objectives are presented below.

Objective one of the study is to identify some of the major characteristics of the tractor-trailer trips made in Tennessee. Items of interest include determining the percentages of intrastate and interstate truck trips, learning how many of the interstate trips involve trucks hauling a shipment without an origin or destination in Tennessee, and measuring the distribution of trip distance for the interstate trips.

Objective two is to estimate how many tractor-trailer accidents could have been avoided had the shipment been transported intermodally instead. An estimate of the overall cost of these accidents (expressed in dollars) is also desired.

Objective three is to evaluate the impact that new intermodal technology or other factors could have on the truck market. An estimate of the additional number of avoidable tractor-trailer accidents and the associated monetary cost is important for gauging the need for such improvements.

Objective four is to determine whether or not a shift toward intermodal can generate safety benefits for the State of Tennessee and if so, make recommendations concerning how to achieve those benefits.

II. REVIEW OF LITERATURE

In order to assess the potential for intermodal transportation to reduce tractor-trailer accidents, it is desirable to first comprehend the tractor-trailer safety concerns and also understand how intermodal transportation can affect safety outcomes. Specifically, it is important to recognize: (1) the significance of the safety issue, (2) the characteristics of tractor-trailer travel that influence safety, and (3) whether intermodal transportation can specifically address any of these characteristics. Once the overall tractor-trailer safety concerns are understood, it is then desirable to focus on the two principal competing modes in the domestic intercity freight market--truck and rail--recognizing the strengths and weaknesses of each. Both the trucking industry's competitiveness with intermodal services and the various intermodal opportunities that are available are also examined. Finally, factors that affect the decision of whether or not to use intermodal services to transport shipments are identified.

Tractor-Trailer Safety Concerns

There does not exist a wealth of data to assess the true tractor-trailer accident problem. Nationwide statistics on fatal accident involvements are available from the National Highway Traffic Safety Administration (NHTSA) Fatal Accident Reporting System (FARS). Nonfatal accident involvement statistics are less certain. The National Accident Sampling System (NASS), also under NHTSA, compiles such data but the sample size for trucks is small. The difficulties are compounded when trying to

determine accident rates for tractor-trailers as no single source documents the number of miles traveled. Instead, the Federal Highway Administration (FHWA) indirectly estimates tractor-trailer mileage by combining data from a variety of sources whose validity is uncertain [7].

Tractor-trailers are highly visible on the highway system. Combination trucks[3], which include the various tractor-trailer combinations and also tractors not pulling trailers (bobtails), account for less than 1 percent of the registered vehicles but almost 5 percent of the total vehicle-miles traveled (VMT). Whereas the average passenger vehicle accumulates a little under 11,000 miles of travel per year, combination trucks accrue an average of 60,000 miles per year [1].

Nationwide between 1980 and 1990, it appears that the number of fatal crashes involving combination trucks is decreasing somewhat while VMT is increasing. These trends are shown in Table 1. It is also evident that the occupants of combination trucks, when involved in a fatal crash, account for a small percentage of the total number of fatalities. Both the involvement rate and occupant fatality rate for combination trucks can be calculated from the data in Table 1. These rates are displayed in Figures 1 and 2, along with the respective rates for passenger vehicles[4]. Combination trucks tend to be

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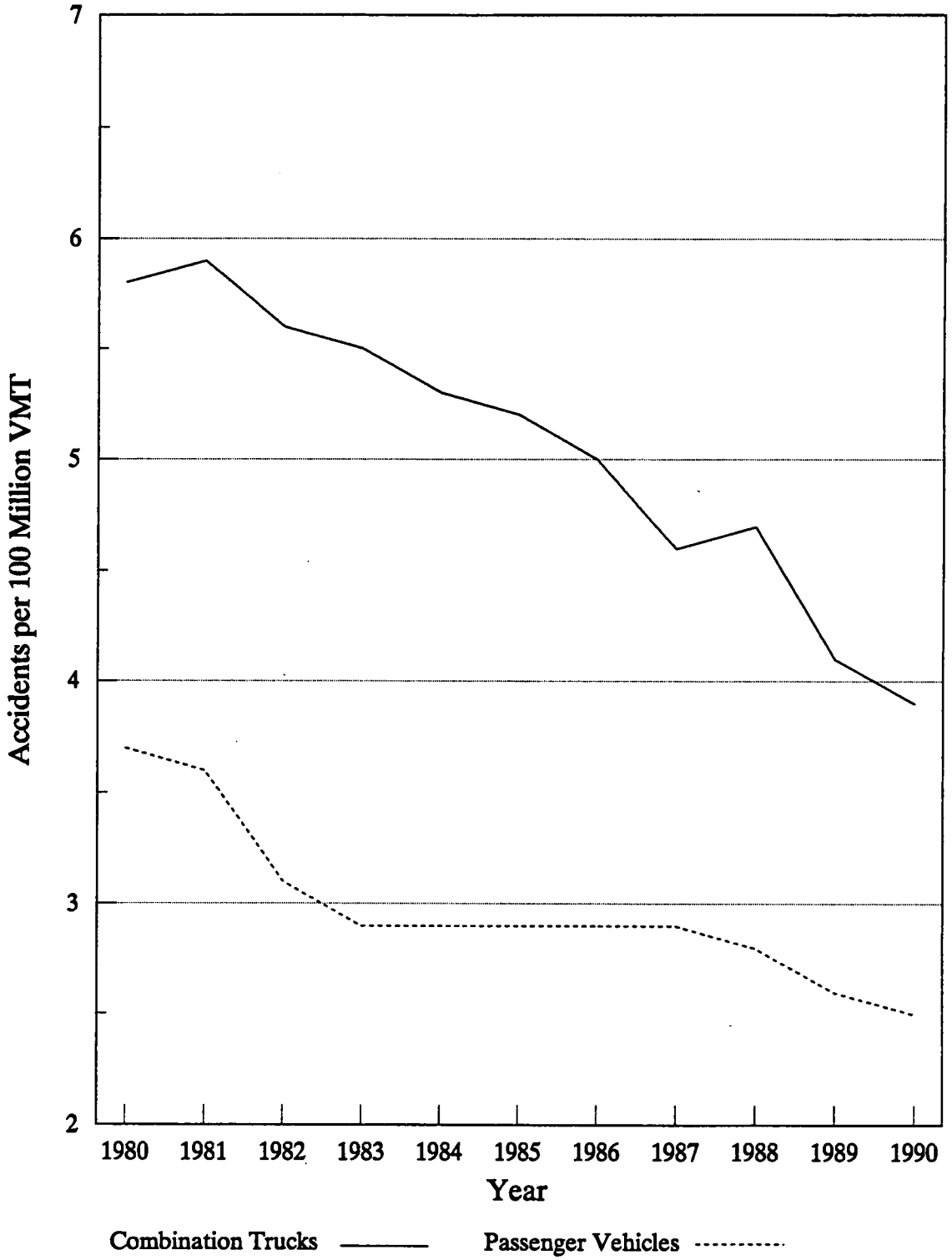
[3]Sufficient data specific to tractor-trailers only were difficult to locate. The data are instead usually presented in terms of combination trucks, which includes all the tractor-trailer combinations as well as bobtails. Assuming bobtails to represent a small portion of the total, the data for combination trucks may be used, roughly, as a surrogate for tractor-trailer data.

[4]Passenger vehicles have a gross vehicle weight rating (GVWR) of 10,000 pounds or less. They typically include passenger cars, light pickup trucks, light vans, and utility vehicles.

Table 1. Combination Trucks Involved in Fatal Crashes and Vehicle-Miles Traveled

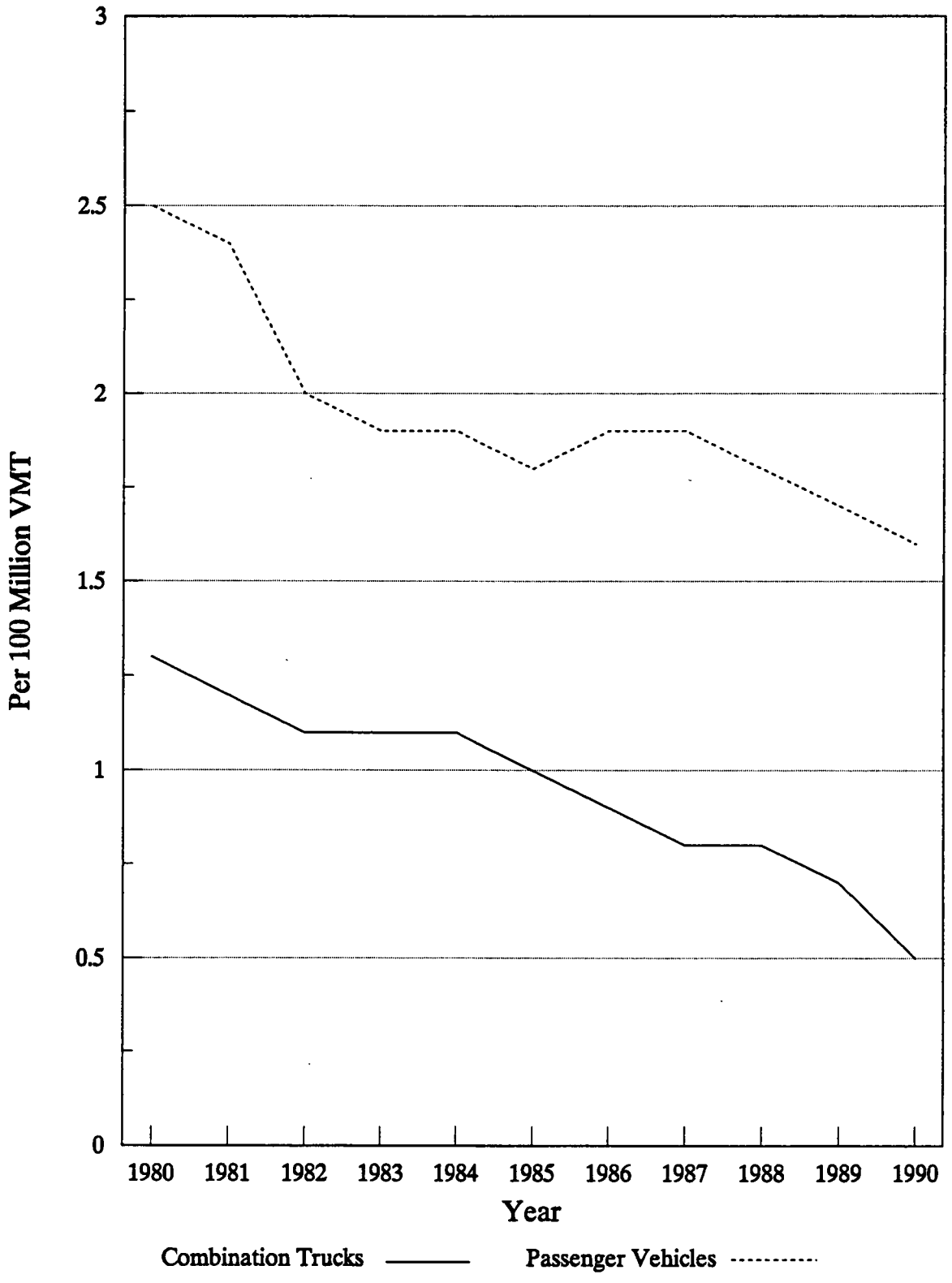
Year	Number of Fatal Crashes	Combination Trucks Involved	Truck Occupant Fatalities	Total Fatalities	Vehicle-Miles of Travel (Millions)
1980	3,731	3,957	904	4,473	68,678
1981	3,863	4,070	850	4,594	69,134
1982	3,519	3,708	744	4,226	66,668
1983	3,645	3,839	756	4,365	69,754
1984	3,907	4,122	872	4,605	77,367
1985	3,892	4,124	772	4,655	79,600
1986	3,825	4,060	718	4,493	81,833
1987	3,746	3,971	675	4,403	86,064
1988	3,939	4,212	731	4,609	90,158
1989	3,680	3,909	671	4,372	95,349
1990	3,574	3,771	521	4,206	96,482

Source: *Summary of Medium & Heavy Truck Crashes in 1990*, National Highway Traffic Safety Administration, U.S. Department of Transportation, February 1993.



Source: *Summary of Medium & Heavy Truck Crashes in 1990*
National Highway Traffic Safety Administration, U.S. DOT, February 1993

Figure 1. Vehicle Involvement Rates in Fatal Crashes by Vehicle Type and Year



Source: *Summary of Medium & Heavy Truck Crashes in 1990*
National Highway Traffic Safety Administration, U.S. DOT, February 1993

Figure 2. Occupant Fatality Rates by Vehicle Type and Year

involved in fatal accidents at a higher rate than passenger vehicles, yet the occupants of these trucks are less likely to be fatally injured than the occupants of passenger vehicles. However, caution should be exercised when drawing conclusions based on a comparison of truck and passenger vehicle crashes. Differences in the drivers, the vehicles, and the environment in which they typically operate make such comparisons unreliable.

While the number of fatal crashes involving combination trucks is decreasing, injury crashes are on the rise. Table 2 presents the number of vehicles involved in crashes by severity for both combination trucks and passenger vehicles while Table 3 displays the respective involvement rates. The injury and property damage only data for both vehicle types are actually estimates that are based on a sample of crashes. However, the increases and decreases in the number of yearly crashes associated with these estimates were tested at the 95 percent level of statistical significance [1].

More recent tractor-trailer accident data in Tennessee were also available. The data are presented in Table 4 by crash severity for 1990 through 1992. However, information indicating vehicle-miles of travel for tractor-trailers was not available and therefore accident rates could not be obtained. As Table 4 indicates, fatal crashes involving tractor-trailers account for about 2 percent of all tractor-trailer crashes occurring in Tennessee. A similar percentage exists for combination vehicles on a nationwide basis.

The review of tractor-trailer safety would be incomplete without considering the operating characteristics that influence safety levels. These characteristics are embedded in driver, vehicle, and roadway environment variables that are, to some extent, reflected

Table 2. Vehicles Involved in Crashes by Vehicle Type and Crash Severity

Crash Severity	Year	Combination Trucks	Passenger Vehicles
Fatal	1988	4,212	52,263
	1989	3,909	51,110
	1990	3,771	49,573
Injury	1988	49,000	3,454,500
	1989	55,500	3,357,000
	1990	55,500	3,332,500
Property Damage Only	1988	159,000	7,180,000
	1989	169,000	6,880,000
	1990	153,000	6,711,500

Source: *Summary of Medium & Heavy Truck Crashes in 1990*, National Highway Traffic Safety Administration, U.S. Department of Transportation, February 1993.

Table 3. Vehicle Involvement Rates by Vehicle Type and Crash Severity

Crash Severity	Year	Combination Trucks[a]	Passenger Vehicles[a]
Fatal	1988	4.7	2.8
	1989	4.1	2.6
	1990	3.9	2.5
Injury	1988	54	185
	1989	58	174
	1990	58	168
Property Damage Only	1988	176	384
	1989	177	356
	1990	159	339

[a]Involvement rate per 100 million vehicle-miles of travel.

Source: *Summary of Medium & Heavy Truck Crashes in 1990*, National Highway Traffic Safety Administration, U.S. Department of Transportation, February 1993.

Table 4. Tractor-Trailer Crashes in Tennessee by Crash Severity

Crash Severity	Year	Tractor-Trailer Crashes	Percent of Tractor-Trailer Crashes
Fatal	1990	83	2
	1991	75	2
	1992	66	1
Injury	1990	1,292	28
	1991	1,206	28
	1992	1,217	28
Property Damage Only	1990	3,278	70
	1991	3,021	70
	1992	3,130	71

Source: State of Tennessee Motor Vehicle Accident Database

in accident statistics. Particular emphasis is given to the driver- and roadway environment-related variables as they are likely to be affected most by a switch from over-the-road trucking to intermodal transport.

Operating a tractor-trailer over-the-road is very demanding. The drivers are legally permitted to drive for 10 hours or be on-duty as much as 15 hours before being required to go off-duty for an 8 hour period. The drivers' schedules often requires them to stay on the road three to four weeks at a time. Thus, it is not unusual for drivers to be off-duty only three or four days a month at their home terminals. In addition, over-the-road tractor-trailer drivers are often faced with delivery deadlines. If they do not "make the window" (e.g. deliver the shipment within the specified time period), future business with the customers will likely be in jeopardy. Both prompt and on-time delivery standards often necessitate that the drivers operate for extended periods of time and/or travel at excessive speeds.

In addition to these demands, over-the-road drivers must also be cognizant of the different operating characteristics of their vehicles relative to passenger vehicles. These characteristics even vary among tractor-trailers, according to their shape, configuration, and weight. Unfortunately, the performance characteristics of these trucks appear to be largely not understood by the majority of the motoring public [8]. This makes the truck drivers' job increasingly difficult.

One of the major concerns regarding the safety of over-the-road tractor-trailers is driver fatigue. According to the American Automobile Association Foundation for Traffic Safety, fatigue was judged a probable cause in 41 percent of heavy truck

accidents [9]. Fatigue was the most frequently cited probable cause or factor (31 percent) in the National Transportation Safety Board (NTSB) fatal-to-the-driver heavy truck accident investigation [9]. Surveys of truck drivers support these findings. The 1989 Regular Common Carrier Conference (RCCC) survey of truck drivers revealed that driver fatigue was the cause of an estimated 36 percent of truck accidents [10]. Also, driver fatigue was mentioned as one of the two most important factors in truck accidents according to a survey by Patten et al. of truck drivers in Pennsylvania [8].

The long driving hours required, the frequent need to drive at night, and the highly irregular driving schedules are all conditions that can contribute to driver fatigue. Research indicates that accident rates for trucks increase dramatically beyond 8 hours of continuous driving [9]. Driving at night is also a high risk action for truck drivers as truck accidents peak between midnight and 6 a.m. [11,12]. The probable cause for this occurrence is that a truck driver's body may not be accustomed to these hours. The body operates according to a circadian, or 24-hour, cycle that includes regular, defined periods of rest [13].

Lin et al. recently analyzed the effect of driving schedule on accident risk using data from one national motor carrier [14]. Driving time had the strongest direct effect on accident risk. Risk was lowest during the first four hours of driving, and it then increased by about 50 percent until the seventh hour of driving. The eighth and ninth hours of driving showed even greater increases. The nature of drivers' operating schedules also had an effect on accident risk. Daytime driving had the lowest risk, while

infrequently scheduled drivers and individuals who do some of their driving at night exhibited higher risk levels.

In broad terms, length of haul may influence accident occurrence. The U.S. Government Accounting Office (GAO), in a study to predict motor carriers' safety risks, sampled accident and mileage totals for 537 carriers and classified their average haul lengths into one of four categories [15]. Carriers with average haul lengths of 500 to 750 miles had the highest group accident rate, which was about 9 percent above the accident rate for the entire sample. The second highest group accident rate was for carriers with average haul lengths greater than 750 miles. This group's rate was 2 percent above the entire sample rate. Carriers with average haul lengths between 250 and 500 miles and those with less than 250 miles had accident rates below the rate for the entire sample (3 and 4 percent, respectively). The sample consisted of relatively large, interstate, for-hire, ICC-regulated carriers and, consequently, the findings cannot be applied to the trucking industry as a whole.

Because of the demands placed on over-the-road tractor-trailer drivers and other factors, retaining qualified drivers is becoming increasingly difficult. Motor carriers may have to rely on younger and less experienced drivers. Drivers of commercial motor vehicles that operate in interstate commerce must be at least 21 years old, yet evidence has shown that young truck drivers are a high risk group. An analysis by the GAO found that drivers with an age between 21 and 39 years were at the highest risk of being involved in an accident. This group was 1.3 times more likely to be involved in an accident than the 40-49 age group and 1.6 times more likely than drivers of age 50 and

above [15]. However, information on the actual mileage driven by each group was not available and thus these rates could not be adjusted for exposure levels.

Inexperienced drivers are also at a higher risk of being involved in an accident. The same GAO study found that truck drivers with 13 or fewer years of driving experience were 1.3 times as likely to be involved in an accident as those with 14-20 years of experience and were 1.6 times as likely to have an accident compared to drivers with more than 20 years of experience [15]. Lin et al., in their study of driver service hours and accident risk, found that drivers having more than 10 years experience consistently had the lowest accident risk when their driving times were kept under 9 hours [14]. Drivers with 1 to 5 years of driving experience consistently had the highest risk. Those with less than one year of experience were better suited for longer driving periods (at least 7 hours) when compared to those with 5 to 10 years of experience.

Roadway environment factors are also key elements in safety analysis as the prevailing geometry of the roadway can create situations where errors are less tolerable, making an accident more likely. The functional class of a roadway, which accounts for geometrics, has a significant effect on single-trailer accident involvement rates. As Table 5 illustrates, the higher functional classes in both the rural and urban settings generally exhibit lower involvement rates for both fatal and injury producing accidents. Focusing on the number of fatal accidents, the 1990 FARS database revealed that two-thirds of the fatal crashes involving a combination truck occurred in rural areas and one-third in urban areas. About 38 percent of the fatal crashes occurred along rural Interstates and other principal arterials while 24 percent occurred along urban Interstates, freeways,

Table 5. Single-Trailer Accident Involvement Rates[a] by Highway Function Class

Functional Class	Fatal	Injury
Rural:		
Interstate	1.87	25.53
other principal artery	3.80	31.43
minor arterial	6.49	41.65
major collector	13.67	50.12
Urban:		
Interstate	2.23	52.73
other principal artery	9.52	103.41
local	27.79	55.59

[a]Involvement rate per 100 million vehicle-miles of travel.

Source: Federal Highway Administration, "Monitoring Operations of Larger Dimension Vehicles Report," Jan. 14, 1987.

expressways, and other principal arterials. These findings are shown in Table 6, along with the distribution for passenger vehicles.

Accounting for vehicle-miles of travel, combination trucks involved in fatal crashes have higher involvement rates in rural areas than in urban areas. However, their involvement rates in both injury crashes and property damage only crashes are higher in urban areas. The findings are similar for passenger vehicles. Table 7 displays these involvement rates, while Table 8 shows the number of vehicles involved in crashes by crash severity and land use.

Of great interest is assessing the degree to which intermodal transportation can address some of these safety concerns. On the surface, it would appear that widespread use of intermodal services would reduce the incidence of fatigue. Intermodal transportation substitutes rail service for the line-haul portion of the over-the-road truck trip. Therefore, truck drivers would not be needed to drive such long distances, trip after trip. There may also be less need to drive at night or on an irregular basis.

Another impact that intermodal may have on tractor-trailer safety is reflected in the motor carrier industry's ability to retain qualified drivers. The demands associated with over-the-road driving contribute to the high turnover rates. J.B. Hunt, a motor carrier who has pioneered the use of intermodal services in the truckload industry, reports an annual turnover rate for its over-the-road drivers of about 95 percent, compared to just 30 percent for regional routes [16]. By concentrating on shorter routes, motor carrier management may be able to retain the types of drivers that exhibit low-accident risk traits (e.g. experienced, middle-aged drivers).

Table 6. Vehicles Involved in Fatal Crashes by Roadway Function Class

Roadway Function Class	Combination Truck	Percent	Passenger Vehicle	Percent
Rural:				
Interstate	596	16	2,612	5
Other Principal Arterial	823	22	5,111	10
Minor Arterial	641	17	6,236	13
Major Collector	373	10	7,662	15
Minor Collector	52	1	1,830	4
Local Road or Street	83	2	4,009	8
Unknown	1	*	19	*
Total Rural	2,569	68	27,479	55
Urban:				
Interstate	388	10	2,492	5
Other Freeway/Expressway	128	3	2,178	4
Other Principal Arterial	402	11	7,825	16
Minor Arterial	180	5	4,594	9
Collector	28	1	1,501	3
Local Road or Street	65	2	3,343	7
Unknown	0	0	5	*
Total Urban	1,191	32	21,938	44
Unknown Urban or Rural	11	*	156	*
Total	3,771	100	49,573	100

* Less than 0.5%

Source: *Summary of Medium & Heavy Truck Crashes in 1990*, National Highway Traffic Safety Administration, U.S. Department of Transportation, February 1993.

Table 7. Vehicle Involvement Rate[a] by Land Use

Vehicle Type	Urban	Rural	Average
Fatal Crashes			
Combination Trucks	3.5	4.1	3.9
Passenger Vehicles	1.8	3.6	2.5
Injury Crashes			
Combination Trucks	119	24	58
Passenger Vehicles	216	92	168
Property Damage Only Crashes			
Combination Trucks	327	67	159
Passenger Vehicles	423	205	339

[a]Involvement rate per 100 million vehicle-miles of travel.

Source: *Summary of Medium & Heavy Truck Crashes in 1990*, National Highway Traffic Safety Administration, U.S. Department of Transportation, February 1993.

Table 8. Vehicles Involved in Crashes by Crash Severity and Land Use

Crash Severity	Urban	Percent	Rural	Percent
Fatal Crashes:				
Combination Trucks	1,191	32	2,569	68
Passenger Vehicles	21,938	44	27,479	55
Injury Crashes:				
Combination Trucks	40,500	73	15,000	27
Passenger Vehicles	2,620,500	79	712,000	21
Property Damage Only Crashes:				
Combination Trucks	60,000	73	42,000	27
Passenger Vehicles	5,131,000	76	1,580,500	24

Source: *Summary of Medium & Heavy Truck Crashes in 1990*, National Highway Traffic Safety Administration, U.S. Department of Transportation, February 1993.

The last major tractor-trailer safety impact associated with greater use of intermodal services that is considered here is the effect of road functional class on accident experience. Fatal crashes involving tractor-trailers are most prevalent along interstates and other roadways with limited access, especially in the rural environments. Yet, a significant portion of their mileage is accumulated on these segments and is thus reflected in their fatal accident involvement rates. By eliminating the line-haul portion of the over-the-road trip, tractor-trailer vehicle-miles of travel would be reduced significantly over these road segments and with it, likely, the number of fatal crashes. At the other end of the functional classification scheme, roads having considerable access account for a small percentage of the fatal crash involvements but possess high involvement rates. Increased use of intermodal services would necessarily require additional drayage movements, which could result in a greater number of crashes occurring on the local road networks.

Having considered the tractor-trailer safety concerns, the characteristics that influence safety, and how intermodal transportation can address some of these characteristics, attention is now given to the domestic intercity freight market and the two principal competing modes--truck and rail.

The Rail/Truck Intercity Freight Market

Together, the rail and trucking industries competed for 6.578 billion tons of domestic intercity freight in 1992. Trucks captured 2.854 billion tons for a 43.4 percent share of the total market while the railroads hauled 1.646 billion tons which represents

one-fourth of the market. Pipeline and water account for the rest of the intercity freight market [17].[5] With some exceptions, it is thought conceivable for rail to be physically able to haul any commodity transported by truck, and vice versa. However, cost and service factors usually dictate a preference for one mode over the other.

Freight transported by truck is usually of higher value and is more service sensitive relative to its rail counterpart. The higher dollar value represents shippers' concerns about susceptibility to damage during transport. Trucks generally offer a smoother ride compared to conventional rail and also require less handling of the cargo. The service provided by the trucking industry is usually thought to be of higher quality relative to the railroads. Trucks excel in providing door-to-door service with a dependable delivery time. Their loss and damage record is superior to the railroads and they are better able to trace a shipment if requested to do so.

While the trucking industry can tout its ability to provide superior service, the railroads can usually claim an advantage in price. The ability of the railroads to offer a low price is nested in their relatively large economies of scale. In other words, adding a few cars to a train already operating between two points does not significantly increase cost. However, the "slack action" associated with the movement of a train and the frequent need to reclassify freight shipments in yards can result in damage or even loss of freight. Commodities shipped via rail are therefore usually of low value and/or bulk.

A compromise between rail and truck is intermodal. This alternative combines the high service offered by the trucking industry with the low cost advantages of the

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[5]Air freight is negligible in terms of tonnage.

railroads. Intermodal involves one or more motor carriers providing the short-haul pickup and delivery service and one or more railroads providing the long-haul. It offers the opportunity for railroads to attract medium and high value freight while providing the long-haul trucking companies a chance to reduce their operating costs. Intermodal is not a new concept, having been first introduced in the 1920's. However, recent improvements have made it a more viable option. Although intermodal only captures about 3 percent of the $199 billion intercity freight market, its share of the over 500 mile sector of that market was 15 percent in 1990 and is projected to be at 20 percent by 1993 [18].

Competitiveness From Within The Trucking Industry

The trucking industry is broken down into different segments to better capture the varying degrees of competitiveness with intermodal. These segments include the parcel, private, less-than-truckload (LTL), and truckload (TL) carriers [6].

Parcel Carrier

Parcel carriers, such as United Parcel Service (UPS), are highly specialized in terms of the cargo they carry. They are competitive with LTL carriers in the smaller shipment size ranges and use intermodal quite extensively in intercity trailer markets [6]. In fact, UPS is the largest single user of intermodal, accounting for about 9 percent of the intermodal shipments in 1991. Future intermodal usage by UPS is expected to be in line with company growth [19].

Private Carrier

Private carriers are not in business for the purpose of hauling freight, rather they elect to move the goods they produce or sell. Private truck fleets are used mainly to handle pick-up and delivery and to move shipments that require special service or handling [6]. Private carriage is usually restricted to short haul movements and therefore the opportunities to use intermodal are limited. Private fleets account for 31 percent of the motor carrier business [20].

Less-Than-Truckload Carrier

Less-than-truckload carriers are those that haul multiple small-sized shipments in a single trailer (e.g. each shipment alone would not completely fill a trailer). The individual shipments are picked-up from the shippers and brought to a terminal for consolidation into full truckload quantities. Cargos with similar destination points are loaded into the same trailer for carriage to another terminal. The shipments are then separated (a process known as break-bulk) and individually transported in smaller delivery trucks to the consignee. Thus, LTL carriers operate using an array of terminals (similar to the hub-and-spoke system used by airlines) for the purpose of transporting small-sized shipments. However, an LTL carrier can still accept a full trailerload shipment if it chooses to do so.

The structure of the LTL companies provide excellent opportunities for using intermodal service. Specifically, intermodal can be used for the longer hauls between their hubs, especially during times of shipment imbalances. This practice allows LTL

carriers to accommodate additional business without having to invest in new equipment or hire more drivers.

Despite these excellent opportunities, LTL companies have had limited success tapping into the intermodal market. The four largest companies report using intermodal for between 3 and 8 percent of their line-haul miles and they do not anticipate future growth to be dramatic. Recently negotiated Teamster contracts place greater restrictions on the use of intermodal by LTL carriers. For example, a load can be required to go by truck if a driver and equipment are available within a two hour time period [19].

Truckload Carrier

Truckload carriers transport shipments tendered by the shipper in full truckload lots directly from the point of origin to the final destination [6]. At $8.2 billion, the long-haul truckload sector offers the greatest direct competition to the railroad industry, and in effect, intermodal. In fact, as much as 25 percent of the intercity trucking market is susceptible to competition between intermodal and truckload companies, according to a 1987 analysis by the investment banking firm of Alex Brown and Sons [19]. Recent developments between truckload companies and the railroads indicate that intermodal may be gaining ground. In 1990, J.B. Hunt, the nation's second largest truckload carrier (in terms of revenue), agreed to use Santa Fe Railway for part of their line-haul movements. The largest truckload carrier, Schneider International, followed suit in 1991 when it entered into an agreement with Southern Pacific. While both carriers have expanded

their use of intermodal, other truckload carriers are beginning to shift some freight to intermodal.

Despite the recent success of intermodal in long-haul truckload markets, it is doubtful that truckload carriers will use intermodal for all of their line-haul movements. The present growth has occurred mainly in the West, with the Chicago-West Coast traffic lane representing the largest share. This is because the greater distances between western markets make movement by rail more economical than by over-the-road truck. East of the Mississippi River, intermarket distances are smaller and trucks can usually claim the advantage. Another limitation to greater usage of intermodal by truckload companies may be the size of the market. The third largest truckload carrier, Werner Enterprises, has been hesitant to adopt intermodal, citing a diverse market filled with many niche opportunities that are not compatible with intermodal at present [21]. Also, many of the smaller truckload companies could find it difficult integrating intermodal service into their operations. An intermodal movement requires drivers and equipment at both ends and small companies usually lack the required network [19].

Intermodal Opportunities Within the Rail Industry

The railroads have been engaged in intermodal for quite some time yet only recently has this service began to attract the shipper's eye. In the past, both trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) have been used extensively by railroads. However, the commodities shipped have generally not been truck competitive (e.g. low-value freight transported long distances and requiring short drayage). Sparking the new

interest among shippers has been the railroads commitment to providing better service while still offering a low price. Improved flat car design has helped reduce the "shake, rattle, and roll" effect experienced by the commodities shipped TOFC and the ability to stack two containers on one flatcar (doublestack) has allowed the railroads to lower their rates ("two for the price of one effect"). Refocusing on the ability of the boxcar to move freight directly from the shipper's warehouse to the receiver (rail transloading) is another opportunity. Finally, new intermodal technologies such as the Iron Highway appear capable of penetrating both the short-haul and low-volume markets that trucks currently dominate. All of these offer promise for the railroad industry and are thus examined in this section.

TOFC/COFC/Doublestack

For years, both TOFC and COFC were the backbone of intermodal. Both of these services did pose some problems for shippers, though. In particular, TOFC was often criticized for poor ride quality that often resulted in damage to the freight. Also, the railroads had a difficult time meeting shippers' demands on travel time and on-time performance measures for both TOFC and COFC movements. However, improved car design, a change in attitude, and the emergence of the railroads to move marine freight inland from ports on the West Coast (bypassing the Panama Canal) has had a profound effect on the TOFC/COFC services that they provide. Fueling the railroads success in capturing the marine container market has been the advent of doublestack technology. Instead of hauling a single container on a flat car, railroads can now haul two containers

per car without significantly increasing cost. Because of the United States' large trade deficits with the Pacific Rim countries, there has been more marine freight moving west to east across the United States than east to west. To avoid empty backhauls, the railroads sought to fill the containers returning west with domestic freight. The ability of the railroads to offer relatively low rates on the backhaul has enabled them to capture domestic traffic. Thus "domestic containerization" was born, causing a decrease in the use of COFC (except where overhead clearances do not permit the use doublestack) and is beginning to cause railroads to switch from trailers to containers. Railroads are finding that containers are easier to lift on and off rail cars and they also provide greater protection against vandalism and/or theft relative to trailers. In short, COFC is being replaced with doublestack where clearances permit and TOFC is also being phased out in favor of containers.

Rail Transloading

The use of boxcars has steadily declined over the years, but a practice known as rail transloading may stem the tide. Rail transloading involves loading large shipments of a commodity into boxcars directly at the manufacturing plant for travel to a warehouse in the vicinity of the destination. At the warehouse, the commodity is "transloaded" into trucks for delivery to a number of separate consignees. Thus, rail transloading is similar to a traditional intermodal movement but it is without the necessary drayage on the front-end. This technique is well suited to manufacturers who ship truckload-sized lots to a number of receivers all located within the same region. It also offers shippers an

opportunity to "forward position" their inventory to a location that is only a short distance from the final users. Ultimately, the ability to forward position freight may enhance just-in-time processes [6].

New Intermodal Technology

A number of improvements in rail car design offer tremendous opportunities for intermodal by making this service more viable in the short-haul and low volume markets. Specific intermodal technologies currently being developed or just entering into service include the Iron Highway, RoadRailer, and the stand-alone doublestack car. Each technology is introduced below.

Iron Highway: The Iron Highway is the name given to a radically new train design that is intended to offer the transportation customer a cost effective and service equivalent alternative to the concrete highway [22]. Instead of the usual train concept that most people are accustomed to, the Iron Highway is a 1,200 foot long continuous platform (referred to as an element) articulated at 28 foot intervals. Connected to each end of the "element" is an AC powered control cab. Any size trailer or container may be loaded onto the platforms. Trailers or containers on chassis can be loaded using a truck tractor or hostler vehicle while containers without chassis are loaded using traditional gantries or cranes [23]. A split ramp in the center of the element provides two loading ramps. This splitting can be easily accomplished with one man operating a hand-held control box that plugs into the ramp. The system thus forms a continuous deck for rapid roll-on, roll-off loading [24].

There are a number of advantages associated with the Iron Highway that are not available with conventional trains. These advantages are intended to translate into greater market share for the railroads at the expense of over-the-road trucking operations. Among the benefits are [22]: better ride quality which should reduce damage and increase customer satisfaction, lower maintenance and fuel costs, and the ability to accommodate varying trailer and container sizes. The split ramp design used for loading and unloading of trailers and containers on chassis permits two hostler tractors to work an element at the same time, and the distance each much travel is cut in half compared to conventional loading/unloading methods. Because of these efficiencies, twenty trailers can be loaded in fifty minutes while the same number of trailers can be unloaded in thirty minutes. Another advantage is the low cost and relative ease of establishing a terminal. All that is needed is approximately 100 feet of pavement level to the rail. Terminals can thus be established quickly at key locations to reduce drayage times.

The Iron Highway is expected to be cost competitive with over-the-road trucks at distances as low as 350 miles [23]. The service is currently undergoing testing and will then be made operational by CSX Intermodal.

RoadRailer: RoadRailer is the name given to a trailer that contains two different sets of wheels--a steel set used in train operations (referred to as bogies) and a set of rubber tires for use on the highways. An early version of the RoadRailer incorporated a retractable bogie, allowing the trailer a quick transition from the tracks to the highway. However, shippers complained that the higher tare weight of the RoadRailer equipment reduced load capacity. The current version uses detachable wheels that are stored at rail

terminals, thus making the RoadRailer trailer more similar to conventional highway trailers. The RoadRailer concept was tried by a number of railroads during the 1980s but only Norfolk Southern has consistently embraced the service. RoadRailer trains currently operate over a network that includes St. Louis, Kansas City, Chicago, Detroit, Toronto, Buffalo, Atlanta, Jacksonville, and Bellevue, Ohio. In 1987, Norfolk Southern carried 25,000 loads using its RoadRailer equipment. By 1991, 112,000 loads had been carried. The average haul with RoadRailer equipment is 732 miles, although Norfolk Southern believes the service is competitive at distances as low as 400 miles [19]. Some believe that RoadRailer has the potential to almost double rail's share of time-sensitive goods. This would be the equivalent of attracting about 20 percent of the over 250 mile intercity market back to rail [25].

One of the more recent developments involving the RoadRailer service is a joint venture between Norfolk Southern and Conrail. The venture will integrate Norfolk Southern's RoadRailer service with Conrail's doublestack service to give combined access to states having 80 percent of the nation's consuming population. The new network will form a triangle linking the Northeast, Southeast, and Midwest, thus providing two forward-haul opportunities for each back-haul shipment [26].

One of the advantages of the RoadRailer service is its ability to simplify terminal operations. Unlike containers, no lift equipment is needed and thus capital costs can be kept to a minimum. In addition, the amount of space needed to change wheel sets and load onto rail cars is no more than that currently used in TOFC. Perhaps RoadRailer's

greatest advantage is its ability to accept trailers up to 30 minutes prior to departure whereas current intermodal operations usually impose a 2 hour cut-off time [19].

RoadRailer does have some drawbacks when compared to trailers used on the highway. Most significant is its heavier weight and also higher transport cost. However, a new version has recently been unveiled that is comparable in weight, door opening, and interior capacity to a 53-foot highway trailer [19].

Stand-Alone Doublestack Car: The benefits of doublestack containers were previously discussed. In order to garner the line-haul cost savings of doublestack, railroads need to assemble large trains. However, it can take considerable time to acquire enough freight to fill a large train. As this time increases, railroads begin to lose time sensitive freight. Seemingly, the railroads are forced to compromise between line-haul cost savings and service frequency. Railroads have been able to avoid this dilemma in Western markets where there has been plenty of international freight to fill their trains. Eastern markets do not have the luxury of being able to rely on international freight to satisfy volume requirements. Hence, a more flexible doublestack operation is needed and the stand-alone doublestack car may be the answer.

The primary difference between the stand-alone doublestack car and the standard doublestack car is capacity. The standard doublestack is often built as an articulated five-unit car, capable of hauling ten containers. It is thus ideal for the long, high volume corridors found between the West Coast and Chicago. The stand-alone doublestack car, on the other hand, only has a capacity for two containers. It is thus more suitable for purely domestic corridors, which are often characterized as low volume markets. In

other words, it is much easier to fill two slots every day with domestic freight on a single stand-alone doublestack car for transport on low volume traffic lanes than it would be to fill all ten slots on a five-unit doublestack car [27].

While the stand-alone doublestack car is being highly touted, there are some disadvantages to using this service. The improved flexibility comes at the expense of articulation, which can result in a rougher ride. To overcome this, the couplings are made with very little cushioning, thus requiring additional care when switching. Another disadvantage of these cars is that they are more expensive and heavier, relative to their payload [19].

At present, Norfolk Southern appears to be pioneering the use of the stand-alone doublestack car in the East. In 1992, the railroad initiated a doublestack service between Kansas City and Jacksonville, with stops in St. Louis and Memphis. Norfolk Southern could expand the network to include the following anchor cities: Norfolk, New Orleans, Chicago, and Buffalo. The company believes it can offer this service in markets as small as 500 miles apart [19].

Competition Issues

Recognizing that the safety benefits (reduction in the number of tractor-trailer accidents) can accrue primarily by shifting freight that is currently transported in over-the-road trucks to intermodal, there is a strong need to determine the viability of the intermodal alternative. Three issues have been identified as being critical to the success of intermodal in capturing the over-the-road tractor-trailer market. They are: (1) to what

extent are intermodal services available to shippers and receivers, (2) how does the cost and service quality of intermodal compare with other competing modes, and (3) can intermodal be accepted and used by shippers. Each of these are discussed in detail below.

Availability of Service

A unique feature of intermodal apart from transport using only a single mode is the intermodal terminal. The terminal serves as the interface between railroads and trucking companies and therefore its proximity to the user is very important. Theoretically, intermodal becomes more attractive as the line-haul portion of the trip accounts for a greater percentage of the total trip distance. Therefore, as the distance between the terminal and the user increases, intermodal becomes less attractive as both the transit time and cost of providing the service increase. Compounding the problem is the need for the terminal to be convenient to both the shipper and receiver. Without good access at both ends, intermodal essentially becomes impractical [28].

It would appear that an obvious solution would be to increase the number of terminals available to potential intermodal users. However, building new terminals require large capital investments by the railroads and once running, their operational costs are significant. In fact, many of the railroads that engage in intermodal activities have reduced their number of terminals, citing efficiency reasons [28]. In 1975, there were about 1,500 intermodal terminals in the United States while by 1990, that number had dropped to about 230 [19].

Closely related to the users' proximity to the intermodal terminals is the availability of both the railroads and drayage firms for a particular market. The origin-destination pair may not be served by a single railroad nor the same drayage operator at both ends. The willingness of other carriers to participate in the intermodal move then becomes a major factor. It is quite possible that a given traffic lane will not be available to a potential intermodal user. Even when arrangements can be made to use multiple carriers, the customer may have to pay a higher price, reflecting each carrier's desire for a share of the service provided. The quality of service received by the customer is also likely to not be as good.

Perhaps most importantly, shippers and receivers have to be aware of the intermodal opportunities available to them. Potential users could have good terminal proximity and available traffic lanes, but if they are unaware of the intermodal alternative then in a sense the service is not available to them [28]. Unfortunately, many shippers report being "left out in the dark" with respect to intermodal marketing efforts. A 1991 survey of shippers' intermodal use and perceptions conducted by Mercer Management Consulting, Inc. revealed that intermodal companies have a long way to go to match the marketing efforts of the motor carriers. Of the shippers polled who use a motor carrier, 70 percent indicated that they had received sales calls in the past year from that carrier. Less than 20 percent could say the same thing about their intermodal providers. Additionally, 35 percent reported that they had received calls from motor carriers looking for their business, while only 7 percent had been contacted by prospective intermodal

providers. Perhaps most damaging, one-third of the respondents indicated that they had never received a sales call about intermodal [29].

Cost and Service Issues

Assuming that intermodal is available to customers, the next question that needs to be answered is whether or not intermodal is cost and service competitive with over-the-road trucking. Both the cost and service components are typically examined by potential intermodal customers, with the two often weighed against each other before arriving at a decision.

Cost has always been an important factor in the marketing of transportation services in the United States as users of transportation are often very price conscious [28]. In difficult economic times, customers place greater emphasis on cost. As John McQuaid, president of the Intermodal Association of North America, indicated [30]: "Shippers historically have taken a somewhat harder look at their shipping costs during tough economic times. And over the last two years, that has obviously led many of them to intermodal."

Intermodal generally enjoys a price advantage compared to over-the-road trucking, especially as the length of haul increases. According to a 1991 study by Temple, Barker & Sloane: 38 percent of intermodal is offered at approximately 10 percent off comparable truck rates, another 20 percent is between 11 percent and 20 percent less, and 42 percent has rates that are 20 percent below what truckers charge [18]. This price advantage can become a major selling point when intermodal has a service handicap.

Customers place great importance on the quality of service provided by carriers. A 1992 survey of shippers on their use of intermodal services revealed that quality of service was the most important factor in their choice of mode [31]. The results of that survey are shown in Table 9. Hence, in order for intermodal to be used extensively, the service must be of sufficient quality to be competitive with over-the-road trucking companies. Interestingly, service is very difficult to quantify and as a result shippers do not have in place a formal method for evaluating service quality. In fact, the survey revealed that only 31 percent measure the performance of their transportation-service providers. As Dean Wise, Vice President of Mercer Management Consulting, the firm who conducted the survey, indicated [31]: "Clearly their (shippers) decisions about intermodal use aren't being made on a scientific basis...[T]hey're going on gut feelings..."

Again referring to Table 9, it is interesting to note that safety was not specifically included among the criteria listed. It may be that safety aspects are accounted for in some of the other factors. Another possibility is that shippers are not concerned with the safety consequences of cargo in transport, and instead only focus on those considerations which involve them directly.

Without analyzing specific service quality issues, it is difficult to imagine intermodal exceeding the service standards of the over-the-road motor carriers. Intermodal, by definition, requires the transfer of cargo between at least one railroad and one motor carrier, which presents more opportunities for problems to develop than if the shipment was transported using only a single carrier. The goal then, could be to provide

Table 9. What Shippers Consider When Choosing a Mode

Criterion	Importance Rating[a]
Quality of Service	94 %
Service Reliability	93 %
Quality of Pickup	91 %
Availability of Equipment	90 %
Customer-Service Quality	87 %
Door-to-Door Transit Time	86 %
Ease of Doing Business	86 %
Likelihood of Damage	85 %
Low Risk of Service Failure	85 %
Price	84 %
Freight Bill Accuracy	83 %
Equipment Availability	81 %
Payment of Damage Claims	78 %
Information on Shipment Status	68 %
Equipment Dimension/Size	59 %
Quality of Salespeople	59 %
EDI Capability	33 %

[a]Percentage of respondents rating the criterion 4 or 5 on scale of 1 to 5, with 5 being "very important."

Source: *Traffic Management*, April 1993.

a quality of service that is as a minimum, acceptable to the customer to the point that the cost savings of intermodal can make a difference.

There are a number of specific service issues where intermodal is at a disadvantage, including transit time, frequency and reliability of service, loss and damage, and liability. Slower door-to-door transit time is perhaps one of the primary disadvantages of intermodal. A truckload shipment moves directly from door-to-door whereas an intermodal move is routed through railroad terminals at each end. These terminals are not always close to the users, thus requiring long drayage times. Also, the line-haul portion of the trip on rail is sometimes more circuitous than via highway. If more than one railroad is involved in the line-haul, additional time is usually required to interchange the shipment [32].

Because of the obvious differences in capacity between a train and a truck-trailer, trains usually cannot depart as frequently as individual trucks, especially in low volume markets. Therefore, small shippers that require immediate transportation services may find over-the-road motor carriers more suitable than intermodal providers. On a related note, a shipper who narrowly misses the cut-off for a daily intermodal movement will have to wait 24 hours for the next departure.

Service reliability is another concern of intermodal users. With so many industries employing just-in-time procedures, many receivers are demanding narrow delivery windows, some as small as 15 minutes. If the carrier fails to deliver in the specified time period, production processes can be disrupted. While on-time performance of intermodal has been improving, it is still below truckload standards.

The extra handling associated with the transfer of cargo between road and rail makes the freight transported in intermodal more susceptible to damage than by over-the-road truck. Damage has been reduced significantly in recent years through the introduction of articulated cars with "wells" that reduce slack action and lower a shipment's center of gravity. However, the damage issue is still a hindrance [32].

When freight is damaged in intermodal transport, questions can arise as to which carrier is liable. Generally, it depends upon at what point in the trip the damage occurred and this can be difficult to determine [32].

Acceptance and Use by Shippers

The final issue critical to the success of intermodal concerns shippers' perceptions about intermodal service. An intermodal provider may view a particular shipper to be in a strong position to use intermodal (e.g. has close proximity to facilities and is in line to receive high quality service at low cost), yet if the shipper perceives any of these or other characteristics to be unsatisfactory, for whatever reason, then the intermodal option will not be exercised. Additionally, certain shipper traits may preclude widespread use of intermodal services. The size of the shipper's operation and the types of products marketed are two such traits [28].

Many shippers have been reluctant to give intermodal another try, citing past damage problems experienced from the old TOFC cars that had high centers of gravity. But TOFC service has improved, at least enough to the point that major truckload carriers like Schneider International and J.B. Hunt are beginning to use railroads for

some of their line-haul moves. This should begin to attract the attention of shippers not currently using intermodal services. However, changing a shipper's perception of intermodal can be very difficult, especially if a bias exists. Unfortunately, the 1991 survey of shippers' intermodal use and perceptions confirmed that shippers that do not use intermodal service firmly believe that it has inherent service disadvantages compared to trucking [29].

Company size appears to have an effect on the use of intermodal, with the larger companies more apt to shift freight from truck to intermodal. Table 10 lists the percentage of companies that shifted freight from truck to intermodal in 1992, according to annual company revenue. One reason for the differences is that big companies require a wider diversity of transportation options to accommodate the large volumes of freight moved [31]. Conversely, smaller companies may only require one type of transportation service. Also, smaller companies may lack the resources to analyze different transportation options. In such cases, the philosophy may be to stick with what works or "if it ain't broke, don't fix it."

Commodity type also has an effect on intermodal use. In general, intermodal has a hard time attracting high-value freight. This should not be too surprising, given shippers' concerns about the extra handling required of intermodal and the greater potential for damage.

Table 10. Effects of Company Size on Intermodal Use

Annual Company Revenue	Percentage[a]
Less than $50 million	27
$50 million to $100 million	26
$100 million to $400 million	33
$400 million to $1 billion	33
$1 billion or more	52
All respondents	31

[a]Percentage of companies--large and small--that have shifted freight from truck to intermodal in the last year.

Source: *Traffic Management*, April 1993.

Future Opportunities and Challenges for Intermodal

In addition to the competitive issues discussed in the previous section, there are a number of other factors that could affect future use of intermodal. Some of the factors present opportunities for intermodal growth while others could prevent intermodal from reaching its full potential. A discussion of these factors is therefore warranted.

Conditions offering promise for the intermodal industry include new opportunities for penetration into the truck dominated short-haul and low volume markets, and the continuing shortage of truck drivers for long-haul trips. Perhaps the new opportunities in the short-haul and low volume markets have intermodal activists the most excited, most likely because of its relative permanency.

Currently, trucks dominate the short-haul and low volume markets. Short trips prevent railroads from producing their line-haul cost savings and when freight volumes are low, it can become difficult to assemble trains on a frequent basis. New rail car designs, such as the Iron Highway, RoadRailer, and stand-alone doublestack car, offer the railroads great opportunities to penetrate these markets. A comparison of the current lengths of haul of truck shipments relative to the anticipated market distances of the above intermodal technologies tells the story. The average truckload shipment moves 250 miles while the average less-than truckload shipment moves 558 miles, both well below the generally accepted 750 mile threshold of when intermodal becomes economical [23]. However, CSX's Iron Highway is designed to compete with trucks at distances as low as 350 miles, while Norfolk Southern believes it can target its RoadRailer services to markets as small as 400 miles apart and its stand-alone doublestack cars in 500 mile

markets. In addition, all three of these new intermodal opportunities are designed to be more flexible than current intermodal operations, which should help attract smaller volumes.

While the above technologies aim to make intermodal more attractive, another factor exists which does not directly involve intermodal but nonetheless could produce similar benefits. This external factor is the continuing shortage of over-the-road truck drivers. Such drivers are often on the road for three to four weeks at a time, depriving them of a decent home/family environment. Their work schedules are often too unpredictable and the environment in which they work is generally unsatisfactory and high-risk. On top of this, recent laws requiring commercial drivers licenses and mandatory drug testing can make driving a truck a less attractive profession. These and other concerns help explain why two out of three truck drivers will leave the company currently employing them within five years, according to a job satisfaction survey of truck drivers conducted by the Upper Great Plains Transportation Institute of North Dakota State University [33]. The remaining one-third indicated that they will leave the trucking industry entirely within five years. According to Paul Bergant, executive vice president of J.B. Hunt, the trucking industry generally has a 150 percent annual turnover among drivers [16].

While the above factors offer promise for intermodal, there remain a number of concerns which could restrict its growth. Two significant challenges for intermodal are the ability of the railroads and trucking companies to (1) provide integrated or "seamless"

service to their customers, and (2) ensure that equipment will be both available and compatible.

In today's transportation marketplace, shippers and receivers are demanding near perfect service and setting the standard for such service has been the truckload carriers. Truckload carriers provide door-to-door service using only a single truck, thus eliminating the need to transfer cargo anywhere along the route. Door-to-door service with intermodal, on the other hand, involves two different modes and possibly more than two carriers. In order for intermodal service to match the service offered by the truckload carriers, and in turn attract market share, all of the parties involved in an intermodal movement must work in concert. In the intermodal industry, this is referred to as providing seamless service. Depending upon the agreement between the railroad and the motor carrier and/or drayage operator, there can be a tendency for each participant to sub-optimize. When this occurs, the overall service provided to the customers is less than optimum, forcing many to switch to a single mode of transport.

Closely related to the seamless service issue is the availability of intermodal equipment to the customers and standardization of the equipment among the carriers. A lack of intermodal equipment for a given market can arise from a number of different factors. The simplest explanation may be that the equipment is tied up elsewhere. Volume imbalances can result in an accumulation of flat cars in a particular region and it may be not be cost effective to reposition the empty cars. Another explanation for the lack of equipment may involve similarities in operating philosophy between the railroad and motor carrier, when railroads agree to transport the motor carrier's freight over the

line-haul. According to Ronald Sorrow, vice president of sales and marketing for CSX Intermodal, his company and J.B. Hunt may find it difficult learning how to coexist, given their same intermodal philosophy of controlling all aspects of their intermodal service [34].

In order for intermodal to flourish, the types of equipment used by motor carriers must be compatible with the equipment used by the railroads. Complicating matters is the large differences in the useful lifespans of each mode's intermodal assets. Motor carriers anticipate getting about 7 years out of their trailers and containers, while the railroads expect to receive approximately 30 years of use from each flatcar. Thus, the railroad industry has a more difficult time adjusting to changes in equipment.

It appears the future success of intermodal transportation will be determined by a number of factors. Some factors, such as new rail car designs and both the availability and standardization of equipment, appear to be within control of the rail and motor carrier industries. Others, such as the driver shortage and increasing shipper and receiver demands, fall less under the control of the industries. Perhaps most significantly, the economic impacts to both the rail and trucking industries that might be created by a shift toward intermodal will determine the future success of this transportation alternative. Accordingly, forecasts of intermodal activity should reflect these conditions.

III. METHODOLOGY

The primary purpose of the study is to estimate the number of over-the-road tractor-trailer accidents occurring in Tennessee that could be avoided through greater use of intermodal to haul freight. The number of avoidable tractor-trailer accidents can be measured by determining how many truck accidents occur for situations where the shipment in transport is conducive to movement by an intermodal service.

Perhaps the best way to determine whether a shipment can be transported intermodally would be to gather all the cost and service characteristics associated with a potential intermodal movement and compare them against what competing trucking companies have to offer. This procedure would be followed for every shipment that, as a result of the existing transportation network, has a potential to pass through Tennessee. In a practical sense, this is not possible because of the enormous amounts of data that would be required and the fact that much of the data would be difficult to obtain. In addition, many shippers probably do not evaluate their transportation options for every shipment in great detail (major commodity movements are an exception), and therefore, such a procedure would not be representative of current industry practice. Nonetheless, an intermodal decision model is developed that incorporates many of the factors that receive consideration in choosing a transportation mode.

Development of Theoretical Model

The model for gauging whether a shipment can be transported intermodally is based in part on the three competition issues mentioned in the Review of Literature: (1) availability of intermodal to customers, (2) cost and service of intermodal relative to over-the-road trucking, and (3) acceptance and use of intermodal by shippers. Some additional factors that were not considered in the literature review are also included. Essentially, the model consists of a series of questions that test the suitability of a shipment for intermodal. These questions form the basis of a flowchart which is illustrated in Figure 3.

As Figure 3 indicates, the decision to use intermodal is a function of the type of commodity to be transported, proximity of both the shipper and receiver to an intermodal terminal, and cost and quality of service. Other factors that affect the decision include whether a particular travel mode was specified by the receiver, the urgency of the shipment, and the size of the shipment. Each of these considerations are discussed below in the order in which they appear in Figure 3.

Commodity Type: Certain cargos are better suited for truck transport than others. Recent developments in rail car design are allowing commodities that traditionally were transported by truck to begin moving by rail. However, intermodal still has a hard time attracting certain commodities, especially those that are high in value or of unusual size or shape.

Receiver Specifies Mode: Often, the receiver will specify a particular mode or even carrier. One of the reasons for requiring a certain mode may involve personal bias.

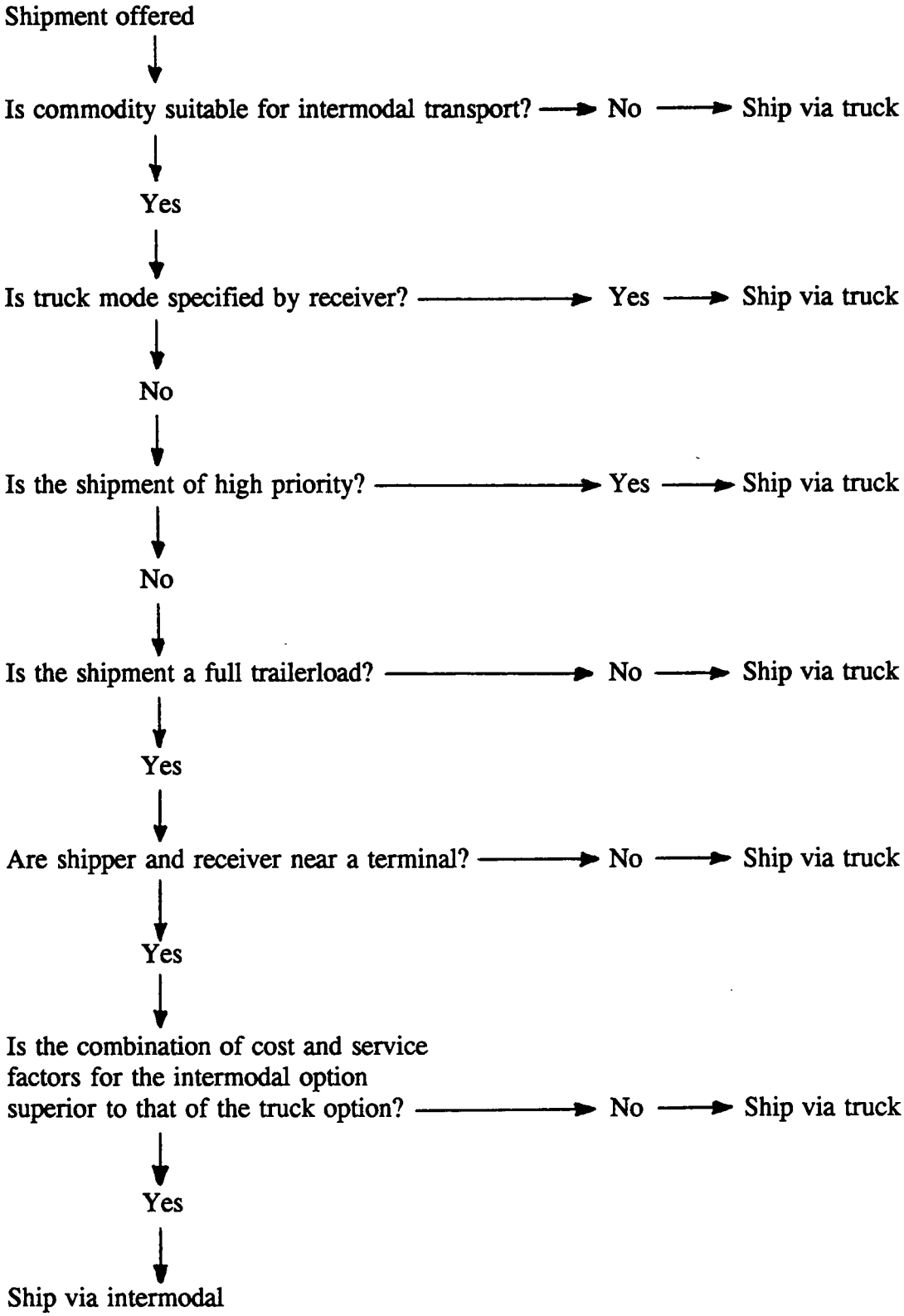


Figure 3. "Theoretical" Intermodal Decision Flowchart

Unfortunately, this practice can prevent the realization of a superior transportation option [35].

Priority of Shipment: Shipments that require a fast delivery time will likely go by truck, because truck operations are inherently more flexible than rail operations.

Shipment Quantity: Railroads are somewhat reluctant to transport shipments that are less than carload, unless the shipments have already been consolidated and are moving between two terminals. This reluctant nature reflects the inflexibility of intermodal services; no stop-offs are allowed enroute [35].

Terminal Proximity: Both the shipper and receiver should be relatively close to the intermodal terminal to reduce drays. When drayage distances are great, the cost savings associated with intermodal transportation tend to be eliminated.

Cost and Service Factors: Cost and service factors were alluded to in the Review of Literature. Intermodal usually claims an advantage in cost, especially as the haul lengths increase. Trucks, on the other hand, provide better overall service. As the intermodal move becomes more complex (requiring participation from multiple railroads), some of the cost savings can be reduced and service qualities lessened.

This "theoretical" decision model requires that a significant amount of information be available. While this information is typically within the grasp of the transportation manager or other person responsible for making modal decisions of a shipper, data for all the freight markets, taken collectively, are difficult, if not impractical, to obtain and analyze. A simpler decision model is therefore needed if it is going to be used for a variety of commodities, markets, shippers, etc.

Development of Model Used in This Study

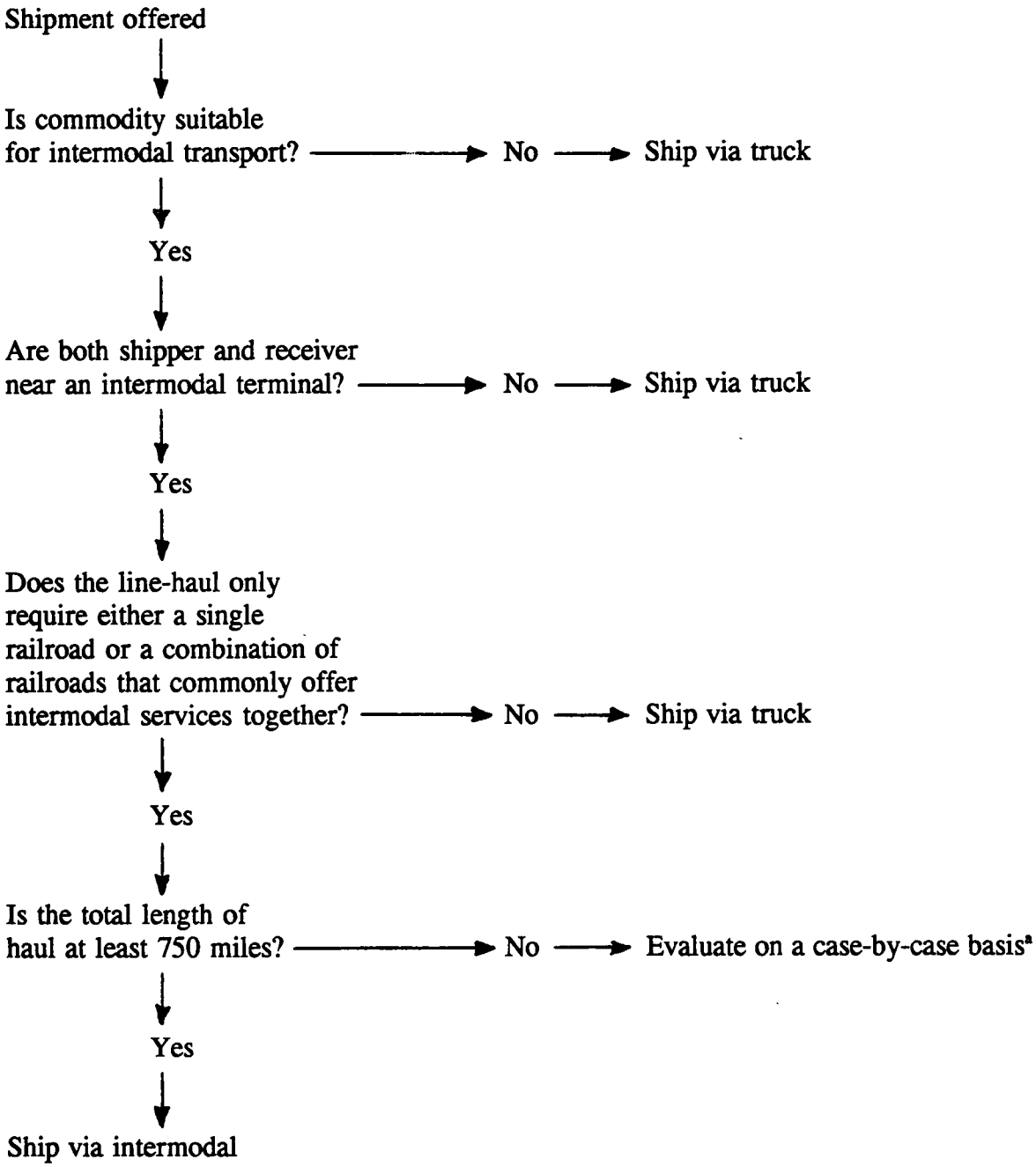
A relatively simple decision model has been developed for use in this study to determine whether a given over-the-road truck movement can be replaced with an intermodal movement. The model is based on the findings of the previous section, specifically considering the three competition issues mentioned. Similar to the theoretical model, the model formulated for this analysis also consists of a series of questions that test the suitability of a shipment for intermodal transportation. This model is illustrated in Figure 4. Limitations to the available database prevented a more complete model from being developed. Consequently, this model is somewhat general in nature and certain markets may deviate from what the model would predict. Each of the factors listed in Figure 4 are discussed below. Differences between the theoretical model and the model used in this study are also accounted for.

Commodity Type: In order to apply the model, information concerning the suitability of various commodity types for intermodal transportation was needed. The present mix of intermodal freight served as the basis for determining whether a commodity was suitable. Estimates of this mix were possible by referencing *Carload Waybill Statistics*[6] and by consulting individuals knowledgeable about freight traffic.[7]

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[6]*1989 Carload Waybill Statistics: Territorial Distribution, Traffic and Revenue by Commodity Classes*, Federal Railroad Administration, U.S. Department of Transportation, September 1991 (annual).

[7]Conversations with Barton Jennings, Research Assistant, The University of Tennessee Transportation Center.



[a]Shorter hauls can be accommodated when markets are large and drays are short.

Figure 4. Intermodal Decision Flowchart Used for This Study

Thus, only commodities that are currently shipped intermodally were eligible for consideration.

Terminal Proximity: The geographic location of both the shipper and receiver are important considerations in evaluating the potential for a shipment to be transported intermodally. Both the shipper and receiver should be relatively close to the intermodal terminal to reduce drays. However, measuring terminal proximity is a difficult task as regional variations exist. Burlington Northern's terminals may service a 250 mile radius while Conrail targets markets within about 50 miles of their terminals [35]. Acceptable drayage distances are likely a function of the overall trip distance and will vary from market to market. Therefore, whether the required drays would be acceptable is based on current industry practices and/or personal judgment.

Multiple Carriers for the Line-Haul: Intermodal transportation is generally associated with long or inter-regional trips. Individual railroads do not serve every market for which it is desired to move freight. Therefore, railroads sometimes work jointly to transport a customer's shipment (a process known as interlining), and when multiple railroads are required for a shipment, the prospects for using intermodal are lessened. Therefore, if the shipment requires multiple railroads to complete the line-haul, intermodal is not acceptable. An exception to this is if the railroads in question already have an interlining agreement (e.g. Santa Fe and Conrail for shipments between Los Angeles and New York).

Length of Haul: As indicated earlier, railroads gain an advantage in price over trucking companies as length of haul increases. The point at which intermodal becomes

cost competitive with over-the-road trucking is about 750 miles. As the overall trip distance increases beyond 750 miles, intermodal becomes even more attractive to shippers. Thus, trip distance is a surrogate for cost in the model. Trip lengths of at least 750 miles were considered to be suitable for intermodal while those less than 750 miles required further evaluation. These shorter trips qualified for intermodal transport if the markets served were relatively large and the estimated drays were short.

It is evident from comparing the theoretical model with the model formulated for this study that some very important differences exist. Limitations associated with the available database are responsible for these differences. The first dissimilarity is consideration of whether a receiver specified that trucks be used to transport the shipment. The available data on truck movements in Tennessee do provide the name of receivers. However, it was impractical to contact the intended receivers to determine if they had dismissed the intermodal option altogether. This is because the shipments analyzed were between one and two years old and it was not known if they were part of a regularly occurring movement or a one-time only movement. Thus, receivers might find it difficult to recall how they evaluated a shipment, especially if it was an infrequent one. Some of the shipments that were analyzed and determined to be eligible for intermodal transport may in fact could have been required to be transported by truck instead. It is unknown to what degree this is occurring.

A second difference between the two models concerns the priority of the shipment. Since the data did not indicate the relative urgency of each shipment, it was not possible to determine the number of shipments requiring movement in tractor-trailers that arise

from the quicker delivery times available with this transportation option relative to intermodal.

Shipment size was another factor that could not be addressed due to database limitations. Occasionally, some indication of the size or weight of the cargo being transported was available. However, this information was provided too infrequently to be of any value. Since it is likely that some of the shipments were less than trailerload, some of the movements judged to be suitable for intermodal probably would have moved by truck.

Perhaps the biggest difference between the theoretical model and the model used for this analysis was the treatment of cost and service variables. Theoretically, intermodal becomes attractive when its quality of service provided, relative to the service available from the trucking industry, is sufficient to the point that cost savings make a difference. As previously indicated, quality of service is difficult to measure except in relative terms. While trucks generally provide better service, railroads have been gaining ground. Customers that are trying intermodal have been pleased, including those that used to rate the performance of the railroads as poor. Nonetheless, information about the quality of service provided by either the motor carrier or the parties that would be involved in a potential intermodal move was not available.

One factor that has a major influence on the quality of intermodal service, yet could not be accounted for, is market volume. Railroads that serve high volume markets are able to provide dedicated intermodal service (e.g. a train whose consist is strictly intermodal). Where freight volumes are lower, there might not exist sufficient

intermodal freight to justify a dedicated train and instead, the railroads will offer to include the freight in their "general purpose" trains. Such trains may be required to pass through classification yards several times, and this would increase transit times, making the intermodal alternative less attractive to shippers and receivers.

The treatment given to transportation cost factors also differed between the two models. In the theoretical model, the shipper will obtain rates from different carriers indicating the price to move the load. These rates are typically quoted on a dollar per mile transported or dollar per trailer or container basis. This type of information was not available for this analysis. Instead, length of haul was used as a surrogate for cost factors. Trip lengths could be determined readily and it greatly simplified the process.

Consideration is given to some additional factors that are not reflected in either the theoretical model or the model used in this study, but nonetheless can influence modal choice decisions. One of these factors is shipper awareness of the intermodal alternative. This is a very important consideration that was alluded to in the Review of Literature. The data used in this analysis do not provide any evidence as to how well-informed the shipper is about his/her transportation choices. Since intermodal is in a position of having to prove itself against the well-established trucking option, shippers at this time are likely to be less informed about intermodal than truck. However, this situation could change in the future.

Another factor which is closely related to shipper awareness is shipper bias. The intermodal option may appear to be the preferred transportation alternative, yet an over-the-road truck may be chosen instead if the shipper has, for whatever reason, a bias in

favor of trucks. Bias is a difficult factor to measure and would therefore be difficult to incorporate into any model.

The final factor considered recognizes that the frequency with which a shipment is transported can have an effect on the attractiveness of the intermodal option. The shipper typically allocates the time spent for modal decisions according to the significance of the move. Infrequent shipments will receive little analysis while major movements will involve a detailed study of transport options. With little time to devote to infrequent shipments, the shipper will likely choose to either continue with the present carrier or, at the very most, choose the carrier offering the lowest rate.

Having developed a model to test the suitability of a shipment for intermodal transport, data were needed to apply the model. A description of the data used in this study is provided in the following section.

Database Description

The data used to apply the decision model are a sample of tractor-trailers involved in accidents in Tennessee during 1991 and 1992 for which the characteristics of the shipment were known. The data were provided courtesy of the Tennessee Public Service Commission's Transportation Division. The Tennessee Public Service Commission (TPSC) is responsible for the enforcement of both federal and state motor carrier regulations throughout Tennessee. As such, the TPSC routinely inspects truck drivers and their vehicles to ensure compliance with appropriate regulations. Inspections are performed at scalehouses located throughout the state, and roadside following an accident

involving a truck. Because of the large number of truck movements in Tennessee (and a large number of truck accidents) coupled with a limited amount of resources, the TPSC is unable to inspect every truck that passes through the state. Approximately 100,000 inspections are performed at the scalehouses each year while about 350 inspections per year concern trucks that were involved in an accident.

The data collected by the TPSC are significant in two respects. First, much of the information that is recorded cannot be obtained from other state accident databases, particularly the types of information needed for this analysis. Second, the TPSC takes a rigorous approach to collecting data. It is believed that more truck inspections are conducted in Tennessee than in any other state--approximately ten percent of all truck inspections in the 50 states.

Tractor-trailer accident data from 1991 and 1992 were analyzed. In 1991, 296 tractor-trailers involved in accidents in Tennessee were examined while in 1992, that number totaled 235. These represent every tractor-trailer accident investigated by the TPSC in each of those years for which a report was filed by their enforcement officers. However, the total number of tractor-trailer accidents occurring in Tennessee each year, as reported in the State motor vehicle accident database, is far greater. Unfortunately, the State accident database does not record the types of data needed for this analysis, and therefore a greater number of tractor-trailer accidents cannot be analyzed. Each accident investigated by TPSC officers are also investigated by police or highway patrol officers. As such, the accidents contained in the TPSC database are also reported in the State

accident database. The number of accidents in the TPSC database consists of about 6 percent of the accidents found in the State database.

Typically, an accident involving a truck is reported to the Tennessee Emergency Management Agency, which in turn contacts TPSC officers via call radios or pagers. The officers then decide whether or not to investigate the accident. TPSC characterizes the response by their officers to these truck accidents as random with respect to the severity of the accident. A new policy effective January 1993 established criteria for determining whether or not to investigate a particular accident. Prior to 1993, officers attempted to investigate as many accidents as practical with little regard to the nature of the accident.

It was not possible to statistically test the accident data compiled by TPSC officers to determine whether injury outcomes influenced the decision to investigate an accident as information about the number and types of injuries was not always available. This resulted primarily because TPSC officers sometimes arrived at the accident scene after the police investigation was completed and the vehicles had left. It is possible to cross-reference accidents investigated by the TPSC with those found in the State accident database. However, the index number needed for the cross-reference was not provided frequently enough to warrant a closer examination.

TPSC officers are positioned across the state in either permanent or temporary locations or as part of mobile road crews. The permanent sites include four scalehouses located along Interstates 24, 40, and 65 near bordering states (at Knoxville, Brownsville, Manchester, and Portland). Temporary inspection sites are located throughout the state,

while mobile road crews travel from county to county to conduct roadside inspections. As a general policy, TPSC tries to position its officers in locations where truck accidents have occurred frequently. Therefore, it is assumed that the geographic locations of the accidents investigated by TPSC enforcement officers are representative of the locations of all truck accidents occurring in Tennessee.

The TPSC's primary purpose for investigating truck accidents is to determine compliance with federal and state motor carrier safety regulations and exact appropriate fines and/or other penalties for truck drivers and trucks found not in compliance. As such, the accident investigations center around the truck driver's fitness for duty and the operating condition of the truck. As part of this investigation, the TPSC officers examine the shipping papers required of each truck driver operating in interstate commerce. The shipping papers provide the following information useful to this study: (1) type of cargo carried including whether or not it is a hazardous material, (2) the origin of the shipment, and (3) the intended destination of the shipment. Other pertinent information available from the officer's investigation include the geographic location of the accident (identification of route traveled and approximate distance from a town or city at time of the accident), and the number of vehicles involved in the accident. Figures 5 through 7 show the report forms used by the TPSC officers when investigating tractor-trailer accidents. The specific types of data useful to this analysis are identified in the figures.

Although the TPSC data do not provide the overall mileage of the intended trip that is requested in the decision model, or the specific travel path that the driver had planned

POST ACCIDENT INSPECTION REPORT

FATALITIES ___ SERIOUS INJURY ___ MINOR INJURY ___ NO INJURY ___ HAZ-MAT: YES ___ NO ___

DATE ACCIDENT OCCURRED _____ TIME _____ RMI/INTERSTATE _____

COUNTY _____ CITY _____, TN

DETAILS OF LOCATION _____

COMPANY NAME _____

ADDRESS _____ PHONE _____

PRIVATE _____ U.S. DOT NO. _____ EXEMPT-FOR-HIRE _____ ICC NO. _____

OWNER'S NAME _____

ADDRESS _____ PHONE _____

1. VEHICLE YR/MAKE _____ CABOVER ___ CONV. ___ STRAIGHT ___ TRACTOR-TRAILER ___

VIN _____ LICENSE NO./YR/ST _____ LOCATION _____

1. DRIVER'S NAME _____

ADDRESS _____ PHONE _____

BIRTHDATE _____ SSN _____ DRIVER'S LICENSE NO./ST _____

INJURIES _____ LOCATION _____ PHONE _____

OTHERS INVOLVED:

2. NAME _____
ADDRESS _____ PHONE _____
AGE ___ INJURIES _____ LOCATION _____

3. NAME _____
ADDRESS _____ PHONE _____
AGE ___ INJURIES _____ LOCATION _____

OTHER VEHICLES:
2. YR/MAKE _____ LICENSE NO./ST _____ LOCATION _____
3. YR/MAKE _____ LICENSE NO./ST _____ LOCATION _____

COMMODITY _____

T.P.S.C. VIOLATIONS _____

_____

_____

WITNESS/NAME _____ ADDRESS _____ PHONE _____
WITNESS/NAME _____ ADDRESS _____ PHONE _____

OTHER AGENCIES ON SCENE:

AGENCY _____ OFFICER _____ REPORT NO. _____

AGENCY _____ OFFICER _____ REPORT NO. _____

AGENCY _____ OFFICER _____ REPORT NO. _____

WEATHER CONDITIONS _____ ROAD CONDITIONS _____ NO. OF LANES _____

DESCRIBE ACCIDENT _____

_____

_____

_____

_____

_____

_____

Figure 5. TPSC Tractor-Trailer Accident Investigation Form

HAZARDOUS MATERIALS

COMMODITY _____ H.M. CLASS _____ PACKAGE _____ AMOUNT _____

COMMODITY _____ H.M. CLASS _____ PACKAGE _____ AMOUNT _____

COMMODITY _____ H.M. CLASS _____ PACKAGE _____ AMOUNT _____

SHIPPER'S NAME _____

ADDRESS _____

CONSIGNEE'S NAME _____

ADDRESS _____

IS THERE A SPILL? _____ COMMODITY & AMOUNT SPILLED _____

DESCRIBE INJURIES AND/OR PROPERTY DAMAGE DUE TO H.M. INCIDENT _____

WHAT ACTION HAS BEEN TAKEN TO NEUTRALIZE DANGERS AND CLEAN-UP SITE? _____

PLACARDS DISPLAY _____

CARGO TANK MC NO. _____ VIN _____ LAST TEST DATE _____

DRIVER'S LOG INFORMATION: 100 AIR-MILE RADIUS DRIVER ____ YES ____ NO
LAST CHANGE OF DUTY STATUS: DATE _____ TIME _____ LOCATION _____
TOTAL HRS DRIVING SINCE LAST CONSECUTIVE OR ACCUMULATED 8 HRS OFF-DUTY _____
TOTAL HRS DRIVING AND ON-DUTY SINCE LAST CONSECUTIVE OR ACCUMULATED 8 HRS OFF-DUTY _____
TOTAL HRS DRIVING AND ON-DUTY SINCE LAST SEVEN (7) DAYS _____ LAST EIGHT (8) DAYS _____

CO-DRIVER'S LOG INFORMATION: 100 AIR-MILE RADIUS DRIVER ____ YES ____ NO
LAST CHANGE OF DUTY STATUS: DATE _____ TIME _____ LOCATION _____
TOTAL HRS DRIVING SINCE LAST CONSECUTIVE OR ACCUMULATED 8 HRS OFF-DUTY _____
TOTAL HRS DRIVING AND ON-DUTY SINCE LAST CONSECUTIVE OR ACCUMULATED 8 HRS OFF-DUTY _____
TOTAL HRS DRIVING AND ON-DUTY SINCE LAST SEVEN (7) DAYS _____ LAST EIGHT (8) DAYS _____

ORIGIN _____ DESTINATION OR TURN POINT _____

VEHICLE LOCATION _____ PHONE _____

DATE & TIME NOTIFIED _____ 10-97 ____ 10-98 ____ BY WHOM _____

T.P.S.C. COMPLIANCE CHECK NO. _____ CITATION NO. _____

OFFICER'S NAME _____ BADGE NO. _____ DATE _____

_____
OFFICER'S SIGNATURE

Figure 6. TPSC Tractor-Trailer Accident Investigation Form

TENNESSEE PUBLIC SERVICE COMMISSION
460 James Robertson Parkway, Nashville, TN 37243-0505

DRIVER VEHICLE INSPECTION REPORT
TN 20176836

INTER ☐	INTRA ☐	EXEMPT ☐	PVT ☐	FOR HIRE ☐	KB OFFICER:	DATE:	TIME START:	TIME END:
INSPECTION LOCATION:		ICC NO.	US DOT NO.	TPSC STAMP	TYPE OF INSPECTION (Circle) 1 Full 2 Walk Around 3 Driver 4 Special Study 5 Terminal			

CARRIER	Driver Name	Date of Birth	Train ☐	DRIVER IS: A- EMPLOYED B-TERM LSED C-TRIP LSED
Address	Driver License No. / State / Soc. Sec. Number	CDL ☐ Yes ☐ No		
City / State / Zip Code	Driver Name	Date of Birth	Train ☐	DRIVER IS: A- EMPLOYED B-TERM LSED C-TRIP LSED
Phone / Lessor	Driver License No. / State / Soc. Sec. Number	CDL ☐ Yes ☐ No		

HAZARDOUS MATERIALS TRANSPORTED

Y = YES N = NO

	CODE	RQ?	HW?

A - EXPLOSIVES A
B - EXPLOSIVES B
C - EXPLOSIVES C
D - FLAMMABLE LIQUID
E - FLAMMABLE SOLID
F - FLAMMABLE GAS
G - NONFLAMMABLE GAS
H - CORROSIVES
I - OXIDIZERS
J - POISON A
K - POISON B
L - COMBUSTIBLE LIQUID
M - RADIOACTIVE MATERIAL
N - ORGANIC PEROXIDE
O - IRRITATING MATERIAL
P - ORM A, B, or C
Q - ORM E
R - ETIOLOGIC AGENT
S - BLASTING AGENT
T - CRYOGENICS
Z - OTHER

PLACARDS REQUIRED? ☐

IF H.M. BEING TRANSPORTED UNDER EXEMPTION, ENTER "E" NUMBER. _____

IF CARGO TANK, ENTER MC SPEC OR "NON" _____

CARGO CLASSIFICATIONS (circle)

A. GENERAL FREIGHT
B. HOUSEHOLD GOODS
C. METAL: SHEETS, COILS, ROLLS
D. MOTOR VEHICLES
E. DRIVEAWAY/TOWAWAY
F. LOGS, POLES, BEAMS, LUMBER
G. BUILDING, MATERIALS
H. MOBILE HOMES
I. MACHINERY, LARGE OBJECTS
J. FRESH PRODUCE
K. LIQUIDS/GASES
L. INTERMODAL
M. PASSENGERS
N. OILFIELD EQUIPMENT
O. LIVESTOCK
P. GRAIN, FEED, HAY
Q. COAL/COKE
R. MEAT
S. GARBAGE, REFUSE, TRASH
T. U.S. MAIL
U. CHEMICALS
V. COMMODITIES DRY BULK
W. REFRIGERATED FOOD
X. BEVERAGES
Y. PAPER PRODUCTS
Z. _____

COMMODITY

SHIPPING PAPER NO.

Origin

Destination

From

To

A MEMBER OF THE TPSC REMOVED SEAL NO. _____ IN ORDER TO INSPECT THE CARGO BEING TRANSPORTED. THE SEAL WAS REPLACED WITH TENNESSEE P.S.C. SEAL NO. _____ ON COMPLETION OF INSPECTION.

BRAKE ADJUSTMENT		AXLE 1	AXLE 2	AXLE 3	AXLE 4	AXLE 5	AXLE 6	AXLE 7
	RIGHT							
	FRONT							
	LEFT							

VEHICLE IDENTIFICATION — GVWR: — CVSA DECAL

UNIT NO.	VIN	UNIT TYPE	OWN LSD	MAKE	CO. NUMBER	LICENSE NO. and STATE	OLD QTR/YR	OLD NO.	NEW NO.
1									
2									
3									
4									

UNIT NO.	OUT OF SVC	49 C.F.R. Section No.	Citation No.	VIOLATION DISCLOSED

Unit Type: TR = Straight Truck TT = Truck Tractor ST = Semi Trailer PT = Pole Trailer FT = Full Trailer DC = Dolly Converter BU = Bus OT = Other
OWN-LSED: A = Owned B = Term Leased C = Trip Leased

VEHICLE/DRIVER OUT OF SERVICE ORDER

Pursuant to authority in Title 49, Code of Federal Regulations, Section 396.9, I hereby declare vehicles with defects followed by an "X" in the "Out of Service" column in the violations discovered section of this report *Out of Service*. No person shall remove the out of service stickers applied to these vehicles, or operate such vehicles until the out of service defects have been repaired and the vehicles have been restored to safe operating condition.
Pursuant to authority contained in Title 49, Code of Federal Regulations, Section 395.13, I hereby notify and declare the driver named on this report *Out of Service*. No motor carrier shall permit or require this driver to drive or operate any motor vehicle until: _____ (TIME) ON _____ (DATE).

REINSPECTED: ☐ YES ☐ NO	SUPERVISOR NO:	REVIEW/REINSPECTED	NOTE TO DRIVER: FURNISH THIS REPORT TO MOTOR CARRIER LISTED ON THIS FORM.

REPORT PREPARED BY:	LAST NAME (PRINT):	OFFICER NO.:	DRIVER SIGNATURE:

TPSC 1. PSC

IMPORTANT INFORMATION ON REVERSE SIDE

Figure 7. TPSC Tractor-Trailer Accident Investigation Form

as a way of determining this distance, a reasonable estimate of the trip length is still possible. It is assumed that the driver would follow the shortest path that passes through the accident location while utilizing Interstate and U. S. highways as much as feasible. Obviously though, the road preference does not apply in the vicinity of the origin and destination. Since over-the-road truck drivers usually face tight delivery deadlines and prefer routes permitting high travel speeds, the above assumption is probably valid. Trip distances were measured using a United States road atlas and various state road atlases. Distances were rounded to the nearest 10 miles.

Measuring the Reduction in Truck Accidents

Using the available information for each tractor-trailer involved in an accident in the database, a decision was made as to whether the shipment being transported could have been moved intermodally. The flowchart shown in Figure 4 was used for this purpose. A truck whose shipment characteristics satisfied the intermodal criteria set forth in the model was judged to be replaceable by intermodal. However, the number of accident-involved trucks whose shipment characteristics satisfied the criteria does not necessarily equal the anticipated reduction in the number of truck accidents. This is because the model cannot account for accidents occurring within the vicinity of either the origin or destination. It may be that the model recommends intermodal for a given shipment but since the data used to apply the model are from truck accidents, it is possible that had intermodal been used, an accident would have occurred anyway during the drayage portion of the trip. Therefore, if an accident-involved truck was transporting

a shipment suitable for intermodal and the accident occurred within the anticipated drayage distance from either terminal end, then it was conservative to say that an accident would have occurred anyway and consequently, the shift to intermodal did not eliminate the accident occurrence.

Assuming that the tractor-trailer accidents analyzed in this study are representative of the entire tractor-trailer accident population in Tennessee (as contained in the State accident database), it is then possible to estimate the total number of tractor-trailer accidents in Tennessee for which the cargo in carriage could have instead been transported intermodally. The total number of avoidable tractor-trailer accidents would be estimated as the number of avoidable accidents as determined from the TPSC sample multiplied by the ratio of tractor-trailer accidents found in the State database to tractor-trailer accidents analyzed in this study.

IV. ANALYSIS

The intermodal decision model was applied to a number of tractor-trailers involved in accidents in Tennessee for which the characteristics of the shipment were known. The data were from 1991 and 1992. There was a total of 282 tractor-trailer accidents involving 296 tractor-trailers in 1991, which accounted for 6.6 percent of the tractor-trailer accidents that were reported in the Tennessee motor vehicle traffic accident database for that year. However, 12 accidents involving 12 tractor-trailers were discarded because of either inadequate or unreadable information, reducing the share of tractor-trailer accidents observed to 6.3 percent of the total number of tractor-trailer accidents reported in the state accident database. In 1992, there were 224 tractor-trailer accidents involving 235 tractor-trailers (5.1 percent), of which 8 accidents involving 8 tractor-trailers were eliminated because of inadequate/unreadable information. Thus, the effective share of tractor-trailer accidents observed in 1992 was reduced to 4.9 percent of the total number of tractor-trailer accidents reported in the state accident database.

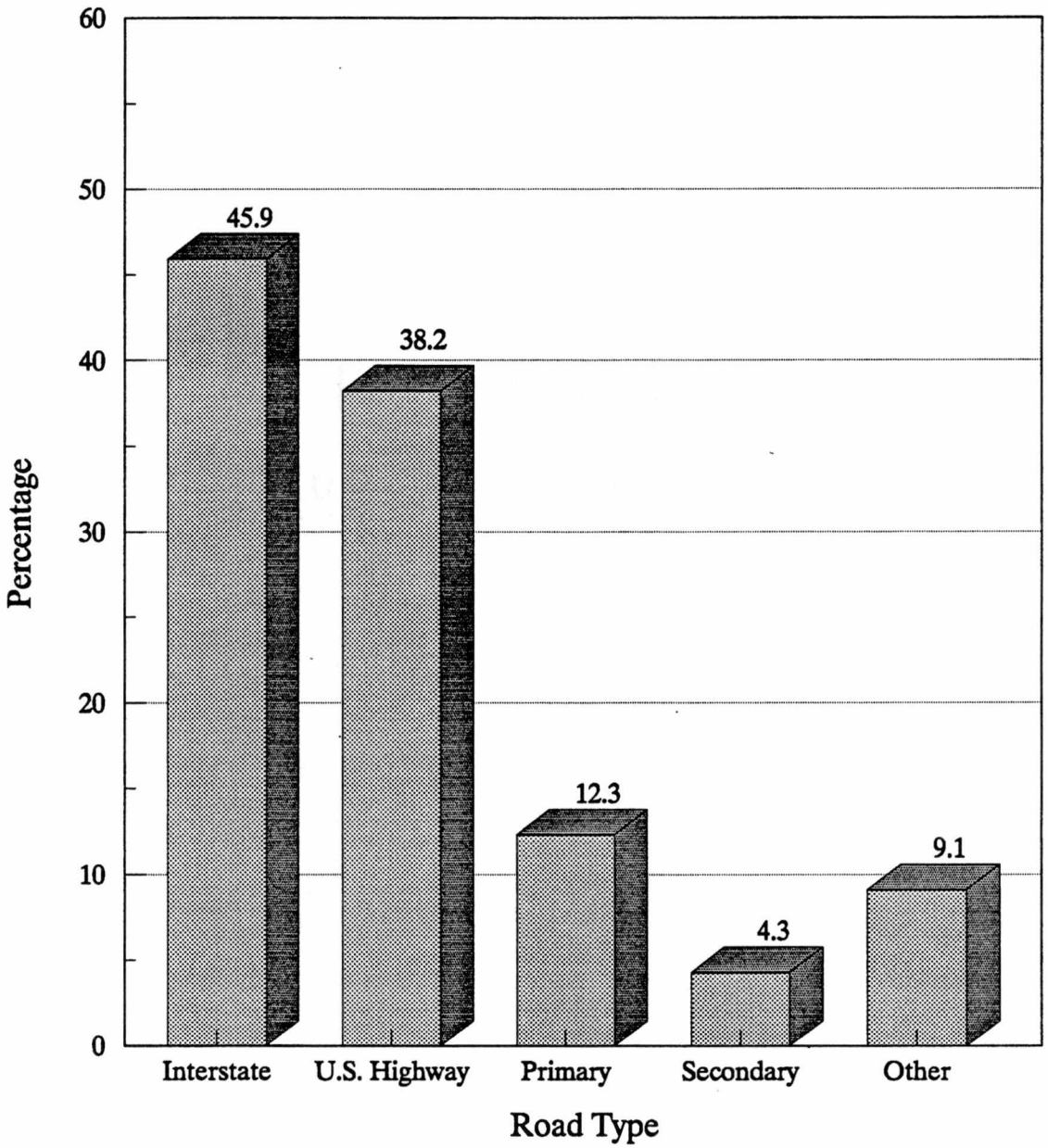
The distribution of the observed accidents according to road functional class was determined. By analyzing the distribution, it became possible to get some indication of where the TPSC officers conducted their inspections and also if the officers concentrated their efforts on certain types of truck trips (e.g. interstate as opposed to local). Unfortunately, information about tractor-trailer vehicle-miles of travel in Tennessee for different road classifications was not available. This prevented a more accurate assessment about the nature of truck trips analyzed in this study. The distribution is

shown in Figure 8. Almost half of the tractor-trailer accidents analyzed occurred on Interstate highways, while an additional 28 percent occurred on a route designated as a U.S. Highway. A more accurate descriptions of the road network was not possible as TPSC officers merely described the accident locations by highway number. About 9 percent of the tractor-trailer accidents were categorized as "other," that is, the accident occurred on a local street and/or the officer only indicated a particular town when asked to describe the accident location. Limitations associated with the reporting process also made it difficult to classify some of the tractor-trailer accidents as either urban or rural. However, a cursory analysis revealed that the vast majority of the accidents analyzed occurred in rural areas.

Before presenting the results for each objective, it should be remembered that even though the trip data analyzed in this study included every tractor-trailer accident investigated by TPSC, the sample size is small. Attempts to extrapolate the findings of this study to the entire accident population in the state require caution as it could not be statistically determined whether the TPSC data were representative of the entire accident population. Nonetheless, the results have been extrapolated where appropriate, and the reader should interpret these findings with some caution.

Trip Characteristics of Tractor-Trailers Traveling in Tennessee

Objective one was to identify some of the major trip characteristics of the tractor-trailers traveling in Tennessee. Items of interest included determining the percentages of intrastate and interstate truck trips, learning how many trips occurred for which no



Sample size: 269 observations in 1991
216 observations in 1992

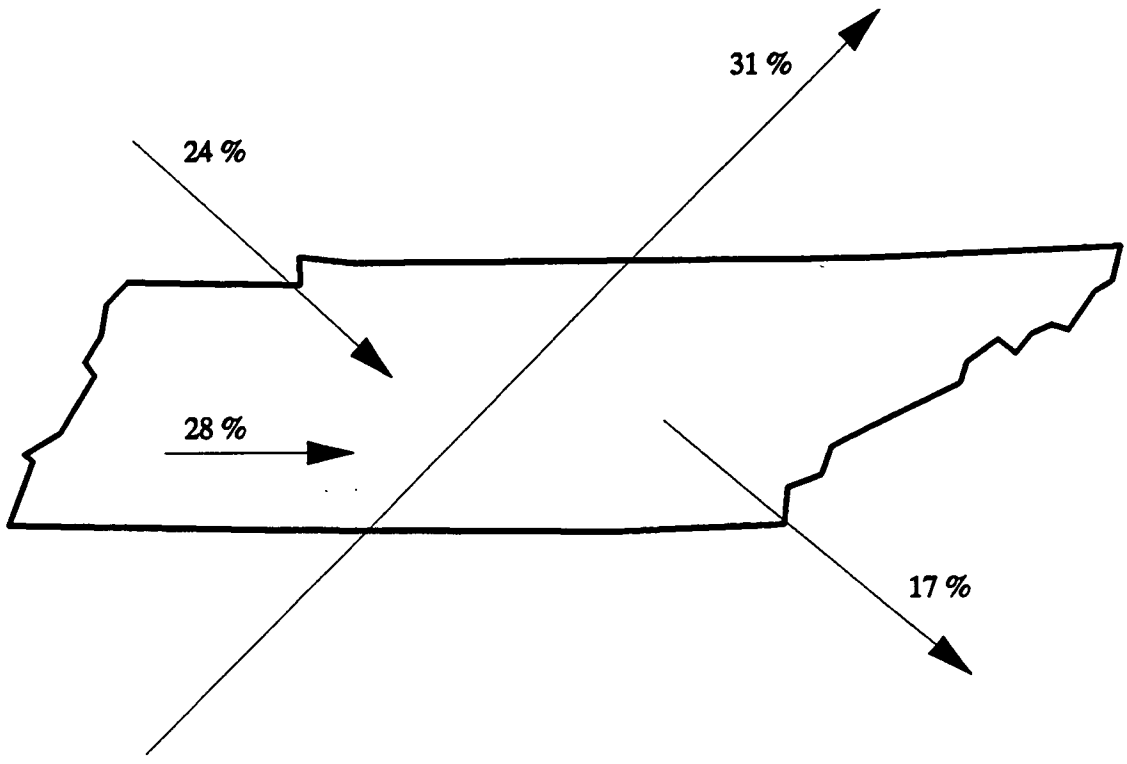
One observation was removed; accident location not given.

Figure 8. Distribution of Observed Tractor-Trailer Accidents by Road Type

cargo was being transported (e.g. empty backhaul), and measuring the distribution of trip distance for the interstate trips. This information is useful in that it provides some initial insight into the nature of the tractor-trailer trips occurring in Tennessee.

Using the origin and destination data, each trip was classified as either intrastate or interstate. Interstate trips were further categorized as having either an origin or destination in Tennessee or as having neither an origin or destination in the State. Figure 9 summarizes the findings. As Figure 9 indicates, intrastate travel accounts for 28 percent of the tractor-trailer trips in Tennessee. Intrastate trips are unlikely candidates for intermodal, given their relatively short distance. About 31 percent of the trips represent tractor-trailers having both origins and destinations outside of Tennessee but whose routes result in travel through the state. While all tractor-trailer trips impose some threat to highway safety, these "pass-by" trips jeopardize safety in Tennessee without providing the state with the primary benefits that these trucks have to offer (e.g. delivery of a shipment).

The percentage of tractor-trailers that were not hauling any cargo is shown in Table 11. Approximately 15 percent of the tractor-trailer trips did not have any cargo in carriage. Empty truck movements are certainly undesirable from the motor carriers' perspective and they may also be undesirable from a highway safety perspective. Motor carriers incur expenses on empty backhauls without generating any revenue. While it is in the carrier's financial interest to minimize the number of empty truck movements, circumstances do not always permit this to occur. From the standpoint of safety, empty tractor-trailers are more prone to crashes than fully loaded trucks [36]. This probably



Sample size: 284 observations in 1991
227 observations in 1992

Figure 9. Distribution of Tractor-Trailer Trips by Origin-Destination: Average of 1991 and 1992

Table 11. Presence of Cargo Among the Tractor-Trailer Trips

Presence of Cargo	1991	1992	Average of 1991 and 1992
Cargo in carriage	86 %	84 %	85 %
Empty carriage	14 %	16 %	15 %
Total	100 %	100 %	100 %
Sample size	284	227	511

reflects the increased difficulties of maintaining control when braking an empty truck as opposed to a partially-loaded or full tractor-trailer. In light of this characteristic and recognizing that this study purposely analyzed trips resulting in accidents, the percentage of trips determined to be empty may in fact be higher than is really the case.

The empty truck trips were classified according to their origins and destinations and compared against truck trips with cargo. Table 12 shows this comparison. Intrastate trips were twice as likely to be without cargo while "pass by" trips were almost four times as likely to have cargo. These results should not be surprising considering that the number of market opportunities available is directly related to the geographic area of coverage. In other words, fewer market opportunities exist when the travel boundaries are restricted to within Tennessee and with less opportunities, it becomes increasingly difficult to find a commodity to transport on the backhaul. Truck trips neither originating or terminating in Tennessee have the greatest number of market opportunities available and, as such, empty movements are not as much of a problem.

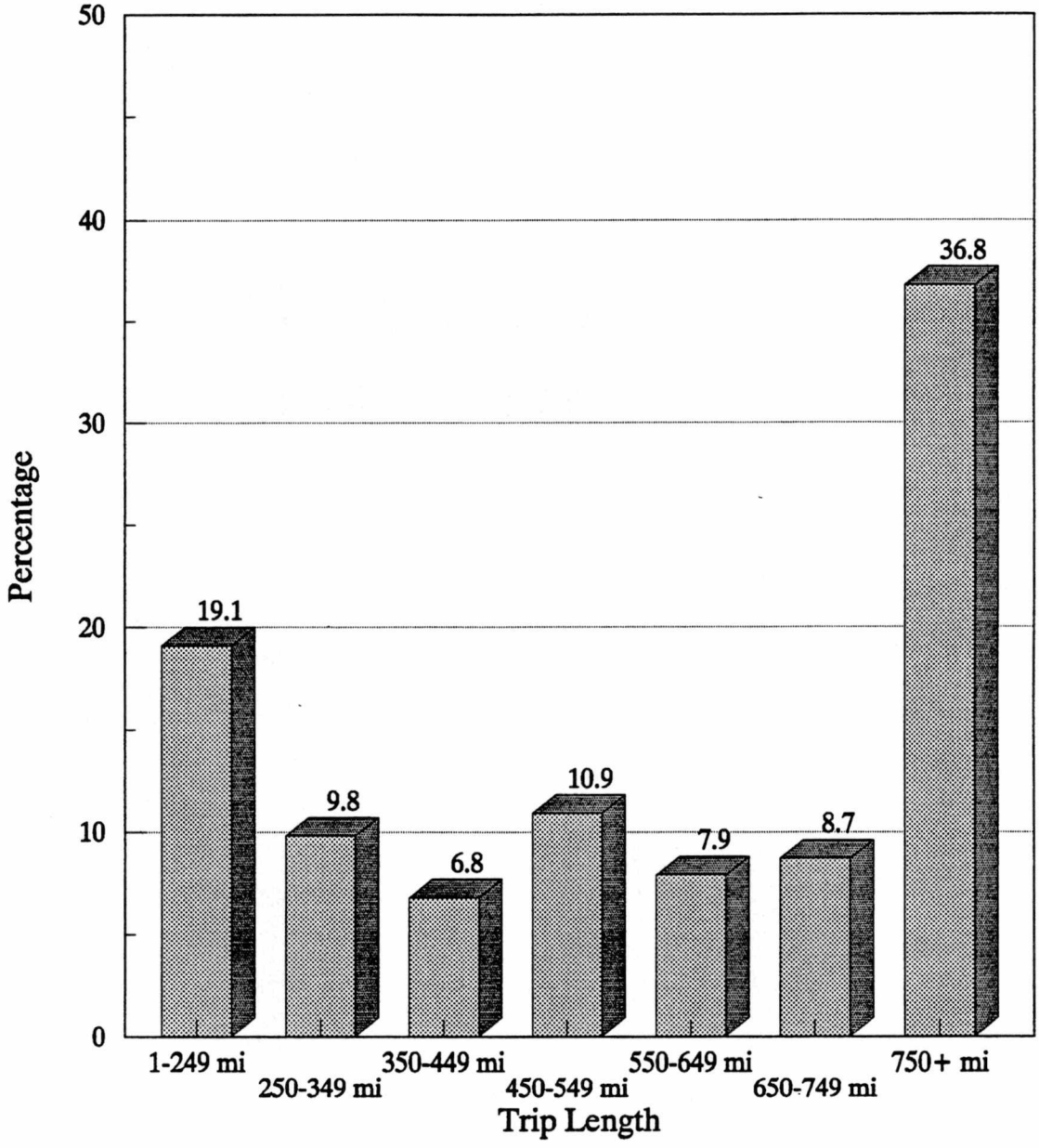
Figure 10 shows the distribution of trip length among interstate trips. These trips are not restricted to State lines and can therefore result in long lengths of haul. Intrastate trips, on the other hand, inherently are of relatively short distance (possessing little, if any, intermodal potential) and were therefore not included. As Figure 10 indicates, 37 percent of the interstate trips had haul lengths exceeding 750 miles, the distance at which intermodal generally becomes cost competitive. At the other end, 29 percent of the interstate trips had haul lengths less than 350 miles. At present, none of the intermodal

Table 12. Comparison of Trip Origins/Destinations Based on Cargo Presence: Average of 1991 and 1992 Data

Trip Description	Cargo in Carriage	Empty Carriage
Intrastate trips	24 %	49 %
Interstate trips having origin in Tennessee	17 %	18 %
Interstate trips having destination in Tennessee	24 %	23 %
Interstate trips having origin and destination outside of Tennessee	34 %	9 %
Total[a]	99 %	99 %

[a]Totals may not equal 100 percent due to rounding errors.

Sample size: 284 observations in 1991
227 observations in 1992



Sample size: 214 observations in 1991
153 observations in 1992

Figure 10. Distribution of Trip Lengths Among Interstate Trips

technologies discussed in the Review of Literature are considered to be cost-effective under the 350 mile markets.

Measuring the Reduction in Tractor-Trailer Accidents

Objective two was to estimate how many tractor-trailer accidents could have been avoided if intermodal was utilized wherever feasible. An estimate of the overall cost of these accidents (expressed in dollars) was also desired.

Based on the sample of accidents investigated by TPSC, almost 25 percent of the tractor-trailer accidents were determined to be avoidable through the use of intermodal services. Also, 21 percent of the accidents involving tractor-trailers carrying hazardous materials were found to be avoidable.

Extrapolation of the estimated reduction in tractor-trailer accidents, based on the TPSC sample, to the entire population of tractor-trailer accidents occurring in Tennessee (as measured by the state motor vehicle accident database) is shown in Table 13. As Table 13 indicates, slightly more than 1000 tractor-trailer accidents annually need not have occurred. The total number of other vehicles involved in the avoidable accidents averaged around 700 for the two years studied, of which approximately 50 were other tractor-trailers.

It was also desired to estimate the costs associated with these avoidable tractor-trailer accidents. By assigning a dollar value to these accidents, some estimate of the accident cost savings can be achieved. Determining the true cost of an accident is a difficult task as it requires social judgments. The dollar amounts used in this analysis

Table 13. Estimated Reduction in Tractor-Trailer Accidents Through Intermodal Usage

Reduction Measure	1991	1992	Average of 1991 and 1992
Extrapolated to Accidents Statewide:			
Avoidable truck accidents	988	1165	1076
Number of other vehicles involved			
Other trucks	61	42	51
Passenger vehicles	771	568	670
Total	832	610	721

Sample size: 270 observations in 1991
216 observations in 1992

represent the average cost associated with a typical motor vehicle accident, based on its severity. Factors such as property damage or loss, medical and legal costs, future loss of earnings, and court awards serve in part as the basis for determining accident costs. The numbers chosen for this analysis represent the most current information available on this subject and are presented in Table 14.

Table 15 displays the costs associated with these accidents, when extrapolated to a statewide level. The impact of these avoidable tractor-trailer accidents is estimated at about $21 million to $29 million. The range provided in Table 15 attempts to account for the different operating environments under which accidents occur. The low end of the range represents accidents that occur in an urban environment characterized by intersections and/or interchanges while the high end is reflective of accidents occurring in rural highway (uninterrupted flow) surroundings. As previously indicated, it was not possible to accurately describe the accident locations for the sample observed. Consequently, the range of accident costs provided cannot be narrowed any further. The procedure used to estimate these numbers is detailed in Appendix A.

Intermodal's Potential to Further Reduce Tractor-Trailer Accident Occurrence

In the Review of Literature, a number of new intermodal technologies (Iron Highway, RoadRailer, and the stand-alone doublestack car) were alluded to as being capable of attracting freight in the short-haul, low volume markets. In addition, factors such as the persistent shortage of over-the-road truck drivers were mentioned as a way for intermodal to gain acceptance. The purpose of objective three was to provide some

Table 14. Accident Cost Data by Severity (in 1990 $)

Severity Type	Cost
Fatal Accident	
Urban area, intersection or interchange	$932,000
Rural area, highway (not including intersection/interchange)	$1,111,000
Injury Accident	
Urban area, intersection or interchange	$14,300
Rural area, highway (not including intersection/interchange)	$24,900
Property Damage Only Accident	
Urban area, intersection or interchange	$1,350
Rural area, highway (not including intersection/interchange)	$2,140

Source: Texas Transportation Institute, "MicroBencost User's Manual," preliminary version 0.3, Texas A&M University, College Station, Texas, 1993.

Table 15. Estimated Costs of Tractor-Trailer Accidents Occurring in Tennessee That Could Be Avoided Through Greater Use of Intermodal

Severity Type	Estimated Cost (in 1990 $)
1991:	
Fatal accidents	$16 million - $19 million
Injury accidents	$4 million - $7 million
Property damage only accidents	$1 million
Total	$21 million - $27 million
1992:	
Fatal accidents	$16 million - $19 million
Injury accidents	$5 million - $8 million
Property damage only accidents	$1 million - $2 million
Total	$22 million - $29 million

indication of the additional reduction in tractor-trailer accidents should intermodal become accepted in the shorter-haul markets. As was the case in the previous objective, it was desired to estimate the cost savings associated with the anticipated additional reduction in the number of tractor-trailer accidents.

A slightly different procedure for determining whether a shipment can be transported intermodally was used to measure the future accident savings. The intermodal decision model employed in the second objective is too refined for forecasting purposes. Most noticeably, terminal proximity and line-haul characteristics (e.g. need for multiple railroads) played important roles in the decision model. When conducting a future analysis, it is difficult to assess the importance of both these factors in the intermodal decision. This is because one of the new technologies--the Iron Highway--appears to reduce the emphasis on terminals, and also because it is difficult to predict the degree of cooperation that will exist among the railroads. Therefore, the revised decision model only incorporates commodity type and trip distance as factors influencing intermodal usage. Commodities suitable for intermodal transport were grouped by trip distance and the results are shown in Table 16.

Currently, intermodal is cost competitive with over-the-road trucks at trip distances of about 750 miles. The analysis indicated that for every 100 mile reduction in this distance threshold, roughly, about a 5 percent decrease in the number of tractor-trailer accidents is possible. This assumes, however, that truck exposure levels on shorter routes remain the same. Of the intermodal technologies mentioned in the Review of Literature, the Iron Highway has the potential to reduce the trip distance at which

Table 16. Potential Reduction in Tractor-Trailer Accidents As a Function of Trip Length

Intermodal Competitive At:	Additional Reduction in Truck Accidents for 1991[a]	Additional Reduction in Truck Accidents for 1992[a]
650 miles	6 %	5 %
550 miles	11 %	9 %
450 miles	18 %	18 %
350 miles	23 %	21 %

[a]Beyond the base reduction indicated in Table 13, based on a revised/relaxed model.

intermodal and over-the-road truck services compete the most (markets 350 miles apart). If fully utilized and effective at the 350 mile range, the Iron Highway could reduce truck accidents by an additional 22 percent.

The estimated cost savings associated with this potential to reduce tractor-trailer accidents is shown in Table 17. The accident cost data used to estimate the cost of avoidable truck accidents in objective two were also used to estimate future costs. The numbers should be interpreted with caution, however, as it must be assumed that the distribution of accidents according to their severity will remain the same in some future year.

Fostering Intermodal Activity at the State Level

The highway safety benefits of using intermodal services have been documented above. Assuming that these benefits offset any disbenefits that may result from an increase in drayage activity on the local road network around the terminal area, it would appear to be desirable for the State of Tennessee to encourage further use of intermodal activity within its borders. However, intermodal activity is basically an interstate service and, as such, state governments are limited in their actions. As an example, a state cannot use its tax or other powers in a way that discriminates against motor carriers operating in interstate commerce. As such, a state's authority is limited to intrastate matters only [28].

Despite this limitation, there are several actions which could be considered by the State. One such action would be to commission a study that analyzes the intermodal

Table 17. Cost Savings Associated with Additional Reductions in Tractor-Trailer Accidents

Intermodal Competitive At:	Cost Savings for 1991 (in 1990 $)	Cost Savings for 1992 (in 1990 $)
650 miles	$26 million - $35 million	$26 million - $34 million
550 miles	$31 million - $41 million	$30 million - $39 million
450 miles	$37 million - $49 million	$37 million - $49 million
350 miles	$42 million - $55 million	$39 million - $52 million

facilities and services available in Tennessee. The purpose would be to survey railroads, motor carriers, and both users and non-users of intermodal services to learn what services are available within the state and also what their perceptions are with regard to these services. The study would then identify specific measures aimed at improving intermodal service. Some of the probable measures are discussed below.

The State could encourage railroads to develop additional intermodal terminal facilities in Tennessee. Shippers and receivers would then be closer to intermodal facilities, thereby reducing drayage distances and cost. The State's role in such an endeavor might be to assist in land acquisition and help finance terminal construction and operating equipment [28].

Another opportunity for state involvement would be to improve access roads to intermodal terminals. One potential drawback of intermodal is the possibility of increasing the truck volumes on local roads. Often, these roads are not adequately designed for large trucks and an increase in accident occurrence may result. By improving the road networks leading to the terminals, drayage times could be reduced and the safety concerns may be tempered.

The State could also finance research to develop new technology and also to introduce new technology into the intermodal industry. Possible areas for exploration include improving rail cars, containers, truck chassis, lifting equipment, communications systems, terminal procedures, and train scheduling [28].

Of course any of these or other measures cannot guarantee greater use of intermodal services. The interstate nature of intermodal implies that without high quality

service from origin to destination, the intermodal alternative will not be viable. In other words, the benefits of making intermodal more attractive in Tennessee are realized only when this option is attractive in other states as well. Therefore, a consortium of neighboring states may be formed to investigate joint strategies for improving the potential for intermodal transportation.

V. CONCLUSIONS AND RECOMMENDATIONS

Intermodal has the potential to reduce the number of tractor-trailer accidents on highways. However, this transportation alternative only targets the over-the-road tractor-trailer market and, as such, is not a panacea for overall heavy truck safety concerns. A number of conclusions concerning the use of intermodal to reduce tractor-trailer accidents in Tennessee are reached, along with some recommendations for the State of Tennessee to consider in order to realize the full highway safety benefits offered by intermodal. It should be remembered, however, that a number of assumptions was necessary in the analysis, the most significant being that the TPSC sample data analyzed were representative of all tractor-trailer accidents occurring in Tennessee. Also, the intermodal decision model used in this analysis was formulated based on data that was not reflective of the complete modal decision process. Many shipment characteristics (e.g. receiver specifies truck, shipment is less than a full carload, etc.) were unknown and this tended to bias the decision toward using intermodal, although it was unknown to what degree. Therefore, the conclusions should be interpreted accordingly.

1. Approximately 25 percent of the tractor-trailer accidents that occurred in Tennessee over the two year period analyzed was determined to be avoidable through the increased use of currently available intermodal services. This amounts to slightly over 1000 tractor-trailer accidents per year at an estimated cost of $21 million to $29 million.

2. Based on the new intermodal opportunities that are being developed for use in the short-haul markets, intermodal could reduce the number of truck accidents in Tennessee even further. It was recognized that intermodal is cost competitive with over-the-road trucks at trip distances of about 750 miles. The analysis indicated that for every 100 mile reduction in this distance threshold, about a 5 percent decrease in the number of tractor-trailer accidents is possible. If the new intermodal technologies were fully implemented in their targeted markets, almost half of the tractor-trailer accidents occurring in Tennessee could be avoided at a cost savings of $39 million to $55 million. This assumes, however, that tractor-trailer trip patterns remain the same in future years and that the distribution of accidents by severity also remains the same.

3. Not all tractor-trailer trips occurring in Tennessee are suitable for intermodal. About 28 percent of the trips were intrastate. Trips made entirely within state lines are too short for intermodal to be a viable alternative. Memphis to Bristol, at about 500 miles, represents the longest traffic lane in Tennessee that can be expected to attract some freight volume. However, the majority of intrastate trips sampled were much shorter than this example. Thus, it can be expected that a significant portion of the intrastate tractor-trailer trips will remain, even if intermodal is used to its full potential. Additionally, about 29 percent of the interstate tractor-trailer trips had lengths of less than 350 miles, a distance too short for even the new intermodal technologies. About 37 percent of the interstate trips covered distances in excess of 750 miles, yet only 68 percent of them were currently suitable for intermodal. This suggests that cost savings

alone will not attract customers to intermodal. Improvements in the levels of service provided will be necessary.

4. Intermodal planning should be regional as any real safety gains will necessarily require multi-state cooperation. About 31 percent of the trips analyzed were "pass-by trips," which can be characterized as having little susceptibility to modal influence from the State of Tennessee. An additional 41 percent of the trips had either the origin or destination within Tennessee. However, even if the opportunities to use intermodal services appear satisfactory in Tennessee, that may not be the case at the other end.

5. Based on the above findings, it would appear to be desirable for the State of Tennessee to encourage further use of intermodal activity within and outside its borders. The first step toward achieving this would be to commission a study that analyzes the intermodal facilities and services available within the State. Specific measures to improve intermodal activity would likely be based upon a review of the intermodal facilities available and also on a survey of railroads, motor carriers, and potential users of intermodal services to capture their views and requirements. Recognizing the need for multi-state cooperation, a coordinated effort among Tennessee and other states would be desirable.

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APPENDIX

Data

Observed TPSC sample:

Avoidable Tractor-Trailer Accidents for 1991	62
Avoidable Tractor-Trailer Accidents for 1992	57
Tractor-Trailer Accidents for 1991	270
Tractor-Trailer Accidents for 1992	216

Tennessee Motor Vehicle Accident Database:

Tractor-Trailer Accidents for 1991	4,302
Tractor-Trailer Accidents for 1992	4,413
Fatal Tractor-Trailer Accidents for 1991	75
Fatal Tractor-Trailer Accidents for 1992	66
Injury Tractor-Trailer Accidents for 1991	1,206
Injury Tractor-Trailer Accidents for 1992	1,217
Property Damage Only Tractor-Trailer Accidents for 1991	3,021
Property Damage Only Tractor-Trailer Accidents for 1992	3,130

Figure 11. Calculation of Estimated Costs of Tractor-Trailer Accidents

Calculations

1991

Estimated number of avoidable fatal accidents = (62/270) x (75) = 17

Estimated number of avoidable injury accidents = (62/270) x (1,206) = 277

Estimated number of avoidable PDO accidents = (62/270) x (3,021) = 694

Cost of avoidable fatal accidents = 17 x (cost range from Table 15) = $16 million to $19 million

Cost of avoidable injury accidents = 277 x (cost range from Table 15) = $4 million to $7 million

Cost of avoidable PDO accidents = 694 x (cost range from Table 15) = $0.9 million to $1 million

1992

Estimated number of avoidable fatal accidents = (57/216) x (66) = 17

Estimated number of avoidable injury accidents = (57/216) x (1,217) = 321

Estimated number of avoidable PDO accidents = (57/216) x (3,130) = 826

Cost of avoidable fatal accidents = 17 x (cost range from Table 15) = $16 million to $19 million

Cost of avoidable injury accidents = 321 x (cost range from Table 15) = $5 million to $8 million

Cost of avoidable PDO accidents = 826 x (cost range from Table 15) = $1 million to $2 million

Figure 11. Calculation of Estimated Costs of Tractor-Trailer Accidents (continued)

VITA

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