Comprehensive Truck Size and Weight (TS&W) Study

Phase 1-Synthesis

Truck Costs

and

Truck Size and Weight Regulations

Working Paper 7

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Phase 1—Synthesis

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The Federal Highway Administration (FHWA) has recently embarked on a major study of potential changes in Federal policy relating to truck size and weight. The intention of this working paper is to provide researchers and policy analysts involved in this study, or in other studies of state or Federal size and weight policy, with as much information about estimating the effects of potential policy changes on truck transport costs as it is practical to assemble within a limited period of time.

The first section of this paper contains an extended discussion of the ways in which size and weight policy affects truck transport costs and sources of data for estimating these effects. The second section provides a brief discussion of several areas requiring more investigation. The concluding section contains a bibliography of material relating to issues addressed in this paper. One document that was newly reviewed in the course of preparing this working paper is discussed at some length in Section 1.4(g), and all other such documents are annotated briefly in the bibliography. More basic references are listed in the bibliography without annotation, and the more important of these are referenced in the text where appropriate.

1.0 Technical Relationships of Policy Consequence Concerning Truck Costs

1.1 Background

There are several ways in which changes in truck size and weight policy can affect truck transport costs:

1. Changes in size and weight limits affect vehicle operating costs and capacity, thus affecting transport costs per ton-mile, potentially to a significant extent. In general, more restrictive limits increase transport costs while more liberalized limits reduce them. These basic effects of size and weight limits are discussed in Sections 1.2-1.4.

2. The introduction or tightening of vehicle performance or design standards tends to increase operating costs and transport costs per ton-mile. Introduction of such standards probably would occur only in conjunction with a liberalization of size or weight limits, thus reducing the transport-cost savings produced by the liberalized limits. The cost effects of standards relating to hitch design are discussed in Section 1.3(e). The effects of other potential performance and design standards can best be addressed after the standards of interest have been identified.

3. The liberalization of size or weight standards on a limited system of roads or the liberalization of these standards on all roads except those that cannot accommodate the larger or heavier trucks (because of geometrics or bridge limits) would result in some increase in circuity when current vehicles are replaced by larger or heavier vehicles. This increase in circuity would reduce the transport cost savings resulting from the increase in size or weight limits (though it would have no effect on transport costs per ton-mile). The effect of increased circuity is discussed in Section 1.5.

4. The liberalization of size standards may result in the introduction or increased use of vehicle configurations (such as 57-foot semitrailers) that are designed primarily for carrying cube-limited limited cargo; while the liberalization of weight standards may result in the introduction or increased use of configurations (such as six-axle semis) that are designed primarily for carry weight-limited cargo. Utilization rates for these more specialized vehicles may be lower than those for current vehicles, since the new vehicles may have more empty mileage, annual mileage may be lower, or they may occasionally carry loads that do not take advantage of their increased capacity. Such reductions in utilization would reduce the transport cost savings resulting from the increase in size or weight limits. The effects of decreased utilization are discussed in Section 1.5.

In addition to the above effects on transport costs, larger shipment sizes can result in a usually marginal increase in inventory costs and other non-transport logistics costs. These effects are discussed in Working Paper 8.

The above discussion indicates that a liberalization of size or weight limits generally results in a significant decrease in transport costs, due to increased vehicle capacity obtained with only a modest increase in operating costs (Item 1), but that several factors (Items 2-4) may tend to reduce the size of this decrease in transport costs. The circuity and utilization effects (and also the effects on other logistics costs) are necessarily smaller than the Item 1 savings and they are more difficult to estimate. For this reason, these effects frequently are ignored in the estimation of changes in transport costs, thus producing overestimates of the effects on transportation costs. If unbiased estimates of transport costs are to be produced, all of the above effects must be considered.

Table 1.1 lists factors affecting truck costs that may be directly or indirectly affected by changes in size and weight policy.

Table 1.1. Selected Factors Affecting Truck Transport Costs

Vehicle Dimensions
- Height
- Width
- Length of truck or trailer
- Number of trailers

Gross Vehicle Weight
- Effect of bridge formula
- Effect of GVW caps

Axle Characteristics
- Number of axles
- Axle loads
- Suspensions
- Load distribution among axles in a group

Tire Characteristics
- Number
- Type
- Size
- Tire pressure
- Load distribution between tires

Other Vehicle Characteristics
- Type of trailer or body
- Engine horsepower
- Brakes
- Hitch design

User Fees
- Heavy-vehicle permit fees
- Graduated weight-distance taxes
- Fuel taxes
- Tire taxes

Enforcement Activities
- Weight checks
- Safety inspections

Route Restrictions
- Circuity
- Access to origins and destinations

Other Operational Factors
- Availability of backhauls
- Density of loads
- Availability of full loads
- Speed

Driver Costs
- Pay differentials for driving certain configurations

1.2 Costs Per Vehicle-Mile

A relatively extensive set of estimates of cost per vehicle-mile for various vehicle configurations, trailer types and operating gross vehicle weights (GVWs) has been produced by Jack Faucett Associates (JFA) (1991) for FHWA and is available in spreadsheet form. Table 1.2 shows these estimates for selected configurations and trailer types. All cost estimates are forecasts of 1995 costs expressed in 1988 dollars. The forecasts were developed in 1991, but they were developed primarily from data collected during the 1980s. Although these cost forecasts are somewhat old and warrant updating, they provide a particularly comprehensive set of estimates of the effects of size and weight regulation on truck costs.

The cost estimates are for typical intercity hauls. Hence, they do not reflect the inverse variation of costs with distance — a factor that has a relatively significant effect on the magnitude of costs per vehicle-mile (particularly for shorter hauls), but which has a much more marginal effect on the percentage change in these costs caused by potential regulatory changes. (This point is discussed further in Section 1.3(f).)

Table 1.3 shows the various pairings of configurations and trailer types for which cost estimates exist in the JFA paper, as well as several additional pairings for which estimates were produced for an earlier version of the paper (JFA, 1990) but not updated for the 1991 paper. Complete sets of estimates are contained in Appendix A of the two papers.

The following six subsections describe the source of the six cost components shown in the columns of Table 1.2 (labor, fixed vehicle costs, fuel, tires, repair and servicing, and indirect and overhead costs, including user fees). All costs quoted in these six subsections are forecasts of 1995 costs expressed in 1988 dollars. A seventh subsection provides data on the body and trailer types used for transporting various commodities.

(a) Driver Costs

Driver-cost estimates for less-than-truckload (LTL) and tank-truck operators are meant to reflect averages for union and non-union operators and also to reflect a gradual decline in real labor costs for union operators. These costs were estimated by JFA to be 20 percent below 1988 costs, including fringe benefits, as given by the Central States Area Supplement to the contract negotiated between Trucking Management, Inc., (TMI) and the International Brotherhood of Teamsters. The driver costs were obtained from TMI on a per-hour basis and reflect TMI's conversion factor

Table 1.2. 1991 Forecasts of 1995 Costs Per Vehicle Mile for Selected Vehicle Configurations, Trailer Types and GVWs

(1988 cents/mile)

	GVW (lbs.)	Drivers	Vehicle	Fuel	Tires	Repair	Overhead	Total
Dry Vans (Truckload)								
5 Axle 48'	28,000	30.0	20.0	16.6	3.0	6.1	22.0	97.7
	52,500	30.0	20.0	19.1	3.0	8.5	22.0	102.6
	78,000	30.0	20.0	21.6	3.5	10.9	22.0	108.1
5 Axle 53'	28,900	30.0	20.5	16.7	3.0	6.2	22.0	98.4
	56,000	30.0	20.5	19.4	3.0	8.8	22.0	103.8
	78,000	30.0	20.5	21.6	3.5	10.9	22.0	108.6
6 Axle 48'	29,500	30.0	20.8	16.8	4.1	6.2	23.4	101.3
	54,000	30.0	20.8	19.2	4.1	8.6	23.4	106.2
	79,500	30.0	20.8	21.8	4.2	11.1	23.4	111.3
	86,500	30.0	20.8	22.5	4.4	11.8	23.4	112.9
	90,000	30.0	20.8	22.8	4.5	12.1	23.4	113.7
	94,000	30.0	20.8	23.2	4.7	12.5	23.4	114.6
5 Axle Twin 28'	31,200	30.7	20.8	18.1	3.0	7.0	22.0	101.6
	59,800	30.7	20/8	21.0	3.0	9.8	22.0	107.3
	80,000	30.7	20.8	23.0	3.6	11.8	22.0	111.8
9 Axle Twin 33'	39,500	31.3	25.0	19.3	5.7	7.8	25.6	114.7
	73,200	31.3	25.0	22.7	5.7	11.1	25.6	121.4
	80,000	31.3	25.0	23.4	5.7	11.8	25.6	122.7
	113,500	31.3	25.0	26.8	5.7	15.0	25.6	129.4
7 Axle 40' & 28' RMD	36,300	31.3	23.7	19.0	4.3	7.5	23.4	109.2
	71,000	31.3	23.7	22.5	4.3	10.9	23.4	116.1
	105,500	31.3	23.7	26.0	4.8	14.2	23.4	123.5
Less Than Truckload Vans								
5 Axle 48'	55,400	38.9	16.0	19.4	3.0	8.7	138.0	224.0
Refrigerated Vans								
5 Axle 48'	29,900	35.0	21.9	18.9	3.0	6.3	22.0	107.0
	78,000	35.0	21.9	23.7	3.5	10.9	22.0	117.0
Flatbeds								
5 Axle 48'	27,600	30.0	19.6	16.1	3.0	6.0	22.0	96.7
	78,000	30.0	19.6	21.8	3.5	10.9	22.0	107.8
Tank Trailers								
5 Axle 42'	24,600	48.6	28.8	15.5	3.0	5.8	22.0	123.6
	78,000	48.6	28.8	21.5	3.5	10.9	22.0	135.3
Hopper Trailers								
5 Axle 42'	24,600	30.0	22.0	10.8	3.0	5.8	22.0	93.5
	78,000	30.0	22.0	15.1	3.5	10.9	22.0	103.6
Dump Trailers								
5 Axle 36'	26,400	30.0	21.8	10.9	3.0	5.9	22.0	93.7
	70,000	30.0	21.8	14.5	3.2	10.2	22.0	101.7
	78,000	30.0	21.8	15.1	3.5	10.9	22.0	103.4
5 Axle 36'	27,400	30.0	22.5	11.0	3.0	6.0	22.0	94.6
Longer Wheelbase Tractor	78,000	30.0	22.5	15.1	3.5	10.9	22.0	104.1

Table 1.3. Some Vehicle Configurations Analyzed by Jack Faucett Associates

Trailer and Axle Configuration	Trailer Type						
	Dry Van		Refr. Van	Flatbed	Tank	Hopper	Dump
	Truckload	LTL					
3 Axle Truck							a
4 Axle Truck							a
5 Axle 36' Semi							b
5 Axle 42' Semi					c	c	
5 Axle 45' Semi	a	a		a			
5 Axle 48' Semi	c	c	c	c			
5 Axle 40' Semi							b
6 Axle 48' Semi	c		c	c	c	c	
5 Axle Twin 28'	c	c	a	a	a	a	
7 and 8 Axle 28' A Train	c		c	c	c	c	
7 Axle Twin 28' C Train	a	a	a	a	a	a	
8 Axle Twin 28' B Train	a		a	a	a	a	
9 Axle Twin 28' A Train	c		c	c	c	c	b
9 Axle Twin 28' C Train	a		a	a	a	a	
7 and 8 Axle 33' A Train	c		c	c	c	c	
7 Axle Twin 33' C Train	a	a	a	a	a	a	
8 Axle Twin 33' B Train	a		a	a	a	a	
9 Axle Twin 33' A Train	c		c	c	c	c	b
9 Axle Twin 33' C Train	a	a	a	a	a	a	
7 Axle Rocky Mtn. Double	c		c	c	c	c	
9 Axle Twin 36', 42' or 48'	c	c	c	c	c	c	b
7 Axle Triple	c	c				c	

a - Analyzed in Jack Faucett Associates (1990)
b - Analyzed in Jack Faucett Associates (1991)
c - Analyzed in Jack Faucett Associates (1990 and 1991)

of 41.4 vehicle-miles per driver-hour. The costs reflect wage differentials for driving twin 28s, twin 40s, and triples. The wage differential for twin 33s was assumed to be halfway between those for twin 28s and twin 40s.

Truckload (TL) driver costs for a non-refrigerated single-trailer combination were assumed by JFA to be 30 cents per mile (in 1988 dollars). This figure was based on published estimates and expected increases in labor costs through 1995. Driver costs for refrigerated single-trailer combinations were assumed to be 35 cents per mile to reflect the higher costs of team operation. Operation of doubles and triples were assumed to involve a percentage increase in labor costs identical to that used for LTL costs (with the wage differential for various intermediate-length doubles assumed to be the same as that for twin 33s and the differential for twin 48s to be the same as that for twin 40s).

(b) Vehicle Costs, Depreciation and Interest

Tractor costs were estimated by JFA using a sample of 1988 list prices for new vehicles as given in National Market Reports (1988) and reduced by an assumed 15 percent discount. Prices for trailers and conventional single drawbar dollies ("A Dollies") were based on conversations with six trailer dealers and data from U.S. Bureau of the Census (1988). Tractor and trailer[1] purchase prices used are summarized in Table 1.4. Prices shown include sales tax, assumed to be 5 percent. Tare weights of all vehicles were obtained from the same sources as prices; tare weights are summarized in Table 1.5.

All vehicles were assumed to be purchased new. Tractors were assumed to be kept for five years and trailers for seven. The resale value (in constant dollars) at the end of these periods of time was assumed to be 30 percent of the original price for tractors and 25 percent for trailers. Average interest paid was taken to be 2 percent over prime, or about 11.3 percent; this rate was converted to a real interest rate of 6.0 percent by subtracting an inflation rate of 5.3 percent. For single-trailer configurations, a trailer/tractor ratio of 1.6/1 was assumed. For doubles and triples, ratios of 3.2/1 and 4.8/1 were used.

Vehicle costs per year were converted to vehicle costs per mile by dividing by average annual mileage. The annual mileages were taken to be 104,000 for tractors used by LTL carriers, and 83,000 for tractors used by TL non-

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[1] Hopper trailer prices in Table 1.4 are for grain trailers. Prices for pneumatic-cement trailers are much higher. In 1988, they were $45,000 to $50,000 each. (Mike Rice, Transystems, Inc., June 1988, personal communication.)

Table 1.4. Estimated Vehicle Prices
(1988 dollars)

Tractors	**2 Axles**	**3 Axles**	**4 Axles**
80K Tractor	$51,000	$58,200	
115K Tractor	$60,800	$68,000	
80K Longer Wheelbase Tractor		$60,200	
Trailers	**Single Axle**	**Tandem Axle**	**Tridem Axles**
28' Van	$10,600	$13,300	
33' Van	$11,200	$13,900	
48' Van	$12,800	$15,500	$18,200
48' Van, Spread Tandem		$18,300	
53' Van		$17,300	
28' Flatbed	$ 8,400	$11,100	
33' Flatbed	$ 9,100	$11,800	
48' Flatbed	$11,300	$14,000	$16,700
48' Flatbed, Spread Tandem		$16,800	
28' Tanker	$29,800	$36,100	
33' Tanker	$33,800	$40,100	
42' Tanker		$45,000	$51,000
42' Tanker, Spread Tandem		$48,000	
48' Tanker			$53,000
28' Refrigerated Van	$33,100	$35,800	
33' Refrigerated Van	$33,800	$36,500	
48' Refrigerated Van	$35,800	$38,500	$41,200
21' Full Hopper (2 Axles)	$18,000		
28' Hopper	$13,900	$18,800	
33' Hopper	$15,900	$19,400	
42' Hopper		$20,500	$24,000
48' Hopper			$24,700
28' Dump Trailer		$27,500	
40' Dump Trailer		$30,000	$33,000
45' Dump Trailer			$36,100
A-Dolly	$ 4,200	$ 7,000	

Source: Jack Faucett Associates (1991).

Table 1.5. Estimated Tare Weights

(pounds)

Tractors	**2 Axles**	**3 Axles**	**4 Axles**
80K Tractor	11,200	13,900	
115K Tractor	11,200	13,900	
80K Longer W.B. Tractor		14,900	
Trailers	**Single Axle**	**Tandem Axle**	**Tridem Axles**
28' Van	8,000	9,500	
33' Van	8,900	10,400	
48' Van	11,400	12,900	14,400
48' Van, Spread Tandem		13,500	
53' Van		13,800	
28' Flatbed	7,600	9,100	
33' Flatbed	8,500	10,000	
48' Flatbed	11,000	12,500	14,000
48' Flatbed, Spread Tandem		13,100	
28' Tanker	5,800	8,200	
33' Tanker	6,000	8,700	
42' Tanker		9,500	11,000
42' Tanker, Spread Tandem		10,100	
48' Tanker			11,900
28' Refrigerated Van	9,800	11,300	
33' Refrigerated Van	10,700	12,200	
48' Refrigerated Van	13,300	14,800	16,300
21' Full Hopper (2 Axles)	7,150		
28' Hopper	6,200	8,600	
33' Hopper	6,400	9,100	
42' Hopper		9,500	11,000
48' Hopper			11,900
28' Dump Trailer		10,000	
40' Dump Trailer		12,000	13,500
45' Dump Trailer			14,600
A-Dolly	2,800	4,800	

Source: Jack Faucett Associates (1991).

refrigerated carriers, as estimated by Maio (1986). An annual mileage of 104,000 was assumed for tractors used by refrigerated carriers.

For seven and nine-axle twins, the tare weights and vehicle costs developed by JFA reflect some additional adjustment to reduce the differences in estimated cost per ton-mile of seven and nine-axle twins.

(c) Fuel Costs

The JFA estimates of fuel costs were based on a 1995 forecast price for diesel fuel of $1.25 per gallon (in 1988 dollars) and estimates of fuel consumption as a function of vehicle configuration, body type and payload developed by Knapton (1981). The fuel-consumption formulas used are those presented by Knapton for level terrain and use of all fuel-efficiency options expected (in 1980) to be in use by 1985. Improvements beyond these values were anticipated to be limited by reduced fuel efficiency resulting from compliance with the 1991 and 1994 Environmental Protection Agency emissions standards and by increases in speed limits on most Interstate highways. (Knapton's formulas presume a 55 mph speed limit. With this speed limit, average fuel efficiency is about 10 percent better than with a 65 mph speed limit.)

The JFA versions of the Knapton formulas estimate fuel consumption as a linear function of GVW. The coefficients used in this function are shown in Table 1.6 for several vehicle configurations and trailer types. The indicated fuel efficiency for a fully loaded five-axle semitrailer with a 48-foot dry van is about 5.8 miles per gallon. The forecast 1995 fuel price of $1.25 per gallon (in 1988 dollars) is likely to prove to be high by 10 to 30 percent, so all costs are likely to be overstated. The JFA formulas indicate that, when diesel fuel costs $1.25 per gallon, fuel costs per vehicle-mile increases by about 0.1 cents per mile for each 1,000-pound increase in GVW for a five-axle single trailer combination (and by slightly more for heavier combinations).

(d) Tires

Using published information, JFA estimated tire costs for a five-axle configuration to be 3 cents per vehicle-mile for GVWs below 63,000 pounds, and to increase by 0.7 percent for each 1 percent increase in weight above this value. For configurations with a different number of axles but no tridem axles, tire costs were estimated to be 0.167 cents

Table 1.6. Fuel Consumption Coefficients for Selected Vehicle Types
(gallons per mile)

Vehicle Type	**Fixed**	**Variable** (per thousand pounds)
Vans		
Conventional Semi	0.11068	0.00080
Short Double	0.12030	0.00080
Turnpike Double	0.12889	0.00085
Flatbeds		
Conventional Semi	0.10450	0.00090
Turnpike Double	0.10349	0.00095
Tanks		
Conventional Semi	0.10180	0.00090
Turnpike Double	0.10338	0.00095
Dump Trailers		
Conventional Semi	0.08565	0.00065
Turnpike Double	0.08410	0.00070

Source: Jack Faucett Associates (1991).

per tire-mile (3 cents divided by 18 tires) for GVWs below 3,500 pounds per tire, and to increase by 0.7 percent for each 1 percent increase in weight above this value.

For tridems, tires on one axle of the tridem are subjected to a significant amount of additional wear. This effect was represented by an assumed 67 percent increase in the cost of tires on one axle of a tridem. All JFA estimates of tire costs presume the use of dual tires on all axles except the steering axle.

(e) Repair and Servicing

JFA estimated 1995 costs for repair and servicing to be 9 cents per vehicle-mile (in 1988 dollars) plus or minus 0.097 cents for each thousand pounds above or below 58,000 pounds. These estimates were derived from published estimates and a forecast 10 percent decline in repair and servicing costs between 1988 and 1995. To the extent that a greater decline may have occurred, the JFA repair and servicing costs may be too high.

(f) Indirect and Overhead Costs

For truckload carriers, JFA's estimates of indirect and overhead costs are summarized in Table 1.7.

The first column of Table 1.7 shows estimated fees that were assumed, in the JFA analysis, to be charged to vehicles that would be permitted to operate at GVWs above 80,000 pounds. These fees would be designed to cover the increased costs to the highway system (primarily bridge costs) of allowing the selected configurations to operate at higher GVWs. These cost estimates are developed in Appendix D of Sydec, *et al.*, (1993). The figures in this column represent the estimated annual cost of permit fees divided by annual miles of operations. It was estimated by Sydec that, as shown in the table, these fees could be relatively significant for nine-axle twin 28s and twin 33s.

The second column of Table 1.7 shows estimates of all other indirect and overhead costs. For configurations that normally are used in door-to-door service, these costs were estimated to average 22 cents per mile based on a review of published estimates. For turnpike doubles and triples, these costs were assumed to average 20 percent more (26.5 cents per mile) to reflect the extra cost of arranging for access hauls to and from staging areas and, frequently, for dealing with more than one shipper per linehaul move.

Table 1.7. Overhead Costs for Truckload Configurations
(1988 cents/mile)

Configuration	User Charges	Other Overhead	Total Overhead
5 Axle Semi	--	22.0	22.0
6 Axle Semi	1.4	22.0	23.4
5 Axle Twin 28'	--	22.0	22.0
9 Axle Twin 28'	5.7	22.0	27.7
7 Axle RMD	1.4	22.0	23.4
9 Axle Twin 33'	3.6	22.0	25.6
Turnpike Doubles	1.2	26.4	27.6
Triples	0.9	26.4	27.3

Source: Jack Faucett Associates (1991).

Indirect and overhead costs for LTL carriers are much higher. For LTL carriers, these costs include the costs of owning and operating a system of terminals at which shipments are sorted and transferred between vehicles, as well as the costs of marketing and tracking a large number of shipments per vehicle trip. For a combination with a single 45-foot trailer, the extra costs were estimated by Maio (1986) to be $1.14 per vehicle-mile (after adjustment to 1988 dollars); and for a combination with two such trailers, the extra costs were estimated to be $1.79 per vehicle-mile. Taking 54,000 pounds to be a typical GVW for such a single-trailer combination (based on FHWA Truck Weight Study data) and 45,000 pounds to be a typical GVW for the second trailer produced an estimate of the change in indirect and overhead costs for an LTL vehicle with a change in GVW of 1.45 cents per thousand pounds. Adding in the 22 cents per vehicle-mile for non-LTL-specific indirect and overhead costs produced JFA's estimate for indirect and overhead costs of an LTL vehicle of $1.36 per vehicle-mile plus (or minus) 1.45 cents per vehicle-mile for every 1,000 pounds above (or below) 54,000 pounds GVW.

(g) Commodities by Body Type

Tables 1.8 and 1.9 provide information on the trailer and body types that are used for carrying various commodities. The 20 commodity groups listed in these two tables are those distinguished by the Bureau of the Census' Truck Inventory and Use Survey (TIUS).

For each of the 20 commodity groups, Table 1.8 shows the relative use of various trailer types for carrying products belonging to the commodity group. The data in this table show VMT of combinations with five or more axles and specific trailer types carrying products in a given commodity group expressed as a percentage of total VMT of combinations with five or more axles carrying these products.

Dry vans are the most common trailer type. However, Table 1.8 indicates that only seven of the 20 commodity groups are more likely to be carried in dry vans than in one of the other trailer types. Other frequently used trailers types are: refrigerated vans (for farm products and processed foods); flatbeds (for primary metals, machinery, and lumber and wood products); tanks (for chemicals and petroleum products); hoppers (for grain); dump trailers (for mining products, building materials, and scrap and refuse); livestock trailers; logging trailers; and automobile transporters.

Table 1.9 shows similar data on the relative use of trucks with three or more axles and various body types for carrying products belonging to each

Table 1.8. Distribution of VMT by Product Carried Across Trailer Body Types for Combinations with Five or More Axles

Product	Van	Reefer	Flatbed	Tank	Hopper	Dump	Mixer	Garbage	Other	Total
Farm Products	16.0%	35.9%	13.9%	7.5%	23.2%	3.3%	0.0%	0.0%	0.1%	100.0%
Live Animals	5.6%	8.1%	13.3%	0.4%	0.3%	0.0%	0.0%	0.0%	72.3%	100.0%
Mining Products	2.4%	0.7%	6.7%	18.3%	4.5%	65.7%	0.0%	0.0%	1.8%	100.0%
Forest Products	20.8%	0.0%	14.8%	0.3%	0.0%	2.1%	0.0%	0.0%	62.0%	100.0%
Lumber and Wood	15.6%	0.2%	75.7%	0.0%	0.0%	0.8%	0.0%	0.0%	7.6%	100.0%
Processed Foods	32.9%	58.5%	2.1%	3.1%	1.7%	0.4%	0.0%	0.0%	1.3%	100.0%
Textiles	96.1%	2.3%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	100.0%
Building Materials	10.5%	0.4%	31.0%	0.5%	11.4%	45.0%	0.1%	0.0%	1.0%	100.0%
Household Goods	96.5%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Furniture	88.5%	6.4%	2.0%	1.8%	0.3%	0.6%	0.0%	0.0%	0.2%	100.0%
Paper	94.6%	0.6%	4.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	100.0%
Chemicals	23.3%	3.2%	8.4%	56.2%	6.0%	2.3%	0.0%	0.0%	0.5%	100.0%
Petroleum	5.6%	0.3%	0.7%	91.3%	0.1%	0.3%	0.0%	0.0%	1.7%	100.0%
Plastics	66.8%	1.3%	21.1%	6.9%	1.8%	0.0%	0.0%	0.0%	2.2%	100.0%
Primary Metals	13.5%	0.5%	82.2%	0.3%	0.0%	1.0%	0.0%	0.0%	2.6%	100.0%
Fabricated Metals	58.0%	0.6%	38.5%	0.0%	0.0%	0.9%	0.0%	0.0%	2.0%	100.0%
Machinery	16.9%	0.3%	73.3%	0.0%	0.6%	0.9%	0.0%	0.0%	8.1%	100.0%
Transportation Eq.	20.0%	0.5%	22.0%	0.0%	0.1%	1.5%	0.0%	0.0%	55.8%	100.0%
Scrap and Refuse	28.7%	0.0%	17.0%	7.1%	0.0%	33.2%	0.0%	12.2%	1.9%	100.0%
Mixed Cargoes	92.4%	3.8%	3.5%	0.0%	0.2%	0.0%	0.0%	0.0%	0.1%	100.0%

Source: *1982 Truck Inventory and Use Survey*, personal use tape.

Table 1.9. Distribution of VMT by Product Carried Across Body Types for Single-Unit Trucks with Three or More Axles

Product	Van	Reefer	Flatbed	Tank	Hopper	Dump	Mixer	Garbage	Other	Total
Farm Products	11.1%	4.6%	30.6%	14.7%	33.0%	5.2%	0.0%	0.3%	0.4%	100.0%
Live Animals	0.0%	1.7%	58.9%	0.0%	3.0%	2.4%	0.0%	0.0%	34.1%	100.0%
Mining Products	0.0%	0.0%	2.5%	1.8%	0.0%	90.6%	0.5%	0.0%	4.6%	100.0%
Forest Products	2.8%	0.0%	27.7%	0.0%	0.0%	5.4%	0.0%	0.0%	64.1%	100.0%
Lumber and Wood	8.2%	0.0%	69.4%	0.0%	0.0%	3.9%	0.0%	0.0%	18.5%	100.0%
Processed Foods	20.7%	65.6%	5.9%	0.4%	4.2%	0.6%	0.0%	0.0%	2.7%	100.0%
Textiles	94.8%	0.0%	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Building Materials	0.4%	0.0%	7.9%	0.1%	0.1%	64.7%	25.1%	0.0%	1.6%	100.0%
Household Goods	73.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	26.9%	100.0%
Furniture	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Paper Products	85.3%	0.0%	14.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Chemicals	9.9%	0.0%	39.2%	32.6%	5.8%	6.7%	0.0%	0.0%	5.8%	100.0%
Petroleum	1.0%	0.0%	4.1%	71.5%	1.2%	5.4%	0.0%	0.0%	16.8%	100.0%
Plastics	25.4%	0.0%	24.5%	0.0%	0.0%	0.0%	0.0%	0.0%	50.1%	100.0%
Primary Metals	4.8%	0.0%	79.9%	0.0%	0.0%	7.4%	0.0%	0.0%	7.8%	100.0%
Fabricated Metals	24.8%	0.0%	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%	8.6%	100.0%
Machinery	5.5%	0.0%	43.3%	0.2%	0.0%	0.1%	0.0%	1.1%	49.8%	100.0%
Transportation Eq.	7.7%	0.0%	14.5%	0.0%	0.0%	9.2%	0.0%	0.0%	68.6%	100.0%
Scrap and Refuse	1.0%	0.0%	5.1%	2.0%	0.3%	10.3%	0.0%	71.5%	9.9%	100.0%
Mixed Cargos	80.1%	0.0%	19.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.5%	100.0%

Source: *1982 Truck Inventory and Use Survey*, personal use tape.

of the commodity groups. It should be noted that most of these commodity groups are only infrequently carried in single-unit trucks with three or more axles; building materials, scrap and refuse, and farm products account for over 70 percent of the use of these vehicles.

The data in Tables 1.8 and 1.9 were obtained from a tabulation of data from the 1982 TIUS. Data for two-axle trucks and for three and four-axle combinations were excluded from the tabulation because shipments currently made in such vehicles would not be affected by most potential changes in size and weight limits. It is likely that changes in trailer and body-type usage since 1982 have been small, but subsequent refinements in TIUS' "product carried" question are likely to produce somewhat more accurate results (particularly relating to carriage of "mixed cargos") if corresponding tabulations are developed from the 1987 or 1992 TIUS.

1.3 Costs Per Payload Ton-Mile

The size of shipments may be limited by legal limits on vehicle or axle weights ("weight limited"), by the cubic capacity of the trailer ("cube limited"), or by the maximum amount of material that a shipper wishes to send — a condition that may be referred to as "shipment-size limited." It is important to recognize that some shipments fall into this last category — a category of shipments that generally can be carried most economically in the vehicles that are currently carrying them and that are likely to be affected by changes in size and weight limits only to the extent that these changes may reduce the availability of these vehicles. Also, some shipments are cube limited when carried by some configurations and weight limited when carried by others.

The first three subsections below contain discussions of how costs per payload ton-mile for combination trucks vary with vehicle configuration and weight limit for weight-limited and cube-limited (truckload) operation and for LTL operation. All cost estimates are taken from Appendix B of JFA (1991), which is reproduced as the appendix of this working paper. These estimates were developed in spreadsheet form using vehicle-mile costs discussed above and presented more fully in Appendix A of JFA (1991).

The fourth subsection contains estimates of how costs per payload ton-mile for single-unit dump trucks vary with axle configuration and vehicle weight. These cost estimates are taken from Appendix B of JFA (1990) and are based on vehicle-mile costs discussed and presented in that paper.

The fifth subsection contains a brief discussion of available JFA cost estimates for B Trains and C Trains.

In the sixth subsection, we observe that moderate changes in the cost estimates that apply uniformly across vehicle configurations and GVWs have relatively small effects on the estimates of percentage changes in costs between current configurations and those that might be introduced as a result of changes in size or weight limits. A concluding subsection discusses data produced by Trimac Consulting Services (1994) using their proprietary model (one of several proprietary truck cost models developed by various firms).

(a) Weight-Limited Truckload Operation

Table 1.10 shows cost estimates from JFA (1991) for typical intercity truckload operation of several dry-van and hopper trailers configurations carrying weight-limited payloads under alternative weight limits. The estimated costs per mile for loaded operation of these vehicles, shown in the second column, are taken from Table 1.2 and from similar cost estimates contained in Appendix A of JFA (1991). A complete set of cost estimates from JFA (1991) for six trailer types corresponding to those shown in Table 1.10 is reproduced in the appendix to this paper.

The JFA estimates shown for both dry and refrigerated vans in Table 1.10 and in the appendix assume that, on average, vehicles are operated empty for 15 percent of their mileage and that they are otherwise operated at the indicated GVW. (The estimated cost per vehicle-mile for empty operation of each configuration is shown in the appendix.) The percentages of empty mileage used for other trailer types are 25 percent for flatbeds, 45 percent for tanks, and 40 percent for hoppers and dump trailers. To the extent that carriers experience actual empty mileage ratios that are higher or lower than those used in Table 1.10 and in the appendix, the estimated costs per loaded mile and per payload ton-mile will be higher or lower than those shown, and almost uniformly so. However, for any pair of comparable configurations, the relationships between the costs per loaded mile and between the costs per ton-mile will only change slightly.

The final two columns of the appendix show the absolute and percentage change in cost per ton-mile for operating each configuration at the indicated GVW relative to that of operating a corresponding five-axle semitrailer, and the latter of these columns is also shown in Table 1.10. For weight-limited truckload operations, the comparisons in those columns are to a five-axle weight-limited combination operating at 78,000 pounds.

Table 1.10. 1991 Forecasts of 1995 Cost Estimates for Truckload Operation of Selected Configurations of Weight-Limited Dry Vans and Hopper Trailers

(1988 dollars)

Configuration	Loaded Weight (lbs.)	Cost Per Mile	Percent Miles Empty	Cost per Loaded Mile	Tare Weight (lbs.)	Payload (lbs.)	Cents Per Ton-Mile	Comparison w/5-Axle 48' Semi
Dry Vans								
5 Axle 48 Foot Semi	78,000	$1.08	15%	$1.25	28,000	50,000	5.01¢	--
5 Axle 48' Spread	80,000	1.10	15	1.27	28,600	51,400	4.95	-1.3%
5 Axle 53 Foot Semi	78,000	1.09	15	1.26	28,900	49,100	5.13	+2.4%
6 Axle 48 Foot Semi	79,500	1.11	15	1.29	29,500	50,000	5.17	+3.1%
	86,500	1.13	15	1.31	29,500	57,000	4.59	-8.5%
	90,000	1.14	15	1.32	29,500	60,500	4.35	-13.2%
	94,000	1.15	15	1.33	29,500	64,500	4.11	-18.0%
7 Axle 40 + 28	105,500	1.23	15	1.43	36,300	69,200	4.13	-17.7%
7 Axle 48 + 28	105,500	1.24	15	1.43	37,600	67,900	4.21	-16.0%
9 Axle Twin 28	108,000	1.29	15	1.49	37,700	70,300	4.24	-15.3%
9 Axle Twin 33	80,000	1.23	15	1.43	39,500	40,500	7.06	+40.8%
	113,500	1.29	15	1.50	39,500	74,000	4.04	-19.3%
7 Axle Triple 28	116,000	1.34	15	1.55	40,500	75,500	4.10	-18.2%
9 Axle Twin 48	129,000	1.38	15	1.59	46,200	82,800	3.84	-23.4%
Hopper Trailers								
5 Axle 42 Foot Semi	78,000	1.04	40	1.66	24,600	53,400	6.21	--
6 Axle 42 Foot Semi	82,500	1.07	40	1.72	26,100	56,400	6.09	-2.0%
6 Axle 48 Foot Semi	79,500	1.07	40	1.72	27,000	52,500	6.53	+5.2%
	86,500	1.08	40	1.73	27,000	59,500	5.81	-6.4%
	90,000	1.09	40	1.74	27,000	63,000	5.52	-11.1%
	94,000	1.10	40	1.75	27,000	67,000	5.21	-16.1%
7 Axle 42 + 21	102,000	1.19	40	1.89	31,700	70,300	5.37	-13.6%
9 Axle Twin 28	108,000	1.25	40	2.00	35,600	72,400	5.53	-11.0%
9 Axle Twin 33	113,500	1.25	40	2.00	36,600	76,900	5.19	-16.5%
7 Axle Triple 28	116,000	1.23	40	1.95	36,600	79,400	4.91	-20.9%
9 Axle Twin 42	124,000	1.26	40	2.00	28,900	85,100	4.70	-24.4%
9 Axle Twin 48	129,000	1.29	40	2.04	40,300	88,700	4.60	-25.9%

Source: Jack Faucett Associates (1991).

The costs shown in Table 1.10 and in the appendix are estimates for typical intercity operation of selected configurations and body types operated at various GVWs. The estimates were developed by JFA to indicate how changes in sizes and weights affect the cost of operating alternative configurations. As discussed above, the information provides estimates of the percentage change in transport costs that can result from some of the changes in size and weight limits under consideration. Also, as discussed in Section 1.2(f), the cost figures include estimated user charges for operation at weights above 80,000 pounds, a factor that tends to reduce the attractiveness of short and intermediate length heavy doubles.

It should be observed that the estimates in the appendix do not reflect the varying effects on cost per ton-mile of factors such as annual mileage, length of haul, variation of payload, level of service, and region and/or origin/destination characteristics. However, each of these factors tends to have a similar influence on the cost per ton-mile for the various configurations considered. Hence, the estimates of percentage change in transport costs shown tend to hold for a range of movements having different costs per ton-mile but which conform to the vehicle and weight specifications shown.[2] In the aggregate, the estimates of percentage change in cost per ton-mile appear to be reasonable estimates of the average percentage change for all movements having the characteristics specified in the exhibit, though they could be improved somewhat by using more current cost information. On the other hand, the estimates of percentage change in transport costs do *not* hold for any pair of configurations that have empty-mileage percentages, annual mileages, average lengths of haul, or levels of service that differ from each other.

A comparison of the Table 1.10 figures for dry vans and hoppers indicates that hoppers are slightly less expensive than dry vans to operate per mile. On the other hand, because of their high percentage of empty miles, hoppers are appreciably more expensive than dry vans per loaded mile and per ton-mile. However, despite the appreciable differences in cost per ton-mile, the *percentage* difference in cost per ton-mile between any pair of hopper configurations is quite similar to the corresponding percentage difference for dry van configurations.

A somewhat more extensive comparison of the percentage difference in costs between various trailer types and configurations and corresponding five-axle

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[2] For example, Peat Marwick Stephenson and Kellogg (1993) estimated that the cost advantage of 53-foot semis relative to 48-foot semis for truckload carriage of cube-limited loads increases by only 0.3 percent, from 8.1 percent to 8.4 percent, over lengths of haul considered in their study.

semitrailers is shown in Table 1.11 All figures in this table can also be found in the appendix to this paper.

Table 1.11 indicates that the various configurations shown offer almost the same percentage reduction in costs for flatbeds as they do for dry vans. The percentage reductions for tank and hopper trailers also are quite similar to those for dry vans, though most of these reductions are somewhat smaller, primarily because the comparison is to a 42-foot semitrailer instead of a 48-foot semitrailer. On the other hand, because of the cost of refrigerating additional trailers, the percentage reductions in cost obtained with multi-trailer refrigerated vans are appreciably smaller than they are for the other trailer types. The percentage cost reductions for twin-28 and twin-33 dump trailers are particularly high because the comparison is made to a 36-foot semi, since longer dump trailers pose a stability problem when unloading. The bridge formula limits 36-foot semitrailers to a practical GVW of about 70,000 pounds (though a regulatory exception allows 42-foot semitrailers to be loaded to the same weights as 48-foot semis).

(b) Cube-Limited Truckload Operation

Table 1.12 shows cost estimates from JFA (1991) for typical intercity truckload operation of several dry van configurations carrying cube-limited payloads with a density of 7 pounds per square foot.

The Table 1.12 cost estimates use the same empty mileage assumption (15%) as do the Table 1.10 cost estimates for weight-limited dry vans. Varying the assumptions for empty mileage percentage and for payload density (within the range for cube-limited payloads[3]) would result in proportionate changes in the estimated cost per ton-mile[4] for all configurations and no change in the percentage differ-ence between costs per ton-mile for the various configurations. As discussed above, uniformly varying the assumptions for annual mileage, length of haul, level of service, and region and/or origin/ destination characteristics will also affect the cost per ton-mile and may have a slight effect on the percentage difference between the costs per ton-mile for the various configurations. On the other hand, varying any of these assumptions nonuniformly (e.g.,

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[3] The payload densities at which these configurations will weigh out are shown for various weight limits on the first page of the appendix).

[4] It also is possible to express these costs per cubic-foot-mile -- a measure that, for cube-limited operations, is independent of payload density. However, a general lack of data on the total volume of goods transported by truck (or by cube-limited dry vans) restricts the usefulness of this measure for policy analysis purposes.

Table 1.11. Relative Efficiency of Alternative Configurations for Weight-Limited Line-Haul Truckload Operation

Configuration	Loaded Weight (lbs.)	Percent Change in Cost Per Ton-Mile Relative to Five Axle Semi[1]					
		Dry Van	Reefer	Flatbed	Tank	Hopper	Dump
6 Axle 48 Foot Semi	86,500	-8.5%	-9.3%	-8.4%	-6.1%	-6.4%	NE
7 Axle 40 + 28	105,500	-17.7%	-11.2%	-17.3%	-15.8%	-13.4%	NE
7 Axle 48 + 28	105,500	-16.0%	NE	NE	NE	NE	NE
9 Axle Twin 28	108,000	-15.3%	-9.5%	-14.6%	-13.0%	-11.0%	-21.5%
9 Axle Twin 33	113,500	-19.6%	-14.1%	-19.0%	-17.9%	-16.5%	-25.3%
7 Axle Triple 28	116,000	-18.2%	-4.4%	-21.6%	-18.6%	-20.9%	NE
9 Axle Twin 42	124,000	NE	NE	NE	-21.5%	-24.4%	-26.8%[2]
9 Axle Twin 48	129,000	-23.4%	-19.9%	-24.9%	-23.7%	-25.9%	NE

NE: Not estimated, configuration is of limited interest for use with this trailer type.
[1] Forty-two foot trailer for tanks and hoppers; 36 feet for dump trailers; 48 feet for other trailer types.
[2] Twin 36 foot trailers at 117,000 pounds.
Source: Jack Faucett Associates (1991).

Table 1.12. 1991 Forecasts of 1995 Costs Estimates for Truckload Operation of Selected Configurations of Cube-Limited Dry Vans

(1988 dollars)

Configuration	Loaded Weight (lbs.)	Cost Per Mile	Percent Miles Empty	Cost per Loaded Mile	Tare Weight (lbs.)	Payload (lbs.)	Cents Per Ton-Mile	Comparison w/5-Axle 48' Semi
5 Axle 48 Foot Semi	52,000	$1.03	15%	$1.20	28,000	24,500	9.78¢	--
5 Axle 53 Foot Semi	56,000	1.04	15	1.21	28,900	27,100	8.94	-8.6%
6 Axle 48 Foot Semi	54,000	1.06	15	1.24	29,500	24,500	10.13	+3.5%
5 Axle Twin 28	59,800	1.07	15	1.25	31,200	28,600	8.76	-10.5%
7 Axle 40 + 28	71,000	1.16	15	1.35	36,300	34,700	7.81	-20.2%
7 Axle 48 + 28	76,400	1.17	15	1.37	37,600	38,800	7.05	-27.9%
9 Axle Twin 28	66,300	1.21	15	1.41	37,700	28,600	9.86	+0.8%
9 Axle Twin 33	73,200	1.21	15	1.42	39,500	33,700	8.40	-14.1%
7 Axle Trip 28	83,400	1.27	15	1.47	40,500	42,900	6.87	-29.8%
9 Axle Twin 48	95,200	1.31	15	1.52	46,200	49,000	6.20	-36.7%

Note: The capacity of all configurations is based on a density of seven pounds per cubic foot.
Source: Jack Faucett Associate (1991).

as a result of different utilization rates for different configurations) may have a more significant effect on the percentage differences between the costs per ton-mile for the various configurations.

A comparison of the percentage differences in costs shown in Table 1.12 with the corresponding Table 1.10 values for weight-limited dry vans reveals that some configurations that are more efficient than 48-foot semitrailers for cube-limited hauls are less efficient for weight-limited hauls and vice versa. For example, six-axle 48-foot semitrailers are estimated to be about 8.5 percent more efficient than five-axle 48-foot semitrailers for weight-limited cargo but about 3.5 percent more costly for cube-limited cargo. A similar effect also occurs for nine-axle twin 28s. On the other hand, 53-foot semitrailers (shown in the exhibits) and 57-foot semitrailers (not analyzed by JFA) are more efficient than five-axle 48-foot semitrailers for cube-limited hauls but more expensive for weight-limited hauls. Thus, these configurations are effectively more specialized configurations than five-axle 48-foot semis. The greater specialization of these configurations may result in some reduction in utilization (more empty mileage, lower annual mileage, or poorer use of vehicle capacity) and so reduce the effective cost savings below those shown in the two exhibits.

(c) Less-than-Truckload Operation

Table 1.13 shows cost estimates from JFA (1991) for typical interterminal LTL operation. Empty mileage for LTL operators is very low, and is set to zero in the table, though partial payloads are relatively common. The average payload density of 7.8 pounds per cubic foot used by JFA includes the effect of partial payloads.

(d) Single-Unit Trucks

Cost estimates for single-unit dump trucks were developed by JFA in the original 1990 version of their working paper but not updated in 1991. The following paragraphs describe and discuss the 1990 estimates for dump trucks, and a concluding paragraph briefly discusses garbage haulers and cement mixers.

Single-unit dump trucks are used primarily for short hauls, frequently over city streets, and they spend a significant portion of time waiting to be loaded or unloaded. Furthermore, in most applications they are operated only one shift per day, five days per week, and usually not for a full year. Accordingly, on average, these vehicles travel only 9,300 miles per year (U.S. Bureau of the Census, 1986). If operated 2,080 hours per year, the

Table 1.13. 1991 Forecasts of 1995 Costs for Selected LTL Configurations
(1988 dollars)

Configuration	Loaded Weight (lbs.)	Cost Per Mile	Percent Miles Empty	Cost per Loaded Mile	Tare Weight (lbs.)	Payload (lbs.)	Cents Per Ton-Mile (cents)	Comparison w/5-Axle Semi
5 Axle 48'	55,400	$2.24	0%	$2.24	28,000	27,400	16.35	--
5 Axle Twin 28'	63,200	$2.40	0%	$2.40	31,200	32,000	15.01	-8.2%
7 Axle Twin 33'	74,900	$2.65	0%	$2.65	37,200	37,700	14.07	-13.9%
9 Axle Twin 33'	77,200	$2.74	0%	$2.74	39,500	37,700	14.52	-11.2%
7 Axle Triple 28'	88,500	$2.92	0%	$2.92	40,500	48,000	12.15	-25.7%

Source: Jack Faucett Associates (1991).

9,300 miles-per-year figure suggests that they travel only 4.5 miles per hour operated. Allowing for days not operated, JFA used a figure of 7.5 miles traveled per hour operated, derived from the R.S. Means (1989) estimate of time required for a 10-mile round trip under normal city driving conditions. Since these vehicles spend a portion of the day being loaded and unloaded, we observe that the average effective speed of these vehicles, including stopped time, when *on the road*, is likely to be moderately higher than 7.5 miles per hour.

Driver costs were assumed by JFA to be the same as for union drivers of combination trucks but were converted to a cents per hour basis using 7.5 vehicle-miles per driver-hour. For the reason stated above, this conversion apparently overstates driver costs.

Purchase prices for dump trucks of $93,000 to $106,300 were obtained by JFA from local dealers, adjusted for sales tax, and converted to a per-mile cost using an annual mileage of 9,300 and other assumptions that were identical to those used for tractors.

Fuel usage in 1995 was forecast by JFA using data from Knapton (1981) and incorporating a half-gallon-per-hour adjustment for fuel consumed while idling. It was assumed that dump trucks can spend up to 75 percent of their time idling at origins, destinations and traffic lights. A formula error in the 1990 spreadsheet results in a moderate overestimate of fuel consumption.

Tire costs were estimated by JFA using the same assumptions as used for combination trucks.

Repair and servicing costs for dump trucks were assumed by JFA to be the same per hour of operation (including idling time) as for a refrigerated van with the same GVW. However, the repair and servicing costs used in the 1990 paper did not incorporate the forecast 10 percent decline in these costs that was used in the 1991 paper (and reflected in the previously discussed costs for combination trucks). The average effective on and off-road speed and annual mileage figures used indicate that annual hours operated by dump trucks is only 49 percent of that of refrigerated vans.

Indirect and overhead costs were estimated by JFA using the same markups that R.S. Means (1988) used for overhead and profit: 42 percent of direct labor cost and 10 percent of the cost of equipment and suppliers. Unlike the corresponding estimates for combination trucks (from JFA, 1991), these costs do not include the effect of any permit fees for use of heavy vehicle weights.

With these assumptions, the total cost per mile for a three-axle 12 cubic yard dump truck operating at a GVW of 51,500 pounds when loaded was estimated to be $6.01, that for a four-axle 12 cubic yard truck at 56,000 pounds to be $6.14, and that for a four-axle 17 cubic yard dump truck at 71,000 pounds to be $6.39. These estimates are considerably lower than those published by R.S. Means, which ranged from $10.47 to $25.80 (for a 20-mile round trip).

The resulting estimates of costs, by cost category, are displayed in Table 1.14 for three and four-axle dump trucks with three different capacities; and corresponding costs per ton-mile are displayed in Table 1.15. The estimated costs per vehicle-mile are substantially greater than those for combination trucks (by roughly a factor of five), primarily because of the very low utilization rates of these vehicles. The above discussion suggests that a moderate downward revision of the estimates for driver, vehicle, repair and overhead costs may be appropriate. On the other hand, the JFA cost estimates are already substantially lower than the R.S. Means estimates (by a factor of two to four).

The cost of operating garbage haulers and cement mixers is not analyzed in any of the literature reviewed. These vehicles are likely to have different costs than dump trucks, primarily because of different utilization rates (and, to a lesser extent, because of different vehicle costs). However, when compared to the cost per ton-mile of operation at bridge-formula weights, the percentage cost savings for operating these vehicles at high weights is likely to be quite similar to the savings estimated for corresponding dump truck operations.

(e) B Trains and C Trains

Cost estimates for twin 28 and twin 33 B Trains and C Trains were developed in the 1990 version of the JFA working paper but not updated in 1991. For reasons discussed in the preceding subsection, the fuel and repair costs estimated in 1990 are probably high. However, if these costs are compared to similar overestimates of costs for corresponding A Train configurations from the 1990 working paper the above inaccuracies should have little effect on the resulting percentage comparisons. On the other hand, the costs for C Trains also may be overstated because of technological improvements in the double-drawbar ("C") dollies used by these vehicles.

Table 1.14. 1991 Forecasts of 1995 Costs Per Vehicle Mile for Dump Trucks

(1988 cents/mile)

	GVW (lbs.)	Drivers	Vehicle	Fuel	Tires	Repair	Overhead	Total
3 Axle Trucks								
12 Cubic Yards	22,600	198.0	191.2	19.4	1.7	34.0	134.87	579.2
	51,000	198.0	191.2	21.9	2.2	50.8	136.61	600.8
	54,000	198.0	191.2	22.2	2.3	52.6	136.80	603.1
17 Cubic Yards	25,700	198.0	204.4	19.7	1.7	35.8	137.70	597.3
	51,000	198.0	204.4	21.9	2.2	50.8	139.25	616.6
	71,000	198.0	204.4	23.6	2.3	62.7	140.51	632.1
20 Cubic Yards	27,000	198.0	209.8	19.8	1.7	36.6	138.85	604.7
	51,000	198.0	209.8	21.9	2.2	50.8	140.33	623.1
	80,000	198.0	209.8	24.4	2.3	68.1	142.15	645.6
4 Axle Trucks								
12 Cubic Yards	24,800	198.0	198.5	19.6	2.3	35.3	136.53	590.3
	56.500	198.0	198.5	22.4	2.6	54.1	138.43	614.0
17 Cubic Yards	27,400	198.0	209.6	19.9	2.3	36.8	138.91	605.6
	56,500	198.0	209.6	22.4	2.6	54.1	140.67	627.4
	71,000	198.0	209.6	23.6	3.1	62.7	141.58	638.6
20 Cubic Yards	29,200	198.0	217.0	20.0	2.3	37.9	140.51	615.8
	56,500	198.0	217.0	22.4	2.6	54.1	142.15	636.3
	71,000	198.0	217.0	23.6	3.1	62.7	143.03	647.6
	80,000	198.0	217.0	24.4	3.4	68.1	143.63	654.6

Source: Jack Faucett Associates (1990).

Table 1.15. Comparison of Costs for Dump Trucks Operated at Various Loaded GVWs

	Loaded Weight (lbs.)	Cost Per Mile	Percent Miles Empty	Cost Per Loaded Mile	Tare Weight (lbs.)	Payload	Cents Per Ton-Mile	Comparison w/Line 1
3 Axle Trucks								
12 Cubic Yards	51,000	$6.01	50%	$11.80	22,600	28,400	83.09	--
	54,000	$6.03	50%	$11.82	22,600	31,400	75.30	-9.4%
17 Cubic Yards	51,000	$6.17	50%	$12.14	25,700	25,300	95.96	+15.4%
	71,000	$6.32	50%	$12.29	25,700	45,300	54.28	-34.7%
20 Cubic Yards	51,000	$6.23	50%	$12.28	27,000	24,000	102.32	+23.1%
	80,000	$6.46	50%	$12.50	27,000	53,000	47.18	-43.2%
4 Axle Trucks								
12 Cubic Yards	56,500	$6.14	50%	$12.04	24,800	31,700	75.98	-8.6%
	58,000	$6.15	50%	$12.05	24,800	33,200	72.62	-12.6%
17 Cubic Yards	56,500	$6.27	50%	$12.33	27,400	29,100	84.74	+2.0%
	71,000	$6.39	50%	$12.44	27,400	43,600	57.07	-31.3%
20 Cubic Yards	56,500	$6.36	50%	$12.52	29,200	27,300	91.73	+10.4%
	80,000	$6.55	50%	$12.70	29,200	50,800	50.02	-39.8%

Note: All costs are estimates of 1995 costs expressed in 1988 dollars.

Source: Jack Faucett Associates (1990).

Hence, it is likely that the cost penalty for using C Trains has declined slightly since preparation of the JFA estimates.

Cost estimates for eight and nine-axle twin 28 dry-van A Trains, B Trains and C Trains from the 1990 version of the JFA working paper are reproduced in Table 1.16. The table indicates that eight-axle B Trains and C Trains with loaded weights of 104,500 pounds are 4.8 percent more expensive (per ton-mile) than corresponding A Trains, and that nine-axle C Trains with a loaded weight of 110,000 pounds is 4.9 percent more expensive than nine-axle A Trains with the same loaded weight. The extra cost of the B Trains and C Trains would result in a moderate reduction in the savings that can be obtained with short and intermediate length twin-trailer configurations. (Table 1.10 indicates that, compared to five-axle 48 foot dry-van semis, nine-axle twin 28 A Trains loaded to 108,000 pounds are 15.3 percent less expensive per ton-mile and nine-axle twin 33 A Trains loaded to 113,500 pounds are 19.3 percent less expensive.)

(f) Robustness of the Estimates of Percentage Change in Costs

In the preceding subsections, we have stated that the estimates of percentage change in costs shown in Tables 1.10 to 1.14 are relatively insensitive to changes in the estimates of any cost component that applies reasonably uniformly to all configurations using a particular trailer. Table 1.17 presents a small sample of data that supports this statement.

Table 1.17 shows the relative contribution to total costs of each of the six cost components distinguished by JFA for eight configurations of dry vans and for two configurations of hopper trailers. For both trailer types, the portion of costs attributed to drivers tends to drop with increasing vehicle capacity, while the portion attributed to each of the next four components tends to increase slightly. The portion of total costs attributed to the sixth component, overhead, fluctuates with vehicle capacity because (as discussed in Section 1.2(f)) this component includes estimated user fees that the JFA analysis assumed would be charged to vehicles permitted to operate at GVWs above 80,000 pounds.

We have observed previously (in Section 1.2(c)) that the JFA estimates of fuel costs may be high. Using data in Table 1.17, it can be seen that, for dry vans, a uniform 20 percent reduction in estimated fuel costs would reduce estimated total costs by 4 percent for five-axle 48-foot semitrailers and for nine-axle twin 28s and by slightly more (up to 4.3%) for the other configurations. The percentage cost advantage of nine-axle twin 28s

Table 1.16. Comparison of Costs for Twin 28 Dry-Van A Trains, B Trains and C Trains

	Loaded Weight (lbs.)	Cost Per Mile	Percent Miles Empty	Cost Per Loaded Mile	Tare Weight (lbs.)	Payload	Cents Per Ton-Mile	Comparison w/8 Axle A Train
A Train								
8 Axle	104,500	$1.28	15%	$1.48	36,700	67,800	4.37	--
9 Axle	104,500	$1.31	15%	$1.52	39,200	65,300	4.65	+6.4%
	110,000	$1.32	15%	$1.53	39,200	70,800	4.32	-1.1%
B Train								
8 Axle	104,500	$1.29	15%	$1.50	39,200	65,300	4.58	+4.8%
C Train								
8 Axle	104,500	$1.30	15%	$1.50	38,900	65,600	4.58	+4.8%
9 Axle	104,500	$1.33	15%	$1.54	41,400	63,100	4.88	+11.7%
	110,000	$1.34	15%	$1.55	41,400	68,600	4.53	+3.7%

Note: All costs are estimates of 1995 costs expressed in 1988 dollars.

Source: Jack Faucett Associates (1990) plus additional information from JFA spreadsheet..

Table 1.17. Percentage Contribution of JFA Cost Components to Total Cost

	Loaded Weight (lbs)	Driver	Vehicle	Fuel	Tires	Repair	Overhead	Total
Dry Van								
5 Axle 48 Foot Semi	78,000	27.8%	18.5%	20.0%	3.2%	10.1%	20.4%	100%
6 Axle 48 Foot Semi	94,000	26.2%	18.2%	20.3%	4.1%	10.9%	20.4%	100%
7 Axle 40+28	105,500	25.4%	19.2%	21.1%	3.9%	11.5%	19.0%	100%
7 Axle 48+28	105,000	25.3%	19.3%	21.0%	3.9%	11.5%	18.9%	100%
9 Axle Twin 28	108,000	23.8%	19.1%	20.0%	4.4%	11.2%	21.5%	100%
9 Axle Twin 33	113,500	24.2%	19.3%	20.7%	4.4%	11.6%	19.8%	100%
7 Axle Triple 28	116,000	23.8%	18.5%	21.6%	3.9%	11.9%	20.4%	100%
9 Axle Twin 48	129,000	23.2%	18.8%	21.6%	4.4%	12.0%	20.0%	100%
Hoppers								
5 Axle 48 Foot Semi	78,000	29.0%	21.3%	14.6%	3.4%	10.5%	21.3%	100%
9 Axle Twin 28	108,000	24.5%	22.7%	14.6%	4.5%	11.6%	22.1%	100%

Derived from Jack Faucett Associates (1991), Appendix A.

relative to five-axle semitrailers is unchanged, and that of the other configurations is increased slightly (by up to 0.3 percentage points). It also can be determined that a similar uniform reduction in vehicle, tire, repair or overhead costs would have similarly small effects on the cost advantage of the larger configurations. A somewhat larger effect would occur if estimated driver costs were to be reduced uniformly by 20 percent — in this case the cost advantage of the larger configuration would be increased by 0.3 to 0.9 percentage points.

The preceding discussion indicates that the percentage cost changes shown in the last column of Tables 1.10 and 1.12-1.14 are relatively insensitive to uniform changes in any of the cost components. Accordingly for each trailer type, changes in the cost estimates that are relatively uniform across configurations and GVWs are likely to have only modest effects on the estimates of the *percentage* change in costs and in all study results that are based on this quantity.

The above conclusion, however, does not hold when the cost estimates are modified in a nonuniform way across configurations or GVWs. Thus, for analyses based on percentage change in costs, the accuracy of estimates of how fuel or repair costs vary with configuration or with GVW is more important than the accuracy of estimates of fuel price.

(g) The Trimac Cost Estimates

Trimac Consulting Services maintains a proprietary spreadsheet model for estimating the cost of truck operations. Every two years since 1972, under contract to Transport Canada, selected output from this spreadsheet has been published. In recent years, this output has been available in electronic form only. In 1993, Trimac updated their 1992 costs and added cost estimates for intraregional movements in five U.S. regions (Trimac, 1994).

The Trimac model is relatively well known because of their biennial publication program. Their model is only one of several developed by trucking companies, industry consultants, and vehicle and engine manufacturers. Other such models include those maintained by the Cummins Engine Company (Knapton, 1981, and Abacus, 1991), TranSystems (Mike Rice, personal communication), IBI (Transportation Association of Canada and Canadian Trucking Research Institute, 1994), and Peat Marwick Stevenson & Kellogg (1993).

Trimac publishes estimates of Canadian costs by province and annual miles operated for three vehicle configurations (two-axle truck, five-axle semi, and an eight-axle "tractor train" consisting of a full-length semitrailer and a shorter, two-axle "pup" trailer). Separate estimates are presented for dry freight, for liquid propane carried in two-axle trucks, and for dry bulk carried in combination trucks, but no further identification is provided as to commodities assumed. The U.S. cost estimates are available only for five axle semitrailers and are expressed in 1993 Canadian dollars (with exchange rates that are alternately identified as 0.78 or 0.86 $US per Canadian dollar).

The "electronic infobase" report contains text describing the spreadsheet and separate spreadsheet print files for each province and the five U.S. regions; however, the print file does not contain any formulas nor does it identify how parameters can be changed.

The data contained in the Trimac spreadsheet is almost certainly better than that in the JFA spreadsheet. Trimac Consulting is a subsidiary of Trimac Transportation Company, a very large truck operator. Accordingly, Trimac has access to an extensive amount of proprietary trucking data. Furthermore, since Trimac has developed, maintained and updated their spreadsheet over a 20-year period, they have had a substantial period of time to refine and improve their procedures.

Trimac has developed their cost estimates from somewhat more disaggregate data than JFA. Five of the Trimac cost categories (driver, fuel, repair, tire and vehicle depreciation) correspond to five of the six JFA categories. However, JFA's sixth category, overhead, is replaced by three categories: licenses, administration and insurance (with the last two calculated simply as percentages of total revenues). Two additional Trimac cost categories cover the cost of miscellaneous equipment that may vary with commodity or area of operation, and the cost of cleaning tank trailers (addressed subsequently in Section 1.4) as well as other less significant cleaning costs. Trimac also includes a separate category for profit, suggesting that they really use their "cost model" as a rate model.

Unfortunately, although the Trimac cost estimates apparently are of high quality, they are of limited value to a U.S. truck size and weight study. Costs for U.S. operations currently exist only for five axle semis, so these estimates provide no basis for comparing costs across existing and potential configurations. Costs for Canadian operations exist for a more extensive number of configurations, but these costs do not reflect U.S. conditions and the only combination-truck configurations for which these cost estimates are published are five-axle semitrailers and eight-axle trailer trains. Furthermore, Trimac provides relatively little documentation of their cost estimates, so they generally cannot be easily adjusted for the difference between U.S. and Canadian conditions.

The published Trimac data assumes that, for all vehicles, 50 percent of all mileage is empty mileage and, for all combination trucks, average hauls are 160 km (100 miles). These assumptions are not unreasonable for many bulk hauls, but, on average, the dry van operations that are potentially affected by size and weight policy have a longer length of haul and a much lower percentage of empty miles. To compensate for the above limitation, the Trimac text (Sections 3.3. and 3.4) describes procedures that can be used to adjust the cost estimates to reflect other assumptions for length of haul and empty mileage.

The ability of a spreadsheet to reflect the effect of varying length of haul is important if cost estimates are required for individual hauls. However, it is of less value when using aggregate data, such as data from the forthcoming Commodity Flow Survey, for which only approximate lengths of haul are available; and it is of very limited value when using data from the best data source available at the time of the last Truck Size and Weight Study, the Truck Inventory and Use Survey (U.S. Bureau of the Census, 1986), which distinguishes nonlocal operations only as to whether or not hauls are greater than 200 miles.

For analyses that focus on the effect of changing configurations or weight limits on transport costs, for reasons discussed in the preceding subsection, the effect of length of haul normally becomes relatively unimportant. Peat Marwick Stevenson & Kellogg (1993) found that, for cube-limited truckload shipments, reducing length of haul only resulted in changing the cost advantage of 53-foot semitrailers relative to 48-foot semitrailers from 8.4 percent to 8.1 percent. However, as will be discussed in Section 1.4, length of haul does become important when comparing the costs of operating configurations with different numbers of trailers that require cleaning after each haul - an important consideration for trailers used to carry chemicals or liquid food products.

Trimac publishes separate cost estimates for two or three annual mileages: 80,000, 160,000 and 240,000 km (50,000, 100,000 and 150,000 miles) for dry van combinations; and 80,000 and 160,000 km for dry bulk combination For other annual mileages, Trimac recommends that users of the published data apply linear intropolation. The Trimac values can be compared with JFA's use of Maio (1983) estimates of average annual mileages of 83,000 to 104,000 miles, spreadsheet parameters that can be modified by the user.

In some other respects, the JFA spreadsheet contains important detail that is missing from the Trimac report. The 1991 JFA spreadsheet contains data for about 50 trailer and axle configurations (shown in Table 1.3) and six trailer types, while the Trimac report contains data for only two trailer and axle configurations and two trailer types (insulated dry vans and aluminum dry-bulk trailers).

1.4 Per Trip Costs for Extra Trailers

The cost estimates presented in the preceding section do not reflect the effects on non-linehaul costs of increasing the number of trailers. These effects include: the cost of assembling and disassembling multi-trailer configuration at terminals or staging areas; for tank trailers, the increased cleaning costs per unit of payload when small or intermediate-size trailers are used; and, for operation of non-door-to-door configurations, the extra costs of draying trailers to and from staging areas.

Based on discussions with carriers that operate both semitrailers and twin 28s, JFA (1991) estimated the extra cost of assembling and disassembling twins to be about $30 per trip. This cost applies to truckload operation of dry and refrigerated vans, but not to flatbed, tank and hopper trailers, which generally do not have to be disassembled for loading or unloading. JFA used an adjustment of $15 per trip for twin 28 and twin 33 dump trailers, allowing for disassembly at the destination but not at the origin. The $30 per trip figure excludes any non-operating costs (such as modification or expansion of loading facilities) that may be incurred by shippers wishing to use twin trailers.

The cost of cleaning tank trailers varies with local regulations and the commodities to be cleaned. The cost is lowest for many water-soluble chemicals (such as sulfuric acid) and for most food products. JFA (1991) reported that discussions with tank-cleaning companies indicated that the increase in cost resulting from the use of a second trailer is likely to be between $30 and $150.

Thirty dollars per trip is equivalent to 5 cents per vehicle-mile for a 500 mile trip or 15 cents per vehicle-mile for a 200 mile trip. Accordingly, the cost of assembling and disassembling twin vans substantially decreases the attractiveness of using twin 28 and twin 33 vans on short to intermediate-length hauls. The same is also true for tank trailers that require frequent cleaning (but not for tank trailers that are used for carrying petroleum products).

Morlok and Spasovic (1994) provide data that indicates that the current cost of draying trailers to and from a Contrail intermodal yard averages about $230 per loaded trailer, and they estimate that more efficient operations could reduce this cost by up to 63 percent to $85 per loaded trailer. The cost of draying trailers to and from staging areas used by turnpike doubles and other non-door-to-door configurations is likely to be fairly similar, though differences may exist (due to possible differences in average drayage distance and service requirements).

1.5 Circuity and Utilization

(a) Conventional Operation

The cost comparisons shown in the last two columns of Tables 1.10, 1.12, 1.13 and 1.15 (in Section 1.3) presume that all configurations operate over the same route and have the same percentage of empty mileage and annual mileage.[5] However, this is seldom the case.

Route restrictions may require larger or heavier vehicles to take a less direct route, increasing transit time and the overall cost of a haul, and decreasing the advantage of using these vehicles. Route restrictions may also prevent longer vehicles from serving certain origins or destinations, and they may prevent heavier vehicles from operating fully loaded from some origins and to some destinations. Moreover, some of the larger configurations are efficient only for carrying cube-limited shipments, some of the heavier configurations are efficient only for carrying weight-limited shipments, and, with the notable exception of turnpike doubles,[6] the larger and heavier vehicles generally are not efficient for carrying shipment-size-limited shipments.

For the above reasons, larger and heavier vehicles are not appropriate for all shipments. This is a modest concern when choosing vehicles to provide dedicated service to a limited number of locations. In this case, optimum vehicles can be identified on the basis of the service to be provided and the roads to be used. Examples of such dedicated service include many natural-resource hauls and plant-to-warehouse hauls of private carriers (e.g., Frito-Lay) that are not interested in for-hire backhauls. For use in such dedicated service, cost savings sometimes may be reduced by an increase in circuity or a reduction in annual miles, but otherwise they are likely to be quite close to those indicated in the Section 1.3 tables and in the appendix.

The limitations of larger and heavier vehicles become more significant in the case of vehicles that are not used in dedicated service. For such vehicles, these limitations are likely to reduce the availability of backhauls and to result in some increase in empty mileage operated. Since an increase in empty mileage results in an increase in transport costs per ton-mile, the savings attainable with

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[5] Changes in the percentage of empty mileage (discussed previously) that affect all configurations equally affect costs per ton-mile of all configurations but not the percentage differences in these costs.

[6] Turnpike doubles (and, to a lesser extent, some of the other multiple-trailers configurations) can be used efficiently to combine trailer load shipments made by different shippers. Thus, minimum shipment sizes for turnpike doubles are the same as they are for conventional semis.

larger and heavier vehicles that are not used in dedicated service frequently will be appreciably lower than the savings indicated in the Section 1.3 tables and in the appendix.

(b) Non-Door-to-Door Operation

All single-trailer combinations and most multiple-trailer combinations operate "door-to-door"; i.e., they carry truckload shipments directly from origin to destination and linehaul LTL movements directly between terminals without being reconfigured. Similarly, in pickup and delivery service, all shipments are carried from a shipper to a terminal or from a terminal to a receiver by a single vehicle that is not reconfigurated enroute.

"Turnpike doubles" (i.e., combinations that use two trailers that are each at least 42-feet long), however, usually are *not* operated door-to-door; and triples frequently are not. These two configurations are very efficient for linehaul operation (see Tables 1.2 and 1.3), but, even where legal, because of their length, they are allowed to operate only on relatively limited networks of high-quality roads (e.g., turnpikes). Accordingly, these configurations frequently do not provide door-to-door service. Instead, they are formed at "staging areas" at entrances to a network on which they are allowed to operate and they are disassembled at other staging areas at network exits. The cost of reconfiguring is not reflected in the Table 1.2 and 1.3 cost estimates, but it is an important cost that significantly affects the economics of using non-door-to-door configurations. Indeed, estimating transport costs for these configurations is appreciably more complicated than estimating these costs for conventional configurations. Issues relating to the estimation of transport costs for shipments using turnpike doubles are discussed briefly below.

Cost estimation for turnpike doubles is complicated because there are at least two distinct ways of handling linehaul operations, three alternatives for handling access hauls to and from the network, and two alternatives for pricing turnpike double services, all of which produce a large variety of options affecting the economics and competitiveness of turnpike doubles. An understanding of the economics of turnpike doubles is particularly important to understanding the extent to which a more extensive turnpike-doubles network could result in diverting traffic from rail.

The simplest way of handling linehaul operation of turnpike doubles is to have a single driver operate the configuration from the origin staging area to the destination staging area, regardless of the distance involved. This is the way most turnpike doubles operations currently are handled. For time-sensitive shipments, a two-person team could be used to allow round-the-clock operation of the vehicle.

An alternative that may be attractive to some large companies operating on an extensive network would be to divide the entire network into a set of 200 or 400-mile long relay legs, with separate drivers for each leg of the haul. This type of relay operation currently is being adopted for conventional truckload service by some large trucking companies. Some advantages of relay operation are that it allows round-the-clock driving and, for turnpike doubles, it allows the pairing of trailers to be changed at the relay points, thus increasing the operator's ability to achieve the economies of moving trailers in pairs. On the other hand, reconfiguring at intermediate relay points involves some additional cost and, when trailers from two different incoming rigs are to be "married" at a relay point, some extra delay is entailed by the first of the trailers to arrive.

It should be observed that both types of linehaul operation allow the carrier to combine single-trailer shipments from different origins into one double-trailer configuration. However, typical GVW limits for turnpike doubles (e.g., 127,400 or 129,000 pounds) do not allow such doubles to consist of two trailers loaded to the normal weight limits for semitrailer operations. Moreover, a certain amount of single-trailer operation of trailers intended to be used in doubles would still occur (especially when non-relay operation is used), since individual carriers would not always have pairs of trailers traveling in a given direction at the same time.

Opportunities for marrying trailers could be increased by offering differentially priced priority and nonpriority services, with delays allowed in the movement of nonpriority trailers to increase opportunities for using double-trailer configurations. The likely effects of such split-service pricing are particularly difficult to analyze, since priority shippers would be charged a premium (reducing the cost savings they would obtain by using turnpike doubles), while nonpriority shippers would receive later delivery times (increasing their inventory costs).

There are three possible ways of moving trailers between the turnpike-double network and the actual origins and destinations of the shipments:

- The linehaul driver can be responsible for handling both trailers, moving them in sequence;

- A local *drayage* company can be hired to handle all single-trailer movements to or from the turnpike-doubles network; or

- The linehaul driver can be responsible for one trailer with a local firm hired to handle the second trailer.

All three alternatives are used by existing single-driver turnpike-double operations. However, the second alternative (pure drayage) would appear to be most appropriate for use with relay-type turnpike-doubles operation. Estimating the cost of such a drayage operation adds another complication to analyzing the economics of turnpike doubles. The cost per vehicle-mile for drayage operation would necessarily be appreciably higher than the costs shown in Tables 1.2 and 1.3 for intercity operation of five-axle semis, since drayage operation involves shorter hauls, less highway driving, and, most importantly, lower utilization rates for both tractors and drivers.[7]

2.0 Knowledge Gaps and Research Needs

There are several areas where additional research is needed in order to analyze the effects of potential changes in truck size and weight policy on truck transport costs. These areas are discussed below:

1. Estimates are needed of the effects on truck costs of the various design standards and performance standards that may be incorporated into the policies to be analyzed. Of the potential standards of interest, hitch design standards are the only ones that for which we have identified cost estimates, and even these estimates (discussed in Section 1.3(e)) require some corrections and updating.

   For each standard of interest, information is needed on current practice in the United States (by type of trailer and configuration, where relevant) and the effect on costs of changing this practice to conform with the specified standard. In order to perform this analysis, the likely effect on vehicle design of all proposed performance standards will have to be determined. The research to be performed is relatively straightforward, but this research cannot be performed efficiently until the standards of interest have been identified.

2. The amount of additional research that should be performed into the effects of possible changes in size and weight limits on truck transport costs (excluding issues of circuity and vehicle utilization) depends upon the type of analysis to be performed and resources available.

   If resources are scarce and only aggregate data are to be used, the 1991 JFA cost estimates should prove adequate, and the 1990 JFA cost estimates may be used, preferably with some corrections and adjustments discussed briefly in Section 1.3(d). These are the only two publicly available sources that we have identified that provide reasonable cost estimates for the range of alternative configurations that may be of interest in this study; and, for reasons discussed in Section 1.3(f), these sources are

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[7] The cost of drayage is discussed further in Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates (1993), pp. III-25 to III-33.

likely to provide reasonably good estimates of the percentage differences in transport costs between alternative configurations operating under alternative weight limits.

To the extent that resources permit, the JFA cost estimates should be improved and/or replaced by new estimates. Potential improvements to the JFA estimates include:

- Reviewing and updating the estimates to reflect more current information about forecast-year costs. This review may include comparisons with available estimates from other published sources (including Trimac (1994) and Transportation Association of Canada and Canadian Trucking Research Institute (1994)).

- Expanding the number of cost components distinguished to allow better distinctions to be made between per-trip costs, vehicle-mile costs, and annual costs, thus permitting improved estimates of the effects of length of haul and annual mileage on truck transport costs (important if disaggregate data are to be analyzed, but less so if only aggregate data are used).

3. Better estimates are needed of the likely effects of higher size and weight limits on vehicle utilization; i.e., on empty mileage, on annual usage, and on use of vehicles to carry loads that do not make use of the vehicle's increased size or weight capacity.

4. Better estimates are needed of the extent that longer or heavier vehicles will be subject to more circuitous routings.

5. If any of the policy options allow for a significant increase in the highway systems on which triples or turnpike doubles would be allowed to operate, additional investigation should be performed of the likely operational efficiency actually attainable for network and drayage operations of these configurations.

3.0 References for Truck Costs Working Paper

Basic References

<u>1993</u>

Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates, *Analysis of Longer Combination Vehicles, Part Three: Effects on Transportation Costs and Diversion of Traffic from Standard Combination Trucks and the Railroads*, Final Report, prepared for the Federal Highway Administration, Washington, D.C., November 1993.

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rate of wear of these tires, but the relationship between this source of increased wear for dual tires and decreased wear due to greater total tire width for duals is not addressed. No cost figures given.)

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IBI/ADI, *Impacts of Canada's Heavy Vehicle Weights and Dimensions Research and Interprovincial Agreement*, prepared for Transportation Association of Canada and Canadian Trucking Research Institute, June 1994. (Used IBI Truck Cost Model to estimate cost per vehicle-kilometer (vkm) for five and six axle semitrailers and seven and eight axle A, B and C-Trains for five different load conditions (cube out, weigh out, cube and weigh out, partial, and empty). These values were applied to data on actual and forecast truck usage under current Canadian size and weight regulations and estimated usage that would have occurred under the pre-1988 regulations (ignoring modal diversion). The costs reflect Canadian conditions, and so they are not directly applicable to U.S. conditions; however, some of the data used may be of some interest.)

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Ontario, January 11, 1993. (A proprietary model was used to estimate cost savings per ton-mile for replacing 48-foot semitrailers by 53-foot semitrailers for cube-limited truckload traffic and for LTL traffic. For truckload traffic, the estimated savings range from 8.1 percent for hauls of "less than 400 km" to 8.4 percent for hauls of "more than 800 km." Overall cost reductions estimated for LTL shipments range from 0.8 percent to 2.5 percent. Despite the title, the report does not contain any cost estimates for B-Trains.)

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Cornell University, School of Civil and Environmental Engineering, *Economic and Safety Consequences of Increased Truck Weights,* Final Report, Engineering Research and Development Bureau, New York State DOT, and the Permanent Advisory Committee on Truck Weights, Ithaca, NY, December 1987. (Costs for single-unit trucks are estimated as a function of total time not operated, driver time (operating and standing), miles operated, speed, GVW, and age of vehicle. Basic cost assumptions generally not provided.)

Irwin, N.A. and R.A. Barton, *Economics of Truck Sizes and Weights in Canada,* Final Report, Council on Highway and Transportation Research and Development and the Roads and Transportation Association of Canada, Ottawa, July 1987. (Only the first half of this report has

been received. The remainder has been requested but not yet received. A truck cost model is described in very general terms on pages 15-17, but no further information is contained in the portion of the report available.)

Appendix

Estimated 1995 Truck Transport Costs, Trailer Type and Configuration and Loaded Weight

(1988 dollars)

Jack Faucett Associates (1991)