Longer Combination Vehicle Studies in the United States

Gary E. Maring[1]

ABSTRACT

The Federal Highway Administration of the U.S. Department of Transportation is completing the second of two congressionally mandated studies related to Longer Combination Vehicles (LCVs). The Senate Report on the 1986 Department of Transportation (DOT) appropriations bill called for a study of LCV operations in Western States. This study is a follow-on to DOT's study The Feasibility of a Nationwide Network for Longer Combination Vehicles that was mandated by Sections 138 and 415 of the Surface Transportation Assistance Act (STAA) of 1982. The Section 138 study, which was transmitted to Congress in June 1985, examined factors that would have to be considered before a nationawide network for LCVs could be designated. Among those factors were productivity gains that might be realized from the operation of an LCV network, potential safety impacts associated with LCV operations, pavement and bridge damage, performance and handling characteristics of LCVs, and potential highway improvement needs if an LCV network were to be designated. The vehicles considered in these studies are twin or triple trailer combinations up to about 118 feet in length and weighing up to about 130,000 pounds. The most typical LCV configurations are (1) Rocky Mountain Doubles, that consist of a tractor and two trailing units, one up to 48 feet in length and the other up to 28 feet in length; (2) Triples, which consist of a tractor and three trailing units each up to 28 feet in length; and (3) Turnpike Doubles, which are twin trailer combinations with each trailing unit up to 48 feet long. Based on analyses completed for these two studies, this paper summarizes current LCV operations, reviews various impacts of wider national or regional LCV operations, and presents concluding remarks regarding policy considerations and associated research needs.

INTRODUCTION

The Federal Highway Administration (FHWA) of the U.S. Department of Transportation (DOT) is completing the second of two congressionally mandated studies related to longer combination vehicles (LCVs). The Senate Report on the 1986 DOT appropriations bill called for a study of LCV operations in Western States. This study is a follow-on to DOT's study The Feasibility of a Nationwide Network for Longer Combination Vehicles that was mandated by Sections 138 and 415 of the Surface Transportation Assistance Act (STAA) of 1982. The Section 138 study, which was transmitted to Congress in June 1985, examined factors that would have to be considered before a nationwide network for LCVs could be designated. Among those factors were productivity gains that might be realized from the operation of an LCV network, potential safety impacts associated with LCV operations, pavement and bridge damage, performance and handling characteristics of LCVs, and potential highway improvement needs if an LCV network were to be designated. The vehicles considered in that study, and in this current study, are twin or triple trailer combinations up to about 118 feet in length and weighing up to about 130,000 pounds. (Note: gross weight was constrained by bridge overstress criteria--30 percent for an H-15 bridge and 5 percent for an HS-20.) The most typical LCV configurations are (1) Rocky Mountain Doubles, that consist of a tractor and two trailing units, one up to 48 feet in length and the other up to 28 feet in length; (2) Triples, which consist of a tractor and three trailing units each up to 28 feet in length; and (3) Turnpike Doubles, which are twin trailer combinations with each trailing unit up to 48 feet long.

The Section 138 study concluded that "there is no compelling reason for designation of a federally mandated LCV network at this time. The States are currently providing opportunities for controlled use of LCVs . . . . There are positive aspects of LCV use, but many unresolved issues argue against their immediate widespread use."

In commenting on the Section 138 study report, the American Trucking Associations (ATA) and the Western Highway Institute (WHI) indicated that a regional LCV network in Western States should

1 Chief, Transportation Studies Division, Federal Highway Administration, Washington, D.C.

have been considered since longer combinations have been operated in the west for many years. They suggested that many of the unresolved issues do not apply in the west, and that the productivity and safety of Western LCV operations have already been demonstrated. The 1986 Senate Appropriations Committee Report subsequently directed DOT to reexamine the LCV issue in those Western States where operating experience exists. As of this date, the follow-on report has not been forwarded to Congress so results are only preliminary. Based on analyses completed for the two LCV studies (principally the 138 study), this paper summarizes current LCV operation in the United States, reviews various impacts of wider national or regional LCV operations, and presents concluding remarks regarding LCVs and U.S. size and weight policy considerations.

EXISTING LCV OPERATIONS IN THE UNITED STATES

At the present time, 14 contiguous States in the western United States permit the commercial operation of one or more longer combination vehicle types. In addition, there are five Eastern States that allow limited LCV operation only on turnpikes--New York, Massachusetts, Ohio, Indiana, and Florida. There are three basic configurations of LCVs: Turnpike Doubles (a tractor-semitrailer-trailer combination vehicle with 40- to 48-foot trailers), Rocky Mountain Doubles (a vehicle with one 40- to 48-foot and one 26- to 28-foot trailer), and Triples (a tractor with three 26- to 28-foot trailers). Eight Western States permit the commercial operation of all three types of LCV configurations. Two States, Oregon and Wyoming permit Rocky Mountain Doubles and Triples, and Montana and Oklahoma allow Rocky Mountain Doubles and Turnpike Doubles. Washington State allows only Rocky Mountain Doubles to operate, and Nebraska authorizes the transportation of empty 28-foot trailers in a triples configuration from their point of manufacture to delivery destinations (See Table 1).

The gross vehicle weight (GVW) of truck combinations has both a physical effect upon the service life of highways and an operational effect upon traffic moving along the facility. For this reason, States have enforced vehicle weight limits which may be determined by the Federal "Bridge Formula B" set forth in 23 U.S.C. 127, by State bridge formulas covered by grandfather clauses, or by formulas based on vehicle type, number of axles, and axle spacing as is the case with LCV operations controlled by the Kansas Turnpike Authority. Maximum allowable GVWs for LCVs range from 80,000 pounds in Colorado and Montana to 129,000 pounds in Utah, South Dakota, and Nebraska (See Table 1).

The extent of the highway system open to LCVs varies from State to State. For example, Montana, North Dakota, and Wyoming permit LCVs to operate on the entire State trunk highway system. Arizona, Colorado, and Oklahoma restrict their operation to segments of the Interstate System. In Kansas, LCVs are allowed only on the turnpike. A number of States have also designated routes that are open to travel by a particular type of multiple trailer vehicle, but not others. Table 1 shows the mileage open for combination operations by State and by vehicle type.

The length, weight, and specialized equipment associated with LCVs and their resultant operational characteristics often restricts their travel to roadways with high geometric design and bridge loading capacity. The geometric and functional criteria most frequently required by States in designating highways to be used by multiple trailer vehicles are those of 12-foot minimum lane widths, minimum curvature, maximum grades, traffic volume, and structural capacity. In addition to these qualifications, States may also consider restricting LCV operations based upon the highway's number of lanes, presence and width of roadway shoulders, access control, number and spacing of interchanges, accident rates, and availability of passing lanes. Wherever possible, States have incorporated 4-lane, divided, limited access highways into their designated system to provide long distance route continuity and service to major markets and distribution centers.

Provisions must also be made for access to and from highways open to LCV use. Carriers which operate multiple trailer vehicles must be able to travel not only between points of pick up and delivery, but must reach facilities for food, fuel, repairs, and rest. States have made these service areas accessible to combination vehicles by designating staging areas, special access highways, or zones of access. At the present time, State requirements pertaining to LCV access are extremely inconsistent, often vague, and sometimes nonexistent. Some States leave access to be determined by local authorities, while other States limit access to a specified distance from the designated route. Where zones of access have been established, LCVs may travel from 3 to 20 miles from designated highways depending on State's restrictions.

Table 1 — Longer combination vehicle dimensions and designated highways

	Rocky Mountain Double (RMD) Length (ft.) Weight (lbs.)	Turnpike Triple (TRI) Length (ft.) Weight (lbs.)	Double (TPD) Length (ft.) Weight (lbs)	Route Miles Open for Combination Operations
Alaska			105 109,000	50 miles of 4 lane roads and 425 miles of 2 lane roads open to TPDs
Arizona	90 111,000	105 111,000	105 111,000	29.4 miles of Interstate open to all combination types
Colarado	95 80,000	105 80,000	105 80,000	Except for Interstate system I-70 to Grand Junction a total of 650 miles of Interstate highways are open to all combination configurations
Florida			110 130,000	272 miles of turnpike open to TPDs
Idaho	105 105,500	105 105,500	105 105,500	105 max. length, offtracking over 6.5 but less than 8.75 limited to 612 miles (Interstate only) 105 max. length, offtrack 5.5 to 6.5, above plus 2280 mi. 85 max. length, offtrack less than 5.5, above plus 670 mi
Indiana	Overall length is not specified 127,400	127,400	127,400	157 miles of turnpike open to all combination types
Kansas	119 120,000	119 120,000	119 120,000	231 miles of turnpike open to all combination types
Massachusetts	108 127,000		108 127,000	132 miles of turnpike open to RMSs and TPDs
Montana	95 123,180		95 123,180	RMDs permitted on entire State highway system consisting of 1.193 miles of Interstate, 5,506 miles of primary (dbl. 40's) and 4,706 miles of secondary roads. Dbl. 40's allowed on same
Nebraska		105 95,000		Triples restricted to Interstate Highways totalling 481 mi. Weight restricted to 80,000 lbs. (must travel empty)
Nevada	105 129,000	105 129,000	105 129,000	4,872 miles or roads open to all combination types of which 2,400 miles are designated secondary highways
New York	114 143,000		114 143,000	531 miles of turnpike open to RMDs and TPDs
N. Dakota	75 105,500	110 105,500	110 105,500	State highway system of 571 miles Interstate, 1,506 miles principal arterial, and 93 miles minor arterial open to all combination types
Ohio	108 127,000		108 127,000	241 miles of turnpike open to RMDs and TPDs
Oklahoma	No length restr. 80,000		No length restr. 80,000	RMDs and TPDs allowed on entire Interstate system (926 mi.)
Oregon	75 105,500	105 105,500		6,000 mi. of roads open to RMDs, 3,000 mi. of roads open to TRIs, 2,400 mi. of secondary roads included in above mileage.
S. Dakota	90 114,000	105 105,500	110 129,000	679 miles of Interstate open to TPD's and TRI's.Entire State system including 7,218 mi. of non-Interstateopen to RMDs.
Utah	98 129,000	105 129,000	105 129,000	584 mi. of Interstate open to TRIs, TPds, and RMDs 92-98 RMDs less than 92' allowed on extra 5000 mi. secondary roads
Washington	75 105,500			6,917 miles of roads open to RMds, 5,500 miles of which are secondary roads
Wyoming	95 117,000	105 80,000		Entire highway system of 6,378 mi. open to RMDs, 5,503 of which are secondary roads. TRIs allowed UT line to Evanston (5 mi.), and CO line to Cheyenne (10 mi.)

The Kansas Turnpike Authority, Idaho, and Utah require LCVs to make up or break up at dedicated locations prior to entering or leaving the designated system. The costs of constructing, maintaining, and protecting staging areas in Idaho and Utah are borne by the carriers. The Kansas Turnpike Authority, on the other hand, has paid for the construction and maintenance of staging areas, but requires carriers to bear the cost of providing additional security guards or lighting.

Several States have concluded that potential safety problems could arise if some, or all, of the LCV configurations were permitted to operate on an extensive highway network within that particular State. Where one or more types of multiple trailer vehicles are allowed, their operations are restricted to highways with compatible geometric and functional capacity. In many instances these vehicles are limited in the distances they can travel beyond designated roadways due to the lower geometric design characteristics of secondary highways.

Rocky Mountain Double configurations are authorized to travel in all 14 Western LCV States because, for the most part, they have fewer operating problems than Turnpike Doubles or Triples, while affording more cargo capacity than a Western Double with two 28-foot trailers. The offtracking of Rocky Mountain Doubles is not nearly as great as that of Turnpike Doubles, and closely approximate the offtracking of Triples when negotiating all but the sharpest turns. Rocky Mountain Doubles also exhibit more stable handling characteristics than Triples due to one less articulation point and the additional length of the 40- to 48-foot trailer. The overall vehicle length of a Rocky Mountain Double is also less than that of the other two types of LCVs.

Triple trailer combinations have more points of vehicle articulation than either Turnpike Doubles or Rocky Mountain Doubles. This design characteristic of Triples has contributed to trailer sway. The greater number of articulation points also creates problems when these vehicles attempt to back up. Several States prohibit Triples because of problems that may result when these vehicles try to maneuver in emergency situations. Apparently, the maneuverability of Triples under normal operating conditions, and the opportunities for multiple deliveries afforded by three short trailers makes these vehicles more popular than Turnpike Doubles. Turnpike Doubles are prohibited from operating on many secondary roads as a result of their excessive offtracking.

In contrast to the dissimilar State regulations controlling LCV route accessibility, permissible configurations, and gross vehicle weight, there is considerable uniformity among State laws governing LCV equipment specifications and operations. This uniformity can be attributed to at least two separate sources within the transportation industry. The first source of uniformity was the Motor Carrier Safety Assistance Program which encouraged States to adopt uniform motor carrier safety regulations for interstate and intrastate operations. Uniform LCV operations have also been promoted through the model regulations endorsed by the Western Highway Institute (WHI). Neither of these opportunities for uniform LCV regulations have been adopted by States without some modification.

One of the principal efforts to coordinate LCV regulations has been made through the WHI. For the past 15 years, the WHI has encouraged dialogue between State transportation agencies and trucking associations through the Highway Transport Industry Joint committee, a working group within the Western Association of State Highway and Transportation Officials (WASHTO). This group has submitted periodic updates recommending uniform size and weight standards to State highway agencies. A similar effort to achieve uniformity in State bridge formulas is being sponsored by the Tri-State Northwest Group. Over the past year and a half, this group has facilitated the flow of LCV traffic between Idaho, Oregon, and Washington by encouraging the removal of inconsistent State axle and gross vehicle weights. The 10 States participating in the Multistate Highway Transportation Agreement (MHTA) have also recognized the need to achieve compatibility in LCV route designations and permit provisions and established a standard committee last year to develop recommendations regarding this issue.

The use of certain LCV configurations, primarily Triples, has been recently authorized in several States which did not allow them at the time the Section 138/415 Report to Congress was being written. Within the past 18 months, the States of South Dakota and Wyoming have permitted Triples operations under trial demonstration programs. Nebraska has authorized unloaded Triple trailer movements for delivery from their point of manufacture to purchasers within the State. In December 1984, Oklahoma removed all length restriction on twin trailer vehicles operating on the Interstate System. The spread of LCV operations in Western States continues to be accomplished through the promotional efforts of

transportation associations such as WHI, WASHTO, MHTA, and through voluntary acceptance by the States.

FINDINGS OF LCV STUDIES REGARDING SAFETY, HIGHWAY PERFORMANCE AND PRODUCTIVITY

SAFETY

Safety is one of the most important aspects of LCV operations, but relatively few controlled studies of LCV safety have been conducted. For the Section 138 study, a number of carriers supplied accident and travel data for their fleets. These data were used to develop estimates of overall accident rates for the various LCV configurations. Information on LCV accident rates also was obtained from turnpike authorities and from operational tests conducted by several Western States. Table 2, which is taken directly from the Section 138 study report, summarizes results of the major LCV safety studies. Estimated accident rates for Turnpike Doubles and Rocky Mountain Doubles were consistently lower than overall accident rates for tractor-semitrailers, but Triples had higher accident rates in several studies. After tests of LCVs in Utah and Colorado, a high percentage of drivers who operated Triples indicated that those vehicles were less safe than conventional tractor-semitrailers or Western Doubles, particularly because of their sway. In an operational test conducted by the California Department of Transportation in 1984, Triples were observed to sway more than other combinations. Comments of several drivers, who wrote to the docket, support driver survey comments that Triples are not as safe as other vehicles. Triples are not allowed in several States, partly because of concerns about their safety. However, in testimony at a public hearing held by FHWA in January 1986, representatives of several carriers presented data on the good safety record of their Triples operations. Several indicated accident rates for Triples operated by their companies were lower than the accident rates for tractor-semitrailer operations. At the hearing, and in comments to the docket, carriers noted similarly good safety records for other LCV configurations.

Researchers and highway officials have cited several factors that they believe account for the relatively good safety record of LCV operations to date. Among the most important factors are:

Table 2 — Comparison of accident rates for combination commercial motor vehicles

Study	Singles	Accident rate doubles	Turnpike double	Rocky Mountain double	Triple
ATA/WHI/PTC	5.091	1.00	0.38	1.00	4.14
Utah	1.79	1.79	-	-	3.26
Colorado	2.22	-	0	0	0
Montana	-	-	-	-	0
Ohio Turnpike	-	-	1.16	-	-
Indiana Toll Road	-	-	1.17	-	-
New York Thruway	-	-	1.78	-	-
Highway Safety Research Institute	1.72	-	0.84	-	-
BIOTECH					
Rural	1.10	2.28	-	-	-
Urban	2.14	3.88	-	-	-

1 The accident experience of tractor-semitrailers included in the ATA/WHI/PTC surveys reflects both interstate and local operations. National Safety Council (NSC) statistics typically show accident rates of about 2.5 accidents per million vehicle-miles of travel for interstate operations of common carriers. The NSC accident rate and the rates for singles from other studies shown on this table are more appropriate bases for comparing accideent rates of longer combination vehicles than is the rate for tractor-semi-trailers from the ATA/WHI/PTC study.

1. The LCVs in most States operate almost exclusively on rural Interstate highways with very low traffic volumes;

2. Large carriers, whose overall safety records are generally better than average, have acounted for a preponderance of LCV use, although carriers of all sizes have operated longer combinations; and

3. The LCVs are operated in all States under special permits that can be suspended or revoked if carriers fail to maintain good safety records or if they violate any of the many restrictions on LCV use.

The preponderance of evidence suggests that on most rural Interstate highways, Turnpike Doubles and Rocky Mountain Doubles are safe vehicles when operated by experienced drivers under special permits. Triples are not clearly as safe. Many companies report very good safety records for their Triples operations, but other companies have had accident problems. The fact that Triples are inherently less stable than other vehicle configurations because of their multiple short trailers and their many articulation points suggests that concerns expressed by some drivers must be taken seriously despite the low accident rates reported by several large carriers. Under optimal conditions, Triples can be operated safely, but if any sudden maneuvers must be made, or if equipment is not adequately maintained, Triples are subject to loss of dynamic stability and potential accidents that other LCVs could avoid. The Section 138 report concluded that:

- The LCVs currently operated have very low accident rates, but this safety record cannot necessarily be extrapolated because of the special conditions that govern their operations.

- Performance and handling limitations of LCVs, as well as their higher gross weights, could prove to create significant safety problems if LCVs are used more generally, such as under a greater variety of road, environmental, and traffic conditions.

- An LCV network limited to Interstate highway links would divert some freight to these relatively safer highways from lower-level roadways and thus could decrease accident rates on the lower-level roadways.

- A given amount of highway travel by LCVs can move more freight than the same amount of travel by conventional vehicles and thus accident rates per-ton-mile could be reduced if current LCV accident rates did not worsen.

PERFORMANCE AND HANDLING

In addition to data on LCV accident rates, the Section 138 study report contained information on aspects of vehicle performance and handling that affect safe operations. That information came from several sources including: computer simulations of vehicle offtracking, test track results, operational tests of LCVs under various highway conditions and safety studies of large conventional combinations. Potential problems related to several different aspects of vehicle performance and handling were cited in the Section 138 study report. Among those factors were: stability, braking, offtracking, power to accelerate and climb grades, operations and congested urban highways, operations off the Interstate System, and operations in inclement weather.

All combinations are subject to some instability when forced to make rapid steering maneuvers. In general, short trailing units are less stable than long trailers, and the greater the number of articulation points, the less stable is the combination. Other factors that may affect stability are the height of the center of gravity of the cargo being carried, the distribution of the cargo within the trailer, the type of connectors used, and the road condition. As noted above, Triples, and to a lesser extent Rocky Mountain Doubles, are less stable than tractor-semitrailers because of their short trailers and multiple articulation points. When forced to make rapid steering maneuvers, these vehicles are more prone to jackknifing and rollover due to rearward amplification of the steering maneuver. Triples have been observed in operational tests to sway as much as a foot, even on straight stretches of highway. On 2-lane highways with moderate traffic volumes or on urban freeways where there is little room to maneuver, such swaying would be a serious safety problem. Drivers in two operation tests indicated that they believed trailer sway made Triples less safe than tractor-semitrailers or Western Doubles.

The relative importance of all factors that contribute to trailer sway in Triples is uncertain. Some drivers and highway agency officials believe that improper loading and poorly maintained dollies and fifth wheels contribute to sway while other

experts believe these factors contribute little to the problem. In Canada, double drawbar dollies and other special types of equipment are widely used to improve stability; double drawbar dollies are required equipment in Saskatchewan. These dollies reduce the number of articulation points, however, and thus increase the vehicle's offtracking. Since Triples have relatively good offtracking, this has not been a significant constraint to the use of the special dollies. Many double drawbar dollies sold in Canada have a steering mechanism that largely counteracts the increase in offtracking and also reduces tire wear due to "scrubbing" as the vehicle goes around a corner. One constraint to the use of double drawbar dollies is the stress they create on the trailer; trailers designed for a single pintle hitch connection must be strengthened to safely pull double drawbar dollies. None of the special dollies that increase stability have been used in routine operations by American carriers, but some are now being marketed for specialized operations. Future use of these dollies could help overcome the biggest negative aspect of Triples--their relative instability.

The ability of longer combinations to stop quickly without jackknifing or skidding out of control has been a concern of many researchers and public officials. The greater weight of LCVs, the number of axles, and the number of articulation points all make the braking systems of LCVs more complex than those of tractor-semitrailers and thus more prone to being out of adjustment. The more axles a vehicle has, the greater the number of brakes and thus the greater the braking force that can be applied to stop the vehicle. Turnpike Doubles, even though they weigh 50 percent more than tractor-semitrailers or Western Doubles, have considerably more braking capacity because they have more axles and thus more brakes. Rocky Mountain Doubles share with Turnpike Doubles a braking capacity advantage over conventional vehicles, while Triples have about the same braking capacity as conventional combinations.

Actual tests of braking distances conducted by California and other States do not provide conclusive evidence about the relative stopping distances of longer combinations. In general, it appears that Turnpike Doubles stop somewhat more quickly than Triples, but differences in practice depend more upon the loading of the vehicle, the condition of the brake system, and the skill of the driver than on differences in the vehicles. If longer combinations are loaded properly and their brake systems are properly maintained, their overall braking performance appears to be adequate for them to operate on the Interstate System and highways of comparable design.

PAVEMENT AND BRIDGE DAMAGE

Different vehicle configurations cause different amounts of wear on pavements and bridges depending on the gross weight of the vehicle, the weights on each axle, and the spacing of axles on the vehicle. As pointed out in the Section 138 study, shifts from one type of vehicle to another resulting from changes in allowable vehicle weights or configurations can affect pavement and bridge life and long-term highway investment needs.

Potential impacts of a nationwide network for LCVs were analyzed for the Section 138 study using the pavement deterioration model in FHWA's Highway Performance Monitoring System. The deterioration model uses empirically based pavement performance curves that depend on pavement age and the cumulative equivalent single-axle load (ESAL) applications to estimate pavement deterioration and future improvement needs. An ESAL is a widely used measure of pavement deterioration propensity that allows pavement damage caused by axles of different weights to be directly compared.

Table 3 from the Section 138 study compares the relative pavement damage associated with various LCV units loaded to the heaviest practical limit subject to bridge overstress criteria. Similar relationships exist when estimated operating weights are used for each vehicle type. The ESALs are based on a weighted average of typical, rigid and flexible Interstate highway pavements. In practice, the relative damage to rigid and flexible pavements caused by different configurations varies considerably. Units with single axles cause relatively more damage to flexible pavements than to rigid pavements, while tandem axle units cause relatively more damage to rigid pavements. As can be seen from Table 3, Western Doubles apply more ESALs/1,000 tons of cargo, and thus cause more pavement damage, than other configurations. Triples and Rocky Mountain Doubles, which each have some single-axle trailers, are the next two most damaging units, followed by conventional tractor-semitrailers. The two tandem-axle doubles units cause significantly less pavement damage per 1,000 tons of cargo than the other configurations. The low pavement damage of short tandem-axle doubles is particularly noteworthy since Turnpike Doubles are quite restricted in where they may operate. These relationships indicate

that cargo shifts from Western Doubles to any LCV configuration would reduce overall pavement damage, but that shifts from conventional tractor-semitrailers to Triples and Rocky Mountain Doubles, would increase pavement damage. Shifts from any conventional combination to Turnpike Doubles or shorter tandem axle doubles would reduce damage to highway pavements.

It should be noted that the Section 138 study did not examine potential increases in the gross vehicle weights of Western Doubles, but such increases would be likely if the Federal gross weight cap were lifted and vehicle weights were limited by bridge overstress criteria. Under the existing Bridge Formula, Western Doubles can have a gross vehicle weight of over 90,000 pounds. Under the same assumptions as were made in Table 3, a 90,000-pound Western Double would produce 6.18 ESALs compared to 4.03 ESALs for an 80,000-pound Western Double. Even when the greater payload of the heavy Western Double is considered, it still is much more damaging to the pavement than Western Doubles limited by the 80,000-pound weight cap.

The ESAL relationships shown in Table 3 illustrate that the choice of relatively interchangeable LCV configurations makes a large difference in how much pavement wear could be expected. Total ESAL miles with and without an LCV network were estimated for the 138 study. With freight traffic shifts from rail and conventional trucks to LCVs (Note: Western Doubles were not included as LCVs for this analysis.), 1990 ESAL-miles could actually decrease as much and 7 percent if a majority of the traffic shifted went to tandem axle doubles. However, under a scenario that lifts the weight cap for all vehicles without encouragement of tandem axles, pavement damage could be considerably higher. Further study is proceeding on this issue.

Like pavement damage, any changes in bridge damage associated with shifts of traffic to LCVs would depend on the nature of the shifts. Bridge costs are affected primarily by the maximum loads placed on the structures rather than the frequency that loads are applied. Bridges are designed to accommodate a design vehicle that could be served indefinitely; if vehicles heavier than the design vehicle traverse the bridge regularly, bridge life is reduced. Overloaded LCVs thus could cause considerably more bridge damage than overloaded tractor-semitrailers or Western Doubles.

In addition to vehicle weight, bridge damage is a function of span length, configuration, and axle loadings. When vehicle weights are constrained to avoid unacceptable levels of bridge overstress, conventional tractor-semitrailers cause more bridge damage than longer combinations for most span lengths less than 100 feet. When span lengths exceed 100 feet, and the entire LCV is on the structure, LCVs cause greater damage. This general relationship holds for both the HS-20 bridges typically found on the Interstate System, and H-15 bridges on most other primary highways. Since one-third of the bridges on the Interstate System have span lengths greater than 100 feet, some increase in bridge damage, and a corresponding decrease in bridge life, could be expected if traffic shifted from tractor-semitrailers to LCVs. On shorter spans, bridge stress could decline slightly, assuming that the vehicles do not operate overweight. Bridge damage also increases when traffic shifts from rail to LCVs.

Table 3 — Relative axle loadings of various truck combinations

Configuration	Operating weight (pounds)	Net cargo tons	ESALs	ESALs/ 1,000 tons cargo
Conventional semi (3S2)	80,000	24	3.21	134
Western Double (3S2)	80,000	23	4.03	175
Triple (2S-2-2)	122,000	41	6.69	163
Turnpike Double (3S2-4)	131,000	43	3.44	80
Rocky Mountain Double (3S-2)	112,000	35	5.05	144
Short Tandem Double (3S2-4)	100,000	31	1.23	40

Bridges are currently "protected" from vehicle loads that would cause an unacceptable level of stress by the "Bridge Formula" in Section 127 of Title 23. That formula was first included in Federal law in 1975 when axle weight limits were raised to 20,000 pounds on single axles and 34,000 pounds on tandem axles. When coupled with the 80,000-pound gross vehicle weight limit, the Bridge Formula generally prevents damaging overloads on highway bridges. Some vehicle configurations weighing more than 80,000 pounds, however, can meet the Bridge Formula loadings and still severely overstress certain bridges. For purposes of the 138 study, LCV weights were controlled to produce no more than 30 percent overstress on an H-15 bridge and no more than 5 percent on an HS-20 bridge. A revised bridge formula that would more closely represent these overstress criteria is under study by FHWA.

HIGHWAY INVESTMENT NEEDS

For the Section 138 study, AASHTO conducted a survey of the highway investment needs associated with allowing various LCVs to operate on a nationwide network. States were asked to estimate the number of Interstate interchanges that had adequate geometrics for each of the primary LCV configurations, the average cost to upgrade deficient interchanges, the need for and cost of staging areas where LCVs might assemble and disassemble, and other questions concerning the adequacy of Interstate highways for LCVs.

Highway officials indicated that many Interstate interchanges do not have adequate geometrics to safely accommodate the largest vehicle configurations. Some LCVs offtrack to an extent that they can neither stay on interchange ramps nor negotiate turns at the connecting highways without running off the pavement. This causes shoulders and pavement edges to deteriorate and poses a safety problem for other vehicles on the road. These problems do not necessarily apply to LCVs now being used since many Rocky Mountain Doubles and Turnpike Doubles currently operate with 40-45-foot trailers rather than the 48-foot trailers that were used as the basis for estimating interchange improvement needs. The shorter vehicles offtrack much less than LCV's with 48-foot trailing units. As 48-foot semitrailers become an industry standard, however, they increasingly will be used in long combination units, and more and more interchanges may have to be reconstructed to accommodate the longer vehicles.

Total costs estimated for the 138 study to provide access to essential service and to contract staging areas in rural and urban areas ranged from $750 million to about $2,175 million if all LCV configurations were permitted to operate. To the extent possible, improvement needs estimated by the States were used in estimating the nationwide needs. While there were substantial variations among individual States that are not readily explained, in the aggregate the relative needs to accommodate various longer combinations seemed to be consistent with differences in the operational characteristics of those vehicles. Differences also highlight observations by the States that improvement needs and costs would vary widely depending upon site-specific characteristics. The 138 study concluded, "in practice, it is anticipated that carriers, shippers, and other representatives of the trucking industry would participate in identifying highway improvement and staging area needs, and that those needs would vary with the volume of longer combination traffic. Clear opportunities exist for involving the private sector directly in the financing of needed improvements, and several States indicated the desirability of private sector involvement. Implementation and finance issues would need to be considered much more thoroughly if an LCV network were to be pursued."

PRODUCTIVITY

The Section 138 study examined potential productivity increases that might result from a nationwide network for longer combination vehicles. Information came from several sources including surveys of shippers and carriers that now use LCVs and an econometric modeling system that estimated the use of longer combinations based on their relative costs compared with other vehicle configurations and with rail. In general, fewer trips are required to carry a given quantity of freight in LCVs than in conventional tractor-semitrailers or Western Doubles. With fewer trips required, operation costs are lower, fewer tractors, trailers, and drivers are needed, less fuel is used, and less vehicle maintenance is necessary. At the public hearing for the Western LCV study, carriers indicated that they would transfer a large part of the operating cost savings to shippers who in turn may pass part of their cost savings to consumers.

To provide information on the productivity and operations of LCVs for the Section 138 study, the ATA, WHI, and Private Truck Council (PTC) sent questionnaires to over 1,200 carriers that current-

ly operate longer combinations. Responses from the 219 carriers that returned their surveys were made available to FHWA. Among the major findings from those surveys were:

1. On the average, about 5 percent of the current dispatches by companies that responses to the ATA/WHI/PTC survey are in LCVs. Those companies estimated that if a nationwide LCV network were designated, 35 percent of their dispatches would be in longer combinations. Since the companies that responded to the survey are primarily larger carriers that already operate LCVs, a lower percentage of shipments by all carriers might go by LCV if there were an LCV network.

2. LCV operating costs per vehicle-mile are about 15 percent greater than operating costs for conventional combinations. Union drivers are paid a premium to drive LCVs, and per-mile costs for fuel, tires, and other items slightly higher than per-mile costs for tractor-semitrailers or Western Doubles. The higher per-mile costs are far outweighed, however, by cost savings associated with the reduced mileage that LCVs travel compared to conventional combinations hauling the same amount of freight.

3. The average trip length for LCV operations is considerably shorter than the average trip length for conventional combinations. This suggests that the limited network of highways currently open to LCVs may restrict their use. In addition to the information provided from the ATA/WHI/PTC survey, information on LCV productivity was also provided for the Section 138 study by five shipper organizations--the National Industrial Transportation League, the Southern Forest Products Association, and Aerospace Industries Association of America, the American Plywood Association, and the Maine Potato Sales Association. In the aggregate, over 200 shippers sent information on current and potential future use of LCVs to these shipper groups. Respondents indicated that, on average, they would transport approximately 23 percent of their loads in LCVs if a nationwide LCV network were available.

Information on the productivity of LCVs was also obtained from operational tests sponsored by the Multistate Highway Transportation Agreement. Eight carriers accumulated a total of over 100,000 vehicle-miles of travel during the 1984 tests in Idaho, Nevada, Oregon, and Utah. In all cases, significant productivity increases and fuel savings were achieved compared to operations using conventional tractor-semitrailers. No safety or operational problems were observed, but prior to allowing LCVs to operate, the States reviewed the adequacy of ramps, interchanges, and terminal access roads along each proposed LCV route.

In addition to this information from individual shippers on the productivity of LCVs, a set of econometric models, developed at the Transportation Systems Center, was used to estimate the overall effect of longer combinations on transportation efficiency. A network of about 50,000 miles was identified for analysis. It consisted of all segments of the Interstate System and all connecting Federal-aid highways which have access control, have 4 or more lanes, and are divided for most or all of their length. Access penalties were included in the model to represent off-system constraints on LCV operations. Shipments of commodities with origins and destinations in each Bureau of Economic Analysis area were assigned to rail or to a particular truck type based on differences in transport costs. Only preliminary findings were available at the time the Section 138 report was submitted to Congress, but since that time, more information from the models has become available. Among the general findings from the econometric models regarding LCV productivity and modal diversion are the following:

1. In 1990, if a nationwide network were designated, approximately 15 percent of all over-the-road commercial truck ton-miles could be in long combinations, compared to 1.2 percent without a network. This share would differ significantly among different types of carriers. General commodity carriers could carry almost 23 percent of their ton-miles in LCVs, while carriers of exempt commodities would haul only about 5 percent of their ton-miles in longer combinations.

2. In 1990, the average payload per vehicle for all over-the-road commercial operations would be about 5 percent greater if there were a nationwide LCV network than if current LCV usage patterns remained in effect. This is less than the increase in average payload that has been projected to result from provisions of the STAA of 1982 that required States to allow Western Doubles and 48-foot semitrailers on the National Truck Network.

3. Prices charged for over-the-road commercial trucking services (based on the ratio of estimated gross operating revenues to payload ton-miles) are estimated to be about 3 percent less with a nationwide LCV network than without such a network.

4. Total revenues to trucking companies from over-the-road trucking operations would increase if there were a nationwide LCV network, even though revenues from shipments that formerly went in conventional truck combinations would decline because of competition and lower costs. Additional trucking revenues from freight that formerly went by rail would more than offset revenue losses from conventional truck shipments that shifted to LCVs.

5. The modal diversion model estimated a shift of 4.9 percent of rail ton-miles to truck. Shifted commodities were concentrated in mixed shipments.

6. Total 1990 truck vehicle-miles traveled increases slightly from what it would have been because of the ton-miles shifted from rail.

7. The aggregate cost of all rail and truck transportation services would drop very slightly if a nationwide LCV network were designated.

While the transportation cost savings estimated using the econometric models are less in percentage terms than the savings estimated by individual carriers in the ATA/WHI survey, aggregate savings, nevertheless, could be substantial. In actual operations between various markets, savings would depend on such specific factors as the commodities being shipped, the location and type of operations of the shipper and carrier, and how well shipments could be coordinated among other markets. Neither the estimated productivity increases from the econometric models, nor the increases that some carriers estimate they currently realize, would necessarily apply to general operations of LCVs on a national or regional network.

In addition to information that was collected in conjunction with the Section 138 study, additional information on the productivity of LCV operations was provided by carriers at the public hearing held for the Western LCV study in Denver. Transportation cost savings of from 20 to 50 percent were reported when LCVs are used, and most of these savings apparently are passed on to shippers as lower freight rates: several carriers noted that they offer discounts of from 18 to 40 percent for services using LCVs. LCV operations also use considerably less fuel than operations with conventional combinations. Carriers reported that from 10 to about 45 percent less fuel is used for LCV operations than for tractor-semitrailer operations. These fuel savings not only contribute to lower costs, but also help reduce air pollution which is an increasing problem around Denver and other Western areas. Shippers and carriers at the hearing repeatedly mentioned the low population density of Western States and the large distances carriers typically must travel to pick up and deliver commodities. The additional cubic capacity of LCVs makes those vehicles very productive, and where gross vehicle weights can exceed 80,000 pounds, they are much more productive.

STUDY CONCLUSIONS

The 138 study recognized that LCVs have operated successfully and productively in many Western States and on several turnpikes in Eastern States for a number of years. However, in regard to designation of a national LCV network, the study concluded "that there is no compelling reason for designation of a federally mandated LCV network at this time. The States are currently providing opportunities for controlled use of LCVs. There are positive aspects of LCV use, but unresolved issues argue against their immediate widespread use." Among the unresolved issues cited in the report were:

- Federal regulations currently permit LCVs at the discretion of States, but limit their desirability by restricting gross weights on Interstate highways in most States to 80,000 pounds.

- Permits and many other special driver and vehicle regulations used by States to control LCV use would be difficult to adapt to a national network.

- Enforcement of weight and other operating regulations is an important part of allowing larger vehicles, and a plan for more effective enforcement would be needed if more widespread use of LCVs were allowed.

- FHWA experience in designating a nationwide network for STAA vehicles revealed a myriad of local considerations that would apply with equal validity in designating an LCV network. A more complete understanding of these considerations, with respect to the network already designated, is required.

- Local access is potentially the most troubling aspect of network designation. More analysis of tradeoffs between staging areas and allowances for leaving the network is needed.

- Any network designation plan would need the total cooperation and heavy involvement of State departments of transportation.

- Extending operation of LCVs would substantially increase highway investment costs. Since LCVs would not come close to paying their share of highway costs under current user fees, extending their operation without a substantial increase in user fees would unfairly subsidize them at the expense of other highway users and other freight transportation modes. Two recently begun studies, mandated by the Deficit Reduction Act, will report on user fees for heavy vehicles.

- LCVs vary widely in their performance, handling, pavement damage, and other characteristics and must be considered separately in assessing the desirability of any LCV.

- Heavy gross weights of vehicles, as long as they are controlled to limit bridge stress, are not as damaging to highways as heavy axle weights. Some way to encourage lower axle weights is needed to ease anticipated rehabilitation costs.

Of particular issue are the effects of heavy vehicles on pavements and bridges. The current Bridge Formula is appropriate for the most common vehicle types, but simply does not track well with bridge overstress. Some vehicles are restricted by the formula more than overstress would dictate, while others are allowed too much weight. The FHWA is pursuing development of an improved formula or alternate provisions that would adequately protect bridges.

From a pavement-damage perspective, there is no clear evidence against heavier gross weights associated with LCVs in and of themselves. From a pavement performance perspective, the most important consideration is to achieve lower operating axle weights. Encouraging a shift toward tandem axles on Doubles, for example, could be helpful as has been suggested by former FHWA Administrator, Francis C. Turner. A National Cooperative Highway Research Project is studying this concept.

There is substantial evidence that higher-capacity freight vehicles that are less damaging to the highway infrastructure could evolve through appropriate regulation and control. The compelling driving economic forces behind larger freight vehicles will always exist and could provide the impetus for better designed vehicles. Continued monitoring of LCV operations and analysis of benefits and impact will help build a more complete information base for future decisions on heavy freight vehicles.

The Western LCV study, which is soon to be completed, will further review successful operations in the Western States and analyze options for modified size and weight policies to further accommodate LCV operations.

A number of heavy truck research projects and several congressional studies related to cost allocation and user fees are underway in FHWA and the National Cooperative Highway Research Program to answer some of these critical questions. The FHWA and the Department of Transportation are continuing to study the technical and policy issues involved in any possible change to size and weight limits to enhance the productivity of LCVs.