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LONGER COMBINATION VEHICLES AND ROAD SAFETY

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Abstract. The aim of this paper is to explore the relationship between the features of Longer Combination Vehicles (LCVs) and road safety issues. LCVs are road vehicles that exceed dimensions of a typical or standard heavy truck-trailer or tractor-semitrailer combination vehicles in length or length and weight. The systematization of LCVs is done. Several areas, which are likely to benefit through LCVs, are listed and described. The analysis of literature review is made in the areas where additional problems may be encountered using LCVs. Several engineering factors such as resistance to rollover, swept-path parameters, vehicle capabilities of accelerating and maintaining speed as well as braking performance are analyzed. Several research projects on traffic accident analysis have been looked through to compare their conclusions about traffic safety of LCVs. The analysis of discussions related to LCVs traffic safety issues is provided. Some transportation experts and community groups have conflicting views about road safety issues of LCVs. The opinions and related arguments of both parties are discussed in this paper. Several technical improvements in designing LCVs and the importance of driver training programs are described.

Keywords: Longer Combination Vehicles (LCVs), configurations of LCVs, road safety performance of LCVs, accidents involving LCVs, driver behavior.

1. Introduction

The object of this paper is Longer Combination Vehicles (LCVs) and road safety issues related to them. Longer combination vehicles are unlawful in the major part of countries though some of those have allowed cargo haulage by LCVs in definite geographic regions or on designated roads. Longer Combination Vehicles have from 25% to 100% larger cargo space comparing to typical truck-trailer combination vehicles. Economical benefit is the main reason why road haulage companies are so interested to carry goods using LCVs. Longer combination vehicles can be more efficient comparing to a typical European truck-trailer and tractor-semitrailer combination vehicle for long distance cargo transport.

The aim of this paper is to explore relationships between the technical features of Longer Combination Vehicle, driver training and traffic safety issues.

2. Background

Road infrastructure is built according to technical standards and legislation approved by a country. Truck and trailer dimensions should be harmonized with road infrastructure. Countries by legislation have limited truck and combination vehicle dimensions and maximum allowed Gross Vehicle Weight (GVW). The economical benefit for road haulage companies depends on the amount of transported cargo. Longer Combination Vehicles have larger volumes of a cargo area. Road vehicles with bigger cargo spaces can make long distance road haulage business more economically beneficial. Several countries worldwide have allowed LCVs for long distance road transport. There are several types/categories of Longer Combination Vehicles used in different geographic regions. The definition and classification of LCVs is provided as follows.

Longer Combination Vehicles are road vehicles that exceed dimensions of a typical or standard heavy truck-trailer or tractor-semitrailer combination vehicles in length or length and weight. LCVs do not exceed the maximum width and height of standard vehicles. Longer Combination Vehicles are combined/coupled using legal road vehicles. Any part of LCVs is a fully approved road vehicle in the definite country or state. Longer Combination Vehicles are combined using a truck/tractor and more than one trailer/semitrailer; special dollies are used for some combinations of LCVs. These combination vehicles are used for transporting divisible cargos; LCVs are not vehicles designed for over-size or/and over-weight cargo transport.

In the USA, the Federal Motor Carrier Safety Administration defines the LCV as any combination of a

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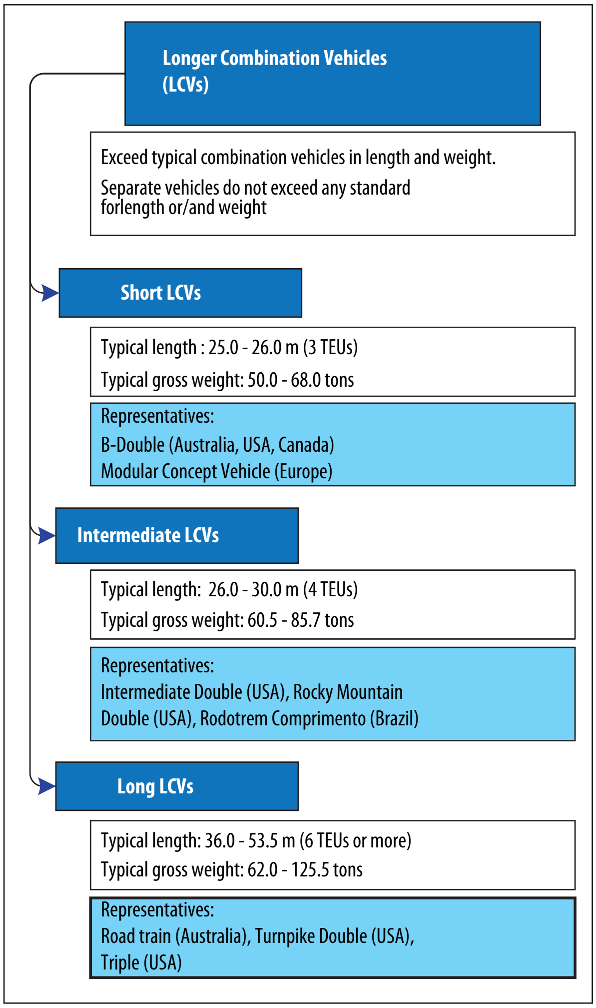
truck/tractor and two or more trailers or semi-trailers that have a Gross Vehicle Weight of greater than 80000 pounds (36363.6 kg) and operating in interstate commerce (Part 658: Size and… 2007). Because of this restriction on weight, combination vehicles called 'twins' or Western Doubles are excluded from this rule. However, all road safety issues described in this paper apply to twins as well as to other types of long and/or heavy combination vehicles not mentioned here. Similar definitions are made in other countries allowing LCVs. Based on several previous studies (Nagl 2007; Knight *et al.* 2008; Åkerman and Jonsson 2007; Schulman 2003; Daniels 2006; Comprehensive Truck Size… 2000), the systematization of Longer Combination Vehicles is shown in Figure.

The first type of Longer Combination Vehicles with total combination vehicle length less than 26.0 meters (Short LCVs in Figure) has been widely operated in the USA, Australia, Canada, Finland, Sweden and some other countries for many years. This type of LCVs is able to accommodate up to three twenty-foot equivalent units (TEUs) and offer the possibility of transporting three 20 feet (or 40 feet container plus 20 feet container) containers (not fully loaded by weight if there are Gross Vehicle Weight restrictions for combination vehicles). Most of the countries (except Australia) limit the GVW for short LCVs at 60 metric tons. On some roads in European countries, the Gross Vehicle Weight for short LCVs is restricted down to 52 tons. In Australia and Canada, a number of short LCVs are formed using tractor and two semi-trailers. These combination vehicles are called 'B Doubles' or 'B-trains' in contrast to the vehicles with drawbars (truck with trailers) known as 'A-trains'.

The European Union has set up regulations permitting only certain types of short LCVs in international traffic. The idea behind this is to ensure that all the elements of freight transport vehicles are compatible as some countries in Europe (Sweden, Finland and the Netherlands) permit LCVs while other countries do not. This ensures easier handling at borders where LCVs have to be detached and split into two vehicles. The European version of short LCVs is called in several ways, like Modular Concept Vehicles, European Modular Combination, Eurocombi, Ecocombi etc. Several research projects have been carried out to analyze the economical benefit and some safety issues related to European Modular Concept Vehicles (Backman and Nordström 2002; Åkerman and Jonsson 2007; Knight *et al.* 2008). The obtained results show economic benefit from using LCVs for long distance haulage instead of typical European truck-trailer/tractor-semitrailer combination vehicles.

The intermediate Longer Combination Vehicles are vehicles with the total length of more than 26.0 meters and less than 30 meters (see Intermediate LCVs in Figure), which makes the transport of four TEUs possible. These combination vehicles are almost impossible to push back for maneuvering and usually have to be decoupled in service areas (warehouses, distribution centers). The intermediate LCVs are designed for long distance (over 400 km) cargo transport between large distribution centers using a freeway network only; cargo carriage in the urban areas with intermediate LCVs is restricted almost in all parts of the world.

The longest LCVs in the world are more than 30 meters (see for Long LCVs in Figure) long. The road vehicles of this type are allowed only on dedicated routes and with specific restrictions in some geographic areas of Australia and in nine States of the USA. Long LCVs are coupled using more than two trailers or semi-trailers ('Road trains' in Australia and 'Triples' in the USA).



The systematization of Longer Combination Vehicles (LCVs)

3. Advantages of Longer Combination Vehicles

The areas that are likely to benefit through Longer Combination Vehicles are listed below.

Productivity. Longer Combination Vehicles improve the productivity of long distance road transportation due to an increase in 25–100% available cargo capacity per driver (Backman and Nordström 2002; Nagl 2008). Since there are restrictions for the total weight of a truck in several countries, an increase in productivity by weight is relatively small if compared to an increase in productivity by the volume of transported cargo.

Costs. Transportation costs are lower due to fewer drivers needed per unit of cargo transported. Efficient use of fuel (calculated by the transported cargo volume or cargo weight) is resulting in lower transportation costs for long distance haulage (Backman and Nordström 2002; Nagl 2008; Åkerman and Jonsson 2007; Knight *et al*. 2008).

Traffic. The improved productivity of road transport is resulting in fewer truck units on roads to carry the same amount of goods (Knight *et al*. 2008). A smaller number of heavy trucks on roads are positively affecting traffic flow.

Environment. Longer Combination Vehicles produce lower emissions per unit of the transported cargo. The total amount of pollution (gas emissions, noise, waste materials) calculated per unit of transport work is reduced using LCVs for long distance cargo shipments (Ramberg 2004; Gunnarsson 2005; Vierth *et al*. 2008).

Road safety. The probability of traffic accident occurrence increases with the mileage (vehicle-kilometers traveled) (Ramberg 2004). Since there is need for fewer road vehicles to do the same amount of work (calculated in ton-kilometers), the vehicle-kilometers traveled are reduced. The number of accidents also declines through the introduction of LCVs.

4. Disadvantages of Longer Combination Vehicles

The areas where additional problems may be faced using Longer Combination Vehicles are as follows.

Road safety. Traffic safety problems are the result of the technical design features of the Longer Combination Vehicle, inapplicable road infrastructure and both car and lorry drivers behavior on the road. Several questions related to road safety will be discussed bellow in this paper.

Pavement damage. Heavy trucks and combination vehicles cause several times higher deterioration of pavement structure than cars or light commercial vehicles. According to literature (Daniels 2006; AASHTO Guide for… 1998), some of the heaviest combination vehicles have the same impact on roadway as 2000 cars. The total weight of a truck or combination vehicle has the highest impact on bridges, viaducts and other over land infrastructure utilities. The damage of road pavement is caused by axle load. The overloaded single axle can cause pavement damage even if the GVW of a combination vehicle is not exceeded. An increased number of axles for combination vehicles can mitigate the damage of road pavement. According to literature (Backman and Nordström 2002; Vierth *et al*. 2008), short LCVs with restricted gross weight and 7-axles or 8-axles (GVW = 60 tons) are potentially less aggressive to road pavement than typical European tractor-semitrailer combination vehicles with 5-axles (GVW = 44 tons).

Road infrastructure damage. Longer Combination Vehicles (especially 'Turnpike Doubles' and 'Rocky Mountain Doubles') demonstrate larger off-tracking (wider swept-path) on roadway curves comparing to typical tractor-trailer or tractor-semitrailer combination vehicles. Here off-tracking is defined as difference in a wheel path between the outside front truck wheel and the inside rear wheel of the last trailer. Road infrastructure is designed to create safe traffic conditions for typical/standard heavy trucks and combination vehicles. It may cause some safety problems on roads if longer combination vehicles are used instead. The limited radii of roadway curves and narrow traffic lanes are the main limitations on Longer Combination Vehicles to drive safely in specific road infrastructure points. The damage of vehicles, road shoulders, curbs, roadway-side signs etc. can be resulted from the larger off-tracking of Longer Combination Vehicles. Maneuvering parameters for many configurations of LCVs are worse than for typical truck-trailer combination vehicles. Some technical solutions, e.g. steered axles for trailers, can improve the maneuverability of LCVs.

Parking areas and warehouses. Most of the rest areas and truck stops in Europe are not designed to accommodate Longer Combination Vehicles. These vehicles could be parked in slots designed for oversize or overload cargo transport but there are a limited number of special parking places. A similar situation can be faced in warehouses and distribution centers. Truck on-load and off-load areas are not always suitable for LCVs. It can cause problems in everyday use of Longer Combination Vehicles and create additional inconvenience to other truck drivers.

Traffic. Longer Combination Vehicles can have an impact on traffic. As shown in several research papers (Mohamedshah *et al.* 1993; Garber and Ehrhart 2000; Hanley and Forkenbrock 2005; Khorashadi *et al.* 2005; Björnstig *et al*. 2008), the major impact of Longer Combination Vehicles is on two-lane highways and in populated/urban areas (towns and cities). Longer Combination Vehicles take more space; acceleration for these combinations can be lower; somewhere at turns/corners, LCVs can block the width of more than one traffic lane and even go into traffic lanes of the opposite direction (road safety issue). The extra length of LCVs can cause additional risk for other road users.

5. Road Safety Problems Related to Longer Combination Vehicles

Road safety performance of trucks or combination vehicles highly depends on engineering factors such as resistance to roll-over and off-tracking, vehicle capabilities of accelerating and maintaining speed as well as braking performance.

Rollover tendency. Truck-trailer and tractor-semitrailer combination vehicles are tended to rollover negotiating curves or steep grades. The risk of static rollover is as great for longer or heavier combination vehicles as it is for typical heavy trucks and trailer combination vehicles. The possibility of rollover is related to the height of the vehicle center of gravity. According to the results of field measures presented by Daniels (2006), an intermediate Longer Combination Vehicle tends to be more stable on curves than a conventional 5-axle tractor-semitrailer combination vehicle because of its additional length; it is possible to reduce the height of the center of gravity spreading cargo over greater length. It is not true if cargo is placed on several levels in the cargo area.

Truck and trailer manufacturers in Europe are working to reduce the height of cargo space floor. The height of the cargo area floor of long-distance truck-trailers is just over one meter. The height of cargo place floor is even less for center-axle trailers (using special low profile and small diameter tires).

Other vehicle design factors positively influencing rollover risk are width, suspension parameters, the number of articulation points and tire properties. Some other factors (not relating to vehicle design) are roadway design, driver performance and behavior.

Low speed off-tracking. Low-speed off-tracking is phenomena when the rear axles of the vehicle are tracking toward the center of the swept path (Harkey *et al.* 1996). Although longer wheelbases of trailers and semi-trailers generally would worsen off-tracking parameters, this does not mean that off-tracking increases with overall vehicle length. According to Daniels (2006), the standard Surface Transportation Assistance Act (STAA) double and triple combinations with 28 foot (8.54 meter) trailers off-track less than a standard tractor and 53 foot (16.15 meters) semitrailer combination. This is partly due to the fact that individual trailers in these multi-trailer combinations have relatively short wheelbases. The result of an off-tracking comparison is opposite if (STAA) double and triple combinations are compared with European standard providing a truck-trailer combination vehicle of 16.5 meters long. The width of the swept-path depends on combination vehicle technical features; the wheelbase of each trailer and the number of articulation/hinge points are the main parameters. Some experts (Knight *et al.* 2008) think that low-speed off-tracking is not a serious safety problem as it has a minimal effect on the likelihood of serious crashes (fatal or injury-producing). The large off-tracking of combination vehicles causes traffic disruption and damage to infrastructure (especially in narrow places). Series of experiments are done measuring the swept path for different configurations of LCVs in Europe. According to the measurements and computer simulations done in Sweden (Aurell and Wadman 2007), all types of LCVs introduced in Europe use a wider swept path on turns. The steered axle at the end of combination vehicles may improve off-tracking (SCM Concept… 2007). On the other hand, the loss of dynamic stability is larger than the gain of maneuverability (Aurell and Wadman 2007).

High speed off-tracking. Rearward amplification occurs when a truck-trailer or longer combination vehicle travels at high speed (above 80 km/h) and a driver sharply maneuvers left then right or right and then left. In situations when a driver tries to avoid collision with an unexpected obstacle and makes a sharp maneuver, the end of a combination vehicle has a tendency to skid sideways into other traffic lanes or to rollover. The relationship between truck size and weight and propensity toward rearward amplification is complex. The procedure of rearward amplification measurements is described in the standard ISO 14791:2000. A slightly different methodology has been used overseas (Sweatman 1993).

Dynamic stability (both rearward amplification and yaw damping) improves with a reduction in the number of articulation/hinge points connecting the components of a combination vehicle. Dynamic stability is not directly related to combination length. According to literature (Luskin and Walton 2001), the substitution of B-train and C-dolly connections for more-widely used A-dollies would effectively eliminate an articulation point. A comparison analysis of different combination vehicle types in Europe according to standard ISO14791:2000 procedure has been conducted. Research results (Aurell and Wadman 2007; Ehrning 2004) are shown in Table 1 the best of which points to tractor semi-trailer combination and the worst one shows a truck and drawbar trailer. The results of dynamic stability for all types of longer combination vehicles allowed in Europe are in the middle of these two vehicle combinations.

Table 1. Results of research on the dynamic stability of combination vehicles (yaw-damping factor measured according to standard ISO14791:2000 procedure)

Ranking	Combination Vehicle	Yaw-damping factor
1	Tractor with semi-trailer	1.26
2	Tractor with B-double	1.55
3	Truck with dolly and semi-trailer	1.77
4	Truck with center axle trailer	2.17
5	Truck with semi-trailer and center axle trailer	2.59
6	Truck with drawbar trailer	3.59

Acceleration and speed maintenance. Acceleration and speed maintenance parameters for longer (especially for heavier) combination vehicles are important safety factors. Commonly, trucks with increased total length but with the same total weight do not have lower acceleration performance. However, accidents involving LCVs can occur when a longer vehicle crosses a non-signalized or signalized intersection after stopping or braking. The safety factor here is intersection clearance time. The LCV with better acceleration capabilities can clear the intersection faster reducing its exposure to opposing traffic. A Longer Combination Vehicle should have higher acceleration capabilities to clear the intersection at the same time as a typical truck-trailer combination vehicle. The increased length of vehicles can influence the potential risk of accident occurrence.

Although some experts found roadway grade parameters as insignificant to the likelihood of accidents involving large trucks (Mohamedshah *et al.* 1993), several analysis have proven the relation between roadway vertical grade, the length of grade and the likelihood of accident occurrence (Miaou and Lum 1993; Milton and Mannering 1998; Vogt and Bared 1998; Milton *et al.* 1998; Vogt *et al.* 1998). If large trucks accelerate more slowly than light vehicles do and upward grade lacks a climbing lane for slow-accelerating trucks (two lane roads), accidents can result when lighter vehicles attempt to pass these slower trucks. Reasons for having accidents on downward grades may vary.

Higher power engines and suitable power trains can enable heavy trucks to perform acceptable performance; high acceleration capabilities for longer combination vehicles can shorten time needed to pass an intersection and can improve speed on upward grades. Special truck climbing lanes on steep grades could improve road safety and prevent traffic conflicts between slow-moving trucks (not only longer combination vehicles) and other faster-moving vehicles.

Braking performance. The theoretical braking distance of a vehicle mainly depends on the performance of vehicle braking system, friction between tires and road, a vertical grade of the road and aerodynamic resistance to the vehicle. Reduction in friction between tires and roadway could be caused by several reasons, e.g. vehicle tire and roadway surface properties or load on axles and the distribution of weight per axle. Longer combination vehicles have a longer braking wire system, more housing and coupling devices comparing to standard trucks. A complex braking system could negatively affect the braking performance of LCVs. The problem could be solved using more advanced technical solutions and high developed electronic devices. According to Swedish legislation (Legal Loading… 2002), every vehicle forming any part of a Modular Combination Vehicle should be equipped with ABS brakes that fulfill the criteria in the EC Brake Directive. According to Federal Highway Administration (Comprehensive Truck Size… 2000), braking performance is a general concern that applies to all trucks and is not particularly influenced by changes in truck size and weight if the requisite number of axles and brakes are added as vehicle weight increases and all vehicle brakes are well maintained.

Practical stopping distance is a more complex problem additionally related to a variety of driver skill levels, attention to driving, reaction time, roadway surface features and weather conditions.

6. Accident Data Analysis

Statistical data about traffic accidents involving Longer Combination Vehicles are available only from the regions where LCVs are legally used and separately classified. In our case, data from Scandinavia and the USA will be provided for analysis.

Although, the number of large trucks involved in injury crashes has decreased by 14% over the 10 years period from 1996 to 2006 and the vehicle involvement rate for large trucks in injury crashes has declined by 30%, the accident rate for large trucks is still high in the United States. There were 4995 fatalities in large truck accidents and more than 106000 people were injured in large truck accidents in 2006 (Large Truck… 2008). A similar situation was encountered in 2007 when 4808 people died (12% of all traffic fatalities reported in 2007) and an additional 101000 were injured in crashes involving large trucks (Trafic Safety Facts… 2008; Fatality Analysis… 2010). More than three-fifths (62%) of all fatal crashes involving large trucks occurred on rural roads in 2006 and 2007 (Large Truck… 2008; Trafic Safety Facts… 2008). According to statistics (Large Truck… 2008), single-vehicle crashes made up 21% of all fatal crashes, 15% of all injury crashes and 27% of all property damage crashes involving large trucks. The most (82%) accidents involving large trucks are multiple vehicle accidents. In 2007, large trucks were 2.7 times more likely than other vehicles to be struck in the rear in two-vehicle fatal crashes (Trafic Safety Facts… 2008).

Several researchers have attempted to estimate the propensity of size and weight differences among various truck-trailer configurations with a particular focus on double-trailer combinations, or more specifically on longer combination vehicles. Experts agree that there is a lack of reliable data on the exact configuration of vehicles involved in crashes as well as a shortage of specific measures of exposure for LCVs. For example, data analysis (Scopatz and DeLucia 2000) performed in Florida, Idaho, Nevada, Oregon and Utah States indicates that none of the five states has a crash reporting system that adequately supports the analysis of traffic safety parameters for LCVs.

The conclusions of several past studies related to the road safety issues of LCV vary from slightly positive (Backman and Nordström 2002) to slightly negative (Räsänen *et al.* 2004) and to no difference (Nagl 2008). This un-uniformity in findings is explained by different methodologies and data sets used to conduct these studies. Some research results are shown below.

Statistical data on the USA (Western Uniformity… 2004) are summarized in Table 2. Fatal involvement rates are calculated according to the vehicle miles traveled (VMT) and large truck fatal involvements among 13 States of the USA (States allowing LCVs). Fatal crash involvement was 2.88 per 100 million VMT for single trailer combinations and 3.13 per 100 million VMT for multi-trailer combinations.

According to statistics from Sweden (Avedal and Svenson 2006), almost a half (49%) of the fatalities in accidents involving heavy trucks are in collisions with oncoming traffic. The majority are frontal collisions with passenger cars mostly caused by the car driver due to sliding, overtaking or inattention. More statistical data are shown in Table 3.

Table 2. Fatal crash rates per 100 million vehicle miles traveled, 13 States of the USA 1995–1999

Road functional class	Fatal crash rate (number of crashes)		Fatal crash rate (number of truck involved)	
	Single trailer	Multi trailer	Single trailer	Multi trailer
Interstate rural	1.35	1.78	1.50	1.83
Other rural	4.58	6.22	4.73	6.36
Interstate urban	1.85	1.03	2.01	1.39
Other urban	2.81	2.12	2.84	2.13
Total	2.75	3.02	2.88	3.13

Table 3. Fatalities in accidents including heavy trucks (> 3.5 tons), Sweden 1999–2001

Accident type	Number of accidents	%
Impact with oncoming traffic	218	49
Impact with pedestrian	48	11
Overtaking	35	8
Impact with crossing vehicle	34	8
Impact with bicycle or moped	34	8
Impact with vehicle when turning	24	5
Miscellaneous	24	5
Single vehicle accident	18	4
Rear impact vehicle in same direction	9	2
Impact with animal	1	0
Total	445	100

A wide range of statistical data about fatal accidents involving Longer Combination Vehicles is provided by the Center for National Truck and Bus Statistics at Michigan University. The authors (Jarossi *et al.* 2007) conclude that statistical data about fatal accidents are related neither to the total number of trucks or combination vehicles (the total number of vehicles or the number of vehicles by type) nor to the vehicle miles traveled.

Statistical evidences on the involvement of LCVs in accidents and particularly on the type of accidents vary in a wide range by country. Slightly different conclusions could be explained considering different data samples of accidents, differences in geography and infrastructure, allowed configurations and technical features of LCVs, driver performance employing LCVs as well as the overall traffic safety situation in this region.

7. Opinions about Longer Combination Vehicles and Road Safety

Road safety is the most controversial issue of Longer Combination Vehicles. Some experts and community groups have conflicting views about Longer Combination Vehicles. One group of experts and people think that traffic safety problems significantly increase if Longer Combination Vehicles are allowed. These people do not like seeing large cargo vehicles on roads; organizations and campaigns such as the Coalition Against Bigger Trucks (CABT) in the USA, Canadians for Responsible and Safe Highways (CRASH) in Canada and NoMegaTrucks in Europe are lobbing state and federal legislatures against LCVs operations. The organizations and enterprises related to railway have a similar opinion and are trying to prove that LCVs are dangerous, ineffective and unsafe. Some experts agree that there are more potential hazards, risks and handling difficulties with LCVs rather than with typical truck-trailer combination vehicles.

The opponents are arguing that the risk of traffic accidents is usually considered very dependent on the number of vehicles in the traffic stream. A reduction of the total number of heavy vehicles in traffic is believed to have a positive influence on road safety and long distance cargo transport using LCVs is economically efficient.

Permitting LCVs offers a great opportunity to allow only new vehicles with the newest safety features for this purpose. So far, no empirical evidence has been found to show that LCVs (in particular Short LCVs) are significantly more dangerous than standard heavy vehicles.

8. Improvements in Road Safety

Longer Combination Vehicles have some problems related to traffic safety. Since trucking companies are highly interested to use longer combinations due to economic benefit, legislators and truck manufacturers are working to make LCVs safer on roads. Some ideas of improvements are described below.

According to research results described above, the main part of accidents, involving Longer Combination Vehicles is multiple vehicle accidents; head collisions between cars and trucks occur most often. Designers have worked to create these accidents potentially safer. Truck manufacturers Scania (Scania Group 2010) and Volvo (Avedal and Svenson 2006) have created under-run protection devices/systems in the front of trucks/tractors. The tests of these devices have shown good results. According to literature (Scania Group 2010), these devices have saved 900 lives on roads in Europe. Front under-run protection devices/systems are now required for all European trucks.

New design dollies and trailers could improve the maneuvering performance of LCVs. Several manufacturers have designed dollies and trailers/semitrailers with one or more steered axles. The technical solutions to and performance of new design vehicles are different; some of these products are provided in the market.

Advanced braking and electronic stability programs for LCVs are some other examples of technical solutions to make LCVs safer on roads.

Traffic safety is not only depended on the technical parameters of trucks and combination vehicles as there are other significant factors, e.g. infrastructure design, landscape and driver behavior. Some people decry the utilization of longer combination vehicles largely because they are afraid of the sheer size of the vehicles which is at least partially due to the fact that special training is required in order to drive LCVs and that the drivers of LCVs should be generally more experienced.

A special training and testing program for LCVs drivers is organized in the USA for several years (Daniels 2006). A better selection of drivers and a higher-level training program can help with reducing the accident risk of larger combination vehicles. According to the Federal Highway Administration (Western Uniformity… 2004), improvements in the training program of LCV drivers could make a significant decline in the rate of fatal accidents involving medium-to-heavy trucks in the USA.

Federal Motor Carrier Safety Administration (Minimum Training Requirements… 2004) has established standards in requirements for LCVs operators/drivers. According to legislation, employers are prohibited from allowing drivers to operate LCVs unless those drivers can provide either a LCV Driver-Training Certificate as evidence of successful completion of an LCV driver-training course or a LCV Driver-Training Certificate of Grandfathering showing that the driver is exempt from the training requirements based on experience. Although all countries have made restrictions on the use of LCVs, only some of them have similar legislative rules related to training LCV drivers. Most countries, including Sweden, Finland and the Netherlands have implemented only a special permit system not related to high professional skills of LCV drivers.

Any vehicle could be safe if driven safely and with respect to road conditions and other road users. One of the main points of road safety is the behavior of all traffic participants. Everyone influences each other on the road; vehicle technical parameters, performance and LCV driver behavior are not exclusive safety related issues. The traffic safety of LCVs is a reflection of the interaction of multiple factors.

9. Conclusions

1. Longer Combination Vehicles (LCVs) have advantages comparing to typical truck-trailer and tractor-semitrailer combination vehicles. Cargo shipments with LCVs are cheaper in long distances due to lower transportation costs (fewer drivers and less fuel consumption per cargo unit). It results in fewer trucks on roads (less traffic congestions, less air pollution, lower noise) in total. A smaller total number of trucks on the road and less vehicle kilometers traveled can result in a lower likelihood of traffic accident occurrence.
2. Longer Combination Vehicles could have disadvantages comparing to conventional large trucks. The design of some elements of road infrastructure is not fully suitable for longer combination vehicles; the limited radii of curves and narrow traffic lanes can cause the increased risk of infrastructure and vehicle damage. A small number of suitable parking slots for LCVs can cause inconvenience to drivers. Longer Combination Vehicles take more road-space; LCVs block an intersection for longer time comparing to a shorter truck with similar acceleration performance; at turns/corners, LCVs can block the width of more than one traffic lane and even go into the traffic lanes of the opposite direction. The extra length of LCVs can cause additional risk for other road users.
3. Statistical evidences about the involvement of LCVs in accidents and particularly considering the type of accidents vary by country and region. Researchers have come to slightly different conclusions about safety issues related to LCVs. It could be explained by different data samples of accidents used for research, differences in geography and road infrastructure, allowed configurations and technical features of LCVs, driver performance employing LCVs and the overall traffic safety situation in this region. There is a lack of data reporting on traffic accidents that could be adequately supported by a detailed analysis of LCVs traffic safety issues. So far, statistically proven empirical evidence has not been found to show that LCVs are significantly more dangerous than a typical truck-trailer and tractor-semitrailer combination vehicles.
4. Road safety is the most controversial issue of Longer Combination Vehicles. Some transportation experts and community groups have conflicting opinions about the safety of LCVs. People who are against longer combination vehicles are trying to prove that LCVs are dangerous, ineffective and unsafe. However, there are community groups having opposite opinions. Both parties are conducting research projects advertising their opinions and lobbing legislators.
5. Vehicle manufacturers are working to decrease the potential hazard of longer combination vehicles. Several new design features of road vehicles are created and introduced in the market. Technical solutions and special electronic equipment is available to make longer combination vehicles safer on the road.
6. A special training and testing program for LCVs drivers could improve the safety of longer combination vehicles. It is statistically proven that more experienced and higher qualified drivers have potential to be involved in a smaller number of traffic accidents.

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