THE ISSUE OF TRUCK BRAKING, THEIR ACCIDENT RATE AND ECONOMIC LOSSES INCURRED IN TRAFFIC ACCIDENTS IN THE CZECH REPUBLIC

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Abstract

The article's theme is the issue of truck braking, their accident rate and economic losses that incur in relation to traffic accidents in the Czech Republic. First, the issue of the accident rate of trucks is outlined here, as well as the consequences of traffic accidents relating to them, development of accident rate of truck drivers between 2006 and 2012, and then the economic losses incurred in traffic accidents are outlined here depending on the type of injury or damage. Then this article introduces the issue of legislation requirements for truck brakes and the results of the performed measurement of braking of trucks and truck trains going in a straight direction depending on the load, as well as braking of trucks with/without ABS and last but not least, truck braking when driving in a curve.

Keywords: Braking, truck, accident rate, economic losses

Introduction

The economy of any country depends on movement of commodities. The movement is performed by road transport, particularly by trucks. Unfortunately, there are also negative effects relating to road traffic, including traffic accidents. The lay public often thinks that most crashes and serious traffic accidents are caused by trucks. The fact is that when an accident occurs involving a truck or a truck train, consequences of such accidents are often serious. However in reality, the number of accidents in the Czech Republic caused by trucks only represented approximately *14%* (of which *9%* were trucks without a trailer or semi-trailer, *1%* trucks with a trailer and about *3.5%* trucks with a trailer) in 2012 for example. It is obvious that in the case of an accident between a truck and a passenger car, the car occupants have much lower chance of survival in comparison with the truck's driver or crew. Moreover, in truck accidents the incurred damage is much more extensive, not only to the vehicles involved and to the transport infrastructure, but also to the transported cargo.

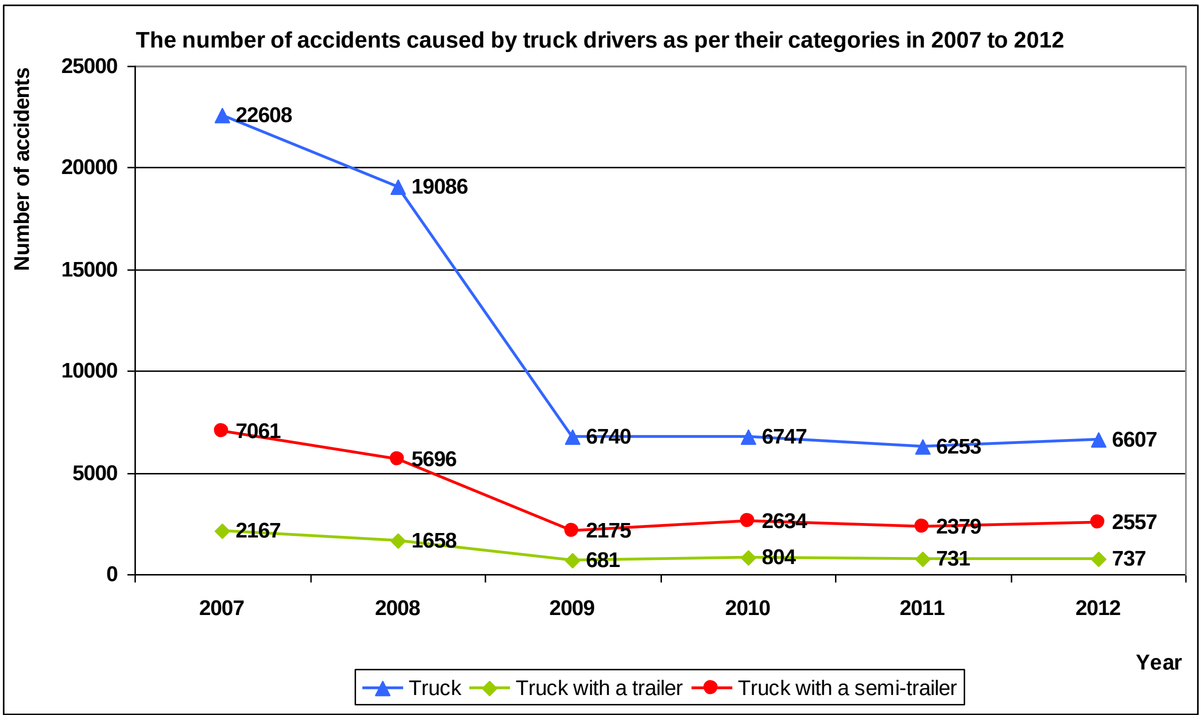
Truck accident rate, its consequences and economic impacts

All advanced countries including the Czech Republic strive to reduce the number of traffic accidents, which is in accordance with the White Book published by the European Commission. The statistical data regarding traffic accidents are the meter of success of such efforts. The accidents caused by truck drivers have a relatively significant share in this statistical data. The extent of involvement is obvious from the following table, from which it is apparent that in 2012 truck drivers caused *17.2%* of traffic accidents of motor vehicles in total as offenders. In these traffic accidents, 86 road traffic participants died. Out of the aforementioned number, *11.5%* were drivers of trucks without a trailer or semi-trailer, *1.3%* drivers of trucks with a trailer and *4.4%* drivers of trucks with a semi-trailer.

Motor vehicle category	Number of accidents	Category share [%]	Killed
Motorcycle	1605	2.8	51
Passenger car	44507	77.3	470
Truck	*6607*	*11.5*	*58*
Truck with a trailer	*737*	*1.3*	*6*
Truck with a semi-trailer	*2557*	*4.4*	*22*
Bus	996	1.7	4
Tractor	263	0.5	3
Tram	133	0.2	0
Trolleybus	44	0.1	0
Other motor vehicle	145	0.3	1

Tab. 1:The number and consequences of TAs in 2012 as per the type of the offender's motor vehicle

The following diagram shows the development of the number of accidents caused by truck drivers in 2007 to 2012. The diagram shows a considerable decline in the relevant number of accidents in 2009 in comparison with the previous year. This decline was caused by the fact that starting from 01/01/2009, the amount of damage incurred in an accident, after which police may be called, was increased from the previous amount of about *EUR 2,000* to *EUR 4,000*. From 2009, the number of accidents caused by truck drivers stagnates on average.



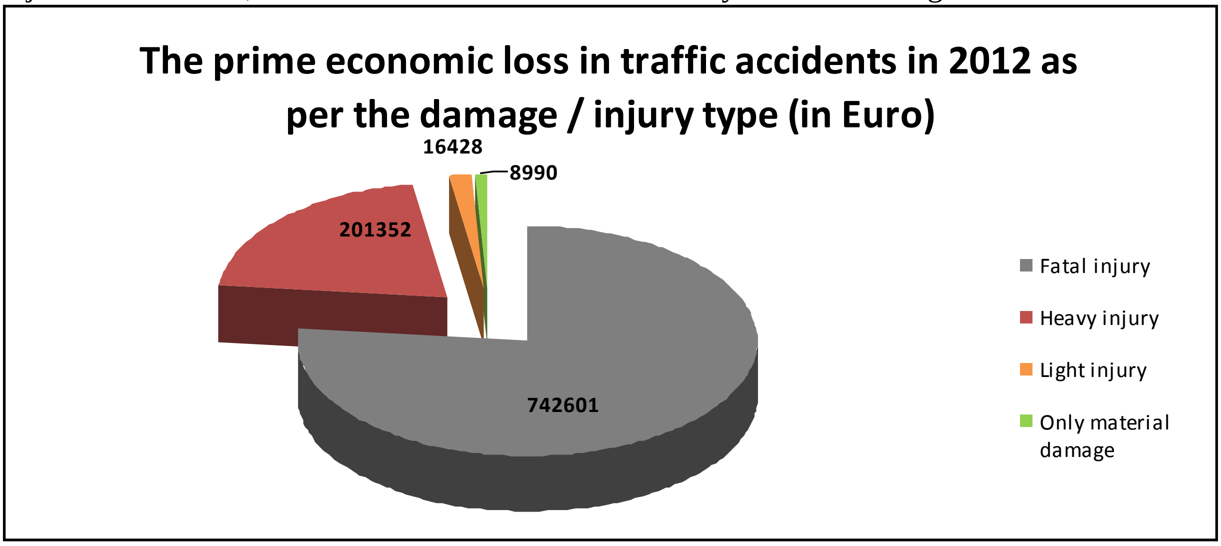
Graph 1: The number of accidents caused by truck drivers as per their categories in 2007 to 2012

A more objective criterion to judge the development of the accident rate in the independent truck categories for the last 6 years is the number of people who died in accidents caused by truck drivers. Such accidents must always be reported to the Police of the Czech Republic according to law. The trend in consequences of accidents caused by drivers of the individual truck categories in 2007 to 2012 is obvious from the following table. It shows that the number of persons killed and injured at traffic accidents caused by drivers of all types of trucks from 2007 to 2012 was decreasing, with the largest decline in 2008. In 2012, there was a slight increase in the number of killed persons (by two) at accidents caused by drivers of trucks with a trailer.

Truck type	Consequences	Year					
		2007	2008	2009	2010	2011	2012
Truck	*Killed*	103	83	80	60	59	58
	Injured	2097	1967	1879	1638	1643	1586
Truck with a trailer	*Killed*	17	8	4	8	4	6
	Injured	191	159	134	163	144	102
Truck with a semi-trailer	*Killed*	41	19	21	22	24	22
	Injured	467	373	348	390	410	337
Total	***Killed***	161	110	105	90	87	86
	Injured	2755	2499	2361	2191	2197	2025

Tab. 2: The number of killed and injured at TAs caused by drivers of the individual truck categories

The important criterion for evaluation in the area of accident rate is the amount of economic losses incurred in traffic accidents. Such losses depend on many factors, including the extent of injury or the extent of material damage. The economic losses caused by traffic accidents are calculated annually in the Czech Republic. In their calculation, the accurately defined methodology of mathematic evaluation of the accident rate economic consequences is applied, using so-called "human capital method". The costs incurred at traffic accidents comprise of the direct and indirect costs. The indirect costs include the costs of medical care, cost of fire fighting unit, cost of police, material damage including the costs of insurance companies and the costs of courts and state authorities. Direct costs include loss of production and social expenses. The following diagram shows quantification of the economic losses in the case of fatal injury, from which it is obvious that the prime economic losses caused by the traffic accident consequences in 2012 amounted to *EUR 742,601* in the case of fatal injuries, *EUR 201,352* in the case of heavy injuries, *EUR 16,428* in the case of light injuries and *EUR 8,990* in the case of accidents with only material damage.



Graph 2: The prime economic loss in traffic accidents in 2012 per person as per the damage / injury type (in €)

Our Institute of Forensic Engineering of Brno University of Technology has many years of experience drawn in analysing traffic accidents. On the basis of the experiences we know that a large part of such accidents is caused by failure to stop the vehicle by braking before the accident. This failure to stop by braking may be caused by late driver's reaction or due to improper function of brakes or by a combination of several causes. To be able to find the cause, it is necessary to know the braking deceleration the trucks are able to achieve. That is why we devoted our investigation to measuring the achievable deceleration of trucks.

Legislative requirements for truck brakes

The Directive 71/320/EEC is applied to testing brake devices in certification of new trucks in the EU. The Directive in particular regulates the manner and the methods of testing the proper functionality of braking devices. Pursuant to the aforementioned Directive, three types of tests are performed:

- Type 0 test (ordinary test of effect with brakes cold)
- Type I test (residual brake performance)
- Type II test (long downhill vehicle behaviour test)

The requirements for braking effects according to the said standard for Type 0 tests are specified in the following table.

Categories of vehicles		Buses (lighter than *5 t*)	Buses (heavier than *5 t*)	Trucks (from *3,5* to *12 t*)	Trucks (heavier than *12 t*)
Type of test		0 - I	0 – I – II	0 - I	0 – I – II
Type 0 test with engine connected	prescribed speed	*60 km/h*	*60 km/h*	*60 km/h*	*60 km/h*
	$s \leq$	$0{,}15v + \frac{v^2}{130}$			
	$d_m \geq$	*5,0 m/s²*			
Type 0 test with engine disconnected	v = 80 % v_{max} but ≤ :	*100 km/h*	*90 km/h*	*100 km/h*	*90 km/h*
	$s \leq$	$0{,}15v + \frac{v^2}{103{,}5}$			
	$d_m \geq$	*4,0 m/s²*			
	$F \leq$	*700 N*			

Tab. 3: Effects of truck braking devices[1)]

where:

v - testing speed [*km/h*]
s - stopping distance [*m*]
d_m - mean full braking deceleration [$m.s^{-2}$]
F - force applied to the brake control [*N*]
v_{max} - maximum vehicle speed [*km/h*]

The values specified in **Table 3** are however according to regulations and it is questionable if such values are achieved by vehicles under normal operating conditions as well. Many measurements were performed (as specified in the following chapter) to identify actual deceleration values.

Measurement of braking deceleration of trucks

The achievable truck deceleration depends to a large extent on the vehicle load, version and type of the braking device and its overall technical condition. The values of deceleration of a fully loaded or even overloaded vehicle are of particular importance. It is obvious that a fully loaded or overloaded vehicle will have much longer stopping distance than an empty vehicle.

[1)]Directive 71/320/EEC: Braking devices of certain categories of motor vehicles and their trailers [online]. [cit. 2014.05.05]. URL <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1971L0320:20070101:EN:PDF>.

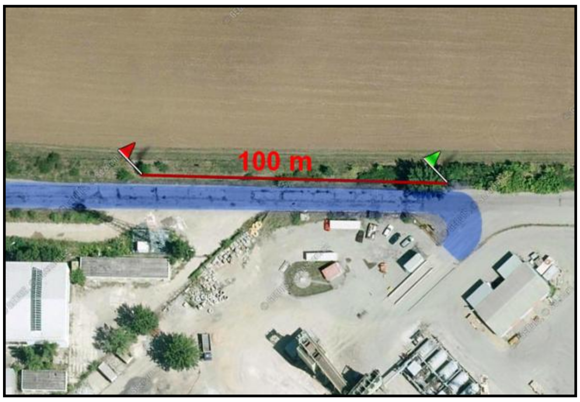


Fig. 1: Orthophotomap of the measurement spot, scale: 100 m

Fig. 2: Location of devices in the vehicle cabin

All measurements were made on the road at the place indicated on **Fig. 1**. The straight section and the following curve are highlighted in blue. In this location, the traffic is minimal and the road surface is bituminous and without any defects. The measurements were performed under ideal weather conditions (sunny). Two appliances were used to measure the braking deceleration. One of them was decelerograph XL MeterTM PRO made by Inventure, which measures deceleration / acceleration with the frequency up to *200 Hz* in two axes *x* and *y* in the interval ± $14{,}00\ m.s^{-2}$ with the sensitivity of $0{,}01\ m.s^{-2}$. The second one was the apparatus Racelogic operating on the basis of the principal of location change using GPS coordinates. Its measuring frequency is *10 Hz*, it measures along three axes in the range ± $39{,}2\ m.s^{-2}$ with sensitivity of $0.1\ m.s^{-2}$. The location of both devices in vehicles is obvious from **Fig. 2**.

Measuring of deceleration in a straight direction for trucks with various loads

This measurement was focused on comparison of braking deceleration (braking distance) in a straight direction if the truck weight is changed. For economic reasons, the trucks are often loaded up to their maximum loading capacity, therefore our trucks were loaded to the maximum; in several measurements, even *2 tons* beyond the permitted limit were loaded. Two similar vehicles were used for measurement. Vehicle I was a three-side dump truck SCANIA, type P 380 (empty weight *11,660 kg*), Vehicle II was a three-side dump truck SCANIA, type P 320 (empty weight *11,500 kg*). First, only empty trucks were braking, then they were gradually loaded. The initial speed for this series of measurements was chosen to be *50* to *55 km/h* (this speed was decreased in the following series of measurements for safety reasons). Several measurements were performed for every load and an average has been calculated for the resulting values. The following **Table 4** shows the results.

Vehicle I		Vehicle II	
Load [kg]	***Average deceleration [m.s^{-2}]***	***Load [kg]***	***Average deceleration [m.s^{-2}]***
11,660	7.2	11,500	6.7
16,980	7.0	26,000	5.0
24,060	6.1	28,000	4.1
---------------	---------------	30,000	3.2

Tab. 4: Achieved deceleration of trucks with various loads in straight direction

Measuring of deceleration in straight direction for trucks with and without ABS

The purpose of the following measurement was to compare braking deceleration, i.e. the braking distance of vehicles fitted with ABS and vehicles without ABS. Two comparable vehicles were measured, when the main difference was in ABS, or respectively in its absence. The vehicle without ABS was a three-side dump truck LIAZ (empty weight *11,870 kg*), see **Fig. 3** and the vehicle with ABS was a three-side dump truck SCANIA (empty weight *11,190 kg*), see **Fig. 4**. A loose mixture of gravel was used as the load, like in the similar series of measurements. For the given initial speed (*40* to *42 km/h*) and every load, several measurements were performed and an average has been calculated for the resulting values. The results of the measurements are shown in the following **Table 5**:

Vehicle without ABS		Vehicle with ABS	
Load [kg]	***Average deceleration [m.s^{-2}]***	***Load [kg]***	***Average deceleration [m.s^{-2}]***
11,870	6.91	11,190	7.49
27,190	4.58	25,860	5.45

Tab. 5: Achieved deceleration of trucks with/without ABS, in straight direction

Fig. 3: Vehicle without ABS - LIAZ 6x4

Fig. 4: Vehicle with ABS - SCANIA 6x4

Measuring of deceleration in a curve for trucks with and without ABS

A critical situation may occur at the moment the truck must brake in a curve. Braking in a curve is more difficult for the vehicle and the driver than braking in a straight direction. Therefore one series of measurements was focused on braking of vehicles in a curve. A curve with radius of *14 m* was selected (see **Fig. 1**). The same vehicles were chosen as in the previous series of measurements, i.e. a vehicle without ABS - LIAZ 6x4 and a vehicle with ABS - SCANIA 6x4. In the case of the loaded truck intensively braking in a curve, puncture of the overloaded front tire might occur due to inertia forces. For safety reasons, this series of measurement was only performed with vehicles without the effective load. The initial speed before braking was chosen in the interval *35* to *37 km/h*. Several drives were performed and an average was then calculated from the resulting values. The results of the measurements are shown in the following **Table 6**.

Vehicle without ABS		Vehicle with ABS	
Load [kg]	***Average deceleration [m.s^{-2}]***	***Load [kg]***	***Average deceleration [m.s^{-2}]***
11,870	5.58	11,190	6.18

Tab. 6: The achieved deceleration for trucks with and without ABS driving in a curve

Measurement of deceleration in straight direction for truck trains

The last series was focused on measuring the braking deceleration of truck trains. The truck trains are most often utilised for transport of commodities between individual countries. Two similar vehicles with the same type of braking device and with ABS have been selected. The Truck Train I comprised of a tractor DAF CF and a semi-trailer SCHMITZ (**Fig. 5**, total empty weight of the Truck Train I was *23,490 kg*). The Truck Train II comprised of a tractor DAF XF and a semi-trailer KRONE (**Fig. 6**, total empty weight of the Truck Train II was *17,240 kg*). The initial speed before braking was chosen in the interval *31* to *33 km/h*. First, empty vehicles were braking, then the semi-trailers were uniformly loaded with pallets with cargo. The Truck Train I was loaded up to the weight of *39,190 kg*; the Truck Train II was loaded up to *42,190 kg*. Eight measurements in total were performed with each vehicle and each load. The results of the measurements are shown in the following **Table 7**.

Truck Train I		**Truck Train II**	
Load [kg]	***Average deceleration [m.s^{-2}]***	***Load [kg]***	***Average deceleration [m.s^{-2}]***
23,490	6.75	17,240	7.42
39,190	5.27	42,190	5.18

Tab. 7: Achieved deceleration of truck trains without any cargo and with a load

Fig. 5: Truck Train I – DAF CF, semi-trailer SCHMITZ

Fig 6: Truck Train II – DAF XF, semi-trailer KRONE

Conclusion

The accident rate statistics showed that trucks caused about *14%* of traffic accidents in 2012 (of which about *9%* were caused by trucks without any trailer or semi-trailer, *1%* by trucks with a semi-trailer and about *3.5%* by trucks with a semi-trailer). From 2009, the number of accidents caused by truck drivers stagnates on average. The number of killed and injured persons in traffic accidents caused by drivers of all trucks declined in the period of 2007 to 2012, with the largest decline in 2008. The prime economic losses resulting from consequences of a traffic accident in the Czech Republic in 2012 were *EUR 742,601* in the case of fatal injury, *EUR 201,352* in the case of heavy injury, *EUR 16,428* in the case of light injury and *EUR 8,990* in the case of accidents with only material damage.

The measurement results of braking deceleration of trucks revealed that there are large differences between braking an empty or a fully loaded vehicle. The decrease in braking deceleration of a fully loaded vehicle when compared with an empty one is *25%*. In the case of an older vehicle without ABS, the difference is even higher, almost *35%*. Also the absolute values of deceleration are lower for the vehicle without ABS than for the vehicle with ABS. In the case of a less loaded truck train, the difference in deceleration for the empty and for the loaded vehicle was about *20%*; in the case of more loaded truck train, it was more than *30%*. In the case of overloading a truck (with ABS) by *2 tons* it was demonstrated that the deceleration value is less than a half and may even get below the value required by regulations in some cases. However, many drivers of trucks and truck trains do not realise this fact when they drive fully loaded or even overloaded vehicles. The distance necessary to stop the vehicle is then considerably longer. Moreover, the overloaded vehicle has much higher kinetic energy at the same speed and therefore the consequences of such accidents are worse. Older vehicles achieve lower braking deceleration. The statistics of registered vehicles clearly show that the older vehicles are most often represented in the vehicle fleet of carriers. The average age of vehicles of category N2 (from *3.5* to *12 tons*) is more than 20 years in the Czech Republic.

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