EFFECTS OF HIGH CAPACITY VEHICLES ON TRAFFIC SAFETY IN SWEDEN

Obtained a Ph.D. in Vehicle Safety from Chalmers University of Technology in 2008. Leads a program that monitors the safety performance of HCVs in Sweden, and conducts research on driver support systems.

J. SANDIN
The Swedish National Road and Transport Research Institute (VTI), Gothenburg, Sweden. (Tel: +46 31 750 2610; e-mail: jesper.sandin@vti.se).

Abstract
In July 2016, there were 38 Higher Capacity Vehicles (HCVs) active in Swedish trial operations. Between 2010 and July 2016, in total 24 accidents had occurred with HCVs involved. Nine of the accidents involved HCVs with an allowed GVW up to 74tonnes. A further 13 rollover accidents had occurred with 90tonne HCVs used for iron-ore transport. Lastly, two accidents involved HCVs longer than 25.25m. Due to the small sample it was not found reasonable to calculate crash risk. Interviewed HCV drivers were overall positive to the vehicles. Compared to conventional HGVs, both the heavier and longer HCVs require more planning when decelerating and accelerating. International experiences of HCVs show that the traffic safety performance of HCVs are as good or better as conventional heavy vehicles. The reason for this is a systematic framework for HCVs involving a match of PBS-approved vehicles and road networks, vehicle monitoring, and qualified drivers. This approach is and should be adopted in order to keep a high level of traffic safety in Sweden.

Keywords: High Capacity Transport, HCT, High Productivity Vehicles, HPV, Long Combination Vehicles, LCV, Articulated vehicles, Overtaking, Passing maneuvers, Lane -change crashes, Merging crashes

1. Introduction

Higher Capacity Vehicles (HCVs) are road transport vehicles with weights and/or dimensions outside that permitted in conventional regulation for Heavy Goods Vehicles (HGV). HCVs are expected to increase transport and energy efficiency and thereby decrease costs as well as carbon dioxide emissions (OECD 2009). Since about two decades, Sweden and Finland allow a maximum length of 25.25m and a gross vehicle weight (GVW) of 60tonnes within the European Modular System (EMS). Recently, the maximum GVW was increased to 64tonnes in Sweden and 76tonnes in Finland. The standard of heavy vehicles in the EU is 18.75m and 40tonnes. In Sweden, and Finland in particular, an increasing number of different HCVs are permitted for transport on designated roads.

In July 2016 there were 39 HCVs in the Swedish trial operations (EnergiEffektiva Transporter, 2016). They can broadly be divided in two groups depending on whether they exceed the normally allowed maximum length of 25.25m and/or a GVW of 64tonnes. In Sweden these vehicles are termed High Capacity Transport (HCT) vehicles. In Australia, they would be termed Higher Productivity Vehicles (HPV). Throughout this paper however, Higher Capacity Vehicles (HCVs) will be used as general term.

The purpose of this paper is to review the international experiences of Higher Capacity Vehicles effect on traffic safety, and discuss them in relation to the experiences of Swedish trial operations with HCVs until today.

2. International experiences of HCV

HCVs are permitted to varying degrees in Australia, Brazil, Canada, Mexico, South Africa and some states in the US.

In Canada, the province of Alberta has more than 40 years' experience of HCVs, with vehicle lengths ranging from 31m to 37m. The vehicles are allowed for an increased carrying capacity but not a higher GVW than the maximum 62.5tonnes. The road network that is provided for the HCVs is 3000km long, which corresponds to about 20% of the main network in Alberta (Woodroffe, 2001). The safety performance of the HCVs in Alberta has been investigated several times. Overall, the investigations show that the HCVs have a higher traffic safety performance than conventional heavy vehicles. On average, the HCVs are involved in around one percent of all the HGVs crashes that result in fatal, severe and property damage outcome. In terms of crash risk, HCVs as a group has the best traffic safety performance of all heavy-vehicle types. The HCV group has a lower crash risk with respect to fatal, severe and property-damage crashes per 100 million vehicle kilometers than other vehicle types. The crash severity associated with HCVs is also lower than for other vehicle types (Kenny m fl., 2000; Woodroffe, 2001; Montufar m fl., 2007).

Woodroffe (2001; 2004) concluded that the overall high safety performance of the HCVs in Alberta was highly related to the strict permit requirements. In short, these entails designated transport routes, speed restrictions, time of day, and under which road and weather conditions the HCV is allowed to drive, as well as requirements on driver experience and additional education.

In the US, the HCVs include the same vehicle types as in Canada but with somewhat shorter trailers. Unlike Canada, the HCVs in the US are allowed a higher GVW than the general maximum level. These vehicle combinations are allowed to drive on designated roads in 12 states (OECD, 2009). As for accidents with HGVs in general it is problematic to estimate the relative crash risk of HCVs in the US due to the lack of reliable information on the vehicle combinations involved in crashes, as well as exposure data for HCVs (Scopatz and DeLucia, 2000; Carson, 2007). FHWA (2000) could not find any studies suitable for the estimation of differences in crash risk between HCVs and non-HCVs. One exception is Craft (2000) who reports that out of the 17 191 vehicle combinations involved in crashes between 1991 and 1996, 221 (1.3%) where HCVs. The risk of fatal crashes where compared with conventional double-trailers and truck-semitrailers with respect to vehicle length, weight, and configuration. The conclusion was that HCVs were neither more nor less safe than other combinations.

Mexico allows LCVs consisting of double trailers around 12.5 m in length. One common combination is an A-double with a GVW of 66.5tonnes and length of 39m. The A-double must display a sign on the rear, indicating that it is a double length trailer in use. Mexico does not place special road restrictions on LCVs other than those already in place for conventional tractor-trailers (OECD, 2009; Wikipedia 2016). An analysis of crashes involving heavy vehicles was conducted by the ANTP (National Private Fleets Association). ANTP represent 10% of the private fleet companies that transport their own products like soft drinks, bread, cement, steel etc. The results showed that crashes per million kilometers as well as crashes per tonne-kilometers were lower for tractors with two trailers than for tractors with one trailers and rigid trucks (ANTP, 2014).

Australia has the greatest experience of different HCVs. Although they are restricted to higher capacity roads, they are allowed on a large road network comprised of divided and undivided highways and arterial roads. Except for the largest HCVs (BAB/AAB Quads and B-Tripels), they are allowed within or close to urban areas. Hassall (2014) presents a comprehensive study based on data from 65 vehicle fleets with over 600 vehicles and insurance records. The results show that the accident rates for HCVs are significantly lower than for their conventional equivalent trucks. For accidents of minor severity (<$5 000) to major severity (>$50 000), the accident rate for articulated HCVs is 18.4 accidents per 100 million km, compared to 72 for their equivalents. The accident rate for rigid HCVs is 53 accidents per 100 million km in comparison with 102 for their equivalents. For a mixed fleet of conventional 50% heavy rigid and 50% articulated vehicles, the combined average accident rate is 87 accidents per 100 million km (from minor to major severity). One of the reasons to the high safety performance is the reduced exposure of heavy vehicles. The mileage with articulated vehicles is carried out with 37% less vehicles and with 37% less kilometers driven with comparable vehicle fleets.

3. Accidents with conventional Heavy Goods Vehicles in Sweden

This section summarizes the accident involvement of today's conventional HGVs with the purpose of identifying accident types and circumstances that need to be considered for HCVs.

Balint et al. (2014) analyzed 2 290 Swedish accidents involving at least one HGV between 2003 and 2012 in which at least one person was Killed or Severely Injured (KSI) (corresponding to 22.5% of all HGV accidents). The results showed that "Long" combinations

(18.76m to 25.25m) had a lower rate of KSI accidents per 100 million vehicle kilometers travelled compared to “Medium” (12.01 to 18.75m) and “Short” (<12m) vehicles. See Table 3.1.

For the sake of comparison, the overall crash rate for HGVs can be calculated based on figures reported by Balint et al. (2014). For the years 2003 and 2012 there were 10 196 police-reported accidents involving at least one HGV. Note that an accident should be reported by the police if there is at least one personal injury; slight, severe or fatal. The total vehicle kilometers travelled in Sweden between 2003 and 2012 for all HGV combinations was 29.42 billion km. Thus the overall crash rate for HGVs become 10 196 accidents divided by 29.42 billion km which is 34.6 crashes per 100 million Km.

Table 3.1 – Crash rates for conventional HGV combinations by length group (Balint et al., 2014)

Combination length	Short (<12m)	Medium (12.01m - 18.75m)	Long (18.76m - 25.25m)
Number crashes with Killed and Severely Injured (KSI)	1 466	390	509
Vehicle kilometers travelled (billion km)	10.72	7.01	11.69
Crash rate (per 100 million km)	13.7	5.6	4.4

Balint et al. (2014) were only able to calculate the overall accident rates for the three combination lengths because detailed exposure data (i.e. vehicle kilometers travelled) were lacking for different road types and areas. However, most KSI accidents occurred in rural environments, especially those with the involvement of “medium” and “long” HGV combinations.

Figure 3.1 shows the length group distribution per accident type for KSI accidents with the involvement of at least one HGV of identified length group. The accident types “Meeting accident” and “Overtaking accident” are combined in this figure because an investigation of the accident narratives suggested an overlap between these accidents. “Intersection accidents” and “Turning accidents” are united for the same reason. The expected share of a length group, displayed in the last column, is the number of KSI accidents with at least one HGV combination in the length group divided by the number of all classified accidents. A comparison of the observed share with their expected share shows that the “Long” combinations are over-represented for “meeting or overtaking” accidents.

Although Balint et al. (2014) found that the average accident rate was lowest for the long combination group, the annual KSI crash rate for this groups tended to increase between 2009 and 2012. In addition, during the winter season (Dec-Feb) the number of KSI crashes increases for the long combinations while they stay nearly the same for the other two length groups. Further analysis showed that the accidents classified as Meeting/Overtaking and Rear-end increase most during the winter season for the long combinations. These tendencies should nevertheless be interpreted with caution due to the limited number of KSI crashes.

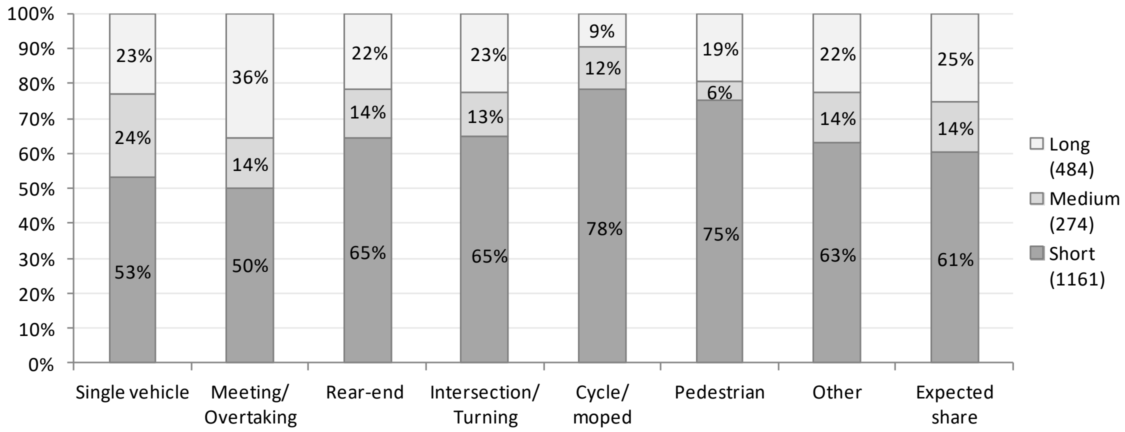

Figure 3.1 - Distribution of length groups by accident type (not adjusted for exposure) (Balint et al., 2014)

Because of the aforementioned overlap between the accidents types “Meeting accident” and “Overtaking accident”, Sandin (2015) conducted an analysis of narratives from Swedish police-reported accidents over all severity levels involving HGVs during the years 2003-2013. The analysis confirmed the overlap between the Meeting and Overtaking accident types, but also that there was an overlap between those two and “Rear-end accident”. Thus, the latter was also included in the analysis. The preliminary results indicate that the top three accident types with HGVs involved are Rear end (25%), Single vehicle (18.6%), followed by Lane change (16.2%). In about half of the lane-change crashes, the truck had changed lane towards the right and collided with a passenger car, which in several cases had been obscured by the truck cabin according to the accident narratives. The vast majority of the lane-change crashes occurred on multi-lane highways passing through larger cities, see Figure 2 for an example. Further analysis of accident sketches is necessary to verify the results. The next step is to distribute the accidents over different combination lengths by using the same methods as Balint et al. (2014).

Figure 3.2 – Lane-change crashes (blue dots) on E6 passing through the city of Göteborg, Sweden, involving conventional heavy vehicles 2003-2013 (picture from Google^{TM} Earth).

4. Traffic safety assessment of Higher Capacity Vehicles in Sweden

4.1 Trial Operations with HCVs

In July 2016 there were 38 HCVs in the Swedish trial operations (EnergiEffektiva Transporter, 2016). Until 2014 there were an additional 31 HCVs with a GVW of 90tonne used for transporting iron ore. These were driven in shift up to every 7th minute on a 162km designated road. The currently active 38 HCVs can broadly be divided in two groups depending on whether they exceed the normally allowed maximum GVW of 64tonnes and/or length of 25.25m.

The first group consists of 33 vehicles allowed to have a higher GVW, in most cases up to 74tonnes, while not allowed to exceed 25.25m in length. Eighteen of them are used for transporting timber. There are two types of 74tonne timber truck combinations. One type consists of a tractor, link and trailer linked together by a fifth wheel (Figure 4.1a). The other consists of a truck and trailer with a crane mounted on the rear of the truck. An additional 10 vehicles carry bulk with allowed GVWs between 68tonnes and 90tonnes, and five vehicles carry general cargo with allowed GVWs between 74tonnes and 80tonnes.

The second group consists of five long combination vehicles, which are allowed a length over 25.25m, ranging from 27m to 32m. Figure 4.1b shows an example of “the longest combination vehicle in Europe”, which is an A-double consisting of a 6x4 tractor unit followed by a three-axle semi-trailer, two-axle dolly and a three-axle semi-trailer unit. All except one of four vehicles that carry general cargo have an allowed GVW over 60tonnes, however in many cases they do not exceed 60tonnes during transports. Lastly, the ETT-vehicle is the largest timber truck in Sweden with its 30m in length and 90tonne in maximum GVW (Figure 4.1c)

a) Timber truck (GVW 74tonne, length 24m) b) A-double (GVW 80tonne, length 32m) c) ETT vehicle (GVW 90tonne, length 30m)

Figure 4.1 - Examples of three HCVs in the Swedish trial operations

The vehicles that are allowed a higher GVW than 64tonnes require special permit and is allowed on a designated road network. The long combination vehicles exceeding 25.25m are only allowed on specific designated roads, and is required to display a sign at the front and rear indicating either “Long load” or the actual combination length under a silhouette of the vehicle. At times with a GVW exceeding 60tonnes and when passing over certain bridges on 110km/h highways, the drivers must reduce the speed to 50km/h. All drivers holding a CE driving license (for heavy truck and trailer) are allowed to drive the HCVs, and no additional driving license or education is required. The speed limit for these vehicles is the same as for all heavy vehicles in Sweden, which is 80 km/h.

At the time of writing, full mileage data is lacking for all 74tonne vehicles in the trial operations. As of July 2016, the long combination vehicles carrying general cargo had as a group travelled 2 642 000 km, and the ETT-vehicle had travelled 1 877 000 km. The no longer active 90tonne HCVs used for iron-ore transport had as a group travelled 12 303 030 km.

4.2 Accidents with HCVs

To the author's knowledge, in total 24 accidents have occurred with HCVs involved during the Swedish trial operations between 2010 and July 2016, where the majority has resulted in property-damage-only, and none has led to serious personal injuries.

Nine accidents involved HCVs with an allowed GVW up to 74tonnes (seven timber trucks, one tank truck and one carrying steel coils). Five of these were single vehicle accidents, whereof two occurred in icy road conditions and three were primarily caused by sudden driver illness, driver distraction or driver inexperience. Four accidents involved collisions with other vehicles, whereof one occurred in icy road conditions, and three accidents when a passenger car overtook the HCV. According to the accident investigations, none of the accidents were caused by the characteristics of the HCV itself and would have occurred also with conventional vehicles. A further 13 rollover accidents had occurred with the 90tonne HCVs used for iron-ore transport, whereof one led to severe truck damage.

Two accidents involved HCVs longer than 25.25m, and resulted in collisions with other vehicles. One occurred when a passenger car was overtaking the 30m long ETT-vehicle (Figure 4.1c) in the section were two lanes merged into one on a "2+1 road" (explained in Section 4.3). According to a witness, the passenger car commenced the overtaking maneuver at a very late stage. It cannot be discerned whether the extra length of the HCV also contributed. The other crash occurred at the end of a temporary lane at a roadwork. Here, an A-double (similar to the one in Figure 4.1b), was about to slowly re-enter the ordinary lane where another truck was driving in very high speed and tried to get past the A-double (possibly because the driver noticed the extra length of the A-double).

4.3 Risk Estimation of Overtaking Maneuvers

Because the time required to overtake a vehicle increases with the length of the overtaken vehicle, there are fears that the number of overtaking-related crashes could increase with longer vehicle combinations (Grislis, 2010; Vierth et al., 2008). There is however a lack of studies that can quantify the risks of overtaking maneuvers in terms of crash rates. One exception is Vierth et al. (2008) who analyzed police-reported accidents involving conventional HGVs in Sweden during the years 2003 to 2005. The authors found no evidence in the data indicating that overtaking accidents were more frequent for combination vehicles up to 25.25 m than for rigid 18 m vehicles.

With regards to the risk of overtaking longer combination vehicles on undivided two-lane roads, there are two vehicles in the trials that drive on such roads. One is the ETT-vehicle partly driving on a road with a speed limit of 90 km/h, and one vehicle is used for container transport on a road with a speed limit ranging from 80km/h to 90km/h. No accident related to passing maneuvers of an HCV has occurred on those two-lane roads.

As an alternative to crash rates, meeting margins have been used as an indirect risk measure for overtaking maneuvers. Meeting margin is defined as the time elapsed from the conclusion of an overtaking maneuver to the moment the overtaking vehicle's front is aligned with the front of an oncoming vehicle in the opposite lane. The smaller the meeting margin the larger is the risk. Andersson et al. (2011) conducted a field-study with video-recorded overtaking maneuvers of a 30m and a 24m truck on a country road with one lane in each direction. They extracted and analyzed meeting margins for passenger cars overtaking the heavy vehicles. The results showed that the average meeting margins were 6.7±1.8s for the 30m truck and 6.9±1.7s for the reference truck – with the median of 7.0 and 7.2s. The differences were not statistically significant, as the observed overtaking maneuvers were too few for a conclusive analysis. An ocular assessment of the video material revealed a few critical situations during the overtaking maneuvers of the 30m truck; all with meeting margins less than 3s.

Sandin et al. (2012) analyzed and compared the results above with two other studies on overtaking maneuvers on two-lane roads. The authors found that meeting margins are not influenced only by vehicle length but also the traffic volume and road width. It was also found that all three studies describe observations of critical situations when meeting margins are below 2-3s. One study argued that it is more important to examine the distribution of the smaller meeting margins than the average margins.

Andersson et al. (2011) also analyzed meeting margins on 2+1-lane highways that are common in Sweden. These are three-lane highways, consisting of two lanes in one direction, and one lane in the other, alternating every few kilometers and usually separated by a steel-cable barrier. The two-lane segments allow for overtaking without the risk of oncoming vehicles. The meeting margin was here calculated with reference to the point where the two lanes has completely merged into one. One field study with video-recorded overtaking maneuvers and one driving simulator study was conducted. The results showed small differences in average meeting margins and which were not statistically significant. These results on meeting margins should be interpreted with great caution, as the number of analyzed overtaking maneuvers was limited, and more data are needed for a thorough analysis.

4.4 Interviews with HCV drivers

Sweden has a relatively small number of HCVs running in trial operations. Therefore, the driver experiences of the HCVs are important for further developing the vehicles and identify potential traffic-safety issues. During 2015, focus group interviews with five drivers of 74tonne HCVs used for timber transport were conducted, as well as interviews with drivers of three long combination vehicles ranging from 27m to 32m in length. The drivers' views are briefly summarized below.

Because the HCVs are driven during trial operations, there are formal and informal demands and driver instructions. The driver instructions involve for example that under no circumstances exceed 80km/h, carry no overload, do not end up in accidents and have no traffic remarks. The drivers seem to have full understanding of these conditions and have minor objections. In fact, some drivers experience that the extra demands, and the responsibility given to them, has made them better drivers. For example, they have to think ahead and plan better before and during driving, and cannot take chances.

Compared to conventional vehicles, increased weight requires more planning when decelerating and accelerating. Thanks to additional axles, the 74tonne vehicles feel more stable. The braking capacity is regarded as fully adequate. More axles however affect the startability in low friction conditions as the load on the driving axle is lower and there are more wheels to start rolling. In such conditions, CTI (central tire inflation) is of good help. The drivers appreciate the vehicles that are very modern, comfortable and equipped with the latest technology and support systems.

The long combination vehicles also require more planning when decelerating and driving downhill. More planning is also needed when the combination takes additional space in curves, roundabouts and intersections. The drivers seem nonetheless not so concerned about this, and there are only a few intersections and roundabouts close to the dock terminals on the designated roads. The braking capacity is regarded as fully adequate. When lane changes are necessary, the drivers are more cautious because of the additional length, and it is sometimes difficult to know exactly where the last meter is. Whether the vehicles are sensitive to strong wind or gusts is dependent on how the load is distributed. Regarding passing maneuvers, three of the combination types drive mainly on 110km/h highways with two lanes in each direction, so passing maneuvers are not an issue. However, for about 30km, one of the highways turns into a 2+1 road section with a speed limit of 100km/h. No accidents or critical incidents involving a long combination (carrying general goods) have occurred on those sections when two lanes merges into one. However, when only one lane is available, and there is no shoulder, the lateral positioning of the combination requires more attention. Because the long combinations are not allowed outside the designated roads, the drivers are concerned over what to do when there is diversion of traffic in case of accidents or roadworks. The drivers have not yet driven in winter conditions but believe that the startability may be an issue in low friction, and that it can be a bit different to drive the long combination depending on the trailers.

The drivers of both the 74tonne and long combination vehicles say that they strictly drive at a maximum speed of 80km/h according to the instructions, and usually somewhat below that to be on the safe side. This irritates especially other truck drivers that generally drive somewhat above 80km/h. Thus they can drive very close to the rear or try to pass the HCV, something which is perceived as stressful by the HCV drivers. The HCV drivers are reluctant to use the shoulder in order to facilitate overtaking maneuvers.

The majority of the HCV drivers do not think there is a need for a new driving license for HCVs. The current CE license for heavy truck and trailer is enough. The drivers of the 74tonne vehicles have participated in a one-day training with the vehicle type in question. They are self-taught on handling the vehicles under winter conditions and low friction. The drivers of the long combinations have not participated in an organized training or education.

When the drivers are asked what characterizes an appropriate driver of an HCV, they say that a few years of experience would be required, and that a driver should be interested in the work and the vehicles. An HCV driver should be calm, stress resistant, able to plan ahead and have an appropriate driving style.

5. Summary and Discussion

Based on the experiences of HCVs in Australia, Canada, Mexico and the US, the traffic safety performance of HCVs are as good or better as conventional HGVs. For Australia, Hassall (2014) clearly shows that one of the reasons to the high safety performance is the reduced exposure of heavy vehicles. The author also mentions other factors to consider behind the much lower accident involvement for HCVs. One probable factor is the match of higher capacity networks and the "tighter engineering hurdles" that have to be achieved through PBS approvals, which is definitely leading to an improved level of safety. Other factors are that HCVs are driven by experienced drivers, and that the vehicles are commanding greater management focus than other vehicles within an operator's fleet.

With reference to the safety performance of the conventional Swedish HGVs, Balint et al. (2014) found that the average accident rate was lowest for the long combination group. However, the annual KSI crash rate for this group tended to increase between 2009 and 2012. In addition, during the winter season (Dec-Feb) the accidents classified as Meeting/Overtaking and Rear-end increased most during the winter season for the long combinations. The authors did not analyze the reasons for these trends in more details, so it is difficult to discuss what they could imply for HCVs. Moreover, the identified overlap and lack of distinction between the accidents classified as Meeting/Overtaking and Rear-end calls for repeated and additional analysis. A preliminary analysis indicates that the top three accident types with HGVs involved are Rear end (25%), Single vehicle (18.6%), followed by Lane change (16.2%) (Sandin 2015). This relatively high share of Lane change accidents deserves some attention regarding long combinations. The interviewed drivers of long combinations were more cautious during lane changes, and they found it sometimes difficult to know exactly where the last meter is.

To the author's knowledge, in total 24 accidents have occurred with HCVs involved during the Swedish trial operations between 2010 and July 2016. Nine of the accidents involved HCVs with an allowed GVW up to 74tonnes. According to the accident investigations, none of the accidents were caused by the characteristics of the HCV itself and would have occurred also with conventional vehicles. A further 13 rollover accidents had occurred with the 90tonne HCVs used for iron-ore transport, whereof one led to severe truck damage. Lastly, two accidents involved HCVs longer than 25.25m. There were several circumstances leading up to these two accidents, but the additional length was not the main cause of the accidents. At the same time, a contribution of the extra length cannot be completely ruled out.

Crash rates for the HCVs were not calculated in this paper for two main reasons. The first is that calculating crash rates on these crashes and over only 39 HCVs in the Swedish trial operations would generate atypical estimates. The next reason applies to what baseline crash-rate we should compare with. As the accidents did not result in serious injuries, the crash rates over Killed and Severely Injured estimated by Balint et al. (2014) are not appropriate. A better choice might be the overall estimate of 34.6 crashes per 100 million for all HGV crashes of all severity levels in Sweden between 2003 and 2012. However, that estimate should be taken with a great pinch of salt as there are great issues with underreporting on the severity levels property-damage-only and slight injuries.

The attempts to estimate the risk of overtaking a long combination vehicle on two-lane roads have so far showed no clear results due to limited data. Although the results indicate a very small increase in risk, the risk cannot be completely excluded without more studies. Field-studies of overtaking maneuvers and longer combination vehicles are ongoing in Finland but has not yet shown clear results (Heinonen, 2016). Concurrently, a long term work is underway in Sweden with the goal of either rebuild undivided higher-speed roads to 2+1 roads or reduce the speed limit to 80 km/h. Thus, the risk of overtaking longer combinations on two-lane roads may be an issue that will become less important in Sweden. Then remains the question of increased risk during overtaking on 2+1 roads. Based on the driver interviews, incidents occur already with conventional HGVs. Passenger-car driver are simply very determined to pass HGVs on these roads. So this should perhaps be treated as a general matter, whatever the vehicle length.

The drivers' views of the HCVs were overall positive. Compared to conventional HGVs, both the heavier and longer HCVs require more planning when decelerating and accelerating. This is in agreement with the views of the drivers of the ETT-vehicle (Andersson et al., 2011). Some drivers experience that the extra demands, and the responsibility given to them, has made them better drivers. For example, they have to think ahead and plan better before and during driving, and cannot take chances.

Although the international experiences show a high safety performance of HCVs, this should not be directly transferred to Swedish conditions without careful consideration. At a general level, Sweden has different legislation, infrastructure, road and transportation networks. In addition, Sweden has large weather variations between the seasons and across the country. Something that is and should be adopted in order to keep a high level of traffic safety in Sweden, is a systematic framework for HCVs. International experiences show that this should involve a match of PBS-approved vehicles and road networks, some level of vehicle monitoring, and qualified drivers.

Acknowledgements

The Swedish Transport Administration and SAFER - Vehicle and Traffic Safety Centre, Sweden are acknowledged for their support of the WP Traffic Safety and the present paper.

6. References

- Andersson, J., Renner, L., Sandin, J., Fors, C., Strand, N., Hjort, M., Andersson Hultgren, J. and Almqvist, S. (2011). Traffic safety effects when overtaking 30 meter trucks. Report 732. Linköping: Swedish National Road and Transport Research Institute (VTI).
- ANTP (2014), "Accident statistics presented by Asociación Nacional de Transporte Privado" (ANTP: National Private Fleets Association). Paper presented at the ANTP Annual Safety Award, Mexico.
- Bálint, A., Fagerlind, H., Martinsson, J. och Holmqvist, K. (2014), Accident analysis for traffic safety aspects of High Capacity Transports. Final report, v2. Chalmers University of Technology, Department of Vehicle Safety, Göteborg, Sweden.
- Blower, D.F. and Kostyniuk, L.P. (2007), Strategies to Reduce CMV –involved Crashes, Fatalities and Injuries in Michigan, the University of Michigan Transportation Research Institute, Ann Arbor.
- Carson, J. L. (2007), Large Truck Crashes In Texas: A Predictive Approach For Identifying Those At Higher Risk. SWUTC/07/473700-00089-1. Texas Transportation Institute.

- Craft, R. (2000), Longer Combination Vehicles Involved in Fatal Crashes, 1991-1996. Paper presented at the 6th International Symposium on Heavy Vehicle Weights and Dimensions, Sasketoon, Saskatchewan, Canada.
- EnergiEffektiva Transporter (2016), Website http://www.EnergiEffektivaTransporter.se Visited July 8th 2016.
- FHWA (2000), Comprehensive Truck Size and Weight Study. Vol. I, II, III, and IV. Federal Highway Administration, U.S. Department of Transportation, Washington D.C., USA.
- Grislis, A. (2010), "Longer combination vehicles and road safety", Transport, 25(3), 226-343.
- Heinonen, T. (2016), The effect of High Capacity Transport vehicles on the traffic flow [in Finnish]. Master Thesis. School of Engineering, Aalto University, Finland.
- Hassall, K. (2014), Quantifying the Benefits of High Productivity Vehicles. Research Report AP-R465-14; Austroads Ltd, Sydney, Australia.
- Kenny, B., Kwan, A. and Morrall, J. (2000), "Design and Operational Considerations to Accommodate Long Combination Vehicles on Rural Highways in Alberta, Canada", Paper presented at the The 2nd International Symposium on Highway Geometric Design.
- Kharrazi, S., Karlsson, R., Sandin, J. and Aurell, J. (2015), Performance Based Standards for High Capacity Transports in Sweden FIFFI project 2013-03881 – Report 1, Review of existing regulations and literature. Swedish National Road and Transport Research Institute (VTI), Linköping.
- OECD (2009), Working Group on Heavy Vehicles: Regulatory, Operational and Productivity Improvements, Moving freight with better trucks improving safety, productivity and sustainability, Organization for Economic Cooperation and Development (OECD).
- Sandin, J., Renner, L., and Andersson, J. (2012), "The effect on passenger cars' meeting margins when overtaking 30 meter trucks on real roads", In Proceedings of the Applied Human Factors and Ergonomics Conference (AHFE), San Francisco, California, USA.
- Sandin, J. (2015), Heavy-vehicle lane-change accidents identified and classified from police reported accidents. Unpublished working paper.
- Scopatz, R. and DeLucia, B. (2000), Longer Combination Vehicle Safety Data Collection. AAA Foundation for Traffic Safety.
- Vierth, I., Berell, H., McDaniel, J., Haraldsson, M., Hammarström, U., Reza-Yahya, M., Lindberg, G., Carlsson, A., Ögren, M., and Björketun, U. (2008), The effects of long and heavy trucks on the transport system. Report on a government assignment. Report 605. Swedish National Road and Transport Research Institute (VTI), Linköping.
- Wikipedia contributors (2016), Page: Road train, https://en.wikipedia.org/w/index.php?title=Road_train&oldid=733991360, Date retrieved: 7 September 2016. Date of last revision: 11 August 2016. Wikipedia, The Free Encyclopedia.
- Woodrooffe, J. (2001), Long Combination Vehicle (LCV) Safety Performance in Alberta 1995 to 1998: Final Report. Woodrooffe & Associates.
- Woodrooffe, J., Anderson, D. and Ash, L. (2004), "The Influence of Policy on Crash Rate of Long Combination Vehicles", In Proceedings of the 8thInternational Symposium on Heavy Vehicle Weights & Dimensions, Johannesburg, South Africa.