**Victorian truck rollover crashes (2003 - 2007)**

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**Abstract**

An analysis of Victorian truck rollover crashes using data from the VicRoads Road Crash Information System database and National Transport Insurance (NTI) was undertaken for 2003 to 2007. Recommendations for reducing the frequency and severity of truck rollover crashes were made based on the analyses and supported by relevant literature.

The Victorian crash data indicated that of all truck crashes in Victoria, 10% (n=478) were rollovers. There was a downward trend in rollovers during the study period, from 110 crashes in 2003 to 83 in 2007, a 25% reduction. Two-thirds of rollovers involved semi-trailers (66%, n=316). Other results included: 86% of the rollovers were single vehicle crashes, 47% occurred on a bend (most in 100 km/h zones), 25% met the criteria adopted for fatigue-related crashes and nearly 60% of truck drivers killed were not wearing a seatbelt.

The NTI dataset included 108 rollovers, and there was substantial variation in annual crash numbers between 2003 and 2007. Other results included: 60% of rollovers involved semi-trailers and 23% involved B-doubles; seven types of loads were carried and dry loads were involved in the greatest number of rollovers (36%); 41% involved inappropriate speed; and 30% involved fatigue.

Fifteen recommendations were made in a number of areas including standards for rollover stability, in-vehicle technologies for trucks, road safety audits, driver education, intelligent rollover warning systems on problematic curves, and coding and collection of truck crash data.

**Keywords**

Truck, heavy vehicle, rollover, crash

**Introduction**

VicRoads is concerned about the number of truck rollover crashes reported in Victoria recently that have not only endangered lives, but also caused severe traffic disruption. On behalf of VicRoads, ARRB Group (ARRB) analysed truck rollover crashes using data from the Victorian crash database and National Transport Insurance (NTI), (who insure up to 40% of trucks in Australia), for 2003 to 2007. Recommendations for reducing the frequency and severity of truck rollover crashes were made based on the results of the analyses and supported by relevant literature. At the request of VicRoads, NTI data was included in the study, as it includes several variables not contained in the Victorian crash database, such as load type and crash causation. The NTI truck rollover crash data included some of the Victorian crash data, but also included crashes not in this data set (as police may not have attended some of the NTI crashes, for example the non-injury crashes).

**Methods**

Truck rollover crashes were extracted from the VicRoads Road Crash Information System database (RCIS) for 2003 to 2007 inclusive. The term ‘truck’ refers to both semi-trailers and rigid trucks. A rollover crash was any crash where the ‘event type’ was recorded as ‘1’, defined as ‘rollover on/off carriageway’ and included at least one person who was killed or injured. NTI insures 30% to 40% of trucks in Australia, more than any other truck insurer. NTI made available its data on all Victorian fatal, injury and non-injury truck rollover crashes (2003 to 2007) for trucks over 10 tonne and where material damage was in excess of $50 000. Crashes that happened as a result of the truck tipping whilst unloading (often while the driver was not in the truck) were removed. Data were analysed in SPSS (Statistical Package for Social Sciences) and Microsoft Excel.
It should be noted that some analyses result in very small numbers in some data cells which makes it difficult to comment on the statistical significance of the results. In addition, exposure data was not available. This is particularly the case for the NTI data where only 108 crashes were analysed.

Recommendations to reduce the frequency and severity of truck rollover crashes were provided based on the data analyses, the ARRB project team’s expertise, advice from the ARRB Heavy Vehicles Group, and in some instances, support from the literature which had arrived at similar recommendations.

**Results**

**Victorian RCIS crash data analysis**

Of all truck crashes in Victoria, 10% (n=478) were truck rollovers. ‘Crash’ is the term used to refer to truck rollover crashes for the remainder of this paper. There was a downward trend in the number of crashes, which reduced by 24.5% (n=27) between 2003 and 2007. This downward trend was due mainly to the trend in ‘other injury’ crashes, which reduced by 35.3% (n=18) during this period. Fatal and serious injury crashes did not decline (Figure 1). The 478 crashes resulted in 41 (7.3%) deaths, 231 (41.4%) serious injuries and 286 (51.3%) other injuries (a total of 558 casualties).

![Figure 1: Rollover truck casualty crashes by year and severity (2003 - 2007)](image_url)

Other Victorian crash data results included:

- Eighty-six percent of crashes were single vehicle.
- Just over three-quarters of crashes occurred in rural environments (77.4%, n=370).
- Just over 7% of rural crashes occurred on gravel or unpaved roads, whereas all urban crashes occurred on paved roads (except one where road type was unknown).
- Approximately one-quarter of all crashes (27%) occurred at intersections.
- Two-thirds of crashes involved semi-trailers (66.1%, n=316). It appears that semi-trailers pose a greater crash risk, as they comprise only 18% of Victorian truck registrations. However, these vehicles travel further than rigid trucks. BTRE [1] indicates that articulated trucks (semi-trailers) have been responsible for the majority of the growth in freight (kilometres travelled) since 1971, at 6.8% per annum, versus 3.4% for rigid trucks.
- More semi-trailers rolled over in rural areas than rigid trucks (55.2% versus 22.2%).
- East Gippsland was the municipality in Victoria with the greatest number of crashes (20 serious casualty crashes).
- Melbourne, Port Phillip and Brimbank had the highest number of serious casualty crashes for urban municipalities (3 serious injury crashes each).
- Most (62%) crashes occurred between 7 am and 5 pm. There was evidence of a slight reduction in crashes between 12 pm and 2 pm before a ‘spike’ in crashes between 2 pm and 4 pm.
- There was no particular pattern to crash occurrence by month, although there were peaks in truck rollover crashes over December and January (the Christmas holiday period).
Most crashes (64.2%, n=307) occurred in daylight. This proportion was greater for urban crashes (74.1%, n=80) than in rural crashes (61.4%, n=227).

The majority (80.3%, n=384) of crashes occurred in clear weather conditions with no major differences between urban and rural crashes.

One-quarter of all rural crashes (25%, n=91), occurred on a right bend (DCA code 180). Crashes resulting from the truck leaving the carriageway on a left bend (DCA code 182), and to the left (DCA code 170) and to the right (DCA code 172) of the carriageway, accounted for another third of rural crashes (n=126).

Urban crashes consisted mainly of off carriageway to the left (DCA code 170), out of control on carriageway (on straight) (DCA code 174) and off carriageway on right bend (DCA code 180) crashes, which combined accounted for just over one in three urban crashes (n=39).

Only 4.5% of crashes occurred on freeway exit and entry ramps (as deduced from the sub-DCA analysis). However, this result may be unreliable as the allocation of sub-DCAs is at the discretion of the VicRoads accident coder and the relevant data field was often empty.

Just under half of the crashes occurred on a bend and 78% of these occurred in a 100 km/h zone, compared to 65% for all crashes. Therefore, higher speeds appear to increase truck rollovers. Of the crashes that occurred on a bend, 132 (59%) occurred on a right bend.

Twenty-five percent of truck rollover crashes met the ATSB criteria for ‘fatigue related’.

An object was struck in 109 (23%) crashes.

The object most often struck was a tree (8% of crashes, 28% of all objects struck). The object second most often struck was guardrail (4% of crashes, 16% of all objects).

Fifty-nine percent of truck drivers involved in crashes had a valid licence (i.e. it was not expired, suspended or disqualified), but 8% did not have a heavy vehicle licence.

There was little BAC data available. Of the 44% of drivers in fatal crashes for whom BAC data was available, only one had a BAC greater than .05. Due to the large amount of missing BAC data, no deductions about the influence of BAC could be made.

The majority (n=431) of truck drivers involved in crashes had a valid licence (i.e. it was not expired, suspended or disqualified), but 8% did not have a heavy vehicle licence.

The proportion of fatally injured truck drivers not wearing a seatbelt (58.8%, n=10) was higher than the proportion of those seriously injured (9.5%, n=11), ‘other’ injured (7.9%, n=14) and not injured (0%, n=0) who were not wearing a seatbelt.

Most other vehicle occupants sustained either minor or no injuries (69.9%, n=65) in the crashes.

**NTI crash data analysis**

NTI data indicated that there was a total of 108 crashes and quite substantial variation in crash numbers during the five year study period, which saw a 20% increase in the NTI fleet (O Driscoll, 2008, pers. comm., November 18) (Figure 2).
Other NTI crash data results included:

- Fatal crashes decreased over the five year period by 66.8%, whereas crashes with injuries and non-injuries increased by 112.5% and 466.7% respectively.
- More than half of the crashes resulted in injuries only (51%, n=54), followed by 40% (n=43) that resulted in no injuries and 9% (n=10) which resulted in fatalities (injury level was not recorded for one crash).
- The majority of crashes\(^1\) were single vehicle (89.8%, n=97).
- The majority of crashes involved semi-trailers (61.1%, n=66), followed by B-doubles (23.1%, n=25). This could be a reflection of the NTI truck fleet, as Victorian truck registration figures indicate that 77% are rigid and 18% are articulated (semi-trailers) [2]. However, B-doubles travel further than rigid trucks [1].
- The ‘general’ freight category had the most crashes (36.1%, n=39). This category covers loads that are dry and loaded onto pallets that sit on flat bed trailers or those in non-chilled tautliner vans.
- Most crashes occurred on A class roads (27%, n=29), followed by C (22%, n=24) and M class roads (17%, n=18). M roads followed by A and B roads are the highest quality roads, with C roads being of lower quality.
- The majority of crashes occurred on the outbound leg of the journey (85.2%, n=92), when trucks were most likely to be carrying a load.
- Just over half of the recorded crashes occurred between 0 and 30 kilometres (29.6%, n=32) from departure, or between 151 and 250 kilometres (21.3%, n=23) from departure.
- Peaks in crash numbers appeared to occur in school holiday periods. The largest were in January (12% of crashes, n=13) and March (14.8% of crashes, n=16).
- There were crash peaks between 3:00 am and 3:59 am (11.1% of crashes, n=12), 5:00 am and 5:59 am (8.3% of crashes, n=9), 11:00 am to 11:59 am (11.1% of crashes, n=12) and 12:00 pm to 12:59 pm (8.3%, n=9).
- The majority of crashes were due to inappropriate speed (40.7%, n=44) or fatigue (29.6%, n=32).
- Between the hours of midnight and 7:59 am, fatigue was found to be the cause of 62.5% (n=20) of the total of 32 crashes. This compares with 15.6% of crashes due to fatigue between 8:00 am and 3:59 pm (n=5), and 21.9% between 4:00 pm and 11:59 pm (n=7).
- Crashes due to inappropriate speed accounted for 54.5% (n=23) of the total between 8:00 am and 3:59 pm.
- Nearly a quarter (21.3%, n=23) of crashes involved the 46 to 50 year old age group. The other age groups that had similar numbers of crashes ranged from 8.3% (n=9) (18 - 25 years) to 15.7% (n=17) (36 - 40 years). Young truck drivers appeared to be over-represented in the data, as there are not many of these drivers in the NTI driver fleet (O Driscoll, 2008, pers. comm., November 18).
- There were more fatigue related crashes among drivers within the 46 to 50 year age group than other age groups. The two age groups that had more crashes due to inappropriate speed were 31 to 35 years, and 51 to 55 years. The only age group involved in more fatigue related crashes than crashes due to inappropriate speed was the 46 to 50 group (64.3% due to fatigue versus 35.7% due to speed).

Comparison of Victorian RCIS crashes and NTI crashes

For all Victoria, there were 478 truck rollover crashes for 2003 to 2007 inclusive, and 108 NTI crashes. The NTI crashes constituted approximately 13.5% of the total Victorian crashes (there were 65 NTI fatal and injury crashes). The nature of the NTI crashes may be biased toward the type of truck companies or individual truck drivers that insure with NTI. Table 1 below outlines a comparison on the characteristics of the crashes between the two data sources. There were 11 crash characteristics that could be compared, nine characteristics were similar and two were different.

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1 The NTI crashes discussed from this point on include all crashes - fatal, injury and non-injury crashes.
Table 1: Comparison of truck rollover crash findings - all Victoria versus NTI crashes

<table>
<thead>
<tr>
<th>All Victorian rollover truck crashes</th>
<th>NTI rollover truck crashes</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease in the number of crashes by 24.5% (n=27) between 2003 and 2007.</td>
<td>Increase in the number of crashes by 117% (n=37) between 2003 and 2007.</td>
<td>Trends vary.</td>
</tr>
<tr>
<td>Downward trend in 'other injury' crashes (35.3%, n=18). No change in fatal and serious injury crashes.</td>
<td>Fatal crashes decreased over the five year time period by 66.8%, whereas injury and non-injury crashes increased by 112.5% and 466.7% respectively.</td>
<td>Trends vary.</td>
</tr>
<tr>
<td>These crashes resulted in 41 (7.3%) deaths, 231 (41.4%) serious injuries and 286 (51.3%) other injuries (a total of 558 deaths and injuries).</td>
<td>More than half of the crashes resulted in injury only (51%, n=54), followed by 40% (n=40) that resulted in no injuries. Only 9% (n=10) of crashes were fatal.</td>
<td>Trends are similar, but note that people versus crash numbers are being compared.</td>
</tr>
<tr>
<td>Eighty-six percent (n=409) of crashes were single vehicle crashes.</td>
<td>Eighty-nine percent (n=97) of crashes were single vehicle.</td>
<td>Trends are similar.</td>
</tr>
<tr>
<td>Two-thirds of rollovers involved semi-trailers (66.1%, n=316).</td>
<td>Just under two-thirds of rollovers involved semi-trailers (61.1%, n=66), followed by B-doubles (23.1%, n=25).</td>
<td>Trends are similar.</td>
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<tr>
<td>The majority of crashes occurred on a weekday (89% and n=425).</td>
<td>The majority of crashes occurred on a weekday (85.2%, n=92).</td>
<td>Trends are similar.</td>
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<tr>
<td>There were peaks in crashes over December and January (the Christmas holiday period).</td>
<td>The periods where the monthly crash rates were highest coincided with school holiday periods. The largest were in January (12%, n=13) and March (14.8%, n=16) while a slight increase took place in June/July (June 10.2%, n=11; July 9.3%, n=10).</td>
<td>Trends are similar with crash peaks in the Christmas holiday period.</td>
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<td>Most (62%) crashes occurred between 7 am and 5 pm. There was evidence of a slight reduction in crashes between 12 pm and 2 pm, before a ‘spike’ in crashes between 2 pm and 4 pm.</td>
<td>The majority occurred between 8 am and 3:59 pm (44%, n=47), 39 occurred between midnight and 7:59 am (36.1%), and 22 occurred between 4 pm and 11:59 pm (20%).</td>
<td>Trends are similar.</td>
</tr>
<tr>
<td>Fifty nine percent of truck drivers involved in crashes were aged between 30 and 50 years.</td>
<td>Sixty percent of truck drivers involved in crashes were aged between 30 and 50 years.</td>
<td>Trends are similar.</td>
</tr>
<tr>
<td>Twenty five percent of crashes were fatigue related.</td>
<td>The majority of crashes were due to inappropriate speed (40.7%, n=44) or fatigue (29.6%, n=32).</td>
<td>Trends are similar.</td>
</tr>
</tbody>
</table>

Discussion and recommendations
There were 23% fewer Victorian casualty truck crashes in 2007 compared to 2003. Similarly, there were 25% fewer Victorian truck rollover crashes in 2007 compared with 2003. This decrease is over a period where there has been an increase of 11% in truck registrations [2]. Further, BTRE [1] indicates that road freight has grown by 5.8% per annum since 1971. The decrease in crashes may indicate that current truck and/or truck rollover crash countermeasures have had an effect on crash numbers. It is worth noting that there was a downward trend in all Victorian crashes during the same period. There were 21% fewer crashes in Victoria in 2007 than in 2003 (13 354 compared to 16 938).
Around two-thirds of the rollover crashes for both Victoria and NTI involved semi-trailers, which comprise the minority of Victorian truck registrations. Of the trucks involved in all Victorian truck crashes during the study period, 59% were rigid trucks. This further points to an increased crash risk of semi-trailers in rollovers. However, this may be an artefact of higher travel distances of semi-trailers in comparison to rigid trucks [1].

There are likely to be a multitude of factors which influence the increased crash risk of semi-trailers involved in crashes as opposed to rigid trucks. One possible factor may be the 'lack of connection' between articulated (semi-trailer) truck movement on the road, and what is perceived by the driver. Some characteristics of articulated vehicles, primarily the compliance in the articulation point, mean that a driver may not perceive a rollover event (which is predominantly initiated by the trailer in an articulated vehicle) until it is too late for corrective action to be taken. This scenario is compared to a rollover event in a rigid truck, where the driver is expected to be more aware of the truck’s roll behaviour.

Rollover risk has been critically linked to vehicle static roll threshold (SRT) performance, which is the level of lateral acceleration that a vehicle can sustain during a steady-state turn without rolling over [3]. SRT performance is influenced by a range of factors including vehicle design and geometry, suspension characteristics and most strongly, vehicle centre-of-gravity (CoG) height. Currently no work has been conducted which has investigated the differences in typical CoG height between rigid and semi-trailer trucks. Such a study may be able to offer a degree of explanation for the apparent increased crash risk of semi-trailers compared to rigid trucks.

The NTI data provided a useful complementary source of truck rollover crash characteristics in Victoria (although it did include non-injury crashes and the Victorian data did not). Overall, the factors found to be associated with rollover crashes common to both data sets were single vehicle nature (only the truck was involved), semi-trailers, weekdays, daytime, truck drivers aged over 30 years and fatigue. Other factors from the Victorian data were non-intersections, curves, higher speed zones and not wearing a seatbelt in fatal crashes. Other factors from the NTI data were general freight load category, class A roads, outbound leg of the journey, between 0 and 250 kilometres from departure, inappropriate speed and young truck drivers.

The Victorian data indicated crashes decreased, but fatality and serious injury crashes increased. Therefore actions need to be taken to address this problem and are outlined below by topic area.

Vehicle:
- Review the standards for rollover stability for all heavy vehicle types, particularly semi-trailers, using the assessment method prescribed by the National Transport Commission’s (NTC) Performance Based Standards (PBS).
- Increase seatbelt use by introducing requirements for fitting integrated lap/sash belts in all new trucks, developing a code for retrofitting integrated seats into existing trucks, providing education programs for drivers, undertaking enforcement (fining drivers who fail to wear seatbelts) and ensuring truck employers have OH&S regulations which ensure safe operations for their truck drivers.

Education:
- Provide the latest information to truck operators and designers on the critical factors affecting stability, to assist in improving truck design and operations to reduce rollover crashes.
- Educate truck drivers about the risk of rollover crashes and how to avoid them. Educational materials could be focussed on the 30 to 50 year old age group. Information about dangerous curves could also be supplied as part of dispatch instructions.
- Create and promote effective programs to improve truck driver awareness of the importance of being alert at all times, the need for adequate sleep and the effect of lifestyle factors such as exercise, diet and stress on fatigue.

Technology:
- Monitor the availability and feasibility of in-vehicle technologies for trucks e.g. ESC systems and in-vehicle data recorders.
- Encourage trucking companies to introduce and maintain internal speed monitoring systems to prevent truck drivers from speeding (breaking the speed limit).
• Continue to search for other ITS solutions and ‘smart compliance’ technologies to prevent truck drivers from speeding (breaking the speed limit).

Engineering:
• Undertake road safety audits on routes and at locations with multiple rollover crashes. Both high and low quality roads should be included in road safety audits. Particular attention should be paid to roadside hazards.
• Provide advisory speed signs and intelligent warning rollover systems (e.g. employing VMS) for trucks on problematic curves once the speeds necessary to prevent truck rollover crashes on these curves are identified.

Research:
• Undertake further analysis to determine the causes of rollover intersection crashes, for example to determine the involvement of other vehicles or factors such as inappropriate speed. If the intersection environment is a contributing factor, road safety audit could also be used to provide engineering solutions to intersection problems.
• Promote an independent trial and evaluation of fatigue monitoring devices to trucking companies, stakeholders and regulatory authorities.
• Consideration should be given to coding trucks in the crash data in the same way they are coded in the registration data, to allow easy comparison. Consideration could also be given to including a greater number of truck codes in the crash data e.g. to include B-doubles.

Enforcement:
• Ensure the new fatigue laws are being followed through enforcement and auditing and evaluate the effects on rollover crashes.
• In order to address speeding truck drivers (those who break the speed limit and those who adopt inappropriate speeds for the conditions), undertake adequate enforcement to apprehend these drivers, ensure truck speed limiters are operational, encourage freight companies to adopt driver payment policies that do not encourage speeding, and educate truck drivers on the dangers of speeding.

It should be noted that this study was unable to control for various types of exposure. The exposure issues of fleet size and kilometres travelled have been mentioned, but there are also exposure issues related to the age distribution of the truck driver population, the typical distribution of workload over the day, length of trip etc.

Conclusions
This project involved the conduct of a detailed analysis of truck rollover crashes based on Victorian crash data and data gathered by a truck insurer, NTI. Common causes or influencing factors in relation to truck rollover crashes, such as type of location, time of day, type of load, vehicle configuration and driver characteristics were identified. Recommendations to reduce the frequency and severity of truck rollover crashes were outlined based on the outcomes of the analysis findings.

Factors influencing truck rollover crashes included truck type (the majority of rollovers involved semi-trailers), rural environments, curves, fatigue, speed, outbound trips when the truck is laden, and older and younger drivers. Non-use of seatbelts appeared to be risk factor for injury (rather than crash likelihood).

Fifteen recommendations were made to address truck rollover crashes. These included, reviewing the standards for rollover stability for all heavy vehicle types, particularly semi-trailers; undertaking road safety audits to address engineering problems; provision of speed signage (both advisory and VMS) to address rollovers on curves; provision of education for truck drivers pertaining to rollover stability, fatigue and lifestyle habits; and employing new technologies.

In future, more research and collaboration with industry groups such as the Bulk Handlers Group and ARTSA (Australian Road Transport Suppliers Association) should be undertaken to assist in addressing the truck rollover crash problem.

References