Aspects of road design and trucks from the analysis of crashes

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Data Capture and Analysis

Abstract

More information can be extracted from crash reports than is usually found in State databases. More processed data can lead to a better understanding of the mechanisms in crashes and potentially lead to countermeasures. To illustrate this, an examination was made of two years of truck crash data using the writer's crash coding system and that gave a data set of about 7,000 crashes involving trucks. The trucks were classified into ' rigid' and ' articulated' and the relative and absolute involvement of the two classes in urban and rural areas by ' accident-type' was investigated and related to road design and roadside features. There are areas of road design that clearly do not cater for large vehicles and while a review would be in order it is also clear that the whole road system cannot be rebuilt to suit large vehicles. The use of large vehicles should be controlled to specific road classes/routes.
The design of big vehicles also needs to be reconsidered. The driver needs to have greater visual knowledge of the area around his vehicle, and a better signalling system.
Traffic regulations should be reviewed and penalties for offences involving big vehicles should be greater than those offences involving cars due to the greater severity of casualties sustained in crashes involving trucks. More of the data that is presently collected should be processed and put into State databases.

1-Introduction

The theme of this conference is Sustainable Transportation and how this relates to road transport should be considered. The costs to the community related to road transport need to be contained as far as is practical. For the area of traffic safety a better knowledge of the mechanism and characteristics of various crash configurations can lead to potential solutions. This better knowledge can be produced by re-examining the information that is already collected on the crash report form and generating more enhanced data for further analysis.

By way of an example of the point made above, this paper shows how a detailed examination of original crash reports involving trucks [rigid and articulated] gave data that allowed aspects of road design in relation to trucks to be derived. The information produced from the forms, by the system referred to later, was more consistent and enhanced than the information that had previously been put in to the State database.
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2 -The enhancement of data

The crash reports involving trucks for two years for Victoria, Australia were examined. There were about 7100 crashes involving 15,000 vehicles, and 19,000 persons.
As stated earlier, instead of using the output from the computer database, copies of the police reports of the crashes were read and the crashes coded into "accident-types" according to the procedures for coding that the writer developed. The current version of the procedures can be found in the 'Defining Crash Attributes ' [Andreassen, 2001].

The procedures provide a system for recording 'prior events' and 'subsequent events' in addition to the event chosen ["chosen cell"] to represent the crash.
[Note- There is a code chart that is similar to the crash code chart used in New Zealand, but the coding process is far more evolved.]
When there is only one event in the crash, the "chosen cell" is the cell on the coding chart that describes that event. Each cell has a written definition.
When there is more than one event a decision tree is used to determine the chosen cell, the other events in the crash are 'prior' and/or 'subsequent' events in relation to the chosen cell.

In addition to deriving the event codes and supplementary codes from the report form, additional information was recorded from the narrative and sketch.
The data collected were -
Whether any vehicle rolled over and whether that occurred in an initial phase or after the vehicle collided with something;
Whether the load was lost off the truck;
Whether the load shifted;
Whether part of the load dropped which someone then ran into;
Whether there was movement of the load within a container;
Whether the truck was towing a trailer; and
Whether the truck was actually part of the crash [ie hit] or a presence in the crash [ie not hit].

There were two items were not part of the originally planned data set but they occurred so often that it was decided to include them. These were - the driver failing to stop after the crash, and the driving failing to give name and address to the other party when he did stop.

The aspect that is considered in this paper is which accident-types were likely to suggest problems with road design.
In thinking about the physical bulk of a truck, anything involving manoeuvring especially in the presence of other vehicles could produce problems.
There are also situations where roadside features such as overhead bridges, lighting columns, trees, and power wires might impinge on the "truck envelope". See Figure 1.
The cross-fall of a road surface can also bring a truck into contact with a shop verandah or other part of a building or structure.

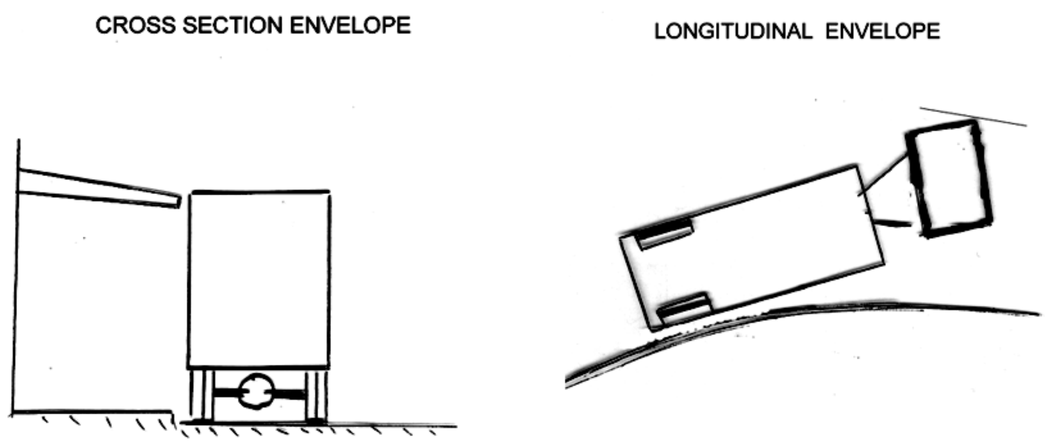

Figure 1 – Truck envelope

Consider first the broad data on truck crashes - The proportion of truck registrations held by articulated trucks is 11 % but the proportion of total truck travel by articulated trucks is 35 %. At a State level the proportions of travel and crashes for articulated trucks are similar.
The proportions of truck travel by articulated trucks between Metro-Melbourne and non-Metro are 17 % and 48 % while the relative proportions of crashes are 32 % and 54 %. This might suggest that travel in the Metro area is considerably more hazardous for articulated trucks than non-Metro travel. This information is shown in the tables below.

	Travel Million- km	percent	Crashes, two years	percent
Cars	33,576	91.4	88,074	92.5
Rigid trucks	2,046	5.6	4,551	4.8
Artic trucks	1,111	3.0	2,603	2.7
Total	36,733		95,228	

	All trucks	Articulated	% artic
Registrations	122,915	13,918	11
Travel, million -km	3,157	1,111	35
Crashes, two years	7,154	2,647	**37**

Travel, million-km	All trucks	Articulated	% artic	% artic crashes
Metro Melbourne	1,306	222	17	32
Non-metro	1,851	889	48	54
Total	3,157	1,111	35	**37**

Table 1 - Travel, registrations, location, vehicle type, and crashes

3 - Crashes by accident-type

The table below shows the distribution of accident-types for truck crashes.

Accident-type	All trucks	Articulated	% artic
Hit pedestrian	86	24	28
Inters, adjacent approaches	859	236	27
Head-on	351	132	38
Right turn/through	364	108	30
Rear-end	1,276	426	33
Lane change	890	357	40
Lanes, turning	528	296	**56**
Hit parked vehicle	265	52	20
Hit permanent obstruction	163	100	**61**
Leaving driveway	132	31	23
Run off straight road, hit object	195	73	37
Run off straight road , hit nil	47	29	62
Sub total - run off road	242	102	42
Run off curve, hit object	123	78	63
Run off curve , hit nil	67	50	75
Subtotal- run off curve	190	128	**67**
Lost control on road, straight	74	34	46
Lost control on road, curve	66	53	**80**
Right turn at inters, lost control	51	35	**69**
Left turn at inters, lost control	37	21	**57**
Hit train	21	11	52
GRAND TOTAL	7,154	2,647	**37**

Table 2 – Truck crashes by accident type

The average involvement of articulated trucks within all truck crashes in the table is **37 %**. [Note that truck crashes are generally around 9 % of the number of total reported crashes.]

Considering those accident-types that show above average involvement by articulated trucks [ie above 37%] it was found, for example,
'lanes, turning" was 56 %,
'hit permanent obstruction" was 61 %,
'off road on straight" was 42 %, [37and 62%, hit/not hit object]
'off road on curve" was 67 % [63 and 75%, hit/not hit object],
'lost control, straight/curve" 46 % and 80 % respectively and,
'lost control, turning right or left at intersection", 69 % and 57 % respectively.

Before moving on to discuss some of the above accident-types, it should be made clear that these classifications are for what is known as the "chosen cell" in the writer's coding system. When there is only one event in the crash, the chosen cell is the cell on the coding chart that describes that event.
When there is more than one event a decision tree is used to determine the chosen cell, the other events are 'prior' and/or 'subsequent' events in relation to the chosen cell.
When trucks are involved in a collision there is generally a greater energy exchange than when only cars are involved and 'multiple-event' crashes are more frequent.
In this study 24 % of the crashes were multiple-event crashes compared with 15 % for all crashes involving all vehicle types.
Of these multiple-event crashes 84 % had subsequent events. Typically the lighter vehicle was sent on a second collision path after being hit by a truck.

In the list of accident-types in Table 2, the crashes relating to 'vehicles in parallel lanes' [ie the sum of 'lane change' and 'lanes, turning'] with a total of 1418 was the most frequent group, followed by 'rear end' crashes with 1276, and 'intersection, adjacent approaches' crashes with 859.

3.1 Out of control, off-curve, and off-road crashes

This was the group with the greatest proportion of articulated trucks in the crashes. There is a clear indication that articulated trucks have greater problems negotiating curves than do other trucks.
For the whole State 71% of the trucks in crashes on curves were articulated trucks.
In the rural area this was 78% compared with 39% in metro-Melbourne.
Articulated trucks even lose control negotiating left and right turns at intersections.

The numbers of 'run off road" crashes on straight sections and curves were approximately the same but the proportion of articulated trucks increased from an average of 42 % on straight sections to 67 % on curves.
The 'loss of control on the road" was similarly higher on curves than on straight sections for articulated trucks [80 % and 46 %]. This suggests that curve design or construction does not cater for the handling characteristics of articulated trucks on rural roads.

Turning right or left at an intersection is more understandable as a road design function.
The accident-type data demonstrates that there is a problem for trucks and particularly for articulated trucks when turning at intersections.

The design for the ordinary [non-arterial] intersection is the one that it appears is most unlikely to be changed to suit big trucks.

3.2 Hit permanent obstruction

The group of crashes with the next greatest proportion of articulated trucks, 'hit permanent obstruction' crashes, reflected aspects of both the longitudinal and the cross-sectional envelopes. The type of obstruction hit is shown in the next Table.

Obstruction	Artic	Rigid	Total
Bridge	49	26	75
Overhead wire	20	12	32
Building	15	10	25
Tree	3	5	8
Guard rail, on road	3	3	6
Guard rail, off road	4	1	5
Pole	2	1	3
Other	4	5	6
Total	100	63	163

Table 3 - Truck Crashes by Accident-type

Articulated trucks were high in the first three categories and these were examined further.
(a) Bridges, in this case overhead bridges, were the greatest problem and going back to the reports these crashes were found to be located mostly in the port/dock area of Melbourne. An area where low bridges are not desirable and provide a trap for vehicles with containers.

(b) Overhead power wires were the next most frequent obstructions hit. This accident-type illustrates the truck "cross-section envelope". Power interruption and the possibility of fire can result from these crashes. This is something should be relatively simple to remedy by raising lines on routes used by articulated trucks or articulated trucks restricted to routes where lines have been raised.

(c) Buildings. The hitting of buildings was often the result of verandahs being too close to the kerb or due to the camber of the road the top of the truck was tilted sufficiently to make contact.

3.3 Lanes, turning crashes

The **'lanes, turning'** accident-types are the accident-types that perhaps best reflect the problems associated with the 'truck longitudinal envelope'.
These cover the left turning and the right turning accident-types at intersections that involve another vehicle.
(a) Left turns
Consider first the left-turn crashes and those cases when a truck and car were involved –
In these the relative frequencies can be compared of the truck as vehicle No 1 or No 2 and the proportion of articulated truck involvement.
There were 20 instances when a truck was vehicle No 1, and 285 when a truck was No 2
This gives a incident ratio of 14.2 to 1. See Figure 2.
Of the 20 cases when a truck was vehicle No 1, 55 % were articulated trucks.

Of the 285 cases " " No 2 , 64 % were articulated.

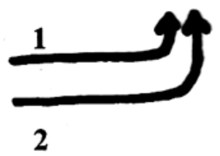

Figure 2 Left turn crashes

Some of the crashes reported involved the car in the inside lane being actually being run over by the truck. That is, the wheels of the articulated truck have mounted the car.

The 'Australian Road Rules', introduced in Jan 2000, altered the previous rule about left turns. They are quoted below, and a similar Rule applies to right turns, -

(2) A driver may approach and enter the intersection from the marked lane next to the left lane as well as, or instead of, the left lane if—

- (a) the driver's vehicle, together with any load or projection, is 7·5 metres long, or longer; and
- (b) the vehicle displays a *do not overtake turning vehicle sign*; and
- (c) any part of the vehicle is within 50 metres of the nearest point of the intersection; and
- (d) it is not practicable for the driver to turn left from within the left lane; and
- (e) the driver can safely occupy the next marked lane and can safely turn left at the intersection by occupying the next marked lane, or both lanes.

The main change was the last clause with the requirement to making the turn 'safely'.
The crashes classified in this study had two lanes available and, for 285 crashes, trucks turned left from the second lane [out from the kerb].
As there were crashes, making the turns ergo was not 'safe' and breached the Road Rules.

While a road rule of this type allocates blame it falls a long way short of addressing the problem for left turns by large trucks at intersections.

There is combined road design and truck driver/truck design problem to be addressed.
In many big trucks the driver has no view of the area immediately surrounding his vehicle. In addition to taking the big truck well forward into the intersection to get the rear of the truck to turn without running up on the kerb and footpath, the driver can not see, well enough, to know if any small vehicle has moved up on his left.
From the crash data it can be seen that this configuration is a particular problem for articulated trucks.

(b) Right turns
Now consider the right turn crashes. See Figure 3.

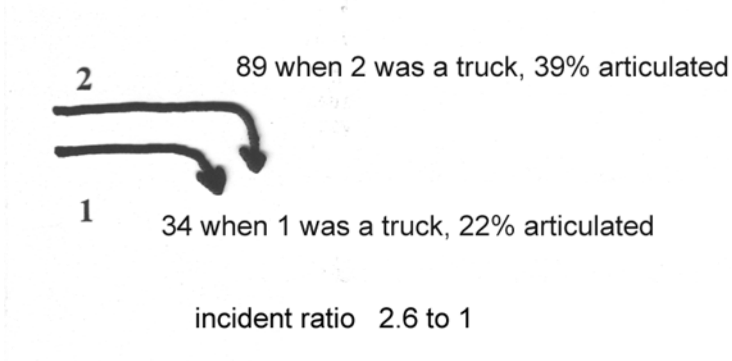

Figure 3 Right turn crashes

There were 34 crashes when a truck was vehicle No 1, and 89 when the truck was No 2, giving an incident ratio of 2.6 to 1. This indicates that even when in the lane with the greater turn radius trucks will hit cars more frequently than when the truck is on the inside of the turn.

Of the 34 cases when a truck was No 1, 22 % were articulated trucks.

Of the 89 cases when a truck was No 2, 39 % were articulated trucks.

The ratio of articulated truck involvement was 1.77 to 1 [veh2/veh1]. Indicating the articulated truck hit the car more often when it was in the outer lane. Perhaps that was due to the trailer swinging in on the car in the inner lane.

3.4 Lane changing

There are three 'lane changing' accident-types and they offered another test of the 'visual capacity' of drivers in trucks.

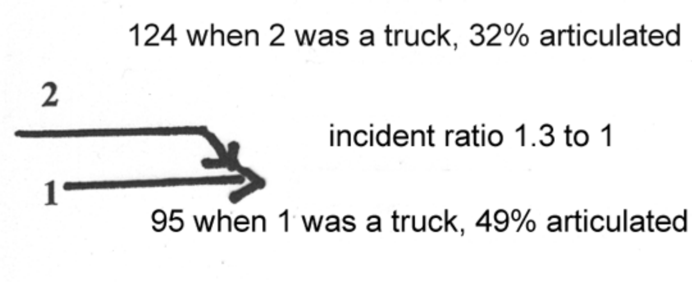

Figure 4 Right lane change

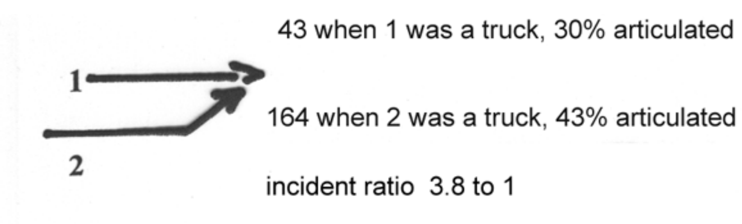

Figure 5 Left lane change

In the accident-types illustrated above the number of incidents when the truck made the lane change outweigh those where the car made the change, by two to one [288 vs 138].

For the 'lane change left" it appears that the view of vehicles in the adjacent lane for the truck driver is not good [or he is taking advantage of his vehicle's size]. See Figure 6.

In the next case illustrated below, where the vehicles in parallel lanes side swiped, the truck was in the right hand lane in 72% [242/337] of the cases. While this case is for crashes where it is not known specifically if it was the car or the truck that changed lanes it could be conjectured that as the truck was in the right lane in 72% of the crashes and that the truck driver did not see the car before he made the move.

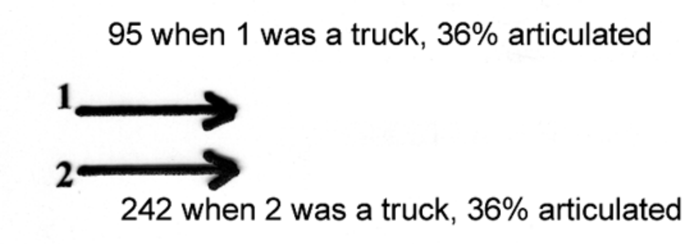

Figure 6 Lane sideswipe

The involvement of articulated trucks was close to average proportion [37 %] in all of these three accident-types [39% of the trucks in first, 40 % in second, and 36 % in the last].

3.5 Rear-end crashes

Although not obviously related to road design, 'rear–end" crashes were one of the most frequent accident-types. When considering whether the truck was the front or rear vehicle in such collisions it was found that the truck was the rear vehicle in 76% of those crashes. [Articulated trucks were 30% of the following trucks.]
Given that travel by trucks is about 8% of the total travel such a high involvement rate is very significant. At present, trucks can not/do not brake as well as cars, a fact that truck drivers should be well aware of. There have been suggestions about introducing anti-lock brakes on heavy vehicles but it is understood that they do not reduce braking distances under normal driving conditions so would not solve this problem. There is some anecdotal evidence that truck drivers slacken front brakes and rely on being pulled up by their rear brakes. This however gives less than maximum braking effort.
The 'tail-gating' of cars by trucks suggests a form of driving behaviour that frequently leads to rear end crashes and deserves a more severe penalty than at present.

4 The human cost of truck crashes

The size and mass of a truck generates greater energy and resulting catastrophe in a crash than a car does.
The driver of one of these big vehicles should, in the writer's view, take the responsibility for the likely outcomes of his behaviour.
When a truck hits a car, on average, greater severity results than when a car hits a car. If the 'person costs' [ie social costs of the injuries, in dollar terms] for a car-hits-car are equated to unity [1.0] for the Metro area, then the person costs for a car hit by a rigid truck is 1.2, and a car hit by an articulated truck is 3.5 [Andreassen, 1992].

In the rural areas these increase to 2.9 [car and rigid truck] and 5.5 [car and articulated].
Increased penalties for offences/crashes involving trucks should be considered on the basis of the increased harm that they could cause.
The degree of death and injury by trucks greatly overshadows recent discussion in Melbourne about penalties for the degree of injury that 4WD vehicles cause to car occupants due to their relatively greater mass.

5 Conclusions

The mechanism and characteristics of various crash configurations should be explored to seek solutions to be able to contain the costs to the community of road transport.
The purpose of this paper was to illustrate what can be done with the existing data found on the police reports of traffic crashes, that at present is not processed, to derive more insights into the mechanism of the crashes. At present information is being wasted by not encoding it. As an example of using more of the data, this paper has addressed truck crashes and road design.

It appears that over the years trucks have grown in size without there being a corresponding consideration as to whether the roads and other road users could cope with them.
The longitudinal and cross section envelopes of trucks [rigid, articulated, and B doubles] need to be considered in road design and in the allowed roadside and overhead appurtenances.
Articulated trucks experience more crashes in Metro Melbourne in relation to km of travel than in the non-metro area, illustrating the effects of different traffic environments.
Trucks, and particularly articulated trucks, generate greater 'person costs' per crash than other vehicle types.

While there are parts of the road network for which it is evident that a review of road design to cater for big vehicles would be in order, it is also evident that the whole of the road network cannot be rebuilt to suit large vehicles.
The use of large vehicles should be controlled to specific road classes/routes where there is space for them or where reconstruction can provide space. The existing design standards for main roads in urban areas need change to cater for the large vehicles. The intersections on such routes require a better design produced for the right and left turning movements of large vehicles.

The question of general road design and articulated trucks requires some urgent attention for the problems on curves. Are the handling characteristics of articulated trucks on curves so different from rigid trucks, or are the current road designs unrelated to articulated truck handling characteristics?

The design of these large vehicles needs to be considered in regard to giving the driver greater visual knowledge of the area surrounding his truck. Also a better signalling/warning system is needed on a truck to alert other road users of the intention of the truck to change lanes or turn.

When trucks are involved in crashes with cars, generally greater death and injury results than when only two cars are involved
A review of traffic regulations and penalties is also called for to assign greater penalties for the greater harm trucks can cause.

Building codes should also be reviewed in regard to the allowed amount of protrusion by a vehicle over footpaths and /or the extent to which buildings can protrude over footways.

More of the data that is presently collected on crash reports should be extracted, processed, and put into State databases, thus allowing greater investigation into the characteristics of various crashes.

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6 References

Andreassen D C, 2001. DCA 2000 Defining Crash Attributes – A system for categorisation of traffic crashes. ISBN 0 9578668 2 8.

Andreassen D C, 1992. Trucks, semi-trailers, and motorcycles - Accident costs for project planning and Evaluation. ARRB Research Report ARR No 232.

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7 Appendix - - Some other information on deaths in truck crashes

<u>1 – Average number of persons killed per fatal truck crash</u>

All fatal crashes 1.155

One-vehicle Crashes 1.107		Two-vehicle Crashes 1.171	
Rigid	Artic	Rigid	Artic
1.038	1.179	1.079	1.266

This shows the increasing average number of persons killed in fatal truck crashes for two-vehicle crashes over one-vehicle and for Articulated trucks over Rigid trucks.
[Note -- one-vehicle crashes includes ‘hit-pedestrian’ crashes]

<u>2 – Average number of persons killed per reported truck crash</u>

All crashes .032

One-vehicle Crashes .05		Two-vehicle Crashes .028	
Rigid	Artic	Rigid	Artic
.048	.055	.02	.045

The use of all reported crashes shows a different pattern to that for fatal crashes. While there are greater numbers of deaths for articulated over rigid as with fatal crashes, the two-vehicle crashes have fewer numbers of deaths per crash than the one-vehicle crashes.

<u>3 Number of crashes by vehicle combinations</u>

Crash combination	Articulated	Rigid	Total
Single-vehicle crash	591	579	1170
2 vehicle, With articulated	46	**71**	117
2 vehicle, With rigid truck	**71**	84	155
2 vehicle, With other vehicle	1725	3332	5057
3 veh., with artic, other [1st col] or [truck, other, 2nd col]	183	518	701
3 vehicle, rigid, artic, other	**5**	**5**	10
	2621	4589	7210

Total, without double counting [as indicated by the bold numbers] = 7134.