PERFORMANCE OF CANADIAN LIGHT TRUCKS AND VANS IN COLLISIONS -FINDINGS FROM A LEVEL IV STUDY

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Abstract

Transport Canada conducted a study of the accident performance of light trucks and vans (LTV) in the early 1980's. Since this period, several trends have evolved which warrant a review of the evaluation, compliance and performance of existing safety standards. LTV vehicles have captured a much larger market share, are used for a wider variety of purposes, and have undergone radical redesigns which create unique safety concerns (e.g., large sliding doors, inboard facing seats, removable seats, large areas of glazing, etc.).

In response to the concerns noted above, Transport Canada and the University of New Brunswick Accident Investigation Team initiated a three year Level IV study of late-model sport utility vehicles, light trucks, and mini-vans which concluded in April 2000. This paper serves as a summary of findings for the study, which covers 106 in-depth case investigations. Although the data are limited, a number of trends are noted which suggest that subjecting these classes of vehicles to the same safety standards as those designed for the passenger car fleet is deficient in some areas. Specific cases are described which exemplify common issues identified by the study.

One of the most blatant deficiencies highlighted by the study is the frequent loss of integrity that results when rear or side glazing fails leaving large openings that expose passengers. Other issues cited include failures of rear cargo doors, seatbacks, window latches, excessive roof crush, vehicle incompatibility in multi-vehicle collisions, body panel retention, and driver mishandling of the vehicles.

The paper concludes by identifying a number of recommendations for the continuation and expansion of the study of light truck and van collisions leading to the modification of federal safety standards.

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1.0 INTRODUCTION

Transport Canada conducted a study of the collision performance of light trucks and vans (LTVs) in the early 1980's. Since this period, several trends have evolved which warrant a review of the effectiveness, compliance and performance of existing safety standards. LTVs have captured a much larger market share, are used for a wider variety of purposes, and have undergone major redesigns which create unique safety concerns (e.g., large sliding doors, inboard facing seats, removable seats, large areas of glazing, vehicle incompatibility, etc.).

In response to the concerns noted above, Transport Canada and the University of New Brunswick=s Collision Research Team initiated a three year study of late model sport utility vehicles, pickups, and minivans in April 1997. A Level IV approach was used in which investigators supplemented police records with first-hand examination of the scene and vehicles, occupant interviews, detailed injury information, and reconstruction analyses.

The primary objective of the study is to evaluate the compliance, performance, and effectiveness of standards that have been transferred to the LTV fleet through the investigation of real world collisions. Furthermore, investigators look for deficiencies in vehicle crash performance not covered by current standards. This paper serves as a synopsis of findings covering 106 in-depth investigations. Although the data are limited, a number of trends evolved which suggest that the extension of the same safety standards as those designed for passenger cars may be inadequate in some areas.

2.0 BACKGROUND

The recent proliferation of LTVs in the national fleet is quantified in Figure 1. The graphic depicts that the proportion of LTV sales, compared with passenger cars has approximately doubled during the last decade to nearly 90 percent (Love, 2000; Fennell, 1998). Furthermore, of all new Canadian vehicle sales in 1997, three of the top four selling models belong to the LTV class.

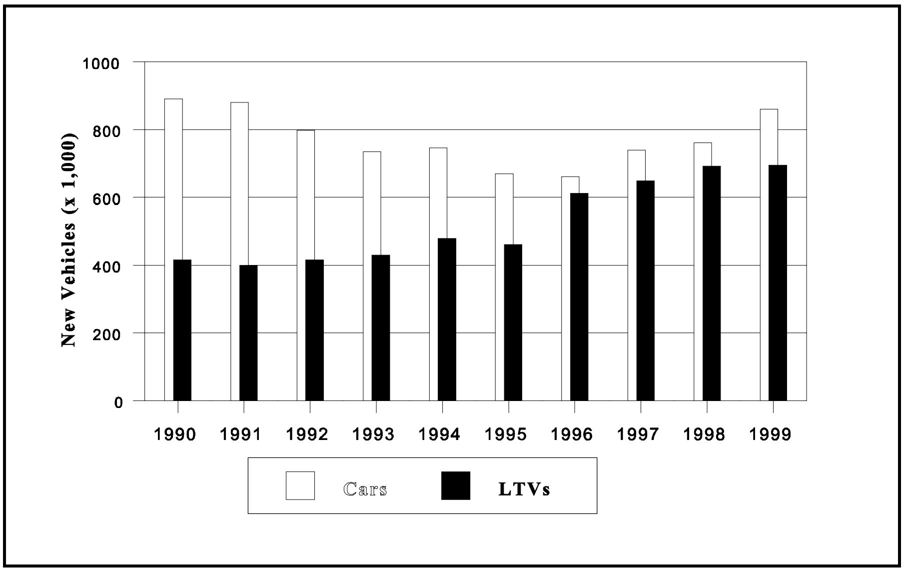

Figure 1: Canadian New Vehicle Sales 1990-1999

Not only have LTVs captured an increasing share of the market, but also their usage characteristics have changed significantly since their initial introduction into the vehicle fleet. They are being used increasingly more as passenger vehicles since the demographics of their owners have changed. For example, households with children are much more prevalent in the van market than they were 20 years ago. Pickup trucks are being used more for the combined conveyance of passengers (through the inclusion of small passenger compartments behind primary seating) in addition to cargo. The sport utility vehicle sub-population includes a wide range of vehicle styles with varying centres of gravity, overturning ratios, weight distributions, and power-to-weight ratios.

The van or minivan fleet has undergone significant interior and exterior design changes since they were last studied by Transport Canada in the early 1980's. Modifications include: large sliding doors with increased glazing which influence occupant integrity and impact protection; and increased use of removable seats and their proximity to large rear doors which highlights a need to examine, among others, door latch and seat anchorage standards.

The Canadian Motor Vehicle Safety Standards (CMVSS), promulgated in the early 1970's, are set out under various schedules. The targets of these standards are vehicles of prescribed classes and their components. At the time of the introduction of the CMVSS, trucks were not required to meet some *200 series* standards applied to passengers cars. As the standards have evolved, an increasing number of those developed for passenger cars have been extended not only to light trucks, but also sport utility vehicles and vans. At issue is whether this extension is adequate or if there is a need to modify the standards to accommodate the peculiarities of the LTV fleet.

3.0 DIMENSIONS OF THE DATA SET

This paper presents findings from a total of 106 in-depth investigations of collisions involving late model (1993 and newer) LTVs. The vehicles in the sample have included sport-utility vehicles (e.g., Nissan Pathfinders, Ford Explorers, Jeep Cherokees, Suzuki Sidekicks, etc.); minivans (e.g., Dodge Caravans, Ford Windstars, etc.); and pickup trucks (including those with both conventional and extended cabs). All LTV vehicles are defined as multi-purpose passenger vehicles or trucks with a gross vehicle mass less than 4,546 kilograms. The cases were sampled from the period of April 1997 through April 2000.

The sampling plan was not designed to represent a population; rather, it can be considered a ›convenience sample‹. A notification system was established under which the research team was informed by police of all collisions involving late model LTVs. Only those collisions involving significant or peculiar damage to the case vehicle were included in the study sample. All collisions involving a fatally injured occupant in the case vehicle were included as well. The intent was to include as many cases as possible that could reveal information regarding the adequacy of safety standards.

Table 1 summarizes the configurations of collisions included in the sampled cases. Of note is the high proportion of collisions involving rollover. Approximately half the 51 rollover cases were judged to represent situations where the high centre of gravity of the vehicle likely propagated or exacerbated the collision. Within the sample of 106 cases, there is a relatively even split between sport utility vehicles, vans, and pickups with 33, 38, and 35 having been sampled, respectively.

The profile of driver ages gives an interesting perspective of the sampled cases. One-third (35 of 106) of the cases involved drivers under the age of 25 years. The cause of all but nine of these collisions could be contributed to either road conditions or driver mishandling of the vehicle. If the age threshold is increased to include all those up to 35 years, nearly 55 percent of all sampled cases are included. Although this is a small sample, a general extrapolation might be that driver inexperience with these classes of vehicles, which often handle differently than passenger cars, might be a factor among younger drivers.

Table 1: Collision Configurations (n= 106)

Configuration	Frequency
Rollover	51
Head-on	29
T-type	19
Side-swipe	5
Rear-end	2

4.0 OBSERVATIONS

The following sections detail some of the more prevalent observations related to the CMVSS from the 106 cases sampled.

4.1 Glazing Materials

It was previously noted that as minivans have become an increasingly more popular family vehicle, its general design has changed to adapt. The traditional cargo area of vans is now often transformed into a passenger compartment. The provision of large areas of glazing along the sides and rear of the vehicles have accompanied this metamorphosis.

In 49 of the 106 sampled cases, occupant compartment integrity was compromised due to side or rear glazing either shattering or dislodging from its mounting with the window frames. The cases involving this problem are highly correlated to the occurrence of a rollover type collision. While the result of side and rear glazing shattering during a collision has been ever present among passenger cars, the issue has become acute among LTVs given the large openings (and subsequent loss of occupant compartment integrity) created when the glazing materials are no longer present. Figure 2 illustrates a typical case where the rear and all side glazing shattered during a rollover collision resulting in a loss of occupant compartment integrity.

Figure 3, illustrates a similar problem documented for pickup trucks. The rear windows shattered during the sequence of a rollover collision. Again, these occurrences are problematic given the loss of integrity to the occupant compartment.

CMVSS 205, Glazing Materials sets out the standards that govern the acceptable types and strengths of materials to be used for glazing. Modifications would be required to this standard for LTVs if the above problem areas are to be addressed.

Figure 2: Loss of Side/Rear Glazing **Figure 3: Loss of Rear Glazing**

4.2 Glazing Mounting

In addition to the cases of glazing materials shattering as noted in the previous section, deficiencies in the mounting mechanisms of side and rear glazing were noted in nine collisions. The latches for side windows were observed to have failed in five cases involving minivans. The result was that the side window either hinged open or (in three instances) became completely detached from the vehicle. Figure 4 depicts a typical occurrence.

A further type of mounting failure was noted for the rear glazing of two pickups. The rubber mounting gasket that provides the seal between the window frame and the glazing failed during a rollover thereby allowing the glazing to separate from the vehicle completely. The problem is exemplified in case LTVS-1228 where a 1993 Nissan Kingcab lost its entire rear glazing during a relatively minor rollover.

Figure 4: Failure of Side Window Latch

4.3 Rear Cargo Door Failures

Sixteen of the 106 cases involved a failure of the rear cargo door=s integrity on either minivans or sport utility vehicles. Most of these cases were instances where the locking mechanism failed thereby allowing the door to open during the collision. The applicable standard, *CMVSS 206, Door Latches,* does set explicit limits for the latches and hinges for cargo-type doors. At issue is whether this standard is sufficient given the findings of the study.

Four of these 16 cases were failures of the door structure rather than the latching mechanism. Both were minivans equipped with a fibreglass rear cargo door that failed structurally during a rollover. In each of the four instances the door frames actually failed, near the hinges at the top of the glazing, allowing the doors to separate from the vehicle completely. There are currently no standards that address this particular issue.

Finally, three cases involving pickup trucks were noted where the rear tailgates separated from the vehicle during the course of the collision events. The separation of body panels as significant as a tailgate obviously can create a hazard to occupants of all vehicles involved in the collision.

4.4 Sliding Side Door Failures (minivans)

Of the 38 minivans included in the sample, four involved a structural failure of their sliding side door assembly. This is of particular concern given the large portal that is created when these type of doors fail. It is important to note that three of the four cases involved deformation of the roof and/or door frame that allowed the door latch or sliding tracks mechanisms to fail. The fourth case (LTVS-1268) was a side impact with a utility pole that resulted in the door sill frame failing at a welded joint. This joint failure allowed excessive intrusion into the occupant compartment.

4.5 Roof Intrusion

Of the 51 cases that involved rollover of the vehicle, 19 were subjectively judged to have sustained excessive roof crush. The standard *CMVSS 216, Roof Intrusion Protection*, is administered as a static loading of a vehicle's roof structure. The applied load is set as 1.5 times the unloaded weight of the subject vehicle. These test specifications were extended from passenger car standards to LTVs in 1994 (Transport Canada, 1996).

Figure 5 illustrates two typical cases where the roof crush might be considered excessive given the collision circumstances. The 1997 Geo Tracker depicted in Figure 5, sustained its roof crush during a rollover with an estimated pre-impact speed of only 60-65 km/h. An interesting observation with this case is that the failure pattern of the left side of the roof suggests that the pillars were subjected to a lateral loading. This kind of load, which is common given the dynamics of rollover collisions, is not specifically reflected by the test procedures of *CMVSS 216.*

Figure 5: Roof Crush: 1997 Geo Tracker

The 1993 Chevrolet pickup depicted in Figure 6 sustained excessive roof crush, particularly in the area over the rear bench seat. The case illustrates the long structural span that is often required of LTV roof systems given the provision of large window openings.

Figure 6: Roof Crush: 1997 Chevrolet Pickup

Figure 7 exemplifies a class of vehicles (convertibles) for which *CMVSS 216* does not apply. The 1995 Geo Tracker (soft-top) depicted was involved in a low speed rollover collision. Had there been any occupants in the rear seat, they would have been completely exposed given that there was no protective roof structure present. It is ironic to note the provision of mounting structures for the D-rings of three-point restraints for the outboard passengers, in the absence of any protective roof structure.

Figure 7: Lack of Protective Roof Structure

4.6 Incompatible Vehicle Geometry

With the recent proliferation of LTVs, much public attention has focussed on the issue of different vehicle sizes. Many LTV models have an inherently higher centre of gravity, larger masses, and stiffer chassis. The combination of these characteristics is sometimes referred to as an LTV=s *aggressiveness*. These features place occupants of passenger cars at a disadvantage should they be struck by an LTV. Gabler and Hollowell found that people in cars are more likely to be injured or die in a collision with an LTV because of the Astriking incompatibility between cars and all categories of LTVs@ (1998). They found that 81 percent of those killed in U.S. LTV-car collisions in 1996 were occupants of the car. Furthermore, collisions in which the LTV Awas the bullet vehicle led to 56.9 percent of all fatalities in side-struck vehicles".

An Insurance Institute for Highway Safety study found similar results as they noted the overall risk of death for occupants of cars colliding with LTVs is about 4:1 (1998). This ratio increases to approximately 25:1 in cases where cars are struck on their side by an LTV (compared with 6:1 if struck by another car).

From the 106 cases sampled, 15 were noted to involve a measure of vehicle incompatibility. In essence, all of these 15 collisions represented two vehicle collisions where the relative height, mass and stiffness of the LTV case vehicle resulted in disproportionate damage to the passenger car involved.

Figure 8 illustrates the consequences of incompatible vehicles. As shown, a 1996 Ford F-150 pickup struck the side of a 1989 Ford Taurus. Given the height and stiffness of the frame and bumper of the pickup, it overrode the sill level of the Taurus thereby exacerbating the intrusion into the rear occupant area.

Figure 9 depicts an example of a frontal collision between incompatible vehicles. The 1989 Pontiac Firefly and the 1993 Ford Explorer impacted in a head-on configuration. The Explorer overrode the front end of the Firefly because of its additional height and chassis stiffness. Note that the mass of the Explorer was nearly 2.6 times that of the Firefly.

Figure 8: T-type Impact Damage Between Incompatible Vehicles

Figure 9: Head-on Impact Damage Between Incompatible Vehicles

Although vehicle size and mass are not likely to be regulated, a standard bumper height and stiffness, mandated through *CMVSS 215, Bumpers,* for all vehicle classes might prove beneficial. While the standard does govern the height of bumpers (between 400 and 500 mm) it currently only applies to passenger cars and not the multipurpose vehicle or truck classes.

4.7 Failed Seatbacks

Ten of the sampled cases yielded observations of seatback failures. The most dramatic case was LTVS-1233 that involved a 1995 Suzuki Sidekick. After spinning out of control on an icy road the vehicle slid backwards striking a snowbank. Both the driver and passenger seatbacks failed, allowing the driver (despite being restrained) to be ejected out through the plastic rear window. The damage is depicted in Figure 10.

CMVSS 207, Seat Anchorages, dictates the static strength that a seat's anchorages and the seatback's self-locking hinge must withstand. The same standard that applies to passenger cars is set out for classes of LTVs. While it is unlikely that occurrences of seatback failures are any more prevalent in LTVs than passenger cars, the consequences may, on average, be more severe given the demonstrated frequent loss of occupant compartment integrity due to side and rear glazing.

Figure 10: Seatback Failure

4.8 Fibreglass Body Panels

Manufacturers have increasingly used fibreglass body panels for hoods and doors, including the rear fibreglass cargo doors noted in section 4.3. In seven of the 106 cases sampled, the subject vehicle had one or more of its fibreglass panels detach from the vehicle. At issue is the hazard these panels could pose to occupants of involved vehicles or pedestrians in the vicinity of the collision.

4.9 Windshield Bond Strength

CMVSS 212, Windshield Mounting, regulates minimal windshield bond strength by establishing a maximum degree of peripheral separation of the windshield from the frame following a fixed barrier impact. The minimum retention following the test is set at 50 and 75 percent depending on whether the vehicle is equipped with an automatic occupant protection system or not. What this test does not account for is structural deformation of the windshield frame during a rollover event.

Within the sample of 106 collisions, 19 cases were noted where windshield bond separation exceeded 50 percent. Expectedly, most of these cases were rollover configurations. Obviously, occupant compartment is compromised where bond separation is excessive. A further 12 cases resulted in bond separations of 25 to 50 percent, while another 10 were observed with bond separations less than 25 percent.

5.0 DISCUSSION

While the preceding observations are admittedly based on a relatively small data set, a number of issues have been raised which question the appropriateness of extending safety standards designed for passenger cars to LTVs with little or no modification.

The study findings suggest that Transport Canada should move toward a more robust sampling of LTV collisions so that a more comprehensive knowledge base can be established upon which suggested improvements can be made regarding LTV safety standards.

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Any opinions presented in this paper are solely those of the authors.

7.0 REFERENCES

Eguakun, G.A., *Evaluation of Potential Safety Benefits From the Introduction of Selected CMVSS to LTVs*, Masters Thesis, University of New Brunswick, Fredericton, NB, 1993.

Fennell, T., *Big Wheels*, in MacLean=s, vol. 111, no. 29, Toronto, ON, July, 1998.

Hollowell, W. and H. Gabler, *National Highway Safety Administration=s (NHTSA) Vehicle Aggressivity and Compatibility Research Program*, 16th International Technical Conference on the Enhanced Safety of Vehicles, Windsor, ON, May 31 to June 4,1998.

Insurance Institute for Highway Safety, *Status Report: Crash Compatibility*, vol. 33, no. 1, Virginia, February 14, 1998.

Love, M., *Industry News: 1999 Sales Riches Spread Across Boards*, in Canadian Auto World, January 17, 2000.

Transport Canada, *Consolidation: Motor Vehicle Safety Act -Motor Vehicle Safety Regulations*, Motor Vehicle Standards and Research Branch, Ottawa, ON, July, 1995 (with amendments in 1996).