Fatal Collision Causation and Potential Countermeasures

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Abstract

A pilot study is underway in Saskatchewan to investigate the causes of fatal motor vehicle collisions and to identify potential countermeasures. The study is being undertaken on fatal crashes occurring in both urban and rural locations. The study methodology consists of in-depth collision investigations to identify the human, vehicle and environmental factors that are involved in individual crashes. From detailed review of case incidents, potential countermeasures are identified that may prevent similar collisions in the future or, at least, mitigate the consequences of such incidents. The present paper reviews a series of the cases studied to date and presents the findings.

Résumé

Une étude pilote est en cours en Saskatchewan pour enquêter sur les causes de collisions mortelles de véhicules automobiles et identifier des mesures de prévention potentielles. Cette étude est basée sur les accidents mortels qui surviennent dans des endroits urbains et ruraux. La méthodologie de l'étude comprend des enquêtes approfondies sur les collisions pour identifier les facteurs humains, automobiles et environnementaux qui ont une influence dans chaque accident. À partir de l'examen détaillé des cas d'accident, des mesures potentielles sont identifiées pour prévenir des collisions similaires à l'avenir ou, à tout le moins, atténuer les conséquences de tels accidents. Le présent document décrit une série de cas étudiés jusqu'à maintenant et fournit les résultats.

Introduction

Road Safety Vision, making Canadian roads the safest in the world, is a national undertaking launched in 1996, and is supported by all levels of government and non-government stakeholders. Road Safety Vision 2010 (RSV 2010), was the result of a renewed longer term plan established in 2000 to carry forward the work of the original national road safety plan.

The main target of RSV 2010 is to decrease the number of road fatalities and serious injuries during 2008-2010 by 30% as compared to the period 1996-2001. RSV 2010 established a number of sub-targets [1], some of which include:

- minimum seat belt use rate of 95%;
- 40% decrease of unbelted fatalities or serious injuries;
- 40% decrease in road users fatally or seriously injured in crashes involving a drinking driver;
- 40% decrease in the number of fatalities or serious injuries on rural roadways.

In order to reduce casualties in motor vehicle crashes on Canadian roads, it is essential to identify causal factors and develop effective counter-measures. The Causes of Fatal Collision Pilot Study has been implemented to investigate a means to achieve these goals.

A notification system was set up with police collision analysts and reconstructionists within the study area (less than a three hour response time) so that the crash investigation team can attend fatal crashes on scene on a best effort basis. In addition, retrospective studies were performed on a number of fatal collisions, using available information and reports from police investigators.

For the field investigations forming part of the present study, the roadway and the vehicles involved were examined at the collision scene, or as soon after the crash as possible. These were supplemented by available information from other sources. Likely causal factors and potential countermeasures were identified for each case.

Case Studies

The following incidents are drawn from the current series of crashes that form part of the pilot study:

Case 1

A 2000 Lincoln LS four-door sedan, heading south along a two-lane urban street, came to a halt at a stop sign controlled intersection. It was clear and bright with the sun high in the southeast. The asphalt pavement was dry and in good condition. The Lincoln's 56-year-old, male driver looked both ways along the intersecting, two-lane, undivided roadway. He did not observe any vehicles approaching and moved the Lincoln ahead, with the intention of travelling through the intersection.

A 1992 Honda 900 RR Fireblade motorcycle was travelling westbound along the intersecting road at an estimated speed of 136 km/h, well in excess of the posted 50 km/h limit. As the Lincoln entered the intersection, the front wheel of the motorcycle impacted the car's left-front side (Figure 1).

The impact by the motorcycle broke the left-front wheel assembly away from the Lincoln and resulted in 39 cm of crush to the vehicle's side structure. The Lincoln rotated clockwise out of the impact and moved diagonally across the intersection. The car, its detached front wheel, and the motorcycle, all came to rest in the southwest corner of the intersection. The motorcycle's rider came to rest along the southwest sidewalk, to the west of the Lincoln. His motorcycle helmet became detached in the collision, and it was found some distance further to the southwest, lodged against a building.

The 19-year-old, male rider of the motorcycle sustained fatal head injuries included multiple skull fractures. He also suffered multiple rib fractures, contusions and abrasions to the chest and abdomen.

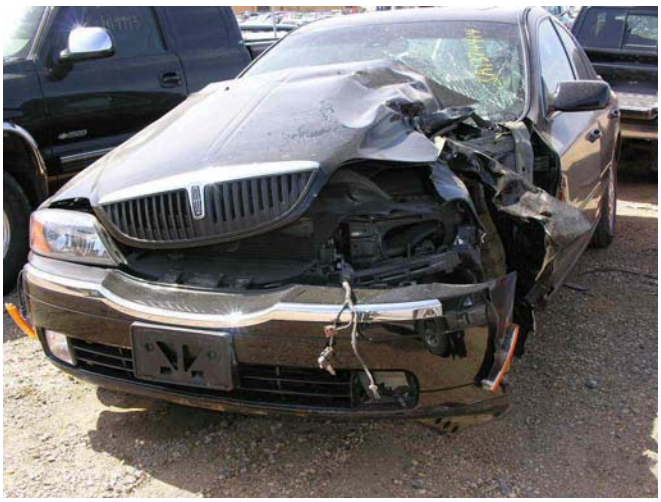

Figure 1: Damage to the Lincoln from the Honda Motorcycle

Case 2

This collision occurred on a two-lane, undivided, rural highway. It was daylight and cloudy. The asphalt road surface was dry and in good condition. The posted speed limit was 100 km/h.

A 1983 Oldsmobile Cutlass Ciera LS four-door sedan was travelling northeast along the roadway. A 1999 Volvo truck tractor, with a van semi-trailer, was travelling in the opposite direction. The Oldsmobile drifted across the centreline and entered the oncoming lane. The Volvo's driver applied the brakes and steered onto the right paved shoulder of the roadway. The Oldsmobile sideswiped the front of the semi-trailer unit and the car's front end ran under the trailer's deck and impacted the unit's rear axle.

There was extensive damage down the left-front side of the Oldsmobile. The left-front wheel was

detached from the vehicle. The left A-pillar and the firewall were displaced rearwards into the occupant compartment.

The Oldsmobile's driver was a fully-restrained, 73-year-old female. She made heavy contact with the intruding steering wheel which was severely deformed. This driver sustained fatal injuries in the collision. No detailed injury information was available; however, on-scene personnel indicated that she had received a major laceration on the left side of her neck, and fractures to both the left leg and left arm. Medical information further reported that this driver did not suffer a heart attack or a stroke just prior to the crash.

Case 3

A 2005 Chevrolet Avalanche pickup truck was travelling northbound along a two-lane, undivided gravel road. It was daylight and the weather was clear. The roadway was dry and in good condition, with a posted speed limit of 80 km/h. The pickup approached a blind hillcrest with an advisory sign indicating a maximum speed of 40 km/h since the roadway jogged to the right over the crest of the hill.

The event data recorder in the Avalanche subsequently indicated the vehicle's speed as 114 km/h. As the Avalanche crested the hill, the truck's driver observed a 1998 Honda ATV, travelling southbound along the roadway, directly in his path. The Avalanche's driver applied the vehicle's brakes, while the ATV rider moved over to the extreme right side of the road. Despite the attempted evasive manoeuvres, the left-front corner of the Avalanche struck the left-front end of the ATV.

The 53-year-old, male rider of the ATV was not wearing a helmet. The impact by the pickup truck sheared off the ATV's left-front wheel, and traumatically amputated its rider's left leg. The rider was thrown from the ATV and sustained multiple head injuries. He was pronounced dead at the collision scene.

Case 4

The case incident occurred on a two-lane, undivided rural highway. It was daylight but overcast. The asphalt-paved roadway was in good condition but was wet from recent light rain. The posted speed limit was 100 km/h.

A 1997 Pontiac Sunfire two-door coupe was travelling northbound at high speed. The driver and five passengers were high school students on a lunch break. They were on a round-trip of 70 km, intending to pick up some belongings from a cabin at a lake, and were likely on a time constraint to return to school for the afternoon session. The vehicle was equipped with a radar detector; however, it is unknown if this was in use at the time of the collision.

A 2004 Chevrolet Silverado LS pickup truck was southbound on the roadway. The truck's 70-year-old male driver had the vehicle's cruise control set at 101 km/h.

As the Sunfire approached a slower-moving north-bound vehicle, the Sunfire's driver braked hard and steered to the left to overtake. The driver of the Silverado observed the Sunfire travelling into his lane, braked hard, and steered his truck onto the right shoulder; however, the two vehicles collided in an offset-frontal impact.

The Sunfire sustained extensive damage to the front end and right side with a maximum crush of 120 cm being measured to the right-front bumper. The vehicle's two front airbags deployed as a result of the collision.

The Sunfire's driver was an unrestrained 16-year-old male. He sustained major injuries as a result of the collision.

The right-front passenger, a fully-restrained, 16-year-old female was fatally injured. Her injuries included a flail chest, an unstable fracture of the pelvis fracture, and open fractures to her right hip and lower leg.

A fully-restrained, 16-year-old male occupied the left-rear seat. He sustained only minor lacerations and contusions in the collision.

The centre-rear occupant was using the available lap belt. She was fatally injured in the crash. Her injuries included multiple fractures to her right forearm, an abdominal contusion and unspecified internal injuries.

A 16-year-old male and a 16-year-old female were sharing the lap/torso seat belt in the right-rear occupant position,. The male passenger suffered multiple fractures and contusions to his leg. The female sustained extensive trauma to the right side of her head and was fatally injured.

The driver of the Sunfire had held a full driver's for no more than six months prior to this collision. Within this time he had received one speeding conviction, had been involved in two at-fault collisions, and had received a one-month licence suspension.

Case 5

The case incident occurred during the afternoon on a two-lane, undivided, rural highway. The weather was clear; the road surface was dry and in good condition, with a posted speed limit of 100 km/h.

A 1995 GMC Suburban sport utility vehicle was travelling eastbound with the cruise control set. The 35-year-old, female driver was travelling home from out of province, a distance of 450 km, when she fell asleep. The vehicle drifted onto the southern roadway shoulder, at which point the driver was awakened. She attempted to steer the Suburban back onto the road but lost directional control such that the vehicle was fishtailing

The driver of a westbound 1981 Kenworth W924 truck tractor, hauling a semi-trailer, observed the errant Suburban. He applied the truck's brakes and steered onto the paved shoulder on the northern edge of the road. The Suburban crossed the centre-line and came into a head-on collision with the truck tractor.

The front of the Suburban was extensively damaged, with a maximum crush of 54 cm at the right-front bumper. The right front wheel assembly was separated from the vehicle. The impact also caused severe damage to the Kenworth's steering axle. The Suburban rotated counter-clockwise out of the initial impact, and its right-rear corner struck the left side of the hopper trailer, just in front of the trailer's 4th axle. This second impact resulted in extensive damage to the right-rear side of the Suburban. The rear windows were broken and the right D-pillar was badly deformed, with a maximum crush of 66 cm (Figure 2).

Figure 2: Damage to the D-Pillar Area of the 1995 GMC Suburban

The Suburban's driver was fully restrained and her air bag deployed in the crash. She sustained only minor injuries. She was accompanied by three children. A fully-restrained, 13-year-old male occupied the right-front seat, while a 6-year-old

female was restrained in a T-shield booster seat on the right side of the second row seat in the Suburban. Both of these children received only minor injuries in the collision.

A 12-year-old male was seated on the right side of the third row seat in the vehicle. Although this occupant was fully restrained, his skull was crushed as a result of direct contact with the intruding hopper-trailer and he was fatally injured.

Case 6

A 1996 Dodge Caravan minivan, driven by a 30-year-old female, was travelling east on a two-lane, undivided rural road, approaching an intersection with a similar roadway. A 1981 Chevrolet El Camino pickup truck, driven by an 80-year-old male, was heading north towards the intersection. Traffic on the north-south roadway was ordinarily controlled by yield signs; however, both the sign and the support post for northbound traffic was missing.

It was evening and the sun was low over the horizon, directly behind the eastbound Caravan. It was clear and dry, and the gravel road surfaces were in good condition. Both roads had 80 km/h speed limits.

The driver of the El Camino failed to observe the eastbound Caravan and entered the intersection. The Caravan's driver steered to the left in an attempt to avoid a collision, but the front of her vehicle struck the El Camino on the driver's door. The impact resulted in 47 cm of crush to the truck's left side surface with associated intrusion into the driver's compartment. The unrestrained driver of the El Camino received fatal head injuries.

Case 7

A 2004 Dodge Ram 1500 pickup truck was northbound along a two-lane, undivided, rural roadway. It was daylight, with cloudy skies and rain. The asphalt-paved roadway surface was wet, but in good condition. The posted speed limit was 80 km/h.

A 1994 Chevrolet Cavalier four-door sedan was westbound on an intersecting two-lane road. The Cavalier arrived at a T-intersection with the major road that was controlled by a yield sign. Visibility between northbound and westbound traffic was limited by a stand of trees in the south-eastern corner of the intersection. In addition, the yield sign for westbound traffic was located 10 m to the east of the intersection, so that Cavalier's driver, when stopped at the yield sign, could only see about 40 m of the main road to the south (Figure 3).

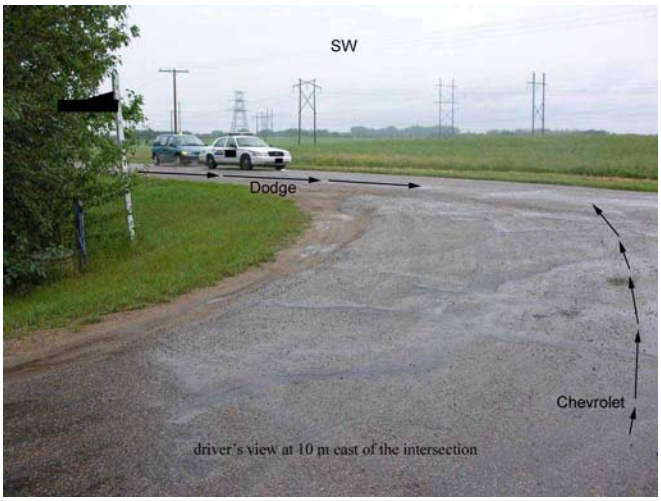

Figure 3: Limited Visibility at the Intersection

The Cavalier's driver entered the intersection, intending to turn left. The driver of the pickup truck reported that he reached down for a paper tissue, and so had taken his eyes off the road. When he returned to an upright seating position, he observed the Cavalier directly in front of him and had no time to take any evasive action.

The front end of the pickup truck impacted the left side of the Cavalier just behind the A-pillar. The pickup truck overrode the Cavalier's sill. The left B-pillar and C-pillar of the Cavalier failed, and the rear third of the body structure was torn away from the rest of the vehicle.

The 82-year-old, male driver of the Cavalier was unrestrained. He was completely ejected from the vehicle and sustained multiple fatal injuries.

The driver of the pickup truck had been licensed for seven years. During this period, he had received two speeding tickets, two tickets for driving too fast for road conditions, and one ticket for failing to use a seat belt. The Cavalier's driver had received 10 tickets for non-seatbelt use over the course of the past 18 years. He had been involved in four prior crashes, had received three tickets for speeding, two tickets for disobeying traffic light signals, and one further ticket for failing to yield the right-of-way.

Case 8

The case incident occurred on a two-lane, undivided rural roadway. It was clear and daylight, and the road surface was dry and in good condition. The posted speed limits for north-south traffic were in transition, changing from 80 km/h to 50 km/h for southbound vehicles, and from 50 km/h to 80 km/h for northbound traffic. The speed limit for south-bound traffic had been reduced from 100 km/h to 80 km/h more than one kilometre to the north.

A 2001 Pontiac Grand Am four-door sedan was southbound at a speed of 142 km/h, as subsequently determined from the vehicle's event data recorder. The Grand Am was rounding a shallow curve to the left, on the crest of a hill, when it approached a driveway on the west side of the highway. A vehicle turned south onto the highway from the driveway. The driver of this slow-moving vehicle saw the Grand Am but, for unknown reasons, moved to the centre of the highway, straddling the centre line. The driver of the Grand Am attempted to pass on the right by steering onto the paved shoulder; however, he lost directional control as he tried to steer back into the southbound travel lane. The Grand Am rotated counter-clockwise across the highway, and onto the east shoulder with its right side leading.

A 1985 Buick Century four-door sedan was travelling north on the highway. The driver of the Century steered to the right but the two vehicles came into collision on the shoulder of the road.

The front end of the Century struck the right side of the Grand Am just to the rear of the A-pillar. The Grand Am's right B-pillar and C-pillar failed during impact. The rear seat and trunk assembly were completely separated from the rest of the vehicle.

The driver of the Century was a fully-restrained, 44-year-old female. She was fatally injured but no autopsy was performed.

The driver of the Grand Am was a fully-restrained, 25-year-old male. He also sustained fatal injuries, including a fractured skull and lacerated medulla, fractures to the spine with damage to the cord, multiple rib fractures with lacerations to the aorta, lungs, liver, spleen and kidneys.

The driver of the Grand Am had been licensed for the past nine years. He had been involved in two previous crashes, had two speeding convictions and one licence suspension. The Century's driver was disqualified from driving at the time of the collision. She received her first license more than 20 years ago, had been involved in four prior crashes, and had three licence suspensions.

Case 9

This incident occurred in the evening, at an illuminated intersection, in a large urban centre. A 2004 Chevrolet Malibu LT four-door sedan was westbound on a four-lane, median-divided urban arterial and came to halt at the intersection for a red traffic light signal. Located 180 m to the east of the intersection were overhead flashing amber lights, warning westbound drivers of the upcoming traffic light signals.

A 1999 Ford F150 XLT pickup truck was westbound on the roadway and approaching the intersection at high speed, directly behind the Malibu. The front end of the F150 struck the rear of the Malibu. The left-rear structure of the Malibu was displaced forwards up to the left B-pillar, with the maximum crush being measured as 137 cm. The Malibu was driven across the intersection, while the F150 continued ahead, went into yaw, and rolled over before coming to rest to the west of the intersection.

The 39-year-old, male driver of the pickup truck had been working long hours on a farm for the previous three days and indicated that he must have fallen asleep prior to the crash. Reconstruction of the collision indicated the truck's pre-impact speed as approximately 130 km/h. The driver had been licensed for the past 23 years, but did not have a valid license at the time of the crash. He had been previously involved in three at-fault and one not-at-fault collisions over the last ten years. He had received five speeding tickets, one ticket for failing to stop at a stop sign, two tickets for failing to wear a seat belt, one ticket for driving through a red light, one ticket for driving with inadequate equipment, and one ticket for driving without due care. His driver's licence had been suspended three times during the past ten years.

The driver of the Malibu was a fully-restrained, 55-year-old male. He had been licensed for the past 25 years. In the last 12 years he had been involved in six collisions, had received two tickets for speeding, and one ticket for failing to wear a seat belt. As a result of the case collision, he suffered a broken neck and multiple head injuries and was pronounced dead at the scene.

Case 10

A 1998 Toyota 4Runner SR5 sport utility vehicle was westbound on a four-lane, median divided, urban arterial. It was dark with good artificial illumination. The asphalt-paved roadway was dry and in good condition. The posted speed limit was 70 km/h.

The 17-year-old, female driver was alcohol impaired, with a blood alcohol level of 240 mg%. She had traces of cannabis in her system, and was using anti-depressant medication. As the vehicle rounded a shallow curve to the right, it began to yaw clockwise. The driver was unable to regain directional control. The vehicle mounted the right curb, and ran onto the grass-covered boulevard. The driver over-steered to the left, putting the vehicle into a counter-clockwise yaw. The 4Runner tripped and rolled over twice, crossing the adjacent travel lanes, and the median, before coming to rest on its wheels on the far side of the roadway (Figure 4).

Figure 4: 1998 Toyota 4Runner

The driver was unrestrained and was completely ejected from the vehicle during the rollover sequence. She received fatal injuries including a fractured skull and crush to the chest and abdomen, with fractured ribs and lacerations to multiple internal organs.

Case 11

A 1993 Mazda B2200 pickup truck was southbound on a two-lane, undivided, urban street in the early morning. It was cloudy and dark, but the road had

good artificial illumination. The asphalt-paved road was wet but in good condition. The posted speed limit was 50 km/h.

The driver of the pickup truck, having finished work on the previous night, had attended an overnight house party and was on his way home from this party when the crash occurred. His blood alcohol level was 150 mg% and traces of cannabis were found in his system.

A 1993 Ford Ranger pick-up was parked against the west curb. The right-front corner of the Mazda struck the left-rear end of the Ford. The Mazda's driver then steered abruptly to the left. His truck ran across the road in a counter-clockwise yaw and mounted the east curb. The right side of the pickup truck sideswiped a large tree on the boulevard before the vehicle came to halt on the lawn of an adjacent residence.

The Mazda sustained damage along both the right-front fender and right-side door as a result of the impact with the tree (Figure 5). A maximum crush of 19 cm was measured at the front edge of the right door. The right side window was broken and the right door was jammed as a result of the impact.

Figure 5: Damage to the Right Side of the 1993 Mazda B2200

The driver of this vehicle was an unrestrained 23-year-old male. He sustained fatal injuries, including multiple fractures of the skull with lacerations and haemorrhaging to the brain.

The Mazda's driver had been licensed to drive for three years. He had been involved in two at-fault collisions, and his driver's licence had been suspended once as a result of unpaid traffic fines. He had received tickets for failing to stop for a red light and for failing to stop at a stop sign. Less than two days before the case collision, the driver had been charged for driving at an unsafe speed on an urban roadway with a 50 km/h speed limit.

Case 12

The case incident occurred on a two-lane, undivided rural highway, during daylight hours, with cloudy conditions. The asphalt-paved road surface was dry and in good condition. The posted speed limit was 100 km/h.

A 1993 Buick Century four-door sedan was southbound on the highway. A 2002 Kenworth T800 truck-tractor, hauling two fully-loaded hopper trailers, in a B-train configuration, was northbound. The tractor trailer had reached the bottom of a sag in the roadway and was beginning to ascend a 4% grade. The Buick crossed over the centreline and collided head on with the truck.

The Buick sustained catastrophic damage due to the high severity of the impact and override by the truck's front structure. A post-collision fire resulted in complete destruction of all the combustible material. The 18-year-old, male driver of the Buick was fully restrained but was fatally injured as a result of the impact and the resulting fire. A suicide note outlining a plan similar to the subject events was found at the individual's residence as part of the post-collision investigation by police.

Table 1: Summary of Contributing Factors and Potential Countermeasures

Case	Location	Configuration	Contributing Causal Factors	Potential Countermeasures
1	Urban	T-collision	Excessive speed Motorcycle conspicuity	Speed enforcement Education
2	Rural undivided highway	Side-swipe	Inattention Fatigue	Heavy truck side under-ride guard Centre line rumble strips Driver fatigue warning system Lane departure warning system
3	Rural fair weather road	Head-on	Excessive speed Illegal use of road	Speed enforcement Education
4	Rural undivided highway	Head-on	Reduced visibility Excessive speed Aggressive driving Inattention Inexperienced driver	Graduated license system Vehicle stability control system Speed enforcement Education
5	Rural undivided highway	Head-on	Fatigue	Vehicle stability control system Lane departure warning system Driver fatigue warning system Rumble strips
6	Rural gravel	T-collision	Perception/sightline Sun glare Missing traffic (Yield) sign Unexpected change of right of way	Timely sign replacement and maintenance Defensive driving techniques
7	Suburban local	Angle	Limited intersection sight distance Failed to yield Inattention	Increase sight distance at intersection Defensive driving techniques
8	Rural undivided highway	Angle	Hidden access road Slow moving vehicle Excessive speed Improper passing	Vehicle stability control system Speed enforcement
9	Urban divided highway	Rear-end	Fatigue Driver inattention Excessive speed	Transverse rumble strips Driver fatigue warning system Speed enforcement
10	Urban divided	Rollover	Alcohol & drug Excessive speed Inexperienced driver	Vehicle stability control system Speed enforcement Seat belt use
11	Urban undivided	Side-swipe	Alcohol Speeding Fatigue	Vehicle stability control system Seat belt use
12	Rural undivided highway	Head-on	Suicide	None

Discussion and Conclusions

Despite the small number of cases presented in the current paper, a wide range of causal factors was identified, and these are suggestive of a range of appropriate countermeasures (Table 1).

One half of the cases involved excessive speed as a major causal factor. This was particularly the case in collisions in rural areas, but a number of urban crashes involved similar risky driving behaviour. Inappropriate passing manoeuvres, combined with high initial travel speeds, were seen to lead to loss of control and subsequent head-on collisions, while driver fatigue was an evident cause of other incidents where drivers crossed the roadway centreline and struck on-coming vehicles.

Extreme alcohol impairment, combined with the use of cannabis, was a significant factor in two of the collisions. Restraint use, of both seat belts and helmets, was mixed for this small sample of road users. The non-use of the available seat belt system directly resulted in the death of one driver (Case 10) who was ejected from her vehicle in a relatively benign rollover crash. Seat belt use would likely have prevented the death of another driver (Case 11).

The relatively high incidence of the use by drivers of alcohol and drugs, and the non-use of restraint systems, provides support for the customary education and enforcement programmes designed to address these issues.

A number of collisions in the current series involved youthful drivers holding either graduated licenses or recently-acquired full licences. Some of these individuals had amassed several driving infractions prior to their involvement in the case collisions. This provides an indication that greater attention might usefully be paid to monitoring such drivers more closely, and attempting to modify their behaviour at an early stage. It should be noted that two of the reported cases involved drivers with either suspended or invalid driver licenses.

Excessive speed, as a causal factor, generally involved drivers exceeding posted speed limits by wide margins. Event data recorders (EDR) proved to be extremely useful in some of the cases, both to indicate pre-impact speeds, but also to demonstrate the actions, or lack thereof, of drivers. Of interest to note, was one collision (Case 9) where the crash severity reported by an On-Star automatic collision notification system installed in one of the involved vehicles proved useful to the collision reconstruction process. As exemplified in some of the cases in the present series, event data recorders provide extremely valuable data to assist in the evaluation of both collision severity and pre-crash factors. The widespread installation of these systems throughout the new vehicle fleet needs to be encouraged, and their datasets and retrieval systems standardized, in order for EDR's to be a truly useful tool to address a wide range of traffic safety issues [2].

In general, vehicle factors per se were not directly involved in any of the current case incidents. No mechanical effects were identified in any of the involved vehicles, and all of the applicable standards functioned as designed. However, two of the case collisions involved fatalities resulting from light-duty passenger vehicles impacting the sides of heavy trucks, notably semi-trailers in truck tractor combinations. Both incidents essentially involved initial glancing impacts, with subsequent underride of the trailer decks by the lower structures of the passenger vehicles. There is some potential here for the use of side underride guards, as has been suggested for European vehicles [3], to mitigate the severity of these types of crashes for the smaller vehicles.

Four of the case collisions involved driver fatigue, two of these resulting in a vehicle crossing the centreline and impacting an on-coming vehicle. Although it could not be positively confirmed in Case 2, driver fatigue was likely a contributing casual factor in the crash. The advent of sophisticated electronic safety systems brings the

potential for countermeasures to such situations. Lane-tracking systems, using forward looking video-cameras and real-time image analysis, provide one means of alerting a driver to changes in their vehicle's heading [4]. Similarly, some driver-fatigue warning systems use on-board cameras to monitor a driver's eye movements, detect when the driver is falling asleep, and sound an alarm [5].

Loss of directional control prior to a collision is not an uncommon event, and is exemplified here in four of the case incidents. Technological solutions, in the form of electronic stability control (ESC) systems being widely available in future vehicles, may provide a valuable countermeasure to these types of situations. ESC uses electronic sensing and control systems to detect an impending loss of directional control, and then modulates the engine power, and/or brake application to various wheels, in order to maintain the vehicle's heading. Such systems are already available on some vehicles and prior studies have suggested that significant fatality reductions might be achieved, especially in single-vehicle crashes, through their use [6].

A number of environmental factors were identified as contributing to the causes of some of the subject crashes. In one case (Case 6), a traffic control sign was missing at an intersection for one direction of travel. In another incident (Case 7) a driver's visibility was restricted by a stand of trees at an intersection. Weather conditions, notably wet roads, snow and ice, played a role in several of the reported collisions. While these factors did contribute to the subject crashes, the involved drivers could have adjusted their actions to the prevailing conditions and probably avoided crashing.

The final case (Case 12) in the present series is a cautionary tale that illustrates that, despite all of our efforts to reduce the toll of mortality and morbidity from motor vehicle crashes to society, it will be extremely difficult to achieve "vision zero" – the ultimate goal of no road traffic fatalities. This fatality was a suicide, involving an extremely severe head-on crash with a heavy truck, a situation that is unlikely to be addressed through any conventional traffic safety countermeasures.

However, notwithstanding the most unusual collision circumstances of the latter crash, the remaining cases in the present series do illustrate the potential for a multi-disciplinary approach to the in-depth collision investigation process to identify causal factors for collisions and to provide considerable insight into potentially effective countermeasures.

Acknowledgements and Disclaimer

The opinions expressed in this paper are solely those of the authors and do not necessarily represent the views and policies of their respective organizations.

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