MOTOR VEHICLE CRASH INVESTIGATION REPORT

Company: XXXX

Index

SUMMARY OF THE EVENT

The driver of an SUV was traveling northbound on a single lane, two-way highway. Upon reaching kilometer marker 75, while traveling uphill on a straight stretch, he crossed over the centerline to overtake a tractor-trailer.

However, oncoming traffic forced him to return to his original travel lane. During this return maneuver he reached, struck, and ran under the left rear-end of the semi-trailer he was trying to overtake.

The impact and underride caused significant crush damage to the SUV and fatal injuries to the driver.

1. Technical Report

1.1. Description and analysis of documented physical evidence

• Visibility and weather conditions

The collision took place at dawn, during twilight, in other words, before sunrise. We therefore infer that the traffic environment was still dark. The crash site has no means of artificial lighting.

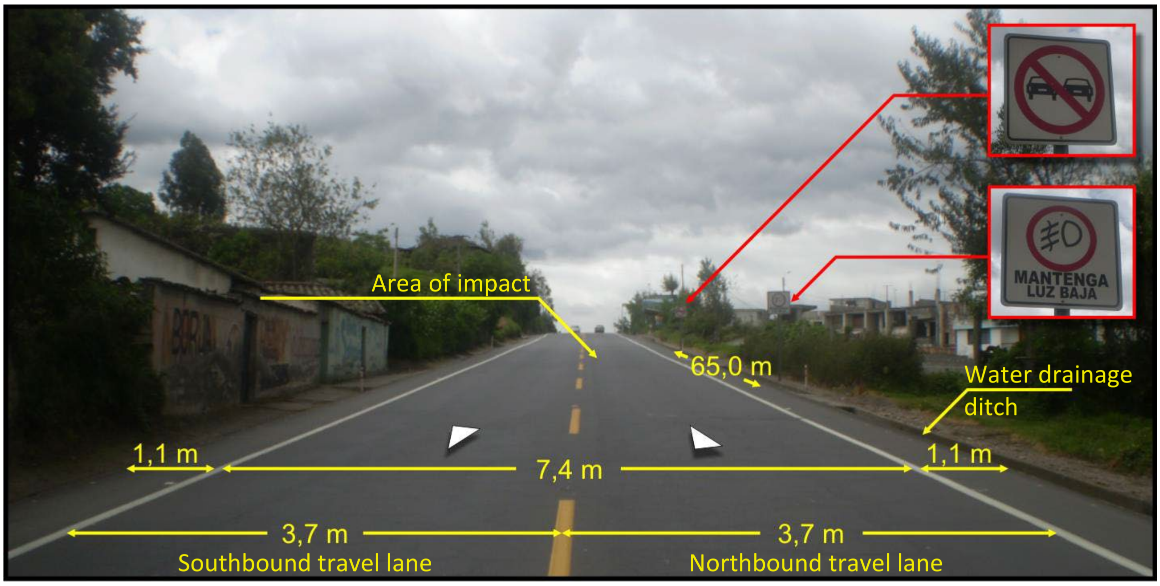
The rain, which had started several hours earlier, was still falling.

• Roadway characteristics

The crash site is located in the vicinity of km marker 75 of a single lane, two-way undivided road. The trafficway is 7.4 meters (24 ft) wide, comprising two opposing travel lanes separated by a broken yellow centerline. Each travel lane is 3.7 meters (12 ft) wide. A white edge line separates the asphalt paved shoulder from the trafficway. Each shoulder is 1.1 meter (3.6 ft) wide.

Roadway pavement (asphalt) is in overall good maintenance conditions, but the surface was wet due to the rain that was falling.

The vehicles involved were traveling uphill on the northbound travel lane and the collision took place approximately 200 meters (656 ft) before the crest of the hill.



Picture 1: Characteristics of the crash site

A water drainage ditch runs along the outer edge of the northbound shoulder, as seen in Picture 1.

The adjacent roadside terrain includes dense vegetation and buildings. Therefore, the crash site does not have a clear zone[1].

[1] **Clear Zone** - Traversable, unobstructed roadside area beyond the edge of the traveled way, available for safe use by errant vehicles.

The inspection of the crash site revealed the following traffic control devices: a regulatory sign indicating *low beam headlight* usage positioned to the right of the northbound travel lane. About 65 meters north of this sign, a regulatory *Do Not Pass* sign was recorded.

Along the left and right edges of the roadway, small kilometer markers painted white and red were recorded.

- **Markings and evidence**

We analyzed the pictures attained from local newspapers, seeing as they registered the crash scene minutes after the event.

These images show the final resting position of the passenger vehicle and debris scattered in an area of approximately 2.0 meters (6.6 ft). Crash debris included vehicle parts and broken glass. This physical evidence helps to pinpoint the estimated area of impact.

Picture 2: Inferred area of impact

The debris was recorded in the middle of the roadway, in an area between the traffic signs indicated in Picture 1, precisely 30 meters south of the regulatory Do Not Pass sign.

A distinct pavement marking was located on the northbound travel lane. This marking, a dual wheel tire track, starts at the “point of impact” (between the two traffic signs) and extends 85 meters (279 ft) north. This mark leads towards the right shoulder of the road (refer to Picture 3).

Picture 3: Dual wheel tire tracks

- **Final rest position of the vehicles involved**

According to pictures published in a local newspaper, and considering the vehicles' original travel heading, the SUV reached its final rest position in the middle of the road precisely between the two traffic signs (indicated in Picture 1), approximately 30 meters (98 ft) south of the regulatory Do Not Pass sign.

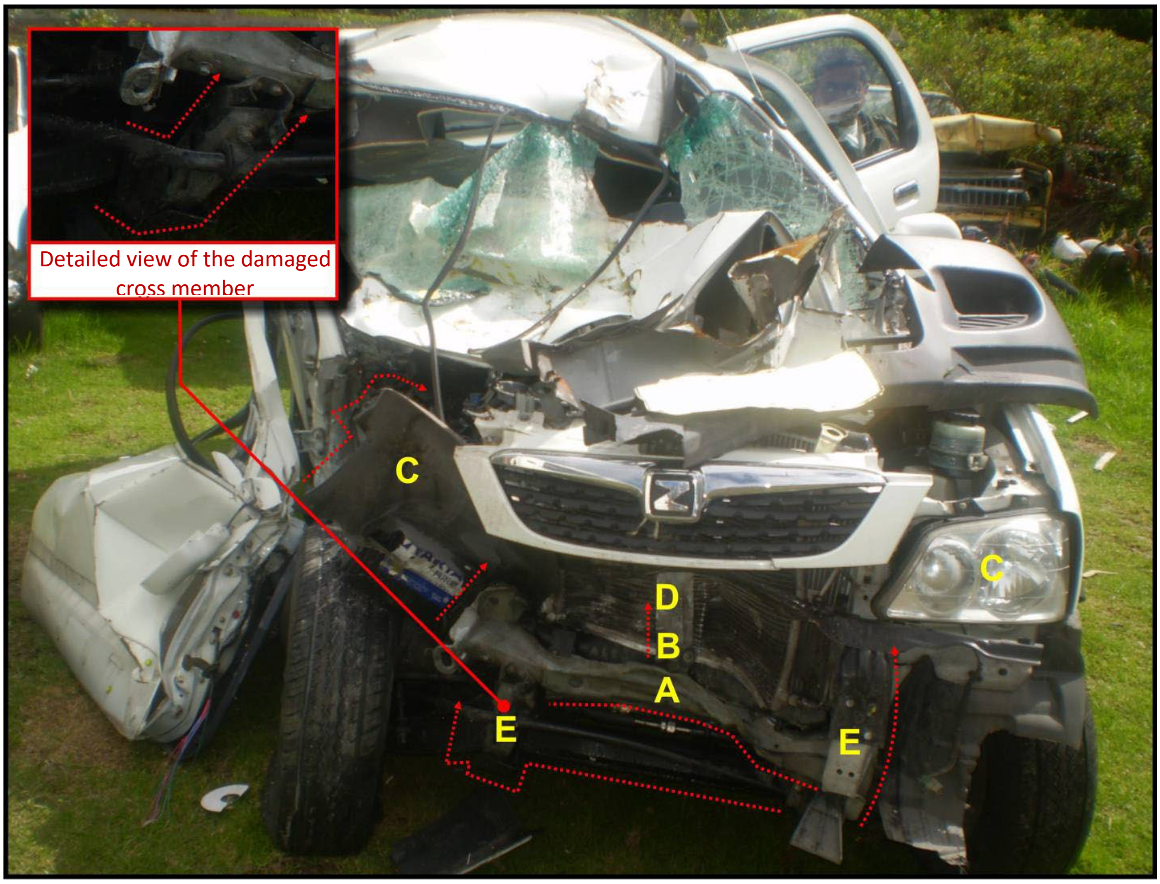
It stopped in the middle of the road with its front-end facing northeast and its rear wheels on the southbound travel lane.

The truck tractor and semi-trailer combination stopped on the northbound travel lane, near the right edge, approximately 150.0 meters (492 ft) after the area of impact. Its front-end was facing north.

- **Crush damage analysis**

The inspection of the passenger vehicle revealed major crush damage and deformation to the front-end and right front side of this unit. Crush force was oriented from front to back and from right to left.

The front-end of the vehicle was crushed inwards (towards the engine compartment), which affected the front bumper (Picture 6, reference A), front grill (reference B), and headlights (reference C). This also caused significant damage to the cooling system (Picture 6, reference D) and cross member (reference E).

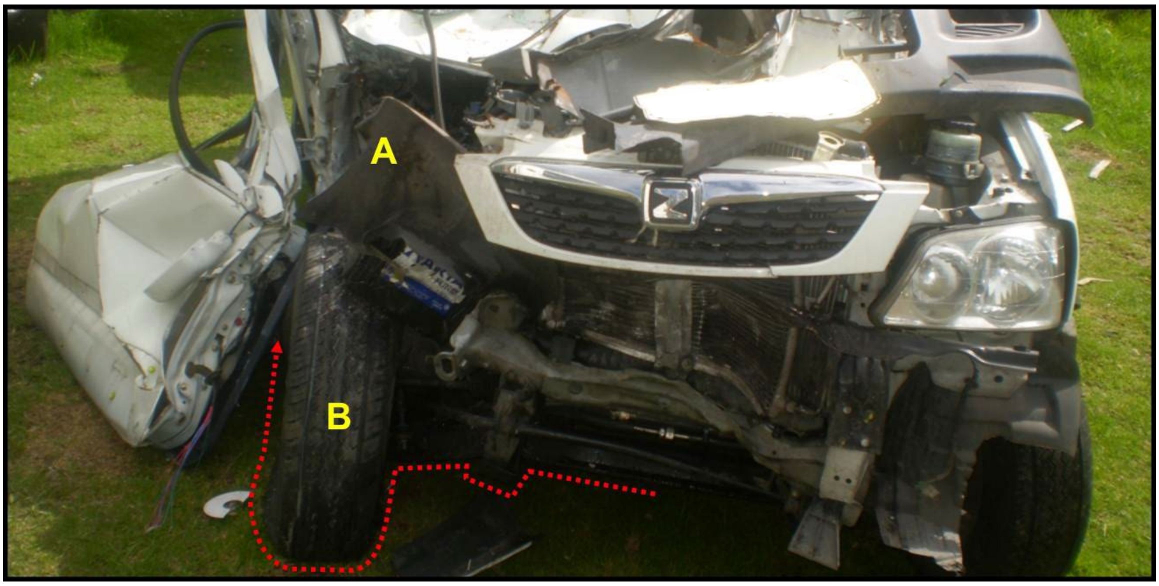


Picture 6: Damages to the front-end of the passenger vehicle

The hood was crumpled back and to the right. It hit and caused the windshield to shatter completely (refer to Picture 7).


Picture 7: Severely damaged hood

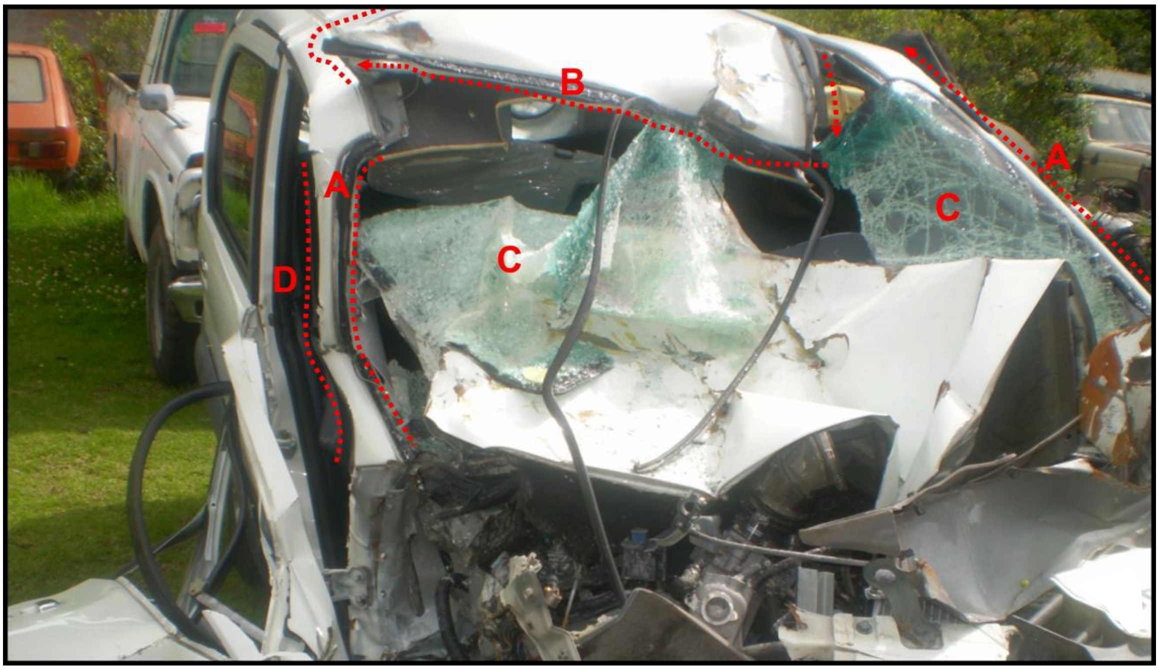
The right front fender also sustained significant crush damage (Picture 8, reference A). The right front wheel assembly was pushed back and the tire blew out (Picture 8, reference B).



Picture 8: Damage to the right front wheel assembly

The A-pillars were distorted, mainly the right one, which ended up in the shape of an “L” (90º), as seen in Picture 9, reference A.

The crush damage also affected the roof and windshield frame, and caused the detachment of the right front door (references A, C, and D).



Picture 9: Distortion affecting the front portion of the passenger compartment

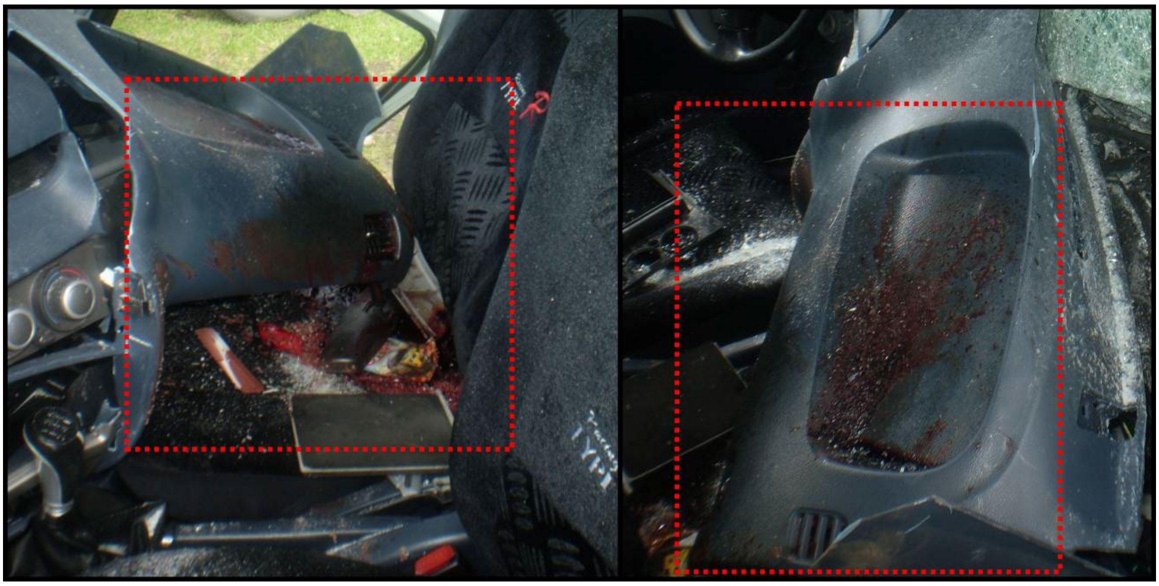
The crush force reduced the internal space on the passenger side. It also induced damage to the entire structure of the vehicle. More specifically, the misalignment of the driver door and left and right rear doors (refer to Picture 10).

Picture 10: Distortion and misalignment of the doors

The dashboard and right side door panel were displaced and reached the passenger seat, as seen in Picture 11.

Picture 11: Damage inside the passenger compartment

A large amount of body fluids was recorded on the right side of the dashboard and front passenger seat, as seen in Picture 12.

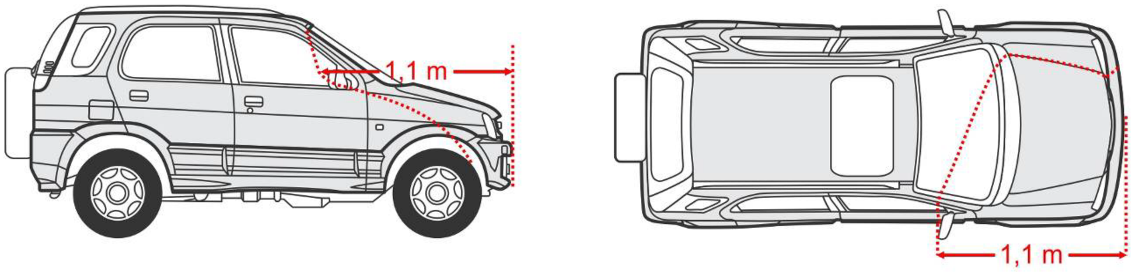


Picture 12: Evidence recorded on the dashboard and passenger seat

The inspection of the steering wheel revealed a distortion of the rim caused by a force that acted mainly on the right side of the rim. The damage was oriented from the driver's seat towards the dashboard (refer to Picture 13).

Picture 13: Damage to the steering wheel

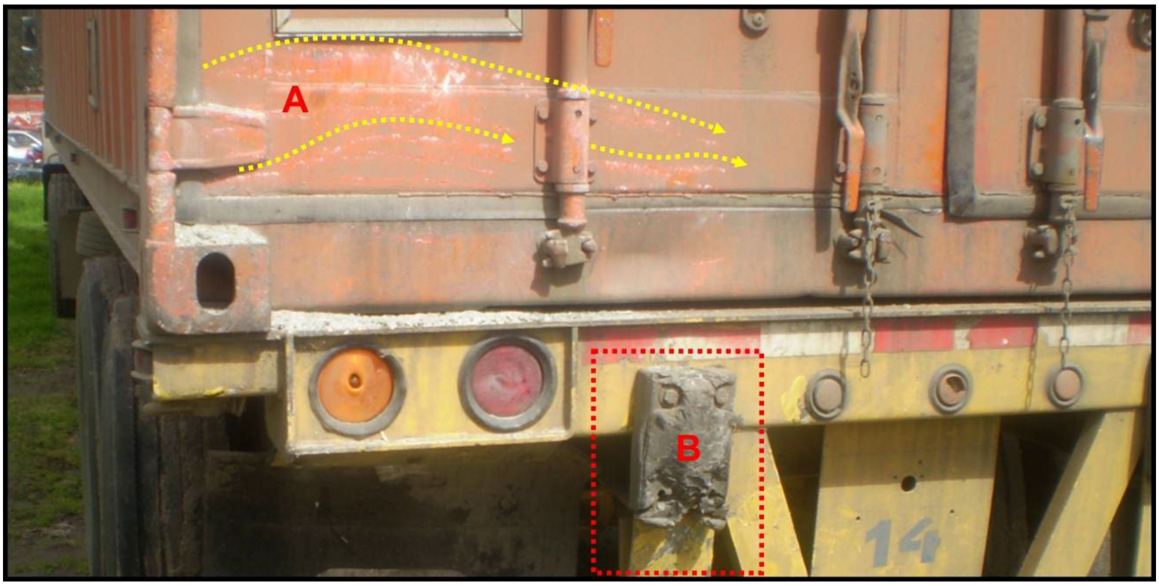
Residual crush damage recorded on the passenger vehicle was measured and recorded. The following illustration shows the average crush depth measured:



Picture 14: Maximum engagement[2]

The inspection of the semi-trailer revealed signs of impact on the left rear corner, which includes:

- Friction marks (scratches) on the left rear door of the van cargo body, as well as on the chassis (see Picture 15, reference A).
- Damage and friction marks (scratches) on the left side of the underride guard[3], indicated as reference B in Picture 15.



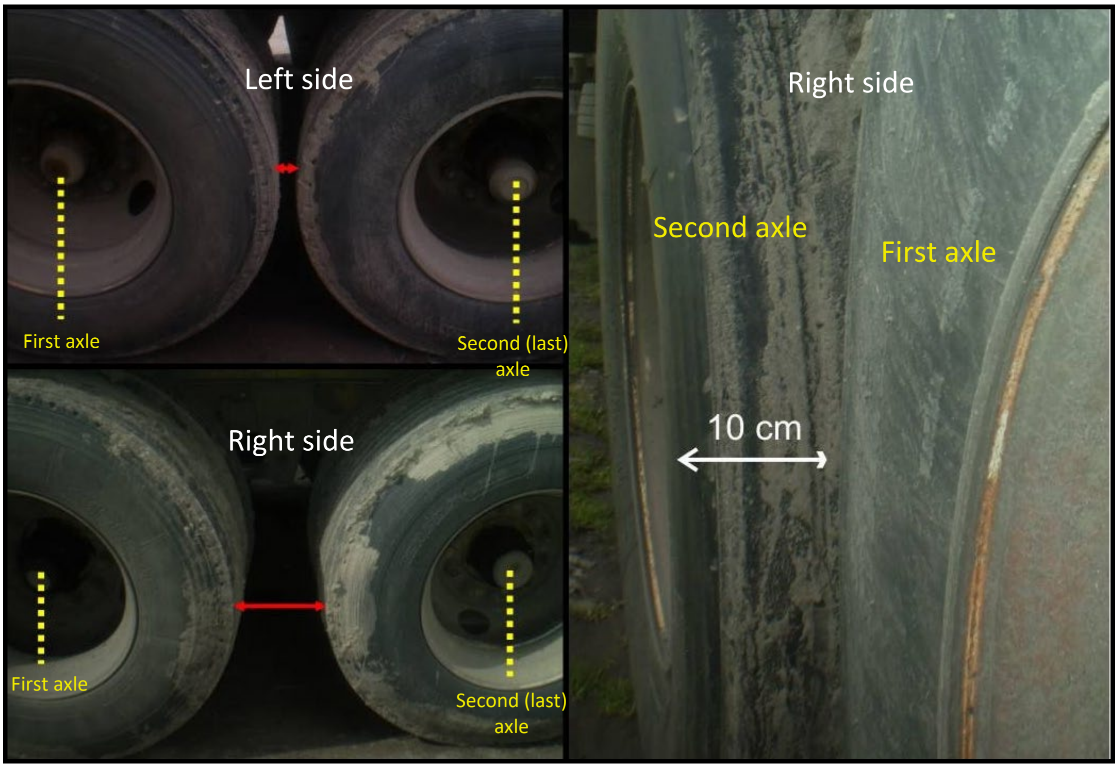
Picture 15: Damage recorded on the rear-end of the semi-trailer

The left side of the underride guard is bent inwards, as detailed in Picture 16.

[2] Maximum engagement – greatest penetration of one body, such a vehicle, by another during collision; moment of greatest force between objects in a collision.
[3] Underride Guard - a rear impact guard installed at the rear or under the rear of the cargo body of a truck or trailer so that when the vehicle is struck from the rear, it can limit the distance that the striking vehicle's front end slides under the rear of the truck or trailer.

Picture 16: Damage to the left side of the underride guard

The inspection of the left side of the semi-trailer revealed that the dual wheels on the second axle (last axle) were pushed forward. This reduced the tandem axle wheelbase and caused a 10.0 cm (3.94 inches) misalignment to the right between the tires on the right side (refer to Picture 17).



Picture 17: Displacement recorded on the last axle

1.2. Safety features and injuries sustained

SUV

The SUV was equipped with ABS brake system, but no airbags.

The tires were in overall good conditions. Tread depth measured was 5 mm on the left front tire, and 6 mm on the other three.

The driver of the SUV was not wearing his seat belt when the collision took place. This assumption is based on the fact that, during the inspection carried out by the CEPA crash investigator, the retractor system did not display signs of being jammed. According to *Moffatt* (1984), when a seat belt is adequately being used during a crash, seat belt webbing and hardware show specific signs called “traditional” load marks. However, in this specific case the seat belt webbing and hardware were in good shape and, moreover, clean. In other words, the webbing did not show signs of body fluids, and no evidence of cuts or damage. Due to the seriousness of the injuries sustained by the driver, the webbing would have needed to be cut during rescue and extrication operations had it been worn. Moreover, it would be impregnated with body fluids.

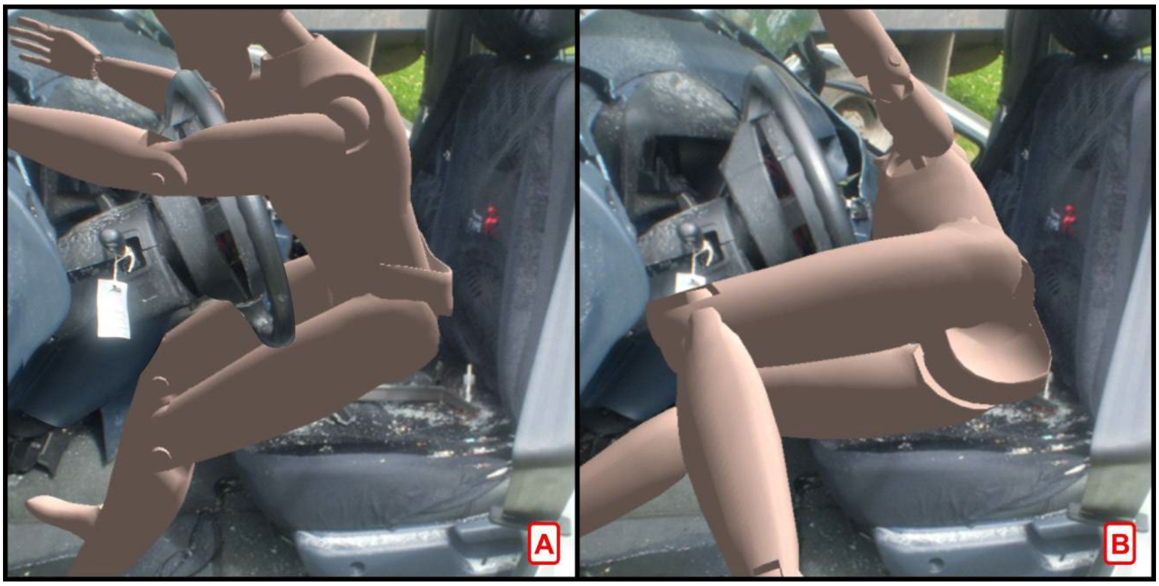
Finally, the inspection of the latch plate and buckle did not reveal signs of friction caused by metallic parts of the locking system, which would help to indicate that the seat belt was being worn.

Picture 18: Driver seat belt with no blood stains. The retractor, webbing, latchplate and buckle did not show signs of being subjected to collision forces

Another indication that the driver was not wearing his seat belt includes the damage to the steering wheel rim shown in Picture 13. This damage indicates that during the collision his body was projected forward, reached, and struck the steering wheel, as shown in Picture 19, reference A.

Due to the crash forces acting on the unit (detailed below), the body was immediately thrown to the right. The blood stains on the right edge of the dashboard and passenger seat corroborate that the driver's body moved towards the right and that his head came into contact with rigid parts inside the vehicle (see Picture 19, reference B).

The position assumed by the body during the development of the crash was also studied (occupant kinematics[4]). This movement is consistent with the damages and evidence recorded inside the passenger compartment. The body was not ejected (through front passenger door) because the dashboard created a "shell-like" area that retained him inside the structure of the vehicle.



Picture 19: Illustration showing occupant motion during the crash

Our investigator interviewed the coroner who stated that the driver died of severe head trauma to the right cerebral hemisphere. He also sustained severe trauma to his right eye globe, closed injury to the humerus and right collar bone, superficial injury to the right side of the thorax, closed injury to the right femur, and laceration of the right knee.

The doctor also stated he did not find evidence of internal bleeding in the chest, and all internal organs in the abdominal cavity were in good shape. If the driver had been wearing the seat belt, he would have sustained internal organ injuries caused by the seat belt sash positioned over the abdomen.

The doctor also stated that there were no injuries to the pericardium. Therefore, no heart failure was detected.

[4] Occupant kinematics involves the study of occupant motion inside a vehicle during a crash.

He reported that no food or alcohol remains were found in the stomach, but he took a 15 ml blood sample for future blood alcohol content (BAC) tests, if so required by the district attorney.

According to the doctor, the cause of death was hypovolemic shock and severe traumatic brain injury (TBI), which means death was instantaneous.

Truck tractor and semi-trailer

With regards to this unit, the taillights (brake, marker lights) were inspected. The wires were not cut and the rear lighting system was functioning properly.

There is no information about the truck driver's health condition and/or possible injuries since he fled the scene immediately after the collision. His whereabouts is still unknown, but it is highly probable that he did not sustain any injuries due to the size of the truck and the area affected in the collision.

Accident survivability

Occupant injury kinematics allows us to pose the following question: what would have happened had the driver been wearing the seat belt during the collision?

Had the driver been wearing the seat belt during the collision, he would have been restrained in his seat and not projected forward against the steering wheel. Despite this, the sash belt (positioned over the chest) would not prevent his body from being thrown to the right during the rotation, the lap belt would have held him in his seat and the sash belt would have prevented his head from reaching and hitting the dashboard. Moreover, the driver side did not display a considerable amount of reduction in terms of internal space. Therefore, we conclude that crash survivability in this case would have been high had the driver been adequately restrained in his seat by the belt.

1.3. Analytical study of motor vehicle crash dynamics

The analysis of the damage recorded on the vehicles revealed that the front end of the SUV sustained most of the crush damage, especially the right half of the unit, causing an average crush depth (maximum engagement) of 1.1 meter (3.6 ft). The semi-trailer showed signs of impact against the left edge of the trailer door, left edge of the underride guard, and the last axle.

The residual crush depth on the passenger vehicle (1.1 meter or 3.6 ft) is consistent with the cargo body overhang (distance between that last axle and the rear of the cargo body - 1.2 meter or 3.9 ft).

The analysis of the damage showed that the right front edge of the SUV struck the left rear corner of the underride guard. The SUV then ran under the cargo body. The underride reached the right A-pillar, windshield, and roof on the passenger vehicle. The shape of the cargo body became imprinted on the structure of the SUV, mainly on the A-pillar (see Picture 9, reference A).

The SUV remained entangled underneath the structure of the semi-trailer until its right front edge reached and struck the left wheels of the semi-trailer (last axle).

The signs found on that axle revealed that collision forces on the left wheels were oriented from the back to front and from left to right. This corroborates our hypothesis that the SUV rotated clockwise around the point of contact — the right front edge and the wheels of the semi-trailer.

The fact that the unit stopped near the area of impact and with its longitudinal axis (Y axis) positioned at a 45 degree angle with regards to the centerline also corroborates that there were two phases in the crash dynamics: phase one, rear impact (including underride); and phase two, rotation around the vertical axis (Z axis).

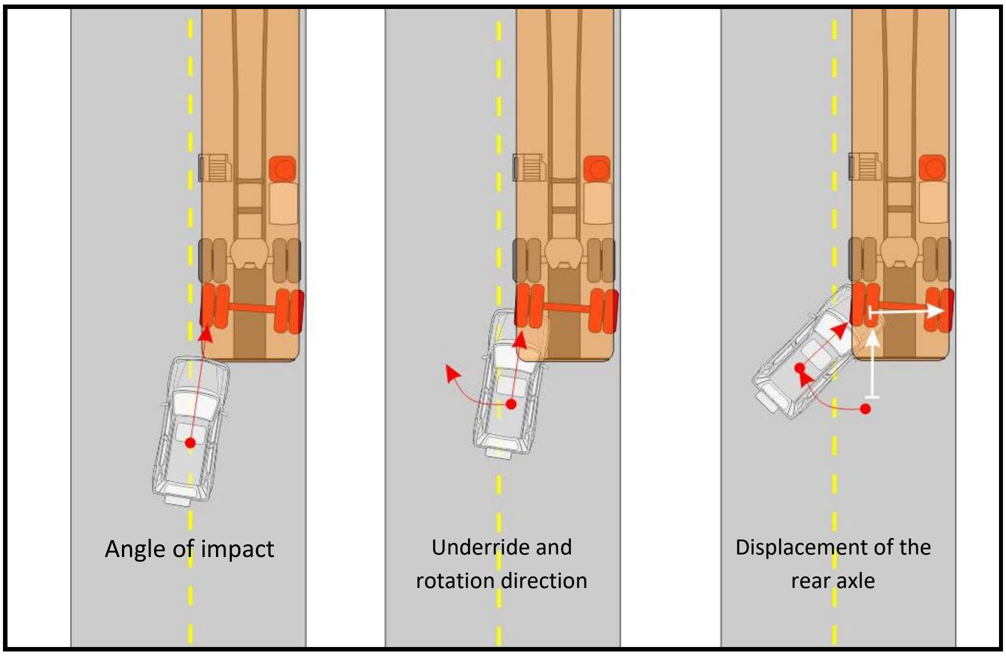
After the collision, the SUV stopped in the middle of the roadway, and the kinetic energy that was moving the car was dissipated as crush work and rotation. The unit stopped no farther than 2.0 meters (6.6 ft) from the point of initial impact.

The tire marks displayed in Picture 3 indicate that, following the collision, the truck started a normal deceleration (braking) process, dragging the rear wheels until it stopped approximately 200.0 meters (656 ft) ahead of the area of impact (as stated in the official police report).

Although the scuff marks[5] left by the right tires of the semi-trailer are only 85.0 meters (279 ft) long, this was not the entire distance covered. Since the surface was wet, the scuff marks were not imprinted on the unit's entire post-impact travel path.

Picture 20: Illustration showing the rear-end collision and underride (the rain is not shown here to ensure a better view of the vehicles)

[5] Scuff mark – a friction mark on a pavement made by a tire which is both rotating and slipping.



Picture 21: Rotation during the underride and damages to the rear axle of the semi-trailer

The underride caused major damage to the engine of the SUV and the deceleration separated the units. After this, the car stopped in the middle of the roadway, with its front end facing northeast.

After the impact, the truck tractor and semi-trailer combination continued moving towards the right edge of the road and stopped approximately 200.0 meters (656 ft) ahead.

The technical analysis of this collision — based on evidence found at the crash site, the study of damages to the units, and information provided in the police report — allowed us to calculate the energy dissipated by the SUV as crush work and rotation. It also enabled us to calculate the estimated the pre-impact travel speed of the SUV. The automobile was traveling at approximately 122 km/h (76 mph) before it struck the semi-trailer.

The physical models concerning post-impact distance traveled by the truck before it stopped (also including the length of the scuff marks found at the crash site) reveals that this unit was traveling at around 89 km/h (55 mph) at the moment of impact.

1.4. Probable crash causation

In order to determine crash causation, the manner of collision (rear-end crash) was taken into consideration and the position of the vehicles at the moment of impact was analyzed.

Therefore, it is possible to state that the longitudinal axis (Y axis) of the SUV was not aligned with the longitudinal axis of the roadway (centerline) at the moment of collision. This means that the passenger vehicle was positioned at an angle with regards to the roadway.

This allows us to establish the reason for the collision.

First of all, problems with target conspicuity and target contrast probably played a major role in this crash scenario. Most commonly with trucks, the misconception is that their large size by itself makes them conspicuous. However, size is only one of the factors that create contrast between the target (truck) and its background. The assumption that this one factor in itself will make the truck conspicuous and in turn allow approaching drivers to see the truck is a fatal mistake.

In this specific case, the collision took place when the driver of the SUV tried to pass the truck in an area where his passing sight distance was significantly hindered by roadway geometry and because he was taken by surprise by oncoming traffic.

The hypothesis of a pure rear-end collision has been dismissed. In this case, the driver of the passenger vehicle would have swerved left to avoid striking the truck, as well as, to protect his position inside the passenger compartment (an instinctive response). In this hypothetical crash scenario the final position of the SUV would also be different. It would have hit the rear underride guard and, due to impact angle, the vehicle would have deflected towards the left oncoming lane, before reaching its final rest position some meters ahead the point of impact.

The analysis of crash dynamics allowed us to determine that the angle of impact was offset to the right, which contributed to the rotation of the smaller unit and displacement of the rear axle of the semi-trailer (refer to Picture 21).

The SUV struck the semi-trailer at an angle, which prevented the rear underride guard from actuating or partially avoiding the underride by dissipating part of the energy during the post-impact travel path.

Because of the offset impact, the SUV ran under the cargo body in such a way that the kinetic energy that was moving it was totally dissipated as crush work and rotation. That is why it stopped only 2.0 meters (6.6 ft) ahead of the point of impact.

We, thus, came to the conclusion that the collision happened when the driver of the SUV was trying to overtake the truck and saw something on the oncoming lane that interrupted this maneuver (most probably oncoming traffic). He then tried to return to his original travel lane. However, his travel speed did not allow him enough time (or space) to complete the return maneuver. Therefore, he struck the rear of the truck he was trying to overtake.

2. Conclusions

The physical study showed that the driver was traveling behind the truck tractor and semi-trailer combination. He was traveling at about 122 km/h (76 mph). While trying to pass the truck, he spotted a hazard that made him return to his original travel lane. His speed prevented him from having enough time (or space) to complete this maneuver. He struck and ran under the semi-trailer. The impact happened at approximately 90 km/h (56 mph).

It is important to state that the driver knew the highway very well.

Besides his travel speed, rain and poor visibility additionally hindered the situation. At the crash site, there is a regulatory Do Not Pass sign precisely because of roadway geometry (uphill slope).

Until the conclusion of the present report, the whereabouts of the truck driver was still unknown. He fled the scene immediately after the collision, leaving his truck behind.

Due to the circumstances of the event, it is probable that he stopped the truck, got out and as he approached the SUV saw the conditions of the driver's body (dead, displaying serious head trauma). This may have shocked him and therefore he fled the scene. This assumption is made because the truck he was driving was legal, he was licensed to drive it, the taillights of the semi-trailer were working properly, and there were no elements that could point to him as the cause of the event.

Finally, according to the police report, anonymous eye witnesses who were traveling behind the SUV mentioned that the SUV driver was speeding and performing hazardous maneuvers. Other witnesses who were present at the crash site mentioned to the police that the SUV driver tried to overtake and ended up striking the truck.

3. References

1] "Manual de Investigación de Accidentes de Tráfico". *Autores: S. Baker and I.B. Fricke. Northwestern University. Editado por Sictra (España), año 2002.*

2] "Accidentología Vial y Pericia". *Autor: Víctor A. Irureta. Ediciones La Rocca. Bs.As. 1996.*

3] "Accidentes de Tráfico: Inspección del Vehículo". *Autores: Juan José Alba López, Alberto Iglesia Pulla. Grupo de Seguridad Vial y Accidentes de Tráfico de la Universidad de Zaragoza (España), Editorial Pons.*

4] "Energy as a Basic for Accident Severity – a Preliminary Study"- *Campbell K.L.-The University of Wisconsin, PhD Thesis Engineering – Automotive – U.S.A. June 1972.*

5] Truck Underride Collision Analysis – John C. Glennon – Crash Forensics.com

6] Crush Analysis with Under-rides and the Coefficient of Restitution - Institute of Police Technology and Management – April 27, 2006 - Jeremy Daily (*et al*)

7] Diagnosing seatbelt use or non-use – E. Todd Tracy

4. Sources

1] Inspection of the crash site carried out on February 07, 2012.

2] Damage inspection of the units involved.

3] Interview with the SUV driver’s daughter held on February 08, 2012.

4] Local Police crash report.

5] News article published in a local newspaper.

6] Interview with the coroner who performed the autopsy.

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CEPA International

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5. Attachment - Calculations

Translational post-impact energy (passenger vehicle)

$$E = W(\mu n + m)d$$

Input Value(s)	Unit	Value
W (Total static weight)	Kgf	1530.000
¼ (Acceleration/Deceleration factor)	G	0.700
n (Brake efficiency)	%	80.000
m (Slope)	%	20.000
d (Distance)	metros	2.000

Result for E (Kinetic energy) (J)

E = Kinetic energy = 22806.261 J

Rotational post-impact energy (passenger vehicle)

$$E = 0.00873Wfl\alpha$$

Input Value(s)	Unit	Value
W (Total static weight)	Kgf	156.017
f (Rotational friction coefficient)	G	0.600
I (Wheelbase)	metros	2.420
± (Angle after the rotation)	degree	45.000

Result(s) for E (Rotational Kinetic Energy of an object) (J)

E = Rotational kinetic energy = 872.740 J

Energy without permanent crush (passenger vehicle)

$$G = \frac{A^2}{2B}$$

Input Value(s)	Units	Value
A (Maximum force per unit of damaged length)	pounds-s	308.000
B (Crush resistance per unit of damaged length)	pounds-s2	135.000

Result(s) for G (dissipated energy with no permanent damage) (N)

G = Dissipated energy without permanent damage = 1562.875 N

Crush energy (passenger vehicle)

$$E=\left\{1+(\tan(\alpha))^2\right\}L_C\left\{\left(\frac{A}{2}\right)(C_1+C_2)+\left(\frac{B}{6}\right)\left(C_1^2+C_1C_2+C_2^2\right)+G\right\}$$

Input Value(s)	Units	Value
A (Angle at impact)	degree	0.000
LC (crush depth)	meters	1.500
A (Stiffness coefficient)	pounds-s	308.000
C1 (Size of crush 1)	meters	0.890
C2 (Size of crush 2)	meters	1.200
B (Stiffness coefficient)	pounds-s2	135.000
G (Stiffness coefficient)	N	1562.875

Results(s) for E (crush energy) (Ncm)

E = Crush energy= 85482055.446 Ncm

Post-impact speed (passenger vehicle)

$$V=\sqrt{\frac{2gE}{W}}$$

Input Value(s)	Units	Value
E (Kinetic energy)	J	878499.555
W (Total static weight)	Kgf	1530.000

Result(s) for V ((Vector) Speed) (m/sec.)

V = (Vector) Speed = 33.893 m/sec= **122 km/h (76 mph)**

Post-impact speed (truck)

$$V=\sqrt{2gd(\mu n+m)}$$

Input Value(s)	Units	Value
d (Distance)	meters	150.000
¼ (Friction coefficient on flat surface)	G	0.015
n (Brake efficiency)	%	80.000
m (Slope)	%	20.000

V = Initial speed (vector) = 24.978 m/sec = **89 km/h (55 mph)**

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