The Effect of Crash Avoidance Technologies on Truck Driver Fatality and Injury, and Identifying Residual Crash Types

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Outline

- Problem dimensions: Number of fatalities & injuries.
- Identification of riskiest crash types for truck drivers.
- Crash avoidance technologies:
  - Stability control.
  - Forward collision warning & mitigation.
  - Lane departure warning.
- Estimate effect of full deployment in the fleet.
- Identification of residual crash population.

Focus is on tractor-semitrailer crashes & drivers.
Truck, tractor-semitrailer & light vehicle driver fatalities

- Truck driver fatalities varied, but about the same as 2001.
- Light vehicle driver fatalities down 30% from 2001.
- Trucking in top 3 for occupational injury.
- Fatality rate about 7 times average.
What is to be done?

- Increase safety belt use
  - Belt use rates 84% in 2013.
  - Approaching light vehicles (87%).
- Deploy crash avoidance technologies
  - Effect of existing technologies.
  - Identification of residual crashes for interventions.
- Improve crashworthiness
  - More protective interiors
  - Improve restraints.
Identification of most dangerous crash types

- Most harmful event in crash.
- Rollover: 4% of crashes; 52% of fatal & serious inj.
- Collisions with other trucks & hard fixed objects.
- Fire, often after a collision.
Impact location for serious/fatal injuries

Impact location for serious driver injuries

- Front, 59.5%
- Right, 20.3%
- Left, 16.7%
- Back, 1.3%

Serious injury rate

- Front: 2.5
- Right: 0.7
- Back: 0.1
- Left: 0.6
Key Crash Avoidance Technologies

- Electronic stability control (ESC)
- Roll stability control (RSC)
- Forward Collision Avoidance and Mitigation Systems (F-CAM)
- Lane departure warning (LDW)
Electronic Stability Control (ESC) Roll Stability Control (RSC)

- Both ESC and RSC respond to lateral acceleration
- ESC senses divergent yaw rate & lateral acceleration
- ESC & RSC have mass-related intervention strategies
- Assess vehicle mass using engine torque and acceleration

- Braking strategies:
  - De-throttle engine
  - Engage engine retarder
  - Apply foundation brakes
  - ESC-selective wheel braking
Target Crash Types

- Untripped rollover
- Crashes precipitated by on-road loss of control

“Untripped rollover” typically on-road, precipitated by lateral acceleration and roadway friction.

Too fast in curve.

Loss of control crashes initiated by power unit yaw and skidding.

7.2% of all crash involvements.
F-CAM system characteristics

- Forward Collision Warning + Autonomous Braking
- Sensor range up to 100m
- FCW: audible, haptic warning
- Braking authority:

<table>
<thead>
<tr>
<th>Generation</th>
<th>Vehicle detected moving</th>
<th>Vehicle never detected moving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>0.35 g</td>
<td>No response.</td>
</tr>
<tr>
<td>Next</td>
<td>0.6 g</td>
<td>0.3 g</td>
</tr>
<tr>
<td>Future</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
</tbody>
</table>
F-CAM Intervention Sequence

- **t0**: Object tracked
- **t1**: Potential rear end collision detected
- **t2**: Hard braking required to prevent collision
- **t3**: Avoidance maneuver not possible
- **t4**: Crash prevented or mitigated

**System Reactions**
- **Warning Tone and Lamp**
  - **Engine Torque Limitation**
  - **Brake Activation**
Target Crash Types

Rear-end, truck striking

- Current generation:
  - Lead vehicle stopped at impact, but seen moving.
  - Lead vehicle slower, steady speed.
  - Lead vehicle decelerating.
  - Lead vehicle cut-in.

- Next, future generation:
  - Lead vehicle stopped at impact, regardless whether ever detected as moving.

8.6% of all tractor-semitrailer crashes
Lane departure warning

system characteristics

- Detect lane markings using windshield mounted camera.
  - Challenges: worn, missing lane lines; glare at night, especially on wet roads.
- Monitor truck position in lane.
  - Lateral position.
  - Speed.
  - Heading.
  - Compute time-to-lane crossing
- Detect lane crossing.
- Issue audible/haptic warning, if turn signal not activated.
- Active above set speeds (25-35 mph).
Target crash types

- Single-vehicle road departure, followed by untripped rollover.
- Single-vehicle road departure, collision with fixed object.
- Lane departure, same-direction sideswipes.
- Lane departure, opposite direction sideswipes and head-on.

5.1% of tractor-semitrailer crashes.
Estimating the Joint Effect of Crash Avoidance Technologies On the Crash Population accounting for:

- Electronic stability control (ESC)
- Roll stability control (RSC)
- Forward collision warning and mitigation (F-CAM)
- Lane departure warning (LDW)
Data

- Fatality Analysis Reporting System (FARS)
  - Census file of **fatal** traffic crashes in U.S.
  - Used 2010-2012.
- General Estimates System (GES)
  - Nationally-representative sample of police-reported crashes.
  - All severities.
  - Weighted to produce valid national estimates
  - Used 2010-2012.
- Combined FARS for fatal crashes with GES for non-fatal crashes.
Method

- Survey literature to identify most reliable estimates of effect of ESC, RSC, F-CAM, & LDW.
  - Based on field operational tests, fleet deployment, or hybrid.
  - Crash type filters implemented in available crash data.
- Develop algorithms to identify crash population applicable to each technology.
- Identify & filter exceptions.
- Apply effectiveness estimates by adjusting crash weights.
- Adjust effectiveness estimates to account for penetration of technologies into the existing fleet.
Effectiveness weight = (1-\(E_{ct}\)) * case weight
Where: case weight is the crash sample weight
\(E_{ct}\) is effectiveness of technology \(t\)
for crash type \(c\).

- Account for penetration of technology into existing fleet.

Case weight adjustment factor (CWAF)=1-\((E_{ct} * (1-P_{ty}))\)
Where: \(P_{ty}\) is penetration of technology \(t\)
for model year \(y\)

Final case weight=CWAF * case weight
Effectiveness estimates based on existing literature

- Field operational tests.
- Track testing.
- Simulation, including hardware-in-the-loop.
- Engineering evaluation of in-depth crash investigations.
- Analysis of carrier-based crash data.
# Effectiveness estimates table

<table>
<thead>
<tr>
<th>Technology</th>
<th>Estimated effectiveness depending on crash type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESC</td>
<td>0% to 75%</td>
</tr>
<tr>
<td>RSC</td>
<td>0% to 71%</td>
</tr>
<tr>
<td>F-CAM</td>
<td>0% to 60%</td>
</tr>
<tr>
<td>LDW</td>
<td>23% to 48%</td>
</tr>
</tbody>
</table>
## Crash reduction with full deployment of ESC, F-CAM, & LDW

<table>
<thead>
<tr>
<th>Measure</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>All crashes</td>
<td>-10.9%</td>
</tr>
<tr>
<td>K &amp; A-injury crashes</td>
<td>-30.8%</td>
</tr>
<tr>
<td>Driver injuries</td>
<td>-22.4%</td>
</tr>
<tr>
<td>Fatal injuries</td>
<td>-32.7%</td>
</tr>
<tr>
<td>A-injuries</td>
<td>-30.0%</td>
</tr>
<tr>
<td>All injuries</td>
<td>-22.4%</td>
</tr>
<tr>
<td>All rollovers</td>
<td>-39.7%</td>
</tr>
<tr>
<td>MHE rollovers</td>
<td>-42.7%</td>
</tr>
<tr>
<td>Frontal collisions</td>
<td>-21.1%</td>
</tr>
</tbody>
</table>
Joint effect on serious injury crash types

- Primary effect is to reduce MHE rollover.
- Collisions with:
  - Other trucks.
  - Hard fixed objects
- Reduce fatal & serious injuries by 30.8%.
Side struck in K & A-injury crashes current & after full deployment

- Front: 60% current, 55% full deployment
- Right: 20% current, 22% full deployment
- Back: 1% current, 1% full deployment
- Left: 18% current, 18% full deployment

Percent crash involvements

[Graph showing crash involvements for Front, Right, Back, and Left sides with blue and red bars]
Implications

- Collision avoidance technologies can have a significant effect on truck driver fatal & serious injuries.
- Rollover the primary crash type.
- Technologies reduce crash types that are the most risky for truckers.
- **However**, crashes remaining after full deployment are largely the same:
  - Rollover
  - Frontal collision
- Current technologies need to be improved.
- Remaining crashes may be more complex & challenging for technological intervention.
- Interventions to improve truck occupant protection in crashes.
Thank you!

Questions?

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