The Essentials of Truck Safety

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Outline

- Road safety introduction and basic concepts
- Influence of policy on safety
- Crash databases
- Crash data examples
- Emerging safety technologies
- Performance based regulation
- Novel special permit system
- Research project design – a case study
How big is the problem

- Commercial trucks involved in 6% of crashes
- They account for 11% of all fatalities
- Truck related crashes cost $19.6 Billion/yr in North America
Technology

Transport Efficiency & Safety

Human

Policy
Contribution to Safety

Time

Safety Benefit

Present time

Policy
State, NHTSA, FMCSA
FHWA, Fleet

Technology

Human
The Influence of Policy on Safety
LCV Safety Performance
(benefits are strongly linked to policy)

Source: Alberta LCV Safety Study
(Woodroffe & Associates)
## Best Practice Managed LCV Benefits

<table>
<thead>
<tr>
<th>Factors</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck VMT reduction</td>
<td>44%</td>
</tr>
<tr>
<td>Cost saving to shipper</td>
<td>29%</td>
</tr>
<tr>
<td>Reduction in fuel, $\text{CO}_2$ and $\text{NO}_x$ emissions</td>
<td>32%</td>
</tr>
<tr>
<td>Reduction in road consumption</td>
<td>40%</td>
</tr>
<tr>
<td>Exposure crash reduction</td>
<td>44%</td>
</tr>
<tr>
<td>Policy affected crash rate reduction (excluding VMT exposure reduction benefits)</td>
<td>500%</td>
</tr>
</tbody>
</table>
The Alberta LCV fleet crash rate is 5 times better than tractor semi-trailers

The LCV safety improvement is attributed to special permit road transport policy

42% of LCV collisions occurred under adverse conditions

Further improvements in safety performance of LCV’s can be expected if more aggressive weather restrictions were applied
Crash Databases
About Crash Databases

- Most consist of data recorded at the scene using police accident reports
- Some are more sophisticated with pre and post-crash information
- Most governments have crash databases
- Few can easily be accessed by the public
International Database

- International Road Traffic and Accident Database (IRTAD)
- 400 variables, includes aggregated data on injury accidents, road fatalities, vehicle population, network length, vehicle distance traveled from 28 countries (for 1965 and for every year since 1970).
- Contains tables – no raw data is available
US Databases

- Each state has a database but there is a lack of uniformity and the databases are not easily accessible.
- Federal databases are highly accessible:
  - Fatal Accident Reporting System (FARS)
  - National Analysis Sampling System (NASS)
Mission: The mission of FARS is to make vehicle crash information accessible and useful so that traffic safety can be improved.

Created in 1975.

Reporting criteria: Death of an occupant of a vehicle or a non-motorist within 30 days of the crash.
Fatal Accident Reporting System (FARS)

- The Accident Forms contain:
  - time and location of the crash
  - first harmful event
  - whether it is a hit-and-run crash
  - whether a school bus was involved
  - number of vehicles and people involved.

- The Vehicle and Driver Forms contain data on each crash-involved vehicle and driver
  - vehicle type
  - initial and principle impact points
  - most harmful event, and drivers' license status.

- The Person Form contains data on each person involved in the crash
  - including age, gender
  - role in the crash (driver, passenger, non-motorist)
  - injury severity, and restraint use
National Analysis Sampling System (NASS)

- Crashworthiness (CDS)
  - 5,000 cases per year
  - extensive detail, includes crush data, photographs, occupant strike data

- General Estimates System (GES)
  - 60,000 cases per year
  - contains data from police accident reports
A representative sample of approximately 50,000 police-reported crashes
60 sites around the U.S.
All severity levels of crash reports (from property damage to fatal)
Data are collected and computerized in a standard format
A sampling weight inversely proportional to the probability of case sampling is applied to each case
Using these case weights a national estimate is produced
NASS Crashworthiness (CDS)

- Detailed data on a representative, random sample of thousands of minor, serious, and fatal crashes
- Field research teams located at Primary Sampling Units (PSU's) across the country
- About 5,000 crashes are studied per year
- Passenger cars, light trucks, vans, and utility vehicles
NASS Crashworthiness (CDS)

- Trained crash investigators obtain data from crash sites
- Studying evidence such as skid marks, fluid spills, broken glass, and bent guard rails
- Locate the vehicles involved, photograph them, measure the crash damage, and identify interior locations that were struck by the occupants
- Researchers follow up on their on-site investigations by interviewing crash victims and reviewing medical records to determine the nature and severity of injuries
UMTRI (TDC) Systems

- TDC has maintained a system of crash data files modified into a common format and software to access the data since the early ‘70s.
- Contains state databases, nationally collected USDOT files, primarily FARS and NASS, as well as miscellaneous files.
UMTRI (TDC) Systems

- Users include the UMTRI researchers, auto company safety engineers, private engineering firms and public agencies

- All these users have a different need for analysis of the crash data and a different emphasis on what is important
UMTRI (TIFA) System

- Trucks involved in fatal accidents (TIFA)
  - Truck fatal crash data
  - Census file – retrospective data gathering
  - Telephone interviews
  - Continuous data from 1982
  - Total cases to date approx. 125,000
  - Cases per year 5,100
UMTRI (BIFA) System

- Buses involved in fatal accidents (BIFA)
  - Bus fatal crash data
  - Census file – retrospective data gathering
  - Telephone interviews
  - Continuous data from 2001
  - Total cases to date approx. 1,200
  - Cases per year 325
TIFA & BIFA

- Sponsored by Federal Motor Carriers Safety Administration
- Used for detailed safety studies involving trucks & buses
- Supports government policy and regulation activity
Crash Data
Truck Involvements in Fatal Crashes

Year
Number of Trucks Involved


Truck Involvements in Fatal Crashes

Number of Trucks Involved

0 1,000 2,000 3,000 4,000 5,000 6,000

Year

Ratio of Truck VMT to Passenger Car VMT

Year


Ratio


Recessions
Vehicles Involved in Fatal Crashes 1975-2005

![Graph showing the involvement rates of different types of vehicles (Passenger Car, Light Trucks, Large Trucks) from 1975 to 2005. The graph indicates a decrease in involvement rates over time.]
Distributions Of Gross Combination Weight (Trucks Involved In Fatal Crashes USA)

Source: TIFA 2002
Distributions Of Driver Age
(Vehicles Involved In Fatal Crashes USA)

Source: TIFA 2002
FARS 2002
Proportions of Drivers In Fatal Crashes With BAC 0.08 g/dl or Greater (USA)

Source: Large Trucks, Safety Facts 2003, NHTSA
Emerging Technologies
Influence of Emerging Technologies

- New technologies not only inform the driver but some also intervene
- Technologies that avoid collisions are highly valued
- Technologies can outperform the human resulting in a new level of benefit
Vehicle Technologies

1. Lane Departure Warning Systems
2. Roll Stability Systems and Electronic Stability Systems
3. Forward Collision Warning Systems with Adaptive Cruise Control
4. Vehicle diagnostic and location systems
Forward collision warning
Adaptive cruise control

- Truck striking rear end collisions are common
- May influence approximately 21% of crashes
- Maintains 2 to 3 second following gap
# Stability Systems

<table>
<thead>
<tr>
<th>Road Surface Coefficient of Friction</th>
<th>Ice (Low)</th>
<th>Wet Asphalt</th>
<th>Dry concrete (High)</th>
</tr>
</thead>
</table>

### Driving Scenario Example
- **Ice (Low)**: Lateral force exceeds surface friction, vehicle begins to slide/jackknife.
- **Wet Asphalt**: Vehicle speed too fast for curve, exceeds rollover threshold, vehicle roll over imminent.
- **Dry concrete (High)**: Vehicle roll over imminent.

### Stability System Action
- **Ice (Low)**: System applies individual brakes to:
  - Reduce speed / correct orientation
  - Reducing tendency to jackknife/slide

- **Wet Asphalt**: System applies all brakes to:
  - Reduce speed
  - Reducing roll over risk

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**UMTRI** 40 Years...

The Science of Driving
Applying Science to Vehicle Performance
(Performance Based Regulation)
Truck Performance Based Regulation

- First developed in 1986 for the Canadian Size and Weight study
- Provides an objective scientific measure of vehicle safety performance and compatibility
- Australia has replaced its prescriptive regulatory system with performance based system
Vehicle Dynamic Performance

- Performance based methods exist to evaluate vehicle dynamic behavior.
- Coupling methods have a significant influence on vehicle stability performance.
- Longer trailers tend to be less dynamically sensitive.
KEY PERFORMANCE MEASURES

- Steady-state roll stability
- Rearward amplification
- Load transfer ratio
- High-seed offtracking
- High-speed transient offtracking
- High-speed friction utilization
- Low-speed offtracking
- Low-speed friction utilization
LANE CHANGE MANOEUVRE

Lateral acceleration

- at trailer COG vs. time
- at tractor COG vs. time

88 km/h
61m
1.46 m

(not to scale)
LANE CHANGE MANOEUVER

Is used to resolve:

- rearward amplification
- load transfer ratio
- high-speed transient offtracking
- high speed friction utilization
HIGH SPEED CONSTANT RADIUS

High-speed offtracking

393.7 m radius

100 km/h

path of steer axle
path of trailer axle
HIGH SPEED CONSTANT RADIUS

_is used to resolve:_

- high-seed offtracking
LOW-SPEED 90° TURN

- path of steer axle
- path of trailer axle

low-speed offtracking

12.8 m radius

5 km/h
LOW-SPEED 90° TURN

Is used to resolve:

- low-speed offtracking
- low-speed friction utilization
Novel Special Permit Systems
The Saskatchewan Initiative Case Study

The Partnership Program:
- support economic development
- provide additional revenue for roads
- promote vehicle efficiency and safety
- control industrial traffic
The Saskatchewan Initiative

- Determine the transport savings

  *If the study results are favorable an agreement is formed:*

- Specifies
  - weights and dimensions
  - specifications and standards
  - haul routes
  - operating and and maintenance details
  - driver qualification requirements
The Saskatchewan Initiative

- During operation, safety and financial audits are conducted to ensure compliance

**THE PAYOFF**

- Truck haul savings attributed to the new vehicle design are determined
- Incremental costs are deducted e.g. bridge strengthening costs
The Saskatchewan Initiative

Of the remaining savings:

- 50% to the transporter
- 50% to a special government account for road improvement projects jointly agreed upon by government and carrier
Special Permit Management

- Acceptance into the program require a minimum performance threshold
- Require special safety technologies on vehicle
- Regular incident reporting by carriers important to ensure maximum benefit
- Highway safety and weight violation information linked to performance evaluation
- Meaningful enforcement is essential
- The system should foster pride – it should be seen as a privilege and not a right
Safety Research Project

Project Design

Case Study
Project Goals

- To define the pre-crash scenarios and identify factors associated with loss of control and rollover
- To review the applicability of stability enhancing technologies to each of the scenarios
- To develop a high fidelity independent measure of the relative safety effectiveness of the approaches to stability control
Technologies to be Investigated

- Full electronic stability control (ESC) on the tractor.
- Tractor-based roll stability control (RSC).
Major Tasks

- Task A: Review data sources from previous and ongoing related work
- Task B: Develop a set of pre-crash scenarios through analysis of crash data
- Task C: Obtain exposure and frequency of occurrence information from existing FOT databases
- Task D: Estimate effectiveness of technology through hardware-in-the-loop simulation
- Task E: Analyze safety effectiveness
- Task F: Prepare final report and final briefing
Prime Activity Modules

- Fleet Case Studies
  - Identify effectiveness of systems in fleets
  - Identify crash types most affected
  - Obtain fleet crash rate reduction estimates
  - Obtain fleet cost effectiveness
  - Identify crash scenarios

- State Crash Analysis
  - Perform clinical analysis of PARs and crash reconstruction documents
  - Confirm / modify crash scenarios hypotheses

- National Crash Databases
  - Determine frequency of selected crash scenarios
  - Determine severity characteristics of selected crash scenarios
  - Estimate likely benefits

- Naturalistic Driving Databases
  - Identify likely pre-crash scenarios
  - Provide insight into probable incident approach speed range

- Hardware in-the-Loop
  - Examine the detailed sequence of various crash scenarios
  - Estimate speed ranges where technologies can be effective for various driving conditions
  - Study the relative performance of the various technologies
Crash Data Analysis

Objectives –

- to determine the primary conditions that contribute to vehicle LOC and/or rollover
- to identify the major LOC and rollover crash scenarios
- to estimate the number of crashes that have the potential of benefiting from this technology
Crash Data Sources

- TIFA/FARS
- NASS GES
- LTCCS
- North Carolina state crash data
- Clinical reviews of rollover crashes from California, North Carolina, and selected other states with high-quality crash reconstructions
Clinical Review of Crashes

- Sample from primary scenarios
- Sources: TIFA, LTCCS, State (NC) PARs
- In TIFA, over-sample CA: very detailed
- NC PARs available

Outcome:
- More detailed scenarios
- Engineering judgment of technologies
- Distribution of speeds
Example Clinical Review Interface

**UMTRI Summary:**
No statement of conflicting by investigator. Scene diagram shows vehicle passed clockwise at rollover. No evidence in change of grade from roadway to roadside (narrow gravel shoulder). Yet, one of the look-back photos (#1) shows a scuff. But the vehicle is virtually unmarked; the scuff is not pronounced, and tires/wheels show no damage or impacted soil. Can't see any evidence that the vehicle actually rolled. There is green paint on the swing set, but vehicle is black. Was the investigation well after the accident? The weeds are tall in front of the guardrail allegedly struck.

**NASS Summary:**
Dynamic Simulation

- Hardware in the Loop (HiL) essential for faithful rendering of critical components:
  - Air brake actuation (nonlinear, transient lags)
  - Control hardware (proprietary control logic)

- Software based simulation for other components:
  - Basic vehicle (via Trucksim)
  - Engine and drivetrain (via Simulink)
  - Driver – closed-loop and fallible
Hardware in the loop

Simulation

- TruckSim offers Real-time Simulation in Combination with SIMULINK and the TruckSim Animator
Overview of Cost-Benefit Methodology

- **Indirect Benefits**
  - Improved Competitiveness
  - Driver Retention & Training costs
  - Reduced Insurance Cost

- **Direct Savings**
  - Number of crashes Preventable
  - Cost of Crashes

- **Total Benefits**
- **Total Costs**

- **Anticipated Payback Period and ROI**
Concluding Comments

Evolution Safety Innovation

- **Passive**
  - Seat belt
  - Collapsible steering column

- **Active**
  - Air Bags
  - Lane departure warning

- **System control**
  - Electronic stability systems
  - “The next big thing”

- **Crash worthiness** → **Crash avoidance**