Evaluating Crash Causation in Commercial Vehicles using Naturalistic Data

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Presentation Overview

• Virginia Tech Transportation Institute (VTTI) overview
• What is naturalistic data collection?
• Commercial Vehicle Field Operational Test
• Key Results
• Hours-of-Service Analysis
• Summary
VTTI Safety Research

VTTI Safety Research Centers

• Center for Truck and Bus Safety
  Rich Hanowski, Director

• Center for Automotive Safety Research
  Jon Hankey, Director

• Center for Vehicle-Infrastructure Integration
  Vicki Neale, Director

• Center for Product Development
  Mike Mollenhauer, Director
Sample Capabilities

- Virginia Smart Road
- Car and truck fleet
- Truck Driving Simulator
- Naturalistic Driving
- Database Analyses
Safety Research Impact

- VTTI conducts research that has a measurable impact on National Transportation Policy
  - Driver distraction
  - Hours of Service
  - Truck driver fatigue
  - Night visibility enhancement
  - Indirect visibility for trucks
  - School bus safety
  - Intersection crash avoidance
  - Teen driving safety
  - Evaluate ITS technologies
  - Transportation policy effects
Naturalistic Data Collection

• “in the natural or original position or place”
• Collecting driver behavior and performance data in a naturalistic environment
• Examples:
  – as light vehicle drivers commute to/from work (e.g., 100-Car Study)
  – as truck drivers operate their vehicles on revenue-producing runs (e.g., Sleeper Berth Study, Local/Short Haul Study)
• High validity
• Low control
Naturalistic Method

- Study participants use an instrumented vehicle for an extended period (e.g., several months to one year)
- Able to get detailed pre-crash/crash information along with routine driving behaviors
- Highly capable data acquisition systems (well beyond EDRs)
- Able to collect crash pre-cursor data and driver performance/behavior data using sensors and video cameras
Drowsy Driver Warning System
Field Operational Test

• Sponsor
  – US Department of Transportation

• Purpose
  – Collect data that can be used to evaluate the effectiveness and operational capabilities, limitations, and characteristics of a drowsiness monitor
Approach

- 46 trucks were instrumented with the DDWS and a Data Acquisition System (DAS)
- 103 drivers participated
- Continuous data collection approach used
- Over 100 data measures collected on driving performance (e.g., lane position), actigraphy, questionnaires
- 4 video cameras also included
Data Collection Statistics

- ~ 2.5 million miles of driving data
- ~ 190,000 hours of actigraphy data
- ~ 12 terabytes of data
- In terms of data collected, largest on-road study ever conducted
- Data are presently archived at VTTI “live” on a Storage Area Network (SAN) system
- Great potential exists to mine the data to explore various issues
Finding Critical Incidents

• How are incidents identified in this large data set?
• Five event triggers
  – Longitudinal Acceleration
  – Time-to-Collision
  – Sw
  – Critical Incident Button
  – Analyst Identified
Data Reduction and Analysis

• Data Directory
  – Used GES, FARS, LTCCS as models
  – Listed all relevant variables
    • Weather, road type, traffic, contributing factors
  – Variables relating to both subject driver/vehicle and other driver/vehicle
Analysis Overview

• Federal Motor Carrier Safety Administration (FMCSA)-sponsored study
  – Investigate research issues relating to:
    • Driver performance
    • Crash causation (crash pre-cursors)
    • NOT the safety benefits of DDWS

• Leveraged data from the DDWS FOT (“data mining”)
  – Preliminary analysis
    • May 2004 to May 2005 (75% of data)
    • 95 drivers (94 males, 1 female)
      • Mean age 39.5 years old
      • Mean CMV experience 10.5 years
Research Issues

• Discussions with FMCSA identified four priority issues:
  – Analysis of heavy vehicle safety events
  – Correlates of driver risk
  – Countermeasure identification
  – Driving patterns and work/rest schedules
Results

- Crashes: $14 + 14$ tire strikes = 28 total
- Near-crashes: 98
- Crash-relevant conflicts: 789
- Total safety-critical events (i.e., the sum of the above): 915
- Baseline epochs: 1,072
Issue 1: Analysis of Heavy Vehicle Safety Events

• Top 5 Critical Reasons coded to truck driver (V1):
  – Inadequate evasive action (14%)
  – Internal distraction (10.8%)
  – External distraction (6.2%)
  – Misjudgment of gap or others speed (5.7%)
  – Too fast for conditions (5.4%)

• Top 5 Critical Reasons coded to other driver (V2):
  – Apparent recognition or decision error (18.4%)
  – Aggressive driving (2.1%)
  – Too slow for traffic (1.5%)
  – Other illegal maneuver (1.1%)
95 Drivers:
- Worst 15
- Middle 30
- Best 50

Exposure (Hours Driving):
- 10.5%
- 34%
- 55.5%

# of At-Fault Events:
- 40.3%
- 47.4%
- 12.3%

Issue 2: Correlates of Driver Risk
What the Results Mean…

• Driver-related factors are most important
• Minimize internal distractions
  – No cell-phone while driving policy?
• Defensive driving is critical and should be a major component of a fleet’s training program
  – Smith System
  – FMCSA-VTTI’s “Driving Tips” website (Winter 2008)
• There is a need to reach/educate the light vehicle driver and there is a need to reach law enforcement officers (need for more aggressive enforcement of existing laws)
• Incidents often occur when driver appears to be really comfortable with things…
Implications Beyond Trucks

- Do these findings apply to car drivers and other fleet drivers?
- YES, with regard to driver behavior being key
- In VTTI’s 100-Car Study, *Inattention to the forward roadway* was the primary contributing factor
- 80% of all crashes and 65% of all near crashes involved at least one form of driving inattention just prior to (i.e., within 3 seconds) the onset of the conflict
- 86% of the lead vehicle crashes, the headway at the onset of the event was > than 2.0 seconds
Summary

• Naturalistic data collection provides a new and unique perspective to assess crash causation
• Provides an “instant replay” of the incident, and allows you to focus on driver behavior and crash pre-cursors
• This information is otherwise gained from eyewitness reports, police reports, second hand observations
• But, these aren’t always accurate…
Analysis of Risk as a Function of Driving-Hours 1 Through 11: Implications for the Hours-of-Service Regulations for Commercial Vehicle Drivers
Project Overview

- The revised Hours-of-Service (HOS) regulations were published on April 28, 2003
- Two main changes:
  - Increase in off-duty time from 8 to 10 hr
    - Hanowski, Dingus, Sudweeks, Olson and Fumero (2005)
  - Increase in allowable driving time from 10 to 11 hr
    - Mixed results
    - Hanowski et al. (2005) & Wylie et al., (1996) found no effect of time-on-task
    - Park, Mukherjee, Gross, and Jovanis (2005) did find an effect, but relied on retrospective fleet crash reports
Method and Research Questions

• Data collected during a Field Operational Test (FOT) of a Drowsy Driver Warning System (DDWS)

• Data collection began in May 2004 and ended in September 2005 (after the implementation of the revised HOS regulations)

• Analysis included:
  – Critical incidents as a function of driving-hours 1 through 11
  – Critical incidents as a function of time-of-day
Critical Incidents

- Critical Incidents = crashes, near-crashes, and crash-relevant conflicts
- Crash = Contact with an object, either moving or fixed, at any speed
- Near-Crash = Any circumstance that requires a rapid, evasive maneuver (e.g., hard braking, steering) by the subject vehicle or any other vehicle, pedestrian, cyclist, or animal, in order to avoid a crash
- Crash-Relevant Conflict = ...less severe evasive maneuver as compared to Near-Crash
Key Results

- Driving Hours 1 through 11
- Conducted 8 sub-analyses, parsing the data in different ways to help ensure no significant findings were overlooked
- For each driving hour, frequency of critical incidents and opportunities (exposure) was determined
Relative Frequency Calculation

• A rate was calculated:

  *Critical Incidents per Driving-Hour*

  *Total Opportunities per Driving-Hour*

• Examples:
  
  – Driving Hour 1: Rate = 0.026

    122 Critical Incidents
    4748 Opportunities

  – Driving Hour 11: Rate = 0.015

    23 Critical Incidents
    1535 Opportunities

• Odds ratios on the rates were evaluated
Time-on-Task Results: At-fault

Critical Incident Relative Frequency as a Function of Driving-Hour where the Subject Driver was At Fault
Time-on-Task Results: 11th Hour Drives (N=1535 trips), At-fault

Critical Incident Relative Frequency as a Function of Driving-Hour for Trips that went into the 11th Driving-Hour, and the Truck Driver was At-fault
Time-of-Day Results

Number of Trips as a Function of Time-of-Day

Number of Trips as a Function of Time-of-Day
Time-of-Day Results

Critical Incident Relative Frequency as a Function of Time-of-Day

Critical Incident Relative Frequency as a Function of Time-of-Day
Time-of-Day Follow-Up Analyses

• First, looked at circadian lows vs circadian highs (nothing significant); this analysis is outlined in the report
• Next, looked at traffic density
• Plotted data from Festin (1996) that was broken up by time-of-day…
Time-of-Day/Traffic Density Results

Critical Incident Relative Frequency as a Function of Time-of-Day, with Traffic Density Plot Superimposed ($R^2=0.69$)
Conclusions

• Study resulted in a major finding that is relevant to the assessment of the 2003 HOS regulations
• A statistically significant difference in critical incident relative frequencies between the 1\textsuperscript{st} driving-hour and all other driving-hours
• However, there was generally no statistical difference between the 2\textsuperscript{nd} through 11\textsuperscript{th} driving-hours
Consistent Results

• 1st hour “spike” was also seen in the LTCCS database
  – Of all hours, 1st driving-hour had the highest raw percentage of crashes (14.7%)
  – Note that the LTCCS database does not account for exposure, however the current study with naturalistic data did

• Findings from this study are consistent with Wylie et al. (1996) with regard to time-on-task; i.e., poor predictor of crashes…except for the first hour
No Difference in Hours 2-11

• Why the 1\textsuperscript{st} hour spike?
  – Sleep Inertia?
  – “Take-off” and “Landing” effects?
  – Time-of-day?

• Study results do not support the hypothesis that there is an increased risk from CMV drivers driving in the 11\textsuperscript{th} hour as compared to the 10\textsuperscript{th} hour, or any driving-hour

• Caution: Though this dataset is perhaps the best of its kind, it represents a small fraction of CMV drivers, vehicles, miles driven, and there were very few crashes
What Can Drivers Do?

• Come to work well rested
  – Need to be ready physically and mentally
• Know that the early in the shift, they may come across relatively more difficult driving situations (for a number of reasons)
  – Be vigilant and “expect the unexpected”
  – Practice defensive driving
• When driving in traffic, situation awareness must be such that it can accommodate the increased demands
Questions?

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