The Essentials of Truck Safety

Presented to
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Midwest Transportation Consortium
Scholar Series

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Outline

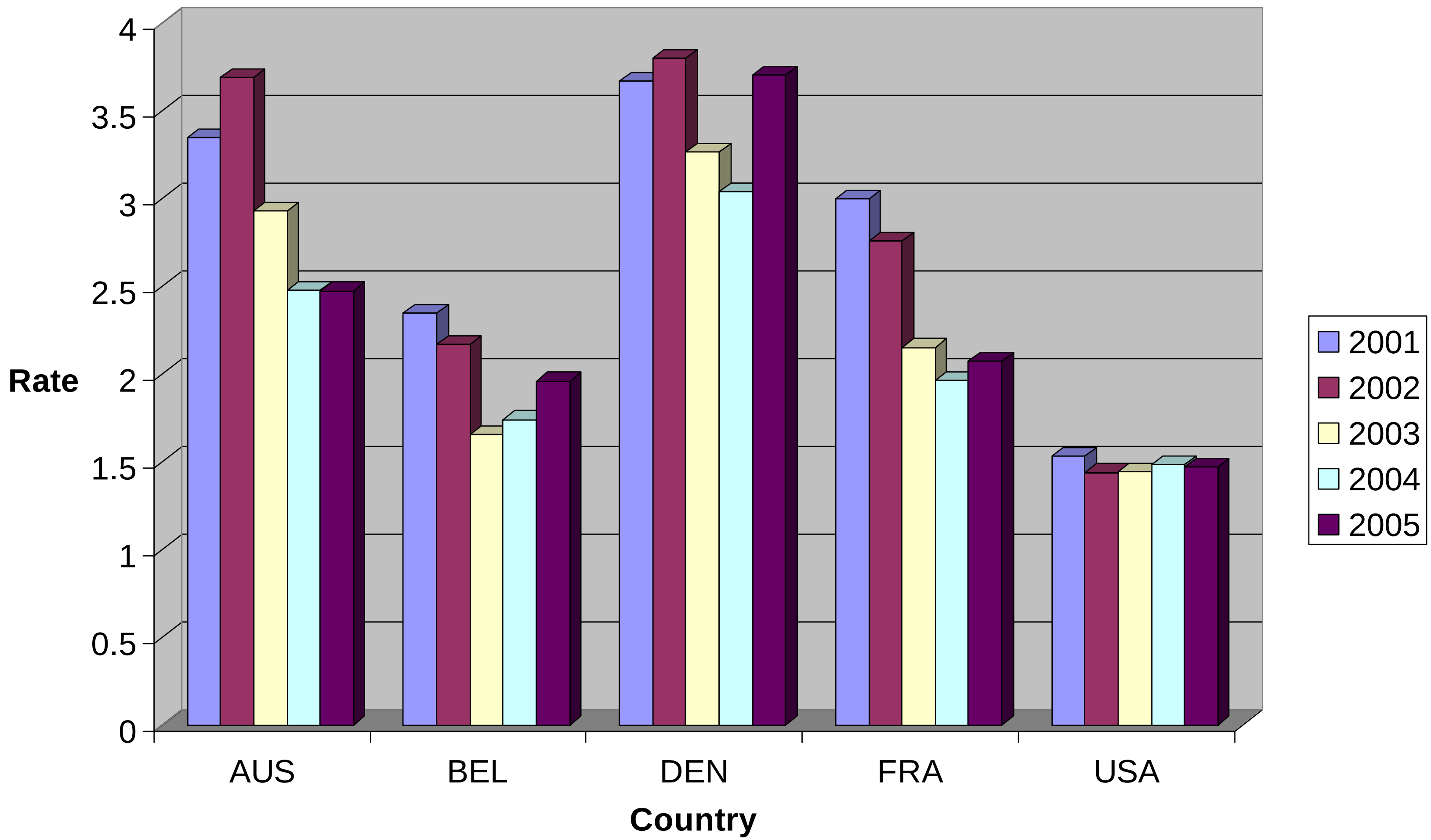
- Road safety introduction and basic concepts
- Influence of policy on safety
- Crash databases
- Crash data examples
- Emerging safety technologies
- Performance based regulation
- Novel special permit system
- Research project design – a case study

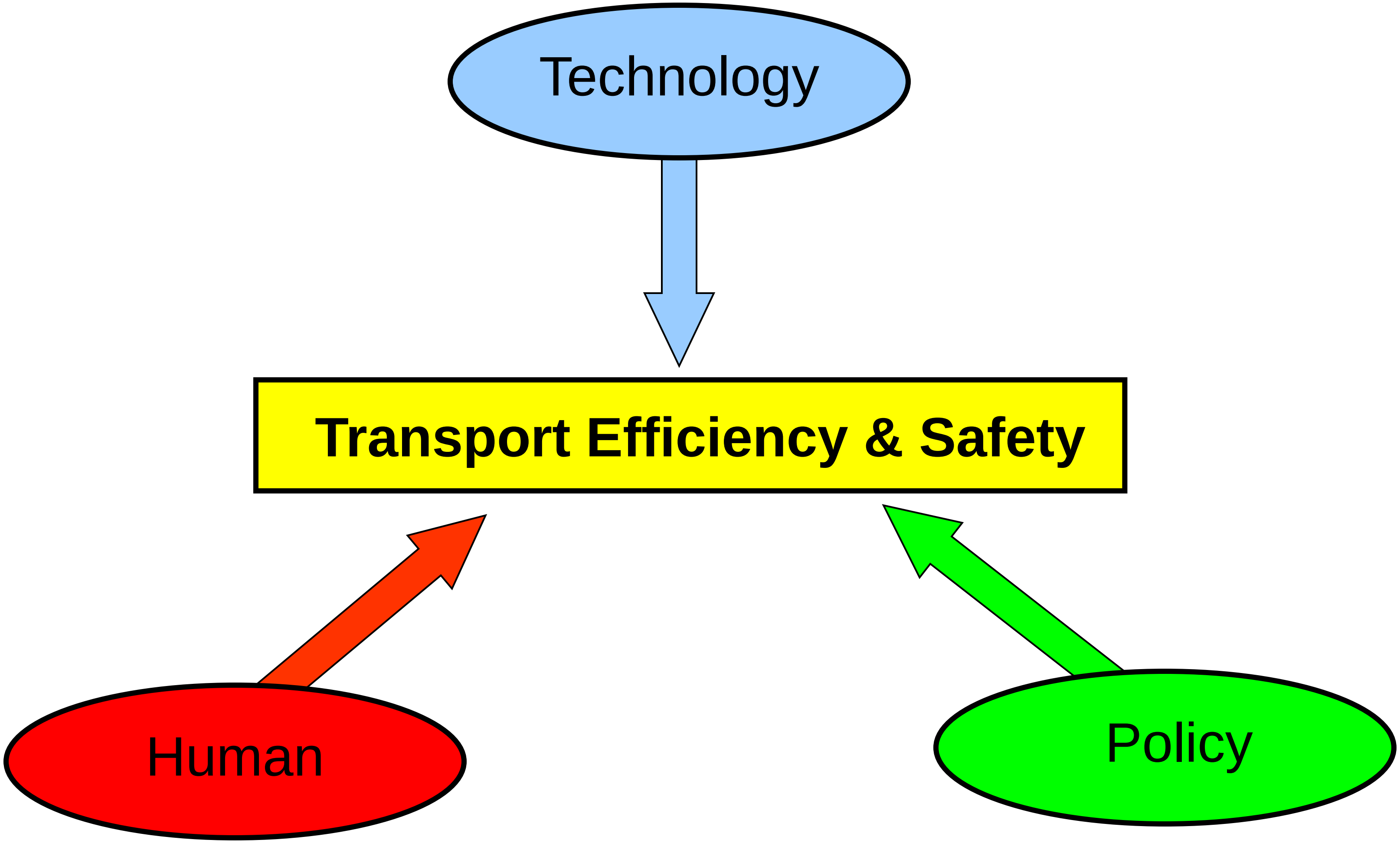
How big is the problem

- 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

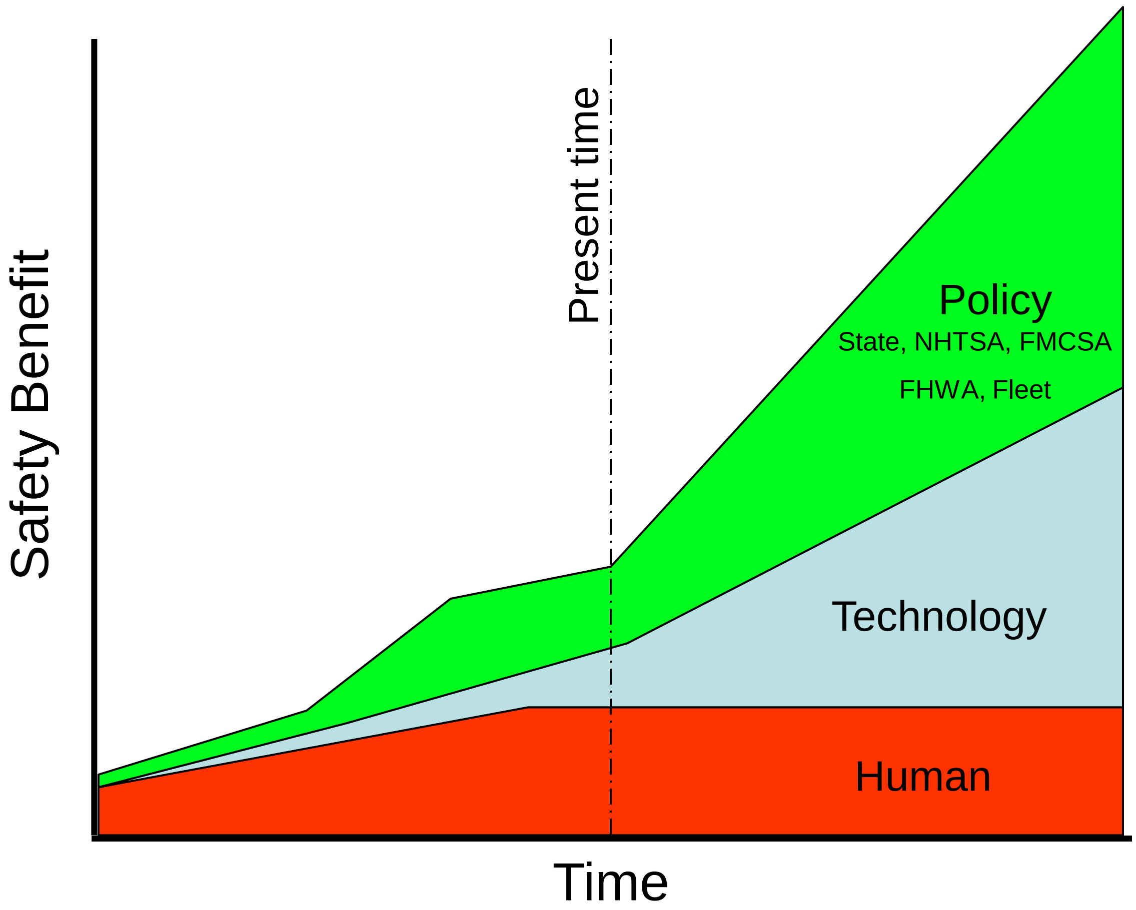
ANALYSIS OF INTERNATIONAL HEAVY VEHICLE SAFETY DATA

Fatalities involving a Heavy Vehicle per 100 million KM travelled

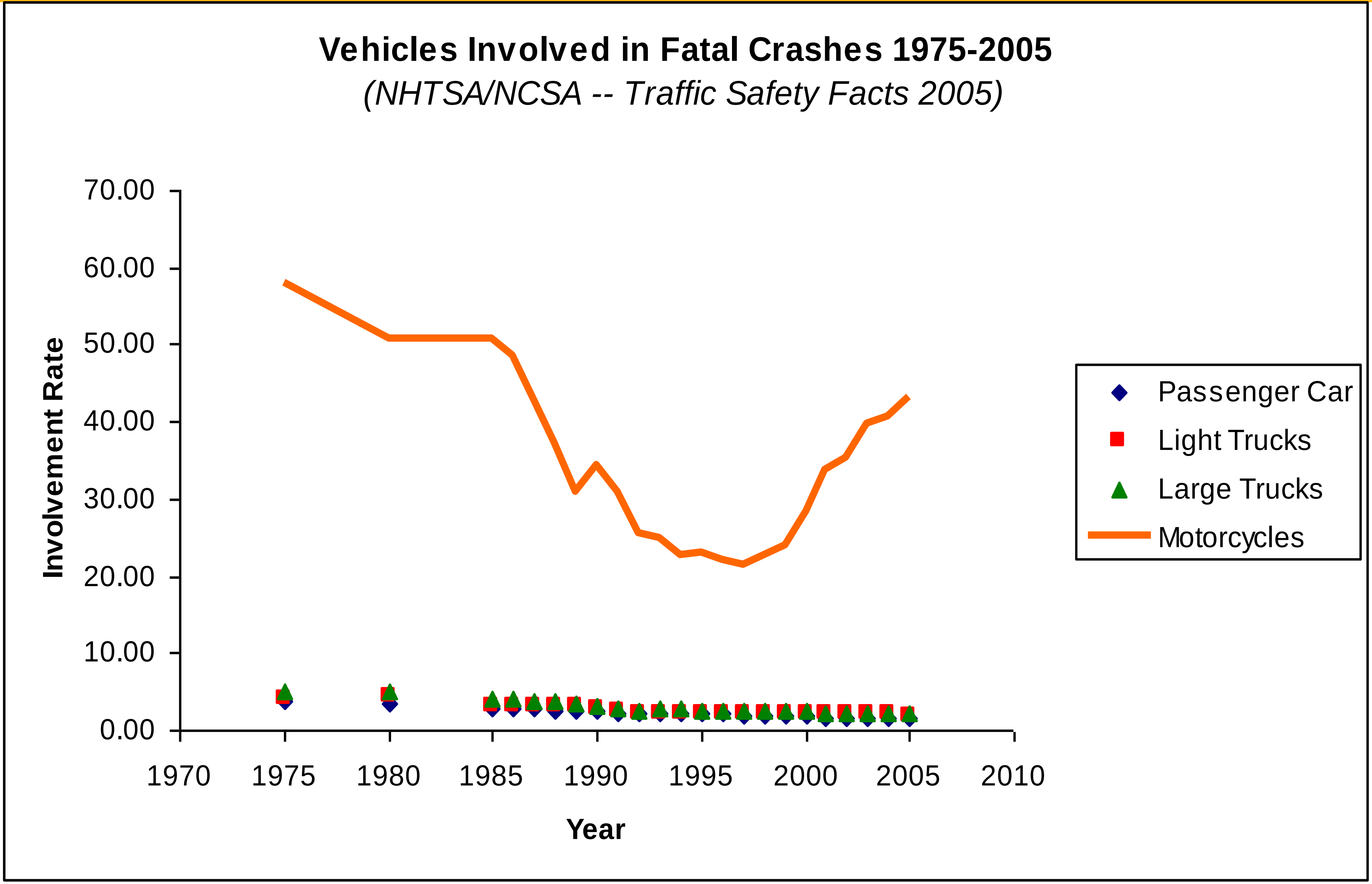



Technology
Transport Efficiency & Safety
Human
Policy

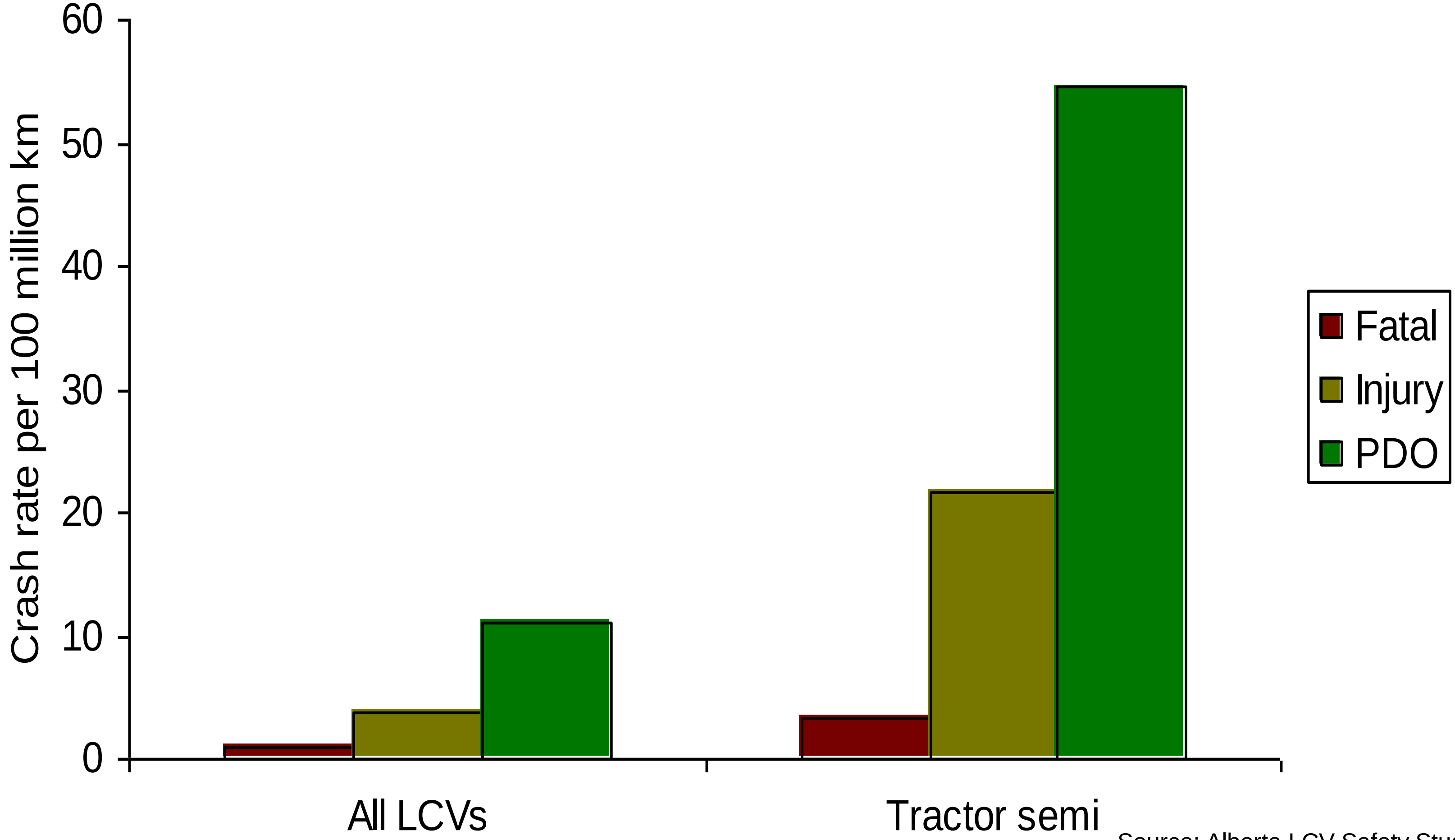
Contribution to Safety



The Influence of Policy on Safety


Vehicles Involved in Fatal Crashes 1975-2005
(NHTSA/NCSA -- Traffic Safety Facts 2005)
Involvement Rate
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Passenger Car
Light Trucks
Large Trucks
Motorcycles

LCV Safety Performance
(benefits are strongly linked to policy)



Source: Alberta LCV Safety Study
(Woodrooffe & Associates)

Best Practice Managed LCV Benefits

Factors	Benefit
Truck VMT reduction	44%
Cost saving to shipper	29%
Reduction in fuel, CO_2 and NO_X emissions	32%
Reduction in road consumption	40%
Exposure crash reduction	44%
Policy affected crash rate reduction (excluding VMT exposure reduction benefits)	500%

Alberta Study Conclusions

- 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 recoded 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 at not easily accessible
- Federal databases are highly accessible
  - ***Fatal Accident Reporting System (FARS)***
  - ***National Analysis Sampling System (NASS)***

Fatal Accident Reporting System (FARS)

- 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

NASS General Estimates System (GES)

- 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

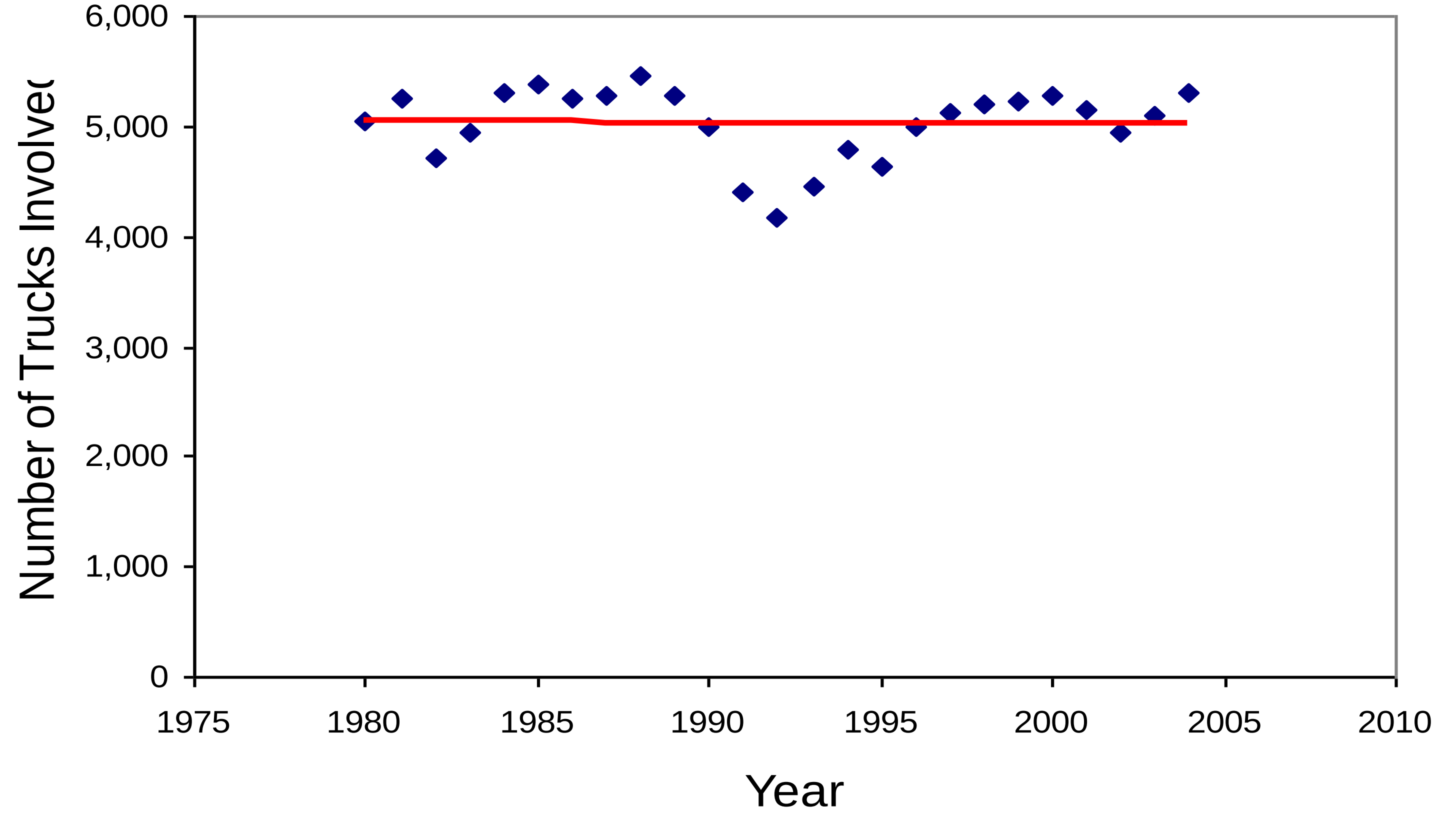
- Buses involved in fatal accidents (BIFA)
  - Bus fatal crash data
  - Census file – retrospective data gathering
  - Telephone interviews
  - Continuous data from 2001
  - Total cases to date approx. 1,200
  - Cases per year 325

TIFA & BIFA

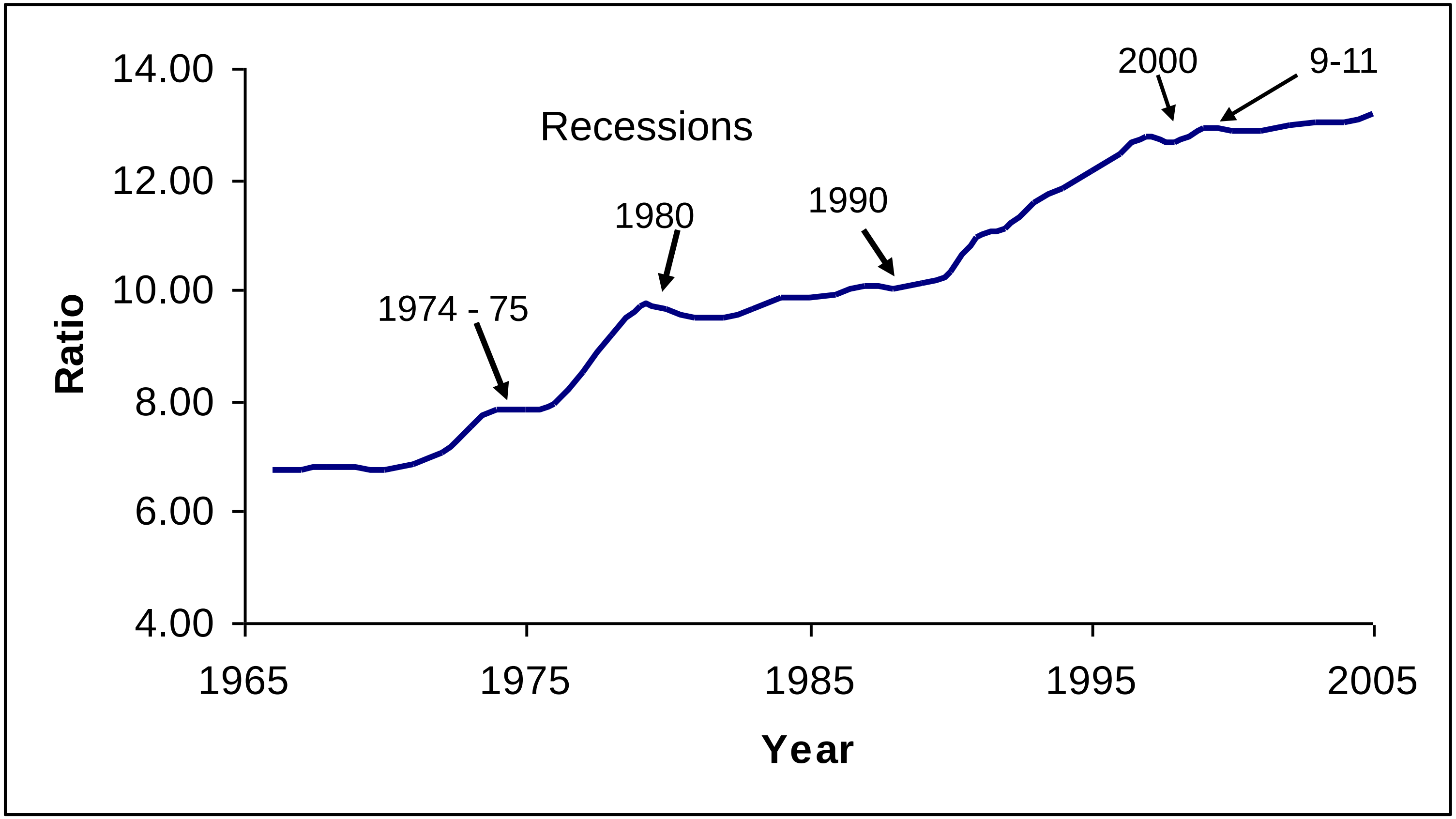
- Sponsored by Federal Motor Carriers Safety Administration
- Used for detailed safety studies involving trucks & buses
- Supports government policy and regulation activity

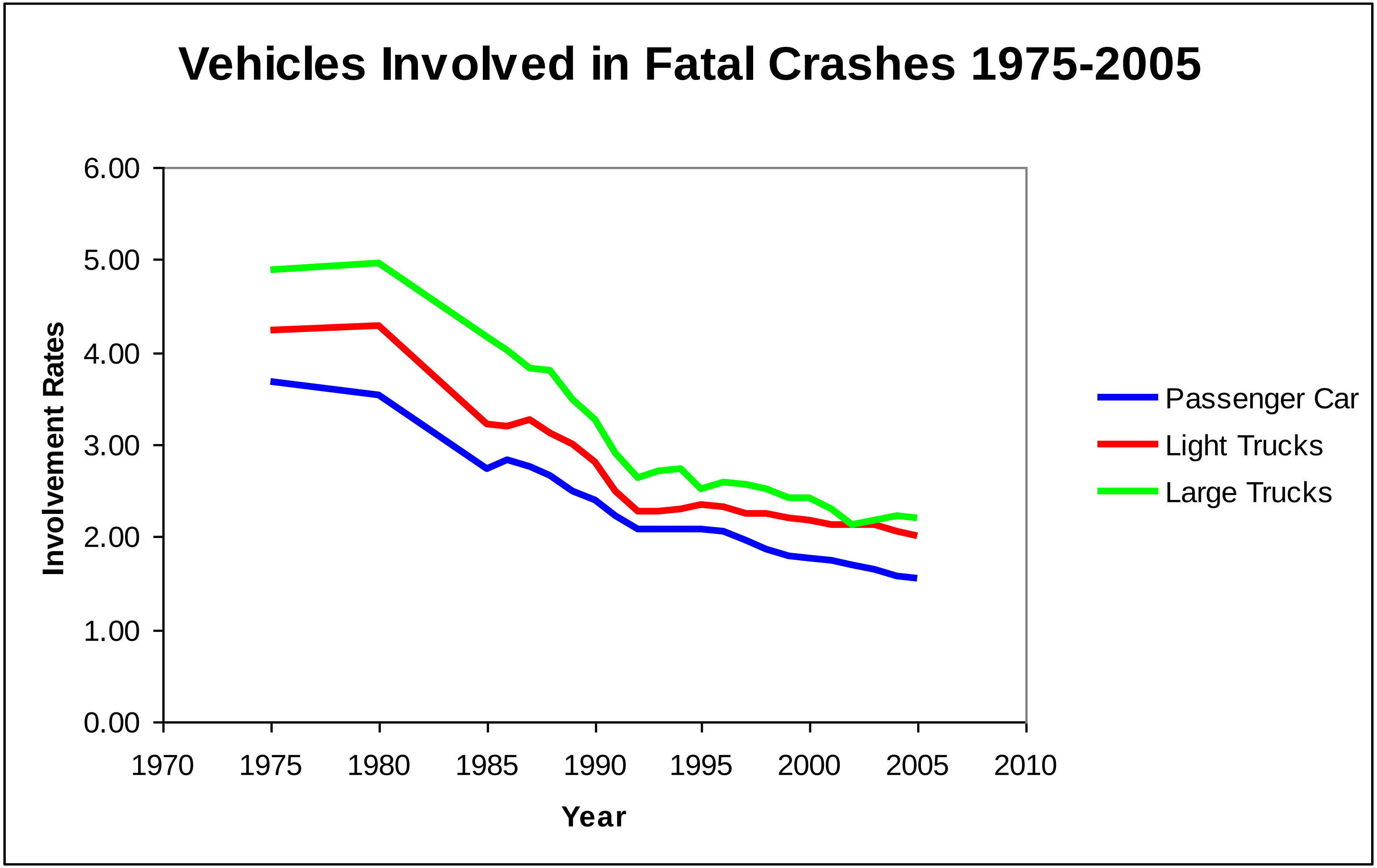
Crash Data

Truck Involvements in Fatal Crashes



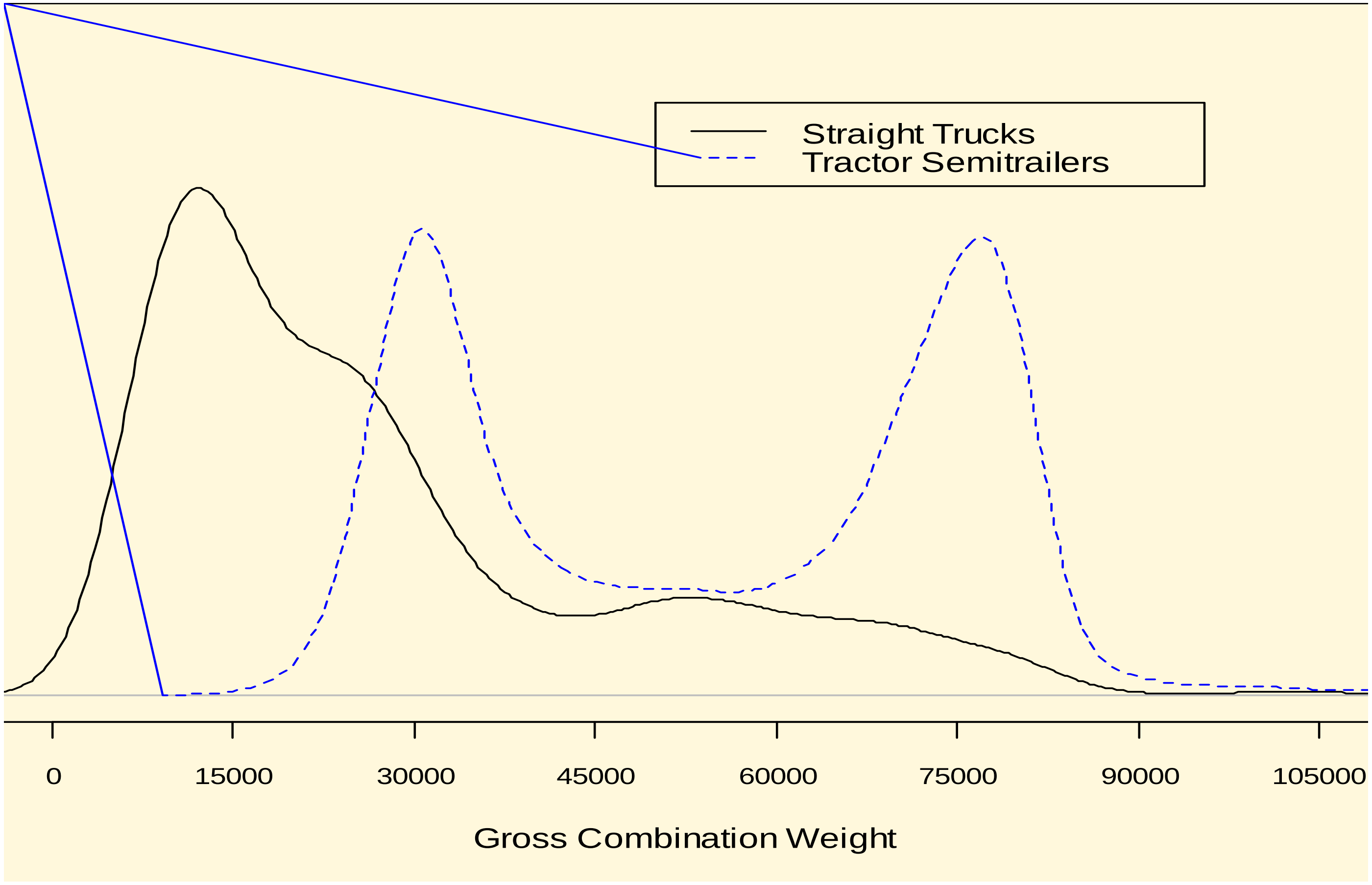
Ratio of Truck VMT to Passenger Car VMT





Vehicles Involved in Fatal Crashes 1975-2005
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Involvement Rates
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Passenger Car
Light Trucks
Large Trucks

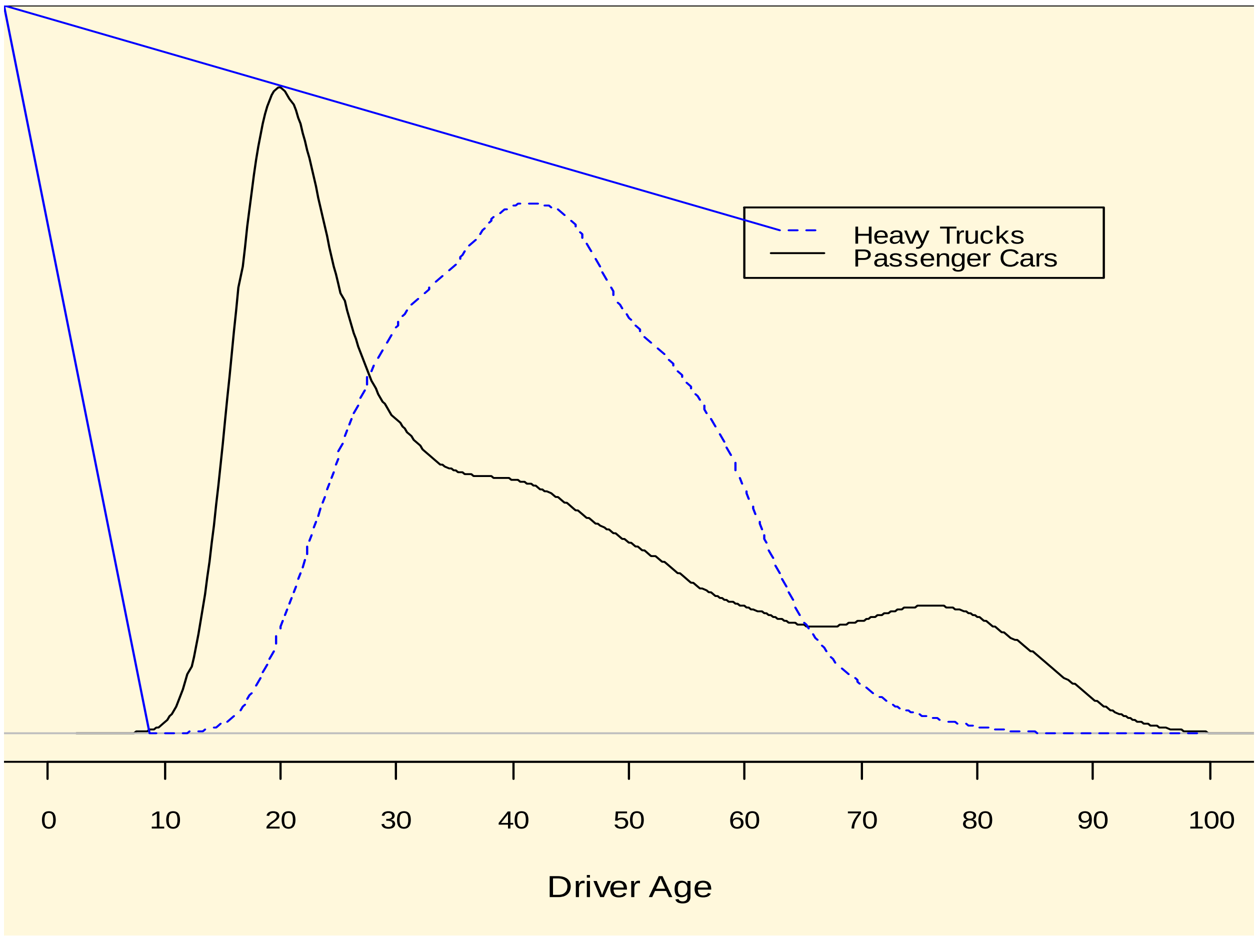
Distributions Of Gross Combination Weight
(Trucks Involved In Fatal Crashes USA)



Source : TIFA 2002

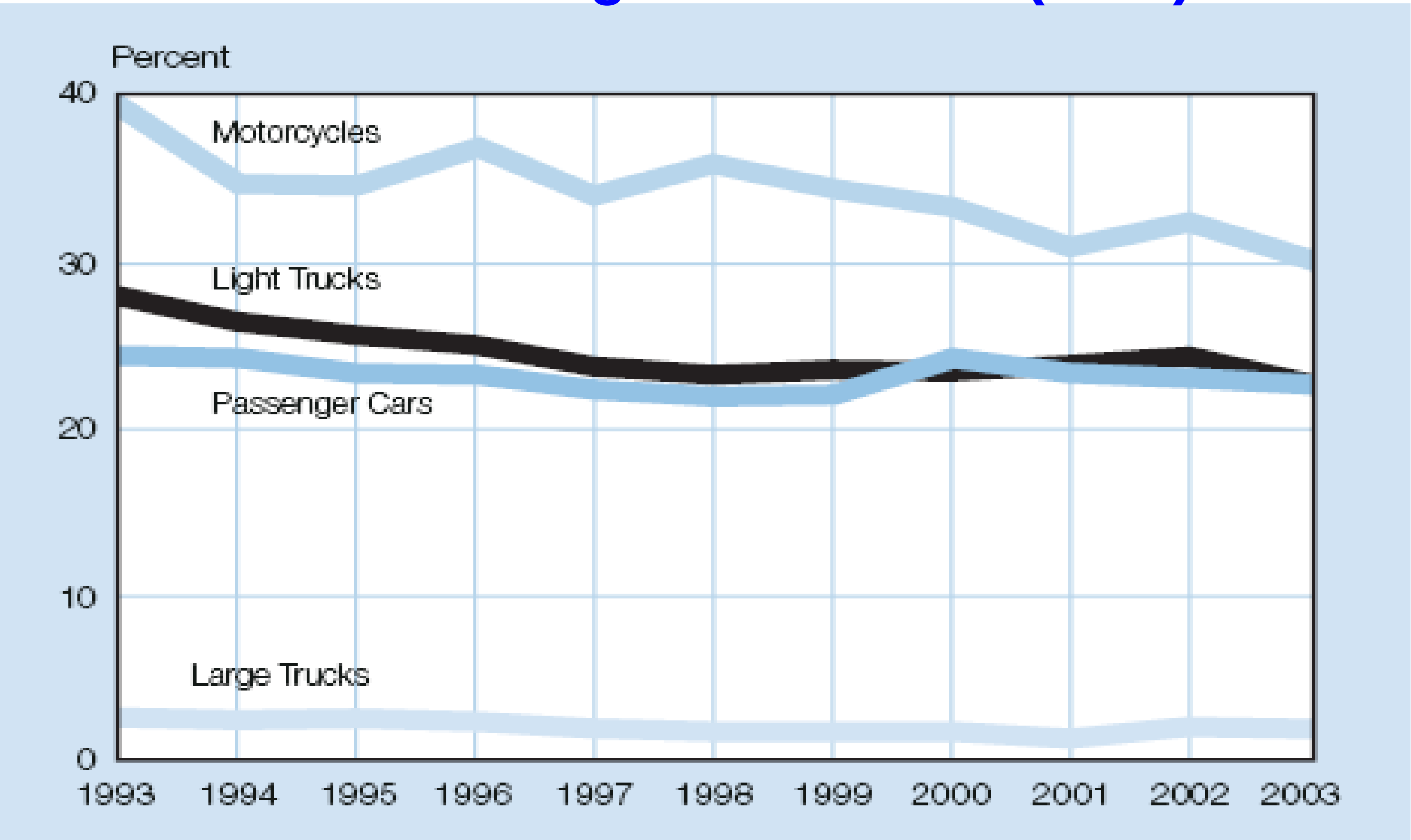
Distributions Of Driver Age

(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)



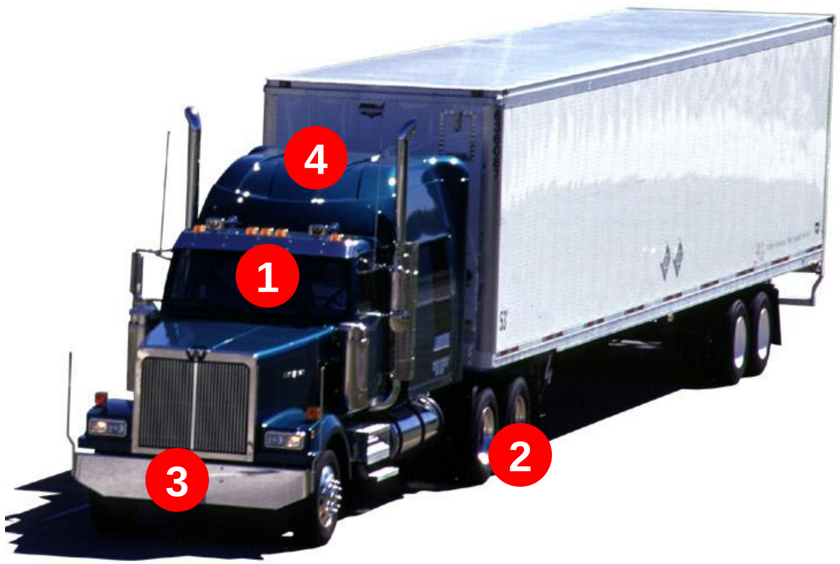
Source: Large Trucks, Safety Facts 2003, NHTSA

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

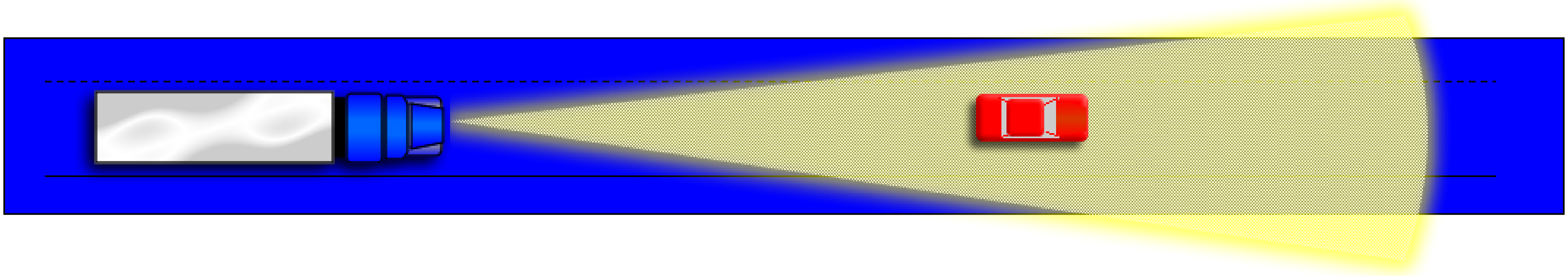
Vehicle Technologies



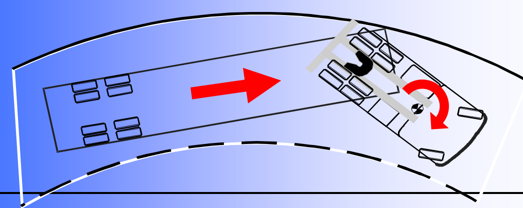
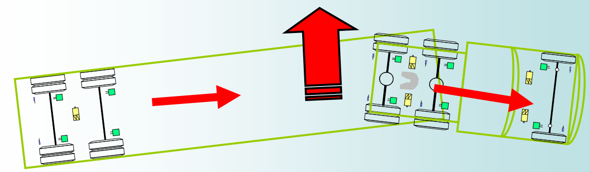
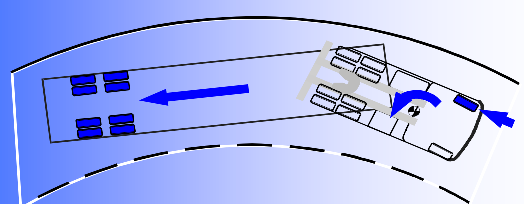
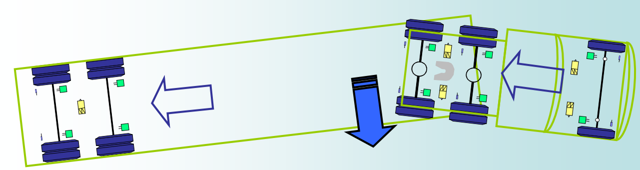
1. Lane Departure Warning Systems
2. Roll Stability Systems and Electronic Stability Systems
3. Forward Collision Warning Systems with Adaptive Cruise Control
4. Vehicle diagnostic and location systems

Forward collision warning
Adaptive cruse control

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



Stability Systems

Road Surface Coefficient of Friction	*Ice* Low	*Wet Asphalt* *Dry concrete* High
Driving Scenario Example	• Lateral force exceeds surface friction • Vehicle begins to slide/jackknife 	• Vehicle speed too fast for curve • Exceeds rollover threshold • Vehicle roll over immanent 
Stability System Action	System applies individual brakes to: • Reduce speed / correct orientation • Reducing tendency to jackknife/slide 	System applies all brakes to: • Reduce speed • Reducing roll over risk 

Applying Science to Vehicle Performance

(Performance Based Regulation)

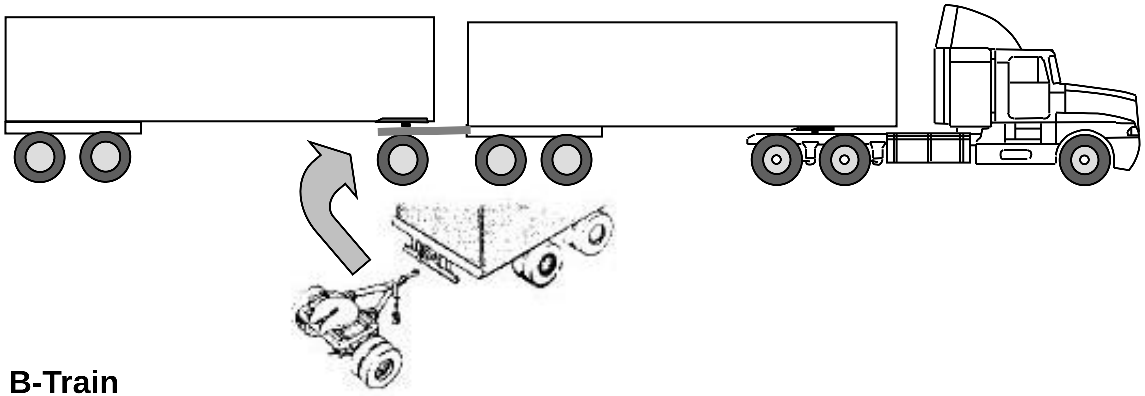
Truck Performance Based Regulation

- 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

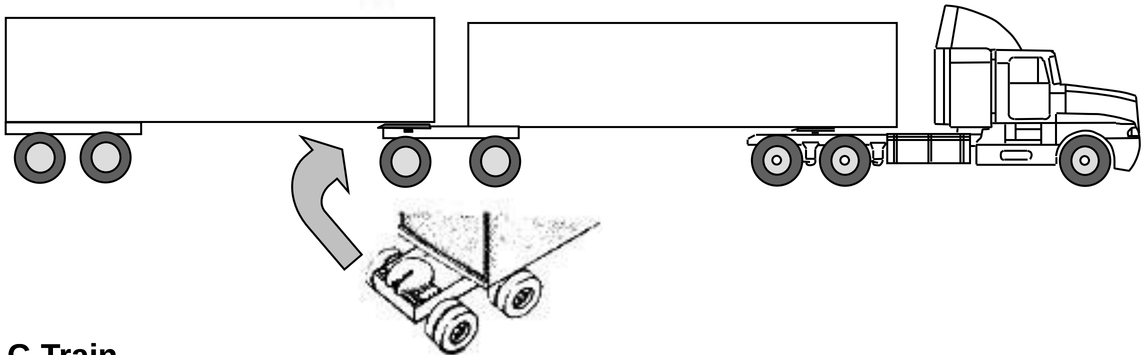
Vehicle Dynamic Performance

- 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

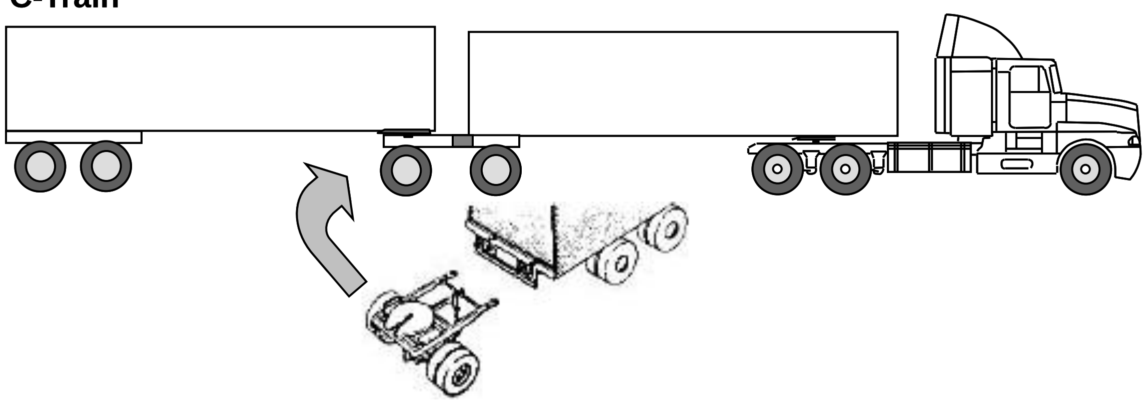
A-Train



B-Train



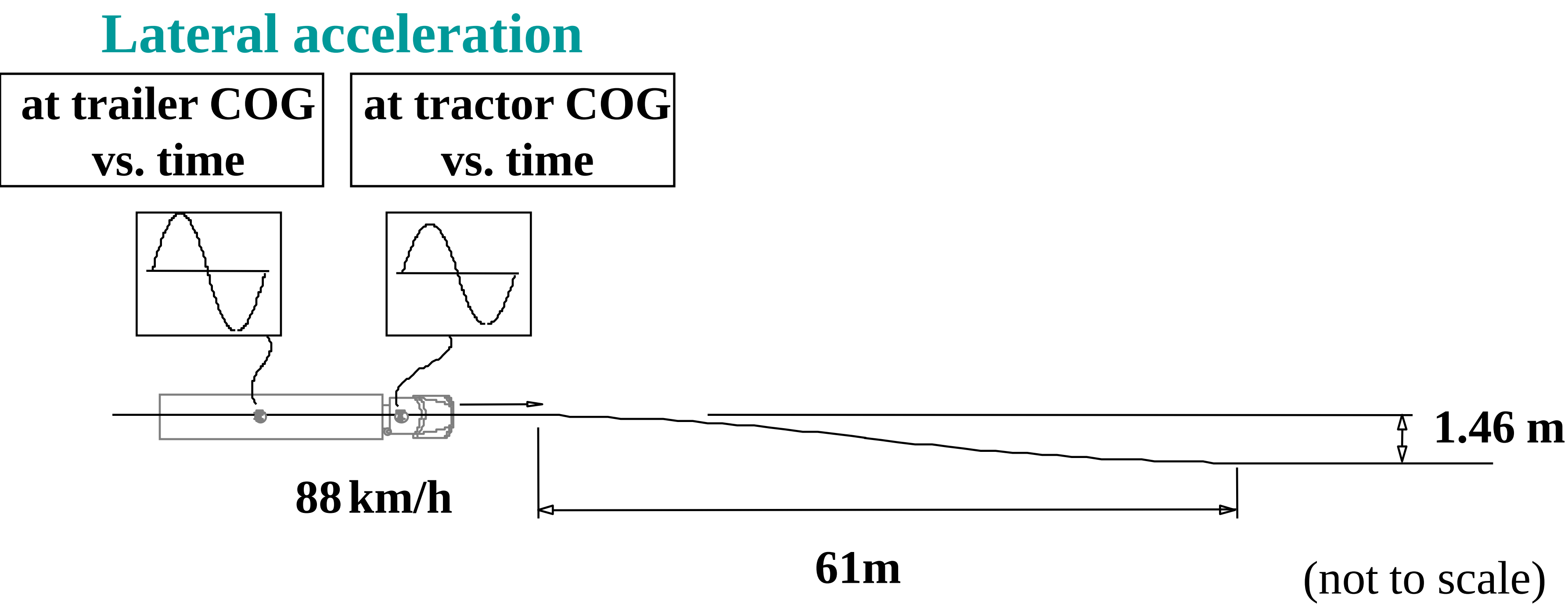
C-Train



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 MANEOUVER

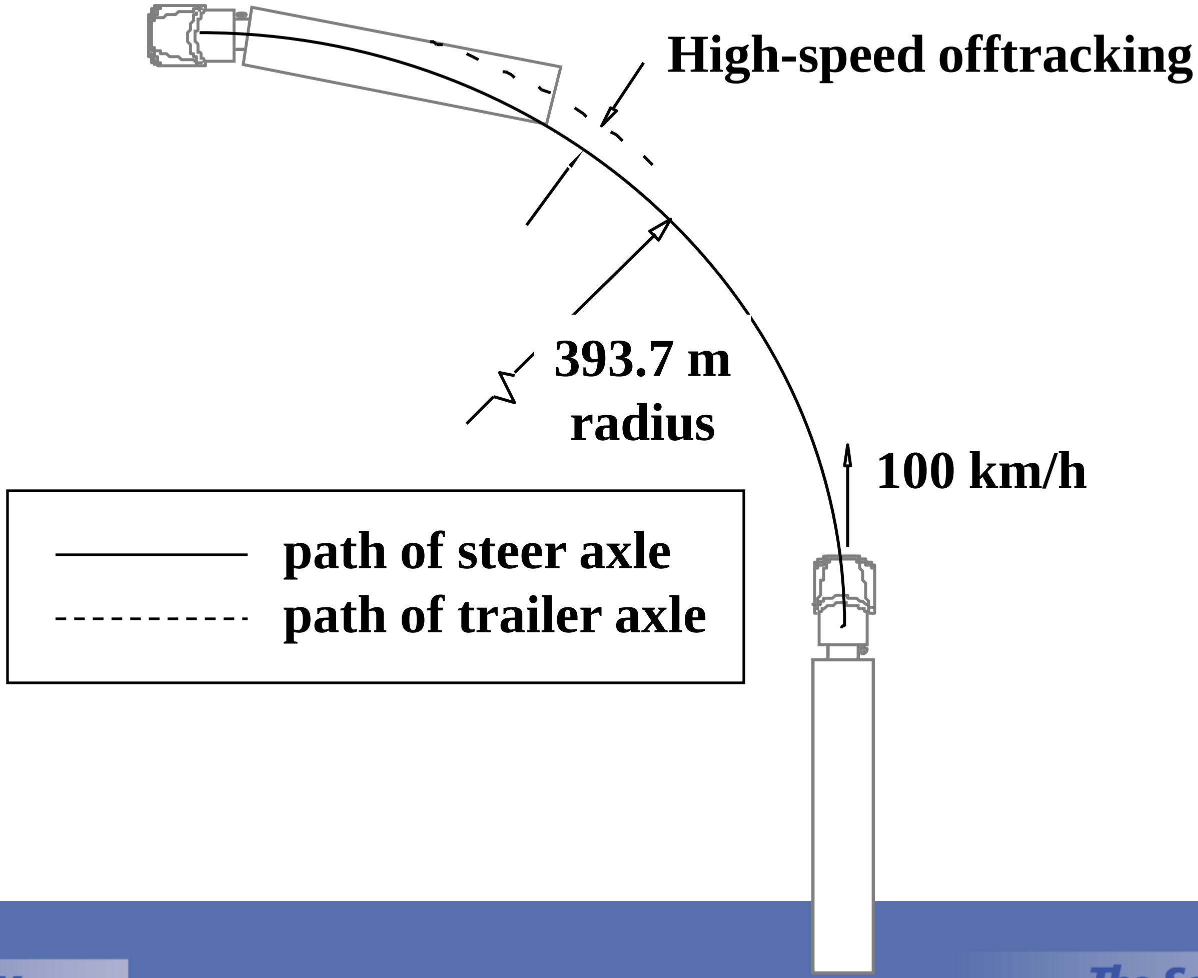


LANE CHANGE MANEOUVER

Is used to resolve:

- rearward amplification
- load transfer ratio
- high-speed transient offtracking
- high speed friction utilization

HIGH SPEED CONSTANT RADIUS

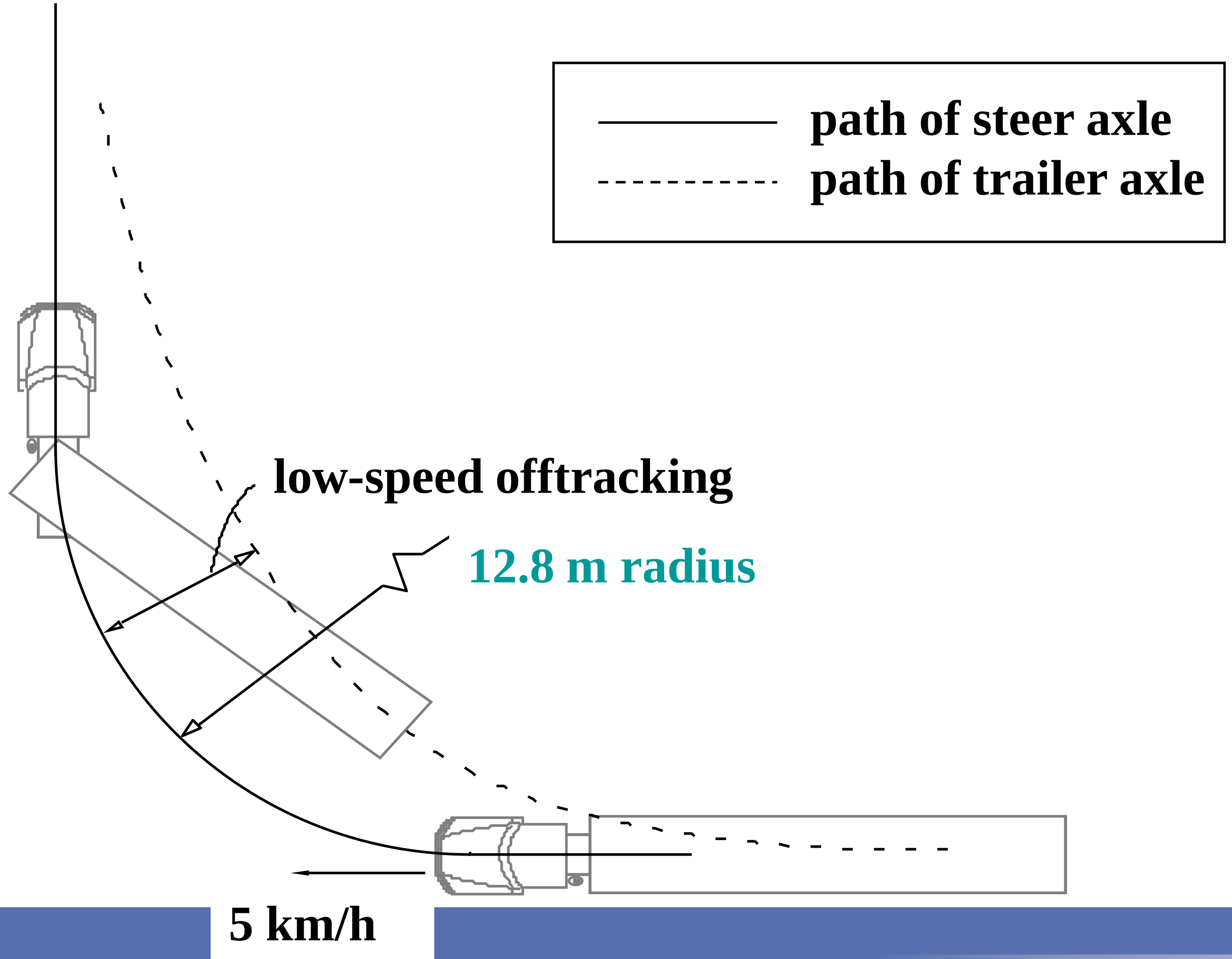


HIGH SPEED CONSTANT RADIUS

Is used to resolve:

- high-seed offtracking

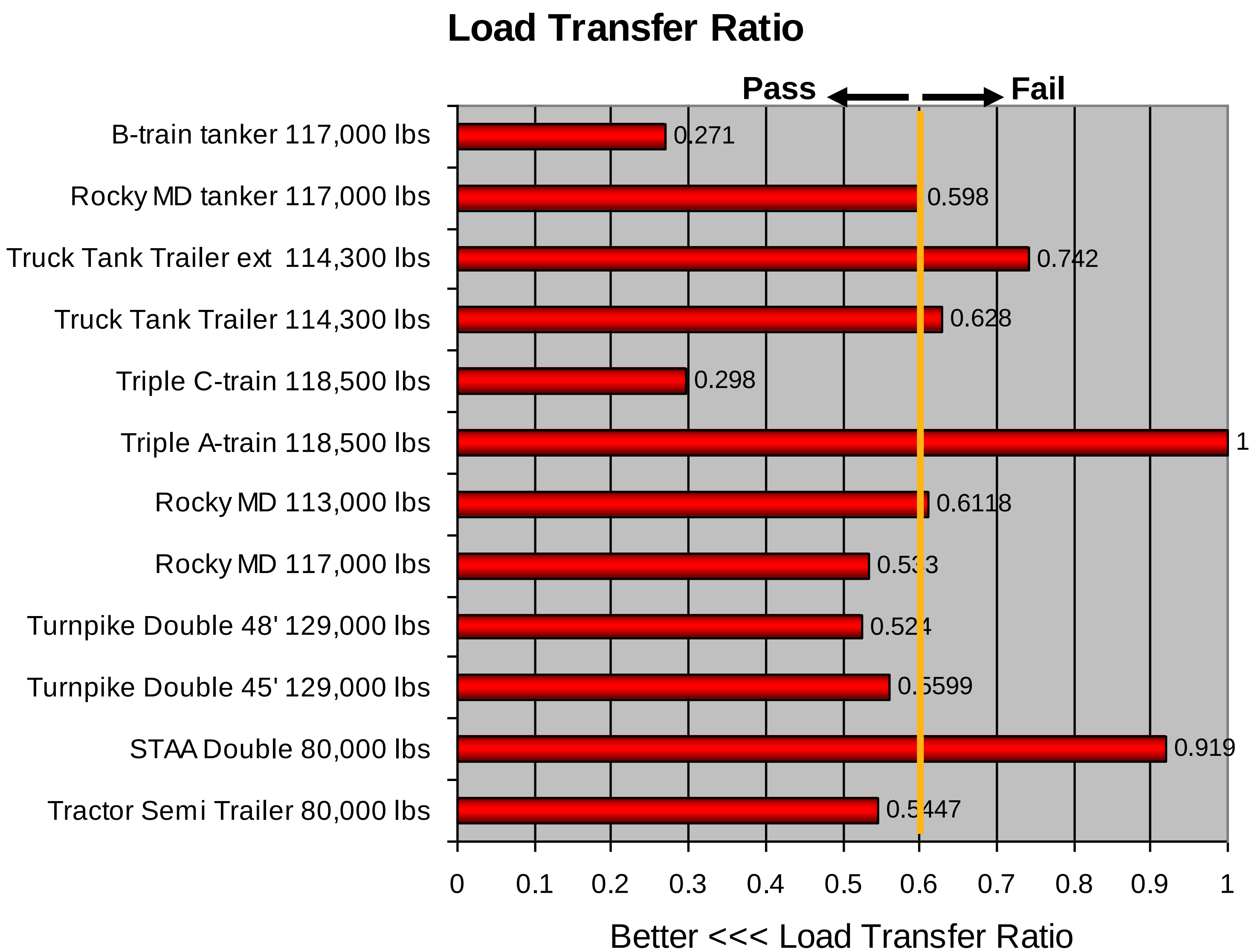
LOW-SPEED 90° TURN



LOW-SPEED 90° TURN

Is used to resolve:

- low-speed offtracking
- low-speed friction utilization



Load Transfer Ratio
Pass
Fail
B-train tanker 117,000 lbs
Rocky MD tanker 117,000 lbs
Truck Tank Trailer ext 114,300 lbs
Truck Tank Trailer 114,300 lbs
Triple C-train 118,500 lbs
Triple A-train 118,500 lbs
Rocky MD 113,000 lbs
Rocky MD 117,000 lbs
Turnpike Double 48' 129,000 lbs
Turnpike Double 45' 129,000 lbs
STAA Double 80,000 lbs
Tractor Semi Trailer 80,000 lbs
0.271
0.598
0.742
0.628
0.298
1
0.6118
0.533
0.524
0.5599
0.919
0.5447
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Better <<< Load Transfer Ratio

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 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

<u>Of the remaining savings:</u>

- 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

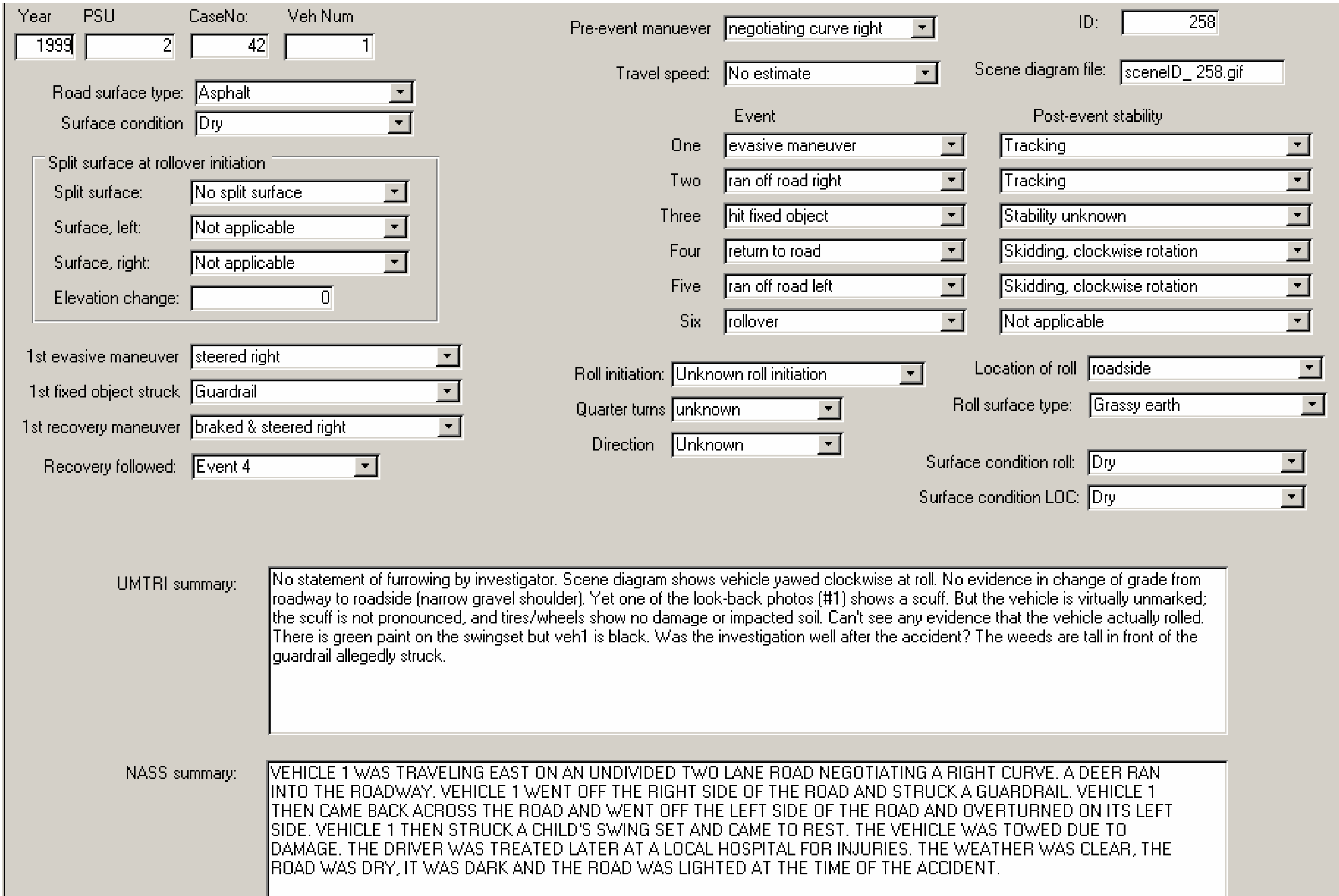
Crash Data Sources

- 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



Year	PSU	CaseNo:	Veh Num
1999	2	42	1

Road surface type: Asphalt
Surface condition: Dry

Split surface at rollover initiation
Split surface: No split surface
Surface, left: Not applicable
Surface, right: Not applicable
Elevation change: 0

1st evasive maneuver: steered right
1st fixed object struck: Guardrail
1st recovery maneuver: braked & steered right
Recovery followed: Event 4

Pre-event manuever: negotiating curve right
ID: 258
Travel speed: No estimate
Scene diagram file: sceneID_ 258.gif

	Event	Post-event stability
One	evasive maneuver	Tracking
Two	ran off road right	Tracking
Three	hit fixed object	Stability unknown
Four	return to road	Skidding, clockwise rotation
Five	ran off road left	Skidding, clockwise rotation
Six	rollover	Not applicable

Roll initiation: Unknown roll initiation
Quarter turns: unknown
Direction: Unknown
Location of roll: roadside
Roll surface type: Grassy earth
Surface condition roll: Dry
Surface condition LOC: Dry

UMTRI summary: No statement of furrowing by investigator. Scene diagram shows vehicle yawed clockwise at roll. 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 swingset but veh1 is black. Was the investigation well after the accident? The weeds are tall in front of the guardrail allegedly struck.

NASS summary: VEHICLE 1 WAS TRAVELING EAST ON AN UNDIVIDED TWO LANE ROAD NEGOTIATING A RIGHT CURVE. A DEER RAN INTO THE ROADWAY. VEHICLE 1 WENT OFF THE RIGHT SIDE OF THE ROAD AND STRUCK A GUARDRAIL. VEHICLE 1 THEN CAME BACK ACROSS THE ROAD AND WENT OFF THE LEFT SIDE OF THE ROAD AND OVERTURNED ON ITS LEFT SIDE. VEHICLE 1 THEN STRUCK A CHILD'S SWING SET AND CAME TO REST. THE VEHICLE WAS TOWED DUE TO DAMAGE. THE DRIVER WAS TREATED LATER AT A LOCAL HOSPITAL FOR INJURIES. THE WEATHER WAS CLEAR, THE ROAD WAS DRY, IT WAS DARK AND THE ROAD WAS LIGHTED AT THE TIME OF THE ACCIDENT.

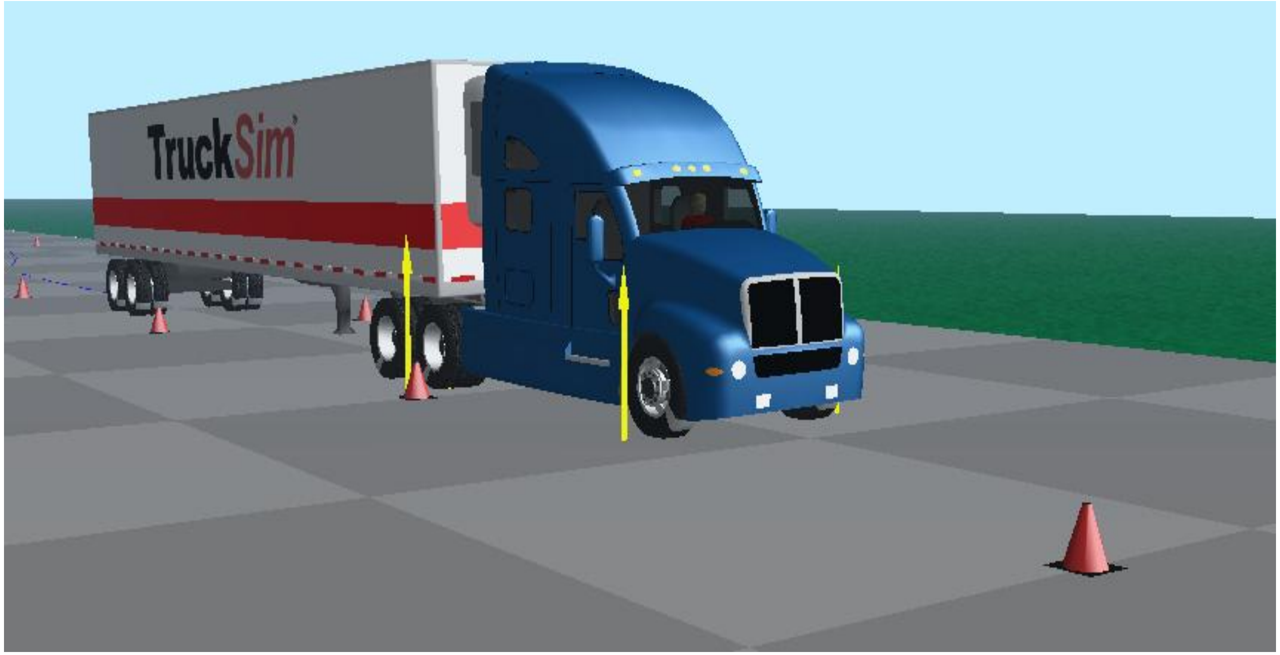
Dynamic Simulation

- 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

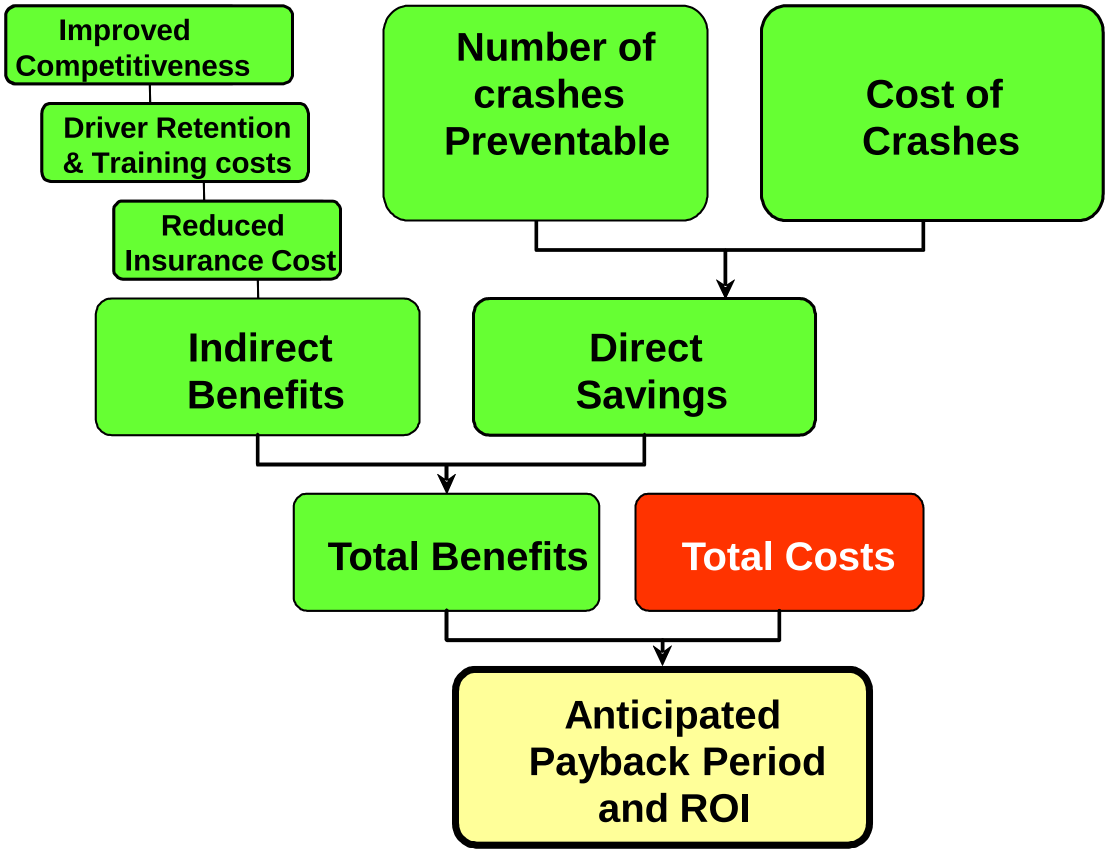
Simulation

- TruckSim offers Real-time Simulation in Combination with SIMULINK and the TruckSim Animator




Prid

Overview of Cost-Benefit Methodology



Concluding Comments

Evolution Safety Innovation

Passive → Active → System control

Seat belt

Collapsible steering column

Air Bags

Lane departure warning

Electronic stability systems
and
“The next big thing”

crash worthiness → crash avoidance