

Impact of Vehicle Design on Outcome: A CIREN Retrospective

Patricia Dischinger, Ph.D.

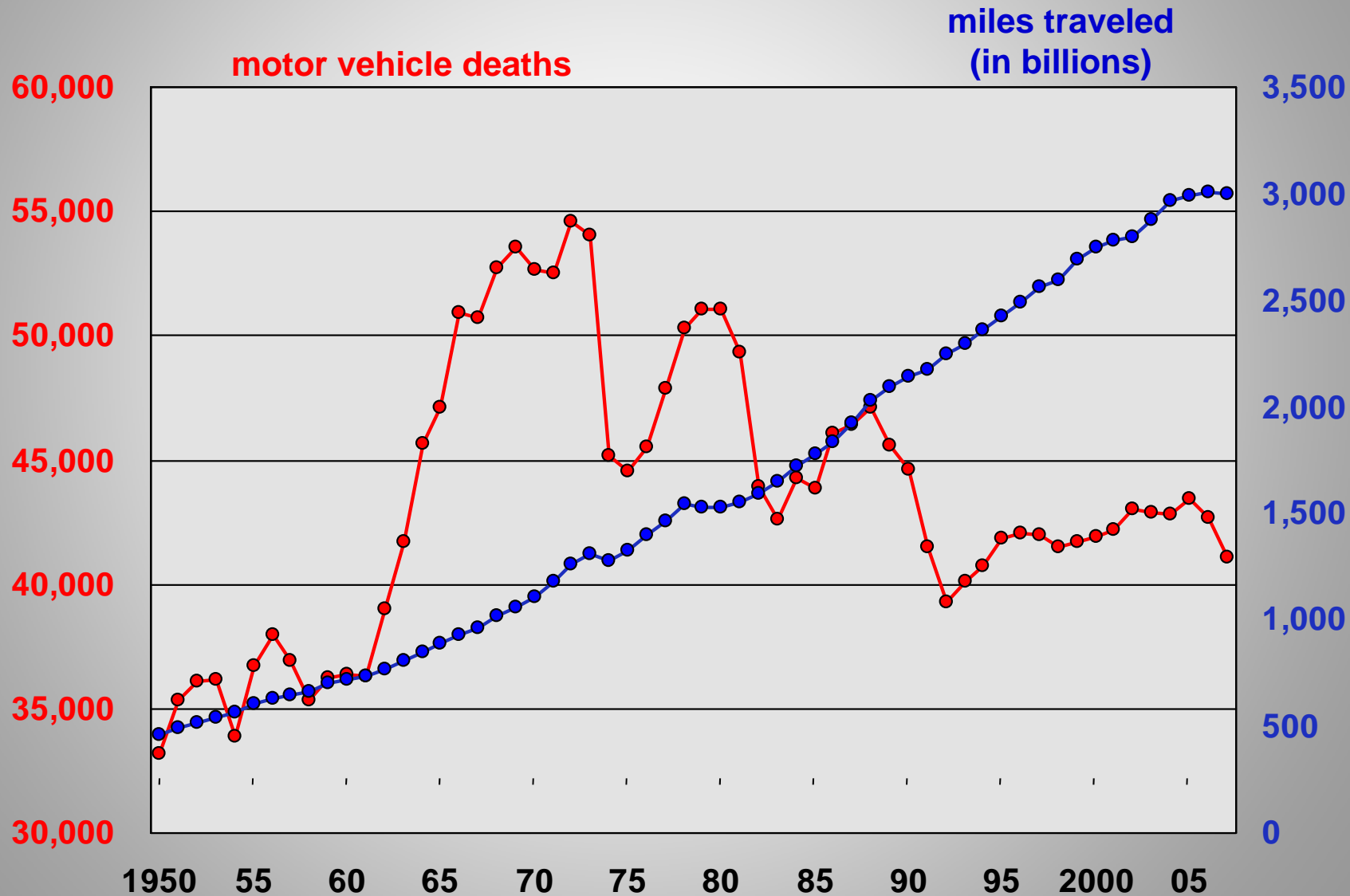
Maryland CIREN Center

National Study Center for Trauma & EMS

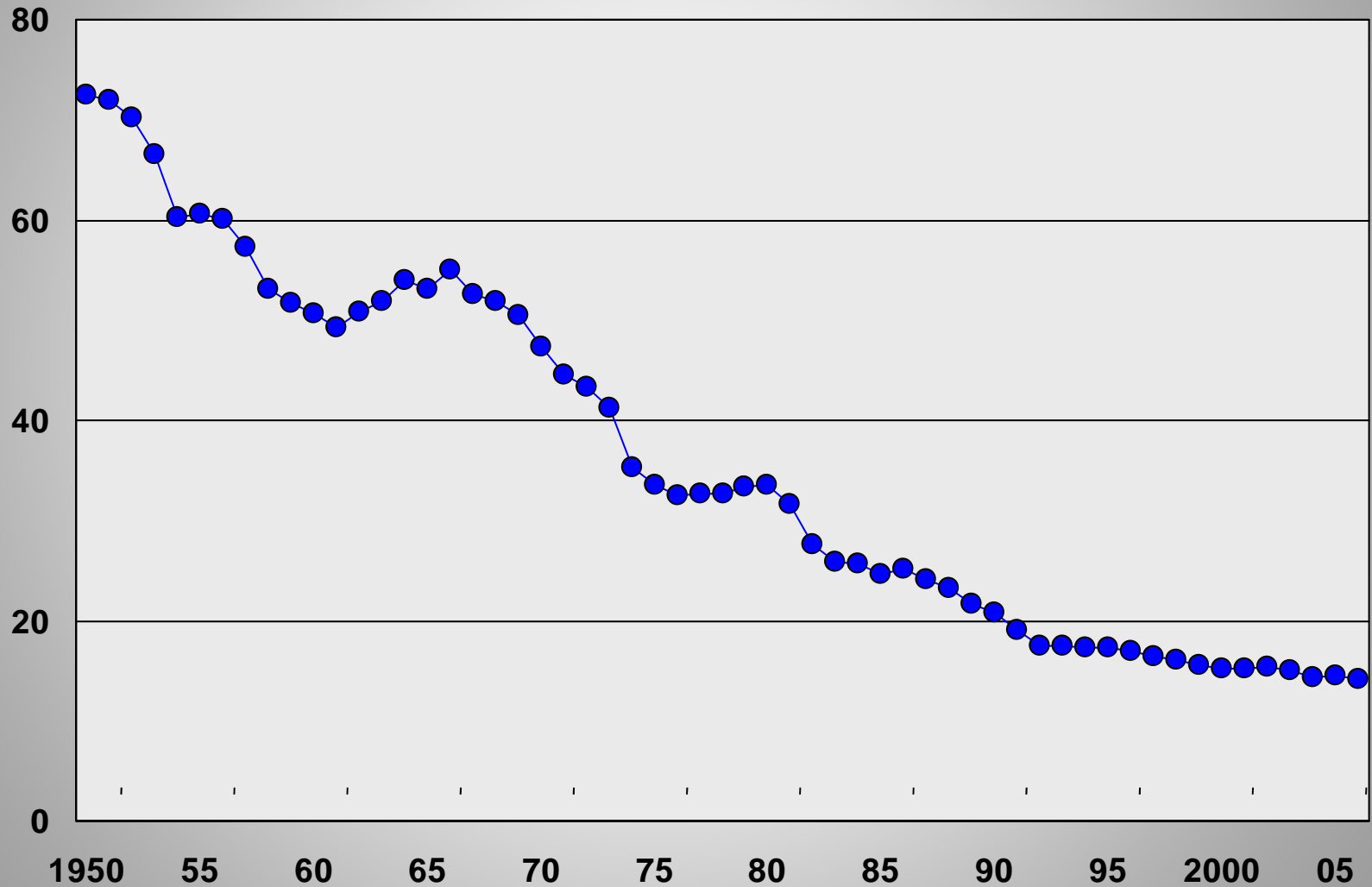
October 8, 2009



Motor vehicle crash deaths and total miles traveled 1950-2007



Motor vehicle crash deaths per billion vehicle miles 1950-2006



10 Leading Causes of Injury Death by Age Group – 2001

Highlighting Unintentional Injury Deaths

Rank	Age Groups										Total
	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	
1	Unintentional Suffocation 614	Unintentional MV Traffic 558	Unintentional MV Traffic 660	Unintentional MV Traffic 884	Unintentional MV Traffic 10,513	Unintentional MV Traffic 6,759	Unintentional MV Traffic 6,891	Unintentional MV Traffic 5,422	Unintentional MV Traffic 3,328	Unintentional Fall 11,623	Unintentional MV Traffic 42,443
2	Unintentional MV Traffic 139	Unintentional Drowning 458	Unintentional Drowning 168	Unintentional Drowning 165	Homicide Firearm 4,200	Homicide Firearm 3,308	Unintentional Poisoning 5,036	Unintentional Poisoning 3,547	Suicide Firearm 2,083	Unintentional MV Traffic 7,256	Suicide Firearm 16,869
3	Homicide Other Spec., Class. 117	Unintentional Fire/burn 230	Unintentional Fire/burn 164	Suicide Suffocation 163	Suicide Firearm 2,130	Suicide Firearm 2,564	Suicide Firearm 3,030	Suicide Firearm 3,023	Unintentional Fall 1,004	Unintentional Unspecified 5,806	Unintentional Fall 15,019
4	Homicide Unspecified 107	Homicide Unspecified 146	Homicide Firearm 59	Homicide Firearm 121	Unintentional Poisoning 1,362	Unintentional Poisoning 2,507	Homicide Firearm 1,978	Suicide Poisoning 1,439	Unintentional Poisoning 798	Suicide Firearm 3,943	Unintentional Poisoning 14,078
5	Unintentional Drowning 68	Unintentional Suffocation 138	Unintentional Other Land Transport 48	Suicide Firearm 90	Suicide Suffocation 1,235	Suicide Suffocation 1,373	Suicide Poisoning 1,541	Unintentional Fall 1,024	Suicide Poisoning 578	Unintentional Suffocation 3,204	Homicide Firearm 11,348
6	Unintentional Fire/burn 50	Unintentional Pedestrian, Other 81	Unintentional Suffocation 44	Unintentional Fire/burn 88	Unintentional Drowning 596	Homicide Transportation-Related 842	Suicide Suffocation 1,534	Suicide Suffocation 952	Unintentional Fire/burn 395	Adverse Effects 1,995	Unintentional Unspecified 7,218
7	Undetermined Suffocation 47	Homicide Other Spec., Class. 80	Unintentional Fall 33	Unintentional Other Land Transport 83	Homicide Cut/pierce 481	Suicide Poisoning 753	Undetermined Poisoning 1,121	Homicide Firearm 934	Suicide Suffocation 392	Unintentional Fire/burn 1,147	Suicide Suffocation 6,198
8	Homicide Suffocation 40	Homicide Firearm 55	Unintentional Pedestrian, Other 26	Unintentional Suffocation 68	Suicide Poisoning 337	Undetermined Poisoning 549	Homicide Transportation-Related 1,061	Undetermined Poisoning 761	Unintentional Unspecified 385	Unintentional Poisoning 722	Unintentional Suffocation 5,555
9	Adverse Effects 26	Homicide Other Spec., NEC 49	Unintentional Struck by or Against 25	Unintentional Firearm 39	Unintentional Fall 256	Homicide Cut/pierce 472	Unintentional Fall 647	Homicide Transportation-Related 644	Adverse Effects 384	Unintentional Natural/Env. 621	Suicide Poisoning 5,191
10	Unintentional Fall 23	Unintentional Natural/Env. 42	Unintentional Other Transport 22	Unintentional Pedestrian, Other 38	Unintentional Other Land Transport 250	Unintentional Drowning 374	Unintentional Drowning 462	Unintentional Suffocation 461	Unintentional Suffocation 381	Unintentional Other Spec., NEC 578	Unintentional Fire/burn 3,423

Note: Homicide and suicide counts include terrorism deaths associated with the events of September 11, 2001, that occurred in New York City, Pennsylvania, and Virginia. A total of 2,926 U.S. residents lost their lives in these acts of terrorism in 2001, of which 2,922 were classified as (transportation-related) homicides and 4 were classified as suicides.

Source: National Center for Health Statistics, (NCHS) Vital Statistics Systems.

Produced by: Office of Statistics and Programming, National Center for Injury Prevention and Control, CDC.

Early Automobile Design



Scientific Approaches to Injury Control

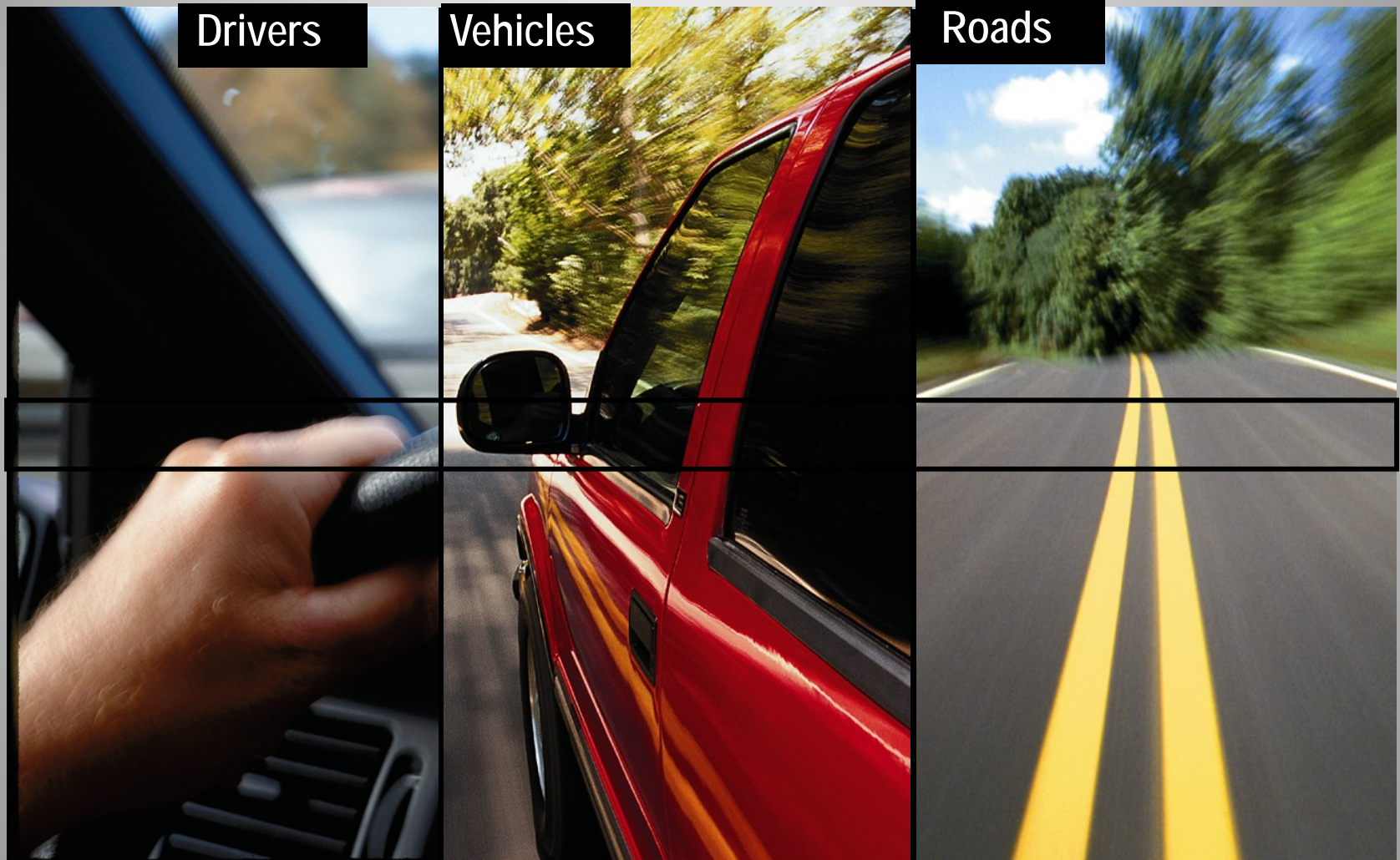
Haddon matrix:

incorporates concept of host, agent for
transmission of energy, environment

Haddon Matrix

Factors Phases	Person	Vehicle/ Vector	Physical Environ.	Social Environ.
Pre-event	Emphasis often here Pre-1960s			
Event		CIREN emphasis is here		
Post- event				



There's no reason to prefer highway safety efforts aimed at drivers over those aimed at vehicles or roads. Preference should go to programs shown to be effective.



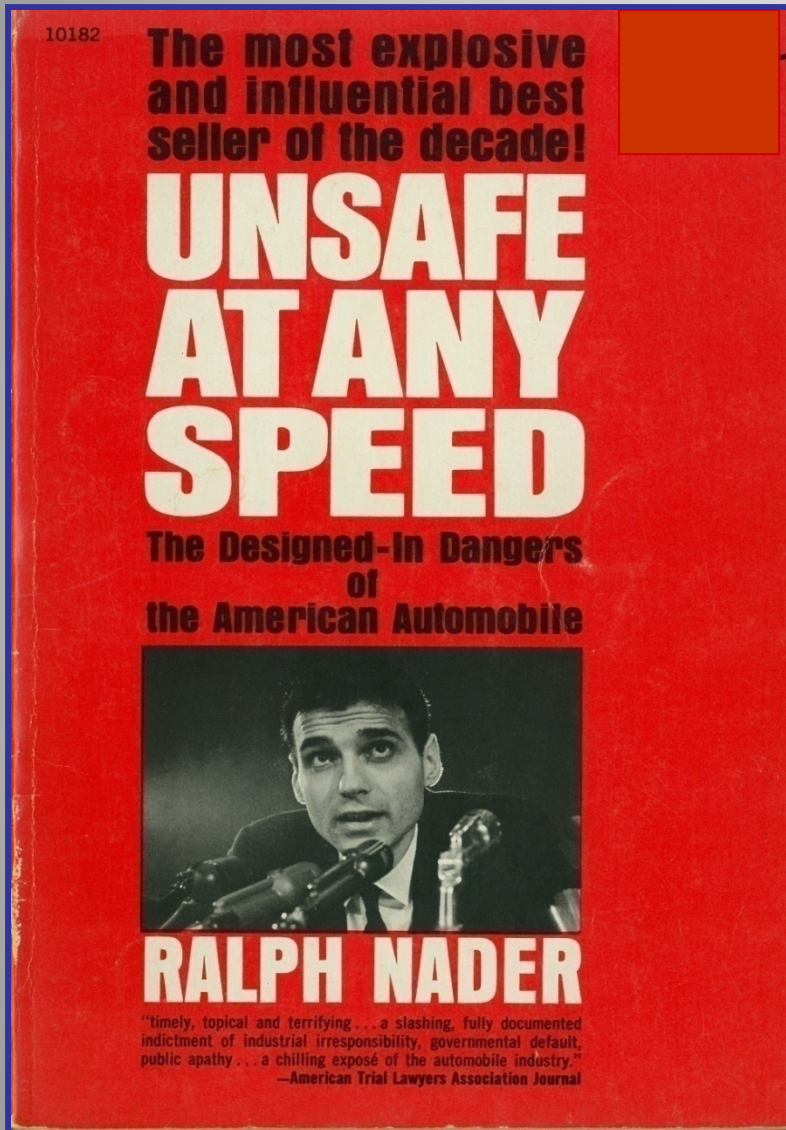
Haddon's strategies for reducing toll of motor vehicle crashes

- Prevent or reduce creation of energy.
- Strengthen structure that can be damaged.
- Prevent release of energy.
- Modify rate or spatial distribution of energy release.
- Separate the energy in space or time from the vulnerable structure.
- Block energy transfer with barrier.
- Modify contact surface that is struck.
- EMS/damage control

1960s – 1970s

Factors Phases	Person	Vehicle/ Vector	Physical Environ.	Social Environ.
Pre- event		Style, not safety 	Poor roads	<ul style="list-style-type: none"> •No DUI laws •Speed limits = 55 •Highway Safety Act Passed
Event (crash)	No seat belt use	<ul style="list-style-type: none"> •Collapsible steering column •Bumper •Non-deformable interior 	Injury causing guardrails 	
Post- event				Minimal EMS/trauma care

1965



“...the consumer’s expectations regarding automotive innovations have been deliberately held low and mostly oriented to very gradual annual style changes.

“It is in the post-accident response that lawyers and physicians and other specialists labor. That is where the remuneration lies and this is where the talent and energies go. Working in the area of prevention of these casualties earns few fees....”

1966 Highway Safety Act



"We have tolerated a raging epidemic of highway death....which has killed more of our youth than all other diseases combined. Through the Highway Safety Act, we are going to find out more about highway disease- and we aim to cure it."

-President Johnson 1966

Mid 1980s – Mid 1990s

Factors	Person	Vehicle/ Vector	Physical Environ.	Social Environ.
Phases				
Pre- event	Increased safety belt use	<ul style="list-style-type: none"> •Center mount rear-brake light •Intro of airbags 	Increased traffic congestion	Seatbelt laws Speed limits raised Decreased driver safety training
Event (crash)		<i>Deformable interior components</i>	Improved highway safety	<ul style="list-style-type: none"> •Increased DUI laws and enforcement •IIHS offset frontal crash testing
Post- event				Development of trauma centers Improved EMS communication

1. Report No. DOT HS 808 156		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle The Medical Consequences of Car Crashes: An Automobile Crash Trauma Study				5. Report Date July 15, 1992	
7. Author(s) Siegel J, Dischinger P				6. Performing Organization Code 52-600203 (EIN)	
				8. Performing Organization Report No. FINAL REPORT	
9. Performing Organization Name and Address Maryland Institute for Emergency Medical Services Systems 22 South Greene Street Baltimore, MD 21201				10. Work Unit No. (TRAIS)	
12. Sponsoring Agency Name and Address Department of Transportation National Highway Traffic Safety Administration Washington, DC 20590				11. Copy or Original No. DTNH 22-88-C-07007	
				13. Type of Report and Period Covered Final 10/01/88 - 12/31/91	
13. Supplementary Notes				14. Sponsoring Agency Code NAD-30	
				16. Abstract	
<p>The objective of this multi-disciplinary study was to characterize the causes and consequences of injuries to vehicle occupants admitted to a trauma center as a result of high-speed crashes. The study includes data on 145 patients admitted to MIEMSS as a result of 128 crashes. Patients with an injury severity score (ISS) of at least 16 were eligible for inclusion. Detailed information was obtained on injury diagnoses, operative procedures and complications; in addition, photographs of injuries were taken by a trauma surgeon. Details of pre-hospital care were obtained from interviews with field providers. The study social worker obtained background information on the patient, the family, and any pre-crash "stressors" which might have played a role in the crash. Financial information on the charges for hospital care and professional fees were also obtained for each case. For patients with head injuries, data were obtained by a speech pathologist. Finally, for fatalities, autopsy reports were obtained from the Office of the Chief Medical Examiner.</p> <p>Specific aims, methods, findings, and conclusions of the study are presented in Volume 1 of the Final Report. Timeline narratives for each of the study cases are presented in Volumes 2, 3, and 4, representing years 1, 2, and 3 respectively.</p>					
17. Key Words Trauma Contact Points Car Crashes Extrication Biomechanics Psychosocial factors Intrusion			18. Distribution Statement Document is available to the U.S. Public through the National Technical Information Service, Springfield, Virginia 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages	22. Price

Comparison of Pre-CIREN crash with recent CIREN crash



Exemplar Case Vehicle
1987 Ford Tempo

Exemplar Case Vehicle
2003 Chrysler Sebring



Crash Characteristics

1987 Ford Tempo

2003 Chrysler Sebring

Delta V 35 mph

38.5 mph

PDOF 350 (12:00)

0-10 (12:00)

Intrusions Left A-pillar=9.1 cm Long
 Left Toe Pan=19.3 cm Long
 Left Kick Panel=10.4 cm Lat

Left Toe Pan=3 cm Long
Right Toe Pan=5 cm Long
Right IP=2 cm Long

Occupant Characteristics

	<u>1987 Ford Tempo</u>	<u>2003 Chrysler Sebring</u>
Age	42	56
Sex	female	female
Height	66 in.	66 in.
Weight	139 lbs.	168 lbs.
Role	driver	driver
Belt	yes	yes
Airbag	no	yes



1987 Ford Tempo
1987 Ford Tempo vs.
1980 Oldsmobile Cutlass
Total Delta V 35 mph (56 km/h)
Weight: 1140 kg

2003 Chrysler Sebring
2003 Chrysler Sebring (2-door sedan)
Vs 1997 Chevrolet Cavalier
Total Delta V of 38.5 mph (62 km/h)
Weight: 1413 kg





**Case Vehicle
Interior**

**1987 Ford Tempo
Belted 42 year old female driver
(not equipped with frontal air bag)
(Height: 66 in / 167 cm,
Weight: 139 lbs / 63 kg)**

**2003 Chrysler Sebring
Belted 56 year old female driver
Frontal airbag deployed
Height: 66 in. (168 cm)
Weight: 168 lbs (76 kg)**





1987 Ford Tempo
Case Occupant
projected forward

2003 Chrysler Sebring

Air bag prevents
occupant contact to
steering rim/hub





2
to
nd
nel

2003 Chrysler Sebring
None to slight rim/column
deformation by occupant

1987 Ford Tempo

Occupant contacts to the steering wheel and lower instrument panel



2003 Chrysler Sebring

Knee bolster contact
(prevents occupant
from “submarining”)



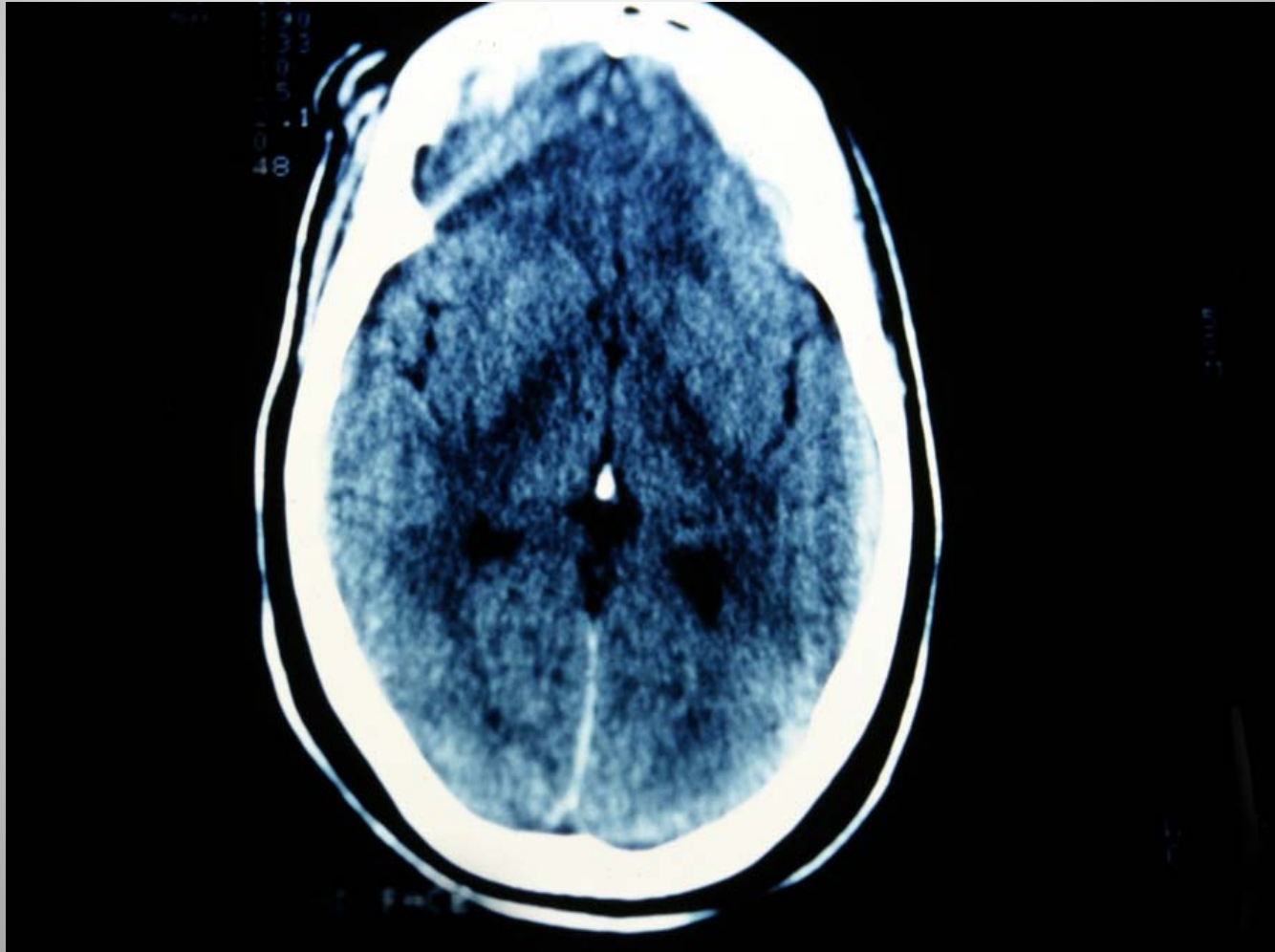


1987 Ford Tempo
Forehead avulsion
&
facial lacerations

2003 Chrysler Sebring
Eyewear abrasion
to forehead (air bag)



1987 Ford Tempo
Subdural Hematoma





1987 Ford Tempo
Hip fracture





2003 Chrysler
Sebring

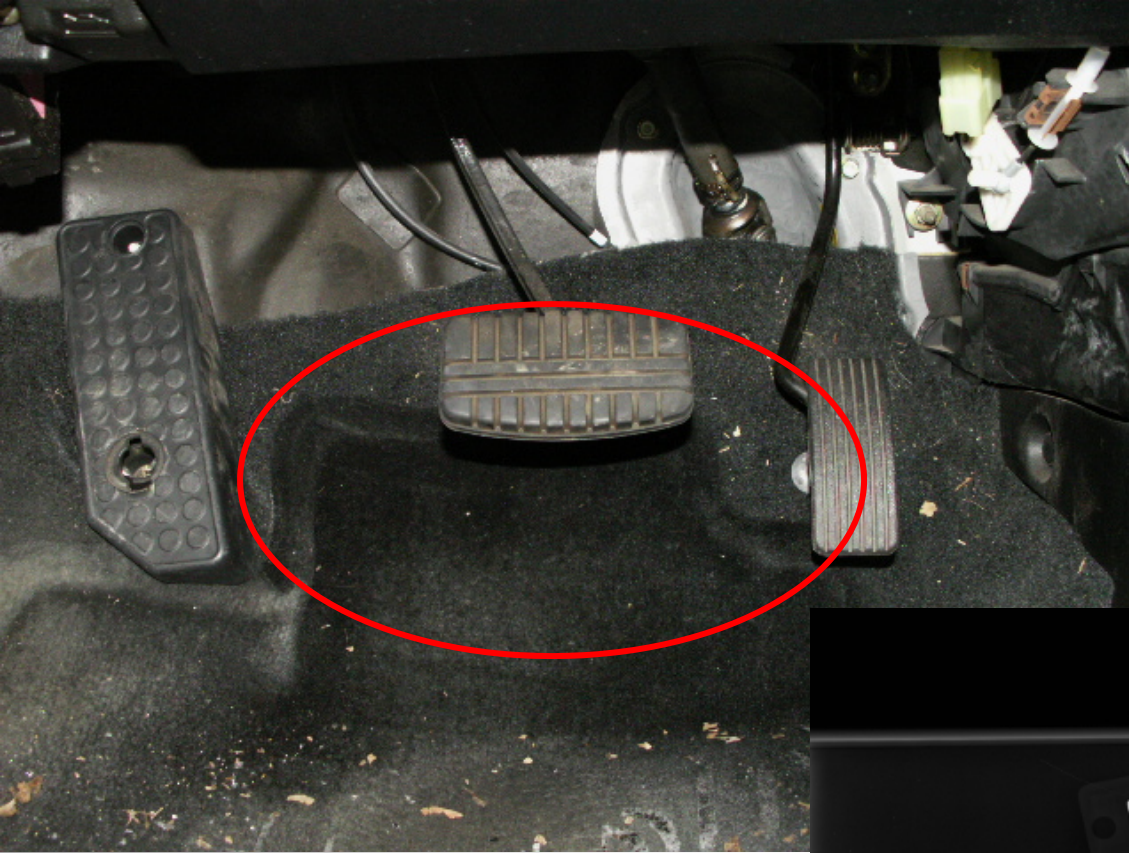
Evidence of seat
belt usage and
spooling
(pretensioner and
load
limiter present)



2003 Chrysler Sebring
Abdominal contusion

2003 Chrysler Sebring
Left clavicle, 1st & 2nd
rib fractures





2003 Chrysler
Sebring
Toe pan contact
(inferred)



2003 Chrysler
Sebring
Right talus & fibula
fracture

Injuries

1987 Ford Tempo

<u>Injuries (AIS)</u>	<u>Contact Point</u>
Subdural hematoma (4)	Steering rim
Forehead avulsion (2)	Steering rim
Right orbital blowout fracture (3)	Steering rim
Laceration, right eyelid (2)	Steering rim
Nasal fracture (1)	Steering rim
Laceration nasal column / lip (2)	Steering rim
Left chin laceration (1)	Steering rim
Right C7 facet fracture (3)	Steering rim
Left pneumothorax	Door Panel
Right hip fracture (2)	Instrument panel
Right femur fracture (3)	Instrument panel

2003 Chrysler Sebring

<u>Injuries (AIS)</u>	<u>Contact Point</u>
Left Clavicle Fracture (2)	Shoulder Belt
Left 1 st & 2 nd Rib Fractures (2)	Shoulder Belt
Sternum Fracture (2)	Shoulder Belt
C7 transverse process fracture (2)	Shoulder Belt
Right Talus Fracture (2)	Toe Pan
Right Fibula Fracture (2)	Toe Pan
Left Shoulder Contusion (1)	Shoulder Belt
Bilateral Knee Contusions (1)	Knee Bolster
Abdominal Skin Contusion (1)	Lap Belt

Crash Outcomes

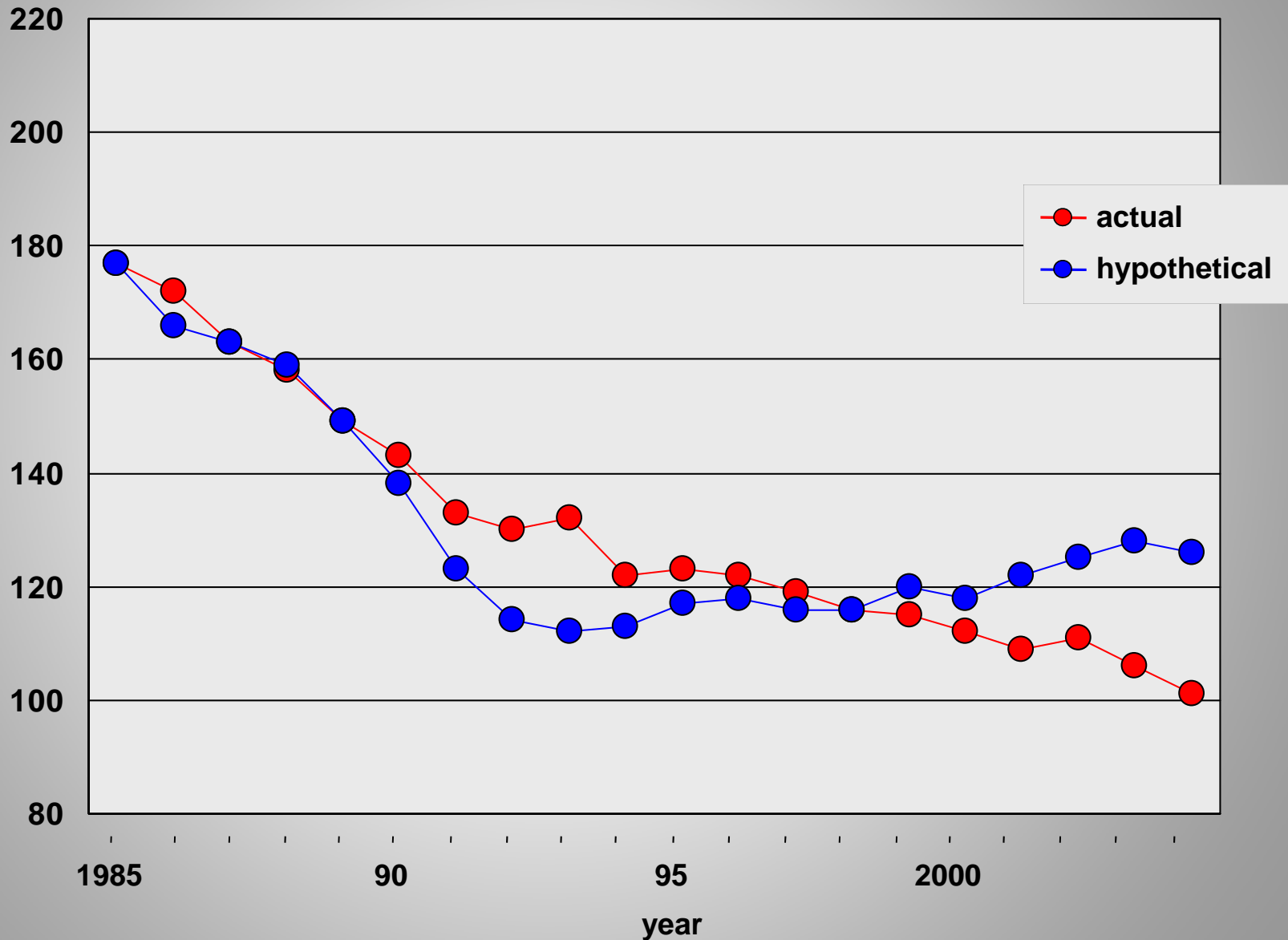
	<u>1987 Ford Tempo</u>	<u>2003 Chrysler Sebring</u>
ISS	34	12
Length of Stay	16 days	5 days

Mid 1990s – Present

Factors Phases	Person	Vehicle/ Vehicle	Physical	Social
Pre-event	Obesity More aggressive driving behavior Cell phone use	-Increase vehicle weight - Improved avoidance technology (ABS & ESC)	Advanced “smart” safety systems Side airbags Pretensioners Load limiters Knee bolsters	
Event (crash)		<u>Greatly improved crash-worthiness*</u>		
Post-event	Obesity Aging population	Automatic Crash Notification Systems		Integrated EMS and trauma care systems

Driver death rates per registered vehicle

Actual vs. hypothetical, based on 1985 fleet



Studying risk in CIREN

- Cannot use CIREN to estimate risk of injury because we select people who are injured
- Can study risk of death, given injuries serious enough to be admitted to a trauma center (we do not select cases based on death)

Why Risk Analysis Can't Be Performed Using Only CIREN Data

$$risk = \frac{\# \text{injured}}{\# \text{exposed}} = \frac{\# \text{injured}}{(\# \text{injured} + \# \text{uninjured})}$$

Not in CIREN

Why Case-Fatality Risk Estimates CAN Be Made Using Only CIREN Data

$$risk = \frac{\#killed}{\#injured}$$

CIREN population

Current CIREN Database

- CIREN database
 - 3,951 cases enrolled
 - 443 deaths
- Inclusion criteria
 - Newer model year vehicles
 - Minimum injury criteria
 - One AIS 3 injury or two AIS 2 injuries in separate body regions

Characteristics of Fatalities in the CIREN Database

Peter Martin

Stephen Ridella

National Highway Traffic Safety Administration

U.S. Department of Transportation

Washington, D.C., USA

Patricia C. Dischinger

Gabriel E. Ryb

Cynthia Burch

Shiu Ho

National Study Center for Trauma & EMS

University of Maryland School of Medicine

Baltimore, Md., USA

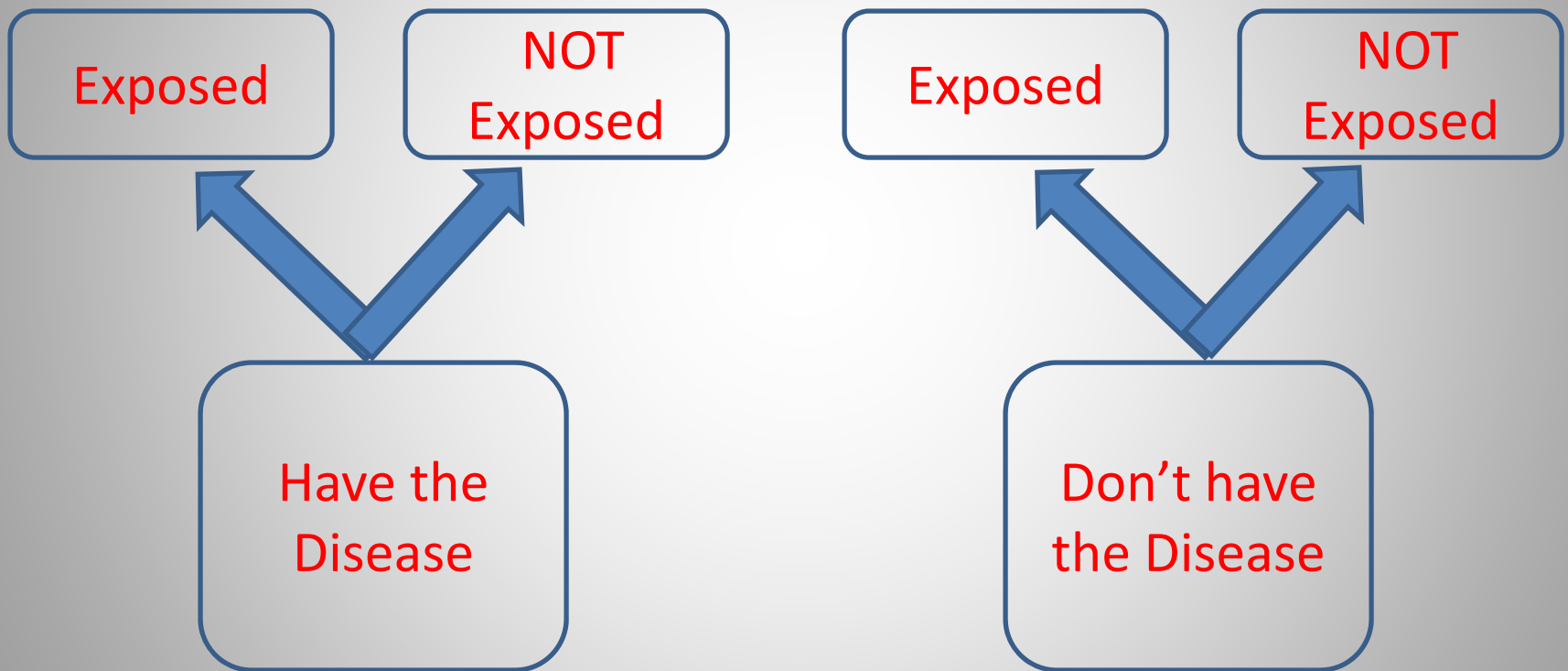
Paper Number 09-0253

- Findings suggest that the CIREN dataset is representative of real-world fatalities in terms of the fraction of deaths occurring within 30 minutes.

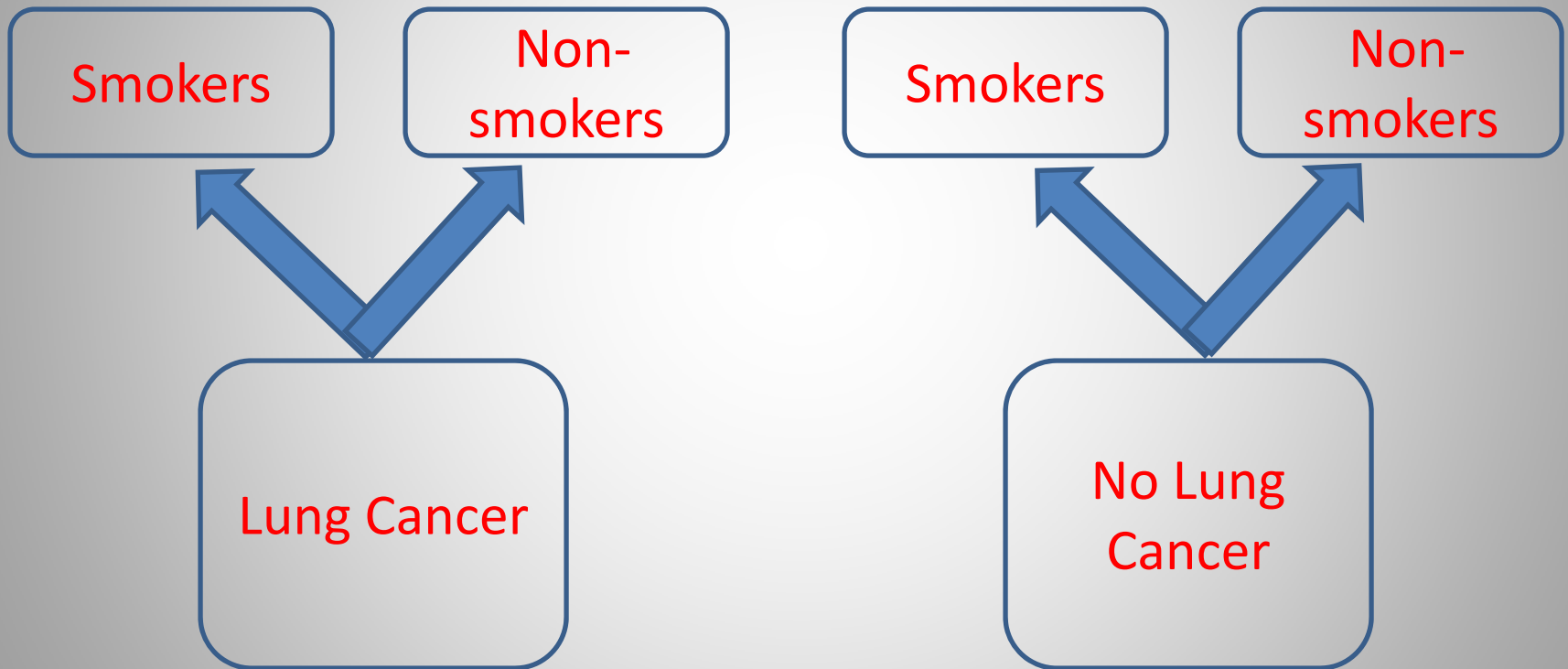
Study Design

- CIREN is appropriate for case-fatality studies
 - Case=individual injured in a crash
- CIREN is also appropriate for case-control analyses examining mortality
 - Particularly if enhanced by adjustment by crash, occupant and vehicular factors

Design of a case-control study

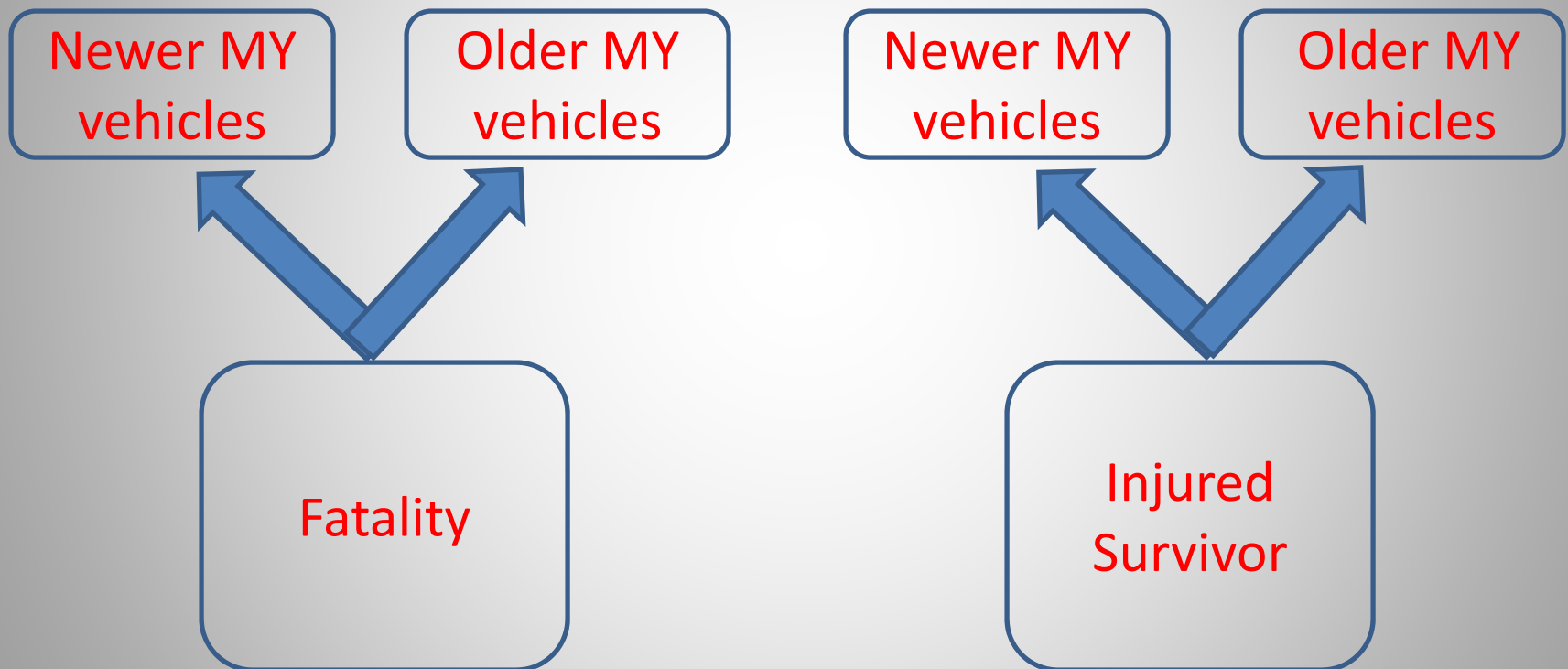


Example – Lung Cancer



A Cohort study would follow smokers and non-smokers over time to see if they develop lung cancer.

Case-control study of mortality in CIREN



If model year (MY) is associated with death, expect a proportion of cases 'exposed' to older vehicles to be greater than the controls who were exposed.

Adjustment variables based on previous CIREN research

- Previous analyses have identified factors associated with mortality in CIREN
- Driver Characteristics
 - Age
 - BMI
- Crash Characteristics
 - Delta V
 - Restraint Use
 - PDOF

Multiple Logistic Regression Predicting Death *

Delta V, principal direction of force, and restraint use contributions to motor vehicle crash mortality

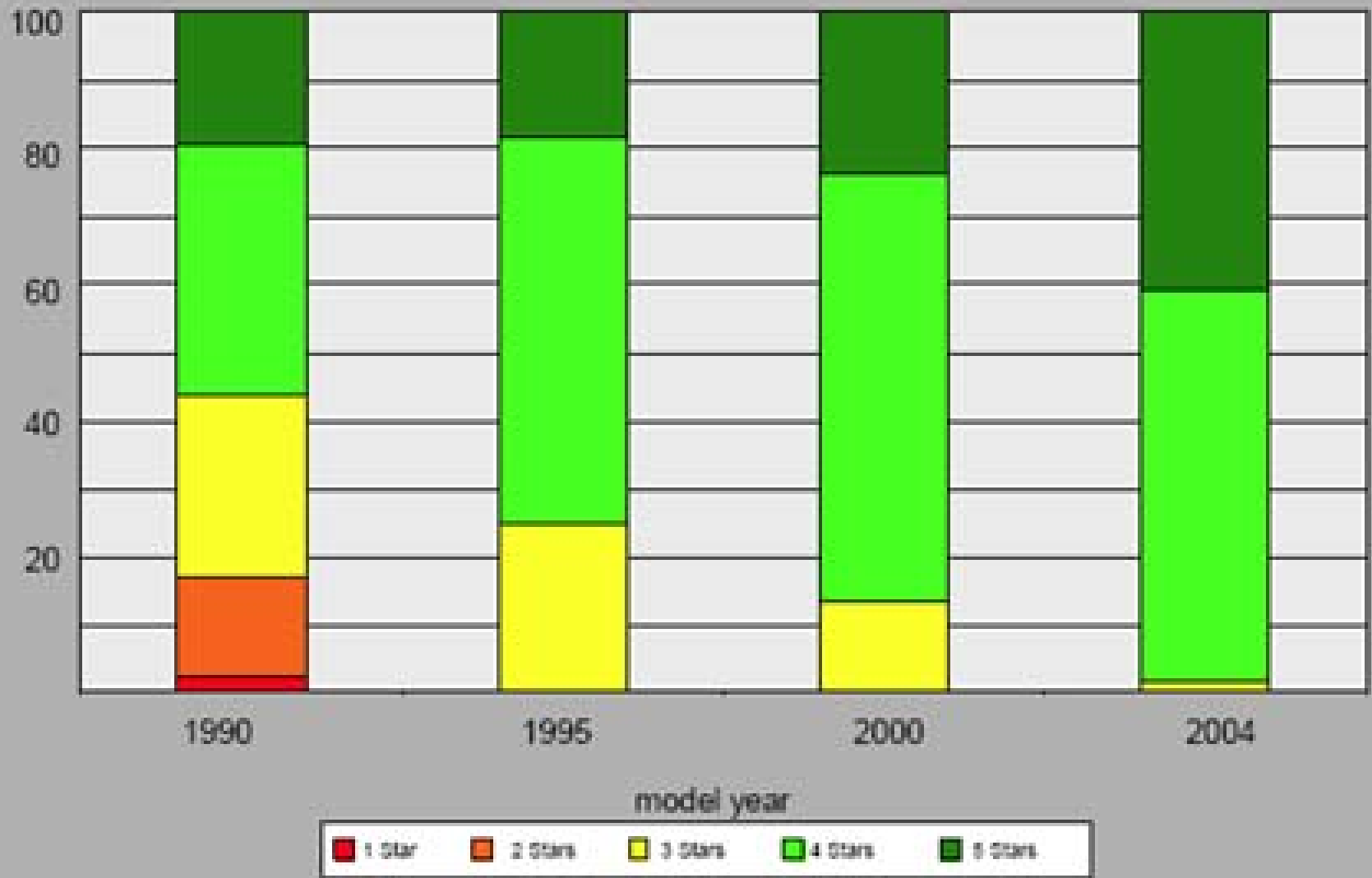
Ryb, G. et al., J Trauma 2007

	Odds Ratio	95% Confidence Limits
Overweight	1.81	1.14-2.87
Obese	2.81	1.75-4.53
Age 31-40	0.52	0.27-0.98
Age 41-50	0.65	0.32-1.22
Age 51-60	0.95	0.49-1.75
Age 61-70	1.88	0.99-3.48
Age 71-80	4.50	2.44-8.23
Age >80	11.07	5.18-23.83
Δv 40-80	3.65	2.44-5.44
Male gender	1.11	0.76-1.62
Lateral	3.06	2.03-4.61
Unrestrained	2.95	2.01-4.38

* Normal weight, age 16-30, $\Delta v < 40$, Female gender, frontal PDOF, and restrained status, used as reference.

NHTSA frontal NCAP ratings for drivers

Percent of results by star rating



Mortality by Vehicle Model Year

	MY 1994-1997 (n=644)	MY 1998-2004 (n=1,163)	MY 2005-2007 (n=81)	P value *
Death (%)	18	9	4	<0.0001
Odds Ratio***	Reference	0.46 (0.34-0.61)	0.17 (0.05-0.56)	

Mantel Haenszel chi-square unless noted otherwise

** Kruskal-Wallis statistic

***compared to MY 94-97, 95% confidence intervals in parentheses

Vehicle Model Year and Crash Outcomes: A CIREN Study Ryb, G. et al., *Traffic Injury Prevention*, 2009 (in press)

Multiple Logistic Regression Predicting Death *

Vehicle Model Year and Crash Outcomes: A CIREN Study

Ryb, G. et al., *Traffic Injury
Prevention*, 2009 (in press)

	Odds Ratio	95% Confidence Limits
Male gender	1.14	0.88-1.49
Age 61-70	1.97	1.23-3.06
Age 71-80	3.56	2.34-5.33
Age >80	8.52	4.95-14.52
Overweight	1.59	1.16-2.19
Obese	2.40	1.75-3.32
Near side PDOF	2.94	2.15-4.01
Far side PDOF	2.20	1.35-3.47
Unrestrained	2.11	1.62-2.75
Δv 40-69	3.31	2.34-4.70
Δv 70-79	7.53	3.60-15.11
$\Delta v \geq 80$	17.72	9.10-34.34
Unknown Δv	2.55	1.81-3.61
Light truck/SUV	0.79	0.56-1.11
Van	0.88	0.49-1.50
Make year 1998-2004	0.57	0.44-0.75
Make year 2005-07	0.22	0.07-0.50

* Normal weight, age 16-60, $\Delta v < 40$, Female gender, frontal PDOF, restrained status, automobile, make year 94-97 used as reference.

Death and ISS by IIHS Vehicle Rating

IIHS Rating	Good (n=164)	Average (n=194)	Not Rated (n=723)	Poor (n=142)	P value *
Death (%)	7.3	8.3	13.1	12	0.03
ISS (median q1-q3)	14 (26-10)	14 (22-10)	14 (26-10)	17 (29-10)	0.04**

Mantel Haenszel chi-square unless noted otherwise ** Kruskal-Wallis statistic

Multiple Logistic Regression Predicting Death *

Crash Test Ratings and Real-World Crash Outcomes: A CIREN Study

Ryb, G. et al. Presented at AAST, 2009.

	Adjusted Odds Ratio	95% Confidence Limits
Age		
61-70	2.48	1.26-4.64
71-80	6.45	3.38-12.07
>80	23.83	8.60-66.57
Change in Velocity		
Δv 40-69	1.07	0.50-2.62
$\Delta v \geq 70$	4.04	1.63-10.95
Abnormal BMI		
Overweight	2.24	1.29-4.03
Obese	3.34	1.94-5.95
Belted	0.36	0.24-0.55
Vehicle Rating		
Acceptable	0.52	0.23-1.16
Good	0.38	0.16-0.90
Not rated	1.00	0.55-1.90

* Normal weight, age 16-60, $\Delta v < 40$, Female gender, restrained status, and 'poor' rating used as reference.

Summary

- Injured occupants of recent model year vehicles experience a significantly lower mortality rate than earlier years
- CIREN vehicles rated 'good' by IIHS crash test standards were also associated with lower mortality
- As older vehicles (pre 1998) are retired, these declines in injury mortality should continue to increase

Conclusion

- **Several factors have contributed to decline in driver fatality rates over past 20 years:***
- **-From 1985 to mid 1990's:** reduction mostly due to changes in driver behavior (increased belt use, reduced alcohol-impaired driving). In fact, improvements in driving environment offset reductions in level of safety associated with changes in vehicle designs and vehicle purchase choices.
- **-Since mid-1990's** driving environment riskier, but improved safety of vehicle fleet has kept overall fatality risk declining.
- **Reducing the burden of motor vehicle crashes requires addressing *all* aspects of crashes: the driver, the vehicle, and the environment in which the crashes occur.**

Future...

- Mortality trends should continue as vehicle fleet changes
- Future improvements will address
 - Crash avoidance
 - Specs for older drivers
 - OnStar

Volvo Promises an Injury-Proof Car by 2020

2020

Aim is that by 2020 no-one should be killed or injured in a Volvo



Thank You

University of Maryland CIREN

Patricia Dischinger

Jim O'Connor

Gabe Ryb

Deb Stein

Mike Kleinberger

Liming Voo

Andy Burgess*

Tim Kerns

Cindy Burch

Joe Lloyd

Nafeesa Jawed

Kathy Read

Shiu Ho

Joe Kufera