Headwinds on the Road to Zero: ADAS, crashworthiness and macro effects

International Center for Automotive Medicine
Ann Arbor, MI
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Adrian Lund, Ph.D.
President
IIHS is an independent, nonprofit scientific and educational organization dedicated to reducing the losses — deaths, injuries and property damage — from crashes on the nation’s roads. Established 1959.

HLDI shares this mission by analyzing insurance data representing human and economic losses from crashes and other events related to vehicle ownership. Established 1972.

Both organizations are wholly supported by auto insurers.
Institute activities
We do not lobby, legislate, or litigate

- IIHS and HLDI rely on aggressive research and communications to empower people and policymakers with objective information
- Priority 1 – objective research on policy options to reduce injuries and property damage from motor vehicle crashes
- Priority 2 – effective communications to make research information attractive to news media
  - News releases (TV, print, Internet)
  - Films
  - Testimony at state and federal legislative and regulatory hearings
  - Briefings of other stakeholders, including vehicle manufacturers
# Haddon matrix

Recognizing opportunities to make a difference

<table>
<thead>
<tr>
<th>changes in…</th>
<th>before</th>
<th>during</th>
<th>after</th>
<th>losses</th>
</tr>
</thead>
</table>
| **people**  |  • licensing (GDL, elderly)  
  • impaired driving laws  
  • camera enforcement  |  • restraints (use)  
  • helmets  
  • speed cameras  |  • alcohol  
  • medical bracelet  
  • general health  |  • injuries  
  • deaths  
  • income  
  • hospital costs |
| **vehicles** |  • driver assistance  
  • daytime running lights  
  • electronic stability control  
  • advanced headlights  |  • restraints (effect)  
  • vehicle structure  
  • bumpers  |  • automatic crash notification  
  • fuel systems  
  • repairability  |  • damage  
  • insurance costs |
| **environment** |  • intersection design  
  • trouble-spot treatment  
  • rumble strips  |  • roundabouts  
  • breakaway poles  
  • crash cushions  |  • emergency medicine  |  • economic  
  • fuel usage (CAFE)  
  • congestion  |
Motor vehicle crash deaths have declined significantly in the U.S. during the past 50+ years.
Established October 2016
450 members
Headwinds on the Road to Zero
Motor Vehicle Deaths in 2016 Estimated to be Highest in Nine Years

NSC offers insight into what drivers are doing and calls for immediate implementation of proven, life-saving measures.

Itasca, IL – For the first time in nearly a decade, preliminary 2016 data from the National Safety Council estimates that as many as 40,000 people died in motor vehicle crashes last year. That marks a 6% increase over 2015, and a 14% increase over 2014 – the most dramatic two-year escalation since 1964 – 53 years. The preliminary estimate means 2016 may have been the deadliest year on the nation's roads since 2007. An estimated 4.6 million roadway users were injured seriously enough to require medical attention in 2016, and estimated cost to society was $432 billion.
Percent U.S. drivers using cellphones at any given daylight time and motor vehicle crash deaths

2000-15
Crash deaths and their rate are highly correlated with economic conditions.
U.S. motor vehicle crash deaths and unemployment rate
1950-2015

Motor vehicle crash deaths

Unemployment rate

2015
5% rate
35,092 deaths

30,000
35,000
40,000
45,000
50,000
55,000
60,000


0% 10% 15% 20%

3,000,000
U.S. motor vehicle crash deaths per billion vehicle miles traveled and unemployment rate
1950-2015

Crash deaths per billion vehicle miles traveled

Unemployment rate

11.2 per billion

5 percent
Change in U.S. motor vehicle crash deaths per billion miles traveled and unemployment rate
1950-2015
Youth are returning to cars after recession
Insurance exposure and unemployment 2006-14
Effects of economy on miles traveled and crash deaths
1990-2015

- **Miles traveled**
  - Increase by 1.5% each year, on average
  - Increase by another 1.8% for each 1 percentage point decline in unemployment

- **Crash deaths**
  - Decrease by 2% each year, on average
  - Increase by 1% for each 1% rise in miles
  - Increase by another 2% for each 1 percentage point decline in unemployment

- Combined with the effect on miles traveled, each 1 percentage point decline in unemployment is associated with about a 4% increase in crash deaths
Motor vehicle crash deaths, 1990-2015
Actual vs. model containing time trend, miles traveled and unemployment

\[ \log D = -3.2 - 0.022 T + 0.962 \log M - 0.021 U \]

R-Square = 91%
Motor vehicle crash deaths, 1990-2015
With projections for 2016-24

- 30,000
- 35,000
- 40,000
- 45,000


- Motor vehicle crash deaths
- if unemployment remains steady at 4.9
- if unemployment declines by 1.7% each year
- if unemployment declines by 8.0% each year
Vehicle and non-vehicle factors and highway safety
Passenger vehicle driver deaths per million vehicles, actual vs. expected for 1985 fleet
Crashworthiness in 1959 and 2009
2016 ratings for registered vehicles
All registered vehicles

- **Moderate overlap** (start year 1995)
  - Good: 80%
  - Acceptable: 20%

- **Side** (start year 2003)
  - Good: 70%
  - Acceptable: 30%

- **Roof** (start year 2009)
  - Good: 50%
  - Acceptable: 35%
  - Marginal: 10%

- **Small overlap** (start year 2012)
  - Good: 80%
  - Acceptable: 10%
  - Marginal: 5%
Legalizing recreational use of marijuana
Laws legalizing some uses of marijuana
After 2016 general election

source: National Conference of State Legislatures
Combined evaluation of legal recreational-use states

- Study states: WA, CO, OR
- Control states: MT, WY

Correlation with:
- WA: 0.48, 0.38, 0.70
- OR: 0.54, 0.68, 0.80
- CO: 0.69, 0.55, 0.68

Legend:
- Study states
- Control states

Correlation with:
- WA
- OR
Collision claims after legalization of recreational marijuana use  
Combined analysis of Colorado, Oregon, and Washington – HLDI 2017

<table>
<thead>
<tr>
<th>study states</th>
<th>Colorado, Washington, Oregon</th>
</tr>
</thead>
<tbody>
<tr>
<td>additional control states</td>
<td>Idaho, Montana, Nevada, Utah, Wyoming</td>
</tr>
<tr>
<td>calendar years</td>
<td>January 2012-October 2016</td>
</tr>
<tr>
<td>exposure</td>
<td>49,225,462 vehicle years for vehicles up to 33 years of age</td>
</tr>
<tr>
<td>total number claims</td>
<td>2,494,668</td>
</tr>
<tr>
<td>outcome measure</td>
<td>changes in collision claims per insured vehicle year</td>
</tr>
<tr>
<td>result</td>
<td>2.7% increase in collision claims (statistically significant)</td>
</tr>
</tbody>
</table>
Two U.S. studies differ over effects of marijuana on drivers
U.S. News & World Report, June 22, 2017

Studies offer conflicting conclusions on marijuana legalization’s role in car crashes, fatalities
The Cannabist, June 23, 2017

After-legalization traffic studies draw conflicting conclusions
Ganjapreneur, June 26, 2017

Studies differ over impact of legalized pot on highway crash numbers
Portland Press Herald, June 26, 2017

The jury is still out on legalizing marijuana impacting road collision rates
Auto Evolution, June 28, 2017

Two studies about driving and marijuana have very different results
Emerald Report, June 29, 2017

Competing studies leave haze of uncertainty connecting marijuana to traffic accidents
Colorado Politics, July 3, 2017
Pre-period correlations of collision claim rates between study states and control states used by Aydelotte et al. 2017, *AJPH*
**Crash deaths after legalization of recreational marijuana use**  
Colorado and Washington – Aydelotte et al. 2017, *AJPH*

<table>
<thead>
<tr>
<th>study states</th>
<th>Colorado and Washington</th>
</tr>
</thead>
<tbody>
<tr>
<td>control states</td>
<td>Alabama, Indiana, Kentucky, Missouri, South Carolina, Tennessee, Texas, Wisconsin</td>
</tr>
<tr>
<td>calendar years</td>
<td>January 2009-December 2015</td>
</tr>
<tr>
<td>outcome measure</td>
<td>changes in annual motor vehicle crash fatality rates per billion miles traveled</td>
</tr>
<tr>
<td>result</td>
<td>2.7% increase in fatalities (not statistically significant)</td>
</tr>
</tbody>
</table>
Rising speed limits
Effects of National Maximum Speed Limit

- 55 mph NMSL
  - 3,000-5,000 fewer deaths in 1974
  - 2,000-4,000 fewer deaths in 1983

- Partial repeal
  - 19 percent increase in deaths on rural interstates
  - 2,000 more deaths during 1987-90

- Full repeal
  - 17 percent increase in fatality rates on interstates
  - 1,000 more deaths during 1996-97
  - 12,545 more deaths during 1995-2005
Maximum speed limits
January 1993

- 55 mph (DC only)
- 60 mph
- 65 mph
- 70 mph
- 75 mph
- 80 mph
- 85 mph
Maximum speed limits
January 2013

- 55 mph (DC only)
- 60 mph
- 65 mph
- 70 mph
- 75 mph
- 80 mph
- 85 mph

[Map of the United States with speed limit color coding]
Deaths and expected deaths if maximum speed limits had not increased

1993-2013

33,000 deaths

1,900 deaths
Summary

- Speed limits continue to go up
- 8 percent increase in traffic fatality rate on interstates and freeways for every 5 mph increase in maximum speed limits
  - 500 additional deaths in 2013
- 4 percent increase on other types of roads
  - 1,400 additional deaths in 2013
- Approximately 33,000 lives lost due to post-NMSL speed limit increases
  - Three quarters of the 43,000 lives saved by frontal airbags
Maximum speed limits
September 2017

- MD
- DE
- DC
- MA
- OR
- RI
- NJ
- NH
- ME
- PA
- WV
- SC
- GA
- FL
- OH
- MI
- IN
- IL
- WI
- IA
- MO
- LA
- MS
- TN
- AR
- AL
- KY
- VA
- NY
- CT
- AK
- HI
- NC
- MN
- MT
- ND
- SD
- NE
- CO
- WY
- ID
- NV
- UT
- CO
- AZ
- NM
- OK
- AR
- TX

- 55 mph (DC only)
- 60 mph
- 65 mph
- 70 mph
- 75 mph
- 80 mph
- 85 mph
An unlikely headwind: automated vehicles and unrealistic expectations
Front crash prevention systems are reducing police-reported rear-end strikes

Compared with vehicles without any front crash prevention…

…vehicles with forward collision warning only are 27% less likely to rear-end another vehicle.

…vehicles with forward collision warning AND autobrake are 50% less likely to rear-end another vehicle.

If every vehicle on the road had forward collision warning with autobrake in 2014, there would have been an estimated

1,000,000 fewer police-reported crashes

400,000 fewer police-reported injuries
20 automakers have committed to make AEB a standard feature by September 2022

99+% of U.S. market
Two auto suppliers join for self-driving cars by 2019
-USA Today, August 23, 2016

BMW Group, Intel and Mobileye team up to bring fully autonomous driving to streets by 2021
-Reuters, July 1, 2016

Lyft predicts mostly self-driving cars by 2021
-New York Post, September 19, 2016

Kia plans fully driverless cars by 2030
-The Detroit News, January 4, 2016

Ford targets fully autonomous vehicle for ride sharing in 2021; invests in new tech companies, doubles Silicon Valley team
-Ford media center, August 16, 2016
New vehicle series with forward collision warning
By model year

- Standard
- Optional
- Not available
Registered vehicles with forward collision warning
By calendar year
Predicted counts of registered vehicles equipped with front crash prevention

With 2022 voluntary commitment
Estimated registered vehicles by feature
Calendar years 2016 and 2021

- Rear camera
- Rear parking sensors
- Blind spot
- Lane departure warning
- Forward collision warning
- Adaptive headlights
- Automatic emergency braking

- 2016
- 2021
Driver acceptance and safe use of automated systems
Percent of vehicle owners who reported driving with forward collision warning turned on.
# On-off status of front crash prevention systems

By manufacturer

<table>
<thead>
<tr>
<th>Make</th>
<th>Percent with system on</th>
<th>Number observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadillac</td>
<td>92</td>
<td>206</td>
</tr>
<tr>
<td>Chevrolet</td>
<td>87</td>
<td>142</td>
</tr>
<tr>
<td>Honda</td>
<td>98</td>
<td>239</td>
</tr>
<tr>
<td>Lexus</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>Mazda</td>
<td>95</td>
<td>20</td>
</tr>
<tr>
<td>Volvo</td>
<td>94</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>667</td>
</tr>
</tbody>
</table>
Percent of vehicle owners who reported driving with lane-maintenance systems turned on

- Volvo lane departure warning
- Infiniti lane departure warning
- Infiniti lane departure prevention
- Toyota lane departure prevention

- unknown
- never
- sometimes
- always
## On-off status of lane-maintenance systems

By manufacturer

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Percent with system on</th>
<th>Number observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadillac</td>
<td>57</td>
<td>207</td>
</tr>
<tr>
<td>Chevrolet</td>
<td>50</td>
<td>147</td>
</tr>
<tr>
<td>Ford/Lincoln</td>
<td>21</td>
<td>115</td>
</tr>
<tr>
<td>Honda</td>
<td>36</td>
<td>239</td>
</tr>
<tr>
<td>Lexus/Toyota</td>
<td>68</td>
<td>147</td>
</tr>
<tr>
<td>Mazda</td>
<td>77</td>
<td>26</td>
</tr>
<tr>
<td>Volvo</td>
<td>75</td>
<td>105</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>51</strong></td>
<td><strong>986</strong></td>
</tr>
</tbody>
</table>
On-off status by maximum observable lane-maintenance intervention level

Percent with system on

- Lane departure warning (n=547)
- Lane departure prevention (n=288)
- Active lane keeping (n=148)
Active lane keeping ranked least in trust
Average rating and 95% confidence interval by system

- side-view assist  
  (Honda, Audi, Infiniti)
- forward collision warning
- adaptive cruise control
- lane departure warning
- active lane keeping  
  (Honda, Audi)
Technologies had different problem areas
Percentage of drivers by complaint type

You have to get in a wrestling match for control of the wheel on curves.”
Participant 121SA

“On highways this worked well, but … the constant pressure in one direction was fatiguing.”
Participant 301SV

“I did not feel well notified by the system of when it was on and had been working, but no longer could identify the lines.”
Participant 329SV
Level 2 automated driving experience - issues
Lost lane lines
On-road testing of Tesla “Autopilot” 7.1 (hardware version 1)
Stopped lead vehicle
On-road testing – 2017 Mercedes-Benz E-Class
Much of the improved highway safety picture in the USA in recent decades is due to improved crashworthiness.
IIHS testing programs

1995 Front moderate overlap

1995 GOOD First test year 16.2%
2017 100%

2004 Rear (whiplash mitigation)

2004 GOOD First test year 6.2%
2017 98.2%

2009 Roof strength

2009 GOOD First test year 40.2%
2017 97%

2012 Front small overlap

2012 GOOD First test year 11.5%
2017 65.6%

IIIHS testing programs
Passenger-side small overlap tests
Small overlap countermeasures are not always applied to the passenger-side

- Passenger-side moderate overlap tests of two vehicles
  - Moderate overlap tests indicate good protection for the passenger and performance is not affected by small overlap countermeasures
  - Many vehicles sold and tested as right-hand drive in other markets
Toyota RAV-4 has driver-side only countermeasures
### Driver/passenger small overlap crash ratings

<table>
<thead>
<tr>
<th>Model</th>
<th>Driver-side impact</th>
<th>Passenger-side impact</th>
<th>Visible design application</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 Hyundai Tucson</td>
<td>G</td>
<td>G</td>
<td>symmetric</td>
</tr>
<tr>
<td>2015 Buick Encore</td>
<td>G</td>
<td>A</td>
<td>symmetric</td>
</tr>
<tr>
<td>2015 Honda CRV</td>
<td>G</td>
<td>A</td>
<td>symmetric</td>
</tr>
<tr>
<td>2015 Mazda CX-5</td>
<td>G</td>
<td>A</td>
<td>symmetric</td>
</tr>
<tr>
<td>2014 Subaru Forester</td>
<td>G</td>
<td>M</td>
<td>symmetric</td>
</tr>
<tr>
<td>2015 Nissan Rogue</td>
<td>G</td>
<td>M</td>
<td>driver-side</td>
</tr>
<tr>
<td>2015 Toyota RAV4</td>
<td>G</td>
<td>P</td>
<td>driver-side</td>
</tr>
<tr>
<td>Year</td>
<td>Model</td>
<td>Driver-Side Impact</td>
<td>Passenger-Side Impact</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------</td>
<td>--------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>2016</td>
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<td>G</td>
<td>M</td>
</tr>
<tr>
<td>2015</td>
<td>Nissan Rogue</td>
<td>G</td>
<td>M</td>
</tr>
<tr>
<td>2015</td>
<td>Toyota RAV4</td>
<td>G</td>
<td>P</td>
</tr>
</tbody>
</table>
2017 first official ratings test series: midsize cars
## Driver- and passenger-side small overlap ratings

### Midsize cars

<table>
<thead>
<tr>
<th></th>
<th>driver-side impact</th>
<th>passenger-side impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 Subaru Outback/Legacy</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Ford Fusion</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Honda Accord</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Nissan Altima</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Hyundai Sonata/Kia Optima</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2018 Toyota Camry</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Nissan Maxima</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Mazda 6</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>2017 Volkswagen Jetta</td>
<td>G</td>
<td>A</td>
</tr>
<tr>
<td>2017 Volkswagen Passat</td>
<td>G</td>
<td>M</td>
</tr>
<tr>
<td>2017 Chevrolet Malibu</td>
<td>G</td>
<td>M</td>
</tr>
</tbody>
</table>
Range of structural performance

GOOD
2017 Ford Fusion

ACCEPTABLE
2017 Mazda 6
Dummy observations
2017 midsize cars

- All driver dummies indicated low risk of injury
- Range of injury protection for passenger dummies
  - Insufficient airbag protection for passengers
    - In 3 vehicles, passenger dummy’s head contacted dash and sensors measured high risk of injury
    - In 2 vehicles, dummy’s head moved into a gap in airbag protection
  - 2 dummies measured high risk of leg injury from contact with the lower dash/glove box
Range of passenger restraint system performance

**GOOD**
2017 Nissan Maxima

**MARGINAL**
2017 Chevrolet Malibu
Summary of passenger-side small overlap testing

- More vehicles integrating small overlap countermeasures to both driver and passenger sides
  - Countermeasures are improving structural performance
    - In 2015 small SUV series, 3 vehicles received poor structural ratings
    - In current midsize car series, the worst structural rating was acceptable
  - Remaining deficiencies related to restraint system performance
    - 5 models demonstrated insufficient head protection from the frontal airbag
- Results will be published in October 2017
- Good or acceptable passenger-side small overlap performance a requirement for 2018 TOP SAFETY PICK+
Side crashworthiness research
Side impact crashworthiness: what’s next?

- Driver side impact fatality rates in 1-3 year old vehicles:
  - 2005: 22 per million RVY
  - 2015: 5 per million RVY

- 5,593 passenger vehicle occupant side-impact fatalities in 2015
  - Most not rated by IIHS
  - When rated, 49% were Good
Relevance

109 seriously injured occupants of Good-rated vehicles in NASS-CDS & CIREN

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%

Case occupants affected

- Forward impact location
- Increased severity
- Adjust injury criteria (or use different dummy)
- Include far-side dummy
- Increase severity and forward impact location and include far-side dummy

73 year old passenger sustained serious chest injuries

Passenger sustained fatal chest injuries; ~7” more crush than test

75 year-old belted driver with fatal chest injuries

Driver sustained fatal injuries from contact with right door

Driver sustained skull fracture, possibly from contact with window sill through or under the curtain AB.

73 year old passenger sustained serious chest injuries.
Research questions

- Can modified laboratory test configurations predict real-world injuries that the current IIHS SICE test does not?
  - Forward impacts
  - Higher severity

- If so, do newer Good-rated vehicles already perform better than older Good-rated vehicles?
  - Less than 10% of the NASS/CIREN case vehicles were 2010+ models
Camry vs. 2007 Fit chosen to replicate NASS-CDS case

WorldSID 50-M with RibEye deflection measurement system used in all tests
- Better representation than SID-IIs of case occupant anthropometry
- Ribeye allowed comparison of oblique thoracic loading

<table>
<thead>
<tr>
<th>Struck Honda Fit model year</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Fit moving 33 km/h; striking 1999 Camry @ 88 km/h, 19 cm forward of front axle</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
</tr>
</tbody>
</table>

Impact configuration for tests A & C
Results: real-world case vs. reconstruction test

NASS-CDS case occupant: 75-year-old male, 185 cm, 104 kg, belted, fatally injured

AIS $\geq 2$ injuries:
- AIS 5 Bilateral flail chest
- AIS 4 Trachea perforation
- AIS 3 Pulmonary artery laceration
- AIS 3 Left lung contusion, laceration, hemothorax
- AIS 2 Spleen laceration

WorldSID predicted injury risk for 75 year-old
Results: test comparison (structure)

- NASS configuration
  - Most intrusion forward of H-point
  - No B-pillar intrusion
  - 2015 less intrusion than 2007

- SICE tests
  - Peak intrusion centered near H-point and B-pillar
  - 2015 less intrusion than 2007
  - 2015 less B-pillar intrusion at 60 km/h than 2007 at 50 km/h
  - 2015: 5-10 cm more intrusion at 60 km/h than at 50 km/h
Results: test comparison (injury)

- 60 km/h SICE test produced highest injury risks, except for abdomen

- 50 km/h SICE test produced higher injury risk than NASS configuration, except:
  - ‘07 Fit shoulder
  - ‘15 Fit pelvis

- ‘15 Fit produced lower injury risk than ‘07 Fit, except:
  - SICE shoulder
  - NASS configuration pelvis
Results: RibEye data

- All tests produced overall rib displacement in oblique posterior-to-anterior direction
- NASS configuration tests A & C showed only slight initial displacement in the anterior-to-posterior direction
- Unknown whether loading direction controlled by ATD design or rotation around pre-tensioned belt
- Regardless of cause, ATD did not identify unique injury mechanism in NASS configuration
Conclusions

- While NASS reconstruction showed general agreement with real-world case, the injury risk for most body regions was lower than in the current SICE test.
- These tests do not justify an evaluation program with a more forward impact location.
  - The higher impact speed would produce greater injury risks at the current impact location.
- Vehicle designs continue to improve beyond requirements for Good SICE rating; the distribution of injury-producing crash configurations likely is different for current vehicle designs.
- A higher SICE impact speed would likely drive more restraint system changes than structural changes; potential tradeoffs would need to be considered.
More information and links to our YouTube channel and Twitter feed at iihs.org

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