Safety Always Matters: How the Need for Occupant Protection Will Influence Vehicle Design with Increasing Vehicle Automation

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The Current Crash Injury Problem in the U.S.

• Motor-vehicle crashes:
  – account for 40% of trauma admission to US hospitals,
  – are the fourth most common cause of non-fatal injuries treated in EDs, and
  – are one of the leading causes of death for people age 3 to 30 years.

• 35,000 fatalities and ~2.4 million injured road users each year

• Annual economic costs estimated at $277 billion (in 2010), harm associated with lost productivity estimated at $581 billion.

Sources: CDC (2011), NHTSA (2014), Blincoe et al. (2014)
Important Points of Reference

- NHTSA’s Federal Automated Vehicles Policy
- SAE J3016
Important Points of Reference

NHTSA’s Federal Automated Vehicles Policy

“Regardless of whether the ADS* is operating the vehicle or the vehicle is being driven by a human driver, the occupant protection system should maintain its intended performance level in the event of a crash.”

* Automated Driving System
Spot the Fallacy

Drivers cause 95% of crashes

+ 

Driverless cars don’t have drivers

With driverless cars we will have 95% fewer crashes?
Don’t Believe (most of) the Hype

• Driving is exceptionally complex. Going from easy driving to difficult driving is much easier for humans than for computers.

• The infrastructure is not designed for automation.

• AI systems do not respond well to unusual or highly variable events (police officer directing traffic after a crash or sporting event, many weather conditions).

• Current US risk is ~1 fatality/100 million miles (includes weather, drunk, no belts…); how much safer does automation need to be to be acceptable?

Automation in other fields suggests some cautions: de-skilling, mode confusion, humans called upon only in extreme conditions that lead to automation failure, and low acceptance of machine failure.
Near-Term Technology (5 years)

**Crash Avoidance:**
- lane-departure warning, lane-keeping assist
- forward collision warning, automatic emergency braking
- adaptive cruise control (ACC)
- ACC with lane-keeping (“autopilot”)
- low-speed “traffic-jam assist”
- blind spot warning
- adaptive headlighting
Mythical Vehicles

What if my vehicle can’t cause a crash?

(But still might get hit by other cars…)
Crashes Avoided by a Vehicle that Doesn’t Cause Any Crashes

Percentage of crashes prevented with ideal crash avoidance

- All: 63%
- Frontal: 93%
- Rollover: 85%
- Side: 39%
- Rear: 29%

Klinich et al. 2016 IRCOBI
Crash Type Distribution

Current

- Front: 48%
- Rear: 22%
- Left Side: 15%
- Right Side: 15%
- Top: 0%
- Undercarriage: 0%

With Ideal Crash Avoidance

- Front: 10%
- Rear: 43%
- Left Side: 24%
- Right Side: 23%
- Top: 0%
- Undercarriage: 0%
Near-Term Technology (5 years)

Crashworthiness and Occupant Protection:
• improved adaptive restraint systems (weight and seat position)
• improved vehicle structures for reduced intrusion
• expanded airbag coverage in the front seat
• more advanced restraint technology in rear seats
• “active-passive integration”: restraints adapting to real-time crash information from crash avoidance sensors
• improved protection for people who don’t look like crash test dummies.
Phase-In Timelines

- 50% of registered vehicles in the US are more than 12 years old (but people drive their newer cars more miles)
- Technologies take many years to penetrate the fleet because of relatively slow turnover of vehicles
- **Increasing vehicle cost slows turnover**
- People at higher crash risk tend to drive older vehicles: the average age of a **new car buyer** is 52 years
ESC prevents about 40% of all crashes involving loss of control. The greatest reductions were found for rollover crashes (−50%), followed by run-off-road (−40%) and single vehicle crashes (−25%).

Source: Høye (2011). Accident Analysis and Prevention
Phase-In: Electronic Stability Control

Figure 1: Percentage of new vehicle series with ESC

100% Federal Mandate

Source: IIHS
Phase-In: Electronic Stability Control

Figure 2: Percentage of registered vehicles with ESC

100% Federal Mandate

Source: IIHS
Phase-In: Electronic Stability Control

Source: IIHS
Phase-In: Electronic Stability Control

Calendar year features reach 95% of registered vehicle fleet with and without mandate

Source: IIHS
Crashworthiness and Occupant Protection Regs (selected)

FMVSS* 201: Interior head impact **
FMVSS 202a: Rear impact neck protection **
FMVSS 203, 204: Steering wheel & column performance
FMVSS 205: Glazing
FMVSS 206: Door locks & retention
FMVSS 207: Seat back strength **
FMVSS 208: Frontal crash protection & belts **
FMVSS 209, 210: Seat belts **

* Federal Motor Vehicle Safety Standard

Remains applicable without driver

**Implications for Seating
Crashworthiness and Occupant Protection Regs (selected)

- FMVSS 212: Windshield mounting
- FMVSS 213: Child restraint systems*
- FMVSS 214: Side-impact protection**
- FMVSS 216: Roof crush
- FMVSS 225: Child restraint anchorages**

* Does not apply to vehicles, but strong interactions with FMVSS 225 and vehicle seating

**Implications for Seating

Remains applicable without driver
Federal Policy Matters

• Airbags were effectively delayed for more than a decade by the Reagan administration [with the encouragement of much of the auto industry], costing thousands of lives

• The prohibition by Congress of belt interlocks in 1974 cost thousands of lives (still not permitted, though research is underway)

• Delays in primary enforcement of belt use laws meant the US lagged behind the rest of the developed world (yes, costing thousands of lives)

• Strong political influence from the trucking industry has delayed changes in hours of surface, truck underride protection, antilock brakes, and other safety improvements
What About Ride Hailing?

1. Rear seating positions are not as safe as front seating positions for many occupants, particularly older adults
2. Belt use is much lower for rear-seated ride-hailing passengers than for the same people as drivers or in the back seats of their own vehicles*
3. Ride-hailing rides may be slightly safer per mile than personally driven miles (+driver state, -congestion exposure) and may replace high-risk (e.g., drunk-driving) miles

Crash protection issues remain essentially the same whether or not a driver is present; unbelted rear-seat passengers are at much higher risk than belted front-seat passengers

* Jermakian (IIHS) 2018
What About (Automated) Ride Hailing Interiors?

1. Plush or utilitarian? Depends on how much money the company is willing to lose per trip.

2. Benchmarks tend toward utilitarian:
   1. Public transportation
   2. Taxis
   3. Airport shuttles

Purpose-built ride-hailing vehicles will experience close scrutiny of their crash safety performance from NHTSA and consumer information groups (e.g., IIHS)
What About Alternative Postures?

Considerable emphasis in the crash safety and interior design domains relating to automated vehicles is focused on rear-facing and reclined postures.

(My favorite absurd vehicle interior pic)

(That belt fit… not so good)
Details of Reclined Postures

Pilot lab study at UMTRI with 24 men and women
Frontal Crashes for Drivers

Stature: 160.4 cm
Sex: female
BMI: 20.4
Age: 61

Stature: 150.7 cm
Sex: female
BMI: 42.0
Age: 66

Stature: 178.8 cm
Sex: male
BMI: 23.1
Age: 34

Stature: 186.1 cm
Sex: male
BMI: 34.2
Age: 67
Effects of Recline On Occupant Kinematics
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43-Degree Recline

Original Anchor Locations

Alternative Anchor Locations
Effects of Recline on Rear Impact

23deg_Rear_Impact : Time = 0.000000 : Frame 1

33deg_Rear_Impact : Time = 0.000000 : Frame 1
What’s a “Low Speed Vehicle”?

FMVSS 500 establishes a class of vehicles to which most FMVSS do not apply:

• <25 mph
• access to roads locally regulated
• seatbelts, headlights, a few other safety features are required
• many opportunities to add automation
• seating opportunities?

aka Neighborhood Electric Vehicles
Implications for Vehicle Seating

• Current-technology seats are going to be sold for a long time
• Safety requirements on seats will continue to increase
• Opportunities to use the seat to improve safety:
  -- improved protection in side impact
  -- dynamic pre-crash posture adjustment
  -- more integrated belt restraints
  -- occupant sensing and adapting restraints
• Much greater emphasis on reclined postures and rear impact protection
Acknowledgements

Government:
- National Highway Traffic Safety Administration
- National Institute of Justice
- National Science Foundation
- U.S. Army TARDEC

Industry:
- Ford
- General Motors
- Toyota
- TRW
- JCI
- Britax
- Faurecia

Other Universities:
- Wayne State U.
- Hunan U.
- Tsinghua U.
- Oakland U.
- UVa

U-M:
- D. of Emergency Medicine
- D. of Pediatrics
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