Safe Driving Vehicles: (DriverLessCars/SmartDrivingCars/SelfDrivingCar/autonomousCars)

*a Public Service & Profit Opportunity for the Insurance Industry*

**BY**

ALAIN L. KORNHAUSER

Professor, Operations Research & Financial Engineering
Director, Program in Transportation
Faculty Chair, PAVE (Princeton Autonomous Vehicle Engineering)  
*Princeton University*

Board Chair, Advanced Transit Association (ATRA)

The 21st Century: Now What?

**Villa Milano**
1630 Schrock Road, Columbus, Ohio 43229

April 9, 2014
“Safe Driving Vehicle”: 1939 -> Today +

- What is a “Safe Driving Vehicle” (aka DriverLessCars/SmartDrivingCars/Self-drivingCar/autonomousCars)
- The 1st 75 years: (1939 -> 2014)
  - 1939 -> DARPA Challenges
  - DARPA Challenges -> Today
- “Safe”: Accident Mitigation v Accident Avoidance
- The **Opportunity** for the Insurance Industry:
  - Trucks; Buses; Cars
- Questions & Discussion
Scope of “Safe Driving Vehicle” & Automation

- Surface Transportation Vehicle
  + Running Surface
    (aka roadway, guideway, railway)
Technology for Technology’s sake

• The Evolution of Safe Driving Vehicle Technology to date
Scope of “Safe Driving Vehicles”
What about Mass Transit
(Vehicles purchased by Agencies to offer mobility to the public at large)
In the late 60s...

Some thought that: “The automation & computer technology that took us to the moon could now revolutionize mass transit and save our cities from the onslaught of the automobile”

Donn Fichter “Individualized Automatic Transit and the City” 1964

Westinghouse *Skybus* Late 60’s-

**Princeton University**

**Transit**
Automated Vehicles Operating in their own Exclusive Roadway
Now exist in essentially every Major Airport and a few Major Activity Centers
Starting in the early 70’s: U of Minnesota became the center of PRT research focused on delivering auto-like ubiquitous mobility throughout urban areas.

- Since Demand very diffuse (Spatially and Temporally):
  - Many stations served by Many small vehicles
    - (rather than a few large vehicles).
- Many stations
  - Each off-line with interconnected mainlines
    - To minimize intermediate stops and transfers.
- Many small vehicles
  - Require more sophisticated control systems,
    - both longitudinal and lateral.
PRT
Personal Raid Transit

Some early test-track success...
DFW AirTrans PRT
Was built and operational for many years
Remains a critical mobility system today & Planning an expansion
Today...

We can Build and Operate them Safely

Morgantown 1975

Remains a critical mobility system today & planning an expansion
Masdar & Heathrow are Operational; Suncheon in testing
Objective: Efficient Utilization of Narrow Bus-Only Shoulders

Methodology: Driver Assistance via
• Virtual Images,
• Haptic Feedback, and
• Tactile Feedback

(It Knows Enough to Steer the Bus, but doesn’t)

http://www.bus2.me.umn.edu/
What about

Motor carriers

(Trucks: both Pick-up & delivery & Long-haul)

(Vehicles purchased by fleet operators for the provision of a service)
Off-Road

Rio Tinto Automated Truck
Volvo Truck Emergency Braking
What about the **Personal Car**  
*(Vehicles purchased by consumers for personal mobility)*
Automated Cars: Pre-DARPA Challenges
Focused on Creating New Roadways
To be used Exclusively by Automated Vehicles

- GM Futurama @ 1939 World’s Fair

- Zworykin & Flory @ RCA-Sarnoff in Princeton, Late 50s*

Cruise Control (1958)
1945 Invented by Ralph Teetor
1958 Chrysler Imperial 1st introduction
GM first offered on the 1959 model year Cadillac.
Automated Cars: Pre-DARPA Challenges

• Anti-lock Braking Systems (ABS) (1971) (wikipedia)
  – Chrysler & Bendix Corporation, introduced a computerized, three-channel, four-sensor all-wheel\(^6\) ABS called "Sure Brake" for its 1971 Imperial.
  – Ford added an antilock braking system called "Sure-track" to the rear wheels of Lincoln Continentals as a standard option.
  – General Motors :"Trackmaster" rear-wheel only ABS . An option on rear-wheel drive Cadillac models and the Oldsmobile Toronado.

• “Wire Sniffing” Cars
  – Robert E Fenton @ OSU, Early 70s*

Automated Cars: Pre-DARPA Challenges

• 1990s
  – National Automated Highway System Research Program (NAHSRP) (1994-97)
    • Goal to develop specifications for a fully automated highway system
    • Benefits:
      – #1. Roadway capacity (led to focus on platooning)
      – #2. Safety
      – #3.... Robust to Weather, Mobility, Energy, Land Use, Commercial efficiency, travel time
    • Focused on automated roadways serving only fully automated vehicles.
  • References
    – The National Automated Highway System That Almost Was
    – Cheon, Sanghyun “An overview of Automated Highway Systems (AHS) and the Social and Institutional Challenges they Face” (Excellent critique, well worth reading)
    – Video Summary of NAHSRP (compare the tone to what Mercedes did in Frankfurt. We’ve come a very long way!)
• Program Cancelled! No Feasible Initial Condition
  – No reason to build Automated Highway If there are no Automated Cars & visa versa.
DARPA Grand Challenge
Created in response to a Congressional and DoD mandate:
a field test intended to accelerate R&D in autonomous ground vehicles
that will help save American lives on the battlefield.
Fundamental Contribution of DARPA:

2004

DARPA
GRAND CHALLENGE

CMU “Red Team”

2005

DARPA
GRAND CHALLENGE

Stanford Racing Team

2007

URBAN
CHALLENGE

CMU “Tartan Team”

Change the mind set to: focus on the Individual Vehicle
Make it “Autonomous”:
Able to “Drive” without any: outside help,
behavior modification of conventional roadway users nor,
physical changes in existing roadways.
Where Are We Today with SafeDrivingCars/AutomatedCars/SmartDrivingCars?
Current State of Automated Cars

• Much of the Public Interest has been induced by the Google Self-Driving Car. http://www.youtube.com/watch?v=cdgQpa1pUUE
  – It is not driverless...
    • Not yet
  – What did they do?
    • Adopted the DARPA “mind Set” ( & Sebastian Thrun from Stanford DARPA Team + others)
    • Bought “Standard Lexus” (w/ electronically controlled Brakes, Throttle & Steering (BTS))
    • “Straped on”
      – Sensors: LIDAR’s “depth point cloud”, GPS, Radars & Cameras (on the expensive side)
      – Communications: to access 3D digital map data
      – Software & Computer: Converts Sensor Output into BTS Inputs
    • Developed a self-driving vehicle that can operate in the existing environment.
    • Stated Motivation: >90% of road traffic accidents involve human error.
      – So... remove the human from the loop.
    • Have Self-Driven over 500,000 miles on Existing Roads in Existing Traffic Conditions

http://www.youtube.com/watch?v=cdgQpa1pUUE
VisLab.it (U. of Parma, Italy)

- Had assisted Oshkosh in DARPA Challenges
- Stereo vision + radar

http://orfe.princeton.edu/~alaink/SmartDrivingCars/Videos/PROUD_Car_Test.072013(driverless%20car)VisLabItaly_dualView.mp4

(Video has no sound)
SmartDrivingCars: Post-DARPA Challenges
(2010-today)

- University Efforts:
  - CMU + GM
  - Stanford + VW
  - Va Tech + Google?
  - Oxford + Nissan
  - Parma + Fiat
  - Princeton (PAVE)
  - ...
Automated Vehicles: Post-DARPA Challenges
(2007 -> today)

Driverless (Level 4); Non-Exclusive Roadway; Low Speed (< 25kph)

- **CityMobil** (2008 -> 2012)
  - Low speed (< 25 kph),
  - Lidar pedestrian detection
  - Non-exclusive simple roadway
    - just lane markings
    - Includes pedestrians & low speed vehicles
  - La Rochelle (CyberCars/Cybus/INRIA)

- **CityMobil2** (2012->...)
  - Slated for 5 city deployments + Singapore + ???
Mercedes Benz
2014 E & S – Class w “997” Package

Driver Assistance Package
- Active Blind Spot Assist
- Active Lane Keeping Assist
- DISTRONIC PLUS® with Steering Assist
- PRE-SAFE® Brake with Cross-Traffic Assist
- PRE-SAFE® PLUS

!! Introduction dates vary. See your dealer for availability.
What are the Current Challenges?
Google has “shown”: “We can build it!”

Don Draper (Mad Men) Has Done a Great Job Convincing Us that We Love to Drive!
(Or, do we?? Are we any good at it?)

Safety Hasn’t Been Great at Selling Cars
Otherwise, everyone would own a Volvo

What is a salient “Value Proposition”?

What will Consumers & Fleet Owners Buy?

Forces for: Commercialization not Deployment?
The Automobile’s 1st 125 Years (1886-2011)

Delivered: Enormous Personal Freedom & Mobility

But...Safe Operation Requires a Safety-Designed Vehicle
Since Safety Doesn’t Sell: It is Regulate as a Public Necessity!

Up to today: Safety is the Primary Purview of

Focus on Crash Mitigation
(air bags, seat belts, crash worthiness, ...)

Good News: Effective in reducing Deaths and Accident Severity
## Early Estimate of Motor Vehicle Traffic Fatalities in 2012

<table>
<thead>
<tr>
<th>Quarter</th>
<th>1st Quarter (Jan–Mar)</th>
<th>2nd Quarter (Apr–Jun)</th>
<th>3rd Quarter (Jul–Sep)</th>
<th>4th Quarter (Oct–Dec)</th>
<th>Total (Full Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>9,239</td>
<td>11,005</td>
<td>11,897</td>
<td>11,369</td>
<td>43,510</td>
</tr>
<tr>
<td>2006</td>
<td>9,558 [+3.5%]</td>
<td>10,942 [-0.6%]</td>
<td>11,395 [-4.2%]</td>
<td>10,813 [-4.9%]</td>
<td>42,708 [-1.8%]</td>
</tr>
<tr>
<td>2007</td>
<td>9,354 [-2.1%]</td>
<td>10,611 [-3.0%]</td>
<td>11,056 [-3.0%]</td>
<td>10,238 [-5.3%]</td>
<td>41,259 [-3.4%]</td>
</tr>
<tr>
<td>2008</td>
<td>8,459 [-9.6%]</td>
<td>9,435 [-11.1%]</td>
<td>9,947 [-10.0%]</td>
<td>9,582 [-6.4%]</td>
<td>37,423 [-9.3%]</td>
</tr>
<tr>
<td>2009</td>
<td>7,552 [-10.7%]</td>
<td>8,975 [-4.9%]</td>
<td>9,104 [-8.5%]</td>
<td>8,252 [-13.9%]</td>
<td>33,883 [-9.5%]</td>
</tr>
<tr>
<td>2010</td>
<td>6,755 [-10.6%]</td>
<td>8,522 [-5.0%]</td>
<td>9,226 [+1.3%]</td>
<td>8,496 [+3.0%]</td>
<td>32,999 [-2.6%]</td>
</tr>
<tr>
<td>2011</td>
<td>6,708 [-0.7%]</td>
<td>8,216 [-3.6%]</td>
<td>8,960 [-2.9%]</td>
<td>8,483 [-0.2%]</td>
<td>32,367 [-1.9%]</td>
</tr>
</tbody>
</table>
Since Safety Doesn’t Sell: It is Regulate as a Public Necessity!

Up to today: Safety is the Primary Purview of

Focus on Crash Mitigation
(air bags, seat belts, crash worthiness, ...)

Good News: Effective in reducing Deaths and Accident Severity

Bad News: Ineffective in reducing Expected Accident Liability & Ineffective in reducing Insurance Rates
The Automobile’s 1st 125 Years (1886-2011)

Delivered: Enormous Personal Freedom & Mobility

But...Safe Operation Requires Continuous Vigilance
We Love the Freedom & Mobility

But...Continuous Vigilance is an unrealistic requirement for drivers

http://orfe.princeton.edu/~alaink/SmartDrivingCars/Videos/HIGHWAY_SING-A-LONG_%20BuildMeUpButtercup.mp4
Txtng while driving is out of control...
TravelTainment Industry Wants Everyone’s Attention
THE RELATIVE FREQUENCY OF UNSAFE DRIVING ACTS IN SERIOUS TRAFFIC CRASHES


Summary Technical Report

By D. L. Hendricks, Veridian Engineering, Inc.
J. C. Fell, Star Mountain, Inc.
M. Freedman, Westat, Inc.

“In 717 out of 723 crashes (99%), a driver behavioral error caused or contributed to the crash”

- DRIVER INATTENTION: 22.7%
- VEHICLE SPEED: 18.7%
- ALCOHOL IMPAIRMENT: 18.2%
- PERCEPTUAL ERRORS (e.g. looked, but didn’t see): 15.1%
- DECISION ERRORS (e.g. turned with obstructed view): 10.1%
- INCAPACITATION (e.g. fell asleep): 6.4%
Early Estimate of Motor Vehicle Traffic Fatalities in 2012

<table>
<thead>
<tr>
<th>Quarter</th>
<th>1st Quarter (Jan–Mar)</th>
<th>2nd Quarter (Apr–Jun)</th>
<th>3rd Quarter (Jul–Sep)</th>
<th>4th Quarter (Oct–Dec)</th>
<th>Total (Full Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>9,239 [ +3.5%]</td>
<td>11,005</td>
<td>11,897</td>
<td>11,369</td>
<td>43,510</td>
</tr>
<tr>
<td>2006</td>
<td>9,558 [ +3.5%]</td>
<td>10,942 [ -0.6%]</td>
<td>11,395 [ -4.2%]</td>
<td>10,813 [ -4.9%]</td>
<td>42,708 [ -1.8%]</td>
</tr>
<tr>
<td>2007</td>
<td>9,354 [ -2.1%]</td>
<td>10,611 [ -3.0%]</td>
<td>11,056 [ -3.0%]</td>
<td>10,238 [ -5.3%]</td>
<td>41,259 [ -3.4%]</td>
</tr>
<tr>
<td>2008</td>
<td>8,459 [ -9.6%]</td>
<td>9,435 [ -11.1%]</td>
<td>9,947 [ -10.0%]</td>
<td>9,582 [ -6.4%]</td>
<td>37,423 [ -9.3%]</td>
</tr>
<tr>
<td>2009</td>
<td>7,552 [ -10.7%]</td>
<td>8,975 [ -4.9%]</td>
<td>9,104 [ -8.5%]</td>
<td>8,252 [ -13.9%]</td>
<td>33,883 [ -9.5%]</td>
</tr>
<tr>
<td>2010</td>
<td>6,755 [ -10.6%]</td>
<td>8,522 [ -5.0%]</td>
<td>9,226 [ +1.3%]</td>
<td>8,496 [ +3.0%]</td>
<td>32,999 [ -2.6%]</td>
</tr>
<tr>
<td>2011</td>
<td>6,708 [ -0.7%]</td>
<td>8,216 [ -3.6%]</td>
<td>8,960 [ -2.9%]</td>
<td>8,483 [ -0.2%]</td>
<td>32,367 [ -1.9%]</td>
</tr>
<tr>
<td>2012*</td>
<td>7,550 [ +12.6%]</td>
<td>8,650 [ +5.3%]</td>
<td>9,250 [ +3.2%]</td>
<td>8,630 [ +1.7%]</td>
<td><strong>34,080 [ +5.3%]</strong></td>
</tr>
</tbody>
</table>
Response is Laudable

April 3: US DOT Launches First-Ever National Distracted Driving Enforcement and Advertising Campaign

But... Not Likely to be Effective
Even though Safety Doesn’t Sell, Some Automakers are Leading the Way

http://orfe.princeton.edu/~alaink/SmartDrivingCars/Videos/Subaru%20EyeSight_Commercial60secCrashTest.mp4
What’s in the Showroom Today?

• A number of car companies have been offering active Forward Collision Avoidance Systems for several years
  – Volvo
  – Acura
  – Mercedes
  – Subaru
  – ...
Preliminary Results are Disappointing

**Forward collision avoidance**
Percent differences in claim frequency with and without

<table>
<thead>
<tr>
<th></th>
<th>Acura with auto brake</th>
<th>Mercedes with auto brake</th>
<th>Mercedes without brake</th>
<th>Volvo with auto brake</th>
<th>Volvo without brake</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collision</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-5</td>
<td>0</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td><strong>Property damage liability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>-20</td>
<td>-10</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td><strong>Bodily injury liability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>-20</td>
<td>-10</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td><strong>Medical payment</strong></td>
<td>0</td>
<td>10</td>
<td>-10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Personal injury protection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>20</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Medical payment and personal injury protection both cover occupants of the insured vehicle. Personal injury protection is sold in the 17 states with no-fault insurance systems and covers injuries regardless of who is at fault.

or statistically significant
But what has been sold so far doesn’t really work...
### Superior

<table>
<thead>
<tr>
<th>Model</th>
<th>Speed reduction</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subaru Legacy</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Subaru Outback</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Cadillac ATS</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Cadillac SRX</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Mercedes-Benz C-Class</td>
<td>11 mph</td>
<td>2</td>
</tr>
<tr>
<td>Volvo S60</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Volvo XC60</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Model</td>
<td>12 mph Test</td>
<td>25 mph Test</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Subaru Legacy</td>
<td>12 mph</td>
<td>25 mph</td>
</tr>
<tr>
<td>EyeSight</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Subaru Outback</td>
<td>12 mph</td>
<td>25 mph</td>
</tr>
<tr>
<td>EyeSight</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cadillac ATS</td>
<td>12 mph</td>
<td>15 mph</td>
</tr>
<tr>
<td>Forward Collision Alert, Automatic Collision Preparation</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>When the ATS is equipped with only Forward Collision Alert it earns a BASIC rating.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadillac SRX</td>
<td>12 mph</td>
<td>19 mph</td>
</tr>
<tr>
<td>Forward Collision Alert, Automatic Collision Preparation</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>When the SRX is equipped with only Forward Collision Alert it earns a BASIC rating.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercedes-Benz C-Class</td>
<td>11 mph</td>
<td>13 mph</td>
</tr>
<tr>
<td>Distronic Plus and Pre-Safe Brake</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Volvo S60</td>
<td>12 mph</td>
<td>14 mph</td>
</tr>
<tr>
<td>City Safety/ Collision Warning</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>with Full Auto Brake and Pedestrian Detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volvo XC60</td>
<td>12 mph</td>
<td>11 mph</td>
</tr>
<tr>
<td>City Safety/ Collision Warning</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>with Full Auto Brake and Pedestrian Detection</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## 12 mph test

<table>
<thead>
<tr>
<th>ADVANCED</th>
<th>Speed reduction</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acura MDX 2014 models</td>
<td>7 mph</td>
<td>1</td>
</tr>
<tr>
<td>Forward Collision Warning/Collision Mitigation Brake System When the MDX is equipped with only Forward Collision Warning it earns a BASIC rating.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audi A4</td>
<td>11 mph</td>
<td>2</td>
</tr>
<tr>
<td>Audi pre sense front</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audi Q5</td>
<td>11 mph</td>
<td>2</td>
</tr>
<tr>
<td>Audi pre sense front</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jeep Grand Cherokee 2014 models</td>
<td>4 mph</td>
<td>0</td>
</tr>
<tr>
<td>Forward Collision Warning with Crash Mitigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lexus ES</td>
<td>6 mph</td>
<td>1</td>
</tr>
<tr>
<td>Pre-Collision System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mazda 6 2014 models</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>Smart City Brake Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volvo S60</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>City Safety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volvo XC60</td>
<td>12 mph</td>
<td>2</td>
</tr>
<tr>
<td>City Safety</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tested: Autonomous Emergency Braking (AEB) Systems

Mercedes Benz E-Class E250 CDI ‘Elegance’

AEB Tested System: PRE-SAFE Brake

AEB City

AEB City systems are assessed by Euro NCAP at a speed range of 10-40 km/h. Even at lower speeds, the driver does not have sufficient time to respond to a warning. Therefore, Euro NCAP only evaluates the automatic braking function for these low-speed situations.

AEB TEST RESULTS

3.0 Good

AEB Inter-Urban

For AEB Inter-Urban systems, Euro NCAP evaluates the automatic braking function and the forward collision warning function in three different driving scenarios: inter-urban systems operate over the speed range 30-50 km/h.

AEB TEST RESULTS

2.7 Good

AEB Detailed Test Results

APPROACHING A STATIONARY VEHICLE

APPROACHING A BRAKING VEHICLE

APPROACHING A SLOW MOVING VEHICLE

APPROACHING A BRAKING VEHICLE (long braking)
**Tested: Autonomous Emergency Braking (AEB) Systems**

<table>
<thead>
<tr>
<th>Model</th>
<th>Score: City</th>
<th>Rating: City</th>
<th>Score: Inter-Urban</th>
<th>Rating: Inter-Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes-Benz E-Class</td>
<td>3.0 points</td>
<td>Good (video)</td>
<td>2.7 points</td>
<td>Good</td>
</tr>
<tr>
<td>Volvo V40</td>
<td>2.1 points</td>
<td>Good (video)</td>
<td>2.2 points</td>
<td>Good</td>
</tr>
<tr>
<td>Mitsubishi Outlander</td>
<td>2.1 points</td>
<td>Good (video)</td>
<td>1.9 points</td>
<td>Adequate</td>
</tr>
<tr>
<td>Volvo XC60</td>
<td>1.9 points</td>
<td>Adequate (video)</td>
<td>- - -</td>
<td>- - -</td>
</tr>
<tr>
<td>Fiat 500L</td>
<td>1.8 points</td>
<td>Adequate (video)</td>
<td>- - -</td>
<td>- - -</td>
</tr>
<tr>
<td>Ford Focus</td>
<td>1.7 points</td>
<td>Adequate (video)</td>
<td>- - -</td>
<td>- - -</td>
</tr>
<tr>
<td>Volkswagen Golf</td>
<td>- - -</td>
<td>- - -</td>
<td>2.2 points</td>
<td>Good (video)</td>
</tr>
<tr>
<td>Honda Civic</td>
<td>- - -</td>
<td>- - -</td>
<td>0.44 points</td>
<td>Marginal (video)</td>
</tr>
</tbody>
</table>
However, it seems that some manufacturers are finally... 

Getting Serious about Collision Avoidance

And Serious about using it sell cars

And Serious about having it work
Grim Reaper

http://orfe.princeton.edu/~alaink/SmarDrivingCars/Videos/MB_Commercial_Grim_Reaper.mp4

http://orfe.princeton.edu/~alaink/SmartDrivingCars/Videos/MB_Clown_Commercial.mp4

**Driver Assistance Package**
- Active Blind Spot Assist
- Active Lane Keeping Assist
- DISTRONIC PLUS® with Steering Assist
- PRE-SAFE® Brake with Cross-Traffic Assist
- PRE-SAFE® PLUS

!! Introduction dates vary. See your dealer for availability.

$2,800

S-Class WW Launch May '13

MB @ Frankfurt Auto Show Sept '13

Intelligent Drive (active steering 😊)

Ohio Insurance Institute

PAVE Princeton Autonomous Vehicle Engineering
History and Development of DISTRONIC:

Price reduction, intelligent packaging and availability cross-carline

**MY 2000**

- **Introduce DISTRONIC**
  - Adaptive Cruise Control
  - In package for **+$3,700**
  - Only available on S/CL

**MY 2006 - Current**

- **DISTRONIC PLUS**
  - Autonomous Braking Intervention
  - In “Driver Assistance Package” with Blind Spot
  - Assist/Lane Keeping Assist **+$2,950**
  - Available Cross-Carline on almost every model

**MY 2014 - Future**

- **Enhancements to Driver Asst. Package**
  - Steering Assist
  - BAS with Cross-Traffic Assist
  - PRE-SAFE Brake with Pedestrian Detection
  - PRE-SAFE PLUS – protection during rear collisions

  - In “Driver Assistance Package” with Blind Spot
  - Assist/Lane Keeping Assist **+$2,800**
  - Only available on S/E
What is a “Driverless Car”
(aka SmartDrivingCar)

• “Drive Less” Car
  – Well yes, How much Less?
Preliminary Statement of Policy Concerning Automated Vehicles

Extending its vehicle safety standards from **Crash Mitigation** to **Crash Avoidance** with Aim at Full Self-Driving Automation

**Level 0 (No automation)**
The human is in complete and sole control of safety-critical functions (brake, throttle, steering) at all times.

**Level 1 (Function-specific automation)**
The human has complete authority, but cedes limited control of certain functions to the vehicle in certain normal driving or crash imminent situations. Example: electronic stability control

**Level 2 (Combined function automation)**
Automation of at least two control functions designed to work in harmony (e.g., adaptive cruise control and lane centering) in certain driving situations.
Enables hands-off-wheel and foot-off-pedal operation.
**Driver still responsible for monitoring and safe operation and expected to be available at all times to resume control of the vehicle.** Example: adaptive cruise control in conjunction with lane centering

**Level 3 (Limited self-driving)**
Vehicle controls all safety functions under certain traffic and environmental conditions.
Human can cede monitoring authority to vehicle, which must alert driver if conditions require transition to driver control.
**Driver expected to be available for occasional control.** Example: Google car

**Level 4 (Full self-driving automation)**
Vehicle controls all safety functions and monitors conditions for the entire trip.
The human provides destination or navigation input but is not expected to be available for control during the trip. **Vehicle may operate while unoccupied.** Responsibility for safe operation rests solely on the automated system
Preliminary Statement of Policy Concerning Automated Vehicles

What the Levels Deliver:

Levels 1 -> 3: Increased Safety, Comfort & Convenience
Where Are We Now?

Available in ShowRooms for Consumers

“Level 2- Combined Automation with Constant Vigilance”
Current State of Automated Cars

• Much of the Public Interest has been induced by the Google Self-Driving Car. [http://www.youtube.com/watch?v=cdgQpa1pUUE]
  – It is not driverless...
    • Not yet
  – What did they do?
    • Adopted the DARPA “mind Set” ( & Sebastian Thrun from Stanford DARPA Team + others)
    • Bought “Standard Lexus” (w/ electronically controlled Brakes, Throttle & Steering (BTS))
    • “Straped on”
      – Sensors: LIDAR’s “depth point cloud”, GPS, Radars & Cameras (on the expensive side)
      – Communications: to access 3D digital map data
      – Software & Computer: Converts Sensor Output into BTS Inputs
    • Developed a self-driving vehicle that can operate in the existing environment.
    • Stated Motivation: >90% of road traffic accidents involve human error.
      – So... remove the human from the loop.
    • Have Self-Driven over 500,000 miles on Existing Roads in Existing Traffic Conditions

[Image of a Google self-driving car and a man inside it]
Expected Safety Implications of “Google Cars”

- Using **AAA** Liability Rates per Fatality and Injury

<table>
<thead>
<tr>
<th>Incident</th>
<th>Av Liability ('05$)</th>
<th>Number (2011)</th>
<th>Annual Liability ('05$)</th>
<th>Liability Per Driver - Human Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x1,000</td>
<td>x1,000</td>
<td>xBillion</td>
<td>Annual</td>
</tr>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
<td>32.4</td>
<td>$104</td>
<td>$537</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
<td>2239.0</td>
<td>$153</td>
<td>$791</td>
</tr>
<tr>
<td>Total</td>
<td>$256</td>
<td></td>
<td></td>
<td>$1,328</td>
</tr>
</tbody>
</table>

**Estimated Safety Benefits**

- Analysis based on NHTSA
- For Highway relevant scenarios
  - 71% fewer crashes
  - 65% fewer injuries
  - 81% fewer fatalities

**DOT HS 810 767 Pre-Crash Scenario Typology for Crash Avoidance Research**

**Ohio Insurance Institute**

**PAVE**
Expected Safety Implications of “Google Cars”

- Using **AAA** Liability Rates per Fatality and Injury

<table>
<thead>
<tr>
<th>Incident</th>
<th>Av Liability ('05$) x1,000</th>
<th>Number (2011) x1,000</th>
<th>Annual Liability ('05$) xBillion</th>
<th>Liability Per Driver - Human Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td><strong>$3,200.0</strong></td>
<td>32.4</td>
<td>$104</td>
<td>Annual</td>
</tr>
<tr>
<td>Injuries</td>
<td><strong>$68.2</strong></td>
<td>2239.0</td>
<td>$153</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td><strong>$256</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incident</th>
<th>Liability US Google Cars</th>
<th>Liability Per Driver - Google Car Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td><strong>$3,200.0</strong></td>
<td>$102</td>
</tr>
<tr>
<td>Injuries</td>
<td><strong>$68.2</strong></td>
<td>$277</td>
</tr>
<tr>
<td>Total</td>
<td><strong>$73</strong></td>
<td>$379</td>
</tr>
</tbody>
</table>
**Expected Safety Implications of “Google Cars”**

- Using [AAA](https://www.aaa.com) Liability Rates per Fatality and Injury

<table>
<thead>
<tr>
<th>Incident</th>
<th>Liabilities US 2011</th>
<th>Liability Per Driver - Human Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
<td>32.4</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
<td>2239.0</td>
</tr>
<tr>
<td>Total</td>
<td>$256</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Liabilities US Google Cars</th>
<th>Liability Per Driver - Google Car Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
</tr>
<tr>
<td>Total</td>
<td>$73</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Safety Savings US</th>
<th>Liability Savings Per Google Car Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
</tr>
<tr>
<td>Total</td>
<td>$183</td>
</tr>
</tbody>
</table>
Near Term Opportunities

<table>
<thead>
<tr>
<th>Incident</th>
<th>Liabilities US 2011</th>
<th>Liability Per Driver - Human Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Av Liability ('05$)</td>
<td>Number (2011) x1,000</td>
</tr>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
<td>32.4</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
<td>2239.0</td>
</tr>
<tr>
<td>Total</td>
<td>$256</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incident</th>
<th>Liabilities US Google Cars</th>
<th>Liability Per Driver - Google Car Driver (193M drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
<td>783.7</td>
</tr>
<tr>
<td>Total</td>
<td>$73</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incident</th>
<th>Safety Savings US</th>
<th>Liability Savings Per Google Car Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>$3,200.0</td>
<td>$435</td>
</tr>
<tr>
<td>Injuries</td>
<td>$68.2</td>
<td>$514</td>
</tr>
<tr>
<td>Total</td>
<td>$183</td>
<td>$949</td>
</tr>
</tbody>
</table>

$475 are Pass-through Dollars
Expected Safety Implications of “Google Cars”

- $475/yr are “Pass-through” Dollars
- Assume: Emergence of “Price Leaders”
- $450/yr Discount for Me
- $25/yr for Flo or the Gecko or ???
  To enhance “Combined Ratio”
- Could Discount Finance:

??

Google

Ohio Insurance Institute

PAVE: Princeton Autonomous Vehicle Engineering
Could “Pass-through” Finance Mercedes Intelligent Drive??
(Available in ‘14 S-Class)

May well Deliver 2/3rds the safety of Google Car

$475 Pass-through becomes: $320

$20/yr for Flo or the Gecko

$300/yr to Mercedes

Therefore: I get Intelligent Drive for Free (thank you Google)!!  Plus:
• Prob. of my car killing me is reduced factor: 2/3*.81= 0.54 (half)
• Prob. of my car injuring me is reduced factor: 2/3*.65= 0.44
• I “Save” my expected “deductible self-insurance”: $247/yr
• I have more Comfort
• I have more Convenience
• I have “Anxiety” relief

What a great Business Case!  I’m a Buyer!
Alain’s Car Insurance on ‘14 S-Class

Annual Comprehensive: $2,000/yr (I walk to work)

Assume:
10% Profit ($200)
10% Operating Costs ($200)
80% Expected Liability Exposure ($1,600)

“997 package has to reduce my Expected Liability Exposure by 50% ($800)
Potential Applications of SmartDriving Technology to Bus Transit

How can transit benefit?
Use Autonomous Collision Avoidance Technology to Address a BIG CURRENT Transit Problem
Good News! Travel by Bus is getting safer!

Injuries per Million Bus Passenger Miles
Source: Federal Transit Administration National Transit Database

![Graph showing decreasing injuries per million bus passenger miles from 2002 to 2012.]
Good News! Injuries have been trending down!

US Bus Transit Industry Annual Reported Injuries
2002-2011
Source: Federal Transit Administration National Transit Database
Terrible News! Claims are going through the roof!

Figure 2 US Bus Transit Industry Reported Casualty and Liability Expense 2002-2011
Average Increase 2.8% per Year
Source: Federal Transit Administration National Transit Database
### 2011 Nationwide Bus Casualty and Liability Expense

Source: FTA NTD

<table>
<thead>
<tr>
<th>Casualty and Liability Amount</th>
<th>Vehicle-related</th>
<th>$483,076,010.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Buses</td>
<td></td>
<td>59,871</td>
</tr>
<tr>
<td>Sub-Total Casualty and Liability Amount Per Bus</td>
<td>$8,069/Bus/Year</td>
<td></td>
</tr>
</tbody>
</table>
Casualty and Liability Claims are a Huge Drain on the Industry

- For the 10 year period 2002-2011, more than $4.1 Billion was spent on casualty and liability claims
- For many self-insured transit agencies these expenses are direct “out-of-pocket”
- Large reserves for claims must be budgeted
- Claims experience also is reflected in insurance premiums
- There are gaps in data reporting
Impact of Level 2 Technology - Transit

Key Features:

• Pedestrian and Bicycle Detection
• Autonomous Emergency Braking
• Lane-centering
• Blind-spot Monitoring
• Adaptive Cruise Control

Potential Impacts:

• Fewer Collisions
• Fewer Injuries and Fatalities
• Claims Reduction > $$
The **Cost** of Installing an Active Collision Avoidance System on a Bus Could be Recovered in as Little as **One Year** Through Reductions in Casualty and Liability Claims
Discussion!

Thank You

alaink@princeton.edu

www.SmartDrivingCar.com