Addressing Patterns of Risk: Driver Assist Technologies For Reducing Road Fatalities

from Leonard Evans (2004)
"Traffic Safety"

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Southwest Minnesota TZD Workshop
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Intelligent Transportation Systems Institute
a National University Transportation Center
authorized under SAFETEA-LU, TEA-21, ISTEA

Human-Centered Technology to Enhance Safety and Mobility

…and many other state DOT's and counties

Intelligent Transportation Systems Institute

Intelligent Vehicles Laboratory

Develop, test and evaluate innovative, human centered technologies that improve the operations, safety, mobility, and productivity of vehicles.

Minnesota Traffic Observatory

Develop, test and evaluate innovative transportation management and operational strategies, and traveler information technologies.

HumanFIRST Program

Investigate *human* strengths and weaknesses to gain an understanding of the role of the individual in complex technological transportation systems.

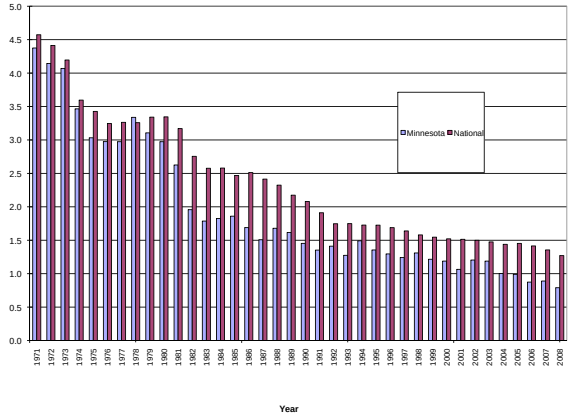
Modeling Traffic Impacts on the Visitor Trip Experience and Wildlife on the Denali Park Road

Road Mortality

- **In the US, traffic crashes cause more deaths between the ages of 2 and 33 than any *other injury or illness*.**
  - 25% of all deaths in this age range are from traffic crashes.
- **Traffic crashes are the leading cause of *unintentional injury-related death between the* ages of 2 to 76.**
- **By 2020, traffic crashes are predicted to become the *third largest cause* of death and disability worldwide.**
  - Globally, more deaths and disability are expected from traffic crashes than from wars or AIDS.

[WHO, 2000; NSC, 2006, p. 14]

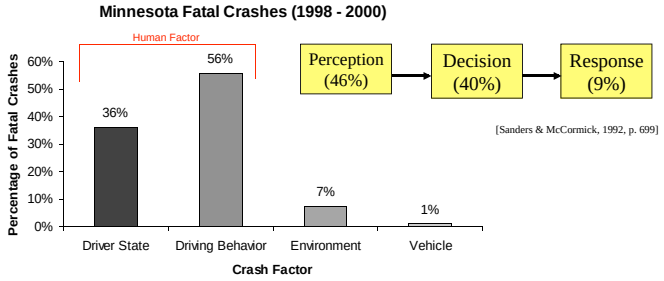
Fatalities per 100 Million VMT
Minnesota vs National Totals (1971 – 2008)



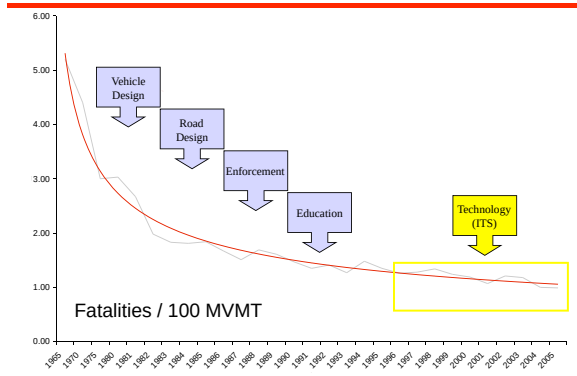
Vision:
We can reduce fatalities and life changing crashes

- Focus on those at highest risk (teens, rural roads, older drivers, unsignalized intersections, lane departure)
  - Nationally, teens (16-19 years old) make up only 4.7% of all licensed drivers, but are involved in 10.3% of all fatal crashes (2007)… a higher fatality risk than any other driver age group on the road.
  - Rural road fatalities outnumber urban fatalities (over 2:1)
  - Older driver fatalities are over-represented at rural unsignalized intersections
  - Lane departure crashes represents over 1/3 of all road fatalities; 2/3 of these occur on rural roads

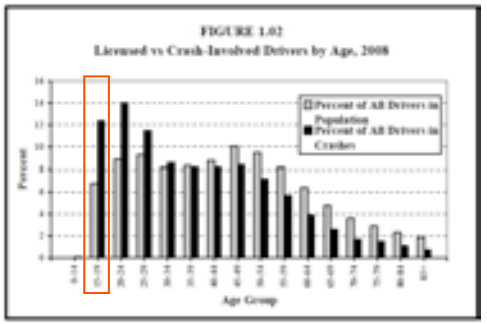
Human Centered Technology:
Need to Focus on the Driver (Human Factor)



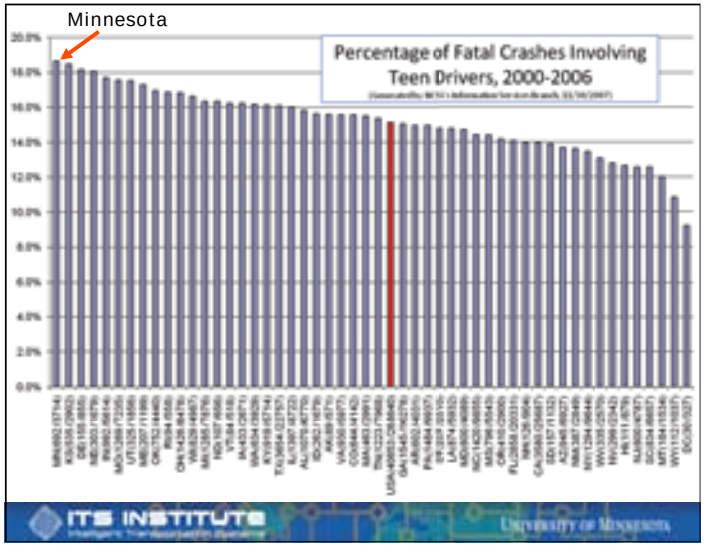
Traditional approaches have been effective, but over the last 15 years their impact has been marginal: Need Innovation



In MN, teens (15-19 years old) represent under 7% of licensed drivers, but over 12% of crash-involved drivers.
(Minnesota Crash Facts, 2008)

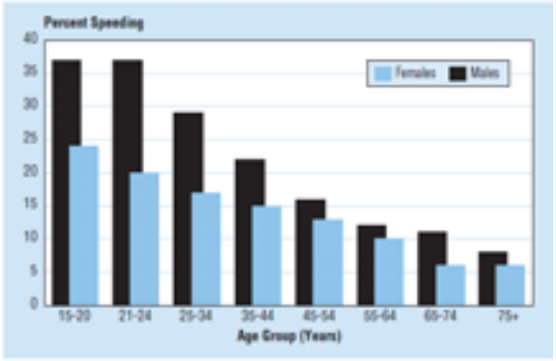


- Teen drivers represent most crashes and years of lost productive life.
- Changing teen behavior early may improve their behavior later.



Speeding Drivers in Fatal Crashes by Age and Gender, 2008

(Source: Traffic Safety Facts 2008 Data , NHTSA - DOT HS 811 166)



Teen monitoring technology: The details do matter

From Zits (May 15, 2006)
By Jerry Scott and Jim Borgman

Cellphone prototype as platform for Teen Driver Support System (TDSS)

Cellphone prototype as platform for TDSS

Exceeding speed limit

Text message will be sent

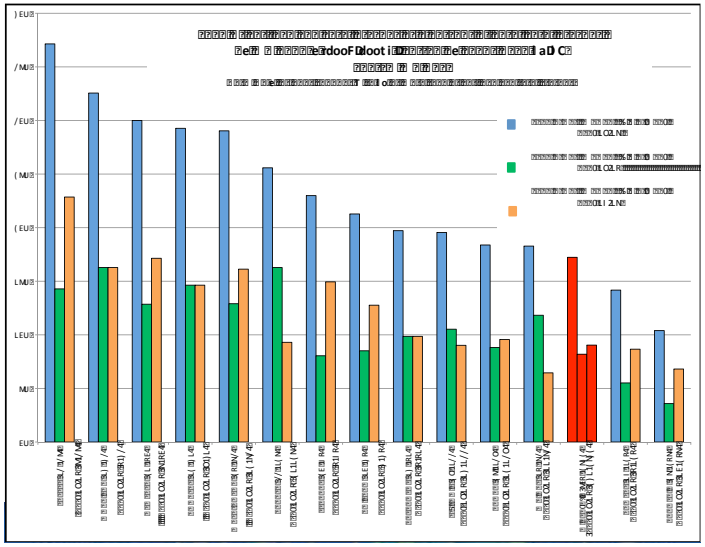
Parents & DMV can track infractions

Technology: Next steps - GDL support tool (Partnership with MnDOT and MN DPS)

- Focus on real-time driver feedback. Alerts driver of speed limit changes, curve-speed warning, stop signs, hard accel/decel, etc.
- Issue: Accurate geospatial speed limit databases. Evaluating Navteq DB.
- New “open” cellphone platforms (e.g. Google Android)
- Driver identification:
  - RFID tag in key FOB (to identify parent who can opt out)
- Incoming calls to voicemail; no outgoing calls while vehicle in motion (except 911)
- Passenger occupancy (piezoelectric strip in passenger seats)
- Software-based systems, independent of proprietary hardware
- Make sure TDSS is ON when teen is driving
- Anti-hacking subsystems; “watchdog” background process
- Goal: Field Operational Test that demonstrates effectiveness, and no unintended consequences

Driver Reporting Systems: The issue is not only “technology”

- What are the tests? The performance criteria?
  - Speed violation? Stop sign behavior? Stability of accel/decel, headway? Lane wandering? Distraction measure?
- What thresholds does one set for pass/fail on each?
- How does one come up with an overall “grade”?
- Does one exam (i.e. report card) fit every state? …every teen?
- What feedback mechanisms will change behavior? Auditory? Incentives? Consequences?
  - Need feedback that is effective for teens.
- With new tools, GDL requirements can change to better focus on measurable behavior rather than surrogates.
- Can also handle most prevalent excuses for not expanding or enforcing GDL, e.g. provide for ‘special’ events at specific times
- Must build in adequate privacy safeguards.



Intersection Crashes

- 2.307 million intersection related crashes (2008).
- Represents 40% of all 5.811 million police reported crashes.
- In the US, 7,421 of 34,017 (22%) of fatal crashes were intersection related:
  - 34% occurred at signalized intersections
  - 66% occurred at unsignalized intersections (stop sign, no controls, other sign)

NHTSA, *Traffic Safety Facts 2008 Table 29 Chapter 2*

Minnesota Fatal Crashes: Rural Intersections

Fatal Crashes	2003	2004	2005	2006	2007	2008
Rural (R), Non-Signalized (NS), Intersection-Related (IR)	118	127	98	96	117	93
All Fatal Crashes	583	520	500	456	463	420
R, NS, IR as % of All Fatal Crashes	20%	24%	20%	21%	25%	22%

Fatal Crashes (Rural as % of Total)

Fatal Crashes	2003	2004	2005	2006	2007	2008
Rural	401	366	349	308	326	283
Total	583	520	500	456	463	420
Rural as % of Total	69%	70%	70%	68%	70%	67%

Intersection Crashes: Driver Error

- In study of over 100 straight crossing path crashes at thru-STOP intersections, Chovan et al. (1994) found that the primary causal factors for drivers that stopped before entering the intersection was:
  - Driver looked but did not see other vehicle (62.1%)
  - Driver misjudged the gap (lag) size or velocity of approaching vehicles (19.6%),
  - Driver had obstructed view (14.0%), or
  - Roads were ice-covered (4.4%)
- Of these 4 driver error types, the first 3 can be described as either problems with gap (lag) detection or selection.

Test Intersection: MnDOT District 6 US52 & CSHWY9 Goodhue County, MN

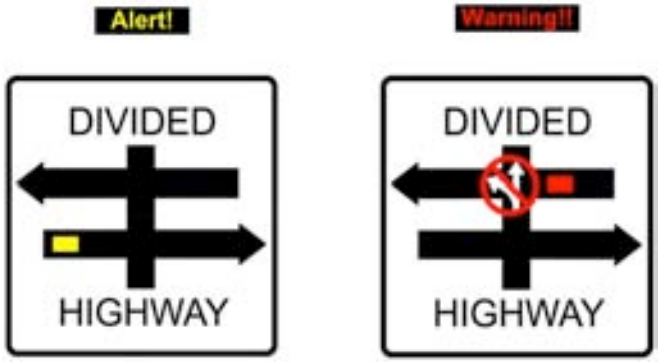
Sensors installed in Summer, 2004. FOT started January, 2010

Sensors (for measuring gaps and lags)

Power, Communication Local Processor

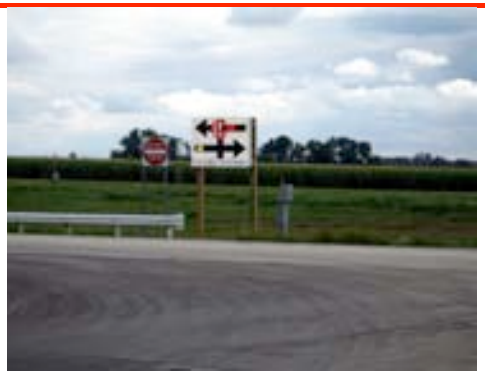
Radar Sensor

Final sensor driven sign



View of the installed near-side sign

Mainline traffic approaching from the left is at least 7.5 secs, but less than 11.5 secs away.
Mainline traffic approaching from the right is less than 7.5 secs away.



Cooperative Intersection Collision Avoidance – Stop Sign Assist (US DOT & Mn/DOT): Focus on Driver Error Causal Factors

- Deploy where the fatalities/ crashes warrant deployment
- Assist driver with judging gap intervals, clearance and timing
- Reduce rural expressway intersection crashes without adversely affecting mainline traffic flow
- 3 Year FOT @ US52&CSAH9 began Jan, 2010; Minong, WI began April, 2010.
- Two more intersections will be instrumented and “turned on”.

Video: WB on Goodhue County 9 at US 52

Potential intersection under consideration

USTH 23 & CSAH 7, Lyon County (just outside Marshall, MN)

MnDOT District 8

14 crashes of which: 1 fatal, 1 Type A, 4 severe crashes;
8 right angle crashes over 3 year period (2006-8)

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Designing Human Centered Systems: DGPS Based Augmented Reality - "Seeing" the Road

Human Centered Technology for Driver Lane Assist (Lanekeeping)

Handling low visibility and staying in the lane

First prototype developed for snowplows operating in whiteout conditions

- Blowing snow even without snowfall
- Heavy snowfall

Why snowplows?

- Professional drivers operating under stressful conditions
- Need to be out there under terrible conditions
- At-risk driver population
- Early feedback for other apps

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An Alaska Perspective: Snowpoles

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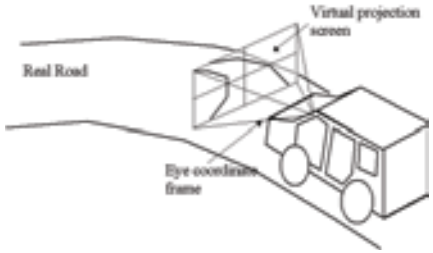
The Snow is Plentiful

You Can't Just Stop

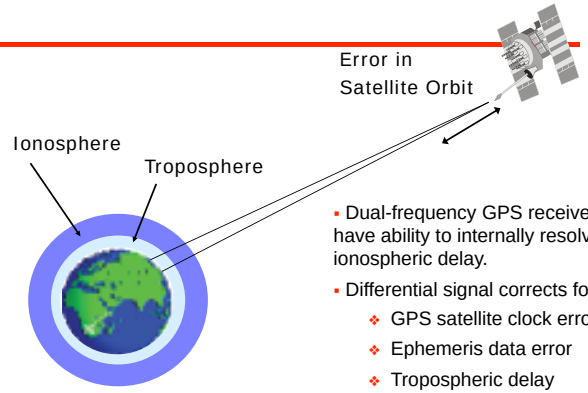
An Augmented Conformal Head Up Display

- By referencing the vehicle AND the driver's eye position within an accurate digital map, one can accurately recreate the field of view from the driver's eye perspective.



- System allows all lane boundaries and obstacles to be drawn and projected in real time on a virtual screen 10 meters in front of vehicle (to reduce eye fatigue)

Dual Frequency Differential GPS



- Dual-frequency GPS receivers have ability to internally resolve ionospheric delay.
- Differential signal corrects for:
  - GPS satellite clock error
  - Ephemeris data error
  - Tropospheric delay

Video through HUD on Minnesota Hwy 101 (Radar OFF)

Day time view to show accuracy of projected lane markings

Video of HUD (Approaching intersection)

Driver Interfaces

How do drivers best receive relevant information?

Projector HUD Virtual mirror

Steering

Seat

Redesigned Driver Interfaces (2010)

Projector HUD

Vehicle Technologies

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Snowplows: DGPS based Head Up Displays (HUD) & other feedback elements

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Lane Assist Modality: Haptic Feedback

Under current operations, drivers often like to use the guardrail to determine the extent of the drivable surface

When curb is not there, can use DGPS, geospatial database, and steering actuator to provide "virtual curb."

Steering wheel is actuated to feel like a curb when one is not there.
Can create a detent or torque valley to identify the center of lane.

Seat with vibration actuators indicates "out of shoulder lane."

Guardrails get Clobbered by Snowblowers and Plows

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DGPS Correction Station at Divide

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Installation on Blower and Plow at Thompson Pass Station

Snowblower cab

Cab roof in plow

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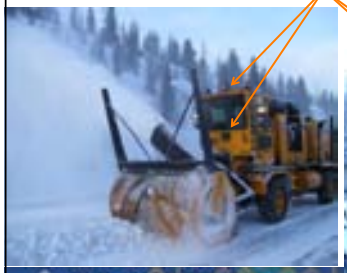
Radar on plow and blower

PDA for operator control

Radar



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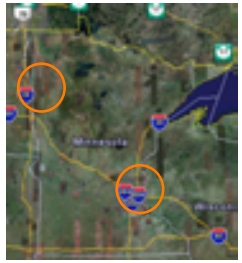
Current deployment

Deployed on Mn/DOT, Minnesota State Patrol, McLeod and Polk Counties, MVTA, Alaska DOT and Deadhorse Airport vehicles.



2008 Interview with Operator (8 winters experience at Thompson Pass)

- **Q: Benefits?**
  - DD: Wonderful when visibility is poor. It is like running on 'autopilot.' It is nice to have a 'direction' to get through nasty storms. Also, the front facing radar picked up a car that I would not otherwise have seen coming towards me in the wrong lane. I moved over and was able to avoid a head-on wreck by 'whiskers'. During the previous winter that feature was turned off. I like it on since I do want to know where the cars are on the road.

2008 Interview with Operator (8 winters experience at Thompson Pass)

- **Q: Can you operate more efficiently with it? Can you go faster?**
  - DD: I am not computer literate, but this system is very user friendly – easy to use. I think it makes me more efficient.
  - When it is so bad out that I am using it, I am going very, very slowly (creeping along at about 1 mph). I am worried about drifts or a car stuck in a drift, so I can't go faster.
  - The screen is surprisingly accurate. I follow the screen. I can follow a straight line much better with it.

2008 Interview with Operator (8 winters experience at Thompson Pass)

- **Q: Are you now able to plow without it?**
  - DD: Yes, but it is a great tool. It makes the job less stressful. I guess that I would say that it makes me feel safer. I wonder how we did it before we had the technology. I learned to rely on it.

Deadhorse Airport Rescue & Firefighting (ARFF) Vehicle

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Driver Assist Technology: Deploying Bus Rapid Transit along Narrow Road Shoulders to Bypass Congestion

As part of Minnesota Urban Partnership Agreement (UPA), will deploy 10 buses into passenger service in 2010. Partnered with MVTA, FTA, Met Council, Hennepin County

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Urban Partnership Agreement: Minnesota's Congestion Mitigation Initiative

UPA — Innovative Choices for Congestion Relief

Heading N on I-35W at MN13 on opening day - 9/30/09

See http://www.dot.state.mn.us/upa/

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Sequence Showing Bus Operating in Narrow Lane with Adjacent Truck

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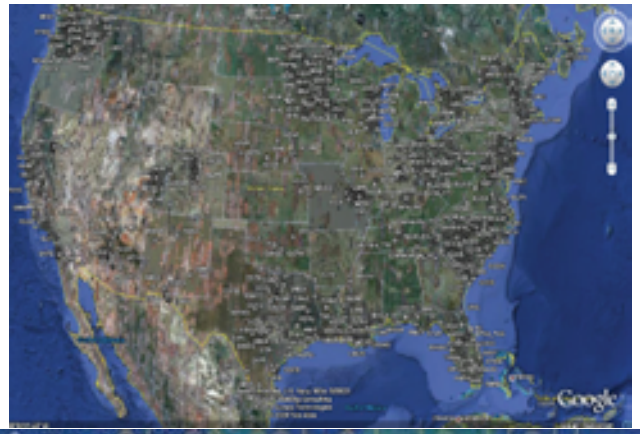
Hi-Accuracy DGPS Correction Signal Coverage in Minnesota April, 2010

From http://mncors.dot.state.mn.us/

VRS Network

- All 260 miles of I-94 corridor in MN covered
- Minnesota first one to start
- 12 states with operational VRS
- 4 states with Trimble VRS Now
- 25 states have plans to set up VRS networks
- Green & Taupe: Operational
- Brown: Proposed; Orange: Pending (to be shared with Iowa)

VRS: Trimble RTKNet Systems (Sept 08)



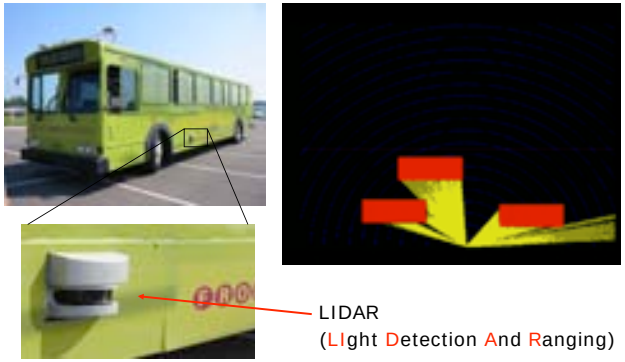
Video: Haptic Feedback Assist for Lane Keeping

Additional Lane Assist Tool: Virtual Mirror - Assists with Collision Avoidance and Merging

- Rationale for development of virtual mirror:
  - Optical blind zones make achieving speed differentials between shoulder and driving lane traffic more difficult. Hard to see on right or left.
  - Blind zones make it difficult to merge back into traffic.
  - Bad weather reduces forward visibility, reduces effectiveness of mirrors mounted on bus (moisture, ice, close proximity to bus body)

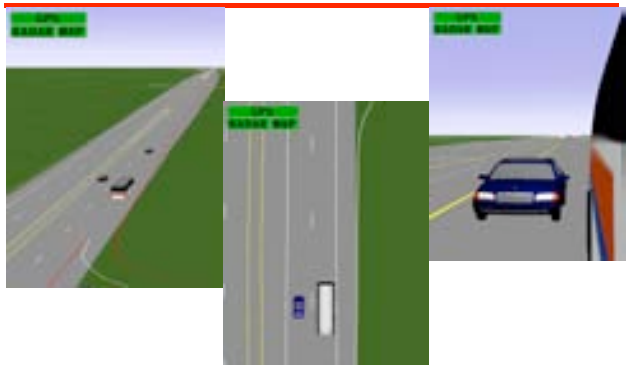
Feedback to the Driver: Sensors and Displays

Video: Stationary LIDAR scanning vehicles in adjacent lanes



LIDAR
(LIght Detection And Ranging)

Side Collision Avoidance: Merge Assist and Blind Zone Reduction Virtual Mirror Displays Based on LIDAR



Economic Benefits of Bus Only Shoulder BRT: Capital Cost Comparison

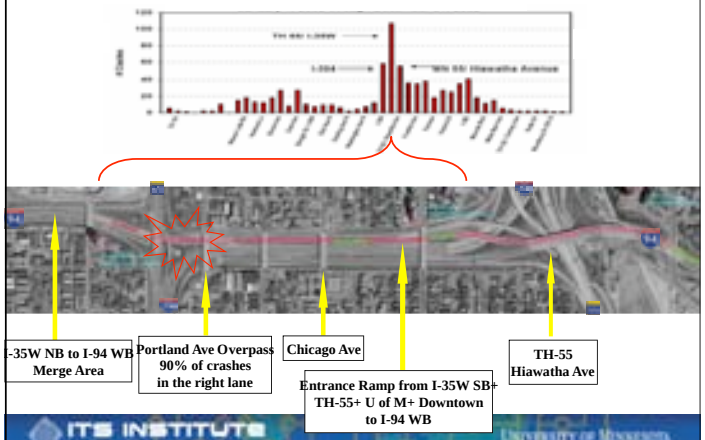
- LRT projects vary in cost from $15 million to $100 million per mile, with the average cost per mile approximately $46 million
- Cheapest BRT option - $2.5 million to $2.9 million per mile, mixed flow with general traffic, excluding any cost associated with acquiring the right of way.
- **Bus Only Shoulder BRT in the Twin Cities range from as little as $1,500 per mile to $200,000 per mile**

  (2007 dollars: avg $150,000 per mile)

Where Driver Assist Technology (Lanekeeping and Merging) Applies

- Limited right-of-way due to environmental conditions (e.g. lakes, wetlands), valuable property, existing structures
- Squeezing busway into and around existing neighborhoods
- Existing highway shoulders or medians
- Tunnels, bridges
- Historical areas
- Former rail lines, canals
- Re-allocation of traffic on existing road from n lanes to n+1 lanes
- Lane departure prevention (Causal factor in 1/3 rural fatalities)

Leveraging technology to I-94 WB High Crash Location



High-accuracy DGPS and overpasses

- Problem with suburban / urban highway applications:
  - DGPS isn't sufficiently robust on roads with bridges, overpasses, etc.
  - If initial heading angle error = 1 deg, then 8 sec loss of DGPS "fix" @60mph => 12ft lateral error
- Issue addressed by U of MN which developed a unique non-inertial 2D velocity sensor-based DGPS augmentation system.
  - Maximum heading angle error is now 0.06 degrees.
  - If initial heading angle error = 0.06 deg, then 8 sec loss of DGPS "fix" @60mph => 0.737ft lateral error over 704 ft of travel (8 sec @ 60mph)
  - Part of driver assist system on 10 buses (9 ft wide) deployed by Minnesota Valley Transit Authority for bus-only shoulder operation on expressways used to bypass congestion (MN UPA).

"Avalanche Road"
Broadcast March, 2010
Speed Channel

Recorded 3 day storm that occurred in October 2009

Driver assist system for operating snowplows in Alaska mountain pass

"Alaska Most Extreme"
Broadcast April 18, 2009
Discovery Channel

"Driving by Braille"
Thompson Pass (Elevation: 2678 ft)

Starts: 37:34 minutes into 60 minute program