A Preliminary Examination of Lane Keeping Support Systems

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What Crashes Can LDW / LKS Address?

- The 2004 GES crash data contain 5,942,000 police reported crashes that involved at least one light vehicle.
- Using these crash data, Najm, et al. have identified three common pre-crash scenarios relevant to LDW and LKS.
- Frequency and cost of these crashes = high societal harm.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Frequency; Rank Order</th>
<th>Economic Cost ($); Rank Order</th>
<th>Functional Years Lost (Harm Metric); Rank Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Edge Departure Without Prior Vehicle Maneuver</td>
<td>975,000; 5th</td>
<td>9,005,000,000; 3rd</td>
<td>270,000; 2nd</td>
</tr>
<tr>
<td>Vehicle(s) Not Making a Maneuver – Opposite Direction</td>
<td>124,000; 15th</td>
<td>6,407,000,000; 7th</td>
<td>206,000; 4th</td>
</tr>
<tr>
<td>Vehicle(s) Drifting – Same Direction</td>
<td>98,000; 17th</td>
<td>1,383,000,000; 17th</td>
<td>37,000; 17th</td>
</tr>
</tbody>
</table>
System Overview

- Lane Keeping Support (LKS) is an extension of lane departure warning (LDW) technology
  - Cameras used to track lane lines
  - LKS requires more hardware than LDW
- Key difference: while LDW warns the driver if they breach their lane, LKS attempts to actively help the vehicle maintain and/or reestablish lane position
  - LKS expected to have greater effectiveness than LDW
  - LKS is not necessarily “lane centering”
- LKS systems do not necessarily include separate LDW alerts
How Does LKS Work?

- LKS interventions are presently executed in one of two ways
  - Automatic brake intervention
    - Brake torque applied at one or more wheels
    - Used to create a yaw moment
    - Use of the vehicle’s steering system to automatically turn the steering wheel in the necessary direction
  - Other options may appear in the future
    - Active differentials
    - Sophisticated all-wheel drive systems

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Vehicles Equipped with LKS

- Thus far, the only vehicles sold in North America with LKS are select Infiniti and Toyota/Lexus models

2010 Toyota Prius 2008 Infiniti EX35

- Intended to assist the driver, not to provide autonomous control
- Some vehicle manufacturers offer LKS in other markets
2009 LKS Test Track Evaluation

- Straight lane departure effectiveness
  - NCAP LDW test courses; single lane line markings
  - Lanes delineated with two solid white lines
  - Steering capable of producing low to high lateral velocities

- Curved lane departure effectiveness
  - 500 m nominal radii (ISO/WD 11270)
  - Lanes delineated with solid white markings (one and two lines)
  - Straight-to-curve transitions
  - Lane position established, steering released

- 35, 45, 55, 65 mph test speeds (except NCAP course)

- Left and right departures

- Prohibited operation tests (turn signal-based)
Preliminary Results
Straight Lane Performance

- For the vehicles tested, LKS interventions occurred after the audible LDW alerts
- Generally speaking, LKS effectively mitigated low lateral velocity lane departures
- LKS interventions often produced secondary departures
  - Effect observed with steering and brake-based interventions
  - Typically invoked subsequent LKS interventions
- Some secondary interventions were unable to effectively manage the LKS-induced departures
  - Example: The LKS intervention found to prevent a right side departure produced a left-side departure later down the road.
LDW vs. LKS Intervention Comparison
(45 mph, Two Solid White Lane Lines)

2008 Infiniti EX35

2010 Toyota Prius
Straight Lane Performance Example

Straight Road, Single Lane Line
NCAP LDW Course
(TRC Vehicle Dynamics Area)

Straight Road, Two Lane Lines
(TRC Skid Pad Lane 4)
Ping Pong Example
When should LKS systems “time out”?

Cabin view

Outside view. Test has multiple LKS interventions, concludes with a lane departure.
Curved Lane Performance

- LKS was unable to effectively mitigate straight-to-curved road lane departures
  - Departures occurred almost immediately after the transition
- Inconsistent low lateral velocity performance
  - Low lateral velocity tests first required the driver establish lane position
  - Important to avoid the rapid release of the steering wheel
  - Steering-based performance found to be better than that observed for brake-based operation
  - Very few curve-based departures were actually prevented by LKS
- No LKS-induced secondary departures were produced
Curve Performance Example
500m Radius

Without an initial steering input

With an initial steering input
Concluding Remarks
Concluding Remarks (continued)

- LKS is a new technology with low market penetration
  - Population of vehicles so-equipped is very limited
  - Intervention strategies have not yet converged
  - Control authority of contemporary systems appears to be low

- Many factors must be considered when estimating LKS safety benefits
  - Test track performance
  - Real world effectiveness
Concluding Remarks (continued)

- Understanding real world availability is essential
  - Percent of time the system is tracking the travel lane correctly

- Effect of environmental factors must be quantified
  - Glare
  - Lane line quality
  - Pavement cracks
  - Test surface grade
  - Crosswinds

- Difficult to accurately assess real world performance within the confines of a test track
  - Field operational tests (FOT) better suited to this quantification
Concluding Remarks (continued)

- NHTSA is presently considering the most appropriate way to objectively quantify LKS performance
  - Test procedures
  - Evaluation metrics
  - Operational limits

- Test track performance expected to coincide with driver interface assessment
  - Should the driver be alerted when an LKS intervention occurs?
  - What should the relationship between LKS and LDW be?
  - Driver understanding and acceptance are important considerations

- An agency decision point on LKS is expected in 2011
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