Controllability of steering system hazards by drivers: from risk analysis to driving tests

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A quick reminder on Active Front Steering –
System Overview

Electronically controlled superposition of an active angle to the steering wheel angle

- Permanent mechanical connection between steering wheel and road wheels
  - i.e. we have a safe state
- Reduced steering effort
  - Comfort (driver)
- Enhanced lateral response
  - Agility
- Vehicle stabilisation
  - Active Safety
Active Front Steering – Variable Steering Ratio (1/2)

Vary steering ratio between hand wheel and road wheel with respect to:

Vehicle Velocity
• Decrease steering effort in lower and middle velocity range.
• Indirect – safe ratio at higher velocities.

Pinion & steering wheel angle
• High precision when driving straight
• Less steering effort for large steering angle (parking, ...)
• Modification of the steering behaviour (but same steering kinematics)
Outline of the talk

• **Assistance vs stabilisation** functions
  (or: feedforward vs feedback (using inertial data) on a vehicle level)

• The **driver** in this control loop

• Derivation of **relevant driving tests**, in particular for new systems, to assess hazards

• How to **evaluate** these driving tests
To start with: a quick remark on feedback control systems

- actuators usually contain an electric motor.
- motor needs feedback control to achieve desired position, speed, torque etc.
- feedback controller usually is a cascaded controller controlling current, torque, speed position in various loops.
- design of these loops is done by specifying rise time, overshoot, steady state error etc.

⇒ There will always be a mismatch between desired actuator position and the real position.
⇒ Question: how much deviation is acceptable or distinctly normal feedback behaviour from system hazards?
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The driver in the control loop

The driver deals with

- steering system hazards as an outer control loop
- YRC hazards as an inner control loop

⇒ The driver can correct things – how much?
Hazard control by drivers

Categories from: MISRA - Development Guidelines for Vehicle Based Software.

**Difficult to Control** failures whose effects are not normally controllable by the vehicle occupants but could, under favourable circumstances, be influenced by a **mature human response**.

**Debilitating** failures whose effects are usually controllable by a **sensible human response**

**Distracting** failures which produce operational limitations, but a **normal human response** will limit the outcome to no worse than minor.

Q: what is a “mature/sensible/normal human response”?

**DS 00-55** states:
“... Capturing the important human factors aspect is still an active research area.”
Is the driver part of the system or part of the protective measures?

From IEC61508 - The general model assumes that
• there is an EUC and an EUC control system;
• there are associated human factor issues;
• the safety protective features comprise
  • external risk reduction facilities,
  • E/E/PE safety-related systems,
  • other technology safety-related systems.

[..] 
Residual risk [actual risk]: in the context of this standard, the residual risk is that remaining for the specified hazardous events for the EUC, the EUC control system, human factor issues but with the addition of external risk reduction facilities, E/E/PE safety-related systems and other technology safety-related systems.

Conclusion: drivers are considered as part of a safety related system but not part of the protective features.
HAZOP on functionality (extract)

<table>
<thead>
<tr>
<th>WHAT IF…</th>
<th>…Variable Steering Ratio command IS…</th>
<th>…Stabilisation command IS…</th>
</tr>
</thead>
<tbody>
<tr>
<td>…late? [i.e. in time]</td>
<td>Steering with time delay, feels awkward. Depends on delay.</td>
<td>YRC too late, vehicle not stabilised.</td>
</tr>
</tbody>
</table>

HAZOP on driver reaction (extract)

<table>
<thead>
<tr>
<th>WHAT IF driver reaction…</th>
<th>…to too much Variable Steering Ratio command IS…</th>
<th>… to too much Stabilisation command IS…</th>
</tr>
</thead>
<tbody>
<tr>
<td>…fast? [i.e. almost releases hand wheel]</td>
<td>No vehicle reaction, since hazard evolves towards hand wheel.</td>
<td>Vehicle destabilised or not stabilised correctly, depends on amplitude.</td>
</tr>
</tbody>
</table>

**Conclusion:** same guideword gives different result for VSR and YRC.
### Controllability of active front steering system hazards: From risk analysis to driving tests

#### From HAZOP to driving tests & design

<table>
<thead>
<tr>
<th>WHAT IF…</th>
<th>…<strong>Variable Steering Ratio command IS</strong>…</th>
<th>To investigate:</th>
</tr>
</thead>
<tbody>
<tr>
<td>…<strong>no?</strong> [zero angle added]</td>
<td>Falls back to mechanical steering. Step depends on VSR layout. Depends on driving situation.</td>
<td>What should mechanical and variable ratio layout look like?</td>
</tr>
<tr>
<td>…<strong>less?</strong> [amplitude than correct, but same direction]</td>
<td>Steering too indirect. Depends on driving situation and amplitude.</td>
<td>Allowed amplitude (speed, delay) of regulation error</td>
</tr>
<tr>
<td><strong>WHAT IF driver reaction…</strong></td>
<td>…<strong>to too much Variable Steering Ratio command</strong> IS...</td>
<td></td>
</tr>
<tr>
<td>…<strong>fast?</strong> [almost releases hand wheel]</td>
<td>No vehicle reaction, since hazard evolves towards hand wheel.</td>
<td>Should we consider a warning lamp encouraging the driver to release the hand wheel?</td>
</tr>
<tr>
<td>…<strong>reverse?</strong> [turns hand wheel in opposite direction as hazard]</td>
<td>May correct steering ratio. Depends on driving situation and amplitude.</td>
<td>What is the variation in the driver behaviour?</td>
</tr>
</tbody>
</table>
How to find “normal human response” (cf. Neukum et. al.)?

- use driving situations as derived so far
- average over drivers in terms of age, gender, experience,…
- independent experiments
- accepted/easy to understand evaluation criterion
- sufficiently much data
- statistical evaluation of that criterion
- real vehicle experiments preferred over simulator experiments (for hazard assessment)
Key aspects of the talk

• **assessment of vehicle controllability** because of (sub-)system hazards one of the first things to do

• **quantification of acceptable hazards** is the starting point for getting numbers in the technical safety concept.

• **assistance and stability functions** are to be treated differently

• **HAZOP can be used to do experiment layout/planning**

• **combine driver ratings and vehicle reaction measurements**
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References


