Improving car-carrier safety through Performance-Based Standards

Emerging Researcher Symposium

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Outline

1. Background
2. Objectives
3. Tail swing study
   - South African car-carryer fleet
   - South African legislation
4. Detailed PBS assessment
5. Conclusions
Background: Problem identification

• Until recently, South African car-carriers operated under abnormal load permits
  • +0.3 m height, +0.5 m length over legal limits
• This practice is in the process of being phased out
• South African regulations will be enforced, unless (proposal):
  1. Vehicles comply with the Australian Performance-Based Standards scheme (as part of the South African PBS demonstration project)
  2. Operators are RTMS accredited
• South African car-carriers have very large rear overhangs (4 to 6 m) vs. the Australian limit of 3.7 m
  • Tail swing is likely to be a critical standard
### Background: Performance-Based Standards

<table>
<thead>
<tr>
<th>Prescriptive Standards</th>
<th>Performance-Based Standards</th>
</tr>
</thead>
</table>

**What the vehicle looks like**
- Governs **mass and dimensions**
- Constrains productivity
- Constrains innovation

**What the vehicle can do**
- Governs actual **on-road performance**
- Allows **heavier and/or larger** vehicles
- Promotes **innovation**

Images courtesy of the Australian National Transport Commission
• Australian PBS scheme adopted for SA demonstration project
• Vehicle safety is assessed using five safety-critical manoeuvres:

<table>
<thead>
<tr>
<th>Manoeuvre/Test</th>
<th>Performance Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-speed 90° turn</td>
<td>Low-speed swept path</td>
</tr>
<tr>
<td></td>
<td>Tail swing</td>
</tr>
<tr>
<td></td>
<td>Frontal swing</td>
</tr>
<tr>
<td></td>
<td>Steer-tyre friction demand</td>
</tr>
<tr>
<td>High-speed lane-change</td>
<td>Rearward amplification</td>
</tr>
<tr>
<td></td>
<td>High-speed transient offtracking</td>
</tr>
<tr>
<td>Rollover</td>
<td>Static rollover threshold</td>
</tr>
<tr>
<td>High-speed pulse steer</td>
<td>Yaw damping coefficient</td>
</tr>
<tr>
<td>High-speed on uneven road</td>
<td>Tracking ability on a straight path</td>
</tr>
</tbody>
</table>
Background: Performance-Based Standards

Low-speed swept path

Frontal swing

Tail swing
Background: South African car-carriers

WITH abnormal load permit

Very large rear overhangs

4.3 m

18.5 m

22.5 m

4.6 m

22.5 m

19 m

4.3 m

18.5 m

22.5 m

4.6 m

19 m

WITH abnormal load permit

Courtesy Unipower (Natal) and Khässbohrer.

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Objectives

1. a. Quantify the tail swing performance of the South African car-carrier fleet
   b. Calculate the maximum tail swing permissible within the prescriptive confines of the South African Road Traffic Act

2. Conduct a full PBS assessment of a typical South African car-carrier design
Tail Swing Study
Tail Swing Study: Manoeuvrability model

- Tail swing is dependant on many vehicle parameters and on the prescribed path
  - It cannot be calculated directly
- A step-wise geometric manoeuvrability model was developed in Matlab

= Vehicle reference point
## Tail Swing Study: South African regulations

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Rear Overhang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid truck</td>
<td>3.7 m</td>
</tr>
<tr>
<td>Semitrailer</td>
<td>3.7 m</td>
</tr>
<tr>
<td>Tag-trailer</td>
<td>3.7 m</td>
</tr>
</tbody>
</table>

Up to **417%** times the Australian PBS Level 1 tail swing limit achievable within SA regulations
Detailed PBS Assessment
Detailed PBS Assessment: Research method

- Simulations conducted using truckSIM® and MATLAB
- **Vehicle:**
  - Volvo FM400 6x4 + Unipower Maxiporter Mk3
- **Payload:**
  - 2 562 kg, Centre of Gravity 777 mm above ground.
  - Multiple load scenarios.
Detailed PBS Assessment: Results

• Initial assessments showed the vehicle to fail certain standards
  • The failed standards are highly sensitive to trailer wheelbase
• A parametric study followed to determine a suitable trailer wheelbase that would meet both performance and practical requirements
  • Trailer wheelbase increased from 9 m to 10 m
• Trailer rear corner geometry refined to meet stringent tail swing limit
• Final PBS design:
## Detailed PBS Assessment: Results

<table>
<thead>
<tr>
<th>Standard</th>
<th>Allowable values</th>
<th>Baseline vehicle</th>
<th>PBS vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-speed swept path</td>
<td>≤ 7.4 m</td>
<td>6.7</td>
<td>7.2</td>
</tr>
<tr>
<td>Tail swing</td>
<td>≤ 0.30 m</td>
<td>0.66</td>
<td>0.30</td>
</tr>
<tr>
<td>Frontal swing</td>
<td>≤ 0.7 m</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Steer-tyre friction demand</td>
<td>≤ 80%</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Static rollover threshold</td>
<td>≥ 0.35 g</td>
<td>0.35</td>
<td>0.38</td>
</tr>
<tr>
<td>Rearward amplification</td>
<td>≤ 5.7·SRT&lt;sub&gt;r_{r_cu}&lt;/sub&gt;</td>
<td>1.82</td>
<td>1.27</td>
</tr>
<tr>
<td>High-speed transient offtracking</td>
<td>≤ 0.6 m</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Yaw damping coefficient</td>
<td>≥ 0.15</td>
<td>0.09</td>
<td>0.29</td>
</tr>
<tr>
<td>Tracking ability on a straight path</td>
<td>≤ 2.9 m</td>
<td>3.0</td>
<td>2.9</td>
</tr>
</tbody>
</table>
Detailed PBS Assessment: High-speed lane-change
Detailed PBS Assessment: Rollover
Detailed PBS Assessment: Tail swing
1. About 80% of SA car-carriers fail the tail swing standard

2. The 0.30 m tail swing limit correlates well with the 3.7 m rear overhang limit in Australia
   • In comparison, South Africa allows rear overhangs of up to 7 m → Tail swing up to 1.25 m

3. The baseline car-carrier failed four performance standards. Design modifications yielded a PBS-compliant design, with improved safety in six standards

4. The benefits of a PBS approach to heavy vehicle safety, for car-carriers in particular, have been demonstrated
Thank you
High-speed transient offtracking

Static rollover threshold

Tracking ability on a straight path

Yaw damping coefficient
• SA regulations limiting rear overhang:

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Rear overhang</th>
<th>Wheelbase/Length</th>
<th>Combination Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid truck</td>
<td>60%·WB</td>
<td>WB ≤ 8.5 m</td>
<td>12.5 m</td>
</tr>
<tr>
<td>Semitrailer</td>
<td>60%·WB</td>
<td>WB ≤ 10 m</td>
<td>18.5 m</td>
</tr>
<tr>
<td>Tag-trailer</td>
<td>50%·Trailer length</td>
<td>Trailer length ≤ 11.3 m</td>
<td>22.0 m</td>
</tr>
</tbody>
</table>

• SA definition of “rear overhang”:

Most pronounced for a tridem:

ROH

1.35 m

ROH (SA)
• Maximum width regulations:
  • 2.5 m in Australia
  • 2.6 m in South Africa
• Additional 50 mm either side
• Assume max. tail swing to occur at a yaw angle of 30° relative to the entry tangent
  • Additional 43 mm tail swing

Good correlation between Australian rear overhang and tail swing limits

\[ 50 \cdot \cos(30°) = 43 \text{ mm} \]