Tail swing performance of the South African car-carrier fleet

Christopher de Saxe  CSIR, Wits University
Frank Kienhöfer  Wits University
Paul Nordengen  CSIR, IFRTT President
Outline

1. Background & problem identification
2. Objectives
3. Research method
4. Findings:
   - Existing South African car-carrier fleet
   - South African regulations
5. Conclusions
6. Closing remarks
Background

- 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 being phased out:
  - Misuse of permits
  - Definition of “indivisible load”
  - Stability concerns due to the elevated payload
- Normal South African regulations will be enforced
- ...unless (proposal):
  1. Vehicles comply with the Australian PBS scheme
     • (as part of the South African PBS demonstration project)
  2. Operators are RTMS accredited
SA Car-Carriers

Abnormal
Legal

18.59 m

22.86 m

Courtesy Unipower (Natal) and Khässbohrer.
Problem Identification

• Large rear overhangs → Excessive tail swing
• Australian Level 1 tail swing limit = 0.30 m
  – Initially 0.50 m
  – Austr. NTC (2002): Performance characteristics of the Australian heavy vehicle fleet
    • Only one vehicle exceeded 0.30 m (car-carrier, 0.33 m)
    → Limit reduced to 0.35 m, and subsequently to 0.30 m
  – Australian Design Rule 43/05:
    • Max. rear overhang = 3.7 m (up to 4.9 m incl. load)

→ SA car-carriers unlikely to comply

\(^1\) NRTC. (2002). *Performance characteristics of the Australian heavy vehicle fleet.* Melbourne: National Road Transport Commission.
Objectives

1. Quantify the tail swing performance of the existing South African fleet.

2. Assess the worst possible tail swing allowed within the scope of South African regulations.

Require a means to calculate tail swing
Research Method: Manoeuvrability Model
Research Method: Manoeuvrability Model
Research Method

• Model based on previous work
  – Erkert et al. (1989)\(^1\) → Requires numerical integration
  – McGovern (2003)\(^2\) → Restricted by spreadsheet

• Tyre scrub effects incorporated
  – Winkler & Aurell’s (1998)\(^3\) “equivalent wheelbase”
  – Modified for low-speed turning, trailers
    • Tyre properties fall away

• Steer-tyre path-following (Australian PBS 90° turn)

• Tail swing within an average of 7 mm of equivalent TruckSim® simulations

---


- Low-Speed Swept Path
- Tail Swing
- Frontal Swing
- Difference of Maxima
- Maximum of Difference
SA Car-Carrier Fleet

- Sample of 6 designs
  - 510 vehicles (65%)
    - 3 tractor+semitrailers
    - 3 truck+tag-trailers
  - Proportions and dimensions assumed representative of the fleet at large

<table>
<thead>
<tr>
<th>Veh.</th>
<th>Configuration</th>
<th>Number of vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>“A”</td>
<td>Tractor-semitrailer</td>
<td>90</td>
</tr>
<tr>
<td>“B”</td>
<td>Tractor-semitrailer</td>
<td>110</td>
</tr>
<tr>
<td>“C”</td>
<td>Tractor-semitrailer</td>
<td>30</td>
</tr>
<tr>
<td>“X”</td>
<td>Truck and tag-trailer</td>
<td>105</td>
</tr>
<tr>
<td>“Y”</td>
<td>Truck and tag-trailer</td>
<td>80</td>
</tr>
<tr>
<td>“Z”</td>
<td>Truck and tag-trailer</td>
<td>95</td>
</tr>
</tbody>
</table>
SA Car-Carrier Fleet: Results

- 0.71 m

Austr. PBS L1 max.

Tail Swing (m) vs. Rear Overhang (m)

Truck

Trailer

Semitrailer

Australian rear overhang limit (3.7m)
SA Car-Carrier Fleet: Results

- 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

\[ 50 \cdot \cos(30°) = 43 \text{ mm} \]
SA Car-Carrier Fleet: Results

The diagram shows the percentage of the fleet excluded based on the tail swing limit enforced (m). Two key percentages highlighted are 78% and 18%. The x-axis represents the tail swing limit enforced in meters (m), ranging from 0.25 to 0.75, while the y-axis represents the percentage of the fleet excluded.
• First objective achieved.
  – Tail swing of the existing South African fleet has been shown to be poor due to regulatory differences between South Africa and Australia.

• Now, South African regulations are explored to determine the extent of these differences and the effect on tail swing.
  – Calculate the worst theoretical tail swing
SA Regulations

• 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: 1.35 m
Maximum Rear Overhang

- Overall length
- Rear overhang = f (Wheelbase)
- Wheelbase min/max
- 5.01 m (actual)
- 3.65 m (SA)
- 6.09 m

Graph showing the relationship between wheelbase and rear overhang.
### SA Regulations: Results

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Rear Overhang</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Australia</td>
<td>South Africa</td>
</tr>
<tr>
<td>Rigid truck</td>
<td>3.7 m</td>
<td>5.01 m</td>
</tr>
<tr>
<td>Semitrailer</td>
<td>3.7 m</td>
<td>6.32 m</td>
</tr>
<tr>
<td>Tag-trailer</td>
<td>3.7 m</td>
<td>7.00 m</td>
</tr>
</tbody>
</table>

Up to 417% times the Australian PBS Level 1 tail swing limit achievable within SA regulations.
Sorry, how much rear overhang?
Conclusions

1. About 80% of SA car-carriers fail the Australian Level 1 PBS tail swing limit of 0.30 m (tail swing of up to 0.71 m).
2. The 0.30 m tail swing limit was shown to correlate well with the rear overhang limit of 3.7 m in Australia.
3. In comparison, South African regulations allow rear overhangs of up to 7 m → Tail swing up to 1.25 m.
   – Lack of an absolute maximum rear overhang limit.
   – Unsuitable definition of rear overhang.
4. A consideration to relax the Level 1 tail swing limit was not supported by the SA Smart Truck Review Panel.
5. The manoeuvrability model has proven to be accurate, versatile, and a useful preliminary optimisation tool.
Closing Remarks

• Car-carrier-specific legislation in Australia:
  – South Australia, New South Wales, Northern Territory
  – Up to 25 m maximum length, 3.7 m rear overhang

• A number of recent PBS car-carrier projects in SA
  – Initial optimisation of low-speed manoeuvrability

• TruckSim® assessments of two car-carriers
  – Truck & tag-trailer showed poor dynamic performance
    • PBS compliance achieved by increasing trailer wheelbase
  – A rear overhang limit indirectly prescribes a minimum wheelbase → Positive effect on stability
Acknowledgements

• Research and conference funding:
  – CSIR
  – Wits University
    • National Research Foundation (THRIP)
    • Eskom (TESP)
• Unipower (Natal) & SACTA
• Kässbohrer Transport Technik
Thank you.
\[ \theta(i) = \theta(i-1) - \arcsin \left( \frac{\Delta s_A(i) \cdot \sin(\theta(i-1) - \alpha(i))}{WB} \right) \]
\[ WB_{Eq} = WB + \frac{TF}{WB} + \frac{TF}{WB} \cdot \left( \frac{C_{\alpha,r}}{C_{\alpha,f}} \right) \]
\[ e = \frac{T}{2} \left[ 1 - \cos \left( \psi + \theta - \frac{\pi}{2} \right) \right] \]

\[ \frac{T}{2} \cdot \sin \left( \psi + \theta - \frac{\pi}{2} \right) \]

\[ \frac{T}{2} \cdot \cos \left( \psi + \theta - \frac{\pi}{2} \right) \]

Direction of travel

Steer axle in initial position, laterally offset from path by T/2