Will Automated Vehicles Improve Traffic Flow Efficiency? The case of bottlenecks...

Bart van Arem
Traffic management solution directions

1. Prevent spill-back of queues
2. Increase throughput
3. Manage inflow into (sub-) network
4. Distribute traffic over network efficiently

Hoogendoorn & Bertini (2012), Can we control traffic? Instilling a proactive traffic management culture, Delft University of Technology, Essencia The Hague (Publisher)

Automated Vehicle Symposium 2015, Ann Arbor, Michigan
## General findings on motorway capacity

<table>
<thead>
<tr>
<th>Percentage of CACC Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
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<tr>
<td>-----</td>
</tr>
<tr>
<td>0%</td>
</tr>
<tr>
<td>10%</td>
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<tr>
<td>20%</td>
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<td>30%</td>
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<td>40%</td>
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<td>50%</td>
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<tr>
<td>60%</td>
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<tr>
<td>70%</td>
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<tr>
<td>80%</td>
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<tr>
<td>90%</td>
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<tr>
<td>100%</td>
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A20: bottleneck motorway, no more space to expand

How can AVs relieve congestion here?

3+2 cross weaving

Short on-ramp
The congestion assistant

- Detects downstream congestion
- Visual and auditory warning starting at 5 km before congestion
- Active gas pedal at 1.5 km to smoothly slow down
- Takes over longitudinal driving task during congestion
Traffic flow simulation: merging area A12 motorway, Woerden, the Netherlands

Start
1 2 3 4 5 6 7 8 9 10 11 12 End

4.1 km upstream detector
2.1 km downstream detector

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Results from traffic flow simulations

Speed upstream - 10% CA

- Reference
- 1500 m
- 500 m
- 1.0 s
- 0.8 s

Speed upstream - 50% CA

- Reference
- 1500 m
- 500 m
- 1.0 s
- 0.8 s
## Results

<table>
<thead>
<tr>
<th></th>
<th>Travel time (min)</th>
<th>Delay (min)</th>
<th>Delay reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free flow (110 km/h)</td>
<td>3.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reference</td>
<td>5.7</td>
<td>2.3</td>
<td>-</td>
</tr>
<tr>
<td>500 m / 0.8 s (10%)</td>
<td>5.0</td>
<td>1.6</td>
<td>30%</td>
</tr>
<tr>
<td>500 m / 0.8 s (50%)</td>
<td>4.3</td>
<td>0.9</td>
<td>60%</td>
</tr>
</tbody>
</table>

Driel, C.J.G van & B. van Arem (2010), The impacts of a congestion assistant on traffic flow efficiency and safety in congested traffic caused by a lane drop, Journal of Intelligent Transportation Systems 14 (4), 197-208
The case of dedicated lanes

- Motorway with 4->3 lane drop
- Multi-anticipative manual driving with 0.5 reaction time and 1.0 time headway at 100 km/h
- High traffic volume with 5 minute peaks of 7700 pcu/h
- Congestion starts at lane drop at high traffic volumes with normal traffic.

If we dedicated one downstream lane to CACC vehicles, will that reduce congestion?

Designing a CACC dedicated lane configuration

- Dark lanes are for CACC exclusively, manual vehicles may not use them.
- If on the CACC lanes, CACC vehicles will stay there.
- CACC time headway 0.5 when following other CACC; 1.4 s otherwise
- Consider a 40% and 80% CACC penetration level
- Initially, CACC and manual vehicles are distributed randomly over lanes.
CACC Lane

- Supports formation efficient CACC platoons (0.5)
- Requires lane changes of manual vehicles

Low CACC penetration rate

- Low chance of CACC platoons (0.5->1.4)
- High number of lane changes by manual vehicles

High CACC penetration rate

- High chance of CACC platoons (1.4->0.5)
- Low number of lane changes by manual vehicles

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CACC platoons / headways
Lane changes
Lane distribution manual/CACC
Peak traffic volumes
On going work – adding more complexity

- SR-99 Corridor Sacramento
- ACC, CACC, Active string formation, V2I at bottlenecks
- HOV lanes for equipped vehicles
- MOTUS and VISSIM simulations
- See our poster!

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Outlook and challenges

• Bottleneck capacity may not increase by more than 10%?
• If congestion can not be avoided, then AVs could help solve congestion more quickly.
• Authority transitions may constitute new bottlenecks.
• Lane changes are key! How will AVs influence lane changing?
• New work with simulations ongoing by several groups! Great!
• How will it work on real vehicles? And in real traffic?