Human Factors of Automated Driving: Towards Predicting the Effects of Authority Transitions on Traffic Flow Efficiency.

Silvia F. Varotto¹, Raymond G. Hoogendoorn¹, Bart van Arem¹, Serge P. Hoogendoorn¹

Abstract (272 words)

Automated driving potentially has a significant impact on traffic flow efficiency. Automated vehicles which are able to show cooperative behaviour are expected to reduce congestion levels by increasing road capacity, by anticipating traffic conditions further downstream and also by accelerating the clearance of congestion.

Under certain traffic situations, drivers could prefer to disengage the automated system and transfer to a lower level of automation or are forced to switch off by the system (e.g. in case of sensor failure). These transfers between different levels of automation are defined as authority transitions and could significantly affect the longitudinal and lateral dynamics of vehicles.

Microscopic simulation software packages can be used to ex ante evaluate the impact of automated vehicles on traffic flow efficiency. Currently, mathematical models describing car following and lane changing behaviour do not account for authority transitions. In order to develop an adequate model of driving behaviour for automated vehicles including authority transitions, an empirically underpinned theoretical framework is needed where human factors are accounted for. Figure 1 presents the relationships existing between authority transitions, human factors and traffic flow conditions.

In the proposed research, this theoretical framework is the basis for the prediction of effects of automated driving on traffic flow efficiency. Firstly, empirical data from Field Operational Test and driving simulation experiments will be collected and analysed. Secondly, microscopic traffic flows models incorporating human factors will be developed: within this framework, transient manoeuvres and authority transitions will be investigated taking into account variations within and between drivers. Thirdly, the effects of different penetration rates of automated vehicles and different levels of automation on traffic flow efficiency will be discussed.

Key words: automation, authority transitions, human factors, microscopic modelling, traffic flow efficiency.

¹ Department of Transport and Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands. Emails: {s.f.varotto, r.g.hoogendoorn, b.vanarem, s.p.hoogendoorn}@tudelft.nl
Figure 1. Theoretical framework of relationships between authority transitions, human factors and traffic flow conditions.

Road and traffic flow conditions

- Environmental conditions
- Road design
- Traffic flow characteristics
- Longitudinal and lateral dynamics
- Sensors
- Systems
- Human Machine Interface
- Authority transitions
- Human driving behaviour
- Human factors

Vehicle

Driver capabilities

←--- Relationships that will be investigated.
←--- Relationships that will not be investigated.
Human Factors Of Automated Driving:
Towards Predicting The Effects Of Authority Transitions On Traffic Flow Efficiency

Silvia F. Varotto, Raymond G. Hoogendoorn, Bart van Arem, Serge P. Hoogendoorn
Department of Transport & Planning
Faculty of Civil Engineering and Geosciences
Delft University of Technology
s.f.varotto@tudelft.nl

Introduction
Automation is expected to reduce congestion by:
- increasing road capacity;
- anticipating traffic conditions further downstream;
- accelerating the clearance of congestion.

Transitions between different levels of automation:
- Affect the longitudinal and lateral dynamics;
- Influence traffic flow efficiency.

Levels of Automation investigated in the project
(SAE International’s Draft Levels of Automation for On-Road Vehicles, November 2013)

Research Plan & Research Questions
Theoretical framework of relationships between authority transitions, human factors and traffic flow conditions.

Authority Transitions

Empirics of Automated Driving
Does human behaviour influence the lateral and longitudinal dynamics in automated vehicles?

Field Operational Test
Driving simulator

Theoretical Framework for Human Factors of Automated driving

When do drivers switch on/off the system?
When does the system switch off automatically?

Modelling of Automated Driving in case of Authority Transitions

How can the role of human behaviour in automated vehicles be modelled?

Microscopic simulations

Effects of Automated Driving on traffic flow efficiency

Does automated driving improve traffic flow efficiency in mixed traffic?

Capacity
Capacity drop
Stability

Conclusions and future research

Road and traffic flow conditions
Environmental conditions
Road design
Traffic flow characteristics

Longitudinal and lateral dynamics

Sensors
Systems
Human Machine Interface

Authority transitions

Human driving behaviour

Driver’s capabilities

Relationships that will be investigated.
Relationships that will not be investigated.
Driving Behaviour During Authority Transitions After Sensor Failure

Driving Simulator Experiment on Highway

Experimental Conditions

<table>
<thead>
<tr>
<th>Control Condition</th>
<th>Experimental Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Driving</td>
<td>Adaptive Cruise Control (ACC)</td>
</tr>
<tr>
<td>System switches off</td>
<td>Driver resumes control by pressing gas pedal</td>
</tr>
<tr>
<td>Vehicle slows down</td>
<td></td>
</tr>
<tr>
<td>Manual driving</td>
<td></td>
</tr>
<tr>
<td>Control condition</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance headways [m]</th>
<th>Time headways [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>450</td>
<td></td>
</tr>
</tbody>
</table>

Requirements for the participants (70 persons):

- Driving license;
- > 1 year of driving experience.

Influence of authority transitions on longitudinal dynamics:

- Relative validity (Yan, et al. 2008).

Conclusions and future research

- Authority transitions have significant effects on longitudinal dynamics
- Speed decrease after sensor failure can trigger traffic flow instabilities

What are the limitations of current modelling approaches?

How can the effects of authority transitions on traffic flow be evaluated?

References


Acknowledgments

The research has been performed in the project HFAuto – Human Factors of Automated Driving (PITN-GA-2013-605817).