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

Silvia F. Varotto[1], *Raymond G. Hoogendoorn*[1], *Bart van Arem*[1], *Serge P. Hoogendoorn*[1]

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.

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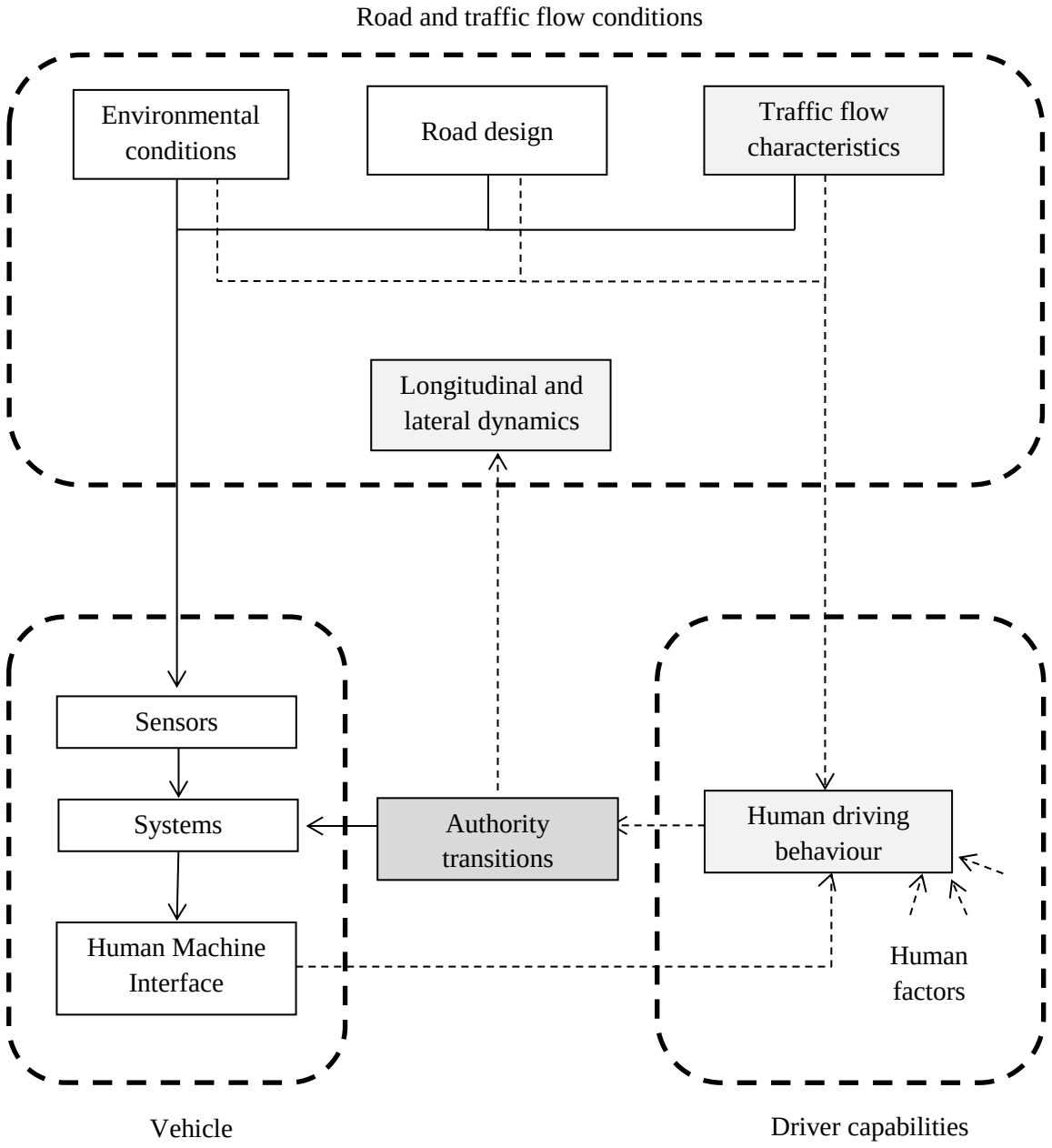
Figure 1. Theoretical framework of relationships between authority transitions, human factors and traffic flow conditions.



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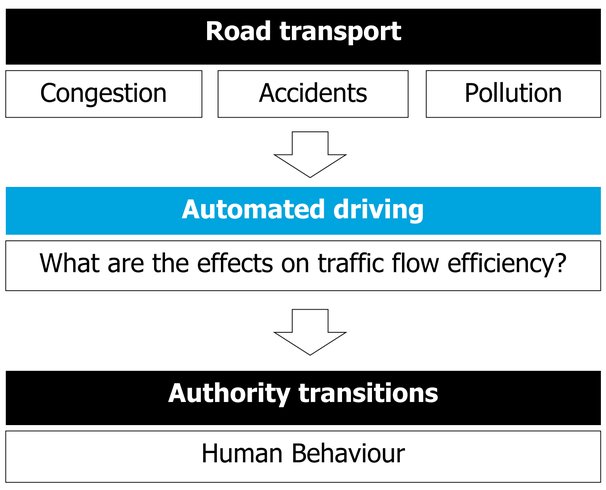
Introduction



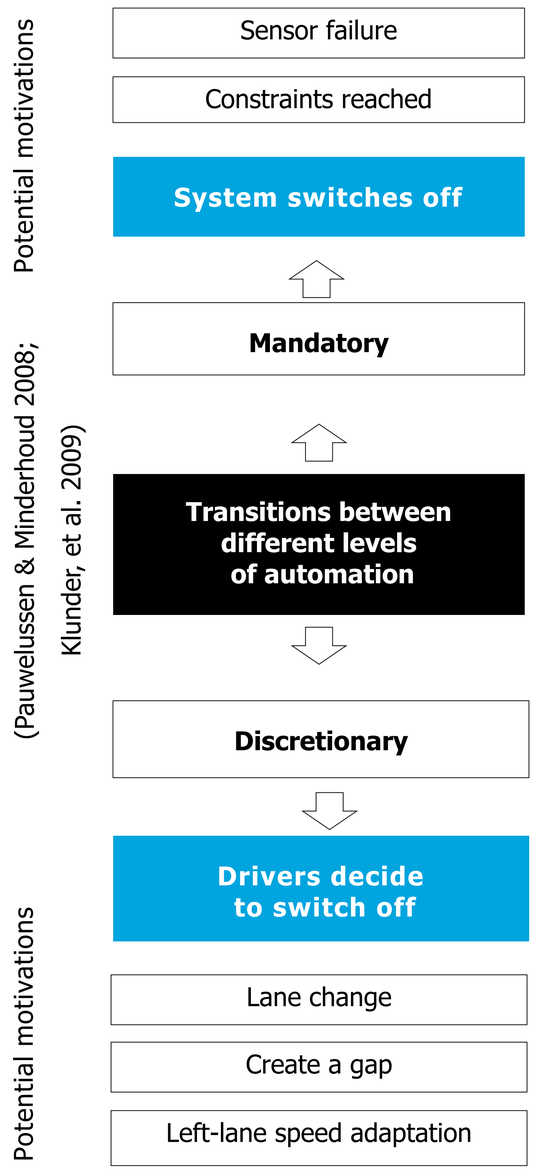
Automation is expected to **reduce congestion** by:

- ✓ 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.

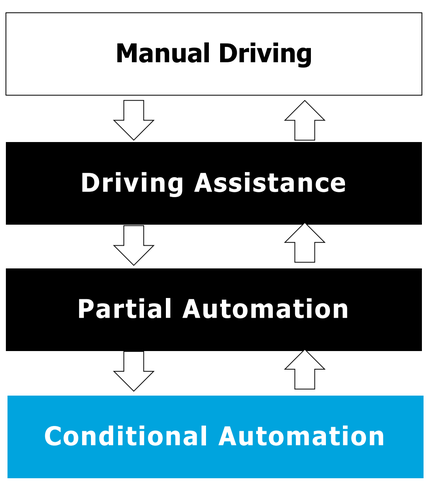
Authority Transitions



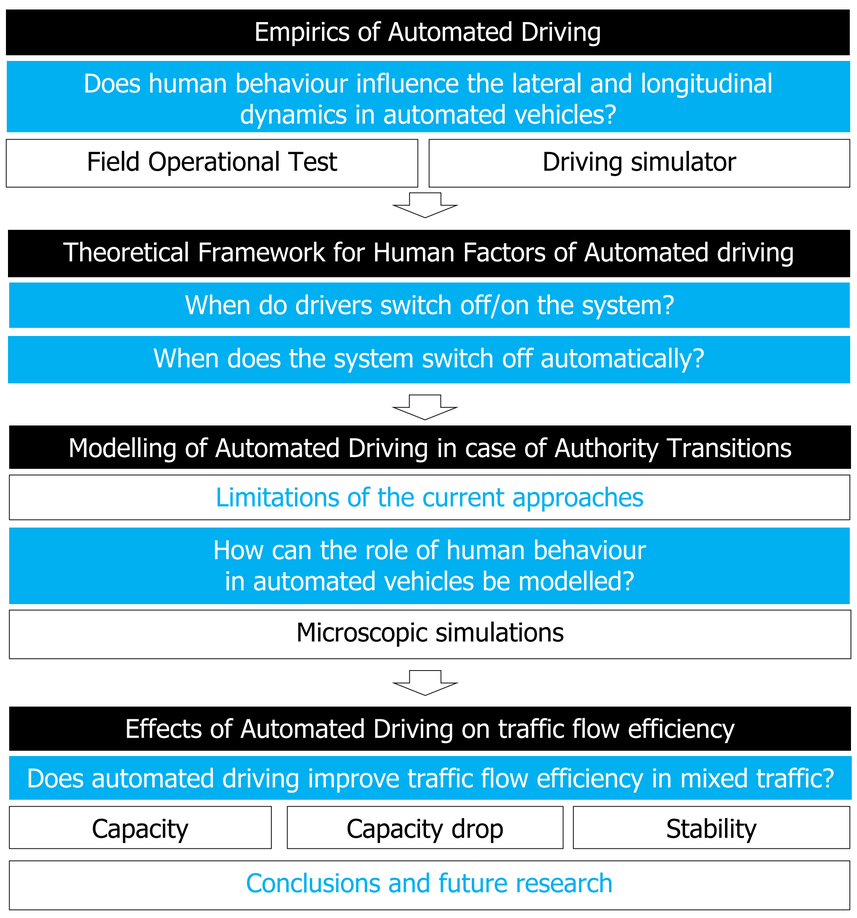
Levels of Automation investigated in the project

(SAE International's Draft Levels of Automation for On-Road Vehicles, November 2013)

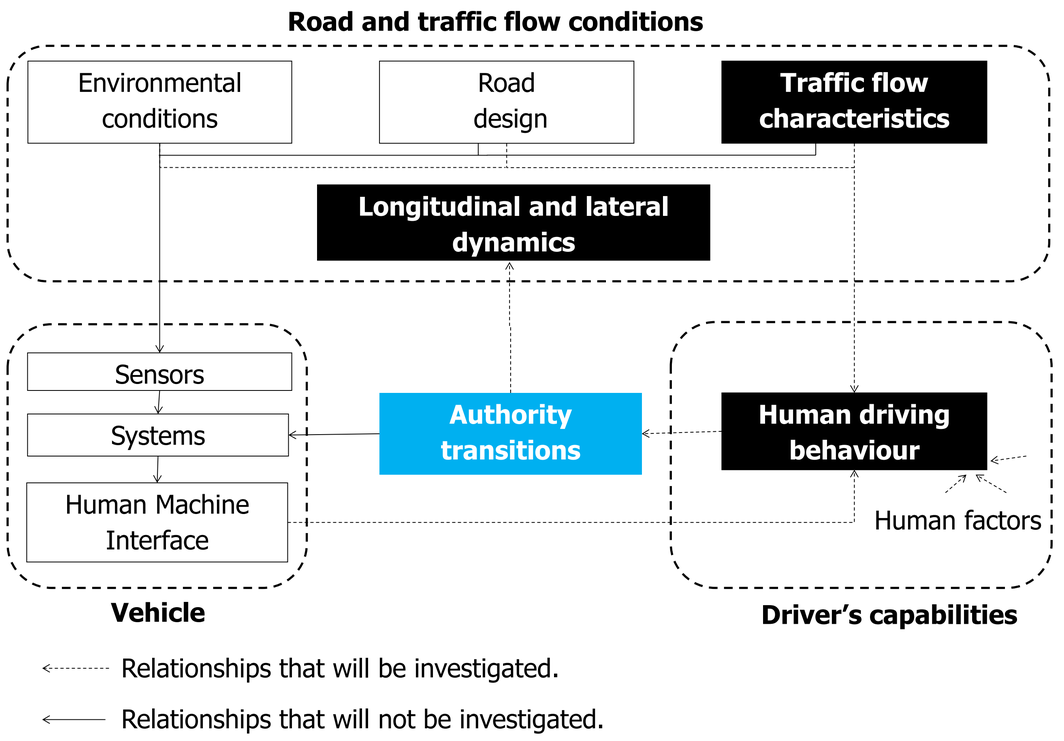
Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
***Human driver* monitors the driving environment**								
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automated	2
***Automated driving system* ("system") monitors the driving environment**								
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automated	3
4	**High Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automated	3/4
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**	-	



Research Plan & Research Questions



Theoretical framework of relationships between authority transitions, human factors and traffic flow conditions.



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Challenge the future

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Driving Behaviour During Authority Transitions After Sensor Failure

Driving Simulator Experiment on Highway

Adaptive Cruise Control (ACC)

Analysis of Authority Transitions After Sensor Failure

Control condition	Experimental condition
Speed	Time Headways
	Distance Headways

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).

Experimental Conditions

Control Condition

Manual Driving

Experimental Condition

Adaptive Cruise Control (ACC)

Sensor failure

System switches off

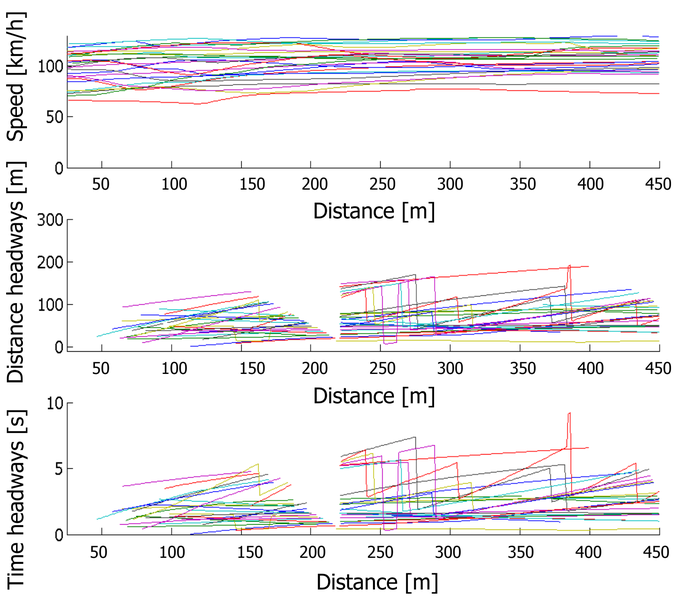
Vehicle slows down

Manual driving

Driver resumes control by pressing gas pedal

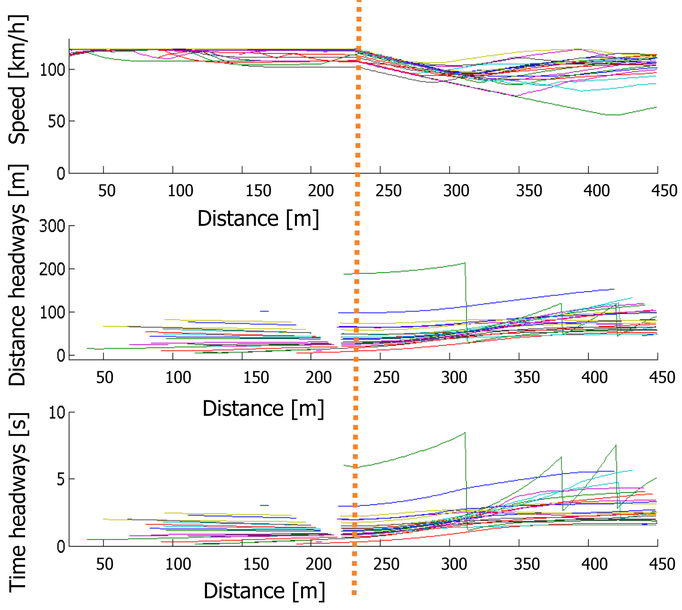
Control condition

Manual driving

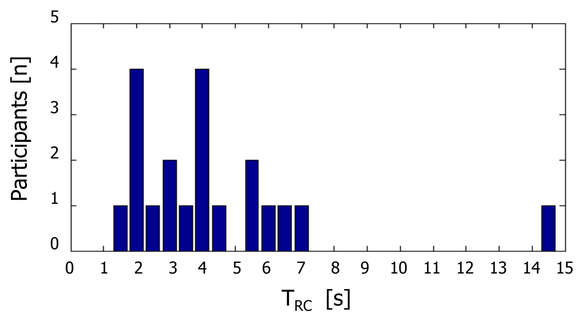


Experimental condition

Adaptive Cruise Control | Manual driving



Time to Resume Control After Sensor Failure



T_{RC} = Time to resume control after sensor failure;

T^* = Median (T_{RC});

V_{SF} = Speed at the moment of the sensor failure;

V^* = Speed at the moment T^*.

T^* = median (T_{RC}) = 3.85 s

ΔV = median ($V^* - V_{SF}$) = -18.18 Km/h

Conclusions and future research

Authority transitions have significant effects on longitudinal dynamics → **What are the limitations of current modelling approaches?**

Speed decrease after sensor failure can trigger traffic flow instabilities → **How can the effects of authority transitions on traffic flow be evaluated?**

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