Combining traffic simulation and driving simulator analyses for Advanced Cruise Control system impact identification

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Abstract

The objective of this research is to combine **microscopic traffic simulation and driving simulator** pilot tests of vehicles equipped with **Advanced Cruise Control (ACC)** systems, aiming to identify **traffic and safety impact** of the introduction of this technology. The relevant outputs of two microscopic traffic simulation and driving simulator experiments were analysed and the similarities between their experimental designs were identified. Relevant outputs were cross-tabulated and analysed, and qualitative results were extracted. Indicators selected for the purposes of this research include **average speed, minimum and desired headways, and Time-To-Collision (TTC).** The analysis indicates that the impact of ACC on the average speed is minimal, while headways and time-to-collision distributions are decreased. While these findings indicate **positive traffic impacts**, shorter headways and TTC values **could have negative safety implications**. Our findings have resulted in conclusions for the future development of ACC systems but also illustrated the usefulness for extracting a more complete assessment through the combination of traffic simulation results with respective results from driving simulators.

Introduction

- This research has been undertaken within the scope of the ADVISORS European Union project
- Results from two methodologies:
  - microscopic traffic simulation and
  - driving simulator experiments

  were combined
- While the two efforts had different objectives, there is sufficient overlap to support this analysis

Microscopic traffic simulation models

- SIMONE (Minderhoud, 1999, and Minderhoud and Bovy, 1999)
  - TRAIL/University of Delft
- SISTM (Stevens et al., 2000)
  - Transport Research Laboratory (TRL)

Driving simulator tests

- Performed by the Swedish National Road and Transport Research Institute (VTI)
  - Detailed description available in Tornros et al., 2002

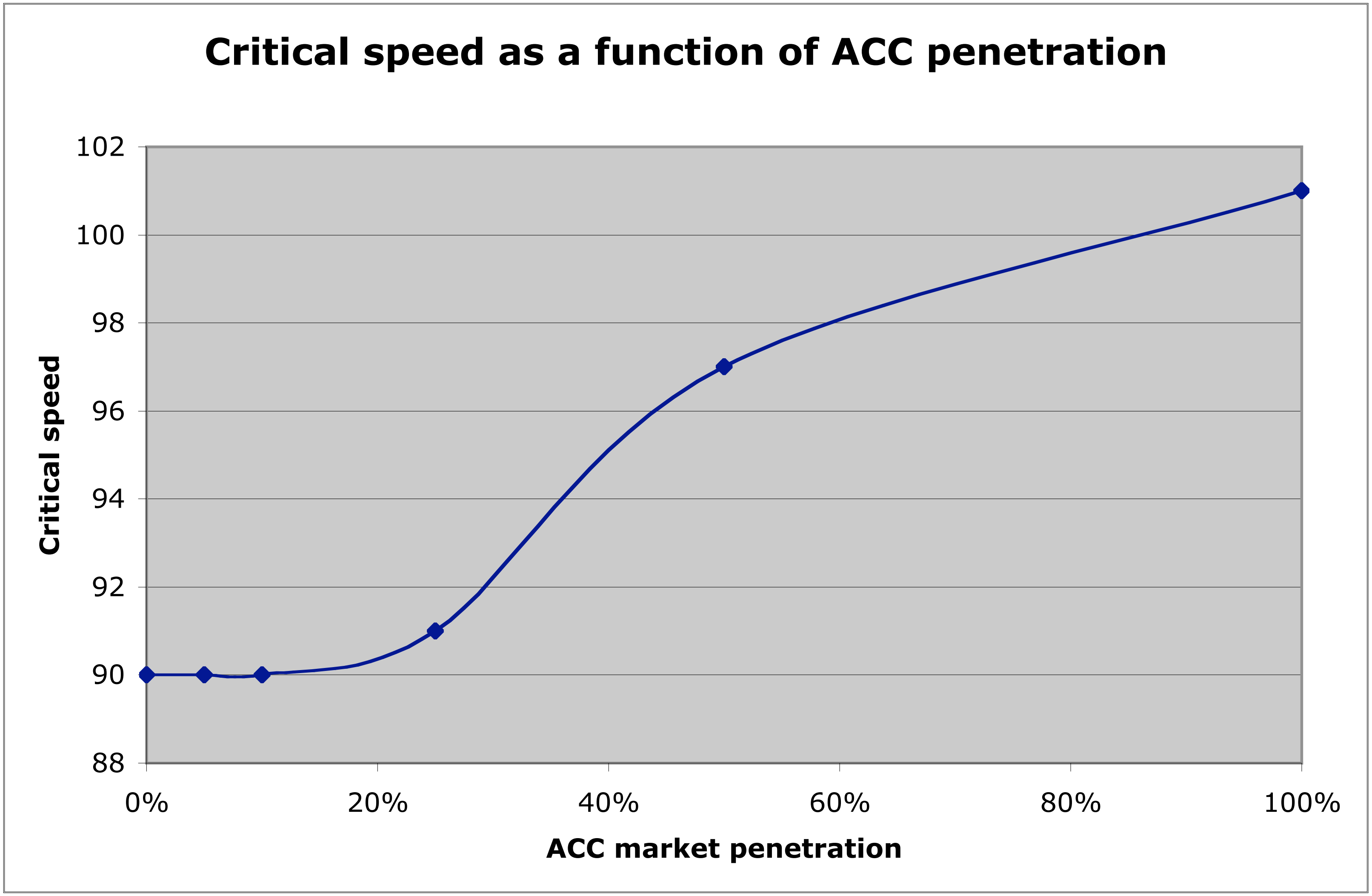
Scope of the analysis

- Adaptive Cruise Control (ACC) was selected for the analysis
- Motorway sections were modeled
- Driving simulator: drivers with various experience levels were used
- The following indicators were selected:
  - Average speed
  - Minimum and desired headways
  - Time-To-Collision (TTC)

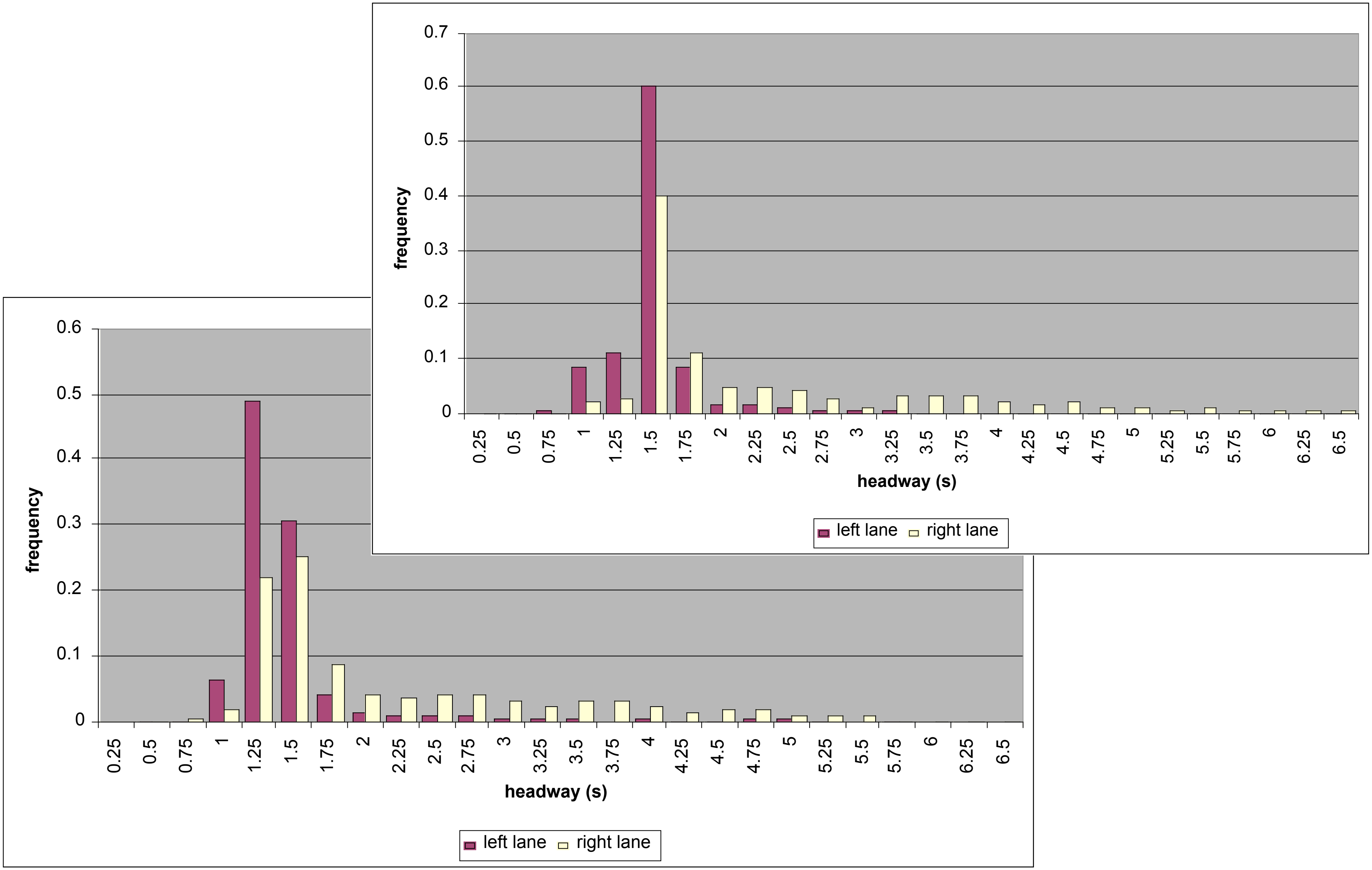
Advanced Cruise Control (ACC) Functional Characteristics

Characteristic	*Microscopic traffic simulation models*	*Microscopic traffic simulation models*	*Driving simulator*
	SIMONE	***SISTM***	***VTI***
Speed range (km/h)	30 to 170	0 to 142	50 to 140
Acceleration range (m/s^2)	0 to 4	0 to 0.28	0 to 1
Deceleration range (m/s^2)	0 to 2.5	0 to 1.25	0 to 2.5
Minimum time headway (s)	1 to 2.5 (based on control settings)	1.5 2.0	0.8 1.0 1.5
Penetration rates	0% 5% 10% 25% 50% 100%	0% 10% 50% 90%	(indirect assessment)

Microscopic simulation sample results



Critical speed as a function of ACC penetration (SIMONE microscopic simulator).



Headway distribution by lane (top: no ACC, bottom: 25% ACC penetration, SIMONE microscopic simulator)

Summary of results (quantitative)

Measure	*Microscopic traffic simulations*	*Microscopic traffic simulations*	*Driving simulator*
	SIMONE	***SISTM***	***VTI***
Average speed	Up to 10% increase in *critical* speed	Up to 7% increase	No change
Headway distribution	ACC leads in a narrower distribution (around the system-dictated headway)	Small increase (1% - 2%) for low flows, 2%-5% decrease otherwise.	Significant decrease in average distance headway from 51m to 31 m. Average preferred headway: 1.4s-2.8s (without ACC) and 1.5s-2.5s (with ACC)
Time-to-collision	50% decrease in "dangerous" values, i.e. less than 1.5s 15-20% increase in "uncomfortable" values, i.e. below 3s	Up to 35% decrease in proportion of TTC less than 10s Up to 15% decrease in proportion of TTC less than 1s	Decreases in large values (e.g. from 17s to 10s), and increases in other cases (e.g. from 2.35s to 2.52s)

Summary of results (qualitative)

Measure	*Microscopic traffic simulations*	*Microscopic traffic simulations*	*Driving simulator*
	SIMONE	***SISTM***	***VTI***
Average speed	0, (+)	0, +	0
Headway distribution	+	+	+
Time-to-collision	+	+	+

Conclusions

- The two methodologies have different properties, advantages and disadvantages
  - However, under certain conditions, their outputs can be compared and analyzed together
- Impact of ACC increases monotonically with penetration level
  - No “critical” penetration level
  - Positive traffic impact
  - Potentially negative safety implications (shorter headways and TTC values)

Directions for future research

- Investigation of more scenarios (e.g. ADA systems and network characteristics)
  - Can the findings be generalized to other ADA systems?
  - Sensitivity analysis/robustness of these findings
  - To what extent are the discrepancies due to differences in the methodologies?
- Use of driving simulator findings for calibration of behavioral models in microscopic simulators
  - For example, behavior of drivers using ADAS, which may not yet be widely available in vehicles (therefore this behavior cannot be directly observed)

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