Predicting Conflict Severity and Safety Impacts of Automated Vehicles in Urban Networks

Simulation-based analysis across European pilot sites

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Introduction

Road safety challenge

Road safety is a fundamental component of sustainable transport systems. However, **human error remains the primary cause of road crashes**, highlighting the need for innovative solutions to improve safety.

Automated vehicles

Automated vehicles are expected to improve road safety by reducing human error. This makes them particularly promising for **public transport applications**, where safe and reliable operation is essential.

Context

This study investigates automated vehicle operations in urban traffic environments across Europe using **simulation-based analysis informed by real-world operations**.

Objective

This study evaluates the **impact of automated vehicles on traffic safety** across different urban environments by analysing conflict frequency, conflict severity and time-to-collision.

Study sites

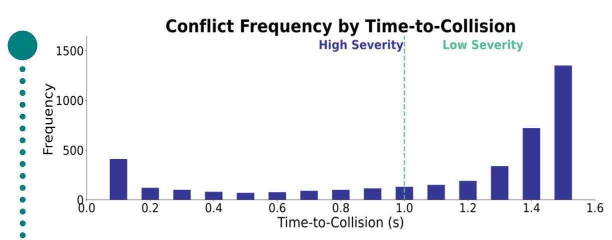
Methodology

Traffic simulation

Microscopic traffic simulations are used to model vehicle movements under baseline and automated vehicle scenarios.

Safety indicators

Conflicts are analysed using surrogate safety measures, such as time-to-collision, and classified into low- and high-severity events.

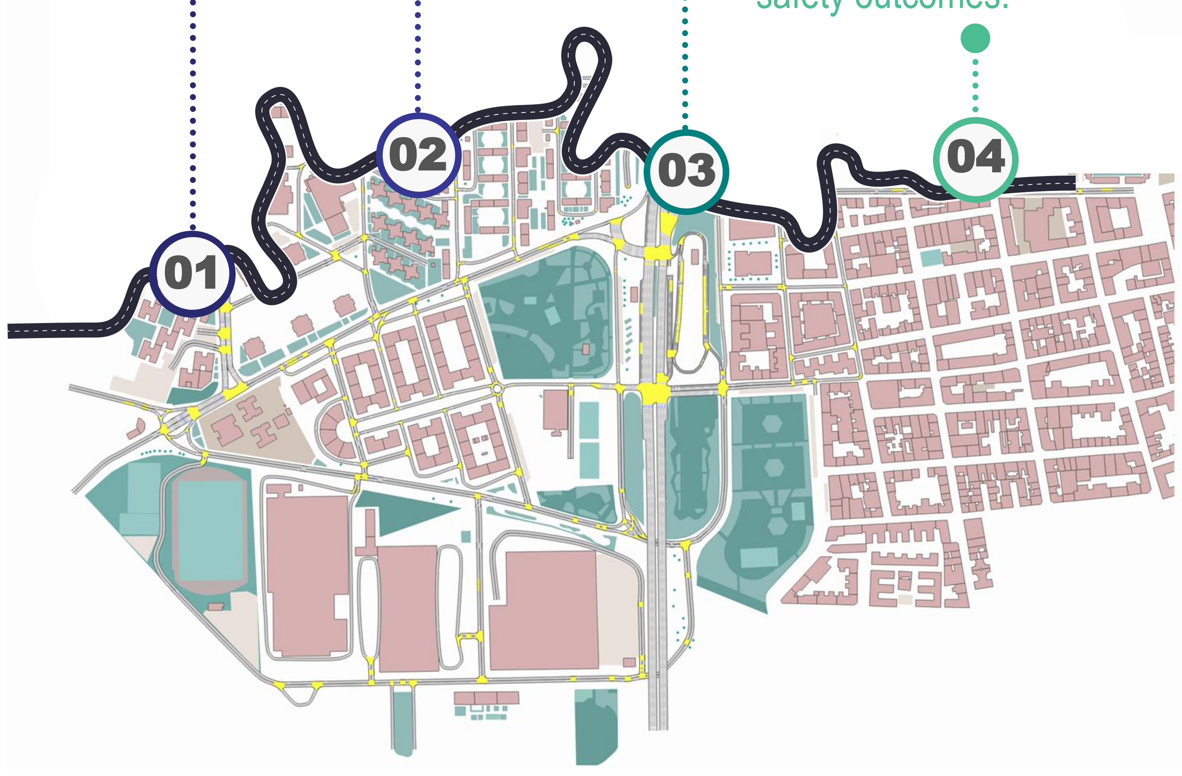


Conflict detection

Simulation outputs are processed to extract vehicle trajectories and identify conflicts using the Surrogate Safety Assessment Model.

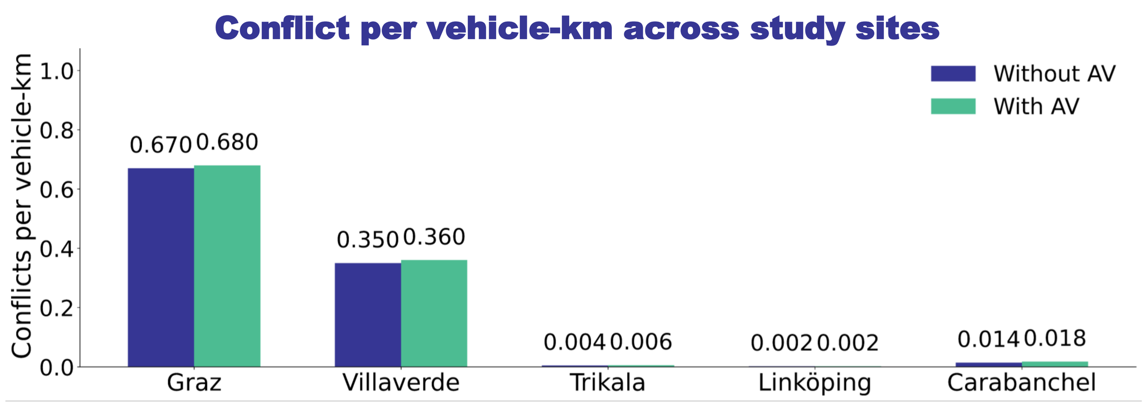
Statistical modelling

Regression models are applied to quantify the effects of traffic conditions and automated vehicles on safety outcomes.



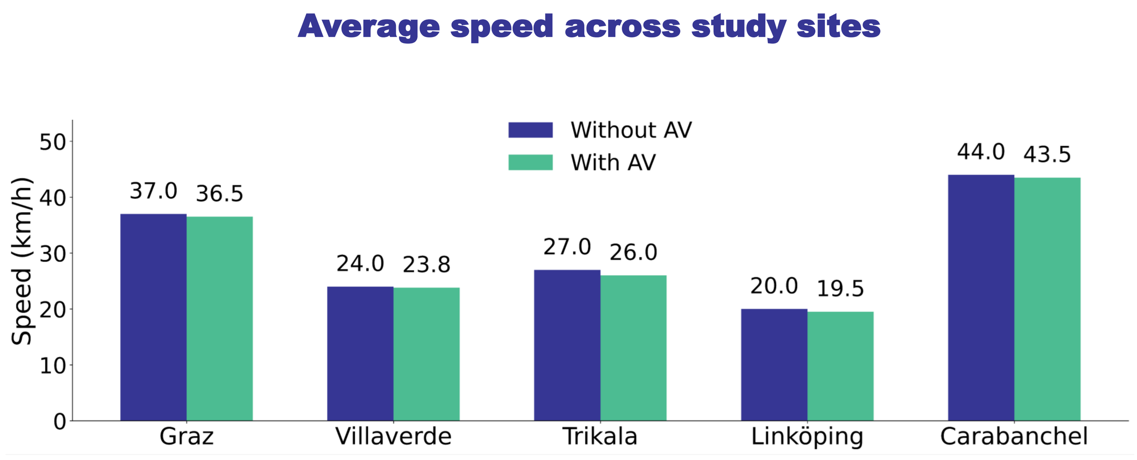
Conflict frequency

The results show that automated vehicle deployment leads to **small changes in conflict frequency** across different urban environments.



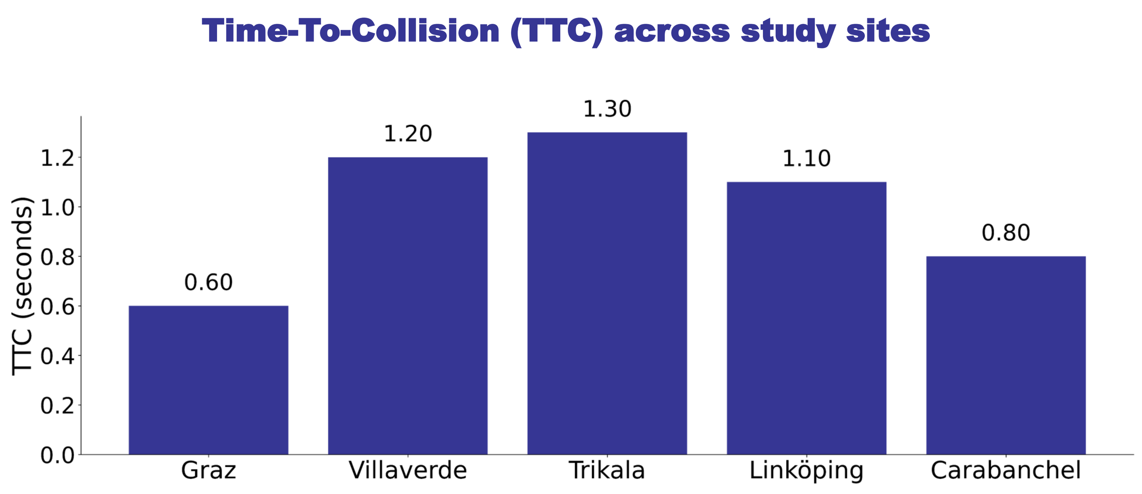
In most cases, conflicts increase slightly, reflecting **more frequent interactions** in traffic.

This increase is related to the **lower operating speeds of automated vehicles**, which result in more cautious driving behaviour and additional stop events.



Time-to-collision

Time-to-collision **varies across sites**, with higher values indicating safer interactions and lower values reflecting more critical conditions.



Loglinear regression for time-to-collision

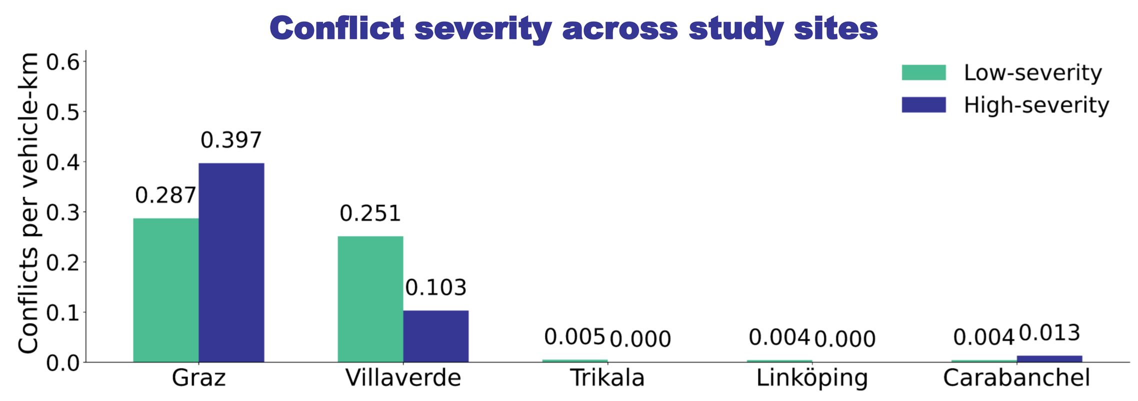
	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.579	0.018	-31.652	<0.001	***
Automated services (Ref: no automation)	0.013	0.007	1.881	0.0599	
Maximum change in velocity (km/h)	-0.063	0.002	-39.379	<0.001	***
Maximum deceleration (m/s²)	0.012	0.000	27.880	<0.001	***
Lane change conflicts (Ref: crossing)	0.328	0.017	18.791	<0.001	***
Rear end conflicts (Ref: crossing)	0.681	0.017	41.082	<0.001	***

Dependent variable: Time-to-Collision (TTC) during conflicts in sec
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.792 on 62136 degrees of freedom
Multiple R-squared: 0.1674, Adjusted R-squared: 0.1673
F-statistic: 2498 on 5 and 62136 DF, p-value: < 2.2e-16

- Results show that **larger velocity changes** are associated with **shorter time-to-collision values**, making conflicts more critical.
- In contrast, **stronger deceleration increases time-to-collision**, providing more time to react and reducing immediate risk.
- Conflict type also plays an important role, with lane-change and rear-end interactions resulting in longer time-to-collision values, while **crossing conflicts remain the most critical**, as they involve less time to avoid collisions.

Conflict severity

Results show that **67.3% of conflicts are low severity**, while 32.7% are high severity, indicating that most traffic interactions are non-critical.



Binomial logistic regression for conflict severity

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.663	0.051	-13.014	<0.001	***
Automated services (Ref: no automation)	-0.099	0.020	-5.051	<0.001	***
Maximum change in velocity (km/h)	0.292	0.005	54.697	<0.001	***
Maximum deceleration (m/s²)	-0.026	0.001	-19.540	<0.001	***
Lane change conflicts (Ref: crossing)	-0.270	0.050	-5.430	<0.001	***
Rear end conflicts (Ref: crossing)	-0.837	0.046	-18.117	<0.001	***

Dependent variable: conflict severity (0 for low severity and 1 for high severity)
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Null deviance: 78733 on 62141 degrees of freedom
Residual deviance: 68154 on 62136 degrees of freedom
AIC: 68166

- **Larger changes in vehicle speed** are associated with **more severe** conflict outcomes.
- The presence of **automated vehicles reduces high-severity conflicts**, demonstrating improved safety performance under AV deployment.
- Conflict type influences severity, with **crossing conflicts being more severe**, while lane-change and rear-end interactions are less critical.

Conclusions

- Automated vehicles **increase interaction** frequency, but these interactions are predominantly **low severity**.
- **Lower operating speeds** lead to more interactions but also reduce the risk of severe outcomes.
- Vehicle dynamics are key, with **higher speed differences increasing risk**, while stronger deceleration mitigates severity.
- **Conflict type strongly influences safety**, with crossing conflicts being the most critical.
- **Traffic environment matters**, as controlled settings consistently show safer outcomes.

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