Summary

Standardized driving cycles remain indispensable for comparability and regulatory enforcement, yet their deterministic nature and weak connection to the operational context make them increasingly inadequate for modern electrified, connected and automated vehicles. Even on-road procedures struggle to isolate key sources of variability, most notably traffic, which can strongly alter energy and emission outcomes even when the route is unchanged. Driven by the research objective of overcoming the limitations of modern testing and enabling realistic vehicle performance simulation, this dissertation proposes a Traffic-in-the-Loop (TIL) methodology in which a high-fidelity vehicle model and a traffic environment evolve in closed-loop interaction. To make scenario-based assessment feasible at scale, the approach is coupled with fully automated scenario creation workflows.

Two complementary TIL platforms are developed. The first implementation, referred to as S-TIL, reproduces the state of the art by coupling the microscopic traffic simulator SUMO with a Simulink ego-vehicle model through MATLAB, enabling traffic-aware longitudinal dynamics and energy analyses. Experience with S-TIL exposes the main practical limitations for systematic studies, namely computational inefficiency, time-step granularity, transparency and maintainability when relying on an external traffic simulator. Building on the acquired experience, a second implementation, referred to as M-TIL, is introduced as an automotive-oriented, integrated platform where road geometry and traffic dynamics are modeled in MATLAB and the vehicle and controllers run in Simulink in parallel, increasing controllability of assumptions and enabling more scalable experimentation. Automation is treated as a core enabler. Real-road scenarios are generated through an external map pipeline that extracts geometry and road attributes, including speed limits, lanes, elevation and intersections, and reformulates them through an equivalent-route representation. A database-based

workflow additionally constructs scenarios from curated road elements and intersections, eliminating dependence on third-party services and improving long-term reproducibility.

The framework is demonstrated using a fuel-cell hybrid electric IVECO eDaily model validated against chassis-dynamometer measurements, and through case studies that quantify sensitivities that are typically hidden by cycle-based testing. The influence of simulation timestep is characterized in terms of both pacing and numerical fidelity, showing that coarse discretization can bias energy estimates under congestion. Controlled variation of macroscopic traffic parameters provides a practical degree of repeatability while preserving stochastic microscopic interactions. Results further show that traffic congestion is a dominant driver of performance variability and can reduce or mask the benefits of advanced speed-planning strategies. Conversely, under free-flow conditions, route composition and driver archetypes strongly affect range, with effects that are amplified in urban operation. Overall, the thesis contributes both conceptually and engineering-wise to a transition from cycle-based to scenario-based testing, delivering TIL platforms and automated scenario pipelines that enable realistic, traffic-aware performance simulation for vehicle design and control development.