

Vehicle Safe Motion in Mixed-Vehicle-Technology Environment

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1. Introduction

The application of Connected and Automated Vehicles (CAVs) is steadily increasing, bringing forward expectations of substantial improvements in road safety, traffic efficiency, and environmental sustainability. A fully integrated vehicle–human–infrastructure ecosystem promises reduced crash rates, smoother traffic flow, enhanced mobility, and more efficient use of road network capacity. However, before such a fully automated paradigm can be realized, transportation systems must navigate a prolonged transitional phase characterized by the coexistence of human-driven vehicles, semi-automated systems, and fully autonomous vehicles.

This mixed vehicle technologies environment introduces complex operational and safety challenges that directly affect vehicle safe motion. Heterogeneity in driving behavior, perception capabilities, communication reliability, and control strategies can amplify traffic disturbances, increase conflict likelihood, and undermine expected safety gains, particularly in demanding conditions such as work zones, lane closures, and dense urban networks. Addressing these challenges requires a holistic understanding of how vehicles interact with both one another and infrastructure under partial automation and connectivity.

The present Special Issue aims to advance knowledge on vehicle safe motion during this critical transition period by bringing together recent research on mixed traffic flow dynamics, safety assessment, and intelligent control strategies. The included contributions examine these issues through complementary methodological lenses, including microscopic traffic simulation, surrogate safety analysis, vehicle-to-infrastructure communication frameworks, and advanced computer vision-based detection and monitoring techniques. Collectively, the papers in this Special Issue provide scientific insights and practical tools that support safer, more efficient, and more resilient vehicle motion in increasingly complex mixed-technology traffic environments.

2. Overview of Selected Papers

This Special Issue brings together ten (10) research contributions that collectively illustrate the multidisciplinary scope of contemporary intelligent transportation research and highlight complementary approaches for achieving safer, more efficient mixed-traffic systems. The papers can be broadly organized into five interrelated thematic categories, addressing the following key research areas: traffic flow and safety impacts of work zones and operational constraints, mixed traffic flow modeling and dynamics in connected and automated driving environments, safety assessment methodologies for mixed and automated traffic, AI-based perception, vehicle detection, traffic incident monitoring, and cooperative decision-making and control strategies for connected autonomous vehicles.



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2.1. Traffic Flow Impacts of Work Zones and Operational Constraints

The papers that fall under this topic analyze traffic flow and safety impacts of work zones and operational constraints by examining moving work vehicles in tunnels and smart work zones supported by vehicle-to-vehicle and vehicle-to-infrastructure communication.

Fang et al. [1] examine how low-speed moving work zones inside tunnels influence downstream traffic flow, queuing, and lane-changing behavior using VISSIM simulations, highlighting critical impact distances and speed–volume thresholds.

Nour et al. [2] propose a smart work zone framework combining vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication to improve lane-change safety under realistic communication constraints, supported by co-simulation results.

2.2. Mixed Traffic Flow Modeling and Evolution with CAVs

This category focuses on the theoretical and simulation-based modeling of mixed traffic flow in connected and automated driving environments, capturing the interactions among human-driven, connected, and automated vehicles, as well as both the day-to-day evolution of traffic networks and the localized influence of automated vehicles on surrounding traffic dynamics.

Huang et al. [3] develop a daily dynamic evolution model capturing route choice, travel cost, and energy consumption in mixed CAV–Human-Driven Vehicles (HDV) networks using a Proportional-switch Adjustment Process (PAP)-based framework.

Heckelmann et al. [4] quantify the spatial influence of a single predictive autonomous vehicle on surrounding traffic, demonstrating benefits in energy efficiency and traffic smoothing.

2.3. Safety Assessment in Mixed and Automated Traffic Environments

The third category concentrates on safety assessment methodologies for mixed and automated traffic, employing surrogate safety measures, such as time-to-collision, speed disparity, and conflict analysis, to evaluate safety risks and the effectiveness of countermeasures, including advisory speeds, managed lanes, and other traffic control strategies.

Sultana et al. [5] use speed disparity metrics to assess safety risks in mixed-vehicle environments and evaluate advisory speed strategies as countermeasures.

Sarran et al. [6] assess safety and operational impacts of automated vehicle managed lanes under varying market adoption rates using time-to-collision (TTC)-based conflict analysis.

2.4. AI-Based Vehicle Detection and Traffic Incident Perception

This category addresses AI-based perception, vehicle detection, and traffic incident monitoring, covering computer vision and deep learning methods for vehicle detection, tracking, and real-time incident recognition in complex traffic environments. It includes studies ranging from comprehensive surveys of image-based detection techniques to advanced deep learning implementations for multi-target detection and accurate incident identification in urban scenarios.

Adam et al. [7] provide a comprehensive survey of classical and deep learning-based vehicle detection approaches, datasets, metrics, and open research challenges.

Wang et al. [8] introduce an improved YOLOv8 architecture with attention mechanisms and advanced loss functions, achieving superior detection performance in complex scenarios.

Karim et al. [9] combine YOLOv8 and Deep Simple Online and Real-time Tracking (SORT) for high-accuracy traffic incident detection and continuous vehicle behavior monitoring in urban environments.

2.5. Cooperative Decision-Making and Control for Connected Vehicles

The fifth category focuses on cooperative decision-making and control strategies for connected autonomous vehicles, emphasizing distributed and game-theoretic approaches to enhance coordination, efficiency, and safety in complex traffic interactions, including critical scenarios such as unsignalized intersections.

Xiao et al. [10] propose a game-theoretic, distributed decision-making framework for CAV coordination at unsignalized intersections, achieving significant reductions in delay and improved efficiency.

3. Conclusions

The contributions in this Special Issue demonstrate that intelligent, connected, and automated technologies are central to the safe and efficient integration of electric vehicles into future road networks. As EVs increasingly operate in mixed traffic environments, interactions with human-driven vehicles, infrastructure, and control systems significantly influence traffic safety, operational performance, and energy efficiency.

The findings show that connectivity-enabled strategies, predictive control, and cooperative decision-making can mitigate safety risks while promoting smoother traffic flow and reduced energy consumption, particularly in complex settings such as work zones, tunnels, and intersections. Moreover, AI-based perception and traffic monitoring emerge as key enablers for real-time traffic management and energy-aware electric mobility.

Overall, the Special Issue highlights the need for integrated, system-level approaches to fully realize the safety, efficiency, and sustainability benefits of electric and automated transportation systems.

Conflicts of Interest: The authors declare no conflict of interest.

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