CTIPS Center for Transformative Infrastructure Preservation and Sustainability
USDOT Region 8 University Transportation Center

The Impact of Connected and Autonomous Vehicle Technologies on North Dakota's Highway Infrastructure

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University

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Research Needs

Reliable highway infrastructure is a cornerstone for sustainable economic development, safety, and connectivity. Highway infrastructure plays a vital role in shaping the social, economic, and environmental landscape of all jurisdictions. Continuous highway infrastructure adaptation is required to meet the evolving needs of road users and disruptive technologies such as Connected and Automated Vehicles (CAVs) and truck platooning. The prospect of vehicle and highway automation promises considerable advantages for surface transportation; however, it could present unprecedented challenges for transportation agencies. These challenges primarily stem from a multitude of uncertainties concerning the interactions between CAV technologies and the existing highway infrastructure. National and local transportation agencies must stay abreast of developments related to the rapid pace of advancements in emerging vehicular technologies. Deploying CAV technologies and truck platooning provides several potential advantages benefiting surface transportation, road user safety and mobility (*1–4*), the trucking industry (*5–8*), and overall economic growth; however, they also introduce a host of new challenges for transportation agencies. These challenges primarily revolve around the uncertainty regarding how CAV and truck platooning will impact existing highway infrastructure.

Most research examining the effects of Connected and Autonomous Vehicles (CAVs) on highway infrastructure has been performed in urban environments; however, the highway network in North Dakota is predominantly rural. Harsh weather conditions, such as snowstorms, blowing snow, strong winds, and fog, present additional challenges for testing and deploying CAV technologies. These technologies rely heavily on sensors and cameras to create a 3D map of their surroundings for efficient navigation. Consequently, the severe weather conditions prevalent in North Dakota significantly impede testing and implementing CAV technologies.

It is increasingly essential that national and local transportation agencies maintain a proactive perspective and stay well-informed due to the rapid evolution of emerging vehicular technologies. Engaging in a thorough and comprehensive evaluation of the impact of CAV technologies on highway infrastructure is crucial. Furthermore, identifying current and future infrastructure requirements in light of these advancements is imperative for effective planning and management within the transportation sector; therefore, embracing this critical effort becomes necessary to ensure the seamless integration of CAV technologies into the transportation system while mitigating potential disruptions and maximizing benefits.

CAVs influence various critical aspects of the transportation domain. Each aspect must be identified to ensure safe and smooth operations for all road users and CAV technologies on our highway system. These aspects and their associated needs can be summarized as follows:

1) Infrastructure: CAVs can impact infrastructure significantly, ranging from adjustments to traffic control devices to optimize traffic flow and ensure safe interactions between CAVs and other road users to upgrading road geometry features. Furthermore, maintenance operations and the quality and reliability of the existing traffic control devices are crucial for CAV operation.

2) Operation: CAVs are expected to enhance road capacity by reducing perception reaction time, leading to a reduced required sight distance for stopping and passing. These enhancements would lead to a more efficient use of available roadway space; however, challenges arise at merge, weave, and diverge roadway sections, in which interactions between other road users are mandatory.

3) Safety: Safety considerations are associated with CAV implementation. Interactions with other vehicles might pose potential risks that should be carefully managed to prevent collisions and ensure the overall safety of the transportation network. Moreover, public acceptability is a concern.

4) Infrastructure Maintenance: Introducing CAVs will impact highway infrastructure maintenance needs. For example, heavy vehicles increase wear and tear on road surfaces, requiring more frequent repairs.

5) Environment: CAV technologies can deliver significant environmental benefits by reducing fuel consumption and emissions. CAV systems can enhance fuel efficiency and minimize gas emissions by optimizing driving patterns, such as smoother acceleration and deceleration and reduced idling time, contributing to broader sustainability objectives within the transportation sector.

6) Workforce: The adoption of CAV technologies might also impact the workforce, particularly regarding emergency management services (EMS) and the trucking industry. CAV systems may enhance the efficiency and productivity of the transportation system; however, they may also lead to a shift in the responsibilities of EMS and truck drivers. Addressing these workforce dynamics requires proactive measures to ensure a smooth transition and equitable distribution of the economic benefits associated with CAV technologies.

There are several issues/challenges with deploying and testing truck platooning technologies. These issues could be classified into 1) Technical and 2) Non-technical. Technical issues could involve problems related to the following:

- Connectivity and communication technologies
- Cybersecurity
- Infrastructure integration
- Operation and connectivity in adverse weather
- Takeover requests

Non-technical issues include 1) organizational implementation challenges, 2) regulatory and legislative challenges, 3) concerns surrounding safety and liability, 4) issues regarding privacy and security, and 5) public acceptance of CAV technologies. These non-technical issues could significantly hinder CAV technology testing and deployment.

The rapid evolution of infrastructure, vehicle, and system transportation technologies, including the emergence of truck platoons, requires intelligent infrastructure, interconnected vehicles, and autonomous driving. Projections indicate a gradual yet significant adoption of automated driving systems, with forecasts suggesting that autonomous vehicles and advanced transportation technologies could represent 50% of the U.S. vehicle fleet by 2050 (*9*). Consequently, transportation agencies must proactively prepare for this era by delineating and addressing the needs for efficient CAV testing and deployment and evaluating the anticipated challenges associated with their implementation.

Research Objectives

This proposal seeks to delineate the requirements and impediments inherent in CAV technology integration while investigating their impacts on rural roadways. The overarching goal is to assist with preparing for safe and efficient CAV technology testing and deployment within the North Dakota highway system.

This study's primary objectives include synthesizing the current state-of-the-practices regarding national, state, and local regulatory frameworks and legislation for testing and deploying CAVs. This analysis will identify infrastructure, traffic management policy, roadway design, and standardization need essential for facilitating the deployment of CAV technologies, such as automated driving systems, advanced driving assistance systems, and truck platooning. Additionally, the research objectives encompass an examination of the impact of CAVs on traffic operation and traffic safety for the highway system. Additionally, the impact on the environment will be explored using a microsimulation analysis.

Research Methods

This research will include three main approaches. Details of the methodologies and tools that will be used to conduct this research are detailed below:

1) *Comprehensive Literature Review:*
   This approach aims to conduct a comprehensive review of Connected and Autonomous Vehicle (CAV) technologies implemented across the United States. Essential information shall be gathered to support legislative sessions for the formulation and development of CAV regulations in the state of North Dakota (ND). As CAV technologies rapidly evolve, understanding their current status, regulatory frameworks, challenges, and best practices in various states is crucial for informed decision-making.

2) *Microsimulation Modeling for CAV Technologies on Rural Roadways:*
   The PTV Vissim software will be used to simulate CAV technologies on rural roadways. It is suggested that the I-29 corridor between Grand Forks and Fargo be simulated since this area has significant regular and freight traffic. A baseline model will be developed to mimic the roadway geometry, traffic volumes, traffic mix, and driving behaviors in terms of car following and gap acceptance models. Speed data will be used to calibrate and validate the baseline model. Internal (parameter modifications) and external (driver model.dll) information will be used to simulate CAV technologies. Basic statistical tests will be used to assess the impact of CAVs on traffic operations on rural roadways. Parametric and non-parametric approaches will be used based on the obtained distributions. Statistical tests will include mean, variance, and distribution methods.

3) *Safety Assessment Using Surrogate Measures of Safety (SMoS):*
   The output of the microsimulation obtained from Vissim will be incorporated into the FHWA Surrogate Safety Assessment Model (SSAM). SSAM is a software application designed to autonomously detect, categorize, and assess traffic conflicts within the vehicle trajectory data generated by microscopic traffic simulation models. SMoS measures will be used to assess safety performance with and without including CAVs on the simulated corridor. SMoS measures will include time to collision (TTC), modified time to collision (MTTC), post encroachment time (PET), and deceleration rate to avoid a crash (DRAC). Similar statistical approaches will be used to identify if there are significant differences between the two simulated scenarios with and without CAVs.

Relevance to Strategic Goals

This proposal’s goal aligns with the USDOT’s strategic goals for safety and transportation. The investigation will result in a better understanding of the impacts of CAV technologies on the ND highway system. This research will provide insights into how CAV technologies can contribute to preserving and enhancing North Dakota's existing transportation system, which aligns with the statutory research priority area of CTIPS. This research will clarify the impact of CAV technologies in enhancing the safety and reliability of North Dakota's highway infrastructure. CAVs will contribute to the overall preservation and sustainability of the transportation system by reducing the frequency of crashes.

Educational Benefits

This project can be used to develop a baseline for a Traffic Simulation course for engineering students. This course will provide students with practical and hands-on experience using microsimulation tools to assess the operation of multiple road users, accounting for emerging technologies. The students will apply theoretical knowledge from their coursework to a real-world problem, enhancing their understanding of traffic dynamics and simulation techniques.

Outputs through Technology Transfer

Several technology transfer approaches will be used to effectively disseminate project outcomes and findings. These approaches will include peer-reviewed research reports, journal articles, conference papers, and the university's website and LinkedIn social media platform. Technology transfer activities will be reported in this project's Semi-Annual Progress Report (SAPR).

Expected Outcomes and Impacts

The emergence of vehicle and highway automation presents novel challenges for transportation authorities. State Departments of Transportation, municipalities, and cities must gain a comprehensive understanding of the implications of Connected and Autonomous Vehicle (CAV) Technologies on highway infrastructure to effectively navigate the transition to autonomous driving. This study aims to proactively identify and address the potential adverse and positive effects of CAVs on the state surface transportation systems by synthesizing research and practical insights. The study will examine the research needs and challenges associated with the statewide deployment of Autonomous Vehicles (AVs) in North Dakota (ND), resulting in valuable recommendations pertaining to regulation and policy development, infrastructure design and management, enhancements to traffic management strategies, and development of a site-specific rural roadway microsimulation model. The primary outcome will be cutting-edge research and practices related to CAV technologies, highlighting current advancements, technological implementations, and potential gaps requiring attention in the short and long term. The study will comprehensively analyze factors influencing the ND residents' perception and acceptability of CAV technologies, offering valuable insights regarding CAV testing and deployment barriers. This research is highly relevant to the strategic goals outlined by the U.S. Department of Transportation (USDOT) for 2022-2026, particularly in enhancing safety and transformation.

Work Plan

Several tasks will be undertaken to accomplish the aims and objectives of this research. These tasks can be summarized as follows:

Task 1: Review regulations and legislation for testing and deploying CAV technologies (3 months)

An examination of existing national and state-level regulations and legislation for CAVs will be used to provide recommendations for ND CAV regulations and legislation. Passed and enacted legislation from all 50 states will be determined and documented to provide guidance for future Connected Vehicles (CV), Autonomous Vehicles (AV), and platooning legislation in North Dakota (ND).

Task 2: Identify highway infrastructure, roadway design, and traffic control device needs to facilitate the operation of CV/AV and platoons (3 months)

A comprehensive literature review will examine the current and future needs and challenges associated with truck platooning deployment, accounting for infrastructure upgrades, safety implications, operational performance, and environmental impact.

Task 3: Quantify the impact of CAVs on the mobility of rural corridors (4 months)

Microsimulation modeling will be used to assess the operational impacts of CAVs on freeway and highway segments, including basic freeway segments, merging sections, diverging sections, and weaving sections. The impact of CAVs on delays, throughput, and emissions will be evaluated. The PTV Vissim software will be the primary platform for modeling. Internal and external interfaces will be utilized to simulate CAVs.

Task 4: Quantify the impact of CAVs on rural corridor traffic safety (3 months)

The microsimulation model results will be used to assess the potential safety benefits associated with CAV operations. The surrogate measures of safety (SMoS) will be estimated using the FHWA Surrogate Safety Assessment Model (SSAM). SSAM will be utilized to identify, classify, and evaluate traffic conflicts in the vehicle trajectory data obtained from the Vissim models.

Task 5: Conduct an expert review of findings and recommendations (2 months)

Active engagement between the research team, CTIPS experts, NDDOT experts, and stakeholders from diverse divisions will be vital. An expert review of the preliminary findings and insights will serve as a robust mechanism for gathering independent perspectives on research needs and assessing the alignment of recommendations. This expert review process will encompass presentations during progress meetings and formal evaluations of working research manuscripts.

Task 6: Document and provide recommendations (2 months)

The final task is to prepare a comprehensive final report documenting this study’s developed literature, analyses, and conclusions. This report will offer in-depth documentation of the research process, including the identification and examination of relevant literature, the methods used for analysis, and the resultant insights gained. The report will also present comprehensive conclusions based on the findings, identifying the potential impacts of CAVs on North Dakota's highway infrastructure, traffic patterns, and safety considerations. Recommendations will also be provided, offering guidance on policy development, infrastructure improvements, regulatory frameworks, and other measures to effectively manage and harness the benefits of CAV technology within North Dakota's highway system. The final report aims to serve as a valuable resource that allows stakeholders, policymakers, and researchers to understand and navigate the impact of CAVs on the highway system in the state of North Dakota. The table below provides the project timeline for the listed tasks.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Task 1												
Task 2												
Task 3												
Task 4												
Task 5												
Task 6												

Project Cost

Total Project Costs: $152,486
CTIPS Funds Requested: $ 76,243
Matching Funds: $ 76,243
Source of Matching Funds: University of North Dakota

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