Assessing The Impacts and Challenges of Truck Platooning on Highway Infrastructure in Montana

by

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PROBLEM STATEMENT

The rapid advancement of transportation technologies, including the emergence of truck platooning, presents both opportunities and challenges for state transportation systems. With the Montana State Legislature expected to introduce legislation on the use and regulation of truck platooning during the 2025 legislative session, the Montana Department of Transportation (MDT) will likely be called upon to provide expert guidance on how this emerging technology will impact the state's transportation infrastructure and systems. Projections suggest that by 2050, automated driving systems could account for up to 50% of the U.S. vehicle fleet, making it imperative for MDT to stay ahead of these developments. Truck platooning, which offers advantages such as improved fuel efficiency, enhanced safety, and optimized traffic flow, holds significant potential for improving the operational efficiency of the trucking industry and contributing to overall economic growth. However, to fully utilize these benefits, MDT must also address the uncertainties and challenges that accompany the integration of truck platooning into the state's transportation network.

While implementing truck platooning provides several potential advantages benefiting surface transportation, trucking industry, and overall economic growth, they also introduce a host of new challenges for transportation agencies to navigate. These challenges primarily revolve around the uncertainty regarding how truck platooning will impact existing highway infrastructure. Additionally, truck platooning holds promise in improving road safety through the utilization of ADAS, ADS and CV technologies, which enables coordinated driving behavior. With vehicles communicating real-time information, platoons could mitigate risks associated with tailgating and sudden braking. However, they might pose other safety challenges related to lane change dynamics, collision risk assessment, and traffic interaction with platoons that need to be addressed [1,2].

With the rapid evolution of emerging vehicular technologies, it becomes increasingly essential for both national and local transportation agencies to maintain a proactive perspective and stay well-informed. Engaging in a thorough and comprehensive evaluation of the impact of truck platooning on highway infrastructure is crucial. Furthermore, identifying both current and future infrastructure requirements in light of these advancements is imperative for effective planning and management within the transportation sector. Thus, embracing this critical endeavor becomes necessary for ensuring a seamless integration of truck platooning into the transportation system while mitigating potential disruptions and maximizing its benefits.

The Montana State Legislature is anticipated to introduce legislation regarding the use and regulation of truck platooning in Montana during the next legislative session in 2025. MDT Planning Division expects to be requested by the State Legislature to provide expert guidance on how the emerging technology of truck platooning will impact transportation infrastructure and systems in Montana.

Truck platooning extends its influence across various critical aspects of the transportation domain. Each aspect has its own needs that should be identified to ensure safe and smooth operation of truck platooning on our highway system. These aspects and their associated needs could be concluded as follows:

1) **Infrastructure:** Truck platooning has the potential to significantly impact infrastructure, ranging from the durability of road pavement to the load-bearing capacity of bridges. The

concentrated weight and dynamic load generated by the frequency of trucks within and between platoons can accelerate pavement distress, leading to considerable deterioration that may affect maintenance and reconstruction strategies. Additionally, road geometry alignment must accommodate the synchronized movements of platooning trucks. Studies have proposed dedicated lanes for truck platoons to reduce interaction with other road users. Bridges must also withstand the increased loads imposed by multiple trucks traveling closely within platoons following a minimum intra-platoon spacing. Moreover, the cumulative impact of multiple platoons following one another and identifying optimal inter-platoon gaps further emphasizes these effects. Furthermore, adjustments to traffic control devices may be necessary to optimize traffic flow and ensure safe interactions between platooning vehicles and other road users. Truck platoons could also have a significant impact on the design of passing lanes, where passing sight distances could be impacted by the presence of truck platoons.

2) **Operation**: Operationally, truck platooning enhances road capacity by reducing the space between vehicles, allowing for more efficient use of available roadway space. However, challenges arise at merge, weave, and diverge roadway sections. Trucks joining or leaving platoons could also pose an impact on the operation and mobility of other road users. Additional challenges could also arise from the truck platoon performance on steep vertical grades. Truck platoons could increase delays and queues while operating on two lane highways, where passing a truck platoon could be a risky maneuver.

3) **Safety**: Safety considerations are associated with the implementation of truck platooning. Interactions with other vehicles on the road might pose potential risks that should be carefully managed to prevent collisions and ensure the overall safety of the transportation network. These interactions could be presented when joining and leaving a platoon, at weaving section, merging and diverging sections. Furthermore, how these truck platoons could affect the traffic safety at two lanes highways.

4) **Environment**: Truck platooning has the potential to deliver significant environmental benefits by reducing fuel consumption and emissions per unit of freight transported. By optimizing vehicle spacing and leveraging technologies like adaptive cruise control and predictive analytics, platooning systems can enhance fuel efficiency and minimize gas emissions, contributing to broader sustainability objectives within the transportation sector.

5) **Workforce**: The adoption of truck platooning technologies also impacts the workforce, particularly within the trucking industry. While platooning systems may enhance the efficiency and productivity of freight transportation, they may also lead to a shift in responsibilities of truck drivers. Addressing these workforce dynamics requires proactive measures to ensure a smooth transition and equitable distribution of the economic benefits associated with platooning technologies.

In addition to the infrastructure, operation, safety, environmental, and workforce needs, there are several issues/challenges with deploying and testing truck platooning technologies. These issues could be categorized into two categories as shown in Figure 1: 1) Technical issues, and 2) Nontechnical issues. The technical issues could involve issues related to:

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

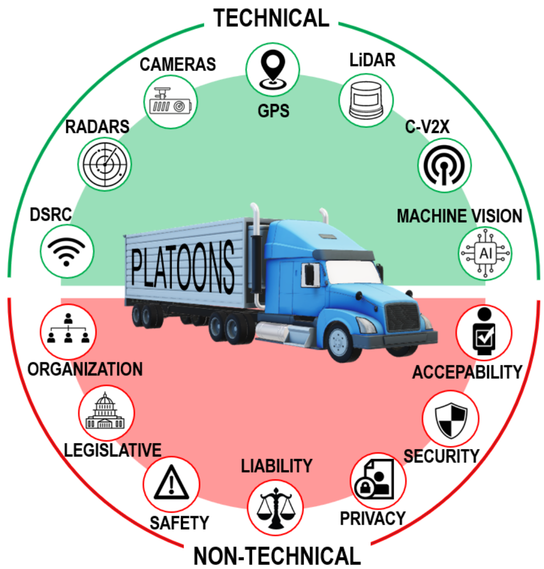

Figure 1: Technical and Non-Technical Challenges for Deploying Truck Platooning

Alongside the numerous technical considerations, non-technical challenges also warrant attention. These 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 truck platooning. These non-technical issues could provide hurdles toward testing and deployment of truck platooning technologies.

The rapid evolution of transportation technologies, including the emergence of truck platoons across infrastructure, vehicles, and systems, indicates a future characterized by intelligent infrastructure, interconnected vehicles, and autonomous driving. Projections indicate a gradual yet significant adoption of automated driving systems, with forecasts suggesting that by 2050, autonomous vehicles and advanced transportation technologies could represent 50% of the US vehicle fleet [3–5]. Consequently, transportation agencies are urged to proactively prepare for this era by delineating and addressing the needs for efficient testing and deployment of truck platoons, alongside evaluating the anticipated challenges associated with their implementation.

In summary, a key concern is how truck platooning will affect Montana's existing highway infrastructure, particularly regarding pavement durability, bridge load capacity, and roadway design. The close spacing and synchronized movement of trucks in a platoon may accelerate infrastructure wear and introduce operational safety risks, particularly in areas such as weaving sections, merging, diverging, and regular roadway segments, which have high interactions with non-platooning vehicles. Additionally, the impact on rural and two-lane highways, where platoons could pose unique challenges, must be carefully evaluated. Public perception and acceptance of truck platooning technologies are also largely untested, raising concerns about how the general public will respond to these new systems. This research will proactively equip MDT with the necessary knowledge and strategies to evaluate infrastructure needs, address safety and operational challenges, and support public acceptance, ensuring the successful implementation of truck platooning in Montana in line with upcoming legislative requirements.

BACKGROUND SUMMARY

The attention of numerous researchers has been drawn to the critical intersection of traffic safety and the mobility of commercial trucks. This focus stems from their significant role in facilitating freight movement, fostering industrial development, and driving the national economy. In 2015, commercial trucks were responsible of transporting nearly 64% of the total US freight tonnage, accounting for 69% of the total freight value [6]. Projections indicated that the freight tonnage will be doubled over the next three decades [7], potentially exacerbating traffic safety concerns. However, the integration of innovative technologies into commercial vehicle operations holds promise for mitigating these challenges.

The trucking industry stands at the forefront of testing and implementing automation technologies. Recognizing the potential benefits, ranging from safety improvements [8–11] and emissions reduction [12–15] to cost and time savings, stakeholders across the industry, including trucking companies, shipping clients, manufacturers, and transportation authorities, are keen to leverage these advancements. Autonomous trucks are considered one of the several cutting-edge innovations that are being adopted by trucking industry as shown in Figure 2.

Figure 2: Top Ten Innovations in Trucking Industry 2024.

Truck platooning represents one of the promising advancements within autonomous trucking technologies. Truck platooning is basically a convoy of trucks autonomously linked together with a small gap forming a platoon. Truck platoons utilize advanced wireless communication systems between the leading and following trucks, as well as adaptive cruise control to maintain specific headways between the trucks. The lead truck is typically controlled by a human driver, while the following trucks operate in a closely coordinated manner, benefiting from reduced aerodynamic drag and improved fuel efficiency. Through connectivity technology, Advanced Driving Assisting Systems (ADAS), and Automated Driving Systems (ADS), subsequent trucks mimic the driving behavior of the lead truck, with no input required from their drivers. This synchronized movement allows for shorter headway gaps and spacing between trucks compared to conventional operations.

The Society of Automotive Engineers (SAE) has delineated six levels of vehicle automation, depicted in Figure 3. Level zero includes no automation, requiring manual operation by the driver who assumes primary responsibility for all Dynamic Driving Tasks (DDT).

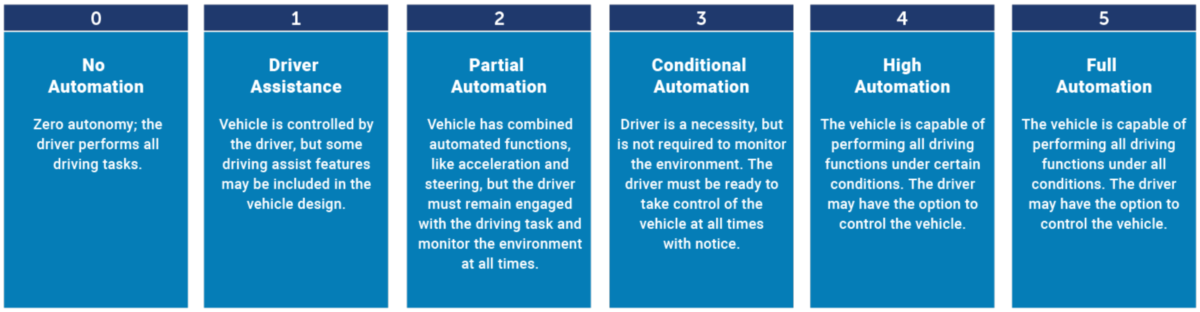

Figure 3: Society of Automotive Engineers (SAE) Automation Levels

Levels 1 and 2 integrate various ADAS to support the driver with DDT, though ultimate navigation and vehicle control remain the driver's responsibility. The latter three levels introduce ADS technologies capable of executing primary DDT. At level 3, Autonomous Vehicles (AVs) can function within specific Operational Design Domains (ODD), with drivers expected to resume control when necessary. In levels 4 and 5, drivers are not essential for vehicle operation.

With respect to truck platooning, the SAE automation levels could be identified as follows:

- Level 0: Truck platooning is not possible at this stage.
- Level 1: Longitudinal control assistance is available; however, the driver retains control.
- Level 2: Both longitudinal and lateral control assistance are provided; nevertheless, the driver remains in control.
- Level 3: Driver cedes control under specific conditions, with readiness for takeover requests.
- Level 4: Trucks can autonomously operate under predefined conditions; the driver is not involved in DDT but must be present.
- Level 5: No driver is designated; trucks can operate autonomously in all conditions.

Truck platoons could be in one of the four identified stages by researchers at the California Partners for Advanced Transportation Technology [16]. These stages could be concluded as:

1- Forming: during this phase, trucks are select potential platoon partners by considering factors such as location, origin, destination, frequency of stops, truck type, weight, cargo, and commodity type, etc.

2- Steady-State Cruising: the cruising stage constitutes most of the active period for the platooning system, where the majority of benefits are accrued.

3- Departing or Splitting: Trucks can exit the platoon as necessary to fulfill their trips or deviate from the route. Once a truck exits, the following trucks rejoin the original platoon, closing the gap left by the departing vehicle.

4- Abnormal Conditions: The final stage encompasses scenarios not covered in preceding stages, such as system errors. A truck platooning system must effectively detect and resolve these unexpected issues.

Truck platooning offers several benefits to the trucking industry. These benefits include improved fuel efficiency, enhanced safety, optimized traffic flow, reduced impact on environment, and cost-efficient operations. Truck platooning offers a major benefit in terms of fuel efficiency. By minimizing aerodynamic drag adopting convoys with short headways, trucks achieve notable fuel conservation. Research indicates potential reductions in fuel consumption, with following trucks seeing decreases ranging from 4% to 10%, while lead trucks could experience up to a 20% decrease [17,18]. Ensuring steady speeds and minimizing gaps between vehicles, holds promise in relieving traffic congestion and maximizing road capacity. This efficient traffic flow not only aids freight operators in reducing delivery times but also supports in providing a greater overall roadway sustainability [19]. Furthermore, truck platooning has the potential to alleviate traffic congestion, improve fuel efficiency, reduce greenhouse gas emissions, and mitigate environmental impact.

Several initiatives have been conducted to understand the impacts of automated vehicles and cooperative automated systems on the highway infrastructure. The aim of these research efforts is to equip stakeholders with critical insights as they prepare for the anticipated infrastructure adaptations necessitated by the widespread deployment of AVs [20]. The findings of the study suggested that automated driving systems (ADS) offer significant potential to enhance the mobility and safety of transportation systems. However, they also pose challenges for infrastructure owner-operators (IOOs) concerning roadway design, maintenance, and operational requirements. Critical areas impacted by ADS deployment include the durability of pavements and bridges, the adequacy of traffic control devices, intelligent transportation systems (ITS), and multimodal infrastructure. Insights from stakeholders, gathered through interviews and national workshops, emphasized the importance of maintaining consistent pavement markings, improving infrastructure quality, and supporting greater collaboration between highway agencies and the AV industry.

Another study provided valuable insights into the public acceptability of connected and autonomous vehicles (CAVs) in Wyoming, with a focus on the infrastructure and operational needs required for successful deployment [21]. The study conducted a massive survey study to identify key factors influencing public acceptability of CAVs. The findings included interest in self-driving paratransit services, levels 4 and 5 vehicular automation, and infrastructure improvements such as smart pavement markings and enhanced intersection safety measures. The study also highlighted concerns around data privacy and liability issues, emphasizing the need for strong security measures and legal frameworks to address these challenges. The public expressed confidence in CAV technology's ability to drive more safely than human drivers, particularly in adverse weather conditions, suggesting that pilot testing on rural roadways and live demonstrations could further enhance public trust.

The Truck Platooning Early Deployment Assessment conducted by the Federal Highway Administration's (FHWA) Intelligent Transportation Systems Joint Program Office (ITS JPO) provides a comprehensive evaluation of the potential for early deployment of truck platooning technologies in the United States [22–25]. The assessment examines the operational, infrastructure, and regulatory challenges associated with implementing truck platooning on public roadways, with a focus on leveraging connected vehicle (CV) technologies and automated driving systems (ADS) to improve freight transportation efficiency and safety. The report emphasizes the potential benefits of truck platooning, such as enhanced fuel efficiency, reduced emissions, and improved traffic flow through coordinated driving behavior. However, it also identifies key barriers to widespread adoption, including the need for infrastructure upgrades, modifications to traffic management systems, and the establishment of regulatory frameworks to address safety, liability, and cybersecurity concerns. The study advocates for pilot programs and field testing to gather data on the real-world impacts of truck platooning, offering recommendations for transportation agencies to support the integration of this emerging technology into national freight operations.

BENEFITS AND BUSINESS CASE

By addressing the potential impacts and requirements of truck platooning technologies, this research will enable the MDT to embrace the era of connected and autonomous vehicle (CAV) technologies with a specific focus on the unique challenges and opportunities presented by truck platooning. Truck platooning, as a key element within the broader CAV landscape, offers distinct advantages in freight transport by improving fuel efficiency, reducing traffic congestion, and enhancing road safety. This proposal will equip MDT with critical insights and strategic guidance for the integration of truck platoons, delivering several key benefits, including:

1) Support for Legislative Development

A critical benefit of this research will be the development of insights to aid Montana's legislators in drafting comprehensive and informed bills related to truck platooning. The research will provide a thorough review of existing truck platooning regulations across various states, identifying commonalities, best practices, and potential gaps. This comparative analysis will offer lawmakers the guidance they need to create a robust legal framework that addresses safety, infrastructure requirements, and operational considerations specific to Montana's transportation environment. By proactively preparing legislation, the state can ensure the smooth integration of truck platooning technologies while safeguarding public interests and promoting economic growth.

2) Improved Infrastructure Planning

The research will provide MDT with a detailed analysis of the necessary infrastructure upgrades and modifications to accommodate truck platoons, including potential changes to roadway design, traffic control devices, and dedicated lane systems. By understanding the specific requirements for platooning operations, MDT can develop long-term infrastructure plans that integrate CAV technologies while optimizing roadway capacity and performance. This proactive planning approach will extend the lifespan of Montana's highways, reduce maintenance costs, and ensure the infrastructure is resilient and capable of supporting future transportation technologies.

3) Efficient Resource Allocation

By identifying the exact infrastructure and operational needs associated with truck platooning, MDT will be able to allocate resources more efficiently. Rather than adopting a reactive approach to emerging transportation technologies, the insights gained from this research will allow MDT to prioritize investments in the most critical areas. Whether it's upgrading pavement markings, implementing intelligent traffic management systems, or reinforcing bridges to handle the concentrated loads of platoons, MDT will have the data necessary to make informed decisions that maximize the impact of available funding. This efficiency will not only result in cost savings for MDT but also ensure that public funds are spent in the most impactful way.

4) Enhanced Safety Measures

Safety is a top priority for both transportation agencies and the public, and this research will significantly contribute to improving safety on Montana's highways. By quantitatively assessing the potential risks and safety impacts of truck platooning, particularly in relation to interactions with non-platooning vehicles and in challenging conditions like two-lane highways, MDT can develop targeted safety interventions. These could include adjusting lane configurations, optimizing merging zones, and enhancing communication systems between vehicles.

Implementing these safety measures will reduce the likelihood of collisions, improve traffic flow, and ultimately enhance the overall reliability and safety of Montana’s transportation system.

5) Improved Operational Strategies

The deployment of truck platoons will revolutionize the operational strategies of freight transportation. This research will help MDT and industry stakeholders understand the operational impacts of platooning, such as improved fuel efficiency, reduced congestion, and increased traffic flow efficiency. The insights gained will allow MDT to collaborate with freight operators to optimize truck routes, minimize delivery times, and reduce transportation costs. Moreover, by identifying the key operational challenges, such as managing truck platoon formation and disbanding, MDT can develop best practices for ensuring that truck platooning integrates smoothly with existing traffic patterns, minimizing disruptions and maximizing efficiency across the highway network.

In summary, the proposed research will position MDT to take a proactive and informed approach to integrating both CAV and truck platooning technologies into Montana's transportation system. By focusing on improved infrastructure planning, efficient resource allocation, enhanced safety measures, optimized operational strategies, and supporting legislative development, MDT will be better equipped to handle the challenges and opportunities presented by truck platooning. This foresight will not only prepare the state for the future of automated freight transport but will also deliver immediate benefits, such as cost savings, safety improvements, and operational efficiencies, ensuring a more sustainable and effective transportation network.

OBJECTIVES

This proposal seeks to delineate the requisites and impediments inherent in the integration of truck platoons, alongside an examination of their multifaceted impacts. The overarching goal is to assist the Montana Department of Transportation (MDT) in preparing for the safe and efficient testing and deployment of truck platoon technologies within their highway system. This endeavor entails identifying and proactively addressing the limitations related to policies and testing/deployment needs associated with operating truck platoons. This proposal has four main objectives:

- Conduct a comprehensive review and analysis of all enacted bills related to autonomous vehicles and truck platooning regulations across the 50 states.
- Identify the necessary highway infrastructure, roadway design elements, and traffic control devices required to support the safe and efficient operation of truck platoons.
- Quantitatively evaluate the impact of truck platoons on the operational and safety aspects of the highway system through an expert survey.
- Assess public perception and acceptance of truck platooning through a public survey.

Objective 1: Comprehensive Review and Analysis of Enacted Bills

One of the primary objectives is to conduct a comprehensive review and analysis of all enacted bills related to autonomous vehicles and truck platooning regulations across all 50 states. This literature review will focus on identifying commonalities and differences among the various state legislations. The insights gained from this comparative analysis will provide valuable guidance for Montana's legislature in formulating a robust and well-informed bill, tailored to the state's specific needs and informed by best practices from other jurisdictions.

Objective 2: Identify Necessary Infrastructure Needs to Accommodate Truck Platoons

Another objective is to identify the necessary highway infrastructure, roadway design elements, and traffic control devices required to support the safe and efficient operation of truck platoons. This will involve a detailed identification of current infrastructure and design standards to assess their adequacy for accommodating truck platooning technology. Additionally, potential upgrades or modifications, such as dedicated lanes, intelligent traffic management systems, and enhanced pavement markings, will be identified to optimize roadway performance and safety for platooning operations. A thorough review of Montana's specific infrastructure and operational needs will ensure that the state's unique conditions are addressed in accommodating truck platoons.

Objective 3: Quantitative Evaluation of Operational and Safety Impacts

A further objective is to quantitatively evaluate the impact of truck platoons on the operational and safety aspects of the highway system. This will be accomplished by developing an expert survey targeting professionals from MDT and other rural Great Plains states (e.g., North Dakota, South Dakota, Wyoming, Nebraska, and Colorado) with similar weather and roadway characteristics. The expert survey will gather insights on operational challenges and safety concerns, and the results will be analyzed statistically to identify key areas for improving the safety and operational performance of truck platoons within Montana's highway system.

Objective 4: Public Perception and Acceptance of Truck Platooning

The final objective is to assess public perception and acceptance of truck platooning. This will be achieved through a public survey distributed online via social media to gather data on public concerns, safety perceptions, acceptability, and potential impacts on driving behavior. Statistical analysis of the survey results will provide recommendations for addressing public concerns and enhancing the implementation of truck platooning technology.

In summary, the outcomes of this research are envisioned to provide comprehensive, data-driven insights that will inform the MDT in its preparation for the safe and efficient integration of truck platooning technology. By addressing legislative gaps, infrastructure requirements, operational challenges, and public perception, this study will offer MDT decision-makers a robust foundation for formulating a strategic plan tailored to Montana's unique transportation environment. The findings will equip policymakers with the necessary tools to draft informed, forward-looking legislation, while also guiding infrastructure owners and operators in adapting roadway designs and traffic control systems for truck platoon operations. Additionally, the research will help ensure public safety and acceptance by identifying potential risks and concerns through both expert input and public feedback. Ultimately, the outcomes of this research are envisioned to furnish practical guidelines for MDT decision-makers, aiding in the formulation of a strategic plan for the implementation of truck platooning activities in Montana.

RESEARCH PLAN

This proposal seeks to delineate the requisites and impediments inherent in the integration of truck platoons, alongside an examination of their multifaceted impacts. The overarching goal is to assist the Montana Department of Transportation (MDT) in preparing for the safe and efficient testing and deployment of truck platoon technologies within their highway system. This endeavor entails identifying and proactively addressing the limitations associated with operating truck platoons.

The primary objectives of this research include synthesizing the current state-of-the-practice regarding national, state, and local regulatory frameworks and legislation pertaining to truck platooning. Such an analysis will serve to pinpoint infrastructure, traffic management policy, roadway design, and standardization needs essential for facilitating the deployment of truck platooning. Additionally, the research objectives encompass an examination of requirements for workforce development. Moreover, an assessment of how truck platoons will impact the operational and safety aspects of the highway system will be quantitatively explored.

The project will commence with a kick-off meeting, serving as the initial activity after the contracting phase. This meeting will ensure a clear understanding of the scope of work, data requirements and sources, deliverables, milestones, and overall project timeline. The research outcomes are intended to provide practical guidelines for MDT decision-makers, supporting the development of a strategic plan for the implementation of truck platooning in Montana. To achieve the objectives outlined in this research, a series of tasks will be undertaken, as detailed below.

Task 1: Review for Legislations and Regulations

This task will be conducting a synthesis of existing national and state level regulations and legislations for truck platooning. Passed and enacted legislation from the 50 states will be reviews and concluded to provide guidance for future truck platooning legislations in Montana. Additionally, commonalities and differences in the enacted bills will be identified among the various state legislations that will help in providing valuable guidance in formulating a robust and well-informed bill, tailored to the state's specific needs and informed by best practices from other jurisdictions.

The review will also integrate the findings from state-of-the-practice reports and working papers provided by various entities such as the National Cooperative Highway Research Program (NCHRP), USDOT Automated Vehicles Activities, FHWA Next Generation Traffic Management Systems, AASHTO Cooperative Automated Transportation (CAT) Coalition, and the ITS Joint Program office (JPO). Following a literature review and accounting for distinctive transportation characteristics and policy challenges in Montana, recommendations will be offered to MDT and stakeholders for the formulation of truck platooning regulations and legislation in the state.

Task 2: Identify Highway Infrastructure, Roadway Design, and Traffic Control Devices Needs to Facilitate the Operation of Truck Platoons.

A comprehensive literature review will conclude the current and future needs and challenges associate with the truck platooning deployment accounting for infrastructure upgrades, safety implications, operational performance, environment impact, and workforce needs and shift. This task shall identify the infrastructure, roadway design, and standardization needs to facilitate a safe and efficient deployment of truck platoons. This task shall explore passing lane designs, dedicated platooning lanes, and standards for designing truck parking lots. A comprehensive assessment of Montana's specific infrastructure and operational requirements will ensure that the state's unique conditions are effectively considered in the implementation of truck platooning. The anticipated outcome of this task is the provision of recommendations aimed at potential updates to the MDT Road Design Manual. These updates are intended to optimize infrastructure, geometry, and traffic control measures to facilitate the future deployment of truck platoons.

Task 3: Conduct An Expert Review of Findings and Recommendations.

As this study endeavors to provide policy recommendations for the Montana Department of Transportation (MDT), fostering active engagement between the research team and MDT project managers, along with stakeholders from diverse divisions, will hold significant importance. An expert review of the preliminary findings and insights will serve as a robust mechanism to gather independent perspectives on research needs and assess the alignment of recommendations with MDT's objectives. This expert review process will encompass both presentations during routine project progress meetings and formal evaluations of working research manuscripts. The experts will be selected from MDT, as well as the USDOT as necessary.

Task 4A: Institutional Review Board Approval

PI will submit the Institutional Review Board (IRB) protocol at the University of North Dakota (UND), including detailed documentation outlining the research plan, such as study objectives, methodology, data collection procedures, risk assessment, and plans for informed consent and data protection. The IRB at UND will review the IRB protocol to assess the ethical acceptability of the research and will evaluate potential risks to participants, the adequacy of informed consent procedures, and the overall protection of participant rights and privacy. The survey will be distributed to collect responses after it is designed, reviewed, and approved by the IRB. The participants will have between 9 and 11 business days to respond to the survey. The first reminder e-mail will be sent 4 to 6 days after the initial invitation. The second reminder e-mail will be sent 9 to 11 days after the initial invitation. A one-time extension of 4 to 6 days will be sent after the deadline has passed. Lastly, a final reminder e-mail will be sent the day before the one-time extension deadline.

Task 4B: Identifying Targeted Stakeholders to Collect the Expert Review Perceptions on Deployments of Truck Platoons

This task involves systematically identifying and engaging key stakeholders who possess the expertise and insight necessary to evaluate the deployment of truck platooning technologies in Montana. These stakeholders will include MDT experts in traffic operations, infrastructure planning, intelligent transportation systems (ITS), and highway safety. In addition, relevant stakeholders from other state Departments of Transportation (DOTs), particularly from states with similar rural and weather conditions such as North Dakota, South Dakota, Wyoming, Nebraska, and Colorado, will be consulted for further insights. Key stakeholders will also include representatives from the freight and logistics industry, such as trucking companies, as well as experts from universities, research institutions, and public safety officials, including law enforcement.

Task 5: Collect Expert Perception of Deploying Truck Platoons on Montana Highway System.

In light of the literature review on the aforementioned tasks and the review comments from MDT experts, this research will design an on-line survey questionnaire to collect perception of experts in rural great plains states that share similar weather conditions in Montana (Montana, North Dakota, South Dakota, Wyoming, Nebraska, and Colorado) on testing and deploying truck platooning. Target audience will include professionals from the states' department of transportation including traffic safety, traffic operation, ITS, construction, and maintenance divisions. The survey will include sections inquiring about demographics, familiarity with ADAS and ADS technologies, perception about benefits of truck platoons, challenges that could face deploying truck platoons, implications and risk associated with truck platoons, what are the infrastructure needs to deploy ruck platoons, gaps and distances for inter- and inta-platoons, restrictions for cargos and truck weight involved in a platoon, and safety, security, and liability implications for truck platoons. A pilot sample of the respondents from the project technical advisory board will be used to identify any potential issues with the questionnaire's clarity, length, or effectiveness in addressing the survey objectives, ensuring the survey's reliability. The survey design will incorporate approaches to minimize biases, such as avoiding leading and loaded questions as well as offering a balanced range of response options to capture the full spectrum of opinions without skewing results.

Task 6: Collect Public Acceptability of Truck Platoons.

A second survey will be developed to assess public acceptance of truck platoons. The survey will evaluate public perceptions related to risks, safety concerns, security issues, and liability implications associated with interactions with truck platoons. Demographic data will be collected, including age, gender, education level, occupation, driving frequency and mileage, driving experience in Montana, crash history, ownership of advanced driving technologies, and preferences or concerns about encountering truck platoons on the road. Respondents will be informed that the survey will take approximately 10 to 15 minutes to complete. The survey will focus primarily on residents of Montana, with a target of collecting a minimum of 500 responses. Participants who successfully complete the survey will have a 10 percent chance of winning a $10 Amazon gift card through a lottery.

The survey will be developed using Qualtrics software and distributed via social media platforms, such as Facebook groups in Montana. To ensure response reliability and prevent bot-generated replies, several "dummy" questions will be incorporated into the survey. Additionally, response times will be analyzed to identify valid responses, with distribution patterns examined to filter out invalid or automated entries.

The responses will be analyzed using statistical software such as SAS, SPSS, and R-studio. Both descriptive and inferential statistical analyses will be performed. The descriptive statistical analysis will determine the central tendency and variability of the collected data, including mean, median, mode, and standard deviation. The results of the descriptive statistical analysis will be presented using bar and pie charts. Inferential statistical analysis will be conducted to draw conclusions about the population from the data sample and test hypotheses derived from the survey objectives. Exploratory factor analysis, confirmatory factor analysis, as well as path models, will be adopted to provide further insights into the collected responses.

Task 7: Documenting

Comprehensive documentation of a final report as a main deliverable will be provided, in which all feedback and comments will be addressed. The last three months before the project's end will focus on completing the final report, review, and addressing MDT comments.

The plan should include a kick-off meeting as the first activity of the project after contracting. The project kick-off meeting serves to ensure everyone involved in the research project is informed of the contractual obligations, scope of work, data requirements and source, deliverables, project milestones, timetable, and other project elements. This meeting will also provide an opportunity to clarify technical issues or concerns with the project. If necessary, an amplified work plan will result from the kick-off meeting. This amplified work plan is due two weeks following this meeting.

Several technology transfer approaches will be used to effectively disseminate project outcomes and findings. These approaches will include peer-reviewed research report, journal articles, conference papers, and the university's website and LinkedIn social media platform.

INTELLECTUAL PROPERTY

This proposal does not anticipate significant intellectual property (IP) issues, as the primary focus of the research is on public infrastructure, transportation safety, and operational improvements for truck platooning technologies.

MDT AND TECHNICAL PANEL INVOLVEMENT

For the successful execution of this research project, assistance from the MDT and the Technical Panel will be required in several areas. The following outlines the specific assistance which and support that will be needed:

- **Detailed Information/Data Requests from MDT**
  The research will require detailed traffic, safety, and infrastructure data, including data on current traffic control systems, truck volumes, and roadway conditions across potential platooning routes. MDT will need to assist in providing access to written information, databases, and other relevant reports.

- **Interviews with MDT Staff and Stakeholders**
  Interviews with MDT staff, including traffic operations, ITS, safety, and infrastructure experts, will be crucial to gathering insights on the operational and logistical challenges associated with implementing truck platooning technologies. The research team will also conduct interviews with stakeholders from rural Great Plains states for comparative analysis. MDT's assistance in coordinating and facilitating these interviews will be vital.

The collaboration and support from MDT and the Technical Panel will be essential for ensuring the successful execution of this research project. MDT's role in facilitating data access and coordinating with relevant stakeholders will not only enhance the quality of the research but also ensure that the findings and recommendations are aligned with the state's specific needs and goals for implementing this emerging technology.

OTHER COLLABORATORS, PARTNERS, AND STAKEHOLDERS

No formal collaborators, partners, or stakeholders have been identified beyond the MDT and relevant internal teams. However, key individuals or organizations that could be involved to create buy-in and ensure the successful review and deployment of the results include MDT staff across different divisions (e.g., bridge bureau, maintenance division, construction division, and asset management section), public safety officials, and representatives from the freight and logistics industry. Their involvement in reviewing results and participating in communications will be crucial for ensuring that the findings are practical, applicable, and aligned with both operational needs and public safety standards in Montana. Additionally, state Departments of Transportation from neighboring states, particularly those with similar rural conditions, may offer insights that can further enhance the project's outcomes.

PRODUCTS

The following products will be delivered during the research project to ensure its successful completion:

- Quarterly Progress Reports: Regular reports outlining the project's progress, including updates on budget and schedule adherence, submitted by the end of the month following each quarter.

- Final Report: A comprehensive document that will provide a detailed account of the project's outcomes, including the Legislative and Regulatory Review, the Infrastructure and Roadway Design Needs Assessment, and the analysis of expert and public perceptions on deploying truck platoons in Montana. The final report will also present the results of the conducted research along with actionable recommendations for MDT, ensuring a clear and thorough understanding of the project's findings.

- Project Summary Report: A concise report summarizing the project's key findings, complete with text and graphics, designed to provide a quick reference for practitioners and stakeholders.

- Final Presentation: A formal presentation summarizing the research, key findings, and recommendations, to be delivered to MDT at the conclusion of the project, ensuring clarity and ease of understanding for all stakeholders involved.

- Research Manuscripts: Research papers will be developed and submitted for presentation and publication in transportation related conferences and journals to support practitioners' understanding and implementation of findings.

RISKS

There are no to minimal risks associated with this project. The tasks and objectives have been carefully planned, and potential challenges, such as delays in data collection or stakeholder availability, are expected to have minimal impact due to early engagement and clear communication strategies. Budget and resource allocations have been thoroughly considered, reducing the likelihood of overruns. Overall, the project is designed with sufficient flexibility to adapt to any minor obstacles that may arise, ensuring smooth progress and timely completion.

IMPLEMENTATION

This research will provide MDT with actionable insights to inform policy development, infrastructure planning, and public communication strategies. The findings will support the drafting of state-specific regulations, align MDT policies with federal standards, and guide infrastructure modifications to safely accommodate truck platooning. Additionally, the public perception survey will help MDT tailor outreach efforts to increase public awareness and acceptance of this technology. The results will enable MDT to efficiently integrate truck platooning into Montana’s transportation system.

The potential parties for applying the research results from this project are several key divisions within MDT. First, the MDT policy and regulatory affairs division will be tasked with drafting and updating state-specific regulations. Their role will involve aligning Montana’s policies with federal standards related to truck platooning, ensuring the state’s legal framework supports the deployment of this technology in a safe and regulated manner. Moreover, the MDT Infrastructure planning division will play a critical role in implementing the research findings concerning infrastructure modifications. Based on the study's assessment of roadways, this division will work to ensure that Montana’s roads and highways can safely accommodate truck platoons, which may require specific upgrades or design alterations to support the unique characteristics of platooning operations. Furthermore, the MDT public outreach team will utilize the findings from the public perception survey to create targeted outreach campaigns aimed at increasing public awareness and acceptance of truck platooning technologies. By addressing public concerns and highlighting the safety and efficiency benefits, this team will help adopt a positive view of truck platooning among Montana residents.

SCHEDULE

Table 1 lists the tentative schedule for the research tasks. The project is anticipated to span over a time frame of 12 months. The MDT will have the last month to review the draft final report.

Table 1: Project Time Schedule

Activities	2025											
	1	2	3	4	5	6	7	8	9	10	11	12
Kick-off Meeting												
1- Review for Legislations												
Task 1 Report												
Decision Point Meeting												
2 - Identify Infrastructure Needs												
Task 2 Report												
Decision Point Meeting												
3 - Conduct An Expert Review												
Task 3 Report												
Decision Point Meeting												
4A - IRB Approval												
Task 4 Report												
Decision Point Meeting												
4B - Identifying Stakeholders												
Task 4 Report												
Decision Point Meeting												
5 - Collect Expert Perception												
Task 5 Report												
Decision Point Meeting												
6 - Collect Public Acceptability												
Task 6 Report												
Decision Point Meeting												
7 - Documenting												
Draft Final Report												
Project Summary Report												
Final Report												
Final Presentation												

◆ Quarterly Progress Reports

🡅 Deliverable Due Dates

BUDGET

Table 2 to Table 4 show the required budget to complete this project. Salaries will be paid to the research team members for their efforts in this research. Any hourly salary rates based on a 40-hour work week shown in this proposal are for evaluation purposes only. UND uses payroll confirmation for effort and does not account for and report on an hourly rate. Fringe benefits have been calculated using 29% for the PI, and 0.5% for the student. These percentages are within the recommended ranges by UND. Amounts shown for fringe benefits are estimates determined by historical data and are provided for proposal evaluation purposes only. Actual fringe benefit costs will be charged to the grant according to each employee's actual benefits. Indirect cost has been calculated based on UND's indirect cost rate of 41.0%. The indirect cost rate included in this proposal is the federally approved rate for UND. Indirect costs are calculated based on the Modified Total Direct Costs (MTDC) defined as the Total Direct Costs of the project individual items of equipment $5,000 or greater, tuition, and subcontracts in excess of the first $25,000 for each award. Tables 3 and 4 includes a detailed travel budget and tasks, meetings, and deliverables budgets as per required by the MDT.

Table 2: Detailed Project Budget

Labor Expenses	
Indirect Cost @ 41%:	$22,154
Total Labor Cost:	$49,810
Tuition:	$9,813
Total Expenses	
In State Travel	
Out of State Travel	$1,141
Expendable Supplies	
Total Project Cost:	$81,654

Table 3: Travel Budget

Travel to MDT				
Assumption		Number	Unit Cost	Total
Airfare	1 flight from ND to MT	850	1	$ 850
Hotel	1 night lodging at $122 per night	122	1	$ 122
Rental Car	$75 for local transport (Uber/Taxi)	75	1	$ 75
Meals	2 days per diem at $47 per day	47	2	$ 94
Travel Total				$ 1,141

Table 4: Task, Meeting, and Deliverable Budget

Task, Meeting, and Deliverable Cost Breakout			
Item	Labor	Travel	Total
Task 1	$ 6,617		$ 6,617
Task 2	$ 6,907		$ 6,907

Task 3	$ 7,199	$ 1,141	$ 8,340
Task 4	$ 7,272		$ 7,272
Task 5	$ 7,272		$ 7,272
Task 6	$ 7,272		$ 7,272
Task 7	$ 7,272		$ 7,272
Deliverable: Final Presentation			
Total:	$ 49,810	$1,141	$50,951

STAFFING

Sherif Gaweesh, Ph.D., P.E., RSP1, is an Assistant Professor at the University of North Dakota's Civil Engineering Department and Principal Investigator (PI) of this research proposal. Dr. Gaweesh has over 17 years of expertise in transportation engineering, specializing in traffic safety. His research interests include traffic safety analysis, Freight Transportation, Connected and Autonomous Vehicle (CAV) technology, Intelligent Transportation Systems (ITS), and Big Data analysis. Dr. Gaweesh is a recognized Professional Engineer in the state of Wyoming and a Road Safety Professional (RSP_1), and has led numerous funded projects at national and state levels, such as "Performance Measures and Independent Evaluation Support for Connected Vehicle Pilot Deployment Program with the U.S. DOT" and "Calibrating Crash Modification Factors for Wyoming-Specific Conditions: Application of the Highway Safety Manual – Part D." His impactful research is evident in his extensive publication record in prestigious journals, such as Accident Analysis and Prevention and Transportation Research Part: F. He has also presented at top conferences, such as the Transportation Research Board Annual Meeting (TRBAM) and the ITE International Annual Meeting and Exhibition. Dr. Gaweesh was the PI for several research projects including:

- "Rapid Safety Assessment Tool for Non-Conventional Roadway Design and Emerging Technologies" project funded by the Wyoming Department of Transportation (WYDOT), totaling $175,115. Link to the WYDOT Published Proposal
- "The Impact of Connected and Autonomous Vehicle Technologies on North Dakota's Highway Infrastructure" Project funded by the Center for Transformative Infrastructure Preservation and Sustainability (CTIPS), totaling $152,486. Link to the Published Proposal

Table 5 provide details on the project staffing involved in this research project.

Table 5: Project Staffing

Team Member	Role	Task								Percent of Time vs. Total Project Hours	Percent of Time - Annual Basis
		1	2	3	4	5	6	7	Total		
Sherif Gaweesh	Principal Investigator	35	35	39	40	40	40	40	269	20.6%	13
Graduate Research Assistant		150	150	150	140	150	150	150	1040	79.4%	50
TOTAL		185	185	189	180	190	190	190	1309	N/A	N/A

Research Team Other Commitments

Information about ongoing or planned research projects, teaching responsibilities, administrative duties, or any other significant commitments of the research team is listed in Table 6.

Table 6: Research Team Other Commitments and Activities

Research Team Commitments			% of Time	
Team Member	Role	Activity	Committed	Available
Sherif Gaweesh	PI	Activity 1: Current Projects	10%	30%
		Activity 2: Proposal Writing	25%	
		Activity 3: Publications	15%	
		Activity 4: Teaching	20%	
		Total	70%	

The level of effort proposed for the principal investigator and professional members of the research team will remain consistent throughout the duration of the project. No changes to the commitment or involvement of these key personnel will be made without the prior written consent of MDT, ensuring that the project maintains the necessary expertise and oversight to achieve its objectives effectively.

FACILITIES

The University of North Dakota (UND) was founded in 1883, six years before the state itself was established. UND is a busy 521-acre campus, the state's largest. It is a public research university located in Grand Forks, North Dakota. More than 2,500 benefited employees work at UND, which serves a community of more than 14,000 students. UND is considered a leading institute in engineering, medicine, aviation, space, and unmanned aircraft systems.

UND has access to high-performance computing (HPC) resources, which can be utilized for complex simulations and large-scale data analysis, such as traffic modeling, safety assessments, and infrastructure evaluation. These resources will support the processing of big data from traffic systems, truck platoon simulations, and predictive analytics.

The libraries at UND will make available the scholarly research, such as articles, data sets, supporting material, and related materials, from the UND community, including faculty, non-faculty researchers, staff, and others, and high-level student research, such as thesis, dissertations, and posters presented at professional conferences.

The Civil Engineering Department has computational resources running various operating systems, including Windows, Linux, and Mac OS. Engineering and statistical software is available on most university computers, such as ArcGIS, AutoCAD, MATLAB, Microsoft Office, Microsoft Visual Studio, PTV-VISSIM, PTV-VISUM, Python, R-Studio, SAS, and SPSS. All machines are password-protected and feature updated software, including strict security programs, and are carefully maintained by the university's IT department.

Additionally, UND's Transportation Technology Research Initiative (TTRI) focuses on advancing transportation technology and conducting research in areas like intelligent transportation systems (ITS), autonomous vehicles, and transportation infrastructure. This initiative offers access to cutting-edge research tools and data for analyzing and evaluating truck platooning technologies, making it an essential resource for this project.

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