Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Truck Platooning Effects on Girder Bridges - Phase I and II

Research Benefits

This research will enable NDOT to strategically and responsibly incentivize platoon operations along the I-80 corridor by optimizing freight transport efficiency. Additional truck traffic will provide economic benefits from direct sale of vehicle fuel, as well as secondary economic benefits to mechanics and technicians who provide vehicle maintenance and smart vehicle control services. Providing a smart corridor for platoons also positions Nebraska for future benefits if a transportation tax is imposed on a vehicle-miles-traveled basis rather than a direct fuel tax. The results of this research will enable platooning operations to increase vehicle weights without compromising service lives of bridges from overloads and repeated cycles of inelastic behavior. This research will build upon a framework developed in the first phase of the research and thereby capitalize on investments previously allocated by NDOT.

Phase I Objectives

1. Evaluate whether truck platooning on highway girder bridges in Nebraska violates safe load limits according to typical assumptions and methods used by NDOT, and under what conditions.
2. Provide guidelines for how to manage truck platooning operations, accounting for more exact knowledge of truck loading magnitudes and distribution and reduced uncertainty with platooning.

Phase II Objectives

1. Calibrate appropriate live load factors for use with platoons to address the Service III limit state for concrete girder bridges.
2. Calibrate appropriate live load factors for use with platoons to address the Service II limit state for steel girder bridges.
3. Propose a framework for characterization of uncertainty from individual contributions within live load effects.
4. Facilitate adoption of platoon permitting with illustrative examples.
5. Approximately assess the significance of platoon-induced fatigue with respect to service life.

Background

Connected and Automated Driving System (C/ADS)-equipped vehicles are expected to become increasingly common in the United States and elsewhere globally. Most research and development efforts have been focused on traffic operations and vehicle control. The structural safety of bridges carrying increased load from truck platoons has not yet been thoroughly studied, but DOTs will need to ensure that their structural assets will not be compromised before allowing platooning operations in their jurisdictions. Truck platooning with CV technologies places trucks much closer than current design codes anticipate. Truck platooning is expected to be deployed imminently, according to the anticipated timeline provided in Trimble. The density of truck traffic and the implications for structural safety and serviceability should be considered as part of a platooning policy to avoid compromising bridge service lives. Platoons of heavy trucks will be economically advantageous for freight operators in the near future, but information currently available is insufficient for bridge owners to establish platoon operation limitations and guidelines ensuring safe and serviceable loading demands in girder bridge structures in terms of vehicle weights, live load uncertainties, and headways.

Phase I Conclusion

Truck platooning – digitally linking two or more trucks to travel in a closely spaced convoy – is increasingly used to save fuel, and reduce driver work and road congestion. Currently, the platoon load effects with several constant headways on bridges have been evaluated and compared to AASHTO design and legal loads. However, reliability assessment and a more rigorous investigation of headway spacing assumptions for truck platoons are lacking. This research provides a framework for determining how much a platoon permit load might be increased given strict control over the load characteristics and operational tactics. The present research evaluates the Strength I limit state for steel and prestressed concrete I-girder bridges designed with LRFD and LFD. Herein, platoons are assumed to be advanced not only with respect to traffic operations but also in their ability to weigh and report axle weight and spacing, moble-WIM (mWIM). Consequently, the live load statistics (bias and CoV) differ from code assumptions, and are perhaps controllable, which poses significant opportunity with respect to operational strategies and associated economies. A parametric study considered different girder spacings, span lengths, numbers of spans, types of structures, truck configurations, numbers of trucks, and adjacent lane loading scenarios. Reliability indices β were calculated for each load case based on the Monte Carlo Simulation Method. The results indicated that loads significantly higher than legal loads are acceptable for truck platoons with lower uncertainties while maintaining a traditional operating target $\beta = 2.5$, consistent with permit loading in the Manual for Bridge Evaluation. Live load factors were developed and presented for a potential new permit load, i.e., a platoon permit. This approach helps to inform owners of effective operational strategies to safely benefit economies on a state or multistate corridor basis.

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Interested in finding out more?

Phase I Final Report Available: NDOT Website

Phase II Final Report Available: HERE

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Phase II Conclusion

Truck platooning—wirelessly linking two or more trucks to travel in a closely spaced convoy—is federally promoted to save fuel, improve the environment, and improve traffic operations. Platooning places trucks much closer than current design codes anticipate. While this strategy can provide higher fuel efficiency, it also can potentially overload structures. Previous reliability-based studies (Steelman et al., 2021; Yang et al., 2021) have focused on the Strength I limit state and have shown that trucks can operate at weights exceeding standard legal load limits even with short headways at operating-level reliability. However, service limit states in the AASHTO LRFD Bridge Design Specifications (2020) were not originally calibrated to produce uniform safety through reliability theory. Currently, no target implicit reliability index (βImplicit) nor reliability-based evaluation guidance for the service limit states is stated in the AASHTO Manual for Bridge Evaluation (2018). In addition, a reliability-based service limit state evaluation protocol for bridges subjected to platoons does not currently exist. A parametric study considered different girder spacings, span lengths, span numbers, structure types, truck configurations, truck numbers, and adjacent-lane loading scenarios. Using Monte Carlo Simulation (MCS), target βImplicit values were identified based on current design loads to calibrate heavy-load limits for the service limit state (e.g., permit vehicles and platoons). LRFR live load factors were developed for service over a range of coefficients of variation (CoVs) and were presented in association with a potential new permit load, i.e., a platoon permit. The framework for explicitly aggregating live load uncertainties based on truck weight, dynamic amplification, and girder distribution factors was developed and proposed. Four representative steel and prestressed concrete girder bridges from the Nebraska inventory were load rated for strength and service. The study also preliminarily evaluated the fatigue performance of welded cross-frame connections to girder flanges and shear studs for the steel bridges and determined cracking probabilities (βCracking) for prestressed concrete bridges. As an illustration of possible operational strategies, headway guidance information and a summary of guidelines were developed for platoon loads, including varying truck weights.

Technology Transfers:

Phase I:

Webinars/Presentations

- Presenting a submitted paper titled “Safe Platooning Headways on Girder Bridges” at the 2021 International Bridge Conference, sponsored by the Engineers’ Society of Western Pennsylvania. Scheduled to be held June 7-10, 2021.

Phase II:

Principal Investigator did not have any technology transfer for this research project.

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Phase I NDOT Recommendations Based Off Research Project – 2020

This research provided the baseline work for the highly automated vehicle systems that will be forthcoming in the future and informed associated policy decisions to manage and assess this technology. The research provided guidelines for how to manage truck platooning operations, accounting for truck loading for strength and shear magnitudes and distribution factor associated with platooning. The research evaluated the Strength I limit state for steel and prestressed concrete I-girder bridges designed with LRFD and LFD. The research team provided guidelines for safe truck platoon configurations corresponding to the data on I-80 between Nebraska and Wyoming. NDOT will be able to guide and manage the information provided by the trucking company and the structures on the targeted route. Platoons of heavy trucks will be economically advantageous for freight operators in the near future, this research provided information currently is insufficient for bridge Division to establish platoon operation limitations and guidelines ensuring safe and serviceable loading demands in girder bridge structures in terms of vehicle weights, live load uncertainties, and headways. The Department proposed a Phase II- Truck Platooning Effects on Girder Bridges in which the research focus will be to calibrate appropriate live load factors for use with platoons to address the Service III limit state for concrete girder bridges and calibrate appropriate live load factors to address the Service II limit state for steel girder bridges.

- *As provided by Jaber Fouad, Lead TAC Member*

Phase II NDOT Recommendations Based Off of Research Project – 2025

This research provides NDOT with headway guidance information and a summary of guidelines for platoon loads with varying truck weights. Information about the fatigue performance and cracking probabilities for prestressed concrete bridges. This information gives the NDOT the ability to quickly implement best practices if/when companies inquire about truck platooning. Currently, this information has not been implemented into practice; however, the research could be implemented when the need arises. The research is considered nearly complete.

- *As provided by Fouad Jaber and Emilie Hudson, Lead TAC Members*

Research Readiness Level (RRL) Assessment

RRL 4

Level 4: Implementation

Research/Technology refined.
Moved up from Level 3: Development/Field-Level (Phase I)

This brief summarizes Project SPR-P1(20) M030 and SPR-FY22(011):
"Truck Platooning Effects on Girder Bridges"
"Truck Platooning Effects on Girder Bridges – Phase II"
Nebraska Department of Transportation Research Program