Effects of Truck Platooning on Bridges

by Dr. Lubin Gao, Federal Highway Administration

Connected and autonomous vehicle technology is advancing both in the United States and abroad. In applications with commercial trucks, the technology is normally referred to as "truck platooning technology." Trucks enabled with this technology can communicate and synchronize with each other and travel closely together in a platoon. The technology offers the potential benefits of improved traveling safety and efficiency, but the concentration of more loading over short distances may adversely affect the safety and long-term serviceability of the highway bridge network. It is important to investigate these potential impacts.

In August 2018, the Federal Highway Administration (FHWA) initiated a project to study the impacts of truck platooning on the structural safety of bridges from the strength limit state perspective.[1]

Literature Review

The research started with a literature search. Although many publications on truck platooning technology were identified, most past work has focused on the development of the technologies, operational issues, and fuel economy. At the time of the literature review, no studies on the effects of truck platoons on bridges were found.

Representative Trucks and Truck Platoon Configurations

A review of weigh-in-motion data from 10 states showed that the most common truck class is FHWA Class 9, a five-axle single-trailer truck (**Fig. 1**). Taking into account long-haul commercial truck traffic on the Interstate System (IS), the National Highway System (NHS), and the National Truck Network (NN), together with the Class 9 truck statistics, a representative model of the most common trucks was selected. This "typical" truck (**Fig. 2**) is a five-axle tractor-semitrailer combination that falls within the truck size and weight limits operating on the IS as set forth in 23 U.S. Code §127(a) and 23 Code of Federal Regulations (CFR) §658.17(b)-(e).

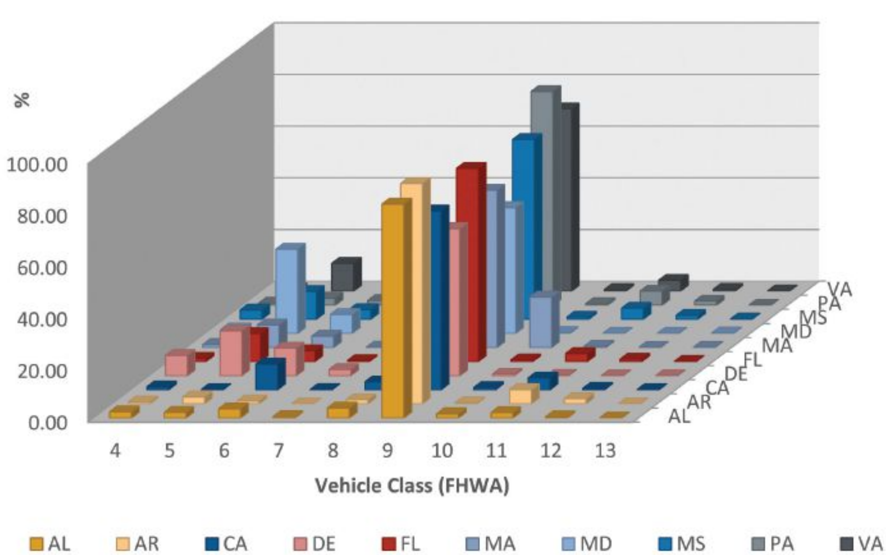

Figure 1. Vehicle class distributions from a review of weigh-in-motion data from 10 states. The bar chart shows the percentage of all vehicles with a gross vehicle weight equal to or greater than 20 kip for each vehicle class in a given state. Figure: Federal Highway Administration (FHWA), Figure 2 from *Truck Platooning Impacts on Bridges: Phase I—Structural Safety*.

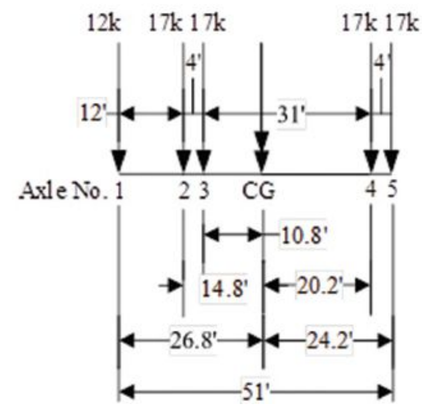

Figure 2. Schematic of axle configuration for a "typical" truck (5-axle, 40-ton truck) used in analyses. Figure: Federal Highway Administration, Figure 11 from *Truck Platooning Impacts on Bridges: Phase I—Structural Safety*.

In addition, two types of American Association of State Highway and Transportation Officials (AASHTO) trucks, Type 3S2 and Type 3-3, were also included in the study. (These types are from AASHTO's *The Manual for Bridge Evaluation*,[2] which is incorporated by reference in 23 CFR §650.317.)

Truck platoons consisting of two, three, and four trucks of the selected truck type with spacings of 30, 50, and 70 ft were included in the study (**Fig. 3**). The spacing was measured from the rear axle of a truck to the front axle of the following truck. In total, 30 different platoon configurations were considered in the analyses.

Bridge Spans and Load Effects

Representative bridge span configurations were selected to determine the load effects from the platoon configurations and AASHTO HL-

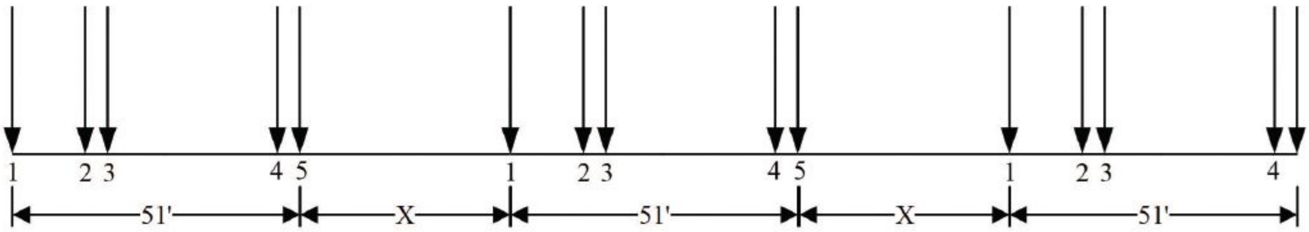

Figure 3. Schematic of axle configurations for a "typical" three-truck platoon. Platoons with X = 30, 50, and 70 ft were analyzed in the study. Figure: Federal Highway Administration, Figure 16 from *Truck Platooning Impacts on Bridges: Phase I—Structural Safety*.

93 and HS-20 design loads. The selected span lengths ranged from 30 to 300 ft.

Load effects at critical sections in simple spans, two equal continuous spans, and three equal continuous spans were considered. For example, the analysis included maximum positive moment in span 1, maximum negative moment at the intermediate support, maximum end shear, and maximum shear on one side of the intermediate support for two equal continuous spans.

The truck platoons were treated as actual vehicles, which means that all axles were considered, regardless of whether they increased or decreased the load effect.

Strength Analysis of Existing Bridges

Data from the 2018 National Bridge Inventory (NBI)[3] were used in this study. The controlling rating factor for each platoon configuration was determined based on load effect ratio, live load factor ratio, and the operating rating factor of design load recorded in the NBI database (item 64). Truck platoons were rated at the operating rating level with the load factor rating (LFR) method or the legal load rating level with the load and resistance factor rating (LRFR) method.

Bridges that have a load rating factor lower than 1.0 for a particular truck platoon configuration were considered to have insufficient structural capacity at the strength limit state to carry the truck platoon. **Table 1** lists the number of bridges with a platoon operating rating factor less than 1.00 on the IS, NHS, and NN for the entire country. The numbers exclude bridges currently having an operating rating factor less than 1.00 for the HL-93 design load using the LRFR method or an operating rating factor less than 1.0 for the HS-20 design load using the LFR method. The data in Table 1 show that 0.9%, 1.4%, and 1.6% of all bridges on the IS, NHS, and NN, respectively, have an operating rating factor less than 1.0 for the truck platoons with a truck spacing of 30 ft with two, three, or four semitrailer trucks, respectively. Altogether, 98.4% of bridges on the three highway systems have adequate capacity to carry the truck platoon configurations investigated in this research.

Table 1. Number of bridges with a platoon operating rating factor less than 1.0

	Interstate System	National Highway System	National Truck Network	Total for the three systems
Total number of bridges on each system	57,640	145,190	102,707	163,292
Loading	Number of bridges with operating rating factor <1.00			
Single truck	0	0	0	0
2 trucks at 30 ft spacing	378	1239	853	1468
2 trucks at 50 ft spacing	141	420	278	497
2 trucks at 70 ft spacing	30	64	43	70
3 trucks at 30 ft spacing	701	2006	1382	2309
3 trucks at 50 ft spacing	190	562	377	652
3 trucks at 70 ft spacing	37	80	54	85
4 trucks at 30 ft spacing	817	2265	1542	2583
4 trucks at 50 ft spacing	196	575	383	665
4 trucks at 70 ft spacing	40	84	57	89

Note: Numbers exclude bridges currently having an operating rating factor less than 1.00 for the AASHTO HL-93 or HS-20 design load. Values listed in the right column account for the fact that some bridges are included in more than one of the systems and should not be counted more than once for the total value of the three systems. Table created by the Federal Highway Administration based on 2018 National Bridge Inventory data.[3]

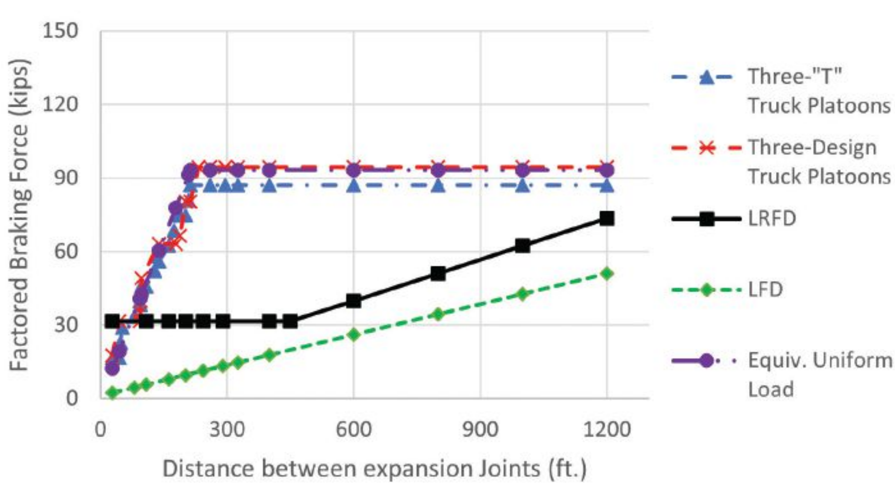

Figure 4. Factored braking force from three-truck platoons. Figure: Federal Highway Administration, Figure 38 from *Truck Platooning Impacts on Bridges: Phase I—Structural Safety*.

Other Truck Platooning Loads on Bridges

Based on a review of other studies, the FHWA project[1] found that a reduced dynamic allowance of 20% may be applied to the entire platoon because the interaction between the trucks in a platoon results in a smaller impact factor than for a single truck. For shorter spans where only one truck can fit on the structure, the AASHTO design loads with the 33% dynamic allowance applied to the truck will continue to control the design over the 20% for the platoon.

In addition to gravity effects, live loads produce, or are subject to, three additional load components: braking force (**Fig. 4**), centrifugal force, and wind load on live loads. These other load components mainly affect the design of the bearings, substructures, and foundations.

Service and Fatigue Limit States

The FHWA study's final report[1] offers a brief discussion of possible truck platooning effects on service and fatigue limit states. A list of bridge components that may be controlled by the service limit state and the possible effects of truck platoons on these components is presented.

Truck platoons may cause some details currently classified as having infinite fatigue life to be reclassified as having finite fatigue life. Depending on the bridge span length and configuration, the presence of platoons may increase the number of higher-stress cycles and affect the remaining life of details.

Closing Remarks

This study investigated the effects of truck platooning on bridges on main highway systems—the IS, NHS, and NN—at the strength limit state.

The study found that some configurations of truck platoons can produce load effects greater than those from the standard design loads at an operating rating or legal load evaluation level. The bridges potentially affected by the platoon configurations (Table 1) are bridges with longer spans. Further detailed structural evaluation will need to be performed to confirm the adequacy of the structural capacity of those bridges. The study also concluded that bridge superstructures having an inventory rating factor greater than 1.0 for HL-93 loading will have adequate capacity to carry the truck platoons investigated.

Additional research is warranted to assess other impacts of truck platoons, which may include performing statistical live load analysis of platoons, establishing appropriate dynamic load allowance applicable to truck platoons, and establishing the effect of truck platoons on the fatigue life and service limit state of bridges.

References

1. Wassef, W. 2021. *Truck Platooning Impacts on Bridges: Phase I—Structural Safety. Final Report*. FHWA-HIF-21-043. Washington, DC: Federal Highway Administration (FHWA). https://www.fhwa.dot.gov/bridge/loadrating/pubs/hif21043.pdf.
2. American Association of State Highway and Transportation Officials (AASHTO). 2018. *The Manual for Bridge Evaluation*. 3rd ed. Washington, DC: AASHTO.
3. FHWA Office of Bridges and Structures. 2019. "National Bridge Inventory: 2018 Data (updated 4/22/19)." https://www.fhwa.dot.gov/bridge/nbi/ascii.cfm.