**Research Problem Statement**

**Research Problem Title:**

Freeway Gore Chevron Markings

**Statement of Problem**

Section 3B.05 paragraph 10 of the 2009 MUTCD indicates that white chevron markings may be placed in the neutral area of exit ramp gores, as shown in MUTCD Figure 3B-8, for special emphasis (see Section 3B.05) or to discourage travel in such areas (see Section 3B.24). Section 3B.24 of the MUTCD further indicates that, when used in paved areas that separate traffic flows in the same general direction (e.g., as with exit ramp gores), the markings shall be white, shaped as chevron markings, and the point of each chevron shall face toward approaching traffic. The MUTCD specifies that the chevrons and diagonal lines used for crosshatch markings should be at least 12 inches wide for roadways with a speed limit of 45 mph or greater, and at least 8 inches wide for roadways with a speed limit of less than 45 mph. It specifies that the chevrons or diagonal lines should form an angle of approximately 30 to 45 degrees with the longitudinal lines that they intersect, and that the longitudinal spacing of the lines should be determined by engineering judgement. Section 3B.01 of the MUTCD was proposed in the NPA for the 11th Edition to be expanded and include additional allowable uses of white-colored pavement to include gore areas at exit/entrance ramps.

While the use of white chevron markings in exit ramp gores is an option in the 2009 MUTCD, several State supplements to the MUTCD provide this as guidance (Delaware Department of Transportation, 2012) or as a Standard (California Department of Transportation, 2021).

Regarding the application of the chevrons, several States provide specific guidance or standards on the longitudinal spacing of the crosshatch markings. Specifically, Delaware DOT indicates that the longitudinal spacing should be 50 feet along interstates, expressways, and freeways and 25 feet along all other roadways. Virginia DOT indicates that the longitudinal spacing shall be three times the width of the markings. The Delaware DOT and Virginia DOT indicate that the chevrons and diagonal lines should or shall, respectively, form an approximate 45-degree angle with the longitudinal lines they intersect, which is slightly different from the range of 30 to 45 degrees provided in the MUTCD. The Virginia DOT increases the width of the markings in some scenarios, indicating that they should be at least 24 inches wide on limited access highways, while Delaware DOT suggests the width should be 12 inches wide along all roadways.

There is further variation between jurisdictions regarding pattern, width, angle, spacing, and use of negative space, and these approaches can vary widely. Additional research is required to attain more consistency in the application of freeway gore chevron markings.

The objective of this research is to:

Determine what freeway gore chevron marking design(s) (e.g., pattern, width, angle, spacing, and use of negative space) is/are most effective on rural freeways and arterials/expressways and/or urban freeways.

**Summary of Existing Literature**

A 2016 study explored alternative highway exit gore treatments to improve road user comprehension and reduce collisions with exit gore signs (Ko et al., 2016). A driving simulator was used to evaluate comprehension and recognition of various treatments including chevrons pointing in different directions, diagonal pavement markings, and horizontal EXIT pavement markings. Initial participant opinions favored horizontal EXIT markings, but some believed it implied a required exit from the right lane. During driving simulations under different conditions, participants recognized the combination of chevrons pointing up with diagonal pavement markings significantly earlier than the treatment with only vertical chevrons in long viewing conditions. However, in short viewing conditions, the traditional exit gore sign was recognized earlier than the treatment with chevrons pointing right and left, presumably due to the height of the sign. Overall, the study suggested that some treatments for highway exit gores have the potential to be as visually noticeable as the exit gore sign, though the researchers recommended further real-world testing to assess driver performance.

Though there is limited research available on freeway gore chevron markings, there has been research that has evaluated varying applications of chevron markings and/or various treatments at exit gore locations. Some of these examples include research on transverse pavement markings on freeway exit ramps (Retting, McGee & Farmer, 2000), chevron pavement markings on freeway-to-freeway connector ramps (Hunter et al., 2010), or the addition of large, colorful, and attention-grabbing objects at the physical nose of gores (Ross et al., 2021).

**Potential Research Approach**

The general approach to the research has been identified as a field study in which varying freeway gore chevron markings are evaluated based on driver behavior.

The behaviors to be evaluated relative to freeway gore chevron markings can be influenced by other factors such as driver states (e.g., distracted, in a hurry, etc.), traffic, vehicle speeds, etc., the complexities of which cannot be naturally recreated in a driving simulator. As such, a field study that captures natural driving behavior would be the most effective approach to capture actual behavior changes and potential safety benefits in response to the pavement markings being tested.

*Task 1 – Kick-off Meeting and Project Management*

Researchers would attend a kickoff meeting with FHWA and the TCD PFS panel. The research team will work with the TCD PFS and other stakeholders to ensure a common understanding of the research objective and research questions.

*Task 2 – Literature and State of the Practice Review*

The research team will review and synthesize literature regarding research that has been performed on freeway gore chevron markings. Additionally, current practices will be gathered from the TCD PFS members, at a minimum, and summarized.

*Task 3 – Research Plan Development*

The research team will work with the TOCOR, TCD PFS, MUTCD team, and other stakeholders to select the specific pavement marking patterns that will be evaluated and refine the characteristics of candidate locations that will be considered. This would involve determining which variables (e.g., pattern, width, angle, spacing, use of negative space), combination of variables, and levels of each variable to be tested, as well as the roadway scenario(s) of interest (e.g., high-speed rural freeway, urban freeway, expressway, etc.). The dependent variables (e.g., crossing over the gore) and methodology will be described in the research plan.

Based on inputs from the kickoff meeting and stakeholder coordination, as well as findings of the literature review, the research team will develop and submit a research plan specifying the pavement markings and methodology that will be used for conducting the study.

*Task 4 – Optional Laboratory Recognition Testing (as needed)*

If the Literature and State of the Practice Review and feedback from the TCD PFS do not sufficiently focus the scope of the research, then the research team may propose to conduct preliminary recognition testing to further narrow the variables to be tested in the field. For example, the project objective lists five potential variables related to marking designs: pattern, width, angle, spacing, and use of negative space. If the State of the Practice Review indicates that there are several levels of each variable that are commonly used (e.g., 3 different widths, 6 different spacings, 2 different angles, etc.), then there could potentially be countless combinations of these different variables, all of which could not be tested in the field. The objective of the optional laboratory testing would be to determine the variables and/or levels of variables that are most likely to be noticeable in the field by motorists, thus narrowing the focus of the field study to increase the likelihood of gathering useful information. The research team would refine the research plan for the field study based on the findings of the laboratory testing, if conducted.

*Task 5 – Field Site Selection and Preparation*

Once the research plan is finalized, the research team will identify appropriate field locations (or sites) that meet the criteria identified in the research plan and enable the collection of sufficient data to address the research questions.

*Task 6 – Data Collection & Analysis*

The research team will collect and analyze data based on the approved, final research plan. This will involve the collection of driving behavior in response to the various pavement marking patterns to be tested.

*Task 7 – Final Report and Presentation*

The research team will develop a final report that describes the research approach and results and provides a discussion of the findings. The team will present their findings to the TCD PFS members.

**Chance of Successful Evaluation**

Low to Medium

The success of evaluating freeway gore chevron markings is primarily dependent on the identification of appropriate sites. It would be difficult to determine the effects of the freeway gore chevron markings on driver behavior unless sites with high frequency of gore crossings are selected for evaluation. Additionally, the levels of variables to be included must be appropriately narrowed such that differences could be detected in the field.

**References**

Federal Highway Administration. Manual on Uniform Traffic Control Devices (MUTCD). U.S. Department of Transportation, Washington, D.C., 2009.

Delaware Department of Transportation. 2012. Delaware Manual on Uniform Traffic Control Devices, Revision 1 2012. [Marking (delaware.gov)](https://regulations.delaware.gov/AdminCode/title2/2000/2400/Part3.html)

California Department of Transportation. 2021. California Manual on Uniform Traffic Control Devices, 2014 Revision 7. [CA MUTCD 2014 Revision 7 Part 3](https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/ca-mutcd/rev7/camutcd2014-part3-rev7-a11y.pdf)

Retting, Richard & McGee, Hugh & Farmer, Charles. (2000). Influence of Experimental Pavement Markings on Urban Freeway Exit-Ramp Traffic Speeds. Transportation Research Record. 1705. 116-121. 10.3141/1705-17.

Hunter, Michael & Boonsiripant, Saroch & Guin, Angshuman & Rodgers, Michael & Jared, David. (2010). Evaluation of Effectiveness of Converging Chevron Pavement Markings in Reducing Speed on Freeway Ramps. Transportation Research Record. 2149. 50-58. 10.3141/2149-06.

Ross, Veerle & Reinolsmann, Nora & Dehman, Amjad & Van Vlierden, Karin & Mollu, Kristof & Bisschop, Erik & Ectors, Wim & Brijs, Tom. (2021). Investigating the effect of marking and delineation treatments on driver behavior at highway exit gore areas. Accident Analysis & Prevention. 161. 106362. 10.1016/j.aap.2021.106362.

Ko, M., Higgins, L., Carlson, P., & Nelson, A. (2016). Examining Driver’s Comprehension and Recognition to Highway Exit Gore Treatments. Transportation Research Board. Washington, DC.