STRIDE | Southeastern Transportation Research, Innovation, Development and Education Center

Technology Transfer Final Report

STRIDE Project J5

Assessing and Addressing Deficiencies in the HCM Weaving Segment Analyses- Phase II

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THE STRIDE CENTER

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DISCLAIMER

ACKNOWLEDGEMENT OF SPONSORSHIP AND STAKEHOLDERS

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1. Project Overview

In this study, the team extends work completed on ramp weaves to major weaves, develops a speed model for all weaving types, and proposes an alternate capacity estimation process. Two lane-configuration parameters were introduced in the speed model the team developed earlier, in order to make it applicable to all types of weaves. The model was calibrated separately for ramp and major weaves. The resultant root-mean-squared error (RMSE) was 3.46 and 2.36 mi/h, respectively, for major and ramp weaves. The application of the models to the corresponding test/ validation dataset not used in the model development also yielded satisfactory RMSE values—4.7 mi/h for major and 2.56 mi/h for ramp weaves. The team proposed a new capacity model which eliminated the limitation of the previous capacity model for low-volume conditions. However, the difference in the capacity estimates from these two approaches diminishes as the observed flow rate approaches capacity. Both approaches showed remarkably higher sensitivity to segment length than the HCM model, whereas the HCM model exhibited a slightly higher sensitivity to weaving ratio.

2. Research Goals

1) To address known deficiencies in the current HCM6 method
2) To build an analysis framework that is consistent across all freeway segment types.
3) To develop capacity estimation methods consistent with the fundamental traffic flow equation
4) To develop easy-to-use methods for estimating weaving and non-weaving flow rates
5) To simplify the approach and remove the separation in the performance of weaving and non-weaving vehicles to enable data collection and analysis using sensor information

3. Findings

Major findings from this research can be summarized as follows:

a) In general, the estimated capacity values using the new framework were found to be more reaslistic than those predicted by HCM6 methods, and closer to field-observed capacities.
b) Most of the observed breakdowns occurred at a lower density than the HCM6 predicts. In fact, an approximate density at capacity of 35 pc/mi/lane is more consistent with field observations than the current default of 43 pc/mi/lane.
c) Incorporating additional weaving segment configuration parameters (number of lanes from which a specific weaving maneuver can be completed in zero or one lane change) improved the speed model predictions for the calibration sites.
d) As a result, the final speed model estimations were within 3.5 mph from the field values for both ramp weave and complex weave models. By contrast, the HCM6 speeds were found to have a higher RMSE of 7.43 mph and generally lower speed.
e) Proposed models have been tested against new merge and diverge models developed under the NCHRP 07-26 project and show consistency in operations by adding an auxiliary lane.

4. Performance Metrics

Metric	# Completed
OUTPUTS	
Product(s)	1 (in partnership with NCHRP 07-26) New HCM proposed method for weaving segments

Technical Report: Number of client-based technical reports published	2 • STRIDE Final Report • TRB Paper: Speed and Capacity Analysis Framework for Complex Freeway Weaving Segments - Submitted for presentation at the 2023 Annual TRB meeting
OUTCOMES	
Body of Knowledge: Number of trainings for transportation professionals	1 Webinar on November 9, 2022
Professionals Trained: Number of professionals participating in trainings	42 • 20 - HCQS committee and friends at the June 2022 midyear meeting, by NCHRP 07-26, the partner and user of the STRIDE approach. • 22 – STRIDE Webinar
IMPACTS	
Stakeholders: Number of stakeholders you met with to encourage adoption or implementation of product(s)	NCHRP 07-26 research team who adopted the study framework
Adoption/Implementation: Number of incidences outputs of research have been implemented or adopted	Likely to be adopted by TRB Capacity Committee for inclusion in a future HCM release

5. Product

New HCM Proposed Simplified Speed and Capacity Model for Weaving Segments

The product addresses known deficiencies in the current Highway Capacity Manual (HCM) weaving segment analysis. The new, simplified speed and capacity models will enable transportation planners and engineers to improve designs of major weaves.

The new capacity model eliminates the limitation of the previous capacity model for low-volume conditions. The model generates relatively lower capacities than the current HCM and should prompt operating agencies to improve the geometry of those sections sooner and mitigate the effects of impending congestion and associated safety risks.

Technical Description

The generalized speed estimation model for complex weaves is below in Equation 5-1

$$S_o = S_b - 20 * \left(\frac{\frac{v_{rf} * (LC_{rf} + 1)}{N_{wrf} + 1} + \frac{v_{fr} * (LC_{fr} + 1)}{N_{wfr} + 1}}{N^{3.85}} \right)^{0.4} * \left(\frac{v}{N} - 500 \right) * \left(\frac{1}{L_s} \right)^{1.12} \qquad \textit{Equation 5-1}$$

The companion capacity equation is derived from the speed at capacity, and is solved from a quadratic equation in C_w, or the weaving segment lane capacity and k_w^c density at capacity.

$$\frac{C_{\mathrm{w}}}{k_{\mathrm{w}}^{\mathrm{c}}} = S_{\mathrm{b}}(C_{\mathrm{w}}, C_{\mathrm{w}}^{2}) - 20 * \left(\frac{\frac{v_{\mathrm{rf}} * (\mathrm{LC}_{\mathrm{rf}} + 1)}{\mathrm{N}_{\mathrm{wrf}} + 1} + \frac{v_{\mathrm{fr}} * (\mathrm{LC}_{\mathrm{fr}} + 1)}{\mathrm{N}_{\mathrm{wfr}} + 1}}{N^{3.85}} \right)^{0.4} * (C_w - 500) * \left(\frac{1}{L_{\mathrm{s}}}\right)^{1.12}.$$

Once speed and capacity are estimated, the average weaving segment density and LOS can also be readily estimated.

6. Who benefits/will benefit from your product?

Primarily the users of the Highway Capacity Manual (which is used by state and local agencies, as well as internationally), as well as software developers of its method. Students in traffic engineering courses and consultants for various public agencies can also benefit.

7. Body of Knowledge & Professionals Trained

1) Presentation to the HCQS committee at the June 2022 midyear meeting, by NCHRP 07-26, the partner and user of the STRIDE approach. (20 attendees)
2) STRIDE Webinar: "Assessing and Addressing Deficiencies in the HCM Weaving Segment Analyses- Phase II" presented by Ishtiak Ahmed, Ph.D., North Carolina State University, and Ehsan Amini, Ph.D., University of Florida on November 9, 2022. (22 attendees)

8. Stakeholder Engagement

Due to COVID-19, all research activities were performed remotely across the project team.

9. Adoption/Implementation

We anticipate that the proposed method will be adopted across all freeway chapters in an upcoming release of the US Highway Capacity Manual. This will require the HCQS Committee to approve those changes. We have produced a paper that is currently under review by the HCQS committee for presentation at the 2023 TRB Annual meeting.

10. Broader Impacts

This research product will improve the reliability of freeway operations evaluation. In the long term, it will affect how complex weaving sections are designed, in order to maximize capacity and reduce the probability of breakdown. The fact that the models generate relatively lower capacities than the current HCM should prompt operating agencies to improve the geometry of those sections sooner and mitigate the effects of impending congestion and associated safety risks.