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

Technology Transfer Final Report

STRIDE Project K2

ASSESSING AND ADDRESSING DEFICIENCIES IN THE HCM WEAVING SEGMENT ANALYSES

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1. Project Overview

The main objectives of this research project were to identify, document, and address the major deficiencies in the current Highway Capacity Manual (HCM6) weaving method through improved modeling of key procedures and their calibration. The research team collected field data and obtained previously collected data at weaves and developed a new framework for evaluating operations at freeway ramp weaves. This new framework uses the basic freeway model and a speed impedance factor that represents the weaving turbulence, which proved to be simpler and more accurate than the models in the HCM6. Speed and capacity models were developed for Type A weaves, which directly predicts the overall segment speed in the weaving segment. The team concluded that the HCM6 model tended to underestimate speed within the weaving section compared to field data. A sensitivity analysis showed that the new model behaves reasonably well when varying the length, lanes, and weaving volumes.

2. Research Goals

The main research goals pursued were to:

1. Conduct a critical review of the HCM6 weaving method and identify deficiencies that this research can address for a subset of weaving segments
2. Create a new framework for freeway segment analyses that can ensure consistency across segment type namely basic, merge, diverge and weaving segments
3. Apply the proposed framework to ramp weave sites in the field and generate a simplified operational method for LOS estimation that is transferable to other segment configurations

3. Findings

1. The drone video technology has proven to be very useful for freeway weaving data collection. It captured traffic in a segment with lengths up to 3,000 ft.
2. Using loop detector data had the following advantages: cheaper to obtain large amounts of data and easier to obtain data for very long sections when a single video camera cannot capture the entire weave. However, it does not provide the volume of each origin-destination and thus those must be estimated manually.
3. The proposed framework, which uses the basic freeway model and a speed impedance factor for weaving turbulence, proved to be simpler and more accurate than the existing HCM6 method. The model directly predicts the average speed and density in the weaving segment.
4. The HCM6 speed predictions were found to deviate from field observations, especially for speeds in excess of 50 mph.
5. Ramp-to-freeway demand was found to have a higher impact on segment speed than the freeway-to-ramp demand. All the parameters for ramp-originating traffic had a higher value than those for freeway-originating traffic.
6. The sensitivity tests indicated that the HCM6 has little sensitivity to the segment short length. By increasing the segment length from 300 ft. to 3,300 ft., the HCM6 predicted that the average speed only increases by about 3.5 mph while the new recommended model shows an average speed increase of 10 mph.

4. Performance Metrics

Metric	# Completed
Product(s): Number of new or improved tools, technologies, products, methods, practices, and processes created or improved	3 • A new Capacity Analysis Method for ramp weave segments • Method for extracting high resolution video data • Computational Engine to exercise the method
Technical Report: # of client-based technical reports published	1 (STRIDE Final Report)
Body of Knowledge: # of trainings for transportation professionals	1 (STRIDE webinar)
Professionals Trained: Number of professionals participating in trainings	127 total (49 live participants; 78 YouTube views as of 2/5/2021)
Stakeholders: Number of stakeholders you met with to encourage adoption or implementation of product(s)	3 (NCDOT, NCHRP 7-26. Danish Road Directorate)
Adoption/Implementation: Number of incidences outputs of research have been implemented or adopted	Underway

5. Products

Product 1: A new Capacity Analysis Method for ramp weave segments

A new method was developed for evaluating operations at freeway weaves. This new method uses the basic freeway model and a speed impedance factor that represents the weaving turbulence. The model predicts the average speed of the weaving segment directly without using intermediate models to predict the number of lane changes. The new method provides an approach that is **simpler** than the current HCM6 method, **consistent** across all freeway segment analyses, and **adaptable** to other types of weaves (B & C) and merge and diverge segments when recalibrated.

Product 2: Method for extracting high resolution video data

A UAS (drone) was used to collect video 400 ft. above the highway, capturing a length of up to 3,000 ft. of roadway. The video was analyzed using a third party video imaging processor (VIP). Additional longitudinal and lateral “gates” were generated by the research team and superimposed on the processed video to capture the volume of weaving and non-weaving traffic. This enabled the team to track where vehicles started, when and where they entered, lane changed and exited at the approach.

Product 3: Computational Engine to exercise the method

To enable end users to test and verify the methodology, a computational engine on an Excel platform has been developed that exercise the computations for the method. The data the method requires is similar to – and in some instances fewer than-- the current HCM method requires. At this time, the engine is available upon request from the project PI through email at rouphail@ncsu.edu. Once the final report is made available to the public, the engine will be posted on the STRIDE website as a supplemental deliverable.

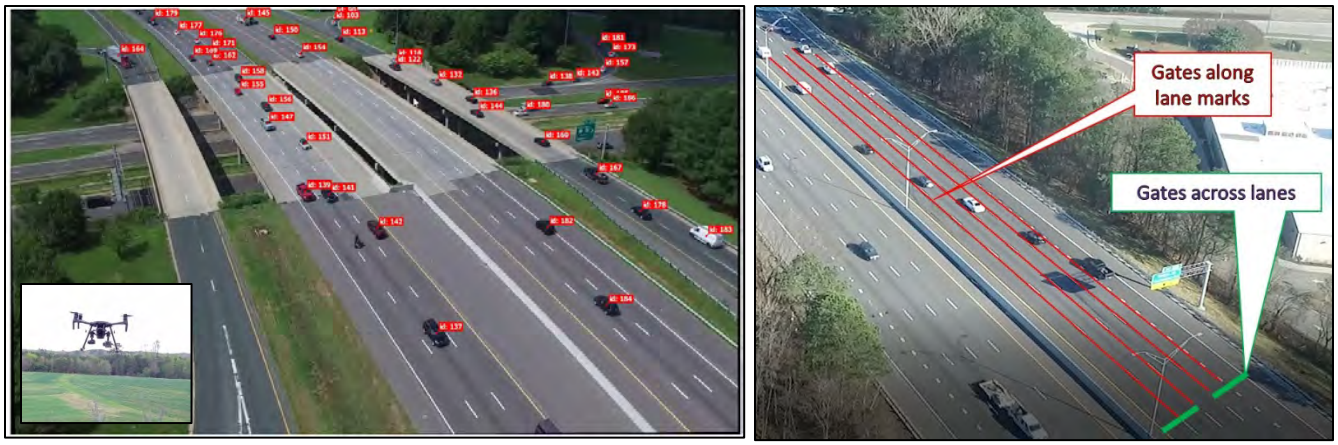


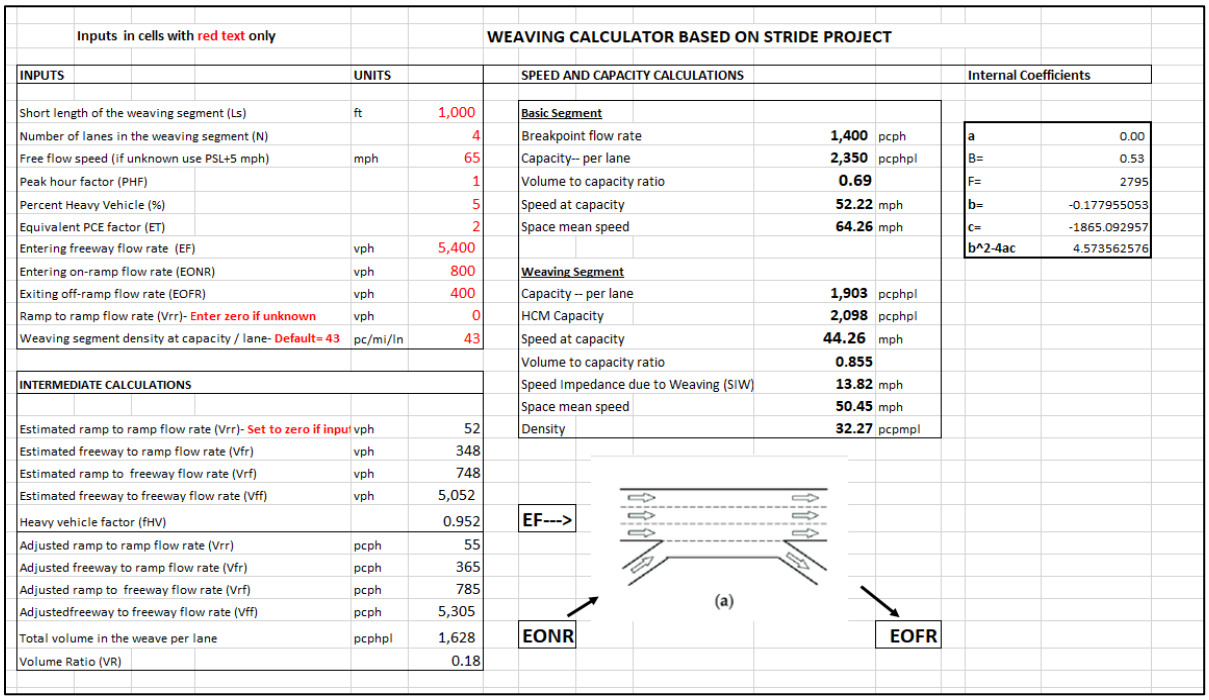
Figure 1: Images showing analysis of high resolution video from drone.

As a result of this project, state agencies will have access to a reliable tool for estimating capacity and quality of service at ramp weaves, and will enable them to improve their decision making in the design and operations of planned freeway improvements aimed at congestion mitigation in urban and suburban settings.

6. Who benefits/will benefit from your products?

- State DOT's in the Southeast and nationwide
- Consultants who use the HCM methods on a regular basis
- Researchers involved in HCM development (e.g. NCHRP 07-26)
- International researchers who use the U.S. HCM for operational analyses

7. Image of Product



Inputs in cells with red text only

WEAVING CALCULATOR BASED ON STRIDE PROJECT

INPUTS	UNITS	
Short length of the weaving segment (Ls)	ft	1,000
Number of lanes in the weaving segment (N)		4
Free flow speed (if unknown use PSL+5 mph)	mph	65
Peak hour factor (PHF)		1
Percent Heavy Vehicle (%)		5
Equivalent PCE factor (ET)		2
Entering freeway flow rate (EF)	vph	5,400
Entering on-ramp flow rate (EONR)	vph	800
Exiting off-ramp flow rate (EOFR)	vph	400
Ramp to ramp flow rate (Vrr)- Enter zero if unknown	vph	0
Weaving segment density at capacity / lane- Default= 43	pc/mi/ln	43

INTERMEDIATE CALCULATIONS		
Estimated ramp to ramp flow rate (Vrr)- Set to zero if input	vph	52
Estimated freeway to ramp flow rate (Vfr)	vph	348
Estimated ramp to freeway flow rate (Vrf)	vph	748
Estimated freeway to freeway flow rate (Vff)	vph	5,052
Heavy vehicle factor (fHV)		0.952
Adjusted ramp to ramp flow rate (Vrr)	pcph	55
Adjusted freeway to ramp flow rate (Vfr)	pcph	365
Adjusted ramp to freeway flow rate (Vrf)	pcph	785
Adjustedfreeway to freeway flow rate (Vff)	pcph	5,305
Total volume in the weave per lane	pcphpl	1,628
Volume Ratio (VR)		0.18

SPEED AND CAPACITY CALCULATIONS		
Basic Segment		
Breakpoint flow rate	1,400	pcph
Capacity-- per lane	2,350	pcphpl
Volume to capacity ratio	0.69	
Speed at capacity	52.22	mph
Space mean speed	64.26	mph
Weaving Segment		
Capacity -- per lane	1,903	pcphpl
HCM Capacity	2,098	pcphpl
Speed at capacity	44.26	mph
Volume to capacity ratio	0.855	
Speed Impedance due to Weaving (SIW)	13.82	mph
Space mean speed	50.45	mph
Density	32.27	pcpmpl

Internal Coefficients	
a	0.00
B=	0.53
F=	2795
b=	-0.177955053
c=	-1865.092957
b^2-4ac	4.573562576

Figure 2: Screenshot of the computational engine required to exercise the method (in Excel).

8. Body of Knowledge & Professionals Trained

1. STRIDE webinar – Dr. Nagui Rouphail, PI, Distinguished University Professor Emeritus, NC State University, presented "Framework for the Operational Analysis of Ramp Weaves" on October 12, 2020. (49 participants, 78 YouTube views as of 2/5/2021)

9. Stakeholder Engagement

STRIDE person at meeting	Nagui Rouphail and Dezhong Xu	The first paper accepted for presentation and publication based on this project was presented at the 99th Annual TRB meeting in a poster session. Paper title is: *Modeling Framework for Capacity Analysis of Freeway Segments: Application to Ramp Weaves*
Date of Activity	January 2020	
Type of Activity	demonstration	
Location	TRB Annual Meeting in Washington, D.C.	
Stakeholder(s)	TRB meeting attendees at poster session	
STRIDE person at meeting	Nagui Rouphail	Dr. Rouphail was invited to present the STRIDE model and computational engine to the NCHRP 7-26 research team that is working on "*Update of Highway Capacity Manual: Merge, Diverge, and*
Date of Activity	October 27,2020	
Type of Activity	phone meeting	

Location	Online- MS Teams	*Weaving Methodologies*". There is a strong likelihood that the NCHRP team will use the STRIDE approach for their modeling.
Stakeholder(s)	NCHRP 07-26 research team	
STRIDE person at meeting	Nagui Rouphail and Lily Elefteriadou	A discussion was initiated on how to best coordinate the STRIDE method developed in this project with ongoing research under the auspices of NCHRP 7-26. Met with Dr. Bastian Schroeder, the NCHRP project PI via a zoom meeting and agreed to coordinate the activities and house the 7-26 database in the STRIDE Zenodo data repository.
Date of Activity	November 9, 2020	
Type of Activity	phone meeting	
Location	Online-Zoom	
Stakeholder(s)	STRIDE and NCHRP 07-26 team	

10. Adoption/Implementation

Created a computational engine to enable any researcher or stakeholder to exercise the method for ramp weaves. Product has been shared with NCDOT, with the Danish Road Directorate, and with the research team for NCHRP 7-26. Assuming a Phase II extension of the research is funded, this will lead to the ability to develop a revised weaving chapter in the HCM covering all weaving configurations.

11. Broader Impacts

The product of this research is intended to improve mobility on the nation's freeway by producing more accurate measures for estimating the quality of service on weaving segments, which are likely to become network bottlenecks.

In the short term, the product will provide an alternative and more accurate measure of mobility metrics at weaving segments. In the longer term, by completing this research to account for other weaving configurations, the product will likely be incorporated in a revised HCM chapter, which has a strong domestic and international user base.

It is too early at this time to have wide ranging impacts.