Driver Population Adjustment Factors for the Highway Capacity Manual Work Zone Capacity Equation

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ABSTRACT
This paper presents a proposed enhancement to the current methodology for assessing capacity in work zones. Research into the impact of driver behavior in work zone related merge areas has revealed the influence of driver behavior on flow quality when drivers encounter and respond to changing roadway conditions and lane configurations. Research suggests the implementation pf a driver familiarity adjustment factor for use in the Highway Capacity Manual work zone capacity equation similar to the factor used in the general highway capacity equation is appropriate. The value of and thereby the influence of the proposed factor is based on assessment of *driver familiarity*, *driver adaptability*, *driver aggressiveness*, and *driver accommodation* tendencies that are unique demographic groups defined by locality, region, driver experience, and/or driver age. The development of the proposed factor and the underlying concepts are a product of several years of theoretical and field-based traffic flow and human factors research. The principle embodied in the adjustment factor is that the efficiency with which drivers adjust to changing roadway conditions while interacting with other drivers on the roadway directly impacts capacity. Quantifying the adjustment factors and developing the measures associated with the assignment of a value to the adjustment factor have the potential to aid transportation professionals in better estimating the capacity of a freeway work zone and ultimately influence the development of optimal work zone strategies.

INTRODUCTION
A significant problem facing transportation planners and traffic engineers is the impact of highway work zones on the local transportation network. The problem is that in order to improve service in the long term, service in highway work zones in the short term is often negatively impacted as highway capacities are reduced by lane closures. According to FHWA (2006), work zone related closures are the cause of about 24% or more $480 billion hours of non-recurrent congestion associated delay. To deal with these consequences, planners and engineers must have a reliable method to forecast the impacts so that locally appropriate mitigating strategies can be tested and implemented. In order for these methods to be reliable and accurate, they must recognize and appropriately respond to each of the key variables that affect highway capacity under lane drop situations. Recent research has focused on the decomposition of the work zone phenomenon into discrete contributing factors and there has been significant work in gathering the empirical data required to develop relationships among individual factors that influence speed shifts and shockwaves in work zones. Previous research by the authors' has identified the critical influence of individual and collective driver behavior. This paper presents a driver behavior factor for capacity analysis purposes that quantifies the effect of driver behavior in the merge area approaching a lane drop. Within the paper, the driver behavior factor is decomposed to examine driver behavior influences related to the drivers' familiarity with the environment, ability to adapt to changing conditions, tendency towards aggressiveness, and the willingness to accommodate the needs of others. Decomposition to this level allows the current HCM work zone capacity assessment methods to be enhanced to recognize the influence of unique demographic groups defined by locality, region, driver experience, and/or driver age. Incorporating the effects of these foundational level influences on merge into work zone capacity assessment will help planners and engineers account for driver characteristics and driver demographics as they change by season, by day of the week, and by hour of the day. The purpose of this paper is to introduce the new driver behavior factor and compare its effect to field studies conducted by the authors and others.

LITERATURE OVERVIEW

The HCM 2000 defines capacity as "the maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger cars per hour, or persons per hour." The HCM 2000 (Chapter 22, Freeway Facilities) distinguishes between short-term and long-term work zones and recommends that a value of 1600 pc/h/ln be used as the base capacity value for short-term freeway work zones, regardless of the lane closure configuration. It is stated that this base value may be higher or lower when adjustments are applied in accordance to the specific work zone's prevailing conditions. The intensity of work activity—characterized by the number of workers, types of machinery, and proximity of travel lanes to work under way—can effect the capacity, increasing or reducing the base value by up to ten percent. Also, the HCM 2000 states that the effect of heavy vehicles should be considered, as truck presence leads to reduction of capacity. Another element reducing the base capacity value is the presence of ramps. The HCM 2000 provides the following equation (Equation 22-2, HCM 2000) for estimating capacity at work zones, which considers reductions due to the three elements discussed above:

$$c_a = (1{,}600 + I - R) * f_{HV} * N \qquad \text{(Eq. 1)}$$

Where:
c_a = adjusted mainline capacity (veh/h)
f_{HV} = adjustment for heavy vehicles; defined in HCM Equation 22-1
I = adjustment factor for type, intensity, and location of the work activity (ranges from -10% to +10% of base capacity, or -160 to +160 pc/h/ln)
R = adjustment for ramps
N = number of lanes open through the short-term work zone

HCM 2000 also provides capacity values for long-term construction zones. For a two-to-one lane closure the average capacity is close to 1,550 veh/hr/ln if a crossover is present and the manual suggests that this capacity may be as high as 1,750 veh/hr/ln if there is no crossover but only a merge to a single lane. In the case of a three-to-two lane closure, the capacity ranges between 1,780 and 2,060 veh/hr/ln (Exhibit 22-4, HCM 2000).

An additional factor discussed in the HCM 2000, which would decrease capacity and can be considered for both short-term and long-term work zones, is the lane width. It is stated that capacity may decrease by 9-14% for lane widths of 10-11 ft. Note that this factor is not included in the capacity estimation equation, nor does the HCM discuss potential interactions between the various factors affecting capacity.

Work Zone Capacity in the Literature

Krammes and Lopez (1994) presented recommendations on estimating the capacities of short-term freeway work zone lane closures. This research served as the basis for the HCM 2000 methodology. The study consisted of analyzing lane closures in Texas between 1987 and 1991. The data collected represent over 45 hours of capacity counts at 33 different freeway work zones with short-term lane closures. The results of their study showed an average short-term work-zone lane closure capacity value of 1600 pcphpl.

Dixon et al. (1996) defined and determined work zone capacity values for rural and urban freeways without continuous frontage roads. Variables studied are as follows:

- Night versus day construction
- Intensity of work activity (heavy, moderate, or light)
- Proximity of work to active lanes
- Proximity of interchanges to the work zone
- Work zone configuration

Research by Maze *et al.* (1999) evaluated traffic flow behavior at rural interstate highway work zones and estimated the traffic carrying capacity of work zone lane closures. Through analysis of these data, a work zone lane closure capacity from 1,374 to 1,630 passenger cars per hour was estimated. Additional research was completed by Maze *et al.* (2000) considering the capacities of work zones in rural Iowa. The research concluded in the report that the capacities in rural Iowa for work zone lane closures varied from 1,400 to 1,600 passenger cars. This capacity estimation assumed a passenger car equivalency (PCE) value of 1.5 for heavy vehicles.

Sarasua *et al.* (2004) conducted a study in South Carolina to determine the number of vehicles per lane per hour that can pass through short-term, interstate work zone lane closures, with minimum acceptable levels of delay. The methodology was developed based on a 12-month data collection period during 2001-2002 from 22 work zone sites along South Carolina's interstate system. The research recommended a base capacity value of 1460 pcphpl.

Al-Kaisy et al. (2000) used field data to investigate freeway capacity at long-term lane closures due to rehabilitation work. Data from two lane closures at the same construction site (eastbound and westbound) were examined. The site is located on the Gardiner Expressway in the southern part of downtown Toronto. Data were collected during 4 days, totaling around 53 hours of congested traffic operations. Results showed significant variation in freeway capacity in the work zones.

Al-Kaisy and Hall, (2001) examined the effect of driver population at Freeway Reconstruction Zones. Driver population refers to the mix of driver types in a traffic stream by trip purpose. Two aspects of driver characteristics are viewed as being related to the trip purpose. The first is the familiarity of drivers with the facility and its environs, which is thought to affect the efficiency of facility use by drivers. The second and less evident aspect is the value of time perceived by drivers for a specific trip purpose and its potential effect on driver behavior and, consequently, on the efficiency of use of a highway facility. On the basis of a factor of 1.0 for commuter traffic, a driver population factor of 0.93 was estimated for the afternoon peak period and a driver population factor of 0.84 was estimated for weekends. Also, the driver population factor is likely responsible for a capacity reduction on weekends compared with the capacity on weekdays. This capacity reduction was 12 percent in one direction of travel and 17 percent in the other direction.

Al-Kaisy and Hall (2003) re-examined freeway capacity of long-term reconstruction zones and developed site specific work zone capacity models. Data collected at six reconstruction sites in Ontario, Canada, with different types of closure indicate that the capacity ranges between 1,853 and 2,252 pcphpl, which suggests a mean estimate of capacity at 2,000 pcphpl.

Ping and Zhu (2006) used CORSIM to derive work zone capacities under various network configurations. The parameters tested for their experimental design consisted of the number of open lanes, the free-flow speed in the normal freeway segment and in the work zone, grade, truck percentage, location of warning sign and location of closed lane. The derived capacity was found to range between 1,320 vphpln and 1,920 vphpln depending on the level of each parameter.

Table 1 summarizes the results of the studies referenced in the literature review. These values will be compared to the values from the simulation study and the field studies conducted in the research.

Table 1: Freeway Work Zone Capacity Studies

Study	Capacity Estimate
Krammes and Lopez (1994)	1600 pcphl (Short Term WZ)
Maze *et al.* (1999)	1,374 to 1,630 pcphl
Maze *et al.* (2000)	1,400 to 1,600 pcphl
Sarasua *et al.* (2004)	1460 pcphpl (Short Term WZ)
Al-Kaisy et al. (2000)	1,600 pcphpl
Al-Kaisy and Hall (2003)	1,853 and 2,252 pcphpl (Long Term WZ)
Ping and Zhu (2006)	1,320 to 1,920 vphpl (Simulation Study)

Speed-Flow Curves and Driver Behavior in Work Zones

The relationship between vehicle density, speed, and flow is the fundamental principle behind highway capacity assessment. Early work conducted by Greenshields offered representations of those relationships that enabled the discipline of capacity-based transportation planning. The relatively simple relationships developed by these researchers, in particular, the Greenshields model, provided a computational schema that provides the basis for generalized link performance curves which power transportation planning and assessment models. Since Greenshields (1935) published his groundbreaking findings in the 1930s, researchers have attempted to improve and adapt the curves to more accurately reflect the actual density, speed, and flow relationships found on modern highways under modern conditions given modern driver behavior. The results of this research are continuously reviewed and incorporated into authoritative capacity analysis methods as presented in the Highway Capacity Manual. The curve fit proposed by Greenshields was parabolic in shape supporting an easy mathematical representation of the speed-flow relationship. Although later research has concluded that the parabolic shape does not hold true through the entire range of speed-flow combinations, the original concept provides the basis for understanding and serves as a point of departure for discussion of the impact of specialized speed-flow relationship influences such as those associated with changes in roadway geometry conditions including those encountered in work zones and/or those associated with different driver population demographics.

While the Greenshields' curve is representative, it is an empirically derived representation of highway performance and, therefore, is reflective of highway sections that have specific geometric characteristics and specific driver behavior characteristics. As these two major factors

change due to construction in the case of geometry, time of day, or in the case of driver behavior characteristics, the actual curve will likely change shape reflecting the real world conditions. Figure 1 illustrates the principle that a change in roadway geometry and the additional visual queues that a work zone provides will have an impact on the way in which the speed flow curve is shaped and on the point of maximum flow. The inside line shows the degradation in traffic flow from "normal" traffic flow.

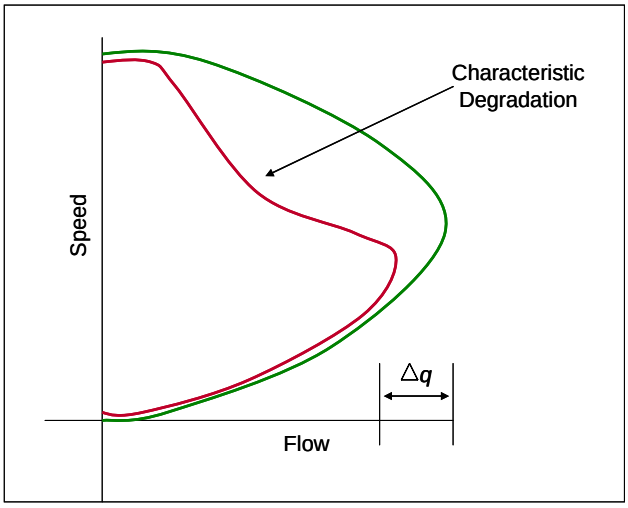

Figure 1: Illustration of Degradation of Traffic Flow Caused by the Introduction of a Work Zone

Two major factors likely to influence the change in shape and the point of apex are the significance in the geometric disturbance associated with the work zone and the ability of the driver population to adapt to the changing conditions. Further, in order to be useful to planners, study of the driver behavior factor must develop linkages with conventional, measurable transportation and highway design considerations. Figure 2 is an illustrative decomposition and linkages with the type of information used in conventional transportation planning activities. The decomposition suggests that driver behavior is influenced by familiarity, adaptability, aggressiveness, and accommodation of others and that these characteristics are specific to different times of the day, different demographic (age/experience) groups, and different populations reflecting regional or local tendencies.

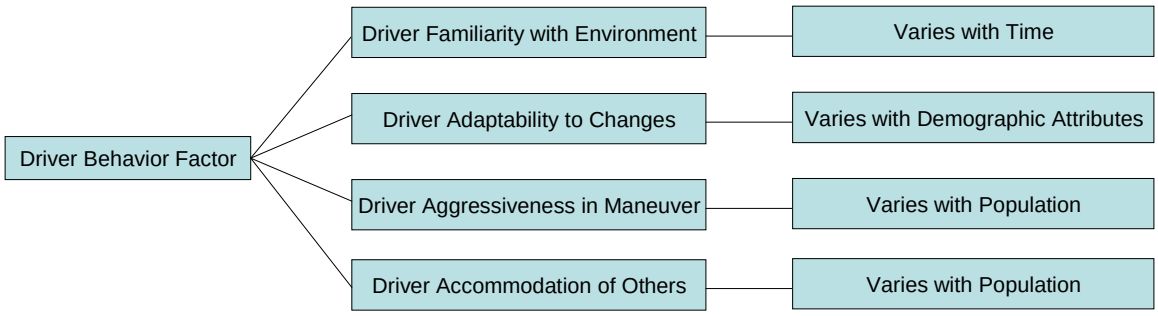

Figure 2: Illustrative Decomposition and Linkages of the Presented Concepts

Appropriate driver behavior factor decomposition and strong linkages with measurable planning factors will aid in calibration of speed-flow diagrams that can more accurately represent non-standard highway conditions such as work zones. Work zones concentrate many of the challenges that influence capacity given changing roadway conditions and increased cognitive loads on drivers. Calibration methods for developing speed-flow relationships need to provide a means for predicting speeds at any traffic volume and need to yield estimates of several key parameters such as the capacity, free-speed, and jam density (Van Aerde and Rakha, 1995).

Calibration efforts require that decisions be made on the process, namely:

- What functional form will be calibrated?
- What will be considered to be the dependent and the independent variables?
- What will be defined as the optimum set of parameters?
- What technique will be utilized to compute the optimum set of parameter values (Van Aerde and Rakha, 1995)?

Calibration considers speed, flow, and density as dependent variables and that relative error in speed, density, or volume of equal magnitude should be considered to be of equal importance. Work zone adjustment factors can be adjusted based upon the drivers that populate the work zone and the type of work zone. The following sections offer new concepts and an approach that may help researchers address the capacity analysis issue in work zones.

Strategic Game Theory and Modeling Driver Behavior in Work Zones

In order to accurately modify the relationships between vehicle densities, speeds, and flows in a work zone requires a structure for the quantification of driver behavior. One of the major challenges in the quantification of driver behavior is that it is not an exact science because, under differing circumstances, the same driver can display very different driver behavior. These situations include running late for a meeting or being unfamiliar with the roadway. This proves that a driver's behavior entering a work zone is an action that includes a large amount of uncertainty. Strategic game theory has been used in the past to model processes that contain uncertainty in many fields including human behavior. John Nash pioneered this simple yet powerful approach to modeling processes and scenarios with uncertainty. Strategic game theory has been proven to be an effective modeling tool for economists and scientists.

Nash's equilibrium states that when all participants are playing their best move to every other participant's best move, no one is going to move. This is especially the case in traffic flow under congested conditions. In free flow conditions and jammed conditions, the driver's decisions are not of consequence. Density under free flow conditions does not warrant a traffic stream impact from the interactions of drivers and at the jam density the impacts are not felt because there is not adequate density for there to be a propagation of the effect. When volume is at the jam density, there is not sufficient speed to propagate the effects in the work zone.

STUDY SITES AND FIELD DATA COLLECTION

Two sites were selected for data collection. The first site was along Interstate 91 Southbound in Greenfield, Massachusetts and the second site was located in Jacksonville, Florida along Interstate 95 Northbound. The Interstate 91 project was a 2 to 1 lane bridge replacement work zone and the Interstate 95 project was a 3 to 2 lane work zone. The Interstate 91 project did not

experience breakdown before the introduction of the work zone, however, the interstate 95 project regularly experienced congestion prior to the introduction of the work zone. The Interstate 91 project is denoted as "Massachusetts Site" and the Interstate 95 project is denoted as "Florida Site". The Massachusetts Site data were collected using pneumatic tubes and automated data collection equipment. The speeds and data were verified with manual counts of vehicles and LIDAR data collection. The Florida Site data were collected via the SUNGUIDE ITS camera system in Jacksonville calibrated with the Florida ITS Central Data Warehouse and Autoscope automated data collectors.

The posted speed limit in the vicinity of the Florida site was 65 mph (approximately 105 kph) and the Massachusetts site had a posted speed limit of 60 mph. Free flow speeds during off-peak time periods were found to range between 65 mph and 75 mph (approximately 105 kph and 75 mph) for the Florida site and the Massachusetts site free flow speeds ranged between 55 and 65 mph. Traffic volumes at the Massachusetts site are very heavy on Sunday afternoons due to recreational traffic from vacation points in Vermont and in the weekday PM peaks due to commuting traffic. The weekend peak periods commonly experienced congestion for several hours while the weekday peak congestion did not persist for more then an hour. The Florida Site work zone experiences heavy congestion during weekday afternoon peak periods, and breakdowns in traffic flow are typical during these peak times. It is not uncommon for congested conditions to persist for several hours.

Figure 3 presents the lane geometry of the Massachusetts Site located south of the interchange of State Route 2 in Greenfield, MA. At this site, data was collected in positions represented by the blue boxes in the figure. Figure 3 also illustrates the lane geometry at the Florida Site, located north of the Golfair Blvd. At both sites data was collected in positions represented by the blue boxes in the figure.

Archived data for seven full days were obtained from the Massachusetts site and for ten weekdays from the Florida site. The sampling periods ranged from 4 to 24 hours per day. The data were closely examined for erroneous detector readings and summarized using a spreadsheet. In addition, the speed and flow rate data were cross-checked with data at adjacent detector stations to ensure that all subsequent analyses reflected work zone imposed capacity constraints, as opposed to merely queue spillback resulting from downstream congestion.

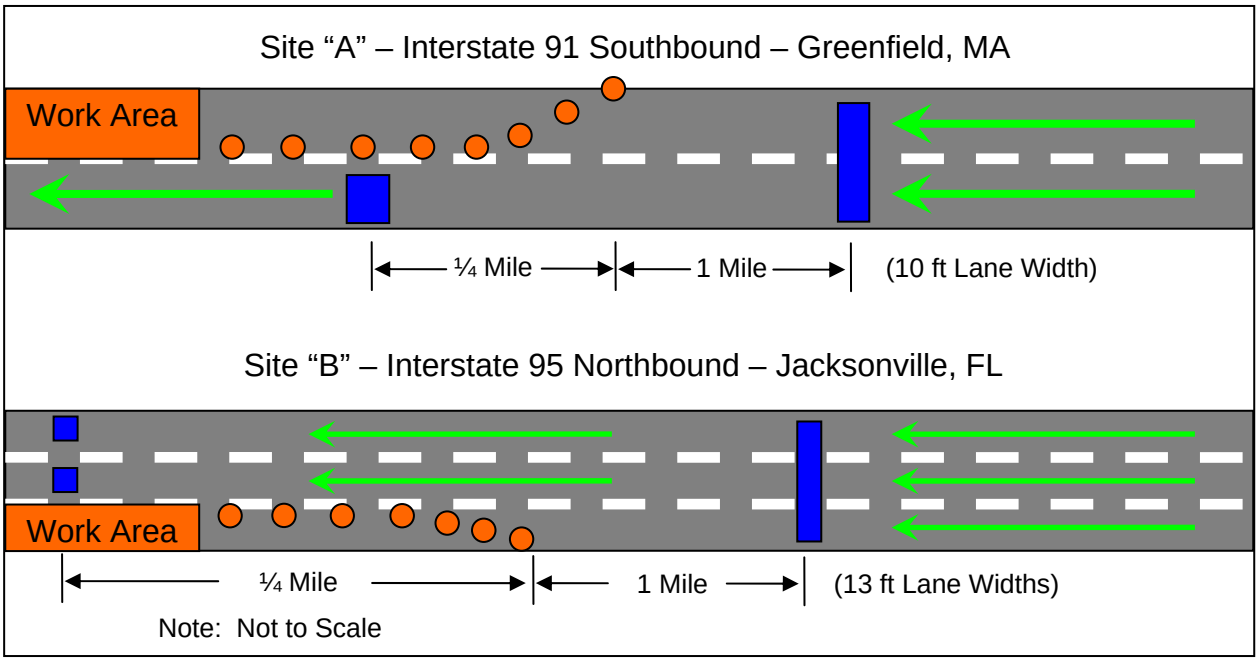

Figure 3: Layout of the Field Study Locations

DATA ANALYSES

Data analysis began with a detailed examination of both field sites focusing on data collected before, during, and after transitions from non-congested to congested flow. For each day of data obtained, time series plots of flow and speed were generated to examine and quantify changes in these variables. This analysis was conducted in accordance to a procedure detailed by Elefteriadou and Lertworawanich (2002). The following analyses were undertaken:

1. *Identify and quantify each transition interval from non-congested to congested flow, i.e., breakdown event, and document the corresponding* ***breakdown flow****.*
2. *Identify and document the* ***maximum discharge flow****.* This flow is the maximum observed at the site after the occurrence of breakdown, and prior to recovery to non-congested conditions.

Figure 4 illustrates these two variables in a single time-series plot (corresponding to a single breakdown event) of flows and speeds. As shown, these flows differ in magnitude.

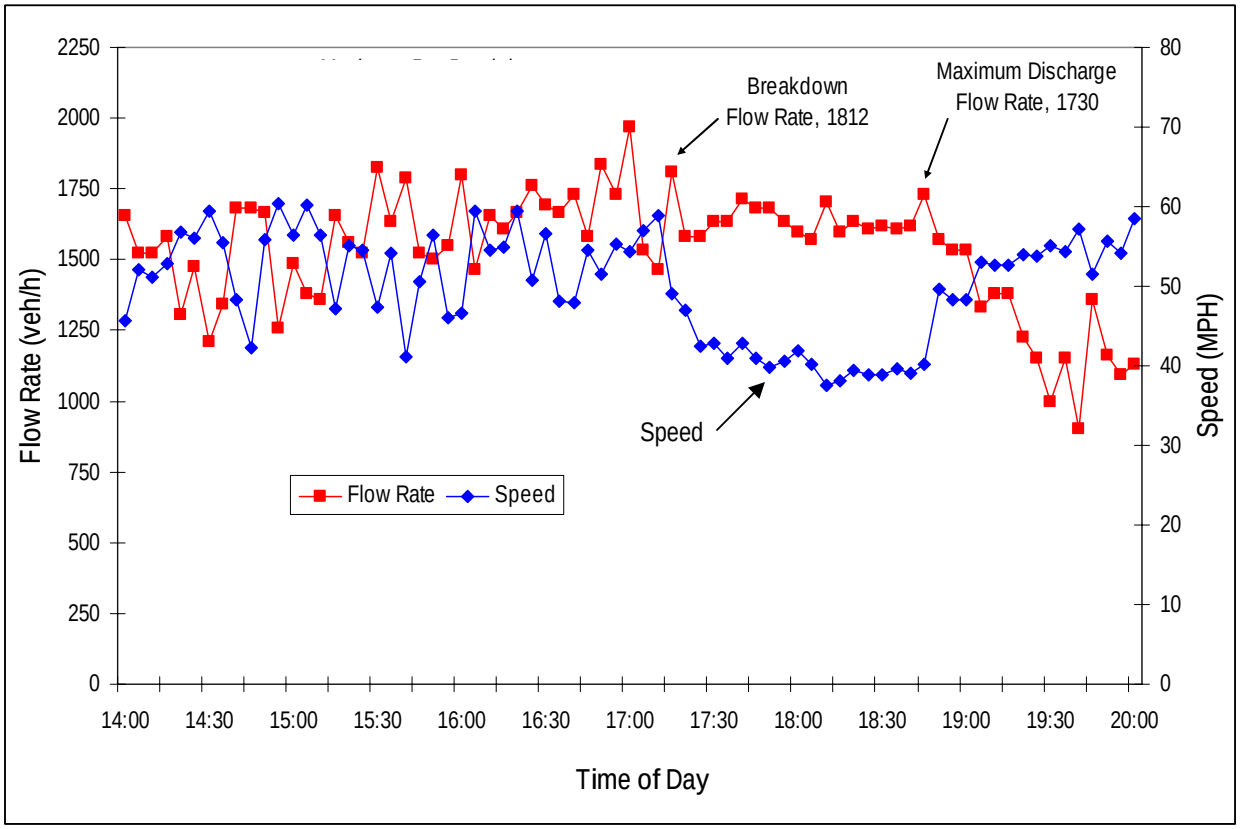

Figure 4: Illustration of the Three Parameters of Time Series

Each of these flow rates (the breakdown flow and the maximum discharge flow) were obtained for each breakdown event. These flows were obtained for 5-min analysis intervals. As the figure shows for the Massachusetts work zone, the maximum flow rate was the pre-breakdown flow rate. The breakdown flow rate was lower then the maximum discharge rate.

Additional detailed analysis was performed in order to determine the capacity in each work zone. In order to visualize the capacity during breakdown in each work zone frequency diagrams were developed for each site and for each of the three flow parameters for all days where data collection was conducted. Table 2 presents the minimum and maximum values, as well as the mean and standard deviation for each flow parameter for a 5-min aggregation interval, at the two sites.

Table 2 : Work Zone Data Collected from Field Studies

Florida Site

Breakdown	Breakdown Flow	Max Discharge Flow	Average Discharge Flow	Std. Dev. Congested Flow
Min Value	1818	1980	1792	33
Max Value	2250	2472	2114	226
Mean	2052	2176	1992	118
Std. Dev.	167	119	79	55

Massachusetts Site

Breakdown	Breakdown Flow	Max Discharge Flow	Average Discharge Flow	Std. Dev. Congested Flow
Min Value	828	1080	858.6	25
Max Value	1692	1968	1658.4	178
Mean	1165	1433	1245	117
Std. Dev.	320	317	293	50

The Florida site experienced 14 breakdowns in the ten observation days and the Massachusetts site experienced nine breakdowns in the seven day observation period. The mean maximum discharge rates were the highest flows and the breakdown flows as the lowest values. The total flow for the Florida site has a standard deviation between 79 to 167 vph for all three of the flow rates and the Massachusetts site had a standard deviation between 320 to 558 vph. The ranges for all three flows were lower for the Florida and Massachusetts sites; however, the flows at the Florida site experienced much higher flow rates in the breakdown, maximum discharge, and average congested flows. The authors' observations from the video data collection suggested that the Florida drivers engaged in more cooperative driver behavior then the Massachusetts drives and the data suggests that this observation was significant.

The next section presents the flow rates under congested conditions for each of the two sites. The flows are presented in a histogram form and provide a view of the flows under congested conditions at both locations.

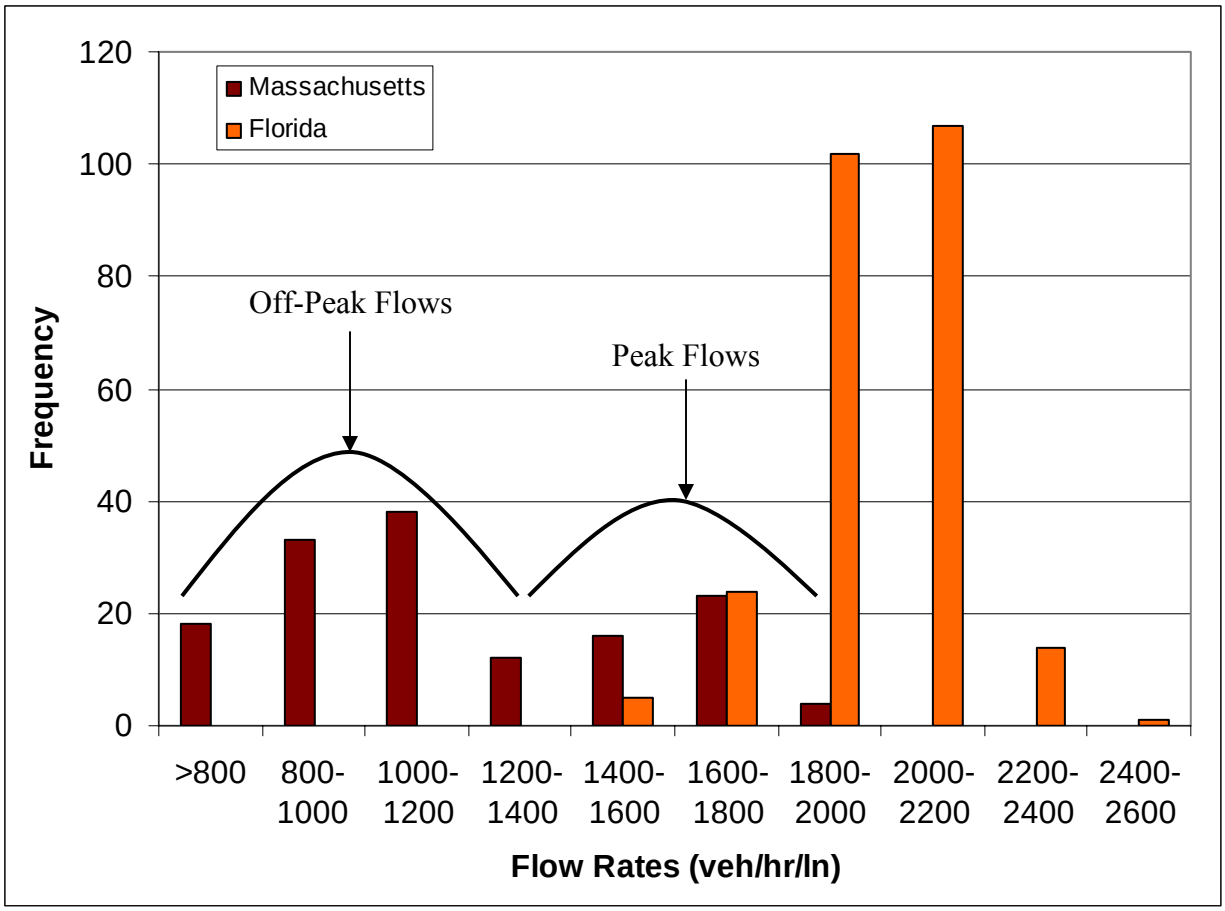

Figure 5: Congested Total Flow Rates w/ 5 Minute Aggregation

Figure 5 shows the congested flow rates for both sites. At the Massachusetts site, there is a two flow regime between flows during congestion. The histogram shows the number of 5-minute observations during congestion for each bin of 200 vph. There are two flows from 700 to 1200 vph centered at 1000 and from 1200 to 2000 vph centered at 1600 vph. At the Massachusetts site, there is a two flow regime between flows during congestion. The peak hour congestion is shown under the right distribution under the black curve and the off-peak congestion is shown under the left curve. There is small overlap area in the range of 1200-1400 vph where the low end of the peak flows meets the high end of the off-peak flows. The Florida site the congested flows were centered in range of 1800-2200 vphpl. The flows at the Florida site show again that more cooperative driver behavior provides a better flow regime which produces a higher flow rate.

Development of a Driver Population Factor

The HCM methodology provides capacity values from 1440 vphpl to 1760 vphpl for freeway work zones. The field study associated with this research along with past research studies have shown that work zone capacity values can vary from the values in the HCM. The field study shows that the saturation flow rates varied from 750 vphpl to 2500 vphpl. The reason for this variation is the driver behavior and the drivers' reaction to the work zone traffic control. The product of this research is to provide adjustment factors to support the current methodologies.

The driver behavior factor was based upon the observations from the field studies and is designed to provide with professionals with an intuitive and simple way to quantify driver behavior on the roadway. The four different factors of *familiarity, adaptability, aggressiveness, and accommodation* should be determined by transportation professionals in the area that experience the driver population. The high, medium, and low values are designed to account for the variability in the driver population. The analyst can describe the driver population as a high, medium, or low without having to account for every vehicle in the population. This methodology can be used to describe the effects of driver behavior and worker intensity. The adaptability variable can be used to describe the presence of workers and the drivers' reaction to the presence of workers.

Based on the data collected, driver population adjustment factors were calculated and are presented in Table 3. As shown in Table 3, the familiarity factors range from 1.25 to .8 which is based upon the video data analysis of the driver behavior at both sites. The determination of these factors was from the analysis of the peak and off-peak populations seen in the Massachusetts site and the high degree of flow that was seen in the Florida site. The driver behavior factors range from 1.1 to .8, which was determined from the capacity decreases caused by incompatible merges seen in the Massachusetts site where the maximum flow is very similar to the HCM capacity estimates and the incompatible mergers that were seen in the video data collection.

Table 3: Driver Familiarity and Behavior Adjustment Factors for Freeway Work Zone Capacity

Familiarity	Adaptability	Familiarity Factor
High	High	1.25
High	Medium	1.1
High	Low	1.0
Medium	High	1.0
Medium	Medium	.9
Medium	Low	.8
Low	High	.95
Low	Medium	.9
Low	Low	.8

Aggressiveness	Accommodation	Behavior Factor
High	High	1.0
High	Medium	.9
High	Low	.8
Medium	High	1.1
Medium	Medium	1.0
Medium	Low	.9
Low	High	.9
Low	Medium	.85
Low	Low	.8

Equation 2 presents the combination of the two factors presented above that are combined to form the driver population factor. The lookup table above provides a simple way for professionals to make adjustments to their capacity estimates by implementing the driver population factor. The driver population factor ranges from 1.375 to .64 which approximately replicates the range of values seen in the field studies. These factors were used to account for the large differences between the capacity values reported from the HCM equation and the data collected from the field studies. Based on the field survey in this study, the range of driver

population factors is summarized and is presented in Table 4. The table also shows the high, medium, and low scenarios.

$$\text{Familiarity Factor} * \text{Behavior Factor} = \text{Driver Population Factor} \qquad \text{(Eq. 2)}$$

Table 4: Driver Population Adjustment Factors for Freeway Work Zone Capacity

Familiarity	Adaptability	Aggressiveness	Accommodation	Driver Population Factor
High	High	Medium	High	**1.375**
Medium	Medium	Medium	Medium	**.9**
Low	Low	Low	Low	**.64**

The driver population factors included in either Table 4 could be used with other adjustment factors in HCM to perform capacity analysis in freeway work zones. Due to the fact that the driver population factor developed in this research is not reflected in the current HCM work zone capacity calculation it is recommended that it be added as a complement to the current equation.

SUMMARY OF FINDINGS

This paper presented an investigation into the effect of the driver population on the capacity of long-term freeway work zones. The work zones examined showed that the characteristics of the driver population may have a significant impact on the capacity. The Massachusetts site showed that difference between peak and off-peak capacity and the effects of familiarity and adaptability to the work zone. The Florida site gave insight to the ability for capacity to be higher then the current values in the HCM because of driver behavior which was observed to be cooperative. The two field studies provided an excellent opportunity to investigate the effects of driver population in freeway work zones.

The Massachusetts site had data that was collected for 24 hour periods which provided insight to the off-peak congestion in a location that would not experience congestion without the presence of a work zone. The Massachusetts site also provided an opportunity to compare the peak period congestion characteristics to the off-peak congestion characteristics. The comparison of the periods confirmed researchers' observations that the traffic flow was much different in the peak and off-peak periods. The Florida site provided an opportunity to compare the Massachusetts driver population with the Florida driving population. The Florida driving population was observed as much more cooperative then the Massachusetts and the data also confirmed that the increased cooperativeness provided a higher capacity on the roadway because of the cooperation between drivers. These values resulted in values that were higher then any other reported work zone capacity in the literature surveyed.

The research results supports that the driver population has a significant effect on the capacity of freeway work zones and also confirmed that higher capacity can be achieved from the recommendations currently in the HCM. The study recommends that a factor of 1.375 can be applied to the work zone capacity formula under cooperative driving conditions and a factor of

.64 can be applied to the most incompatible and uncooperative driving populations. The structure provided allows for analysts to have a simple and intuitive approach to the quantification of driver behavior in work zones and allows for simple recalibration due to the changes in driver population due to time of day, day of the week, season of the year, or special event traffic.

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