

## **GROUP 1 (A)**

### **TITLE: Freight Impact on Highway Capacity and Level of Service for Urban Conditions**

#### **RESEARCH PROBLEM STATEMENT**

Freight traffic growth has contributed to the growth in vehicle miles traffic as truck traffic has increased at a rate faster than person travel. Trucks also have a disproportionate impact on roadway capacity particularly on networks dominated by arterials and local streets. Depending on the context, a large truck can consume the equivalent of several cars worth of roadway capacity due to the physical size, the acceleration, turning radius and other performance characteristics.

This disproportionate growth in truck volume can be attributed to a number of factors including the dispersion of population and employment, the shift of many freight items from rail and other modes to truck and the changes in the economy and business practices such as just-in-time deliveries of inventory items that increase delivery frequencies.

The HCM, the world's leading source for highway capacity and level of service determinations, provides fairly constant passenger-car equivalence factors by roadway type. For example, the equivalence factor for signalized intersections is 2.0. A growing number of professionals question these values, especially under congested conditions. In stop-and-go traffic, large tractor trailers have a much slower start up time than passenger cars. Especially relevant are the equivalencies of trucks in areas where loading zones are present.

There is a growing need to quantify the actual affects of trucks on our urban areas to support the ability to safely and efficiently move goods and people in areas where expansion of roadways is generally not an option. Planners and engineers need to be able to more effectively quantify the impacts of locating shipping intensive land uses and improve the inputs to the tools used to manage traffic.

With increasing numbers of trucks in our cities and towns providing goods more frequently there are three vehicular occupants groups to consider. One group in the traditional perspective of the HCM is the auto-driver, and the impact of trucks on delay and travel reliability. The second group from the perspective of users of the Transit Capacity Manual and transit users is the delay and safety impacts from trucks both along routes and at bus stops. The third group is truck drivers who are concerned with reliability, access, and safety during on-street loading and loading activities.

## **RESEARCH OBJECTIVES**

The objective of this research is to develop improved, nationally accepted capacity and level of service techniques that better account for trucks in urbanized areas with the intent of updating the HCM. As a secondary objective, the research should inform users of the Transit Capacity Manual what topics might be pursued on the interaction between truck and bus activities in urbanized areas.

## **RESEARCH PROPOSED**

The following potential tasks should be considered:

1. Conduct a literature review focusing on two areas: the impact of trucks on arterials, intersections and how truck drivers evaluate level of service.
2. Create a typology of roadway types and elements that are affected by freight movements. For example, roadway types may be Class I arterials or two-lane highways interrupted by signals. Roadway elements may include variable effects of lane width by roadway type, turning radius for right turns and presence or absence of loading zones.
3. Collect field data from around the nation reflecting the impact of truck movements, truck types, roadway types, roadway elements.
4. Assess trucker perceptions of quality of service based on different traffic, roadway, and control conditions, as well as operating results focusing on pick-up and delivery as opposed to long haul activities.
5. Compare the results with procedures in the HCM2000. Coordinate with the HCQS committee and the Committee on Transit Capacity and Quality of Service. Recommend new equivalence factors and or additional variables for use in the HCM's interrupted flow methodologies.
6. Develop technical reports summarizing findings and recommendations.

## **ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD**

Estimate of required funding: \$500,000

Expected duration: 2.5 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 1 (B)**

### **TITLE: Moving America Over the Road -- Trucking's Impact on Highway Capacity and Level of Service**

#### **RESEARCH PROBLEM STATEMENT**

Freight traffic growth has contributed to the growth in vehicle miles traffic as truck traffic has increased at a rate faster than person travel. This disproportionate growth in truck volume can be attributed to a number of factors including the shift of many freight items from rail and other modes to truck and the changes in the economy and business practices such as just-in-time deliveries of inventory items that increase delivery frequencies. At the same time an increasing proportion of the highway system is undergoing rehabilitation without increasing capacity. During construction, work zones can have less than ideal conditions from the passenger car perspective in terms of narrower lanes, but the impact on trucks and their influence on smaller vehicles through the work zone is undetermined.

Depending on the context, a large truck can consume the equivalent of several cars worth of roadway capacity due to the physical size, the acceleration, and other performance characteristics. The HCM, the world's leading source for highway capacity and level of service determinations, provides fairly constant passenger-car equivalence factors by roadway type. For example, the factors for level two-lane highways are 1.1, and for freeways and multilane highways 1.5. A growing number of professionals question these values, especially under congested conditions. In stop-and-go traffic, large tractor-trailers have a much slower start up time than passenger cars. Especially relevant are the equivalencies of trucks in work zones.

There is a growing need to quantify the actual effects of trucks on highway facilities that are either purely long-haul or dual purpose in their need to serve both commuters and long-haul freight. With more of the national system being physically or financially constrained each year, solutions for effectively moving freight traffic are needed. The ability to better quantify the impacts of the trucking fleet on capacity and quality of service as well as provide alternative solutions in terms of routing, timing, or exclusive use facilities would aid planners and engineers in providing more reliable and potentially safer travel conditions.

With increasing numbers of trucks on the nation's roadways, the impact of heavy vehicles has become a more significant factor in level of service analysis. Essentially, the HCM methodologies may be underreporting levels of service on facilities with significant truck volumes. Furthermore, level of service is primarily reported in terms of passenger car driver perceptions. However, truck drivers may experience different perceptions. For example, truckers may evaluate the effect of narrow lanes and stop and go traffic far worse than passenger car drivers or their evaluation criteria may be based on reliability rather than speed.

## **RESEARCH OBJECTIVES**

The objective of this research is to develop improved, nationally accepted capacity and level of service techniques that better account for trucks with the intent of updating the HCM.

## **RESEARCH PROPOSED**

The following potential tasks should be considered:

1. A literature review of the impact of trucks on essentially uninterrupted flow highway facilities, how truck drivers evaluate level of service, and operational experience with truck-only facilities.
2. Create a typology of roadway types and elements that are affected by freight movements. For example, roadway types may be freeways/multilane highways, two-lane highways, and interrupted flow arterials with widely spaced intersections. Roadway elements may include grades, truck lane restrictions, frequency of access via ramps or intersections or work zones.
3. Collect field data from around the nation reflecting the impact of truck movements, truck types, roadway types, and roadway elements on similar facilities with and without work zones to the extent possible. If truck only facilities exist with conditions reasonably similar to U.S. driving conditions and geometry, obtain operational capacity and level of service information.
4. Assess trucker perceptions of quality of service based on different traffic, roadway, and control conditions, as well as operating results.
5. Compare the results with procedures in the HCM2000. Coordinate with the HCQS committee. Recommend new equivalence factors for use in the HCM.
6. Develop technical reports summarizing findings and recommendations.

## **RESEARCH FUNDING AND DURATION**

Estimate of required funding: \$300,000

Expected duration: 2 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 1 (C)**

### **TITLE: Multimodal Intersection Level of Service**

#### **RESEARCH PROBLEM STATEMENT**

Throughout the U.S. there is a desire to evaluate the quality of transportation service of its roadways from a multimodal perspective. The Transportation Equity Act for the 21<sup>st</sup> Century (TEA-21) calls for the mainstreaming of transit, pedestrian and bicycle projects into the planning, design and operation of the U.S.'s transportation system. Largely in response to TEA-21, NCHRP Project 3-70 (Multimodal Level of Service for Urban Streets) has been funded and is nearing completion. Whereas that project concentrated on integrating modal level of service analyses at the facility level and incorporating those techniques into the HCM, it did not concentrate on multimodal interactions at the intersection level, where the greatest amount of interaction among the modes occurs.

The current signalized intersections and unsignalized intersections chapters of the HCM2000 essentially only address the level of service of the automobile mode. Automobiles, buses, pedestrians, and bicycles are all potential users of urban street intersections. At urban street intersections the modes also interact with each other such that improvements in quality of service to one mode may improve or lower the quality of service for another mode.

Compounding the problem of an integrated multimodal approach to evaluate intersections is relatively little research conducted on how actual travelers evaluate quality of service at intersections. Level of service for motorized vehicles in the HCM2000 is based on control delay, but that service measure has not been verified. Recent pedestrian and bicycle research in Florida has involved actual pedestrians and bicyclists in determining level of service thresholds at intersections. Initial conclusions are that the level of service thresholds among the modes do not align well. For example, LOS D for travelers in motorized vehicles may be considered quite acceptable, whereas for nonmotorized vehicle travelers, LOS D may be considered quite bad.

#### **RESEARCH OBJECTIVES**

The objective of this research project is to develop a multimodal urban street intersection level of service analysis methodology and to document the methodology for the next update of the HCM. Major research activities would involve:

- developing and validating quality/level of service performance measures and thresholds for travelers in motorized vehicles based on actual traveler perceptions,
- developing and validating quality/level of service performance measures thresholds for pedestrians and bicyclists based on actual traveler perceptions,

- developing a simultaneous, integrated multimodal urban street intersection analysis methodology, and
- documenting the methodology for use in the next update of the HCM.

#### **ESTIMATED FUNDING AND RESEARCH PERIOD**

Estimate of required funding: \$500,000

Expected research duration: 2 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## GROUP 1 (D)

**TITLE:       Development of a Procedure for Predicting Traffic Capacity in Work Zones**

### PROBLEM STATEMENT

Motorists frequently experience deteriorated traffic conditions caused by work zones. Highway agencies need to predict the effect of work zones on traffic performance to properly design and manage work zones for avoiding excessive delays and risk of crashes.

Volumes VIII and IX of the FHWA Traffic Analysis Toolbox series provide guidance to decision-makers and analysts regarding the role of analytical tools in work zone planning and management, the selection of a transportation modeling approach, and specific project applications<sup>1,2</sup>. Additional guidance can be found in the final report of an FHWA study for developing and implementing transportation management plans for work zones and work zone impact assessment.<sup>3</sup> A number of tools available to analyze the impacts of work zones are reviewed and compared in the above documents. In addition, the freeway facility procedure of the Highway Capacity Manual (HCM) and its computational engine FREEVAL can also be used for the analysis of the impacts of work zones. However, all these analysis approaches require the analysts to provide an estimate of the capacity of the analyzed work zone as an input to the analysis.

The HCM 2010 freeway facility procedure addresses the capacity reductions due to construction activities at work zones and categorizes these activities into short-term work-zone lane closures, typically for maintenance, and long-term lane closures, typically for construction. The values presented in HCM 2010 for the reductions in capacity due to short-term work zones are based on a 1994 study by Krammes et al.<sup>4</sup> For long-term work zones, HCM 2010 presents estimates of capacities from different studies but concludes that capacities through long-term construction zones are highly variable and depend upon many site-specific characteristics. The HCM recommends that it is better to base the capacity estimates on local data and experience. If such data do not exist, and cannot be reasonably acquired, the HCM states that default values provided by the HCM may be used to provide a very approximate estimation of construction zone capacity.

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<sup>1</sup> Federal Highway Administration. Traffic Analysis Toolbox Volume VIII: Work Zone Modeling and Simulation— A Guide for Decision-Makers. Publication NO. FHWA-HOP-08-029, Washington, DC, 2008.

<sup>2</sup> Federal Highway Administration. Traffic Analysis Toolbox Volume IX: Work Zone Modeling and Simulation— A Guide for Analysts. Publication NO. FHWA-HOP-09-001, Washington, DC, 2009.

<sup>3</sup> Federal Highway Administration. Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects. Washington, DC, 2006.

<sup>4</sup> Krammes, R. A. and G. O. Lopez. Updated Capacity Values for Short-Term Freeway Work Zone Lane Closures, In Transportation Research Record 1442, TRB, National Research Council, Washington, D.C., 1994, pp. 49–56.

## **RESEARCH OBJECTIVES**

The research objective of the proposed study is to develop procedures to estimate capacity reductions at work zones. The procedure will account for various influencing factors such as facility types, traffic control, zone configurations, work zone locations, work zone activities, vehicle composition, and other specific influencing factors within the work zone environment. Separate procedures will be developed for long- and short-term work zones.

## **RESEARCH PROPOSED**

The research will include field data collection at a wide variety of work zones in various states throughout the country. Simulation will be considered as option to expand or supplement the number of studied situations if the field data is insufficient. The outcome of this research will be a procedure that predicts varying levels of capacities for specific work zone situations.

## **RESEARCH FUNDING AND DURATION**

Estimate of required funding: \$450,000

Expected research duration: 2 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 2 (A)**

### **PROBLEM STATEMENT TITLE**

Capacity and Quality of Service Analyses for Generally Uninterrupted Flow Facilities

### **RESEARCH PROBLEM STATEMENT**

A significant gap in the HCM2000 is the facility analysis of uninterrupted flow highways. The HCM contains procedural analysis techniques for two-lane and multilane segments, but it does not contain a technique to analyze the capacity and level of service for the facility as a whole. The HCM also contains facility analysis techniques for other roadway types (i.e., interrupted flow urban streets and freeways), but not for these generally uninterrupted flow facilities. Given that the HCM is nationally accepted as the primary source on highway capacity and quality of service, not having a technical technique that addresses many of the nation's highways is a major limitation.

Most of the research conducted on two-lane and multilane uninterrupted flow segments were conducted in rural areas. Although not predominant, numerous situations exist in developed areas (e.g., small towns, causeways in metropolitan areas) in which capacity and quality of service analysis techniques are needed.

In the majority of rural situations, capacity analysis is relatively meaningless because capacity is nearly never met. Capacity for highways containing these segments is usually caused by some isolated signalized intersections or other control conditions related to more developed areas. These factors should be considered in analyses of uninterrupted flow facilities.

In using existing uninterrupted flow two-lane highway segment techniques, states get poor or even failing level of service results in developed situations. This often leads to costly roadway expansion and excessive highway widenings in small communities in order to meet level of service standards. By having more appropriate level of service measures for these types of facilities, states can better allocate their scarce resources.

No research has been performed to determine how actual drivers perceive the quality of service provided by these highways. Level of service thresholds have been set by knowledgeable professionals without actually being based on driver perceptions. Also, no research has been conducted on how bicyclists perceive levels of service on the segments or these facilities as a whole.

### **RESEARCH OBJECTIVES**

The objective of this research is to develop nationally accepted capacity and quality of service techniques for generally uninterrupted flow highway facilities with the intent that the research would lead to development of a new chapter in the HCM.

## **RESEARCH PROPOSED**

The following potential tasks should be considered:

1. For generally uninterrupted flow facilities collect quality of service data in rural and developed areas for the automobile and bicycle modes.
2. Collect field data and determine default values for urban and developed situations on the capacity of generally uninterrupted flow facilities.
3. Create a typology of generally uninterrupted flow facilities considering factors such as development levels (e.g., rural undeveloped, rural developed, suburban), roadway characteristics (e.g., number of lanes, access point density, free flow speed, terrain), roadway analysis lengths and termini (e.g., isolated signalized intersections), and purpose (e.g., through movement, local traffic).
4. Assess the applicability of HCM2000 two-lane segment, multilane segment, signalized intersection, and unsignalized intersection methodologies for use in the development of a generally uninterrupted flow facility analysis.
5. Develop an operational level analytical methodology.
6. Using the operational methodology, develop planning and preliminary engineering applications based on default values and/or simplifying assumptions.
7. Determine appropriate service measure(s) or a way of combining multiple service measures encompassing various segments (e.g., two-lane segment, multilane segment, signalized intersection influence area).
8. Coordinate with the HCQS committee that oversees the HCM for implementation of results.
9. Develop technical reports of sufficient detail that project results can be relatively easily incorporated into the HCM.

## **RESEARCH FUNDING AND DURATION**

Estimate of required funding: \$400,000

Expected research duration: 2 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 2 (B)**

### **TITLE: Two-Lane Highway Safety and Operational Performance**

#### **RESEARCH PROBLEM STATEMENT**

Two-lane highways comprise a major portion of highway miles in rural, suburban, and developing areas. As such, safe and efficient two-lane highway service is important. Many two-lane highways serve as the primary means for rural access to urban areas and the interstate highway system. Recently, the National Surface Transportation Policy and Revenue Study Commission (NSTPRSC) released a long-term plan to ensure the highway system meets the nation's mobility needs<sup>i</sup>. In a similar fashion, AASHTO proposed that the federal surface transportation program focus on six objectives of national interest, which are consistent with the objectives of the NSTPRSC plan. In terms of the AASHTO objectives, two-lane highway performance directly relates to five of their six objectives and these areas are as follows: 1) interstate commerce, 2) safety, 3) congestion reduction and connectivity for urban and rural areas, 4) system operations, and 5) environmental protection.<sup>ii</sup>

Two-lane highways significantly impact key statewide transportation safety and operations performance measures, but the means to predict these measures for existing and proposed designs are very limited. Two-lane highways are a unique element of the surface transportation system, because, in many instances, they serve extreme conditions of access and mobility with often very little intervention from traffic control devices. As urban fringe and rural development continues, two-lane highway service will degrade. Coupled with a decreasing likelihood of funding for highway upgrades to four-lane highways or freeways, the nation increasingly relies on these highways to serve complex combinations of transportation needs. These needs range from accessing adjacent land, commuting, motorized and non-motorized recreation, and freight movement. In essence, designers and decision makers need the ability to analyze two-lane highway service in complex circumstances to evaluate two-lane highway safety and operational capabilities to meet diverse traveler and freight movement needs.

#### **PROBLEM**

To assess safety and operational performance, models must account for the effects of design features that practice has found to significantly impact highway performance. However, practitioners' abilities to perform safety and operational analyses are severely limited because safety analysis tools are unsupported by operations analysis tools in three important areas: 1) operations models are limited, 2) safety tools make limited use of operations data, and 3) operations models are unreliable.

**Operations models are limited:** For traffic safety, the Highway Safety Manual (HSM) and the Integrated Highway Safety Design Model (IHSDM) work in concert to assess the safety of two-lane highway design features. These features include all of the major segment design features related to vertical and horizontal alignment and auxiliary lanes. They also include intersection features and traffic control safety effects. Only the basic elements of two lane highway operations are addressed, where TWOPAS provides IHSDM with highway segment

performance. Similarly, the Highway Capacity Manual (HCM) only allows for variations in demand, grade, passing zone percentage, passing lanes, and truck lanes. However, there is no way to assess operational effects of intersections or highway alignment improvements. Because of these limitations, engineers and planners have no comprehensive means to evaluate traffic operational performance for common two-lane highway conditions.

**Safety tools make limited use of operations data:** Safety analysis tools contained in the HSM and IHSDM use volume and vehicle mix to represent traffic operation effects on safety. Although IHSDM does use a traffic model (TWOPAS) to estimate operational performance measures, these are not used to predict safety impacts. This limited use of operational performance measures restricts HSM and IHSDM predictive abilities to situations where limited vehicle interaction takes place. Vehicle interactions must be considered in order to assess safety performance where more congested conditions exist.

**Operations models are unreliable:** Recent work found the current HCM procedure estimates service measures inadequately<sup>iii,iv</sup>. In 1998, researchers relied almost entirely on microsimulation, TWOPAS, to develop the current two-lane highway procedure. Because of advances in software technology, operating system compatibility, and non-existent technical support, TWOPAS no longer functions to support further development of the HCM procedure or the IHSDM. As a result, advances in two-lane highway analysis cannot rely on the TWOPAS software.

Two-lane highway microsimulation models were developed in several countries, with capabilities similar to those in TWOPAS, such as vehicle following, passing behavior, and vehicle-roadway interaction on curves and grades. However, similar to TWOPAS and the HCM procedure, they all fall short of supporting the safety analysis tools for intersections on two-lane highways.

## **OBJECTIVE and BENEFITS**

Engineers need comprehensive two-lane highway modeling to support design decisions, which currently does not exist. The objective of this research is to develop comprehensive models for the assessment of traffic operations on two-lane highways which at the same time will provide the necessary inputs to the safety models of the HSM and IHSDM. Acquiring this modeling capability would have the following benefits:

1. Enable complete operations and safety analysis of common two-lane highway design features in a variety of circumstances.
2. Support performance analysis in complex situations existing in developing areas, transitioning from rural to denser land use conditions.
3. Advance evaluation of alternative truck routes through developed areas.
4. Fills gaps that exist in highway system congestion information for rural and developing area highways.

## **TASKS**

**TASK 1:** Determine the feasibility of making further developments using existing two-lane highway models and procedures. The major outcome of this task is the evaluation of existing models or procedures. Each evaluation will state if the model or procedure is adequate to estimate performance measures for different variables of two-lane highway traffic operations. If more than one procedure addresses a given aspect of two-lane highway operations, then researchers will rank the different procedures in terms of their suitability for application without revision, effort required to revise them, and support for desired performance measures. Variables that this task should include for this evaluation are as follows: 1) volume in each travel direction, 2) heavy vehicle proportion, 3) % grade and length, 4) no-passing zone frequency, 5) length of analysis section, 6) horizontal curve design speed, 7) sight distance, 8) auxiliary lane length, 9) turning traffic, 10) intersection traffic control, and 11) reduced speed. (Together with Task 2, this could be a potential synthesis project.)

**TASK 2:** Define performance measures that support a comprehensive two-lane highway analysis. Traffic safety, operations, emissions, freight performance, and non-vehicle performance measures are categories that should be considered. Viable measures are those that are feasibly observed with existing technologies, directly relate to user perception, and are sensitive to highway design and/or traffic control parameters. (Together with Task 1, this could be a potential synthesis project.)

**TASK 3:** Collect data to support procedure revisions and development.

**TASK 4:** Revise or develop required model procedures (vehicle only), based on Task 1 and Task 2 results. Deterministic procedures are easier to apply and should be available for two situations: planning level decisions, or quick applications where engineers require practical estimates for a point or small segment. Microscopic simulation procedures require more effort, but should be available for design and operations based corridor studies or more complex circumstances where complex interactions between highway features take place.

**TASK 5:** Researchers will develop procedures to estimate effects that vehicle and non-vehicle traffic have on each other, either at crossings or on parallel immediately-adjacent facilities.

**TASK 6:** Validate adopted procedures for modeling two-lane highway quality of service. Validation constitutes two elements: practicality and accuracy. Validation of practicality includes an assessment of the degree to which the model can be applied in real circumstances. Accuracy assesses a comparison of estimated performance measures to field observed performance measures.

## **COST and DURATION**

Cost: \$1,000,000

Duration: 5 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

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<sup>i</sup> National Surface Transportation Policy and Revenue Study Commission (2007). Transportation for Tomorrow.

<sup>ii</sup> American Association of State Highway and Transportation Officials (2008). Transportation – Are We There Yet? Reform of the Federal Surface Transportation Program – 2009.

<sup>iii</sup> Dixon, M.P., S.S.K. \*Sarepalli, and \*K. Young. 2002. Field Evaluation of HCM 2000 Analysis Procedures for Two-Lane Highways. *Journal of the Transportation Research Board: No. 1802*.

<sup>iv</sup> Luttinen, R.T. 2001. Percent Time-Spent-Following as Performance Measure for Two-Lane Highways. *Journal of the Transportation Research Board: No. 1776*.

## **GROUP 2 (C)**

### **TOPIC AREA: FREEWAYS/MULTILANE HIGHWAYS**

#### **PROBLEM STATEMENT TITLE**

Enhancements to the Current Procedure for Freeway Facilities in the HCM2010

#### **RESEARCH PROBLEM STATEMENT**

The HCM2010 contains a new procedure for estimating the operational characteristics of freeway facilities. This procedure is a collection of the procedures for basic freeway segments, ramp segments, and weaving segments. In addition to combining these segment types, the procedure allows for the analysis of over-saturated, directional freeway facilities. The aggregation of these segment types does not fully describe all freeway facilities, resulting in limitation on the current methodology. This research problem statement attempts to fill some of the known gaps and strengthen the existing methodologies.

The current freeway facilities procedure divides the facility into component segment types. An exact methodology of this segmentation has not been fully developed, particularly for those segment types that do not neatly fit into the HCM freeway segment definition. This includes the treatment of sections of freeways with long auxiliary lanes between on and off ramps; the treatment of closely spaced on and off ramps without an auxiliary lane; the treatment of lane adds and lane drops; and the minimum length of a basic freeway segment.

Research conducted during the initial development of the freeway facilities procedure showed that the weaving procedure produced the least reliable results of the segment types when compared to field observations. This procedure should be enhanced to better estimate the quality of service on freeway facilities that contain weaving segments...

Often volume data collected for the analysis of freeways comes from loop or other detector counts that are part of a freeway management system. These volumes do not necessarily reflect the demand, particularly under congested conditions due to possible metering of demand upstream and queuing within the system. A procedure to estimate demand from volume counts should be developed to expand the use of the freeway facility procedure.

The impacts of limited off ramp capacities are not currently included in the freeway facilities procedure. This impact might be either the capacity of the ramp segment proper, or the capacity of the intersection at the surface street ramp terminal.

The current ramp segment procedures do not provide an analysis tool for the evaluation of major merges and diverges where there is a lane add or drop. The present simplifying assumption is that these segments operate most closely to a basic freeway segment. This should be tested and a new procedure developed if necessary.

In addition, the selection of appropriate performance measures reflecting traveler perception of quality of service should be evaluated. Many highway agencies are

focusing on the use of reliability-based measures of system performance. The HCM2000 does not suggest specific service measures for use in analyzing freeway facilities. The recommended research would seek to gain insight from the traveler population to identify appropriate service measures and thresholds.

## **RESEARCH OBJECTIVES**

The primary objective of this research would be to enhance the current HCM freeway facilities procedure to analyze the situations described above.

## **RESEARCH PROPOSED**

The following potential tasks should be considered:

1. Develop a methodology for segmenting a freeway facility into homogenous freeway segments that can be analyzed by separate procedures.
2. Improve the accuracy of the current weaving procedure.
3. Determine the operational characteristics of atypical freeway segments (e.g., long freeway segments between an on-ramp and off-ramp with an auxiliary lane; short freeway segments between an on-ramp and off-ramp without an auxiliary lane; minimum length of basic segments; etc.)
4. Create a procedure for estimating traffic demands from segment flows.
5. Determine the impacts of off-ramp capacity restraints of freeway operations.
6. Determine the operational characteristics of major merge and diverge segments.
7. Determine appropriate service measures and thresholds from a traveler's perspective.

## **RESEARCH FUNDING AND DURATION**

Estimate of required funding: \$400,000

Expected research duration: 2 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 3 (A)**

### **PROBLEM STATEMENT TITLE**

Modeling Procedure for Congested Arterial Facilities

### **RESEARCH PROBLEM STATEMENT**

Performance of urban arterial streets strongly affects the overall costs and travelers' perception of transportation in the area. The ability to evaluate arterial streets is a critical condition of effective traffic management and control in urban areas. The HCM provides a procedure for evaluating urban arterial streets. This procedure aggregates outcomes from the analysis of signalized intersections to calculate the average arterial travel speed and the level of service. This approach, although appropriate for uncongested arterial streets, cannot properly deal with arterial congestion. Metering of arterial traffic by signals and queues reaching upstream intersections are not considered. The existing HCM procedure may incorrectly calculate travel speed and other measures of arterial performance for congested traffic.

### **RESEARCH OBJECTIVES**

The objective of this research is to improve the HCM model of arterial streets to adequately describe congested traffic. This should be accomplished by incorporating the effect of traffic metering and traffic blockage by downstream long queues. The new procedure will include the effect of signal progression. The new procedure will follow the concepts defined in the HCM. It will require input and produce outcome consistent with the HCM procedures for signalized and unsignalized intersections.

As arterial operations under congestion can last for a considerable time, the new procedure will be able to utilize traffic volumes given in multiple, consecutive intervals. This research should, to the extent possible, utilize the findings of previous research on the effect of metering, filtering, and spillback on urban arterial operation. The resulting procedure will be tested using computer simulation and validated using field data.

### **RESEARCH FUNDING AND DURATION**

Estimate of required funding: \$400,000

Expected research duration: 2 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 3 (E)**

### **PROBLEM STATEMENT TITLE**

Level of Service for Arterial Weaving Segments

### **RESEARCH PROBLEM STATEMENT**

Weaving activity occurs to some degree on almost all arterial street segments. The extent of arterial weaving activity is directly related to the number of vehicles that enter or exit the segment via a turn maneuver. The negative effects of weaving activity on traffic speed are well-documented in the context of freeway weaving areas. Weaving on an arterial segment also tends to reduce traffic speeds; however, very little is known about the magnitude of the effect. The existing procedures for freeway segments are not likely to be applicable to arterial street segments because of their differences in traffic control and driver behavior. The freeway section represents uninterrupted flow with merging control for entering vehicles. In contrast, the arterial segment is often regulated by upstream and downstream signals and may use no-control, yield, stop, or signal control to regulate the both the entry and the exit maneuver. Arterial weaving capacity is significantly affected by the gaps introduced by the upstream signal and the distance available for weaving (which varies with the queue length at the downstream signal).

Arterial weaving is most problematic on street segments associated with large turning volumes. Such volumes are often found near interchanges. For example, intensive weaving activity is often found on the segment between the interchange off-ramp terminal and an adjacent signalized intersection. It is also found on frontage road segments between the freeway off-ramp and the frontage-road/cross-street intersection.

It is possible that the current service measures for freeway weaving are not appropriate for arterial weaving. Therefore, this study should seek to gain insight from the traveler population to identify appropriate measures and thresholds of performance.

### **RESEARCH OBJECTIVES**

The objective of this research is to develop a deterministic procedure for evaluating the level of service in weaving areas on arterial street segments. This includes the identification from a traveler's perspective, of appropriate performance measures and thresholds for the evaluation of level of service and the development of a quantitative methodology for the estimation of those measures.

### **RESEARCH PROPOSED**

The research should define one or more service measures suitable to weaving area performance evaluation. The model should be sufficiently general as to be applicable to the wide range of weaving segment control modes, weave maneuvers (e.g., entry by right-turn with exit by left-turn, entry as through with exit by right-turn, etc.), entry angles, acceleration distance, arterial lanes, and weaving distance. Simulation can be used to develop and calibrate the proposed procedure; however, field data should be used to validate the procedure. The field data should reflect conditions throughout the U.S.

**ESTIMATED FUNDING AND RESEARCH PERIOD**

Estimate of required funding: \$600,000

Expected research duration: 3.5 years

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 3 (F)**

**PROJECT TITLE:** Unsignalized Movements and Geometric Delays at Interchanges

### **RESEARCH PROBLEM STATEMENT**

Some of the comments from review of the current chapter for Interchange Ramp Terminals involve the lack of consideration and analysis for (1)unsignalized movements at signalized intersections (such as a free-right or a yield-right), (2)the lack of consideration of the operation of two-way or multi-way stops at Interchange Ramp Terminals, and (3)the lack of consideration for the impact of geometric delay for various interchange ramp forms (such as the added delay involved in circulating around roundabouts and partial cloverleafs). While not affecting LOS analysis, these omissions can impact the results of an objective analysis when comparing one interchange geometric form versus another. It is recommended that research be initiated to determine the impacts upon LOS and delays when comparing one interchange type with another.

### **ANTICIPATED BUDGET AND DURATION**

Estimated Budget:     \$250,000

Project Duration:     12 mo

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## **GROUP 3 (G)**

**PROJECT TITLE:** Actuated Signal Operations at Interchanges

### **RESEARCH PROBLEM STATEMENT**

The Interchange Ramp Terminal Chapter (and research for 3-60) was initially developed to be consistent with the Traffic Signals Chapter, and assumed fixed-time traffic signal control. In the mean time, the Traffic Signals Chapter has been updated for the 2010 HCM to include signal timing parameters and inputs to allow for the more flexible signal timing afforded by an intersection that is capable of responding to actuated inputs. Since the Traffic Signals Chapter has been updated, it is recommended that the Interchange Ramp Terminal Chapter be updated to include actuated control and that it also be compatible with the Traffic Signals Chapter. Also, it is anticipated that the majority of Interchange Ramp Terminals operate under actuated control – so this change will better reflect current conditions. This research should include the impacts of using single or dual traffic controllers, queue detection, etc.

### **ANTICIPATED BUDGET AND DURATION**

Estimated Budget:     \$350,000

Project Duration:     18 mo

**Committee Sponsor:** TRB AHB40, Highway Capacity and Quality of Service

## **GROUP 4 (A)**

### **PROBLEM TITLE**

Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual

### **RESEARCH PROBLEM STATEMENT**

A Highway Capacity Manual applications guide was developed for the 2000 HCM and is being updated for the 2010 HCM. This guide addresses a broad set of potential HCM applications with emphasis on applications related to design and operations. There is a corresponding need to develop an applications guide with emphasis on planning and preliminary applications. This guide is needed to address the broad use of HCM procedures in planning and preliminary applications such as corridor studies, roadway widening projects, and traffic impact analyses. In addition, guidance is needed for three common issues that go beyond the scope of the 2010 HCM:

- ◆ Analysis of oversaturated conditions in a planning and preliminary engineering context, including use of volume to capacity ratios and other techniques to compare the severity of oversaturated facilities
- ◆ Use of alternative tools in a planning environment, including use of default values and the level of calibration/validation needed for using alternative tools in a planning and preliminary engineering context
- ◆ Use of highway capacity analysis to provide input to sustainability and livability studies, such as air quality, noise, and greenhouse gas emission analyses. This would include documentation of the traffic data input needs for these types of analyses (speed, travel time, delay, vehicle composition, etc.) and provide guidance on how best to use the HCM to determine this data.

In addition to providing an educational tool, the proposed research would enhance the value of the 2010 HCM by providing a reference for conducting planning and preliminary engineering analyses. It is expected that FHWA, state departments of transportation, and other agencies could refer to the Planning and Preliminary Engineering Applications Guide to the HCM to describe recommended or required procedures for conducting highway capacity analyses for various planning and preliminary engineering studies. Following are examples of the issues that would be addressed:

- ◆ When is it appropriate to use default values in various planning and preliminary engineering applications?
- ◆ For oversaturated conditions (i.e. level of service F), what are potential techniques to describe the severity of congestion?
- ◆ When is it appropriate to use alternative tools (e.g. traffic simulation) in a planning and preliminary engineering context?
- ◆ How can sketch planning tools (such as level of service tables) be used in planning and preliminary engineering studies?

- ◆ How can the results of HCM analyses be used (either directly or modified as necessary) to provide input to analyses of sustainability, air quality, noise, and greenhouse gases?

## **LITERATURE SEARCH SUMMARY**

Literature searches on TRIS online and the Research in Progress database yielded the following results:

- ◆ There is no ongoing or completed research that is similar the effort proposed in this problem statement, development of a Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual.
- ◆ Searches related to guides in the areas of planning and highway capacity lead to numerous guides that have been developed for specific facilities that touch on planning issues, but none that are as broad as the proposed effort.
- ◆ Searches related to the specific issues addressed in the proposed research (traffic simulation/alternative tools, oversaturated conditions, sustainability/greenhouse gases) lead to numerous research projects on these issues that may be valuable during the research, but none that provide a comprehensive guide.

Regardless of previous research efforts (many of which will be useful in the proposed effort), the incorporation of planning and preliminary engineering guidance into the Highway Capacity Manual through an Applications Guide will result in a unique opportunity to provide the latest techniques to the community of approximately 10,000 users of the Highway Capacity Manual.

## **RESEARCH OBJECTIVE**

The objective of the recommended research is to develop a Planning and Preliminary Engineering Applications Guide to the HCM. The guide would be prepared by developing sample problems that address typical planning and preliminary engineering analyses that are encountered in actual applications of the HCM. Key stakeholders would be surveyed to select representative situations for analysis. The sample problems would include at least one problem related to oversaturated conditions, at least one problem related to the application of alternative tools, and at least one problem related to air quality, noise, and greenhouse gas analysis. The format and layout of the guide would follow the current HCM Applications Guide that is oriented toward operational and design analyses.

The product of the research would be a guide book that would act as an educational tool and supplement to the 2010 HCM to be produced in both hard copy and appropriate electronic format.

## **TASKS**

The following individual tasks are envisioned to complete this research:

- (1) Literature review to include the HCM Applications Guide and key FHWA and state transportation department documents on planning and preliminary engineering studies

- (2) Survey of stakeholders to determine recommended practices, sources of documentation, and sample problems
- (3) Development of sample problems
- (4) Preparation of Draft Planning and Preliminary Engineering Applications Guide to the HCM
- (5) Review and comment with key stakeholders
- (6) Preparation of Final Planning and Preliminary Engineering Applications Guide to the HCM

## **ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD**

### **Recommendation of Funding:**

Estimate of required funding: \$400K

### **Research Period:**

Expected research duration: 2 years

## **URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION**

This problem statement addresses three areas of the transportation profession that are emerging issues that have not been addressed elsewhere. Currently, transportation professionals in the planning and preliminary engineering environment are writing their own rules with respect to traffic simulation/alternative tools, analysis of oversaturated conditions, and analysis of the effects of transportation improvements on sustainability/greenhouse gases. While the 2010 HCM will form the basis of some solutions to these issues, they go beyond the scope of the HCM and are more appropriately addressed in an applications guide.

Improved understanding of these issues and standardization of techniques to address them is expected to provide huge benefits in terms of making better decisions regarding the billions of dollars that are spent annually on major roadway improvement projects. For example, if a \$40 million dollar interchange improvement project achieves a 10% savings due to a more efficient design to handle oversaturated conditions or greenhouse gas impacts, a \$4 million savings is achieved. This would result in a 10:1 benefit cost ratio for the research dollars spent on this effort achieved in just one practical implementation.

The results of this research project will produce a Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual. As in the case of the Highway Capacity Manual itself, the Planning and Preliminary Engineering Applications Guide will be subject to review and approval by TRB's Committee on Highway Capacity and Quality of Service, which will provide additional oversight and assurance that the products will be applicable for use in the transportation profession. Following publication, it is anticipated that FHWA, State Departments of Transportation, and local agencies will adopt or recommend use of the Planning and Preliminary Engineering Applications Guide for use on analysis of transportation improvement projects.

Following are specific steps to be followed during implementation:

- (1) Completion of research project
- (2) Review and approval by TRB Committee on Highway Capacity and Quality of Service
- (3) Publication by TRB
- (4) Distribution (through TRB) to FHWA, State Departments of Transportation, and the transportation engineering community
- (5) Acceptance and adoption of all or portions of the Planning and Preliminary Engineering Applications Guide by various transportation agencies for use on transportation improvement projects

One potential barrier to implementation is lack of knowledge regarding the Planning and Preliminary Engineering Applications Guide following its publication. The TRB Committee on Highway Capacity and Quality of Service has a subcommittee dedicated to user liaison and has historically been proactive in publicizing the production of a new HCM or key research product. Continued efforts in this area will be needed, possibly with the help of the sponsors of this research project.

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