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DESIGN MEMORANDUM NO. 03-11

TO: Chief District Engineers
Design Engineers
Design Consultants

FROM: Jeff D. Jasper, P.E.
Director
Division of Highway Design

DATE: NOVEMBER 2, 2011

SUBJECT: Traffic Engineering Analysis

The attached *Traffic Engineering Analysis* document provides guidance for the Project Development Team (PDT) and design engineers on the use of traffic engineering principles and procedures when designing a highway project. Effective with this memorandum, the attached guidance should be used when the PDT deems that their project warrants such traffic analysis. While these guidelines can be applied to any project, the PDT should utilize them when the project purpose and need statement identifies the need for operational and/or capacity improvements.

In order to assist the project team, two levels of traffic engineering analysis are identified. The first calls for Highway Capacity Manual (HCM) and/or Highway Capacity Software (HCS) procedures to evaluate the capacity of roadway sections and isolated intersections. Secondly, for corridors with multiple signalized intersections, micro-simulation is recommended to evaluate the interaction and progression between intersections. A listing of preferred micro-simulation software can be found on Highway Design's webpage under Resources » Software and Support. Other software packages may be approved on a project-by-project basis.

Traffic engineering analyses should be thoroughly documented to allow a full review of the analysis and analytical results. This documentation should be placed as an appendix to the Design Executive Summary. More information about this process can be found in the attached *Traffic Engineering Analysis* guidance.

Any questions regarding this memorandum should be directed to this office.

JDJ:AJK

Attachment

INTRODUCTION

The purpose of this chapter is to provide guidance for the Project Development Team (PDT) and design engineers on the use of traffic engineering analysis when designing a highway project. Traffic engineering analysis may be used in the sizing of roadways, intersections and interchanges and may assist in the developing of innovative solutions to constrained design problems.

APPLICATION

While traffic engineering can be an important consideration in any project, this guidance is intended to assist the PDT when the project purpose and need statement identifies the need for operational and/or capacity improvements. When extra emphasis on traffic engineering would be of particular value, the PDT should require traffic engineering analysis to be conducted per the guidance below.

This chapter is not to supersede the application of sound engineering principles and judgment by experienced design professionals, but merely to provide guidance in how traffic engineering may be added as one of many inputs into the transportation decision-making process.

TRAFFIC ENGINEERING DESIGN PROCESS

Procedures and methodologies consistent with the most recent edition of the Highway Capacity Manual (HCM) should be used as the basis for traffic engineering design. These procedures, in conjunction with the KYTC Auxiliary Lane Policy, can be used to 1) determine the basic number of lanes on a facility and 2) determine the need for auxiliary lanes on a facility, as described in the following sections. HCM analysis may be supplemented with micro-simulation analysis as outlined below.

Basic Number of Lanes. The basic number of lanes will identify the recommended number of through lanes on a facility necessary to meet anticipated demand. Initial traffic engineering design should determine the basic number of lanes recommended for the facility to achieve a targeted Volume to Capacity ratio (V/C).

Auxiliary Lanes. Auxiliary lanes are non-continuous lanes used to facilitate the flow of traffic. These include acceleration/deceleration lanes, left and right turn lanes, truck climbing lanes, auxiliary through lanes and passing lanes. Auxiliary lanes may also be incorporated into the design to achieve a targeted Volume to Capacity (V/C) ratio or address other measures of effectiveness (MOEs) discussed below. For further discussion on the design of Auxiliary Lanes refer to Chapter HD-902.

Traffic Control Devices. The determination of appropriate intersection traffic control, including traffic signal, stop and yield control, should be supported by guidance and warrants provided in the Manual on Uniform Traffic Control Devices, the KYTC Traffic Operations Guidance Manual, and the KYTC Highway Design Manual. The installation or removal of any electrical traffic control device, such as traffic signals, school flashers, and flashing beacons, shall require the approval of the Deputy State Highway Engineer for Project Delivery and Preservation.

OPERATIONAL ANALYSIS

Highway Capacity Manual. Operational analysis of highway designs should include identification of the Volume to Capacity Ratio (V/C) for the roadway element. Highway Capacity Manual procedures directly provide V/C estimates for the roadway types except multi-lane highways and freeways. Capacity of these facilities is based on the free-flow speed (FFS)[1] of the facility and can be determined from Equations 1 and 2 below for Freeway and Multi-lane segments, respectively.

Equation 1: Freeway Capacity Calculation (vphpl)

Capacity = 1700 + 10(FFS)

Equation 2: Multi-lane Capacity Calculation (vphpl)

Capacity = 1000 + 20(FFS); not to exceed 2200 vphpl

A targeted V/C ratio of 1.0 in urban areas and 0.90 in rural areas based on the design hour volume is recommended for roadway elements. If it is not possible or recommended by the project team to achieve the targeted V/C value, documentation should be provided in the Design Executive Summary (DES). This documentation may include design life analysis, off-peak traffic analysis, identification of alternative designs, or project impacts (i.e. Engineering, Environmental, and Economic impacts) necessary to achieve the targeted V/C or other measures evaluated by the project team.

Documentation should also be provided for multi-lane facilities if the proposed design is significantly less than the target V/C (i.e., less than 0.80 on urban facilities and 0.70 on rural facilities). This documentation

[1]Refer to the most recent edition of the Highway Capacity Manual for in-depth discussion of determining Free Flow Speed.

may include benefit-cost analysis, design life analysis, identification of alternative designs or other measures evaluated by the project team.

Micro-Simulation Models. While the operational performance of a facility is initially analyzed through HCM procedures, the final design of the facility may be evaluated through the use of a micro-simulation model as deemed necessary by the project team. The use of micro-simulation models may be appropriate where traffic patterns are impacted by nearby traffic control devices and do not follow a random arrival pattern assumed by HCM procedures. This analysis should be used in conjunction with HCM procedures and not in place of it. Micro-simulation may be considered on corridors that:

- operate within coordinated signal systems,
- have multiple signalized intersections where queuing may impact adjacent intersections,
- operate interdependently, such as at interchanges, or
- are deemed necessary by the project team for operational or other reasons such as for use in public involvement activities.

When used, micro-simulation models should be calibrated to the existing conditions based on quantifiable measures to reflect the prevailing conditions and traffic characteristics.

A list of preferred micro-simulation programs for operational analysis and traffic engineering studies is provided on the Highway Design website. Other micro-simulation programs may be considered if the purpose and complexity of the project justifies the application of another model. The use of other models should only be pursued after discussion with the project team.

MEASURES OF EFFECTIVENESS

While the volume to capacity ratio indicates the ability of the roadway to accommodate travel demand, other measures of effectiveness (MOEs) may also be used in the transportation decision-making process. Along with the other factors considered when evaluating project decisions, MOEs may be used for comparative analysis to other alternatives, to refine proposed designs and/or relate traffic flow parameters to the public.

Vehicular Delay. Delay estimates for each approach lane may be used in comparative analysis with other intersection alternatives. When evaluated, delay should be calculated and reported by lane group, approach and intersection average using the appropriate HCM methodology. Micro-simulation models may also be used to provide delay estimates.

Queue Estimates. Queue estimates for each lane group may be used to determine the feasibility of the intersection alternative function within the site constraints, considering adjacent intersections and access points. Additionally, queue estimates may be used to help size necessary auxiliary lanes or be used in comparative analysis with other intersection

alternatives. When evaluated, the appropriate analysis procedures in the HCM should be used to determine the 95th percentile queue for each approach lane at isolated intersections. Micro-simulation models may also be used to provide queue estimates.

Level of Service. Level of Service (LOS) relates the perception of roadway users on the quality of the roadway service. Therefore, it may be appropriate to determine and report LOS to more effectively convey the perceived quality of traffic flow and identify improvements such as auxiliary lanes, or operational parameters (e.g., signal timing).

Other MOEs. Additional MOEs required by project type, such as interchange justification studies, or defined by the project Purpose and Need Statement, e.g., emissions, queues, etc. for CMAQ projects, may be analyzed, and documented as needed.

ANALYSIS SCENARIOS

The traffic engineering study should provide design year analysis. It may be beneficial to provide current year or opening year analysis. A current year analysis should include existing traffic volumes, existing traffic control and should be used to calibrate and/or validate the analysis model. Interim year analysis may also be conducted to facilitate phased improvement strategies. The project team should work with the Division of Planning to obtain interim and design year traffic forecasts, necessary to complete the analysis.

Typical analysis evaluates weekday AM and PM peak periods. When a project is anticipated to experience a high volume of traffic during non-traditional peaks, alternative analysis periods may be examined in addition to, or in lieu of, typical peak periods. Common examples include school locations or high-density retail land uses, which may have high volumes during noon hours, late nights, or weekend periods.

Traffic Data. The measurement of traffic volumes is one of the most basic functions of highway planning and management. A number of traffic volume data and statistics are needed for traffic engineering analyses. For a discussion concerning the types of traffic volume data and their definitions, please refer to the Highway Capacity Manual.

Traffic data necessary to analyze these scenarios may be acquired from the Division of Planning (current and projected ADT, turning counts, etc.) and the Division of Traffic Operations (crash statistics, speed data, etc.). It should be noted that future traffic volumes are based on a given set of assumptions which may change as projects and areas evolve. Thus critical review and application of sound engineering judgment is required when analyzing traffic data.

DESIGN CONSIDERATIONS

As the project moves from preliminary to final design, operational assumptions made in the traffic engineering study need to be carried forward to final design and brought into balance with other project features and requirements. This may include ensuring proper lane configurations and alignment for opposing permitted left turns at intersections, proper number and size of receiving lanes, turn restrictions/permission where appropriate, passing sight distance, etc. Critical issues to the proper operation of a facility may be identified and documented in a technical memorandum if deemed necessary by the project team.

REVIEW AND APPROVAL

Pre-Design Scoping Meeting. When traffic engineering analysis is determined necessary by the project team, the following issues should be addressed during the pre-design scoping meeting:

- assumptions
- description of alternatives
- modeling limits
- analysis time periods (AM, PM peak periods)
- design year
- calibration factors
- micro-simulation program

Traffic Operations Coordination. The project manager should invite representatives from both District Traffic and the Division of Traffic Operations for highway projects that might include the installation or modification of electrical traffic control devices or roadway lighting. While recommended by the project team, electrical traffic control devices and roadway lighting are approved through the Division of Traffic Operations. For additional discussion regarding electrical devices, please refer to the Traffic Operations Guidance Manual.

Documentation. When conducted, traffic engineering analysis should be documented in an appendix to the Design Executive Summary (DES). An explanation should also be included in the discussion of alternatives describing how the traffic engineer findings were considered in the project design decisions.

Documentation should provide sufficient information to allow a thorough review of the analysis and analytical results, document reasoning behind operational assumptions and provide enough information to duplicate the results. At a minimum this includes:

- assumptions (input)
- calibration method and results
- conceptual layout
- MOE summary
- design considerations
- output
- electronic input and output files