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TECH**BRIEF**

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HIGHWAY CAPACITY MANUAL CHAPTER ON ALTERNATIVE INTERSECTIONS AND INTERCHANGES

Development of easy-to-use operational analysis methods for next-generation intersection and interchange designs may facilitate wider adoption of these facilities, whose real-world implementations have achieved outstanding benefit-cost results.

INTRODUCTION

Today's transportation professionals, with limited resources available to them, are challenged to meet the mobility needs of an increasing population. At many highway junctions, congestion continues to worsen, and drivers, pedestrians, and bicyclists experience increasing delays and heightened exposure to risk. Today's traffic volumes and travel demands often lead to safety problems that are too complex for conventional intersection and interchange designs to properly handle. Consequently, more engineers are considering various innovative treatments as they seek solutions to these complex problems.

Highway Capacity Manual (HCM) Chapter 23, Ramp Terminals and Alternative Intersections, provides qualitative guidance and computational analysis procedures for four interchange designs and three intersection designs.[(1)] The original three interchange designs (i.e., the partial cloverleaf (parclo), diamond, and single-point urban interchange (SPUI)) are considered conventional designs. The four new alternative designs are the diverging diamond interchange (DDI, also known as the double crossover diamond interchange), displaced left-turn (DLT) intersection, restricted crossing U-turn (RCUT) intersection, and median U-turn (MUT) intersection. These designs, which are illustrated in **Figure 1**, offer substantial advantages over conventional at-grade intersections and grade-separated interchanges.

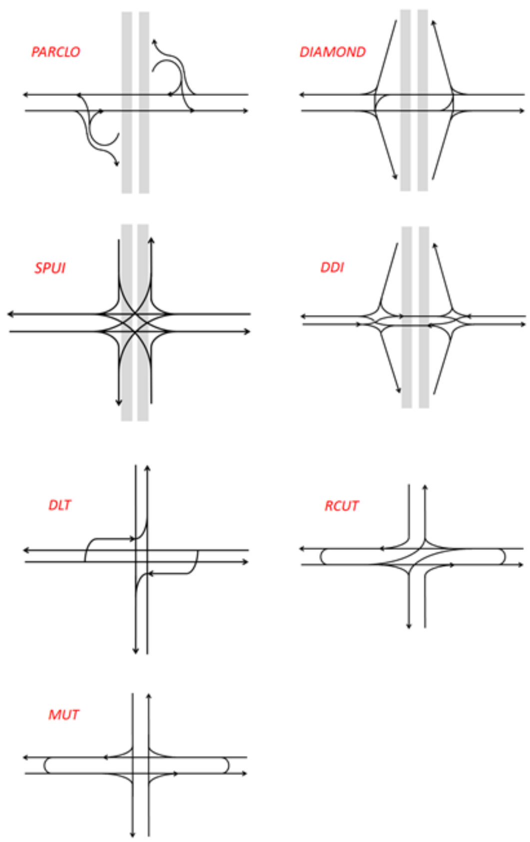

Figure 1: Types of Intersections and Interchanges

The FHWA *Alternative Intersection and Interchange Report (AIIR)* provides information on each alternative treatment covering salient geometric design features, operational and safety issues, access management, costs, construction sequencing, environmental benefits, and applicability.(2) This TechBrief summarizes information on HCM Chapter 23, specifically with regard to the new intersection and interchange designs.

Interchange ramp terminals are critical components of the highway network. They provide the connection between various highway facilities (i.e., freeway-arterial, arterial-arterial, etc.), and thus their efficient operation is essential. Interchanges are typically designed to work in harmony with the freeway, the ramps, and the arterials. Chapter 23 was developed for the 2015 update to the 2010 HCM. Prior editions of the HCM had offered a chapter dedicated to interchange ramp terminals, but did not address the latest alternative intersection and interchange designs, which are gaining popularity in the United States.

Alternative intersections and interchanges are created by rerouting one or more movements from their usual places to secondary junctions. Often, the rerouted movements are problemeatic left turns. Alternative intersection and interchange designs have significantly reduced travel times and delays in many areas, compared to conventional intersection designs. Some designs have substantially reduced the number of conflict points between vehicles, thus improving overall safety. In addition, the alternative designs can often be implemented with minimal disruptions to existing right-of-way. Given the relatively low cost of implementation for many of these designs, the combination of improved mobility and safety has produced outstanding benefit–cost ratios within economic analyses. By moving or eliminating problematic movements, the alternative designs can efficiently mitigate congestion at surface street-freeway interchanges and at signalized intersections.

Interchange ramp terminals and alternative at-grade intersections are combined in this chapter, because they combine multiple intersections in a cluster. “Distributed intersections” consist of groups of two or more intersections that, by virtue of close spacing and displaced/distributed traffic movements, are operationally interdependent and are thus best analyzed as a single unit. The most common distributed intersections are interchange ramp terminals, but other alternative intersection forms—such as those involving displaced left-turn movements—also fall into this category.

ORGANIZATION OF HCM CHAPTER 23

Part A of Chapter 23 provides an overview of alternative intersection and interchange concepts. Within this part, Section 2 documents and describes a number of common concepts associated with interchanges and alternative intersections. This section lists the unique elements and summarizes the shared attributes of such facilities. It further discusses the need for translating between turning movement volume demands at each intersection approach and origin-destination (O-D) demands across the entire intersection or interchange. The section discusses issues related to distributed intersections and interchanges, including an O-D framework. To facilitate unbiased comparisons among distributed intersection types, this section introduces a discussion on experienced travel time and delay, which consists of diverted path delay and control delay.

Part B of Chapter 23 focuses on the evaluation of surface street-freeway interchanges. Following the Section 1 overview, Section 2 describes the features of diamond interchanges, parclos, SPUIs, DDIs, and roundabout interchanges. Section 3 discusses the core evaluation methodology, including scope, required data, and computational steps. Section 4 describes methodology extensions for interchanges with roundabouts, interchanges with STOP and YIELD signs, and a specific procedure for interchange type selection. Section 5 presents applications of the Part B methodology, including example results, analysis types, and the pros and cons of analyzing surface street-freeway interchanges with alternative tools.

Part C of Chapter 23 focuses on the evaluation of alternative intersections. Following the Section 1 overview, Section 2 describes the features of RCUT intersections (also known as superstreets), MUT intersections, and DLT intersections (also known as continuous flow intersections). Section 3 discusses the core evaluation methodology, including scope, required data, and computational steps. Section 4 describes methodology extensions for alternative intersection designs not covered in Section 3.

LOS FRAMEWORK

When developing a level of service (LOS) framework for distributed intersections, it is helpful to consider existing frameworks for similar facilities. For isolated signalized intersections (Chapter 19), average control delay per vehicle is an intuitive measure for LOS determination. For urban street segments (Chapter 18), the average difference between free-flow speed and actual speed is a fundamental quality-of-service indicator. Chapter 23 requires a LOS framework capable of capturing specific signalized and arterial operations in a way that facilitates unbiased comparisons among various types of distributed intersections.

Control delay would not be suitable as the sole measure for determining LOS for distributed intersections (as with Chapter 19), as this would not account for the diverted-path delay present at some facilities. Travel speed would not be suitable as the service measure (as with Chapter 18), because it does not capture the efficiency of sequential major- and minor-street movements. Instead, the distributed intersections are all responsible for a certain amount of experienced travel time. More specifically, each O-D path can experience control delay at signalized or unsignalized locations and extra distance travel time. Some O-D paths may have multiple instances of one or more of these elements. These elements can be used together to determine the experienced travel time, and from this the performance measures of Chapter 23 can be derived. Equation 23-1, shown below, is used to compute experienced travel time (ETT), where d_i is the control delay at each junction *i* encountered on the path through the facility, and *EDTT* is the extra distance travel time.

$$ETT = \sum\left(d_i + EDTT\right) \quad (1)$$

Figure 2 illustrates the concept of providing unbiased comparisons among distributed intersection configurations, using an RCUT intersection example. The dashed line denotes the path of a typical left-turner arriving from the minor street, and entering the major street. Summarizing control delays (per Chapter 19) at all three intersections (i.e., west-most, middle, east-most) would not capture diverted-path travel times between points A and D. Furthermore, average travel speeds (per Chapter 18) in the east-west arterial directions would not consider control delays at points A and C. In fact, an unbiased comparison between configurations would require considering experienced travel times between all origin and destination points encircling the system.

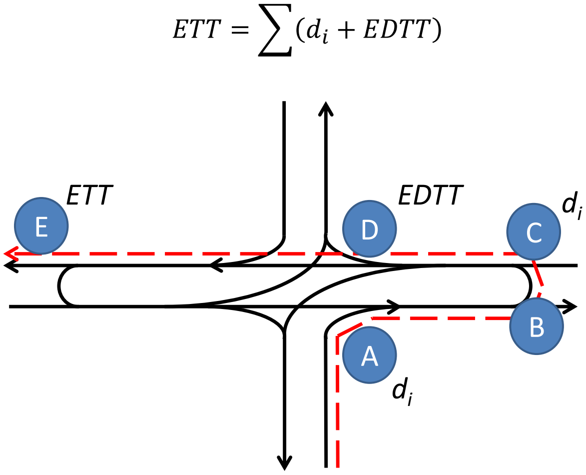

Figure 2: Calculation of ETT at an RCUT Intersection

Despite the increased delays experienced by minor-street left-turning vehicles in this example, intersection-wide delays tend to be significantly lower for the RCUT than for a conventional intersection, due to the elimination of dedicated left-turn phases at the intersections. This elimination of left-turn phases allows through moving vehicles and right-turning vehicles to travel relatively unimpeded through the intersection. This concept of eliminating left-turn phases has inspired and informed the RCUT, MUT, DLT, and DDI designs.

COMPARING DESIGNS

Each of these new intersection and interchange designs has its own advantages and disadvantages, as detailed in the FHWA AIIR report. For example, even though the MUT and RCUT designs both eliminate left-turn phases, only the MUT allows minor-street through movements. Thus, the MUT might be a more beneficial design than the RCUT at locations where minor-street through movement demands are heavy. Further, although the DLT is generally the most operationally efficient intersection design, it tends to require more physical right-of-way (i.e., "footprint") than the RCUT or MUT, especially when right-turn bypass lanes are built. Finally, although the DDI interchange design may process traffic more efficiently than conventional diamonds in many cases, the costs of converting a diamond to a DDI may only be justified when left-turn flows onto the freeway are heavy. In any case, the LOS framework described earlier can help to facilitate unbiased "apples-to-apples" comparisons of the different intersection and interchanges types, at least in terms of operational performance measures.

SUMMARY

Today's traffic volumes and travel demands often lead to safety problems that are too complex for conventional intersection and interchange designs to properly handle. HCM Chapter 23, Ramp Terminals and Alternative Intersections, provides qualitative guidance and computational analysis procedures for four new alternative designs: DDI, DLT, RCUT, and MUT.

Thanks to the elimination of inefficient left-turn signal phases, these new designs offer substantial operational (e.g., reduced delay) and safety (e.g., reduced vehicle conflicts) advantages over conventional at-grade intersections and grade-separated interchanges, without requiring additional new lanes to be built. Perhaps including these new procedures in the HCM will facilitate the analysis and adoption of these innovative designs.

EDUCATIONAL VIDEOS

Educational videos for the four new alterantive designs were developed and are accessible through the links below:

- DDI: https://youtu.be/hHXAeF3b3qI
- DLT: https://youtu.be/g35mNZyJTLw
- RCUT: https://youtu.be/H6w1CaijY1Y
- MUT: https://youtu.be/RHXW1TvS4hM

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Key Words— Displaced left-turn intersection, DLT, diverging diamond interchange, DDI, restricted crossing U-turn intersection, RCUT, median U-turn intersection, MUT, alternative interchange, alternative intersection, Highway Capacity Manual, HCM.