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Development of signal optimization models for asymmetric two-leg continuous flow intersections ☆

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ABSTRACT

Despite extensive studies have been reported to address the operational issues of full Continuous Flow Intersection (CFI) in the literature, the asymmetric two-leg CFI, which is more applicable in practice, has not received adequate attentions yet. To satisfy such need, this study develops two signal optimization models for asymmetric CFI based on its unique geometric features. The first proposed model, following a two-step procedure, determines the cycle length, phase design and sequence, and green split in the first step and optimizes intersection offset in the second step. To benefit both intersections' capacity maximization and signal progression design by optimizing phase plan and sequence, the second proposed model takes the Mixed-Integer-Linear-Programming (MILP) technique to concurrently optimize all signal control variables. With extensive case studies on a field site in Maryland, the simulation results prove that the proposed models can effectively provide signal progression to critical path-flows and prevent the potential queue spillover on the short turning bays/links. Further comparisons between the two proposed models reveal that the second model is more flexible in designing phase plan but the first model performs better in reducing link queue length.

1. Introduction

As well recognized in the literature (Hughes et al., 2010), the main feature of Continuous Flow Intersection (CFI) (or Displaced Left-Turn intersection) is to eliminate conflict between left-turn and opposing through traffic by relocating the left-turn bay to several hundred feet upstream of the primary intersection so that the through and left-turn flows can move concurrently. With such innovative geometric design, a CFI can be operated with reduced number of signal phases at its primary intersection. Existing studies, based on extensive simulation experiments or field evaluations, revealed that CFIs could perform better in dealing with heaving left-turning flows at intersections.

It is noticeable that there are four types of CFI designs (Chang et al., 2011) in practice: full CFI (each of the four approaches contains a CFI leg), CFI-T (T-intersection contains one CFI leg), symmetric two-leg CFI (contains two CFI legs in opposite directions), and asymmetric two-leg CFI (contains two neighboring CFI legs). In review of the literature, most existing studies focused on the research of full CFI. However, due to the high construction cost and its large footprint, full CFI is not commonly used in the USA (only a few are under-construction in Louisiana). In contrast, most states, such as Utah, Ohio, New

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York, Louisiana, Colorado, and Mississippi, have constructed two-leg CFIs for operations. Notably, most of existing two-leg CFIs are symmetric designs. This is due to the complexity nature of signal design in asymmetric CFIs and lack of sufficient studies to solve such issue. Hence, how to design an optimal signal plan for an asymmetric two-leg CFI is a vital issue in traffic engineering.

By relocating the left-turn bay on the left side of the opposite through lanes, a full CFI allows simple two-phase signal control plan at its primary intersection and four sub-intersections (Esawey and Sayed, 2007). At the primary intersection of symmetric two-leg CFIs, only one additional signal phase shall be used to accommodate the left-turning flows from two conventional approaches. Hence, a well-developed full CFI signal optimization model is potentially implementable on a symmetric two-leg CFI with minor modifications. However, due to the unique geometric features of asymmetric two-leg CFI, it has the potential for best utilizing the intersection capacity with new optimization models. As shown in Fig. 1, the intersection has two CFI legs (south and west) and two conventional legs (north and east). With such geometric design, the total number of conflict points has been reduced from 24 to 16 at the primary intersection, compared with conventional four-leg intersections. Particularly, the conflict between the left-turn flows, from a CFI leg, and its opposing through flow has been successfully eliminated. By placing the two CFI legs in mutual perpendicular directions, no conflict exists between their left-turn volumes. Hence, signal phase design for asymmetric CFIs is quite flexible and also challenging. In addition, the short distance between the primary intersection and crossover intersections highlight the need of signal progression designs. In response to those issues, the objective of this paper is to develop effective signal optimization models which can produce the optimal cycle length, phase design and sequence, green split, and offset to a designed asymmetric two-leg CFI.

The rest of this paper is organized as follows: Section 2 will present comprehensive literature review of CFI related studies and classical signal optimization models; Section 3 will introduce the formulations of two signal optimization models for asymmetric CFI; Section 4 will conduct comprehensive simulation test on a field site to evaluate the proposed models; Section 5 will summarize the conclusions and future research directions.

2. Literature review

Due to the recent increasing applications of CFI, some fundamental issues associated with its operational efficiency have emerged as the priority subjects in the traffic community. For instance, Goldblatt et al. (1994) showed that the efficiency of

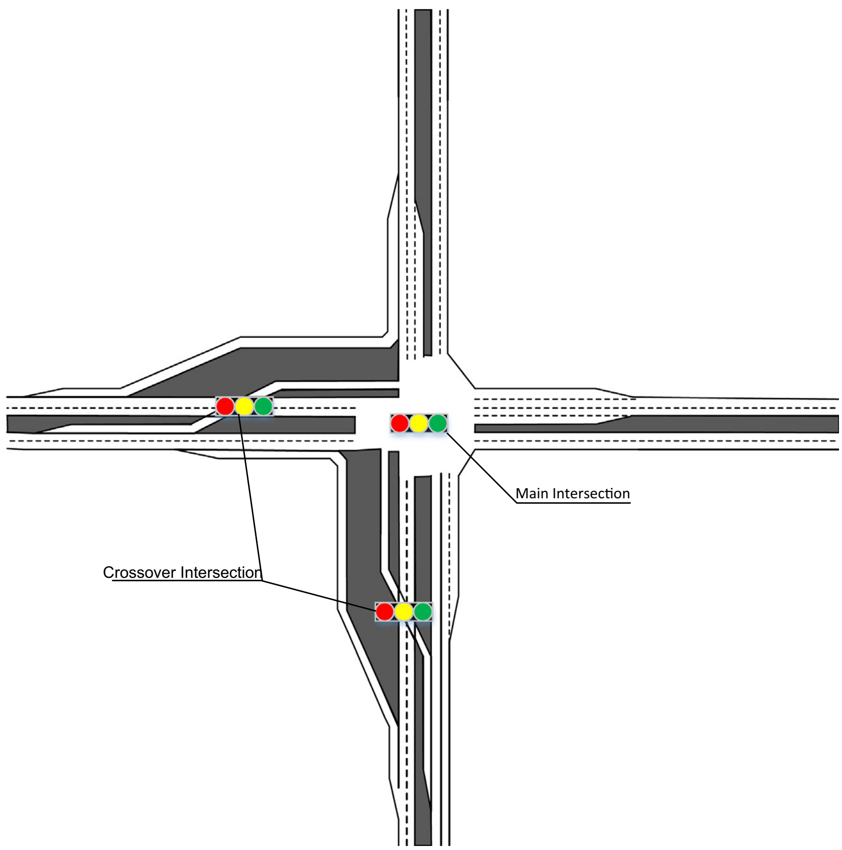

Fig. 1. The geometric layout of an asymmetric two-leg CFI.