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Intersection Operation with Non-Traditional Dynamic Lane Scheme through Vehicle-to-Signal Connection

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Abstract

This paper proposes an information-based dynamic lane (IDYL) scheme for signalized intersections with exclusive left-turn phases. Similar to the tandem design, the proposed scheme aims to increase the capacity of an isolated intersection by sorting incoming vehicles based on their turning movements. Its novelty is to guide vehicles of different movements into pre-designated dynamic lanes without stopping them via pre-signal. The assumption is that vehicles themselves or their drivers have access to, and can act on, real-time signal timing information through vehicle-to-signal connection to select the correct lane to enter as they approach the intersection. A mixed integer program is proposed to optimize jointly the lane configuration, timing plan, and dynamic lane utilization for an intersection. Results from numerical and simulation experiments show that IDYL can increase the reserve capacity by more than 25% when implemented on all legs of a standard four-leg intersection, and reduce the delay by around 15% when implemented on two opposing legs. The results from this study could help traffic engineers to operate signalized intersections with dynamic lanes when vehicle-to-signal connection becomes widely available in the near future.

Excessive traffic congestion remains a daunting challenge in big cities around the globe. Concerns about congestion related problems—prolonged commuting trips, elevated travel stress and discomfort, and dire environment impacts—are being voiced more loudly, especially in developing countries which are experiencing rapid urbanization and expansion of car ownership. Studies suggest that traffic congestion is not only annoying but also extremely expensive. A frequently cited report (*1*) estimates that traffic congestion costs the United States approximately $121 billion in wasted time and fuel. Signalized intersections are a major source of traffic congestion in cities (*2*), and hence they are examined closely for congestion relief measures. In particular, those with exclusive left-turn phases often receive ample attention because these additional phases can lead to significant reduction in the capacity of intersections (*3*).

One of the most studied intersection design problems involves optimizing signal timing plans; this problem has been approached using stage-based (*4*, *5*), group-based (*6–8*), and lane-based methods (*9*, *10*). The stage-based method first assigns compatible traffic movements to separate stages and then computes the desired green time for each stage. The group-based method, on the other hand, assigns the green time to each traffic movement directly. The lane-based method offers the greatest flexibility because it integrates lane/movement grouping decisions with signal timing plans. Owing to this desirable feature, the lane-based method has recently been applied in various intersection-related applications, such as bus signal priority (*11*), and non-traditional intersection management schemes (*12–15*).

Optimizing signal timing plans, while leaving everything else unchanged, has a limited effect on improving the performance of intersections, however (*16*). Researchers and practitioners have increasingly shifted their attention to novel design concepts which seek to reconfigure other operational aspects of signalized intersections. Examples of these efforts include, but are not limited to: continuous flow intersection (*17*), parallel flow intersection (*18*), hook-turn intersection (*19*), tandem design (*20*), superstreet, median U-turn, bowtie, jughandle, quadrant roadway, and split intersection (*21*).

This paper will focus on the tandem design (TD). Xuan et al. (*20*) first proposed this scheme and showed that it

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