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A multi-path progression model for synchronization of arterial traffic signals

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ABSTRACT

To contend with congestion and spillback on commuting arterials, serving as connectors between freeway and surface-street flows, this paper presents three multi-path progression models to offer progression bands for multiple critical path-flows contributing to the high volume in each arterial link. The first proposed model is a direct extension of MAXBAND under a predetermined phasing plan, but using the path-flow data to yield the progression bands. The second model further takes the phase sequence at each intersection as a decision variable, and concurrently optimizes the signal plans with offsets for the entire arterial. Due to the competing nature of multi-path progression flows over the same green duration, the third model is proposed with a function to automatically select the optimal number of paths in their bandwidths maximization process. The results of extensive simulation studies have shown that the proposed models outperform conventional design methods, such as MAXBAND or TRANSYT, especially for those arterials with multiple heavy path-flows. The research results from this study have also reflected the need to collect more traffic pattern data such as major path-flow volumes, in addition to the typical intersection volume counts.

1. Introduction

Providing two-way signal progression for congested arterials has long been viewed by traffic professionals as one of the most effective control strategies. Over the past several decades, researchers in the traffic control community have proposed a variety of signal progression models (Morgan and Little, 1964; Little, 1966) to maximize the progression bands for the target movements. Depending on the selected measures of effectiveness (MOEs), most of those existing studies have made impressive contributions on mitigating arterial traffic congestion. The effectiveness of all progression-based models, in general, are conditioned on the common traffic pattern where through traffic constitutes the primary volume on the arterial, and consequently turning flows are not the main concern of the signal design. However, for many arterials serving as the connectors between freeway commuting flows and urban traffic networks, the traffic volumes, that need to take these paths comprising both turning and through movements, are likely to be at the same level or even higher than the through volume along the arterial. Thus, depending on the required turning volume at each arterial intersection, the conventional progression design for through traffic flows may not be adequate to contend with the potential queue spillback and resulting stop-and-going conditions, especially for arterials having a short link and bay length between intersections.

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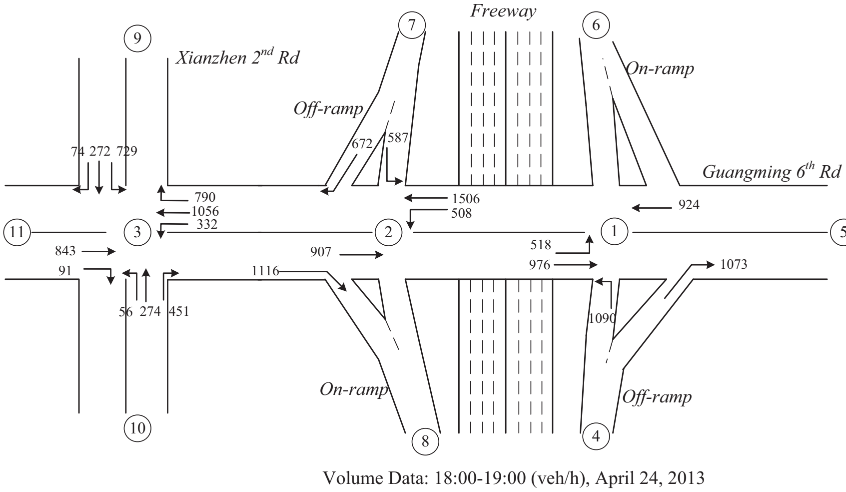

Fig. 1a. An arterial segment and volume distribution in Chupei, Taiwan.

Fig. 1a presents an example of such traffic systems in Chupei, Taiwan, where the arterial segment comprising three intersections to connect a congested commuting freeway and urban network. The heavy turning volumes from-or-to the on-ramp and off-ramps are in conflict with through traffic, and the design of conventional two-way progression often yields both overflow at turning bays and consequently a gridlock for the entire network. A further field survey and analysis has revealed that the traffic patterns along the arterial segment are the collective manifestation of five congested path-flows. As shown in Fig. 1b, Path-1 flows from Node 4 to Node 11 exhibit the highest volume (702 vph), and all vehicles along this path need to first manipulate a turning movement and then join the through traffic on the main arterial. Other primary path-flows, including Path-2 (Node 5 to Node 8), Path-3 (Node 4 to Node 9), and Path-4 (Node 7 to Node 5) also share the common features of having heavy turning volume to merge to the through traffic flows. Moreover, traffic flows on those outbound paths (Paths 1, 2, 3) are in conflict with those inbound paths (Paths 4, 5), inevitably causing the conventional design of two-way progression ineffective. Hence, how to smooth traffic movements on such a congested arterial that serves as a connector between a commuting freeway and primary trip-destination locations is an imperative issue in design of effective urban traffic control.

In review of the literature on arterial traffic control, one may classify most existing studies into two distinct categories: maximizing traffic progression and minimizing total vehicle delay. The core logic of most studies in the former category is to synchronize signals of a common cycle length with optimized offsets on an arterial to facilitate the movement of vehicles over consecutive intersections. Morgan and Little (1964) are the pioneers who first presented a model to maximize the total two-way progression bandwidth on an arterial. Following the same principle, Little (1966) further proposed an advanced model to concurrently optimize the common cycle length, progression speeds, and offsets with integer programming. An

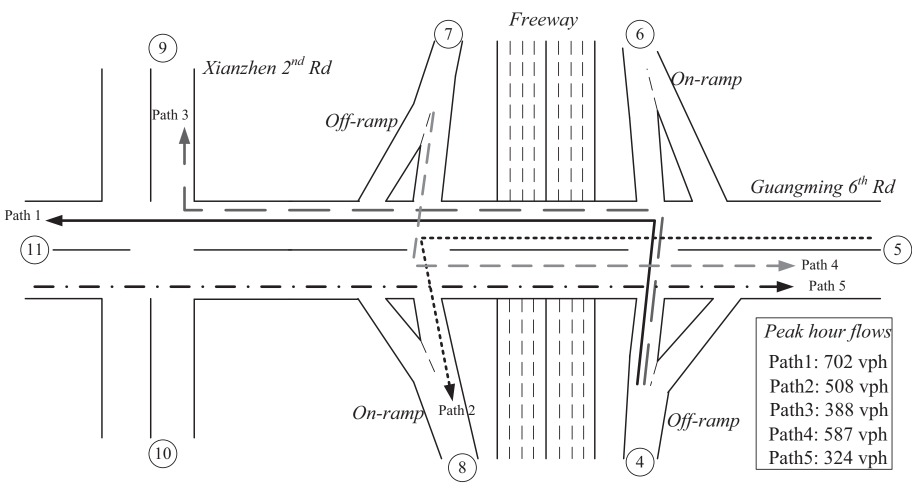

Fig. 1b. Critical traffic paths passing more than two intersections in Chupei, Taiwan.