STOCHASTIC ALGORITHM FOR IMPROVED OPERATIONS AT ISOLATED HIGH SPEED INTERSECTIONS

Anuj Sharma[1a], Darcy Bullock[b], Srinivas Peeta[c],

[a] Graduate Research Assistant; [b] Professor; [c] Associate Professor
School of Civil Engineering, Purdue University

Abstract: The current practice of specifying simultaneous gap out logic at isolated high speed signalized intersections places constraints on the signal controller logic that cannot be satisfied under high congestion level. Further, it often results in degraded signal efficiency and dilemma zone protection. A stochastic approach is proposed in this paper with the objective of increasing safety and efficiency at these intersections. *Copyright © 2006 IFAC*

Keywords: Safety, Traffic Control, Detectors, Efficiency Enhancement, Road Traffic.

1. INTRODUCTION

Intersection crashes constitute a significant portion of total fatalities in the United States; they account for an average of 9,000 fatalities and 1.5 million injuries annually. Red light running (RLR) is a major cause of fatal and injury-related crashes. Also, motorists are more likely to be injured in such crashes. The National Highway Traffic Safety Administration of USA reported that in 2002 there were 921 fatalities and 178,000 injuries resulting from 207,000 crashes attributable to motorists running red lights at signalized intersections. A survey conducted by the U.S. Department of Transportation and the American Trauma Society indicates that 63 percent of Americans witness a RLR incident more than once a week and one in three Americans knows someone who has been injured or killed because of a red-light runner.

Rural high-speed isolated intersections are more susceptible to RLR crashes. Drivers travel at high speeds at such intersections with a high expectancy of proceeding through them without stopping. This expectancy is violated under dilemma zone incursions, leading to elevated risk of crashes. The most commonly implemented strategy to eliminate this problem is enabling simultaneous gap out logic.

Simultaneous gap out logic is adopted at isolated intersections to provide dilemma zone protection for the drivers on the primary street. It is widely believed that the simultaneous gap out logic provides 100% dilemma zone protection at an intersection. On the contrary, simultaneous gap out logic works well under low traffic volumes but the performance deteriorates under congested conditions. This paper will propose a stochastic approach to improve the performance of simultaneous gap out logic under medium to high traffic volumes.

2. PROBLEM DESCRIPTION

2.1. *Dilemma Zone*

The dilemma zone constitutes the area on the roadway where the driver is indecisive about whether to stop or to go on the onset of yellow interval (ITE, 1999). Figure 1 shows this concept graphically. Driver 1 in the "Can Go" zone can safely cross the intersection while staying within the speed limit. Driver 3 in "Can Stop" can come to a safe stop before the stop bar with a comfortable deceleration. Driver 2 in the "Dilemma Zone" can neither cross the intersection before the onset of red if he stays within speed limit nor can stop the vehicle by applying a comfortable deceleration. The concept of a dilemma zone appeared in studies by Gazis et al. (1960), Olson and Rothery (1972), Crawford (1962) and Herman (1963). Sheffi and Mahmassani (1981) identify the dilemma as the drivers' decision to proceed through the intersection or to stop when the signal indication changes from green to amber. Sheffi and Mahmassani (1981) further defined it as the zone within which the driver could neither come to a stop nor proceed through the intersection before the

---

[1] Address: Department of Civil Engineering, Purdue University, West Lafayette, IN-47907.
Email: sharma23@purdue.edu.
Tel: 765-494-2206
Fax: 765-496-7996

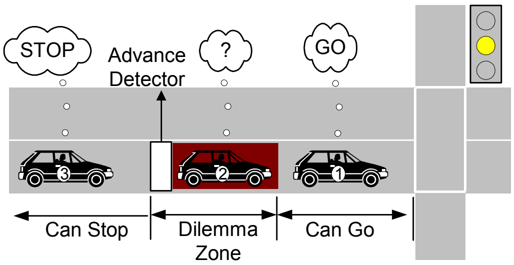


Fig. 1. The Dilemma zone

end of the amber phase. Zegeer (1977) proposed a probabilistic approach by defining a dilemma zone as the road segment where more than 10% and less than 90% of the drivers would choose to stop. Sheffi and Mahmassani (1981) developed dilemma zone curves of 'percent drivers stopping' versus 'distance from stop bar' at the instant when the signal indication changes from green to amber. Dilemma zone is also referred to as the "option zone" or the "zone of indecision" (McCoy and Pesti, 2002).

Occurrences of a dilemma zone incursion (presence of driver/drivers in the dilemma zone) elevate the risk of crashes. Dilemma zone incursions have also been identified as major causes of red light running and rear end collisions. Dilemma zone protection is provided to minimize, and if possible eliminate, the occurrences of dilemma zone incursions. This is usually accomplished by placing an advance vehicle detector just beyond the start of dilemma zone (as shown in Figure 1). Advance detector detects a vehicle and extends the green sufficiently to allow the vehicle to travel past the dilemma zone to the "Can Go" zone. Such an approach is often referred to as green extension system. A "before-and-after" evaluation (Zegeer and Deen, 1978) of the extension system on three intersections in Kentucky to determine their effect on crashes showed a 54 percent reduction in accidents per year at the three sites combined. The duration of the before-period was 8.5 years and the duration of the after-period was 3.7 years. There were 70 accidents in the before-period and 14 accidents in the after-period.

The safety benefits of a green extension system are negated if the phase reaches their maximum green time and arbitrarily terminates (max out). The green extension system usually uses simultaneous gap out logic to pool the through lanes of high speed movement. This is done to ensure that none of the included lanes have vehicles in the dilemma zone under the normal termination of green phase. The simultaneous gap out logic works well during low volume conditions. However, the frequency of max out increases with the increase in traffic volume, jeopardizing both safety and efficiency of operations at the intersection.

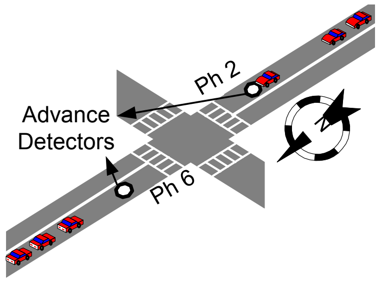
Enhanced systems like the TTI truck priority system (Middleton, *et al.*, 1997), intelligent detection-control system (Bonneson, *et al.*, 2002) etc. are the other forms of green extension/termination systems.

These systems, which promise improved dilemma zone protection but require expensive detection, are not widely used.

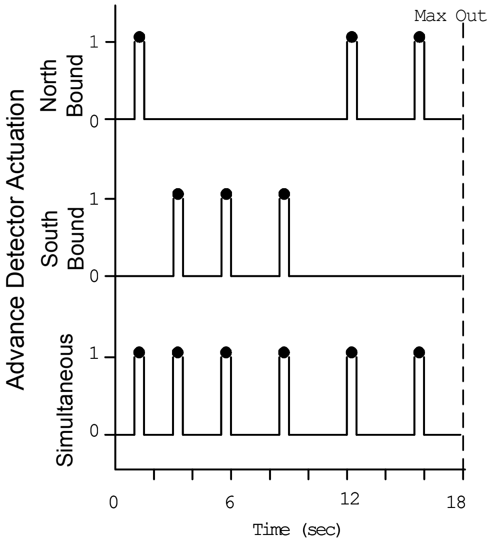
Other methodologies (Saito, *et al.*, 1990) dynamically vary the clearance intervals (yellow clearance and all red) to minimize dilemma zone incursions. These methodologies have not been widely implemented or tested. They can be used as complementary to green extension systems. This paper focuses on the evaluation and improvement of simultaneous gap out logic which is the most commonly used feature (available in almost all the controllers) for dilemma zone protection. The concept of simultaneous gap out logic is explained hereafter.

2.2. Simultaneous gap out logic

As shown in Figure 2, in actuated control, phases 2 and 6 (main street through phases) are most often linked for gap out purposes. This imposes an additional constraint on the control system. The constraint requires that when crossing the barrier, phases 2 and 6 must gap out together in order to terminate the green interval. In the absence of simultaneous gap out logic, if phase 2 gaps out prior to phase 6 both the phases go to clearance as soon as



a) Example intersection



b) Example detector inputs

Fig. 2. Illustration of simultaneous gap out logic