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A comparative study on the operational performance of four-leg intersections by control type

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ABSTRACT

The selection of proper control types at intersections at the planning stage is an important concern considering the difficulty in comparing the performance of different control types. Therefore, several manuals proposed selection charts to guide traffic engineers in identifying the control strategy that yields to the lowest delay and the highest level of service. However, most of these methodologies consider only total major and minor street traffic flows. They do not necessarily suggest to investigate the impact of turning traffic and pedestrian flows, which limits the applicability of their recommendations. Thus, this study aims to propose a procedure to assess the selection of the optimum control strategies among two-way stop, roundabout and signalization using average intersection vehicle delay as the evaluation criterion. The impact of turning traffic on the major and minor streets as well as the impact of pedestrians are integrated into the developed analytical methodology for the estimation of average intersection vehicle delay. A typical layout of isolated four-leg two-way intersection is assumed for the model development. It is concluded that turning traffic and pedestrians play essential roles in the performance of intersections. As pedestrian flow increases, signal control becomes prevailing over the other control types.

1. Introduction

Intersections have a significant role in the operation of road networks. They are key players in determining the amount of traffic that flows in road links. Their capacities are the dominant factor in defining the capacity of the whole road network. Hence, the efficiency of these spots contributes significantly towards the efficiency of whole road network, as they are the main bottlenecks in the system. Traffic control at intersections is a complex process where features related to the efficiency such as capacity and delay are important considerations along with safety and geometrical constraints. Therefore, the availability of rational procedure at the planning stage for the selecting of control type is advantageous. Some manuals such as HCM (2000) and Japan Roundabout Manual (2016) proposed selection charts for the control type at intersections, however, the applicability of these recommendations in the real world is limited since they do not consider turning traffic movements and pedestrian flows.

Typically, intersections are usually controlled by anyone of the followings: regulatory signs, such as two-way stop control (TWSC) and all-way stop control (AWSC); signalization (SIG) and roundabout (RAB). In Japan, there has recently been a growing interest in adopting RABs for the intersection control due to their remarkable efficiency at low to medium traffic flows and their positive safety

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performance. However, to identify the most efficient control type that yields to the lowest intersection vehicle delay under specific vehicle and pedestrian flows at the major and minor streets, it is essential to quantify and compare their performances. Few studies formulated recommendations for the selection of the appropriate control strategies using average control delay as a common measure of effectiveness. Most of these studies did not consider in detail the impacts of turning traffic and pedestrian flows, which significantly limited the applicability of their recommendations. It is important to mention that delay is not the only factor to be considered for the selection of appropriate control types at intersections. Other factors such as safety also need to be considered. However, it is common that capacity and average intersection vehicle delay are the most determinant factors.

Therefore, this study investigates the traffic demand combination under which each of TWSC, RAB and SIG best performs using average intersection vehicle delay as a common measure of effectiveness and assuming undersaturation condition for all control types. Through the analysis, the study examines the impacts of turning traffic and pedestrian flows on the performance area of each control type. The estimated delay does not include pedestrian delay. The impact of pedestrian demand on vehicle movement and the setting of intersection control, which may result in significant additional delay to vehicular traffic, is investigated. The consideration of pedestrian on vehicle operational performance of control types is the unique contribution of this study. Moreover, although few existing studies addressed the impact of turning traffic, they did not examine this impact in various scenarios of different right and left turning volume ratios. Furthermore, this study develops charts for the selection of intersection control types that can assist engineers in the identification of the optimum control type under combinations of major and minor street flows, turning traffic ratios, and pedestrian flows.

The remaining parts of this paper are organized as follows. In the literature review, relevant studies on comparing the operational performance of different control types are discussed. Then the methodology for developing the analytical model and the scenario setting is presented. This is followed by sensitivity analyses on the impacts of turning traffic and pedestrian flows on the estimated average intersection vehicle delay. Then charts for the selection of intersection control types are presented and discussed. The paper ends with conclusions and future works.

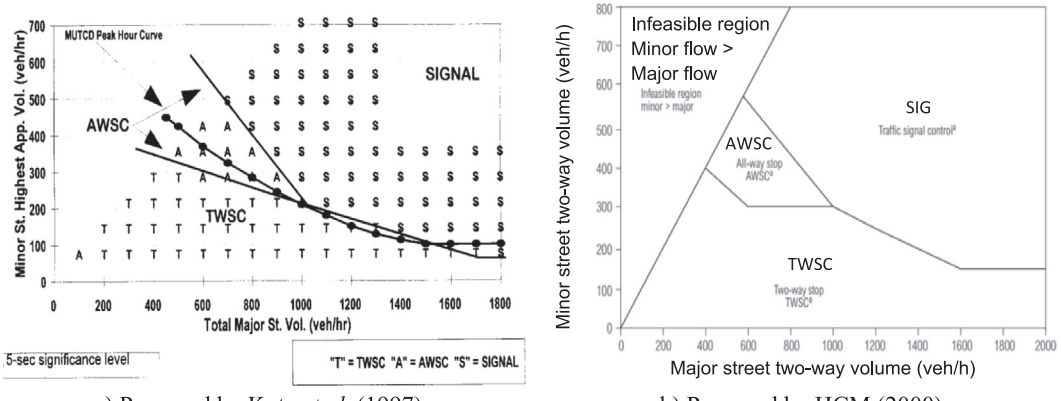
2. Literature review

Few studies compared the performance of various intersection control types to draw recommendations on their feasibility areas. For instance, Manual of Uniform Traffic Control Device MUTCD (2009) provided traffic signal warrants, which served as the guiding principles for the installation of signals at intersections. It stated that the selection and the use of traffic control signals should be based on an engineering study of roadways, traffic, and other conditions. Furthermore, the manual suggested to control intersections with TWSC or AWSC in case a traffic signal is not warranted. However, the manual did not provide any recommendation on the implementation of RAB. Additionally, the impacts of turning traffic and pedestrian flows are not included.

Kyte et al. (1997) proposed an intersection control selection criteria based on the peak hour intersection volume. They compared TWSC, AWSC, and SIG by using average delay and average queue length as measures of effectiveness. They stated that the analysis result reasonably matches peak hour volume warrants of MUTCD (1988). They proposed Fig. 1(a) as a quick method for determining optimum intersection control type. However, RAB was not considered at that time and they did neither investigate the impacts of turning traffic nor pedestrian flows.

Highway Capacity Manual HCM (2000) provided a selection chart for intersection control types of future facilities as shown in Fig. 1(b). This exhibit compares TWSC, AWSC, and SIG control based on the peak hour two-way volumes on the major and minor streets. It did not consider the effects of turning traffic and pedestrian flows. Additionally, the exhibit did not cover RAB as one of the potential control types.

Yoshioka et al. (2008) compared the performance of TWSC, RAB and SIG. They suggested Fig. 2 as a selection criterion of control type at intersections for the future planned facilities. This figure is currently referred to in Japan Roundabout Manual (2016) as an example of the control type selection criteria. Unlike the above studies, their study considered RAB as one of intersection control



a) Proposed by Kyte *et al*. (1997) b) Proposed by HCM (2000)

Fig. 1. Recommendations on the optimum intersection control types based on minimum average delay.