Transportation Research Procedia

Volume 15, 2016, Pages 75–86

ISEHP 2016. International Symposium on Enhancing Highway Performance

Methodology for Timing and Impact Analysis of Signalized Intersections

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Abstract

A new Swedish capacity manual has been developed based on a major research project called METKAP. This paper is focused on the deterministic methods for calculation of signal timing and traffic performance measures for isolated, fixed time signalized intersections documented in the new manual (STA 2013a) and applied in the CAPCAL 4 software (Linse 2013). The use of the methods is mandatory in projects for the Swedish Transport Administration (STA). Special focus has been devoted to the following issues: 1) Modelling of saturation flow for opposed lanes. 2) Impact of short approach and exit lanes. 3) Iterative signal timing process based on critical conflict identification, intergreen and minimum green times.

The deterministic methods can also be applied for selection of maximum green time for VA-controlled intersections, and as planning tool for analysis of the traffic performance alternative intersection types, designs. They can also be used to identify “bottleneck intersections” and for determination of minimum cycle time and required green time ratios for coordinated traffic signal systems.

Micro simulation can be used as an alternative method, e.g. to model complex, signal control strategies and active priority of public transport vehicles. Need for simulation also arises if adjacent traffic facilities influence the studied system, and for animation purposes. However, micro simulation has important short-comings compared to deterministic methods. Simulation models require validated and detailed input data, e.g. regarding vehicle characteristics, arrival distribution, route choice and driver behavior. It is also difficult to estimate saturation flow, capacity and volume-to-capacity ratio since the simulated queue discharge is normally based on car-following models. Determination of optimal intersection design and signal timing requires a very large number of simulation runs and is therefore very time consuming and costly.

Keywords: Methodology, Signal timing, Capacity, Traffic performance, Software

Selection and peer-review under responsibility of the Scientific Programme Committee of ISEHP 2016

doi:10.1016/j.trpro.2016.06.007

1 Introduction

A detailed methodology for signal timing and capacity analysis of signalized intersections was developed in the seventies as a part of a new Swedish Capacity Manual (SRA 1977) by Bang (1978). Computational aids for this method were also developed in the form of the CAPCAL software, which has later been subject to a number of updates including traffic safety, emission and other performance measures for all major types of at-grade intersections (Hagring et al 2010). A new Swedish capacity manual has since been published (STA 2013a) based on major research and development projects (Hagring 2000; Al-Mudhaffar 2006, Wahlstedt 2011, Bang 2014). This paper is focused on revised deterministic methods for calculation of signal timing and traffic performance measures for isolated, fixed time signalized intersections documented in the new manual (METKAP) and applied in CAPCAL 4 software (Linse 2013). Special focus has been devoted to the following issues:

- Detailed modelling of saturation flow for opposed lanes.
- Short lane utilization and contribution to approach bottleneck capacity
- Inter-green times and minimum green periods and their application in the signal timing process.
- Procedures for finding the critical conflict point between conflicting traffic movements as a basis for determination of optimal signal timing.

The paper is concluded with a discussion regarding the use of simulation as an alternative method.

2 Overview of the Methodology

The capacity of a signalized intersection approach is primarily a function of number of lanes and their traffic flow, directional distribution, saturation flow and green time ratio. Saturation flow for a lane depends on its geometry and degree of conflict with opposing vehicle and pedestrian movements that are discharged in the same signal phase. Since the signal timing is not known from the start, iterative calculations must be performed starting from base assumptions regarding cycle time, lost time and green time distribution as a function of intersection type. The obtained signal timing is then applied for new calculations of traffic lane distribution, ratio of turning traffic, saturation flow, critical conflict point, signal timing and resulting flow discharge and capacity in the next iteration.

Initial calculation (Approximate results)
Determine lane type and flow for each lane (***q***)
Determine intergreen and select initial values for signal timing
Determine saturation flow ***(s)*** and load factor **(q/s)** for all bottleneck lanes
Identify the critical conflict point for main phase flows
Determine total lost time (***F***), cycle time (***c)*** and green times ***(g)***
Revise signal timing if calculated $g < g_{min}$
Determine capacity ***(C)*** and degree of saturation ***(DS)*** for all lanes

Iteration 2 … n
Check phase scheme, lane types, minimum green, inter-green, lost time
Repeat all calculations using the resulting values for signal timing, traffic flow and saturation flow for each lane from the previous iteration.

Impact analysis
Traffic performance impacts (delay, queue length, ratio of stopped veh.)
Environment, safety and cost impacts. Analysis for oversaturated conditions

Figure 1: Overview of the calculation process for signalized intersections