Modeling Capacity of Through Movement at Signalized Intersection Impacted by Short Left-Turn Bay under Different Signal Settings

Zhihui Wei, Yunlong Zhang, Ph.D., Xiaoyu Guo, and Xin Zhang
wzh96@tamu.edu, yzhang@civil.tamu.edu, xiaoyuguo@tamu.edu, and zhangxin@tamu.edu
Zachry Department of Civil and Environmental Engineering, Texas A&M University

Introduction

- **Through movement capacity** is an essential factor used to reflect intersection performance. Left-turn spillback and blockage are two main contributors that affect through movement capacity.
- **Oversimplification in the previous models**: Previous works contained assumptions that neglect some of the left-turn spillback scenarios.
- **Previous work is limited to one specific signal strategy**. This model includes 4 different left-turn strategies:
  - lagging protected only (lagging POLT)
  - leading protected only (leading PPLT)
  - permitted plus protected (lagging PPLT)
  - protected plus permitted (leading PPLT).

Methodology

This equation is used to calculate the **through movement capacity** under lagging protected only left-turn setting. The equation contains two parts: the first part is the sum of the product of various probabilities of left-turn spillback scenarios and the corresponding movement through capacity. The second part is the probability that spillback doesn’t happen multiplying the through movement capacity when spillback doesn’t happen.

\[ C_{\text{TH}_{\text{Lagging POLT}}} = \sum_{i=1}^{n} \sum_{k=1}^{m} \frac{n(t + \lambda_{TH} T_{LT}) + (N_{TH} - 1) \lambda_{TH} T_{LT}}{C} \times e^{-\lambda_{TH} T_{LT}} \times \frac{(1 - p_{SP}) N_{TH} T_{TH}}{C} \]

Where:
- \( p_{SP} \): Left-turn spillback probability
- \( \lambda_{LT} \): Left-turn vehicles arriving rate (veh/h)
- \( T_{LT} \): Left-turn red duration (h)
- \( n \): number of cycles per hour
- \( N_{TH} \): number of through lanes
- \( S_{TH} \): saturation flow rate of through movement per lane (veh/h/ln)
- \( g_{LT} \): left-turn green duration per cycle (h)
- \( g_{TH} \): through green duration per cycle (h)
- \( C \): cycle length (h)

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A four-leg isolated signalized intersection was set up in VISSIM, as:
- **Through vehicle volume**: 1,700 veh/h;
- **Opposite through volume**: 1,500 veh/h;
- **Protected left-turn green**: 23 s;
- **Through vehicle red and change time**: 54 s;
- **Cycle length**: 106 s;
- **Left-turn volume**: 400 veh/h;
- **Through vehicle green**: 50 s.

Result

Validation of Proposed Adjacent Through Capacity Models

**Comparisons of Adjacent Through Capacity Models with Different Left-Turn Bay Lengths**

- **Effect of Cycle Length on Through Movement Capacity**
  - Bay Length = 14 veh
  - Bay Length = 13 veh
  - Bay Length = 12 veh
  - Bay Length = 11 veh
  - Bay Length = 10 veh
  - Bay Length = 9 veh
  - Bay Length = 8 veh
  - Bay Length = 7 veh
  - Bay Length = 6 veh
  - Bay Length = 5 veh
  - Bay Length = 4 veh

**Comparisons of Adjacent Through Capacity Models in Different Left-turn Signal Settings**

- **Leading POLT**
  - Bay Length = 4 veh
  - Bay Length = 5 veh
  - Bay Length = 6 veh
  - Bay Length = 7 veh
  - Bay Length = 8 veh
  - Bay Length = 9 veh
  - Bay Length = 10 veh
  - Bay Length = 11 veh
  - Bay Length = 12 veh
  - Bay Length = 13 veh
  - Bay Length = 14 veh

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Conclusion

- **Through movement capacity models** under four left-turn strategies are established considering the effects of left-turn spillback and blockage.
- **Proposed models deliver good accuracy** over all signal settings and also maintain consistent accuracy levels at all left-turn bay length levels.
- **Different left-turn signal settings** have different levels of impact on the through movement capacity.
- **Leading POLT presents significant impact** on the through movement capacity, although it tended to be overlooked by previous studies.
- **When left-turn spillback occurs**, the combination of longer left-turn bay and shorter cycle length is better than combination of shorter left-turn bay and longer cycle length for through movement capacity.

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