# 0-5290: Left-Turn Lane Design and Operation

## Background

Left-turn lanes can improve the safety and operation of intersections by providing space for deceleration and storage of vehicles waiting to make a left turn. The length of the lane is critical in the design of left-turn lanes. The required length of a left-turn lane is the sum of the deceleration length (the distance required for the driver to move laterally into the left-turn lane and decelerate to a stop) plus the required queue storage length. Left-turn lanes must be designed with sufficient length to store the longest queue that can be expected in most situations. Insufficient length will result in lane overflow, which seriously compromises both the operation and safety of an intersection. In the design of left-turn lanes, field engineers face three critical questions: (1) How long should the left-turn lane be? (2) When and where should multiple left-turn lanes be provided? (3) What are the safety benefits of extending the left-turn lane? The exiting methods have limitations in recommending appropriate queue storage lengths for left-turn lanes. In addition, there is a lack of guidelines for installing multiple left-turn lanes. Moreover, few studies have been conducted for quantifying the safety effectiveness of extending the length of existing left-turn lanes. To address these problems, this research examined important issues related to the design and operation of left-turn lanes and recommended best practices that could improve both safety and efficiency of intersections.

## What the Researchers Did

A new analytical model (TSU model) for determining the queue storage length of left-turn lanes at signalized intersections was developed by considering both parts of the left-turn queue: (1) the vehicles that arrive during the red phase (red-phase queue), and (2) the queue of vehicles carried over from previous cycles (leftover queue). The developed model was evaluated by being compared with the field observations from 28 study intersections and the queue length estimates from the existing models.

For storage length estimation, this research examined the procedures for estimating left-turn queue storage length by using three different traffic models: SYNCHRO, SimTraffic, and VISSIM. For deceleration length estimation, a traffic simulation-based method for left-turn deceleration length estimation was developed.

Two types of warrants for multiple left-turn lanes were developed: (1) the capacity and volume based warrants, and (2) the left-turn queue length based warrants. By combining the developed warrants with the existing warrants/guidelines, a decision-making flowchart for installing multiple left-turn lanes was developed. It provides comprehensive guidelines on multiple left-turn lane installation because both operational and safety impacts of multiple left-turn lanes were considered in the development of the guidelines.

The safety benefits of increasing the storage lengths of existing left-turn lanes were analyzed by two methods: (1) accident data analysis, and (2) simulation-based safety analysis.

### Research Performed by:

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This research investigated two other important issues related to left-turn lane design and operation: (1) left-turn bay taper length estimation, and (2) the impacts of signal phasing sequence on left-turn operation. Two different sets of bay taper lengths were recommended for the intersections in urban areas and non-urban areas. The research also suggested the way to select the proper signal phasing sequence for intersections with left-turn lane overflow and/or blockage problems.

## What They Found

Although all of the 28 study intersections were subject to undersaturated conditions, it was found that the left-turn queue carryover problem occurred frequently for the intersections with left-turn volume capacity (v/c) ratios within the range of 50 to 80 percent. Therefore, the leftover queue cannot be neglected in the estimation of left-turn queue lengths. The evaluation results indicated that the developed model considerably outperforms the existing methods by considering both parts of the left-turn queue.

Results of the safety benefit analysis indicated that (1) the average rear-end accident rate at the intersections with left-turn overflow problems was 35 percent higher than that at the intersections without left-turn overflow problems; and (2) after extending the length of the left-turn lanes to eliminate the overflow problem at the study intersections, all of the safety surrogate measures derived from the traffic simulation results changed significantly in a direction that indicated the reduction of rear-end accident risk at those intersections.

The analysis of the operational and safety impacts of the multiple left-turn lanes indicated that traffic delay will be increased quickly when left-turn volume exceeds its capacity. Thus, multiple left-turn lanes should be installed at these intersections. In addition, multiple left-turn lanes should be provided at the intersections where it is infeasible to extend the length of a single left-turn lane to prevent the left-turn overflow problem or the queue lengths on the left-turn lane and adjacent through lane are very unbalanced.

The impacts of signal phasing sequence on left-turn operation were studied by traffic simulation-based methods. The simulation results showed that traffic delay caused by overflow and blockage problems could be significantly reduced by choosing the appropriate signal phasing sequence. It was found that for the intersections with a significant overflow problem, the left-turn movement should start earlier than the through movement. For the intersections with a significant blockage problem, the through movement should start earlier than the left-turn movement.

## What This Means

Based on the results of the research, the following recommendations regarding left-turn lane design and operation were made: (1) left-turn lanes should be designed with adequate storage length, considering both the red-phase queue and leftover queue; (2) multiple left-turn lanes should be provided at an intersection where the left-turn volume exceeds its capacity and an extreme long left-turn queue exists; (3) the length of the left-turn lane should be extended, or the single left-turn lane updated to multiple left-turn lanes, for intersections with left-turn lane overflow problems to reduce rear-end crash risk; (4) longer bay taper lengths should be provided for intersections in the non-urban areas; and (5) appropriate signal phasing sequence should be adopted to reduce the delay caused by left-turn lane overflow and blockage problems.

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