Queue Storage Design for Metered On-Ramps

Zhongren Wang
Division of Traffic Operations, California Department of Transportation,
1120 N Street, MS-36, Sacramento, CA 95814

ABSTRACT
Queue storage at a metered freeway on-ramp is an essential design element for metered on-ramps to prevent on-ramp queue from extending beyond on-ramps. In this paper, various existing methodologies that are used to size the queue storage at metered on-ramps were first reviewed. It was found that queue storage sized using 7% of peak hour on-ramp demand is widely accepted in practice. A limited dataset collected in California helps provide some reality check for this method. It is recommended that queue storage be recognized as an indispensable design element at metered on-ramps, and detailed sizing guidance be developed in the highway geometric design policy of the American Association of State Highway and Transportation Officials (AASHTO).

Key Words: On-Ramp Design, Queue Storage Design, Ramp Metering

1. INTRODUCTION
1.1. Background
Ramp metering is to place a traffic signal at an on-ramp to regulate demand entering a freeway. By doing so, overloading of downstream freeway bottlenecks may be prevented, and in turn, the total delay of both freeway and on-ramp may be reduced. Such benefits of ramp metering have been well documented. As evidenced by the Minnesota study, when ramp meters were turned off, freeway throughput decreased by 9%, travel time increased by 22%, speeds dropped by 7% and crash increased by 26% [1]. Recent studies conducted in the San Francisco Bay Area have indicated that ramp metering system reduced the travel time by 30% along an 18 mile long stretch of Route 580 [2]. In view of the ever-increasing difficult level of adding more capacity to the existing freeway system, ramp metering becomes an even more critical piece of the system

management puzzle. In California, the Department of Transportation (Caltrans) is committed to using ramp metering as an effective traffic management strategy to maintain an efficient freeway system and protect the investment made in constructing freeways by keeping them operating at or near capacity [3].

Ramp metering has profound impacts upon the operations and therefore design of an on-ramp. When an on-ramp is metered, all on-ramp traffic has to stop or queue upstream of the limit line before accelerating and merging with mainline traffic. The entire length of the on-ramp is therefore divided by the limit line into the upstream queue storage portion, and the downstream acceleration portion. Upstream of the queue storage portion, stopping sight distance have to be provided so that the approaching motorists may join the back of queue safely. Therefore, a metered on-ramp may call for longer on-ramp length as compared with its un-metered counterpart. For multilane on-ramps as shown in Figure 1, the necessary transitional distance between the multilane and single lane sections may call for even longer on-ramps.

The challenging fact is that ramp metering came into being after most of the interstate highway system was constructed, and seldom were the existing on-ramps designed with ramp metering in mind. In ramp metering applications, ramp meters can only be retrofitted onto the existing ramps, and this is bound to be met with difficulties. For an existing on-ramp with fixed length, storage needs have to compete against the necessary acceleration distance. As a result, storage needs may not always be satisfied, leading to on-ramp queue overspill if both freeway-mainline and on-ramp demands are high. Indeed, on-ramp queue overspill is one of the most common reasons why ramp metering is not accepted by local agencies. Insufficient queue storage is jeopardizing the implementation of ramp metering.

It is the purpose of this paper to investigate and identify a reasonable approach on how to size the queue storage needs for new or re-constructed metered on-ramps. In the

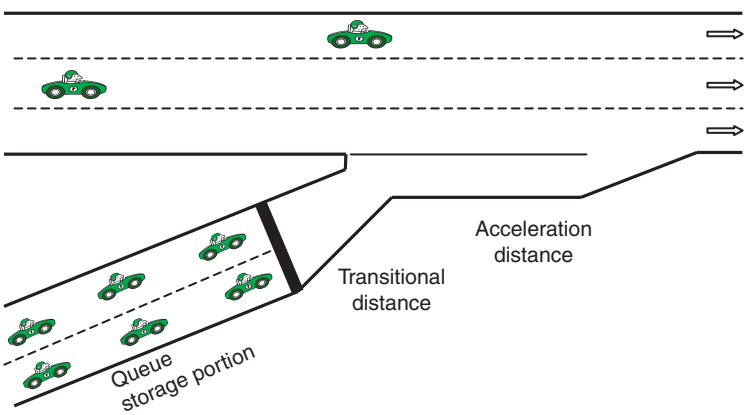

Figure 1. Schematic drawing of a metered on-ramp