Ramp Metering Influence on Freeway Operational Safety near On-ramp Exits

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ABSTRACT
Ramp metering has been widely installed in urban areas where congestion on a freeway or an expressway may occur recurrently during weekday peak periods to enhance mainline throughput and reduce system-wide delay. These operational benefits may also help reduce vehicular emissions and improve air quality in urban areas. However, the impact on traffic safety due to ramp metering hasn't been explored in details before. Supported by physical understanding and arguments, we characterize the ramp metering influence on freeway safety by examining vehicular collisions near on-ramp exits within the ramp meter operating hours before and after the activation of the ramp metering. Collisions for a sample of 19 operating ramp meters along several freeways in northern California were collected and organized to show that ramp metering can help reduce freeway collisions at the vicinity of on-ramp exits. It was found that the average reductions on freeway collisions in the vicinity of an on-ramp exit are around 36%. Although most of the reduced collisions belong to the property damage only category, a 36% reduction shows the significant safety benefit of ramp metering. The traffic congestion induced by each collision, especially during peak hours when ramp metering is in operation, could last for an hour or two. Consequently, ramp metering must be contributing to the reduction of non-recurrent congestion in addition to mitigating recurrent congestion, which is better documented. This study strongly supports the implementation of ramp metering in California.

1. INTRODUTCTION
The primary purpose of installing a ramp meter is to manage the on-ramp traffic volume to be merged into the freeway mainline and potentially smooth the mainline operation and eventually improve mobility in a well connected freeway network. It isn't obvious whether the on-ramp metering would reduce the number of freeway collisions near the on-ramp exit. It is in general observed that on-ramp metering has many effects on the on-ramp traffic but we list a few here in the context of traffic flow interactions between the on-ramp and the main line traffic: first, the ramp metering will

make the on-ramp traffic, usually in queues around peak hours, more visible to the upstream mainline traffic, the mainline drivers become more alerted of on-ramp traffic merging ahead; second, the on-ramp driver would have some stop time to gauge or estimate a possible gap in the mainline traffic, so the on-ramp drivers are more prepared to merge ahead; third, it is likely that the speed at merging would be relatively slow if the portion of the ramp beyond the ramp meter isn't too long, normally in the neighborhood of 500 ft beyond the gore area; and fourth, the time it takes an on-ramp vehicle to travel from the metering spot to the merging completion point would be likely doubled, leaving enough time for an upstream driver to take proper maneuvers. With this in mind and the understanding of a successful merging requires some mutual collaboration between the outside lane traffic and the on-ramp traffic, one may expect the number of collisions near the on-ramp exit should be lower when a ramp meter is installed and activated but there should be no guarantee that the activation will surely reduce the number of collisions on freeways near the on-ramp exits because many factors aren't in traffic engineer's control, e.g., storms or snows, number of rainy days, sobriety of drivers, change of traffic demands due to local or regional developments, change of driver population characteristics/behavior, driver's decision of selecting a different commune ramp, traffic demand fluctuations, or a combination of multiple uncontrollable factors. In this paper, we are not going to examine the effect due to these uncontrollable factors on traffic safety near on-ramp exits but primarily focus on analyzing the possible collision reduction near on-ramps with known traffic volumes and compare the collision reductions 3-year before and 3-year after the installation of an on-ramp metering.

2. FORMULATION

In order to assess the safety impact of ramp metering on freeway traffic, we first define the area of interaction between the merging area of an on-ramp vehicle and the main line traffic as shown in Figure 1. Merging usually is completed by the end of on-ramp weaving length. Most ramps examined in this study have the weaving length around 530-ft (0.1 mile). The elapse duration for traveling 500 ft on the weaving section would be approximately 11 seconds for the average speed of 30 mph and 23 seconds for the speed of 15mph. This elapse time is likely to be sufficient for an on-ramp driver who has stopped at the meter to find a time gap and merge into the mainline traffic for different traffic volumes in the mainline [1]. Meanwhile, a merging on-ramp vehicle can create disturbance to upstream traffic in the mainline. This disturbance can propagate upstream well beyond a ramp exit, and the boundary where it ends depends on freeway features, scenarios, observations, and even traffic flow theories which one may have in mind. It appears reasonable to set the immediate upstream boundary where the primary interactions take place to be around 161 meters (530 ft). This upstream distance may be justified by noting that (1) the traveled distance from the time when the upstream vehicle driver seeing a slow merging vehicle to the time the driver completes the deceleration and/or lane change could be equal to the 7.0 seconds decision time multiplied by speed of 88 kph (55 mph), yielding about 172m (565 ft), (2) the traveled distance from the time when the upstream vehicle driver seeing a nearly stopped