RESEARCH NOTES

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Caltrans

On-Ramp Metering Experiments to Increase Freeway Merge Capacity

Why We Pursued This Research

Caltrans Division of Research and Innovation (DRI) and University of California, Berkeley conducted an On-Ramp metering experiments at test sites in San Diego and Orange County, California in an effort to maintain higher capacity at a freeway/on ramp merge. By setting the stage for more elaborate experiments in the future, the work could lead to preferred metering schemes for saving commuter delay.

What was done?

Field experiments performed at a merge site in San Diego show that automated, traffic-responsive metering can postpone and/or reverse the capacity drop mechanism. Reversing capacity drop can be done first by using restrictive metering until detector occupancies indicate that vehicle accumulation in the freeway shoulder lane has diminished below the critical value. High outflows can then be fully recovered by relaxing the metering rate to bring the freeway queue to the brink of re-forming at the merge. Drivers in this traffic state apparently become sufficiently motivated, such that the merge can pump-out higher outflow. The observations also infer that the capacity drop mechanism can be postponed and even avoided entirely by metering in a proactive fashion, i.e., if metering is implemented in such ways as to always keep vehicle accumulations on the shoulder lane below the critical value, the capacity drop can be averted at the merge.

These experiments yield an important finding regarding relaxed metering rates and outflow recovery. A summary of outflow recoveries on all experimental days is shown in Table 1. Column 2 of this table lists the relaxed metering rates implemented each time the shoulder lane accumulation was mitigated and the freeway queue was cleared. Column 3 shows the average outflows measured from the time when a metering rate was relaxed to the time when a capacity drop re-occurred. The last column (column 4) shows the durations over which these capacity recoveries persisted.

Table 1

Relaxed metering rates and durations of outflow recovery

(1)	(2)	(3)	(4)
Date	Relaxed Metering rates (vph)	Average outflows recovered (vph)	Duration of outflow recovery (min)
Oct 23, 2003	700	-	0
Oct 15, 2003	700	9,730	13
Oct 21, 2003	740	9,600	4
Aug 11, 2004	900	-	0
Aug 11, 2004	620	9,100	17+*
Aug 12, 2004	900	-	0
Aug 12, 2004	600	9,200	13.5

*An incident caused a downstream freeway queue to spillover to the merge after the 17-minute period. If there had been no incident, the outflow recovery would likely have persisted longer than 17 minutes.

The table shows that when using a high relaxed metering rate (e.g., 900 vph), the capacity drop re-occurred immediately. In contrast, high outflows can be sustained for longer periods with a lower relaxed metering rate of 600-620 vph. These findings confirm that after the freeway shoulder lane accumulation is mitigated, low metering rates can postpone the subsequent capacity drop and thus produce higher merge outflows.

The findings verify that automated, traffic-responsive metering can generate higher capacities at an active merge bottleneck. The findings further suggest that less conventional control schemes can also be an effective means of increasing merge bottleneck capacity. The findings are important, since after all higher bottleneck capacities mean commuter delays are reduced system-wide.

Figure 1 displays the San Diego study site. Video cameras were set up on the downstream over-crossings shown in the figure.

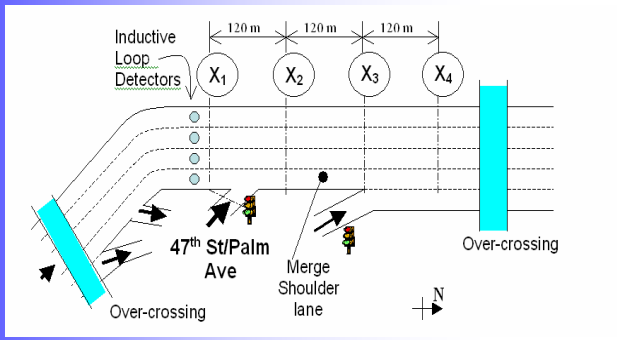

Figure 1: Northbound I-805, San Diego County

Furthermore, the data collected from a second freeway merge (in Orange County) imply that a high capacity can be gained even when the on-ramp inflow is high. This can be achieved when inflows to the merge from the freeway shoulder lane are sufficiently low.

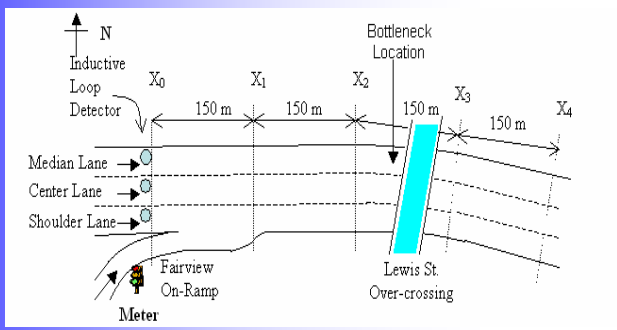

Figure 2: Eastbound SR-22, Orange County

What can be concluded from the Research?

This research has confirmed a capacity drop mechanism at freeway merge bottlenecks and has demonstrated a role for automated, traffic-responsive control strategies to increase capacity at these merges. This research is to deliver the following findings:

1) Field experiment show that metering can favorably affect this capacity drop by responding to loop detector occupancies. The capacity drop can be reversed using restrictive metering until the measured occupancies indicate that vehicle accumulations in the freeway shoulder lane have diminished below the critical value. Then, high outflows can be fully recovered by relaxing the metering rate so that drivers in the upstream freeway queue become motivated and the merge can pump-out higher outflow. The observations also infer that the capacity drop mechanism can be averted by metering in a proactive fashion.

2) Controlling shoulder-lane inflow may be an effective means of generating high merge capacity, even while permitting high inflows from the on-ramp.

What do the Researchers recommend?

Further experiments are needed. These additional experiments could help to refine a capacity-enhancing metering logic; they could verify the effectiveness of this logic at other merge locations; and they could assess the value of less conventional control schemes, such as freeway speed advisories.

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