



Evaluation of Temporary Ramp Metering for Work Zones

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2013 ITS Heartland Conference Presentation



Outline

- Background of ramp metering
- Ramp metering in work zones
- Missouri deployments in maintenance work zones
 - Field studies using temporary ramp meters
 - Detailed microscopic field data collection
 - Safety and operational analysis
 - Use of simulation
 - Main findings and study recommendations





Ramp Metering in the US

- Ramp meters shown to improve mobility and safety
 - California, Minnesota, New York implementations
- No deployments in work zones
 - First field deployment of temporary ramp metering for work zones
 - Sponsored by FHWA Smart Work Zone Deployment Initiative
- Temporary ramp metering for work zones
 - Regulate ramp volume to cope with reduced capacity
 - Potential safety and operational benefits
 - Portable/low maintenance





Evaluation Objectives

- Are drivers compliant with a Temporary Ramp Meter (TRM) in work zones?
- Does TRM make work zone safer?
- Does TRM reduce work zone delays?
- Should TRM be deployed under all traffic conditions?



FIELD STUDIES

Ramp Metering Control Plan

Description of Study Sites





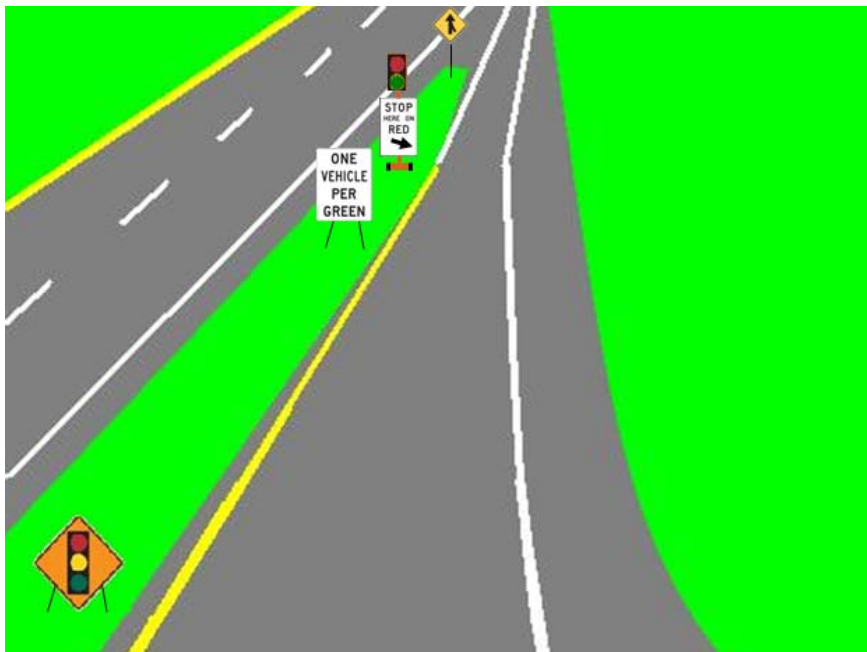
Plan based on....

- MUTCD
- FHWA Handbook of Ramp Management and Control
- AASHTO Green Book
- Permanent ramp meters in Kansas City as template





Conceptual Diagram and Field Implementation





Field study sites





Work Zone Characteristics

Characteristic	Work Zone						
	1	2	3	4	5	6	7
Facility	I-70	I-70	I-70	I-70	I-70	US-63	US-63
Exit	St. Char.	St. Char.	Prov.	West	US-63	Stad.	Stad.
Ramp Vol., veh/hour	147	211	137	55	328	221	211
Lane Closed	Right	Right	Right	Right	Right	Left	Right
Ramp Locat.	After	After	Before	Before	Between	Before	Before
Ramp Truck	0%	0%	0%	0%	8%	2.1%	1%
Grade	-5.7%	-5.7%	-2.4%	1.7%	-0.5%	2.6%	2.6%
Ramp Len., ft	963	963	490	1113	1120	1220	1220
Meter-Gore, ft	471	471	240	632	493	351	351
Taper-Gore ¹ , ft	-3913	-3913	6168	800	7085	1687	2181



METHODOLOGY

Compliance Analysis

Safety Analysis

Mobility Analysis





Compliance analysis

Safety analysis

Mobility Analysis

Compliance Definition

Vehicle went through the signal when the signal display was green

YES

NO

Compliant

Non-Compliant





Comparison of Compliance Rates

- Platoon vs. Free flow
- Passenger cars vs. Commercial vehicles
- Ramp volume with Commercial vehicles vs. without Commercial vehicles
- Congested vs. Near free flow



Compliance analysis

Safety analysis

Mobility Analysis

Radar gun and camera set up





| Compliance analysis

| **Safety analysis**

| Mobility Analysis

Surrogate Safety Measures

- Mean speeds and speed variance for mainline and ramp traffic
- Speed differentials between mainline and ramp traffic
- Accepted merging headways





| Compliance analysis

| Safety analysis

| Mobility Analysis

Speed Differential

- Match mainline/ramp vehicle based on 6-sec platoon-forming threshold
- Calculate speed differentials
- T-test and KS test



| Compliance analysis

| Safety analysis

| **Mobility Analysis** |

Simulation and Calibration

- Simulation model in VISSIM
- Calibration using congested site data
- Car-following model



RESULTS

Compliance Rate

Effect of TRM on Speed

Accepted Merging Headway

Mobility





Compliance
rate

Effect of TRM
on Speed

Accepted Merging
Headway

Mobility

Differences between signal plans

Signal	4R-2G	4R-3G	4R-1Y-2G	4R-1Y-3G
Compliance rate	45.5%	54.0%	75.0%	69.6%

	p-value
4R-2G vs 4R-3G	0.10
4R-2G vs 4R-1Y-2G	0.00
4R-2G vs 4R-1Y-3G	0.00
4R-3G vs 4R-1Y-2G	0.00
4R-3G vs 4R-1Y-3G	0.03
4R-1Y-2G vs 4R-1Y-3G	0.20





Compliance
rate

Effect of TRM
on Speed

Accepted Merging
Headway

Mobility

Platoon, Commercial Vehicles, Congestion and WZ Type

Row	Compliance rate	Ramp Volume	Compliance rate	Ramp Volume	Difference	P-value
	Platoon condition		Free Flow Condition			
A	85.6%	174	63.6%	283	22.0%	0.000
	Passenger Car		Commercial Vehicles			
B	73.3%	655	76.5%	17	-3.2%	0.379
	No Commercial Vehicles		With Commercial Vehicles			
C	65.3%	294	79.5%	378	14.2%	0.000
	Congested		Near Free Flow			
D	67.3%	55	73.8%	619	6.5%	0.161





Compliance
rate

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Accepted Merging
Headway

Mobility

Speeds on mainline and ramp

	Sample Size	Mean, kph (mph)	Std. Dev., kph (mph)	Means, p-value	Variance, p-value
Mainline Speed at Merge Point					
Ramp Meter Off	293	92.15 (57.26)	10.06 (6.25)	0.01	0.00
Ramp Meter On	356	89.77 (55.78)	13.02 (8.09)		
Ramp Speed at Merge Point					
Ramp Meter Off	385	75.45 (46.88)	9.58 (5.95)	0.00	0.07
Ramp Meter On	409	60.74 (37.74)	8.47 (5.26)		





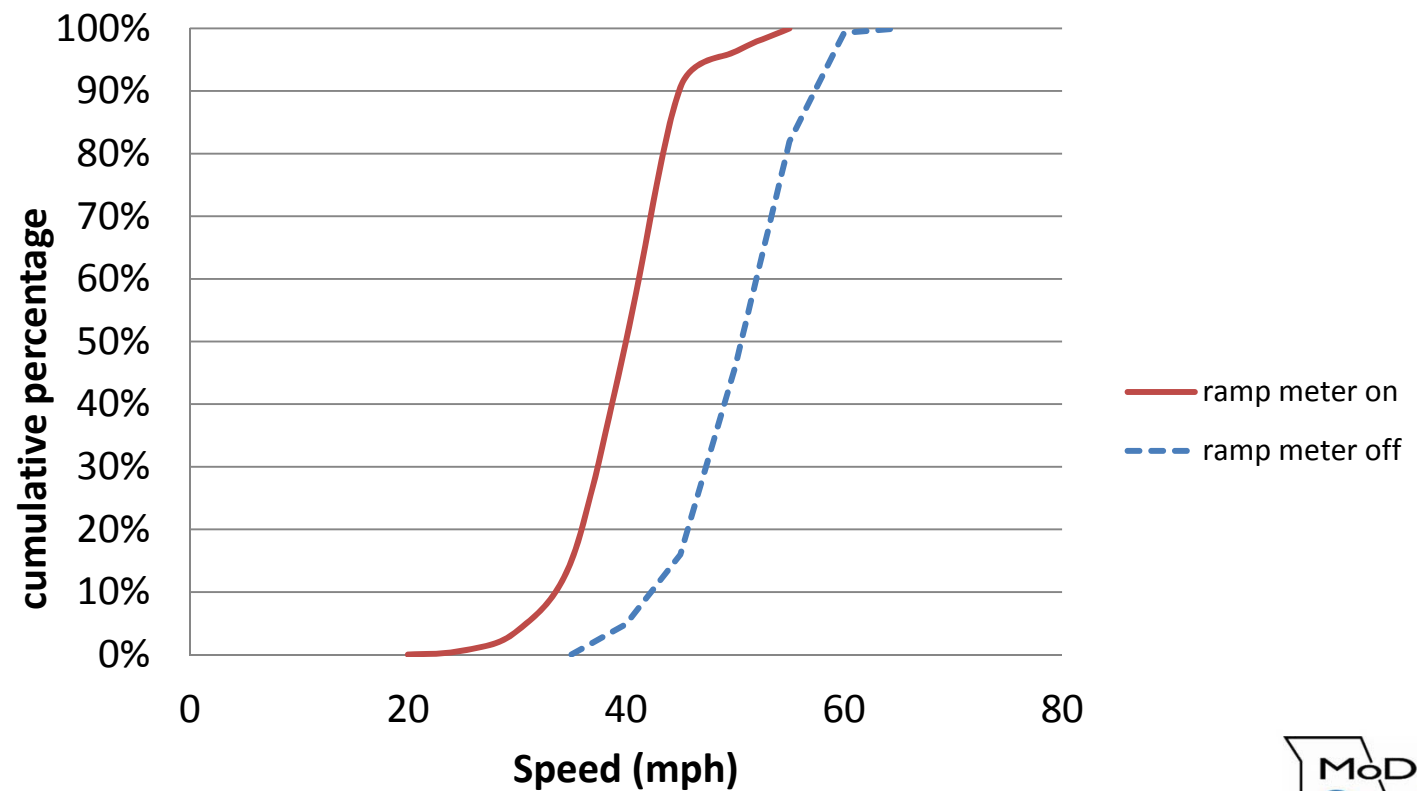
Compliance
rate

Effect of TRM
on Speed

Accepted Merging
Headway

Mobility

Cumulative distribution of ramp vehicle speeds (at gore)





Compliance
rate

Effect of TRM
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Mobility

Speed differentials between mainline and ramp vehicles

Speed Differentials					
	Sample Size Lead/Follow	Lead, Mean, kph (mph)	Follow, Mean, kph (mph)	Lead Means, p-value	Follow Means, p-value
Ramp Meter Off	164/153	-16.64 (-10.34)	-15.74 (-9.78)	0.00	0.00
Ramp Meter On	185/149	-31.21 (-19.39)	-31.27 (-19.43)		





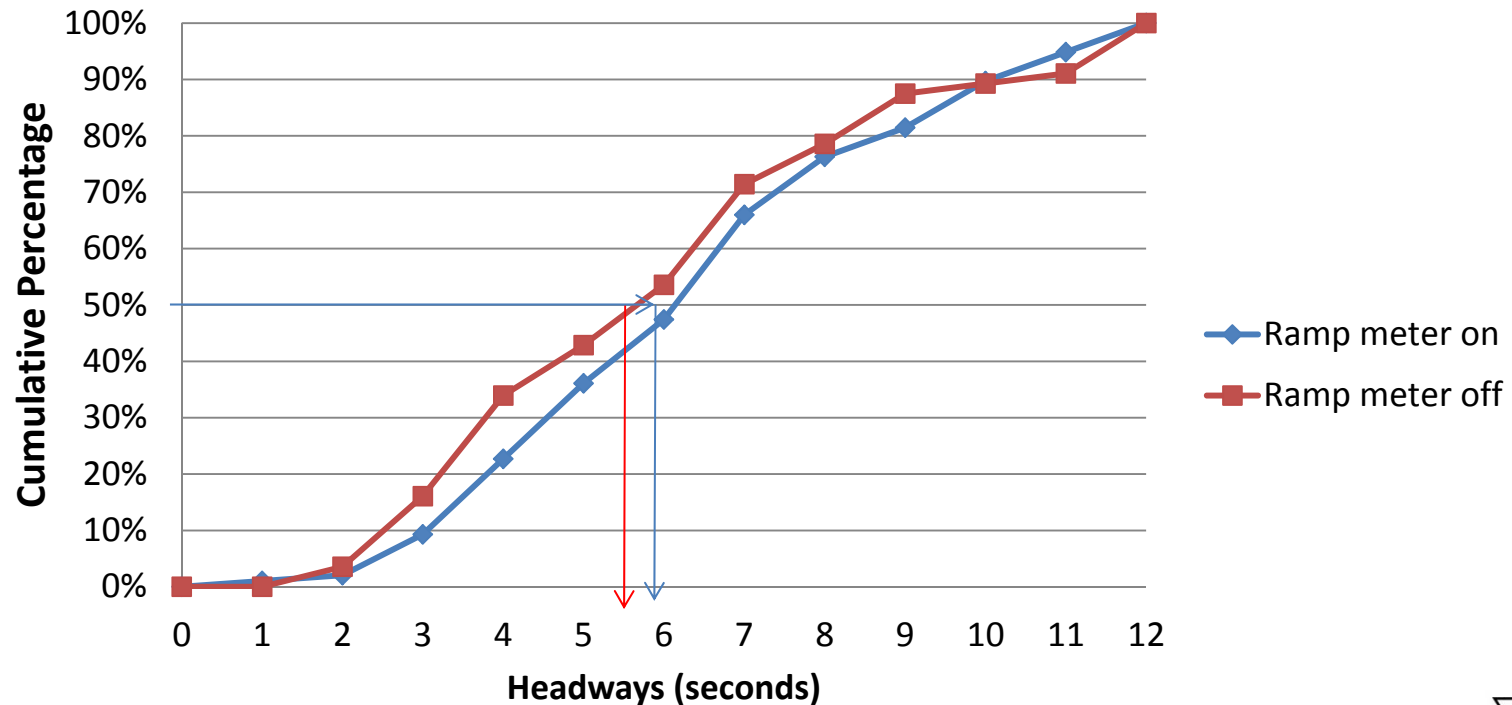
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Cumulative distribution of accepted time headways





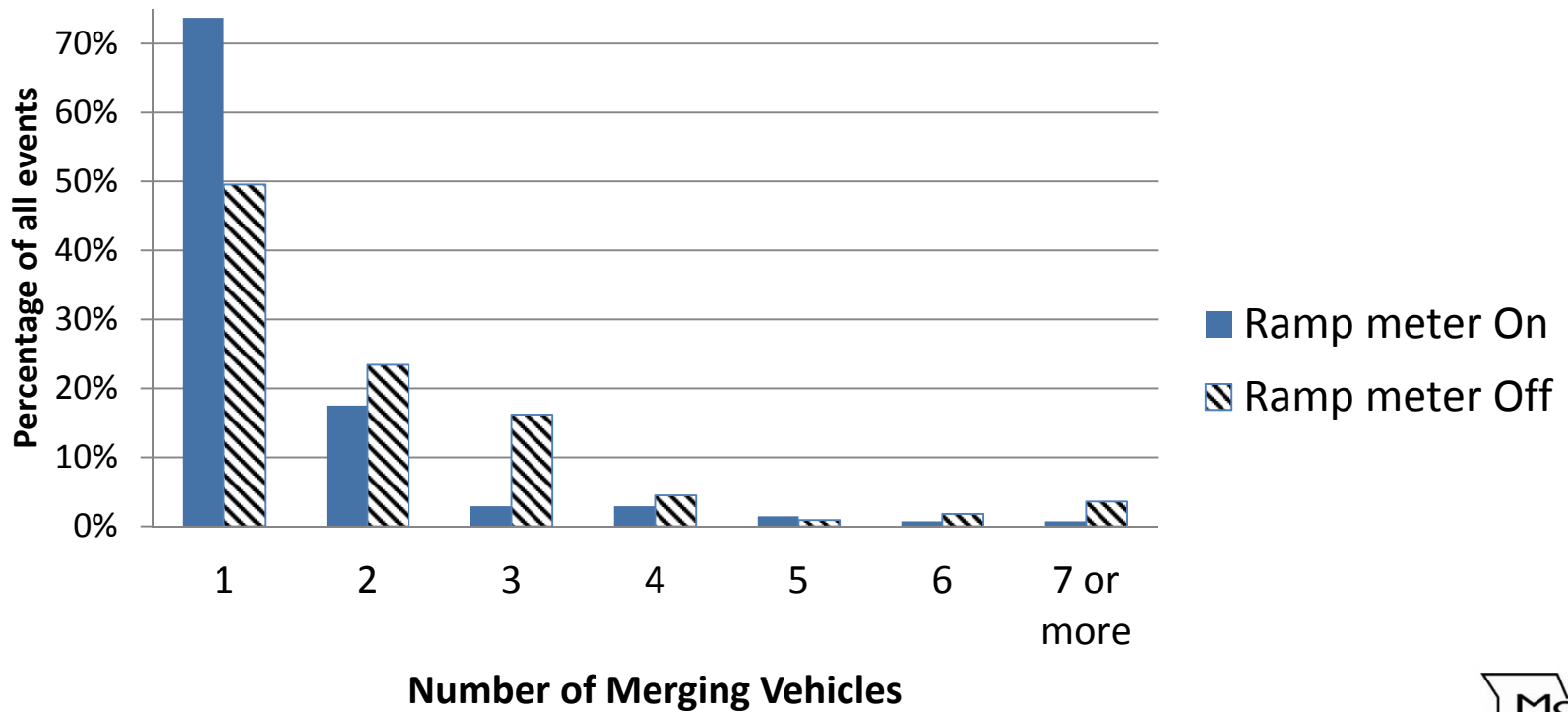
Compliance
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Mobility

Number of vehicles merging in one time gap





Compliance rate

Effect of TRM on Speed

Accepted Merging Headway

Mobility

Change in total delay with ramp metering

	Total volume (mainline + ramp)	Truck %	Work Zone					
			I-70/Prov.	I-70/West	I-70/US 63	US-63/Std.	US-63/Std.	Ave.
Under capacity	900 (650+250)	Low	26%	59%	67%	46%	52%	50%
		High	22%	35%	67%	42%	45%	42%
Capacity	1240 (900+340)	Low	10%	14%	44%	33%	35%	27%
		High	4%	3%	-6%	14%	17%	6%
Above capacity	1754 (1240 +514)	Low	-15%	-56%	-33%	-12%	-2%	-24%
		High	-2%	-4%	-19%	-48%	-21%	-19%





CONCLUSIONS

Recommend TRM at congested/high volume work zones:

- 1) Effectively break up ramp vehicle platoons
- 2) Lower mainline speed thus lower speed differentials
- 3) Reduce total delay





CONCLUSIONS

- Higher compliance rates with three-section signal
- 4R-1Y-2G signal schemes with highest compliance rates
- Lower compliance rate compared to permanent ramp metering
- Commercial vehicles on the ramp improve compliance rates
- High compliance rate with platoons
- Effective in breaking up platoons

Thank You

For additional study details

- Full report can be found:
<http://www.intrans.iastate.edu/smartwz/projects/details.cfm?projectID=79>
- Also published in the TRB Annual Meeting Proceedings and the TRR Journal (2013)

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