Implementing and Optimizing Ramp Metering along I-270 in Maryland in Two Steps

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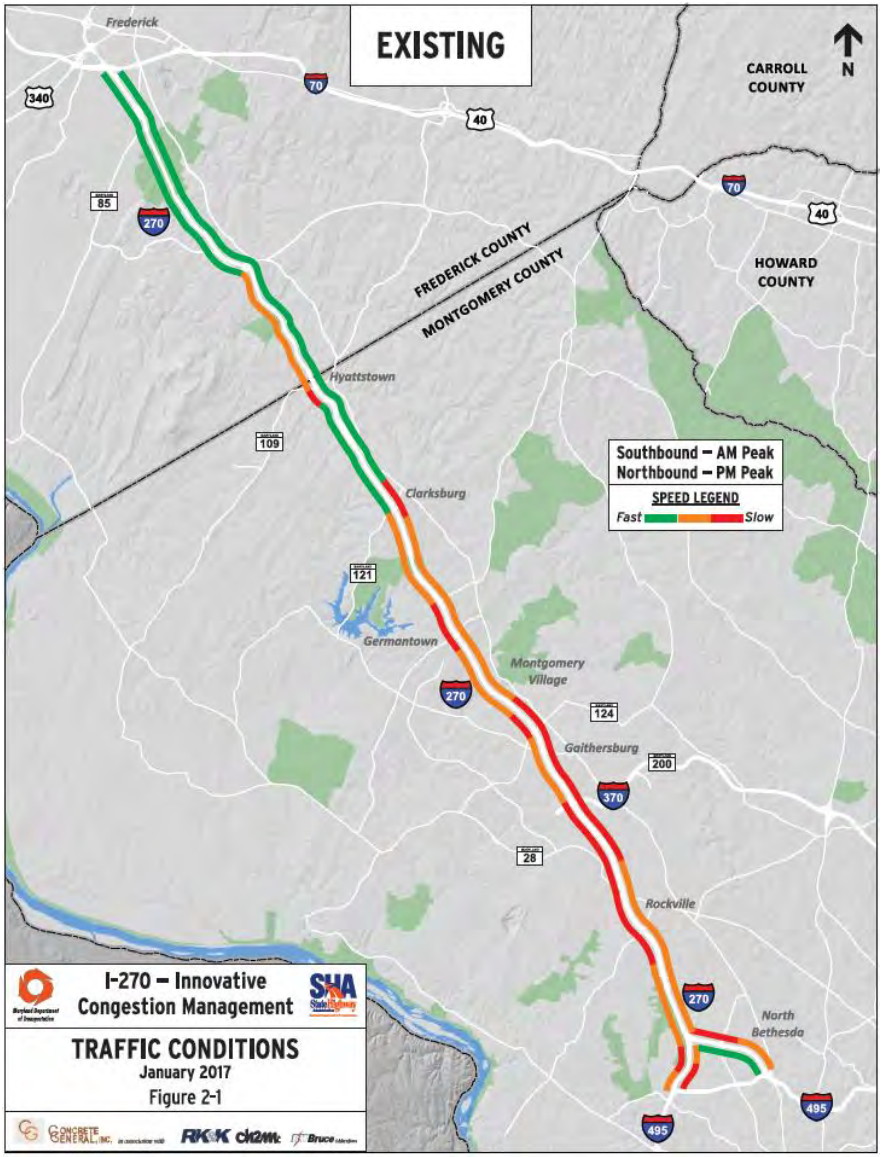
Agenda

- Background Information
- What is Ramp Metering
- Two-Tier Approach
- MOE/Benefit Analysis
- Conclusion

Background Information



- Study Area
  - 32 miles, Freeway Mainline/Ramps
  - Adjacent arterial intersections
  - MD major commute route, most congested corridor in the nation.
- Innovative Congestion Management Project
  - 14 roadway and technology improvements including ATM and Ramp Metering
- First MD ramp metering

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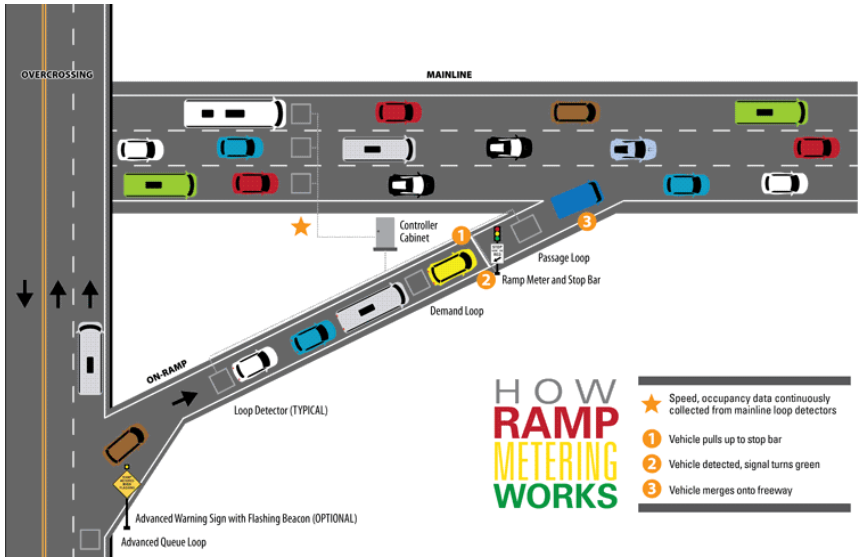
What is Ramp Metering

- Reduce freeway demand
- Break up vehicle platoons
- Control the number of vehicles that are allowed on the facility
- Increase the throughput on the mainline by reducing the frequency and length of periods of flow breakdown



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Source: FHWA Ramp Metering: A Primer

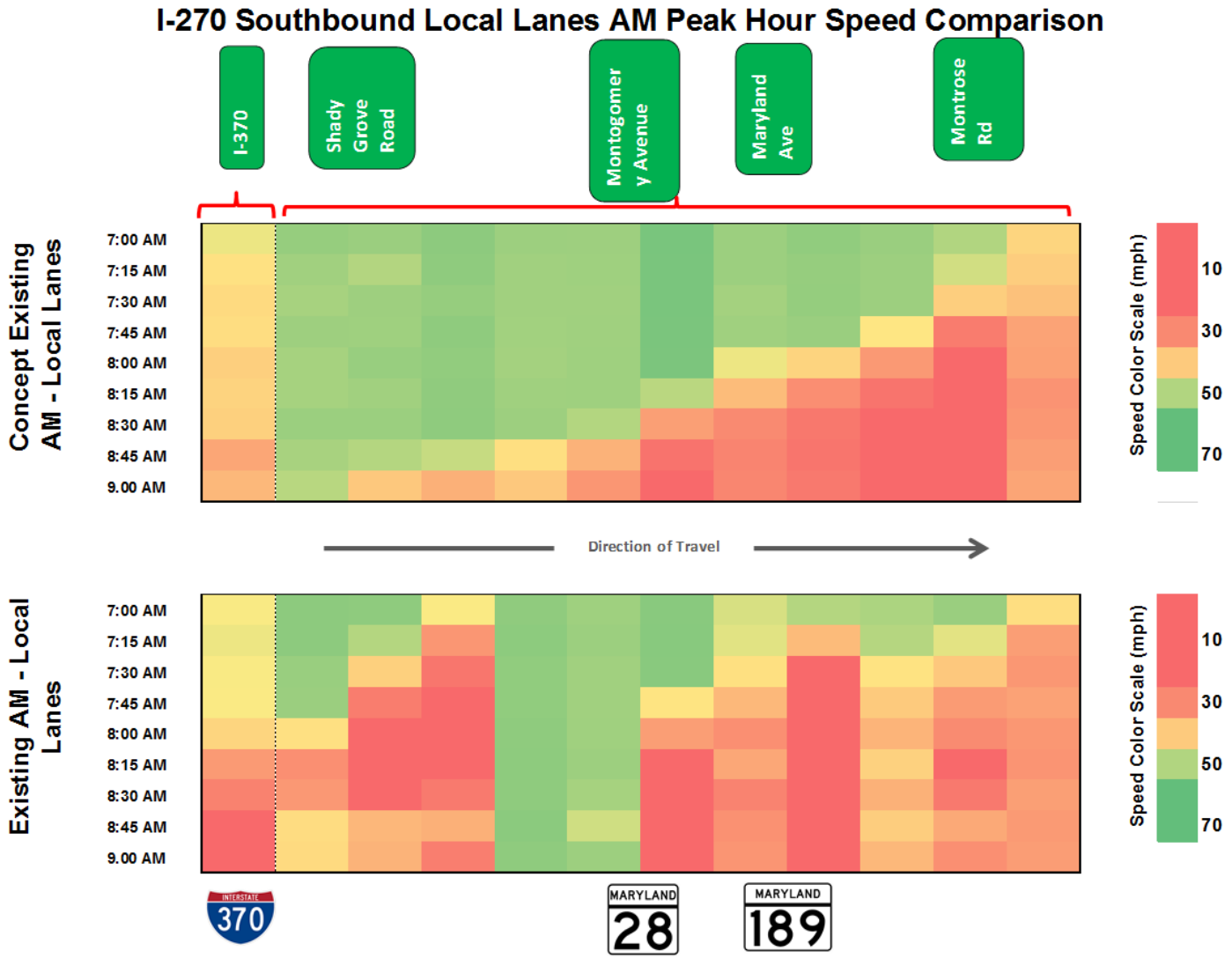
Two-Tier Approach

- Tier 1 - Initial ramp metering assessment determined "where" ramp metering is feasible
  - Existing physical and geometric constraints
  - Identify locations and group them into "zones".
  - Apply ALINEA
- Tier 2 - Second tier assessment analyzed "how much" benefit could be realized from ramp metering
  - Assess various algorithms
  - Implement Intelight
  - Assess benefits from ramp metering

Tier 1

- 1. Determine Existing Geometric/Physical Constraints
  - Acceleration Lane Runout distances from stopped position (60 mph design speed)
  - Potential Storage

Tier 1 – Ramp Meter Zones



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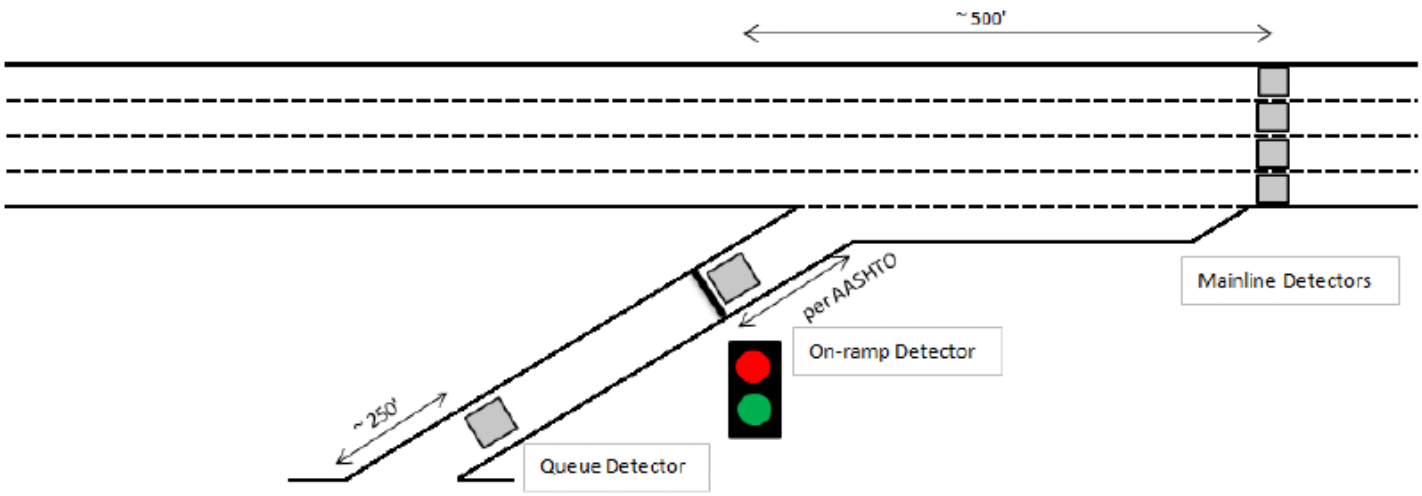
Tier 1 – Ramp Meter Zones

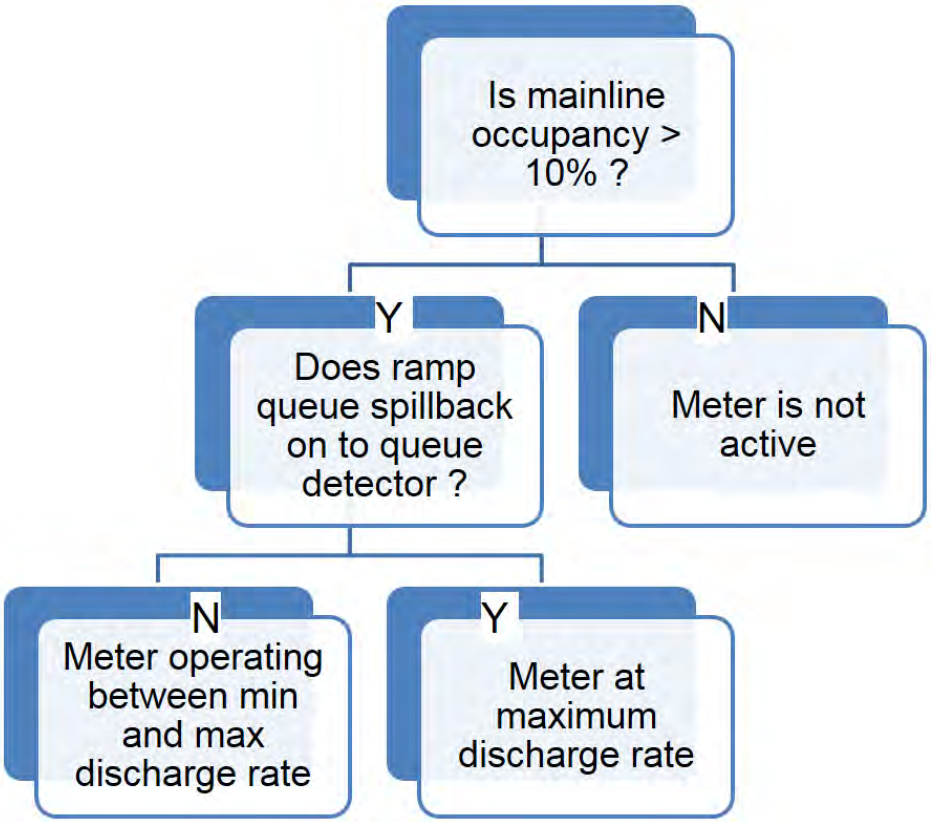
Direction	Ramp	Proposed Ramp Metering	Zone	Direction	Ramp	Proposed Ramp Metering	Zone
I-270 SB	MD 80 on ramp	YES	A	I-270 NB	MD 85 on ramp	YES	F
I-270 SB	MD 109 on ramp	YES	A	I-270 NB	MD 80 on ramp	YES	G
I-270 SB	MD 121 on ramp	YES	A	I-270 NB	MD 109 on ramp	YES	H
I-270 SB	MD 121 NB on ramp (New)	YES	A	I-270 NB	MD 121 on ramp	YES	I
I-270 SB	MD 27 WB on ramp	YES	A	I-270 NB	MD 27 EB on ramp	YES	I
I-270 SB	MD 27 EB on ramp	YES	A	I-270 NB	MD 27 WB on ramp	YES	I
I-270 SB	MD 118 WB on ramp	YES	A	I-270 NB	MD 118 on ramp	YES	J
I-270 SB	MD 118 EB on ramp	YES	A	I-270 NB	Watkins Mill Road	YES	J
I-270 SB	Middlebrook Rd on ramp	YES Widening	A	I-270 NB	MD 124 EB on ramp	YES	J
I-270 SB	Watkins Mill Road on Ramp	YES	A	I-270 NB	MD 124 WB on ramp	YES	J
I-270 SB	MD 124 WB on ramp	YES Widening	A	I-270 NB	I-370 EB on ramp	YES Widening	J
I-270 SB	MD 117 on ramp	YES Widening	A	I-270 NB	I-370 WB on ramp	YES Widening	J
I-270 SB	I-370 on ramp	YES	B	I-270 NB	Shady Grove Rd EB on ramp	Ramp Eliminated By NB3	-
I-270 SB	Shady Grove Rd WB on ramp	YES	C	I-270 NB	Shady Grove Rd WB on ramp	YES Widening	J
I-270 SB	Shady Grove Rd EB on ramp	YES	C	I-270 NB	MD 28 EB on ramp	YES	K
I-270 SB	MD 28 WB on ramp	YES	C	I-270 NB	MD 28 WB on ramp	YES	K
I-270 SB	MD 28 EB on ramp	YES Widening	C	I-270 NB	MD 189 on ramp	YES	K
I-270 SB	MD 189 on ramp	YES	C	I-270 NB	Montrose Rd EB on ramp	YES	K
I-270 SB	Montrose Rd WB on ramp	YES Widening	C	I-270 NB	Montrose Rd WB on ramp	YES Widening	K
I-270 SB	Montrose Rd EB on ramp	YES	C	I-270 Spur NB	Rockledge Dr and MD 187 on ramp	YES	L
I-270 SB	Rockledge Dr on ramp	YES	D	I-270 NB	Westlake Terrace	YES	M
I-270 SB	MD 187 on ramp	YES	D	I-270 Spur NB	Democracy Blvd EB on ramp	YES	M
I-270 Spur SB	Democracy Blvd on ramp	YES	E	I-270 Spur NB	Democracy Blvd WB on ramp	YES	M

Ramp Metering Methodology - ALINEA

- ALINEA algorithm
  - Local Feedback Ramp Metering Strategy
  - Easy to implement
  - Works better than fixed timed schemes



ALINEA Flow Chart



Tier 2

- Only analyze meters found in the “zones” identified in tier one
- Evaluate Other Algorithms
- Select/Implement Intelight
- Run iterations to pick a “best” metering rate
- No queue spill back to the arterial

Evaluation other Algorithms

- System-Wide Adaptive Ramp Metering (SWARM)
- Heuristic Ramp Metering Coordination (HERO)
- Stratified Zone Metering (SZM)
- Corridor Adaptive Ramp Metering Program (CARMA)
- Bottleneck
- Zone
- Milos
- Helper
- Intelight

System-Wide Adaptive Ramp Metering (SWARM)

- SWARM divides a freeway network into sub system bounded two bottlenecks.
- SWARM operates at two competing modes — global and local. Two metering rates are computed, the more restrictive one is deployed.
- Metering rates are calculated based on the current density, the required density, and the number of vehicles that should be removed or added to the freeway zone between each ramp.
- Additional upstream ramps are called to action when a single ramp has exceeded its capacity to balance the zone density.
- Orange County, California
  Portland, Oregon

Heuristic Ramp Metering Coordination (HERO)

- Use the ALINEA algorithm as the foundation for managing local conditions.
- All ramps are linked to each other via a central controller.
- The key advantage is that it balances the queuing on a number of ramps upstream of the mainline bottleneck providing a degree of equity in waiting times for all ramps.
- It also operates successfully when the bottleneck is more than 2 miles downstream of the on ramp.
- Melbourne, Australia
- Not deployed in US yet

I-270 Ramp Metering Ranking

	Impact on congestion					Implementation			Deployments & evidence		Overall	
Algorithm	**1a – local congestion**	**1b- congestion up to 5 miles**	**1c – Congestion over 5 miles**	**1d – On ramp management**	**1e – Off ramp management**	**2a – Ease of implementation**	**2b - Ease of modelling**	**2c - Maintainability**	**3a – Scale of previous implementations**	**3b – Evidence of benefits**	**Total**	**Rank**
System-Wide Adaptive Ramp Metering (SWARM)	8	9	7	8	7	8	8	8	7	8	78	1
Heuristic Ramp Metering Coordination (HERO)	9	9	9	8	6	7	8	7	5	6	74	2
Stratified Zone Metering (SZM)	8	8	3	7	8	7	7	7	7	8	70	3
Bottleneck	7	9	7	7	8	6	6	6	6	7	69	4
ALINEA	10	7	3	7	2	8	8	8	7	8	68	5
Fuzzy Logic	7	7	7	7	7	6	5	6	6	7	65	6
Helper	8	8	6	8	2	6	7	7	6	6	64	7
MILOS	8	8	5	8	2	6	7	7	6	6	63	8
Zone	8	8	3	5	2	6	7	7	6	7	59	9
Corridor Adaptive Ramp Metering Program (CARMA)	8	6	2	5	1	7	5	7	7	7	55	10

Key

	Top in category
	Second in category
	Third in category

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Overview of Intelight

- Proprietary
- Minimum and absolute maximum metering rates for each ramp were set between 240-1400 veh/hr/lane.
- Up to 128 metering plans can be programmed for each ramp meter location.
- Each ramp metering plan can consist of up to 16 levels (metering table).
- Metered Lane Queues (Ramp queue management program)

Implementation of Intelight in VISSIM

```
/* INTELIGHT rates */
INTELIGHT_Rate1 = 1400, /* Occup_rate (0.1 - 0.2]   */
INTELIGHT_Rate2 = 1350,  /* Occup_rate (0.2 - 0.22]  */
INTELIGHT_Rate3 = 1250,  /* Occup_rate (0.22 - 0.24] */
INTELIGHT_Rate4 = 950,   /* Occup_rate (0.24 - 1)    */
INTELIGHT_Ratio_Inter = 0.95, /* Reach QueueDetector_Inter, the rate mu
NumberofDetectors = 7, /** total num. of downstream detectors **/
dd1 = 200, dd2 = 201, dd3 = 202, dd4 = 203, dd5 = 204, dd6 = 205, dd7 =
NumberMeterLane = 1,
/** d_Presence1 = 5 **/ /** presence detector-Lane 1 **/
/** d_Presence2 = 9 **/
/** d_Presence2 = 12, **/ /** presence detector-Lane 2 **/
QueueDetector_Advance = 4,
QueueDetector_Inter = 2,
Occupancy_Opt = 0.20, /** optimal or target occupancy **/
Occupancy_Threshold = 0.10, /** threshold to metering **/
Queue_Threshold = 0.95, /** for ramp queue detection **/
Queue_Threshold_Inter = 0.95; /** for inter ramp queue detection **/

/*****************************************************************

SUBROUTINE INTELIGHT;
```

- Logic coded in VAP
- The queue on the ramp is determined by using detector occupancy.
- Using ALINEA's formula, a metering rate lookup table was developed based on the mainline occupancy rate each metered ramp.
- Two queue detectors are used to avoid queue spill back to the arterials – end of queue detector and intermediate detector. Max rate used if reaching arterial.

Implementation..

- Avoid queue spill back to the arterial, iteratively increase rate.
- Ramp throughput not significantly lower
- Minimum discharge rate: 240 veh/hr/ln
- Maximum discharge rate: 1400 veh/hr/ln

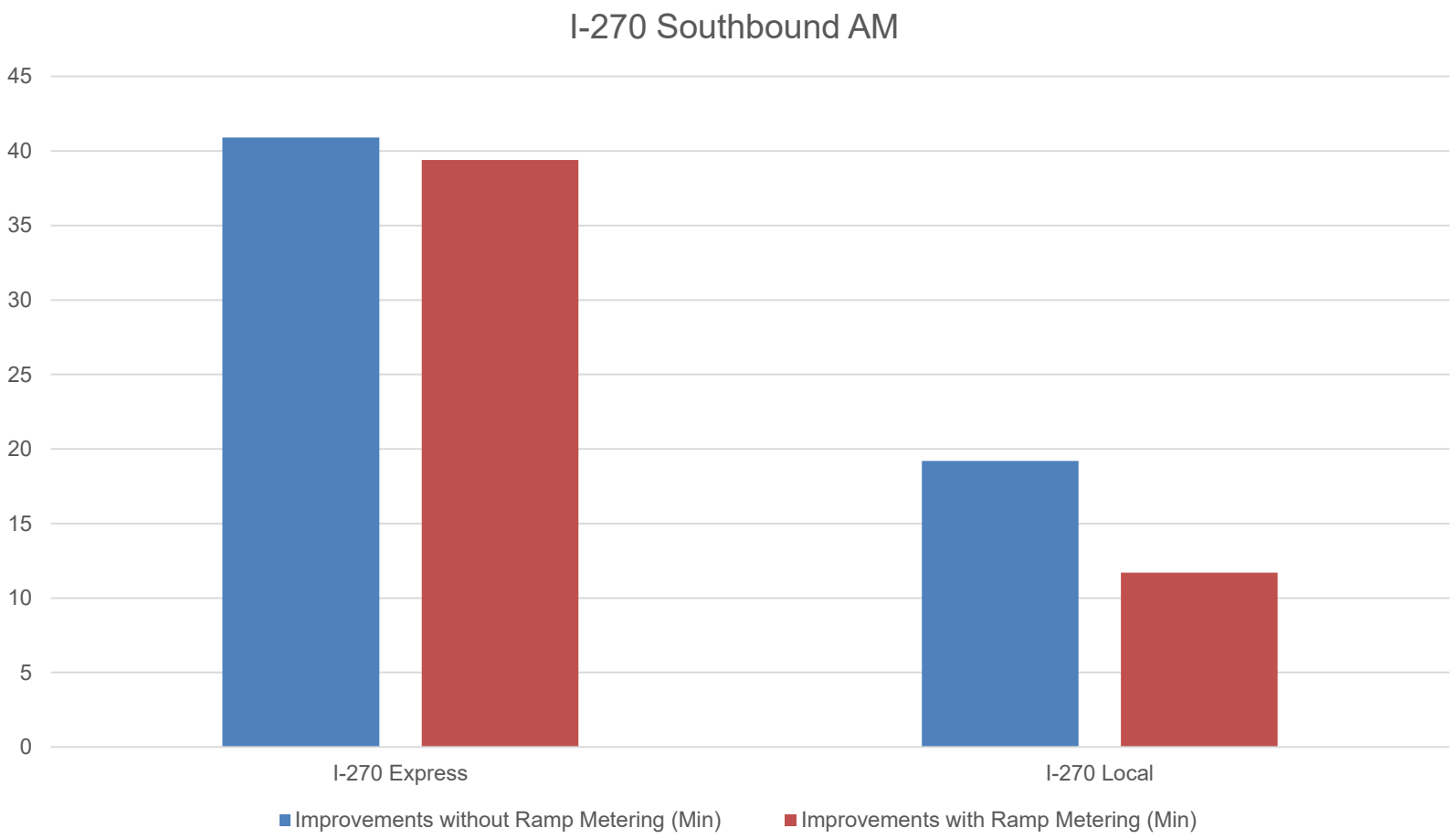
AM Ramp Meter	Storage Length (feet)	Demand (veh/hr)	Existing Throughput (veh/hr)	Ramp Meter Throughput (veh/hr)	Average Queue (feet)	Max Queue (feet)
SB Ramp Meter from MD 80 E	577	670	676	676	19	370
SB Ramp Meter from MD 109 E	845	465	462	463	42	404
SB Ramp Meter from MD-121 W	831	850	858	860	34	472
SB Ramp Meter from MD-27 E	1,715	440	441	442	312	1,430
SB Ramp Meter from MD-27 W	1,573	915	938	937	171	1,090
SB Ramp Meter from MD-118 N	1,531	590	571	578	355	1,334
SB Ramp Meter from MD-118 S	1,580	300	295	295	181	796
SB Ramp Meter from Middlebrook	1,331	1,780	1,763	1,765	142	743
SB Ramp Meter from MD 124 S	783	1,430	1,132	1,200	14	365
SB Ramp Meter from MD 117 W	1,446	1,665	1,622	1,657	277	1,025
SB Ramp Meter from I-370	2,391	2,675	2,237	2,691	390	819
SB Ramp Meter from Shady Grove E	771	380	371	370	172	521
SB Ramp Meter from Shady Grove W	1,261	610	602	605	116	883
SB Ramp Meter from MD 28 E	1,506	1,410	1,069	1,377	261	871
SB Ramp Meter from MD 28 W	327	300	299	298	37	272
SB Ramp Meter from MD 189	1,419	1,135	1,108	1,112	383	933
SB Ramp Meter from Montrose E	1,608	760	738	747	725	1,201
SB Ramp Meter from Montrose W	782	935	906	905	64	631
SB Ramp Meter from Democracy Blvd	596	540	535	536	40	270
SB Ramp Meter from Rockledge Rd	576	165	130	148	1	112
SB Ramp Meter from MD 187	350	345	286	293	1	114

Direction	Ramp	AM Min Rat (Veh/hr)	AM Max Rate (Veh/hr)	Metered Lanes
I-270 SB	MD 80 on ramp	850	1,200	1
I-270 SB	MD 109 on ramp	500	1,100	1
I-270 SB	MD 121 on ramp	900	1,400	1
I-270 SB	MD 27 EB on ramp	300	800	1
I-270 SB	MD 27 WB on ramp	950	1,400	1
I-270 SB	MD 118 EB on ramp	350	900	1
I-270 SB	MD 118 WB on ramp	240	600	1
I-270 SB	Middlebrook Rd on ramp	800	1,400	2
I-270 SB	MD 124 WB on ramp	950	1,400	2
I-270 SB	MD 117 on ramp	850	1,350	2
I-270 SB	I-370 on ramp	740	1,100	3
I-270 SB	Shady Grove Rd EB on ramp	340	1,050	1
I-270 SB	Shady Grove Rd WB on ramp	800	1,250	1
I-270 SB	MD 28 EB on ramp	950	1,400	2
I-270 SB	MD 28 WB on ramp	350	1,150	1
I-270 SB	MD 189 on ramp	650	1,350	2
I-270 SB	Montrose Rd EB on ramp	650	1,350	1
I-270 SB	Montrose Rd WB on ramp	950	1,400	2
I-270 SB	Rockledge Dr on ramp	800	1,350	1
I-270 SB	MD 187 on ramp	800	1,350	2
I-270 Spur SB	Democracy Blvd on ramp	440	900	2

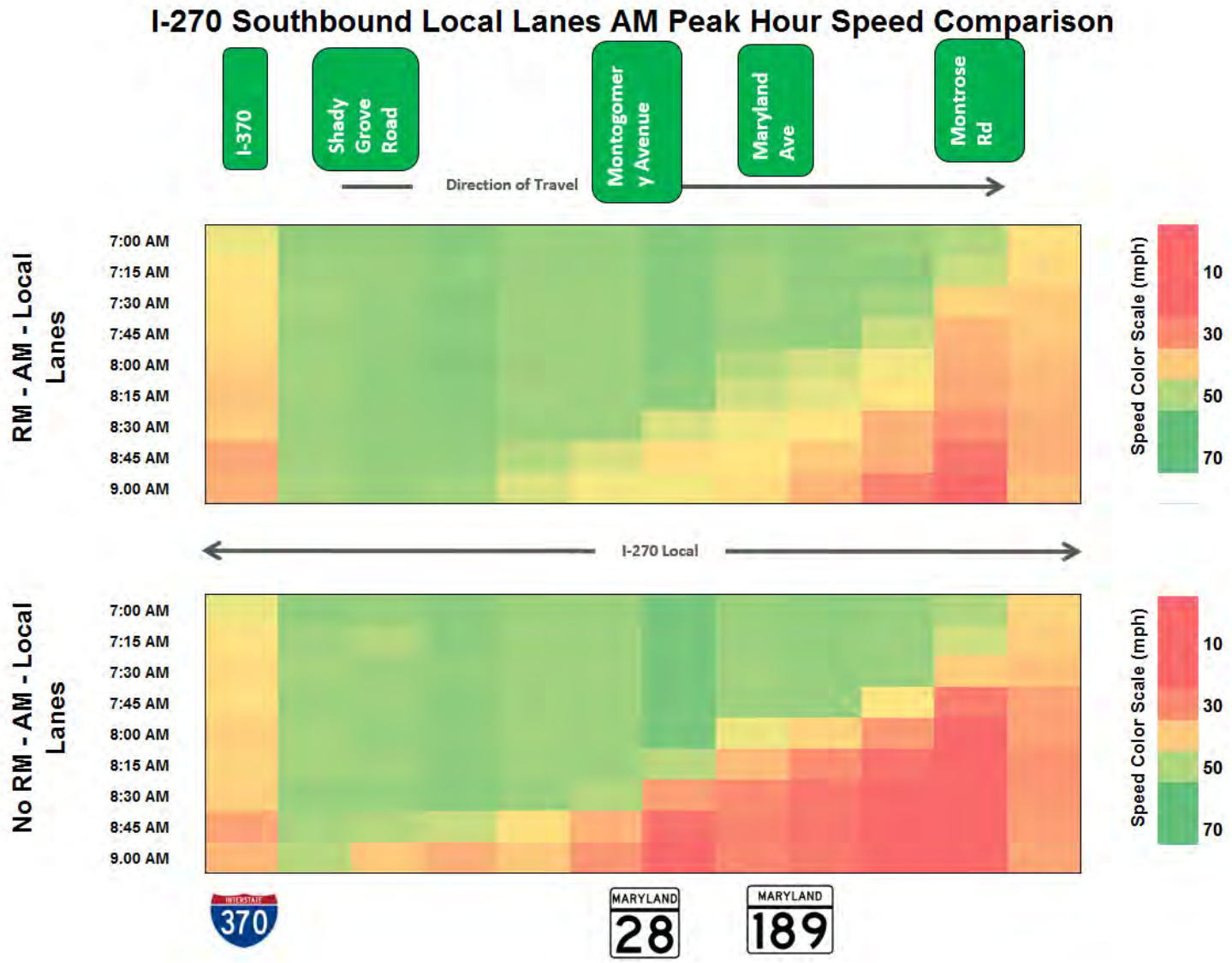
Evaluation of Ramp Metering Modeling

- Assess mainline travel times, throughput, and congestion
- Assess ramp queue lengths, available storage, and expected vehicle delay times at the meter.

MOE – Travel Time Comparison



Speed Congestion Diagram



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Benefits

- FHWA study shows significant travel time reduction and speed improvement after implementation
- Improve Safety – Breaking up platoons to allow a smoother merging traffic
- FHWA study shows significant collision reduction
- Arterial impacts should be considered before implementation
- I-270 Local southbound – up to 40% reduction of travel time during AM
- Improve Non-recurring congestion

Challenges

- Running multiple iterations to pick a “optimal” rate was time consuming
- Automation with optimization is welcome

Questions/Comment