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San Diego I-15 ATDM/DMA Testbed Evaluation Results for Connected Vehicles Applications

Pascal Volet
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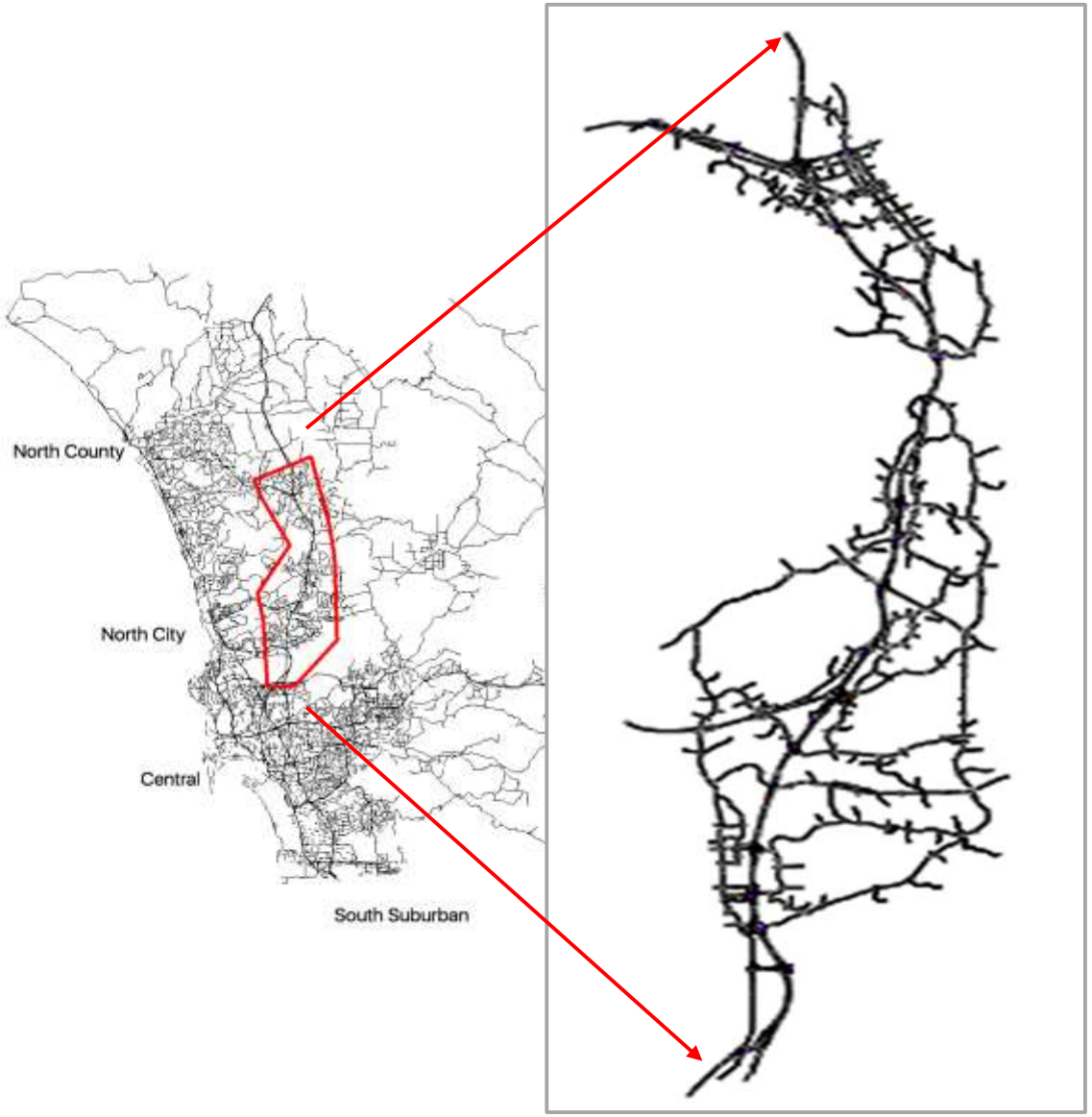
Project description

- USDOT-funded Analysis, Modeling, and Simulation (AMS) Testbed Development and Evaluation to Support Dynamic Mobility Applications (DMA) and Active Transportation and Demand Management (ATDM) Programs
- Six simulation-based testbeds: San Mateo, Pasadena, Dallas, Phoenix, San Diego and Chicago
- Aimsun subcontractor of Booz Allen Hamilton for the San Diego testbed

Testbed description

- 22-mile stretch of I-15
- 5 GP lanes per direction
- 4 HOT lanes in total, with changeable configurat
- 23 entrance ramps/merges SB, 25 NB
- Parallel arterials with actuated signals
- ICM demonstration site



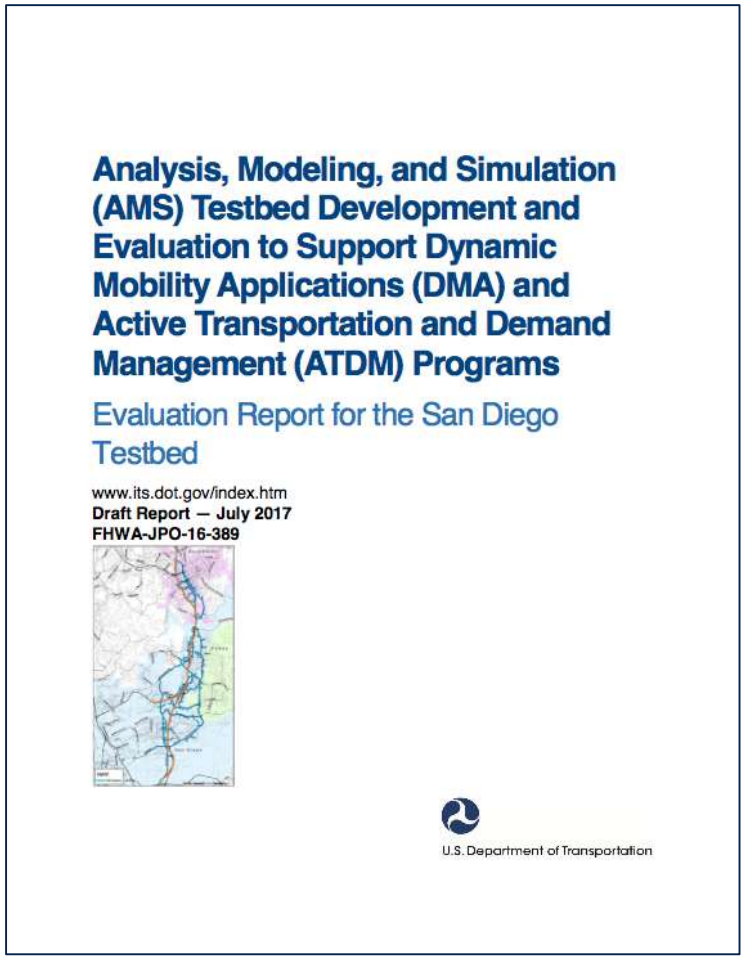
Methodology

- ICM microscopic traffic simulation model (Aimsun)
- Four real-world Operational Conditions
  - Cluster analysis of days with incident and response plan
  - AM from 5 AM to 10 AM, PM from 2 PM to 7 PM
  - Different incident severity and demand levels

	OC 1 (AM1)	OC 2 (AM2)	OC 3 (PM3)	OC 4 (PM4)
Representative day	05/27/15	02/09/15	06/30/15	07/07/14
Operational Condition	Southbound (AM) +Medium Demand + Medium Incident	Southbound (AM) +Medium Demand + High Incident	Northbound (PM) +Medium Demand + High Incident	Northbound (PM) +Medium Demand + Medium Incident
VPH	6201	6348	9034	8870
Total Cluster Delay (min)	49.88	108.03	99.72	63.25
Number of Incidents/Period	1.9	3.7	5.5	2.1

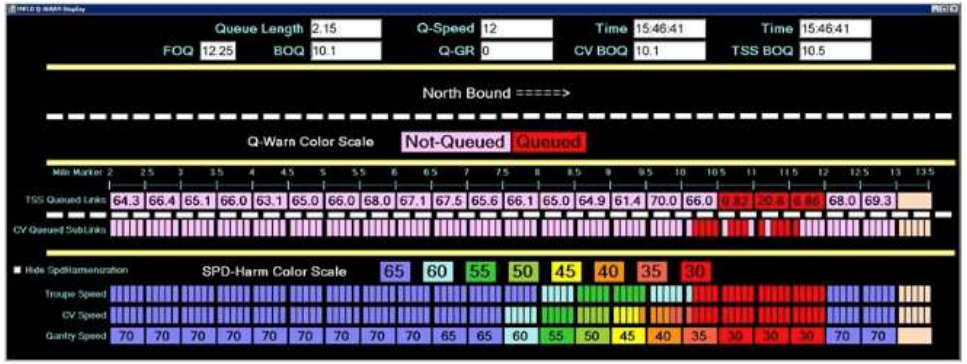
Evaluation scenarios

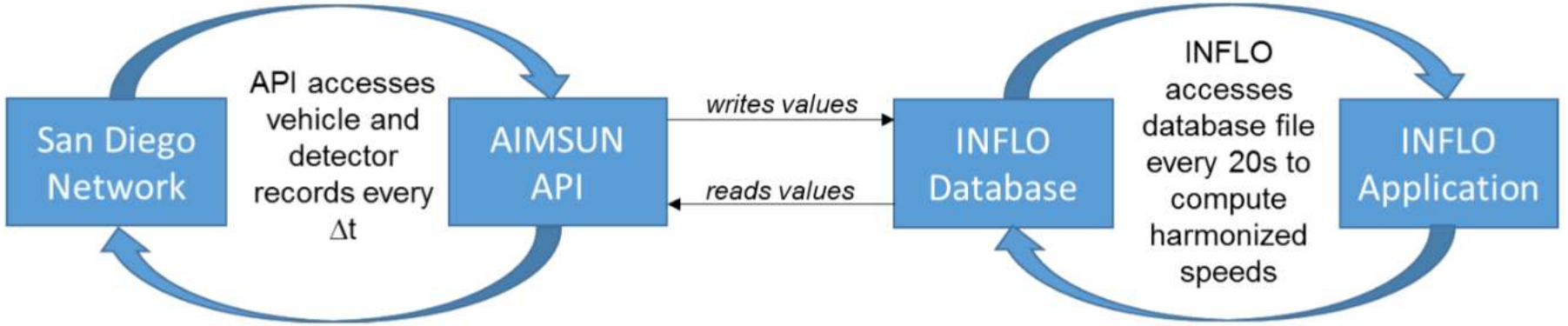
- Six ATDM strategies
  - Dynamic Lane Use, Dynamic Speed Limits, Dynamic Merge Control, Predictive Traveler Information, Dynamic High-Occupancy Vehicle (HOV)/Managed Lanes, and Dynamic Routing
- One DMA bundle
  - Intelligent Network Flow Optimization (INFLO), which includes Dynamic Speed Harmonization (SPD-HARM) and Cooperative Adaptive Cruise Control (CACC)
- In isolation and in combination
- 25%, 50% and 90% CV penetration rates
- Full Evaluation Report FHWA-JPO-16-389 available online (https://rosap.ntl.bts.gov/view/dot/34173)



How SPD-HARM was modeled

- Interface with the INFLO-SIM application in OSADP via database
- Every 20 s
  - Write 20 s speed, volume and occupancy of detector stations
  - Write position and instantaneous speed of CVs
  - Read speed for CVs in 0.1 mi segments
- Published in OSADP as AMS-Aimsun-INFLO

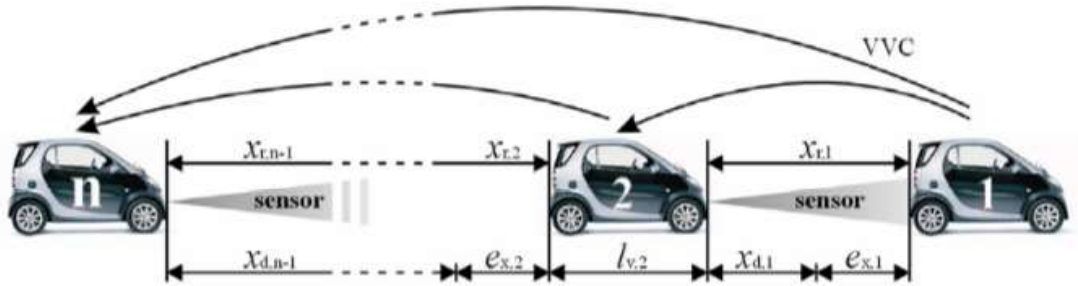




How CACC was modeled

- Algorithm used by Leidos and TFHRC (CACC-Vissim in OSADP)

$$a_{d,n} = (k_2 e_{v,n-1} + k_1 e_{x,n-1}) + \left(\frac{k_2}{n-2} \sum_{i=1}^{n-2} e_{v,i} \right)$$

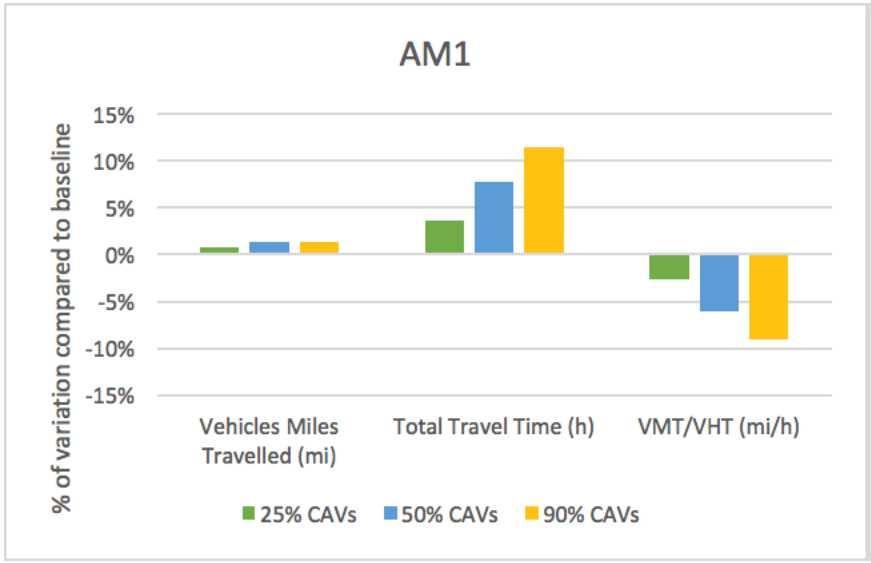


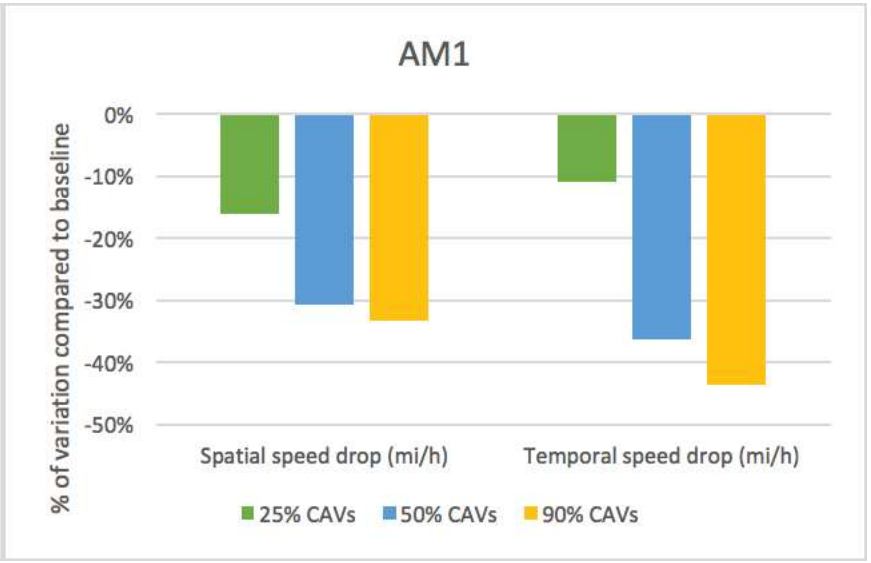
- $k_1 = 0.1$, $k_2 = 0.58$, $n = 6$, $e_v = 0$ m/s, $e_x = 5$ m
- No limit to the platoon size
- CACC allowed on specific GP lanes on I-15
  - The three leftmost for 25% and 50% CV penetration rate
  - All five lanes for 90% CV penetration rate
  - CVs have to use those lanes, but non-CVs can also
  - CVs disconnect CACC when approaching their exit
- Published in OSADP as AMS-CACC-Aimsun

Evaluation of SPD-HARM – AM1

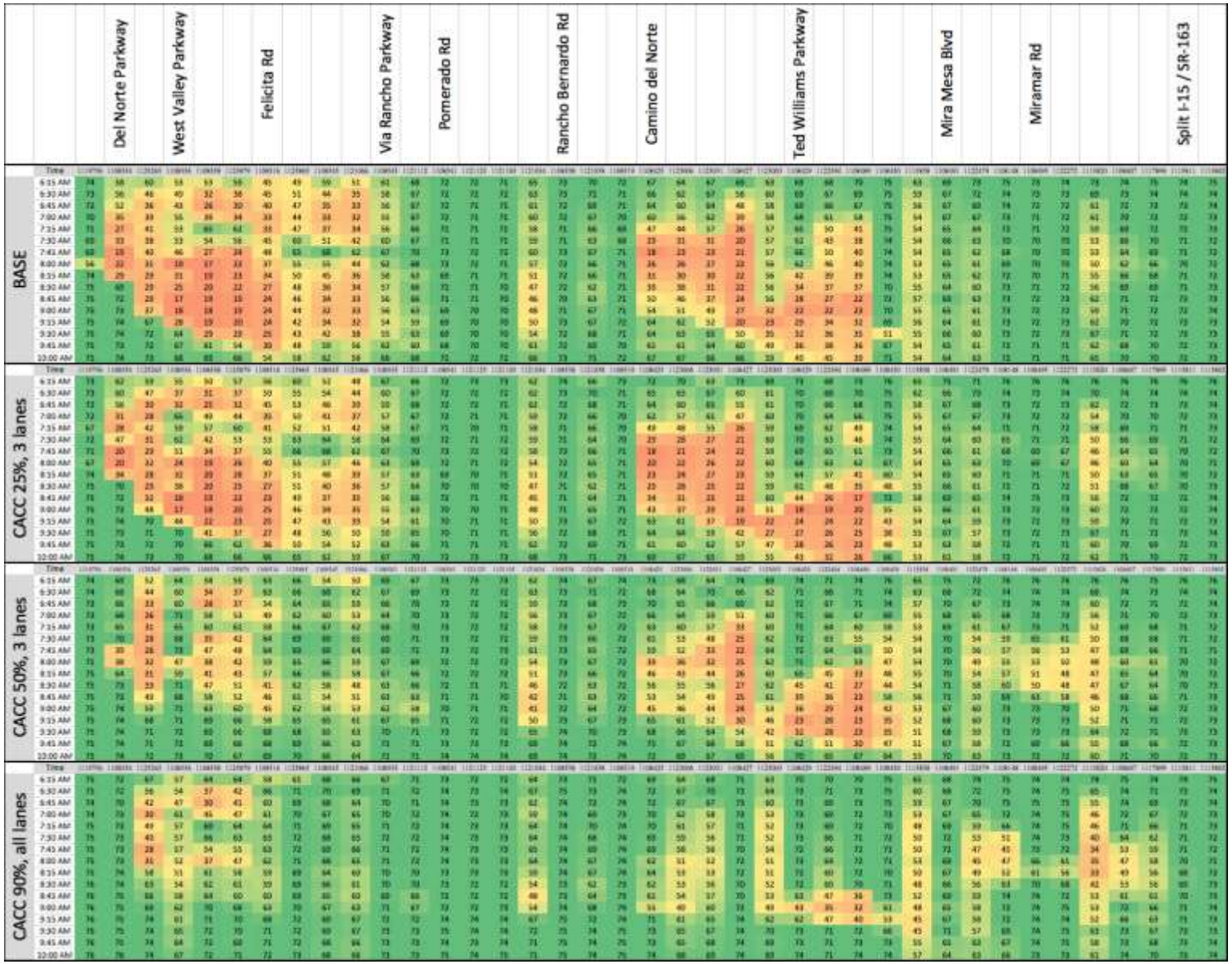
Evaluation of SPD-HARM – AM1

Network Statistics	Base	SPD-HARM 25%	Difference	SPD-HARM 50%	Difference	SPD-HARM 90%	Difference
Vehicles Miles Travelled (mi)	2,320,947	2,340,587	0.8%	2,350,332	1.3%	2,351,385	1.3%
Total Travel Time (h)	61,946	64,185	3.6%	66,744	7.7%	68,997	11.4%
Passenger Hourly Travel Time (h)	78,635	81,499	3.6%	84,659	7.7%	87,306	11.0%
VMT/VHT (mi/h)	37.47	36.47	-2.7%	35.21	-6.0%	34.08	-9.0%
Spatial speed drop (mi/h)	15.0	12.6	-16.0%	10.4	-30.7%	10.0	-33.3%
Temporal speed drop (mi/h)	11.0	9.8	-10.9%	7.0	-36.4%	6.2	-43.6%



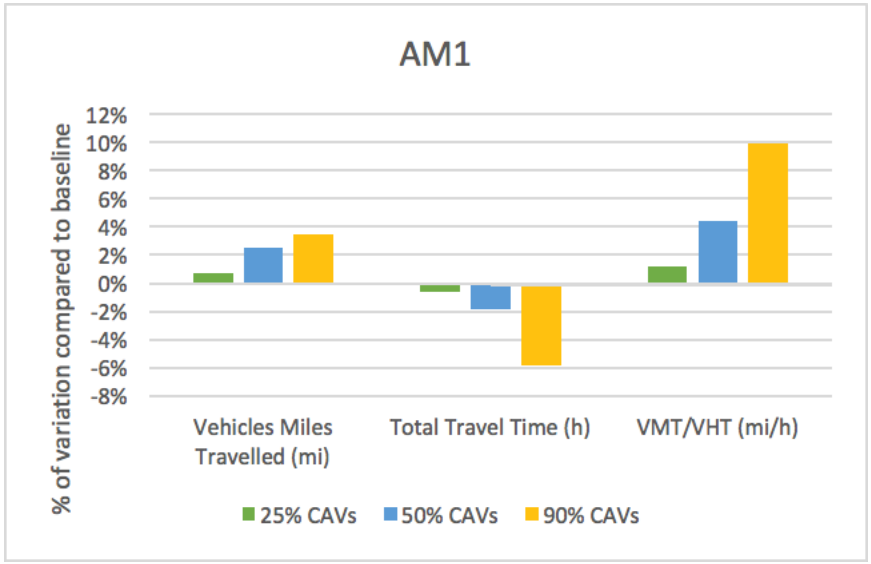


Evaluation of CACC – AM1

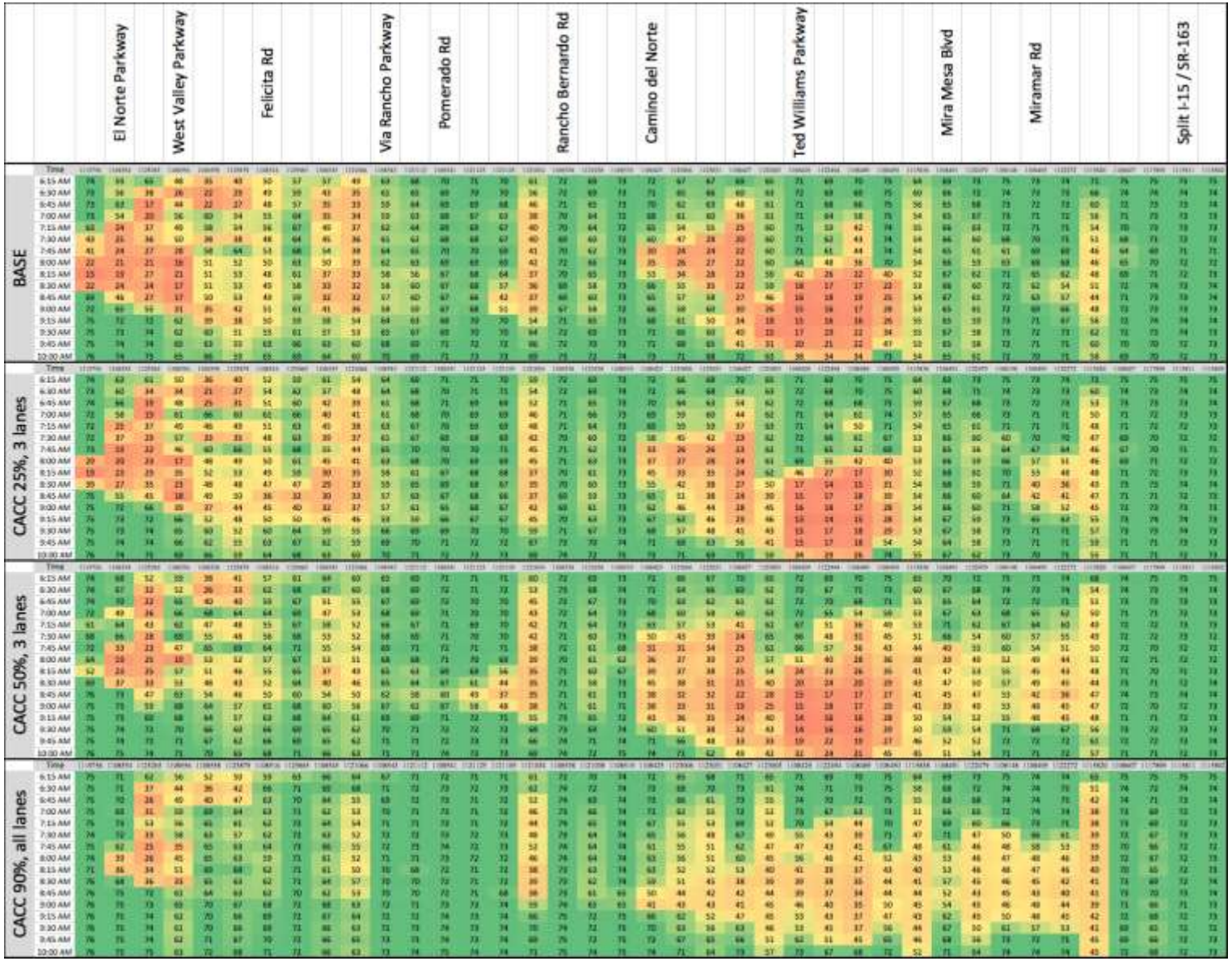


Evaluation of CACC – AM1

Network Statistics	Base	CACC 25%	Difference	CACC 50%	Difference	CACC 90%	Difference
Vehicles Miles Travelled (mi)	2,320,947	2,336,549	0.7%	2,379,451	2.5%	2,402,310	3.5%
Total Travel Time (h)	61,946	61,602	-0.6%	60,803	-1.8%	58,358	-5.8%
Passenger Hourly Travel Time (h)	78,635	78,375	-0.3%	77,461	-1.5%	74,407	-5.4%
VMT/VHT (mi/h)	37.47	37.93	1.2%	39.13	4.4%	41.16	9.9%

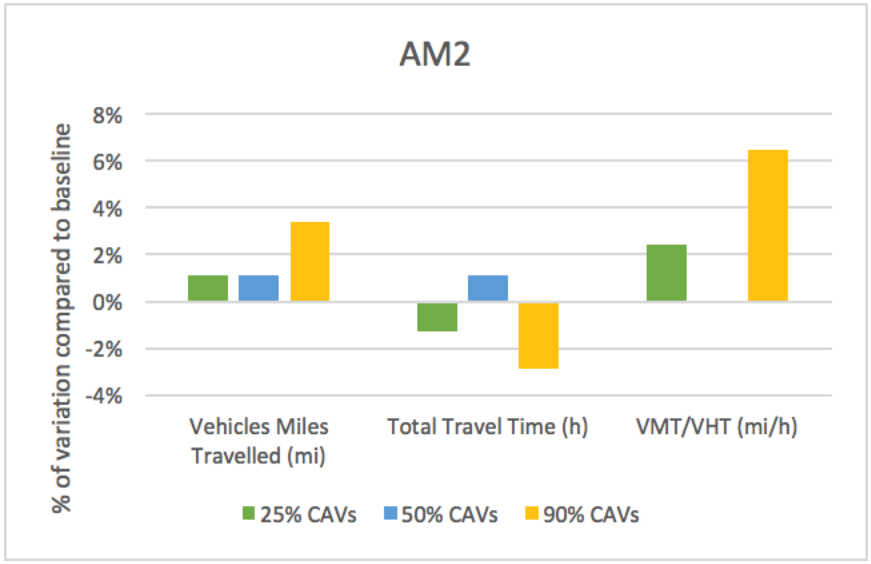


Evaluation of CACC – AM2

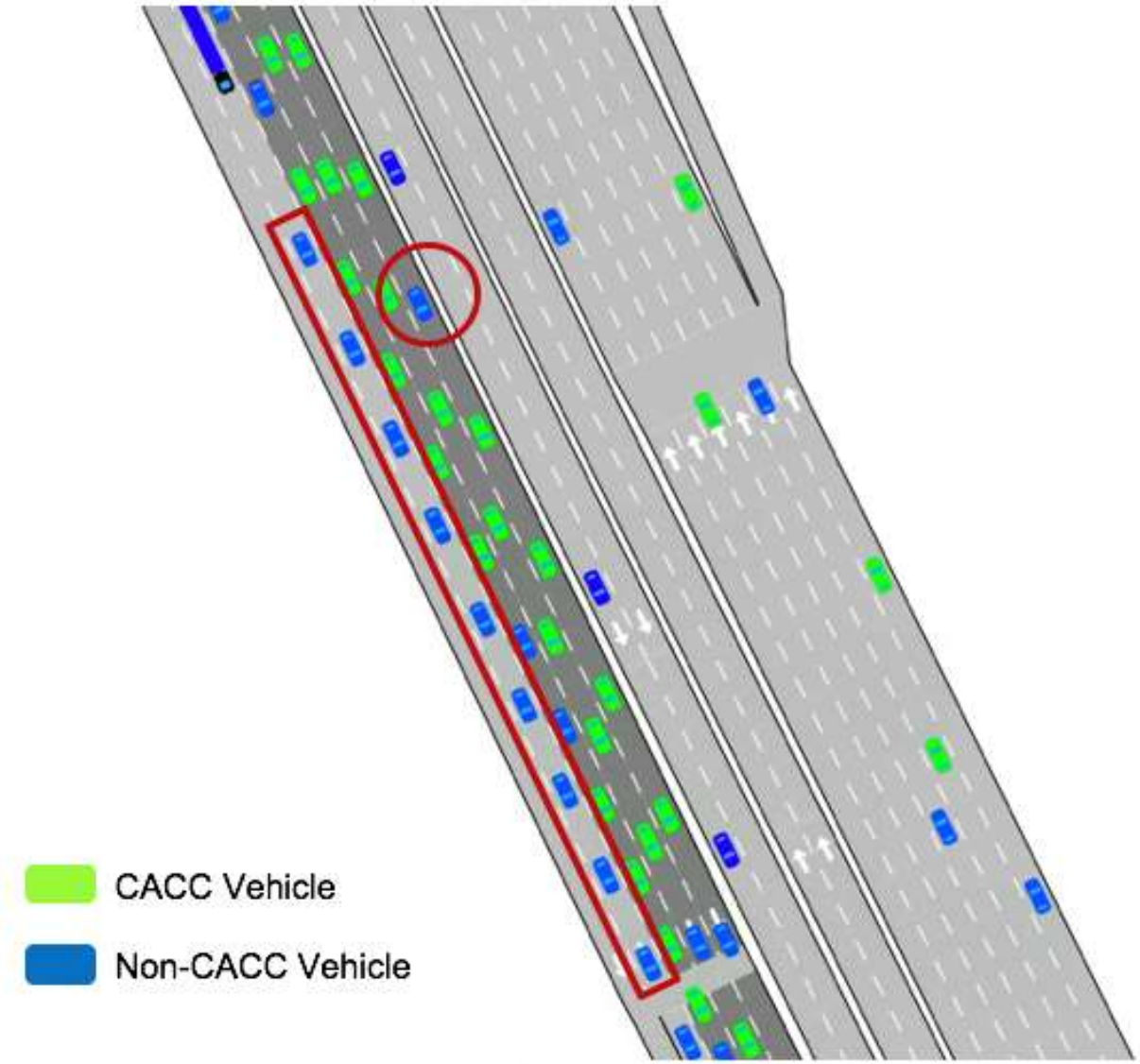


Evaluation of CACC – AM2

Network Statistics	Base	CACC 25%	Difference	CACC 50%	Difference	CACC 90%	Difference
Vehicles Miles Travelled (mi)	2,304,353	2,329,398	1.1%	2,329,302	1.1%	2,382,112	3.4%
Total Travel Time (h)	61,509	60,722	-1.3%	62,206	1.1%	59,719	-2.9%
Passenger Hourly Travel Time (h)	78,853	78,151	-0.9%	79,424	0.7%	76,560	-2.9%
VMT/VHT (mi/h)	37.46	38.36	2.4%	37.44	0.0%	39.89	6.5%



Why 50% CACC is the worst case?



Conclusions – SPD-HARM

- No significant benefits in terms of traffic performance, but a benefit in terms of safety (shockwave reduction)
- Shockwave reduction comes at the cost of a slight increase of travel time
- More effective with distributed congestion throughout the corridor
- With lower congestion, benefit only at high penetration rate

Conclusions - CACC

- Most CACC algorithms available today only deal with car-following in a single lane and with an already formed platoon
  - Some parameters may produce an unstable car-following regime
- To produce tangible benefits in real-world conditions, CACC algorithms should deal also with other aspects of vehicle movement
  - Managing the transition (vehicle joining or leaving the platoon) is key to avoid instabilities
  - Managing the vehicle distribution across multiple lanes is key with multiple reserved lanes (higher penetration rates)
  - Managing the length of the platoon is key with mixed traffic, to prevent blocking non-connected vehicles
  - Managing the lane changing is key to allow connected vehicles take the exit they need to take and to prevent blocking non-connected vehicles

Conclusions - CACC

- CACC appears to be more effective in congested situations; when congestion is low, at some penetration rates even a slight reduction of traffic performance can be observed, because CACC platoons may cause an obstacle for non-connected vehicle that want to change lane, which may have to reduce their speed and look for a gap between platoons
- Policy decisions, like the number of lanes that CACC platoons can utilize, and whether they are shared with non-connected vehicles, have a significant impact on the effectiveness of the technology
- The results should not be taken as an evaluation of the impact of CACC technology in general, but only of one specific implementation, based on the algorithm described above
  - The developers of this technology should make it capable to deal with real and complex situations
  - Studies presenting results of evaluations should be clear about the assumptions made

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Thank you!

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