A Simulation Study for the Static Early Merge and Late Merge Controls at Freeway Work Zones

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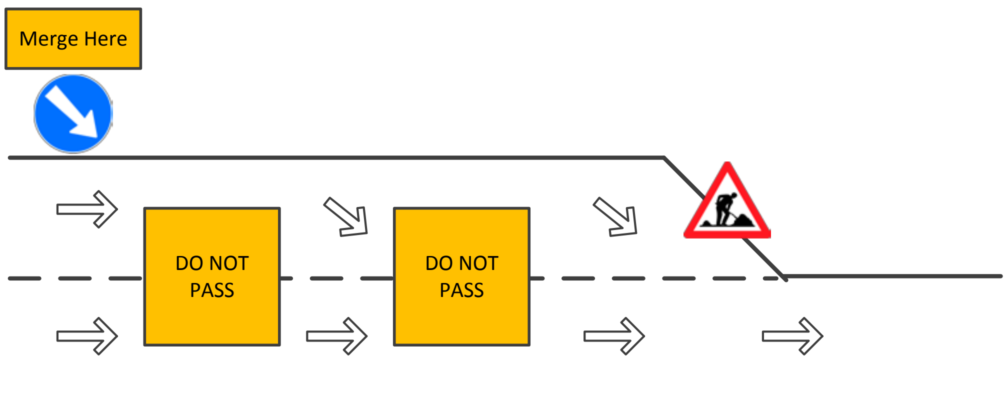
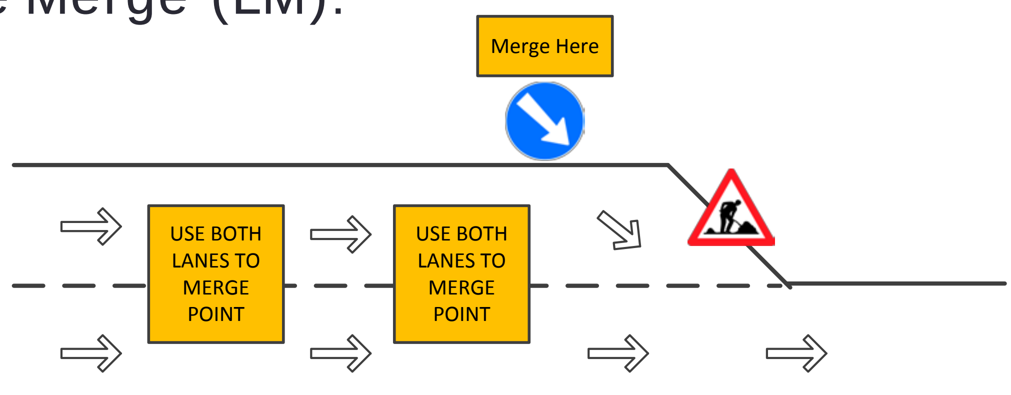
Static Merge Control

Early Merge (EM):



Late Merge (LM):



Source: McCoy et al. (1999)

Literature Review

- **Field studies**
  - Problem: limited time and location; drivers were confused by the merge instructions when they saw it for the first time

- **Simulation studies**
  - Problem: seldom cross compare EM and LM under the same settings; opposite results, for example:

EM is worse than LM when demand is over 750 vphpl (Yang et al., 2009)

V.S.

EM always performs better than LM at high flow levels (Harb et al., 2012)

Objective of the Simulation Study

- Identify the parameters in VISSIM that influence the simulation result
- Compare the EM and LM controls via VISSIM simulations
- Provide preliminary suggestions for the suitable conditions of applying EM or LM

Parameter Selection (1/2)

- VISSIM has over 192 parameters, it is not feasible to check all of them.
- Three influential parameters found from literature:

➢ *CC1* and *CC2* from car-following model (Wiedemann-99)

$$\textit{const.} + CC1 \times v \leq \text{Safety\_distance}_{CF} \leq \textit{const.} + CC1 \times v + CC2$$

➢ *Safety Distance Reduction Factor (SDRF)* from lane-changing model. $0 \leq SDRF \leq 1$.

$$\text{Safety\_distance}_{LC} = \text{Safety\_distance}_{CF} * SDRF$$

Parameter Selection (2/2)

- Sensitivity analysis using quasi-OTEE approach
- Samples are taken in the data ranges based on other simulation studies:

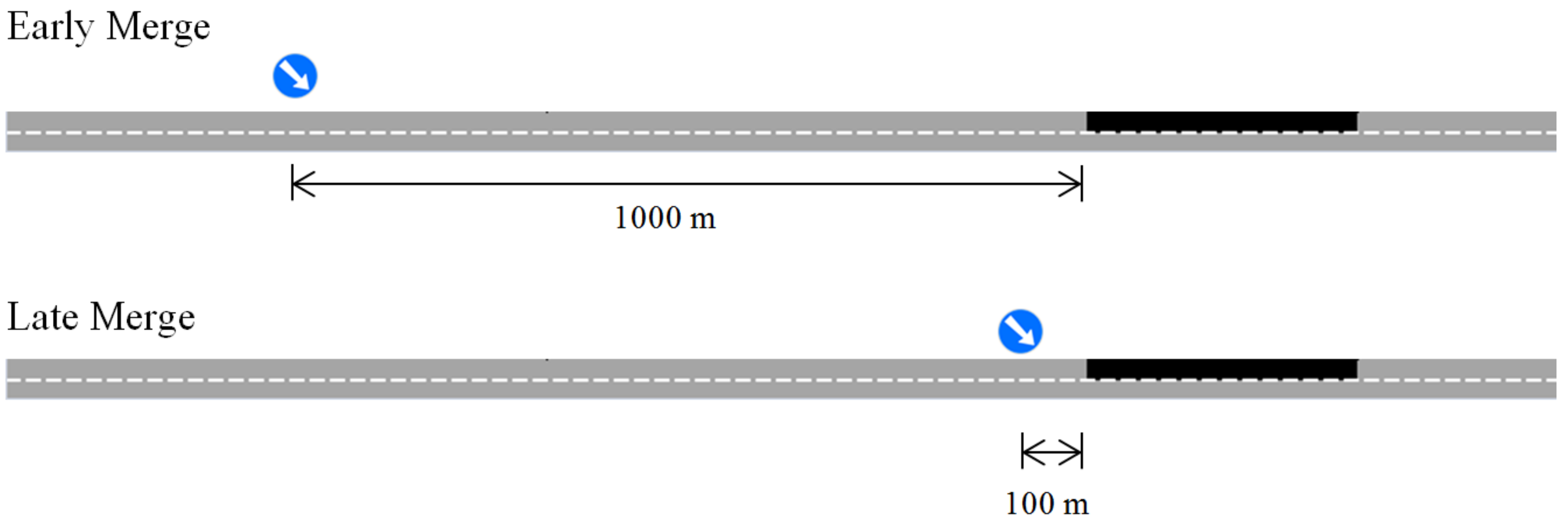
The parameters and their ranges for the sensitivity analysis

#	Parameters	Data Range
1	CC1 (s)	[0.9, 1.8]
2	CC2 (m)	[4, 19]
3	SDRF	[0.15, 0.60]

Source: Ge and Menendez (2013)

Experiment Design

- 2-to-1 lane scenario
- Car (90%): 100 km/h; Truck (10%): 80 km/h
- Simulation time: 3’000 s (including 1’200 s warm-up time)
- Demands: 2’000 v/h, 2’500 v/h, ..., 4’000 v/h

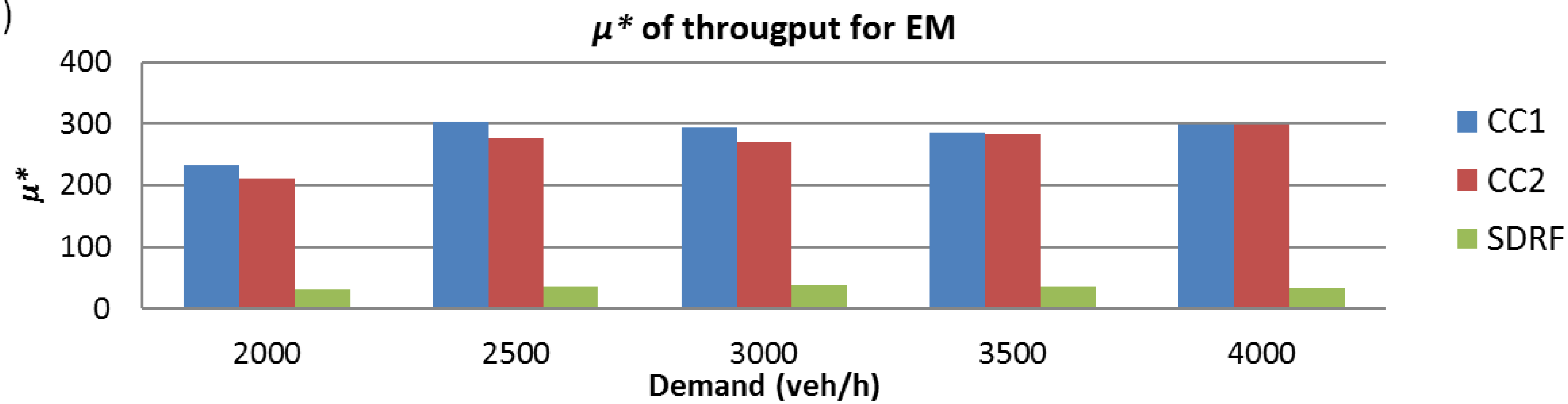


SA Results (1/2)

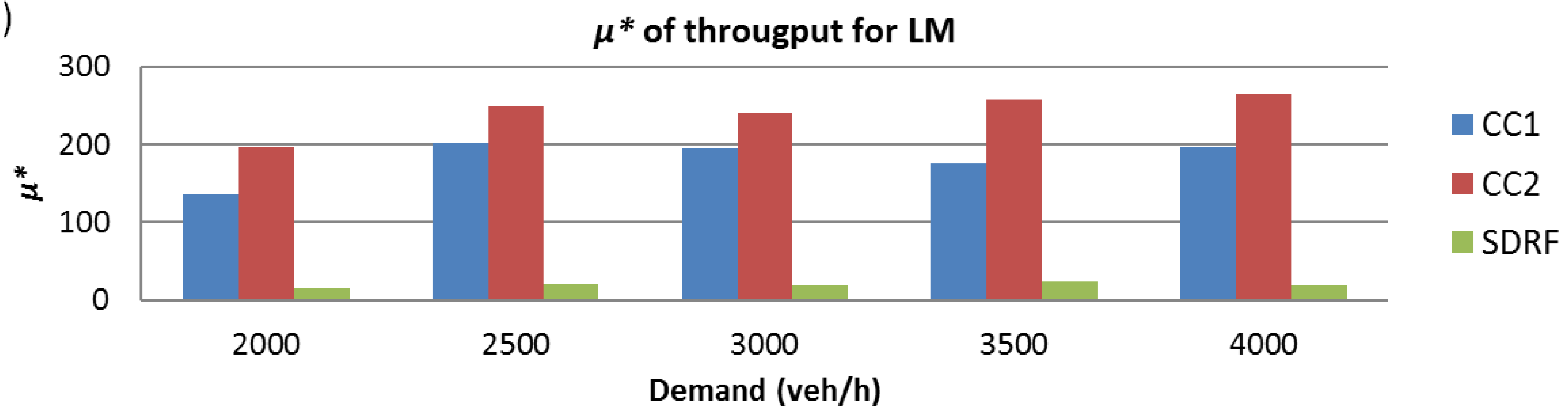
$$EE_{CC1} = \frac{Y(CC1+\Delta, CC2, SDRF) - Y(CC1, CC2, SDRF)}{\Delta}$$

$$\mu_{CC1}{}^{*} = \frac{1}{r}\sum_{j=1}^{r}\left|EE_{CC1}^{j}\right|$$

a)



b)



- *CC1* and *CC2* are much more influential than *SDRF*.

SA Results (2/2)

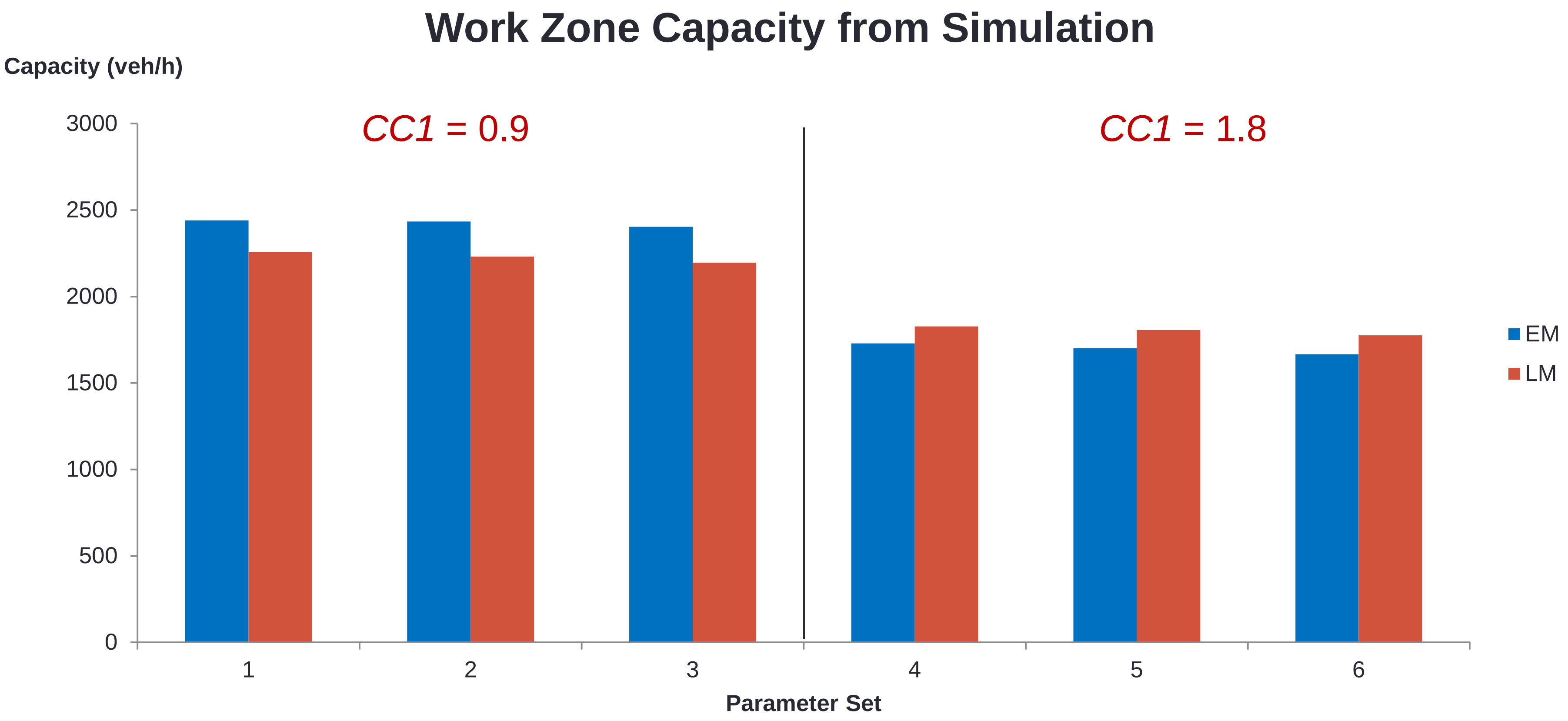
$$\mu_{CC1}^* = \frac{1}{r}\sum_{j=1}^{r}\left|EE_{CC1}^{j}\right| \qquad \mu_{CC1} = \frac{1}{r}\sum_{j=1}^{r}EE_{CC1}^{j}$$

The μ^* and μ of *CC1* and *CC2* under different demands and merge schemes

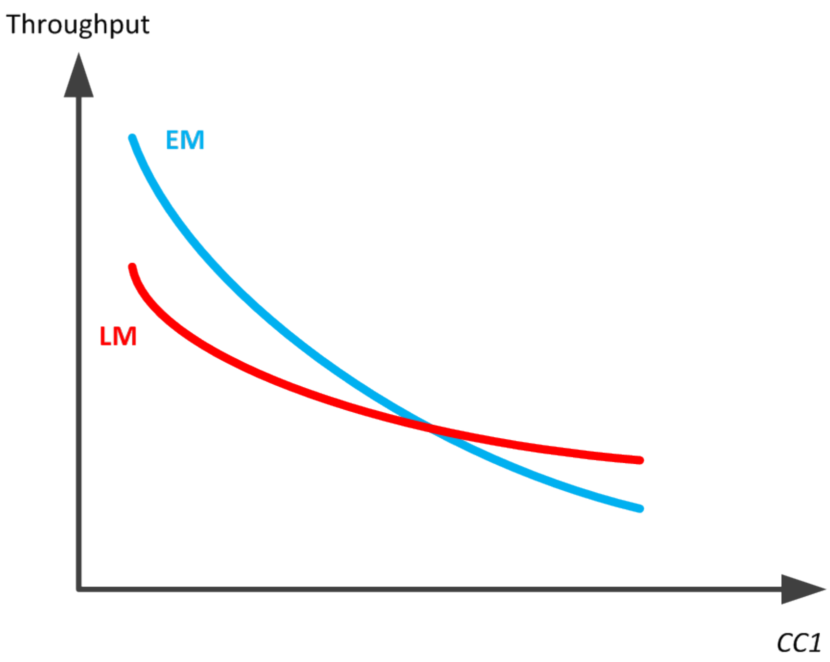
		EM					LM				
	Demand	2000	2500	3000	3500	4000	2000	2500	3000	3500	4000
CC1	μ^*	232	302	294	285	299	136	202	194	176	196
	μ	-232	-302	-294	-285	-299	-136	-202	-194	-176	-196
CC2	μ^*	211	275	270	284	298	197	248	240	257	264
	μ	-211	-275	-270	-284	-298	-197	-248	-240	-257	-264

- Increasing *CC1* or *CC2* monotonically reduces the throughputs
- Increasing *CC1* causes more throughput drops in EM than in LM, while increasing *CC2* decreases almost the same throughput in both control schemes.

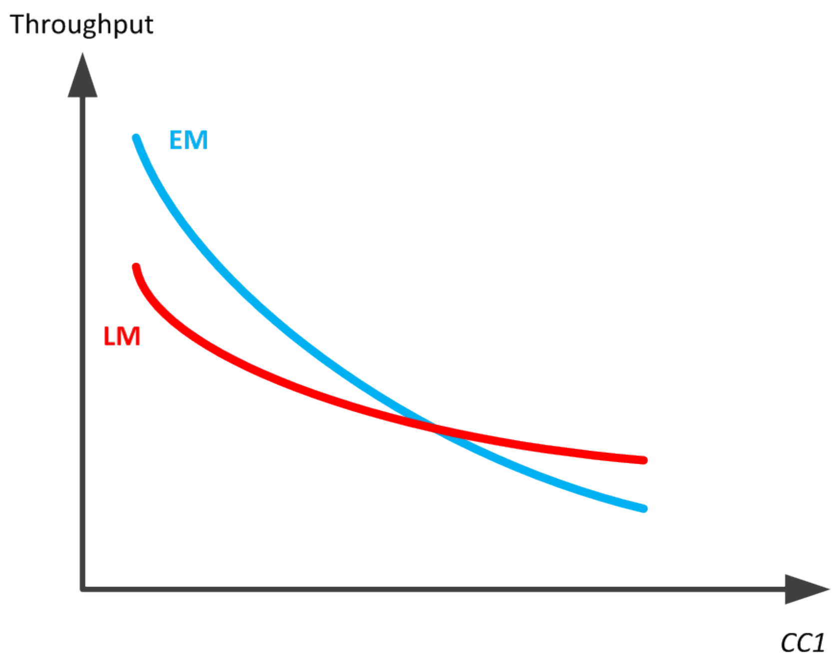
Simulation Results: Capacity (1/2)



Simulation Results: Capacity (2/2)



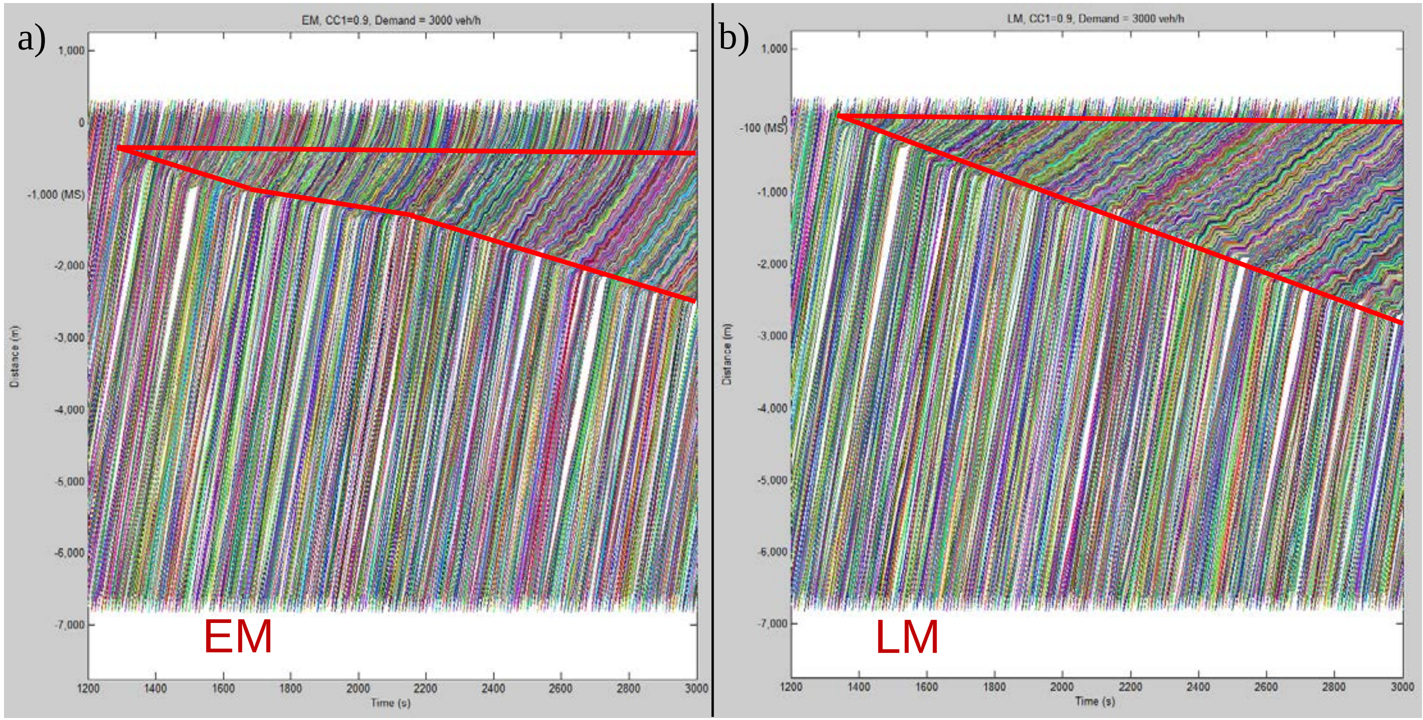
Yang et al. (2009): EM < LM



Harb et al. (2012): EM > LM

Simulation Results: Queue Length (1/2)

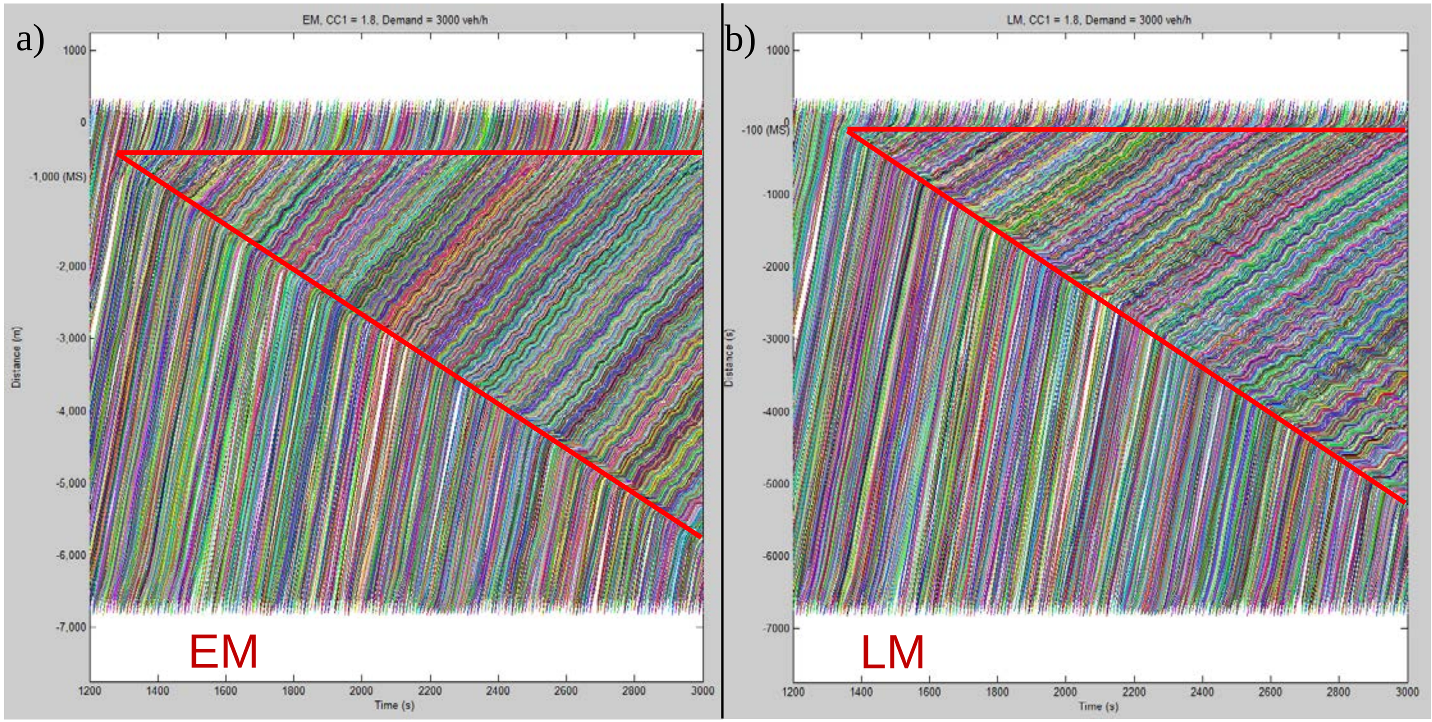
Parameter Set 1 (*CC1* = 0.9), demand = 3'000 veh/h



	Queue Start Time	Queue Length at 3'000 s	Queue Speed
EM	1'300 s	2'145 m	1.26 m/s
LM	1'360 s	2'688 m	1.63 m/s

Simulation Results: Queue Length (2/2)

Parameter Set 4 (*CC1* = 1.8), demand = 3’000 veh/h



	Queue Start Time	Queue Length at 3’000 s	Queue Speed
EM	1’310 s	5’387 m	3.18 m/s
LM	1’350 s	5’222 m	3.16 m/s

Conclusions

- Increasing *CC1* and *CC2* significantly reduces the throughput.

- When increasing *CC1*, the throughput in EM drops faster than that in LM. *CC1* must be carefully calibrated in the simulation study.

For the 2-to-1 lane closure:

- EM is recommended when drivers are aggressive and the safety distance is short (i.e., low *CC1*).

- LM is recommended when drivers are cautious and the safety distance is long (i.e., high *CC1*).

Thank you for your attention!
Questions?

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