Estimation of Freeway Platooning Measures Using Surrogate Measures Based on Connected Vehicle Data

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STRIDE

Introduction

- The availability of Connected Vehicle (CV) data will allow the collection of parameters such as the distributions of the time headway between vehicles, variations of speed between different vehicles, variations of speed of each vehicle.
- There is a very limited work to investigate the potential of the more detailed data obtained from CV in deriving additional measures for use in assessing system operations

Objective

- Producing new performance measure based on level of platooning in the traffic stream and thus the stability and level of congestion of traffic flow in low market penetration of CV.

Methodology

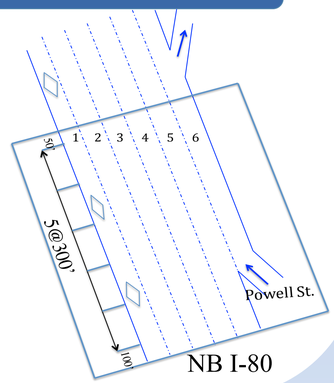
- Determination of two surrogate measures:
  - The standard deviation of speed between vehicles **(SD_T)**
  - The standard deviation of individual vehicles speed**(SD_V)**
- Determination of platooning measures:
  - Percentage of vehicles in platoon
  - The platoon size
- Determination of platoon percentage :
  - Time headway of 4.0 seconds
  - Standard deviation of speed of 1.0 ft/second
- Identification of relationships between the surrogate measures and platooning measures.
- Accuracy examination of estimated platooning measures at relatively low CV market penetrations based on the surrogate measures.

Study Area

I-80 in Emeryville, California

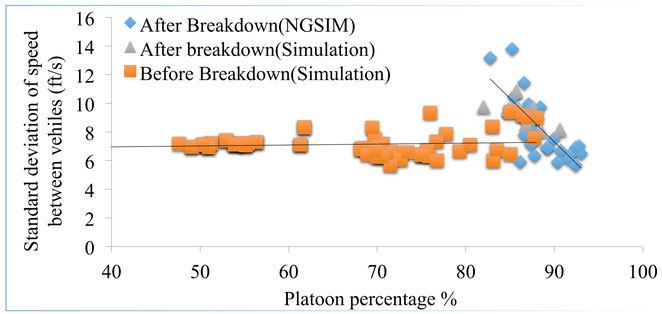
Data Sources:

- Real-world trajectory data collected for NGSIM program for congested conditions
- Trajectory data generated from simulation analysis to supplement the real-world data

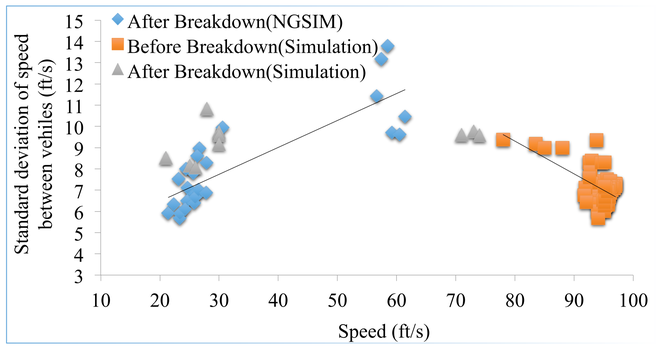


Platoon Percentage Determination

- The relationship between the percentage of vehicles in platoon and the corresponded SD_T was conducted.
  The fitted function between the platoon percentage (P) and SD_T for "after traffic breakdown":
  $P = 111.09 - 10.67 \log (SD_T)$



- At low volumes, Level of Service C to D or better, the SD_T does not change with the increase in demand and the percentage in platoons.
- An increase in the SD_T is observed, as the traffic reaching a maximum close to the traffic breakdown.



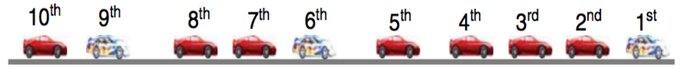
- The maximum observed SD_T is at a speed around 59 ft/sec (41 mph), which is beyond the critical speed at capacity estimated according to the HCM to be around 77 ft/sec (52 mph).
- Around that point, corresponding 84% vehicles in platoon, a significant increase in the SD_T is observed.

- Quality of the estimation of the platoon percentage at different market penetrations :

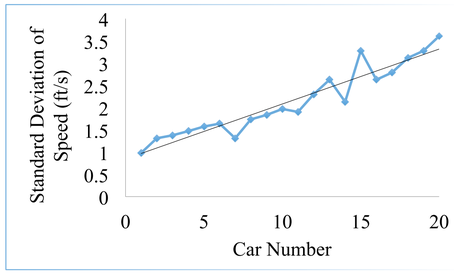
Accuracy measure	5%	10%	50%	80%
MAE	1.7394	0.9460	0.2677	0.1704
MAPE	1.9010	1.0423	0.2968	0.1882
RMSE	2.0979	1.2109	0.3692	0.2161
SDPE	1.2912	0.8532	0.2910	0.1448

Platoon Size Distribution

- Estimating the platoon size distribution, based on the SD_V at different market penetrations was investigated.
- Number of Vehicle in the platoon = $-94.29(\ln(10.56-0.30\ SD_V)-\ln(10.4))$



- The estimation is done, for "after breakdown", based on the concept of the concave growth pattern of traffic oscillation.



- The estimated positions were categorized into four groups:

Sub segment	%. of Vehicles in Platoon Size Group (lane 3,peak period)			
	1<=x<=2	2<x<=5	5<x<=15	x>15
1	0.75	13.43	57.09	28.73
2	3.14	28.63	60.39	7.84
3	3.82	32.44	56.87	6.87
4	2.27	25.38	57.58	14.77
5	4.60	24.52	53.64	17.24

- Results of the t-test on the difference in the mean and the $\chi 2$ test of the platoon size distribution based on the mean of the 20 Monto Carlo runs for different market penetration:

Hypothesis test	Chi-square test on Frequency Distribution		T-test on the Mean	
Market Penetration	Pass	No. of Individual Runs Passing	t-value	Pass
5%	Y	10 out of 20	1.013	Y
10%	Y	14 out of 20	0.5239	Y
20%	Y	18 out of 20	0.6665	Y
50%	Y	20 0ut of 20	1.3209	Y

Conclusions

- Platoon percentage can be accurately and reliably estimated at relatively low CV market penetrations of 5%.
- Platoon size distribution estimation, can be accurately estimated at low market penetration of 5% when using the data for planning purposes based on multiple days. However, a minimum of 20% of market penetration is needed for individual day operations.