ESTIMATION OF THE SAFETY PERFORMANCE OF FREEWAYS IN LOW MARKET PENETRATION OF CONNECTED VEHICLE DATA

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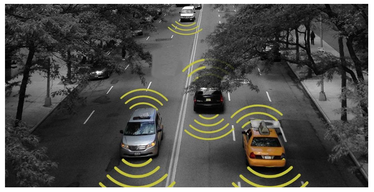
INTRODUCTION

Emerging new technology and Performance measurement:

- Performance measurement :

Key component in off-line and real-time support of transportation system management and operations



- Emerging connected vehicle (CV) technologies:

Significantly affect the demand and supply of the transportation network. They will also increase data quantity and quality, allowing the use of new performance measures and better estimation of existing measures

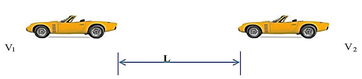
Safety Concerns:

- Main safety concern on freeways: Rear-end collisions
- A technique to assess the safety : Traffic conflicts (Dijkstra,et al,2010)
- Indicators to evaluate the rear-end crash : Surrogate safety measures (Li et al,2014)

SURROGATE SAFETY MEASURES

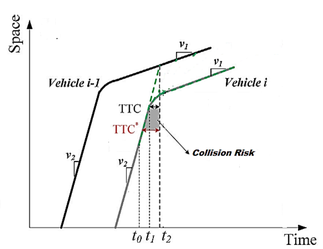
- **TTC**=Time-To-Collision

Lower TTC is a good indicator of the high probability of collision (Hayward,1972)



$$TTC_i(t) = \begin{cases} \frac{x_{i-1}(t)-x_i(t)-\bar{L}}{v_i(t)-v_{i-1}(t)}, & \text{if } v_i(t) > v_{i-1}(t) \\ \infty, & \text{if } v_i(t) \le v_{i-1}(t) \end{cases}$$

$$TTC_{Break}(t) = \frac{x_{i-1}(t)-x_i(t)-\bar{L}}{v_i(t)} \quad \text{if } v_i(t) > v_{i-1}(t)$$



- **TET**=Time Exposed time–to–collision

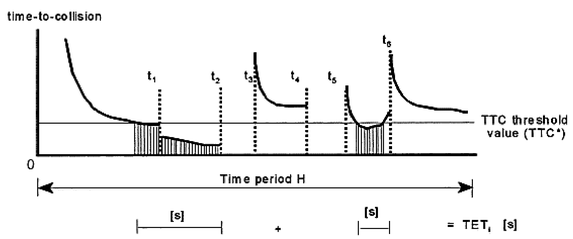
Reflecting the total time spent under dangerous traffic conditions

$TET(t)=\sum_{i=1}^{n} \delta_t \Delta t$ Δt is the time step and n is the number of vehicles

where $\delta_t = \begin{cases} 1, & 0 < TTC_{break}(t) \le TTC^* \\ 0, & \text{else} \end{cases}$

TTC* threshold, set 0.5 - 3.5 s (Li et al, 2017)

Here 2 sec was taken



OBJECTIVES

- Using CV data for real-time assessment of the safety of the system in low CV market penetration
- Examine the use of a surrogate safety measure to allow estimating safety in low market penetration of CV
- Recommend using the safety assessment results to derive a threshold to activate traffic management strategies

STUDY AREA AND DATA SOURCES

VISSIM Simulation (Training data set):

- One mile section
- 3 lanes
- 300 feet subsegment
- 5-minute time intervals for a total period of 15-minutes

Traffic stream with : different congestion levels,

NGSIM Data (Testing data set):

I-80:

- 300 feet subsegment
- 15 minutes (4-4:15 P.M)

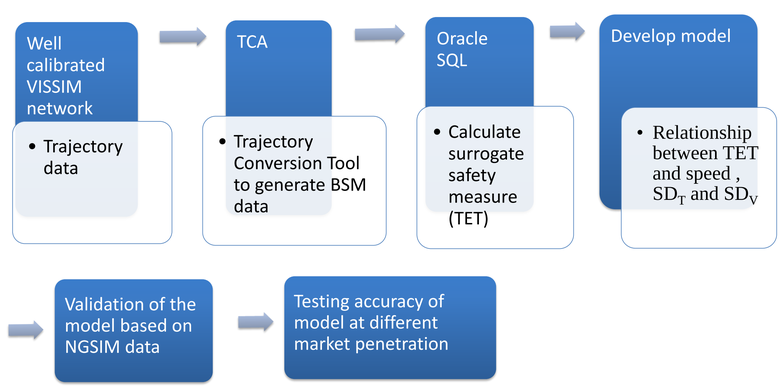
US 101 :

- 300 feet subsegment
- 15 minutes (7:50-8:05 A.M)

5-minute time intervals for a total period of 15-minutes

METHODOLOGY

For measuring safety under low market penetration of CV, the model was developed based on surrogate measures and then the accuracy of the model was assessed

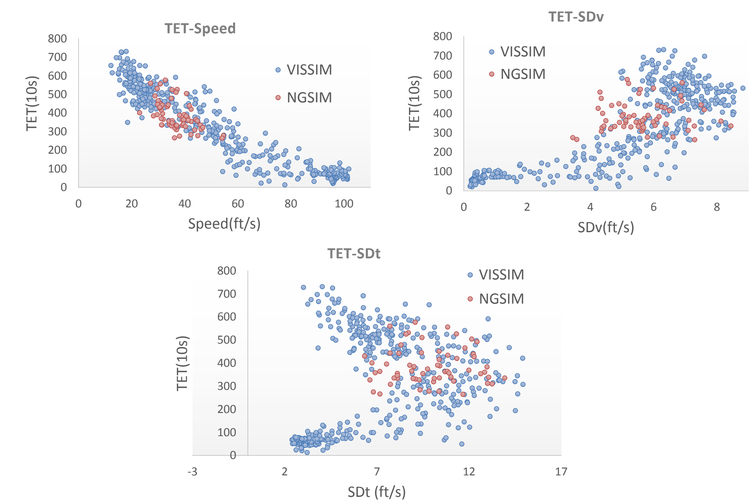


* SD_T is the standard deviation between vehicle speeds,
* SD_V is the standard deviation of individual vehicle speeds

- The market penetrations of CV were varied from 2% to 20%, to identify the lowest market penetration of CV that allows accurate safety assessment based on the developed model

RESULTS

The relationship between TET and speed, SD_T and SD_V :



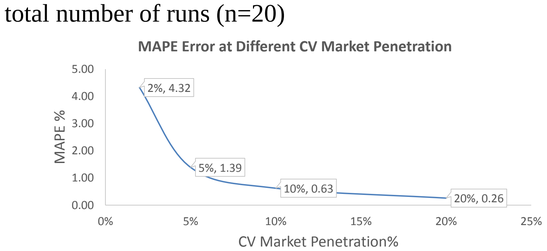
- In congested conditions where the speed is less than 40 ft/sec, total TET is greater than 3000 sec
- Several functions between the TET, Speed, SD_T and SD_V were tested using multivariate regression analysis
- The model based on PLS method was selected
- The error of the model based on the test data set is 15%

$$TET = 713.27 - 6.86 * Speed - 3.48 * SD_T$$

The Quality of the TET Estimation at Different CV Market Penetrations Based on MAPE :

Mean Absolute Percent Error (MAPE)=$\frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i-y}{y_i}\right|$

Where y_i is the estimated value of the ith run, y is the value at 100% MP, n is the total number of runs (n=20)



CONCLUSIONS

- Safety analysis based on surrogate measures can be assessed using CV data at relatively low market penetrations of CV
- TET can be accurately and reliably estimated at relatively low CV market penetrations (2%)
- It can be concluded that the recommended threshold for total TET for activating advanced traffic management strategies is around 3000 s