Transportation Network Reliability and Congestion in South Florida

Chang-Jen Lan, Ph.D., P.E. Town of Jupiter

Background

- A reliable transportation network provides road users a consistent and predictable range of departure-time specific travel time on a daily basis.
- It is widely believed that the system reliability is highly correlated with congestion. A congested transportation network tends to degrade the system reliability.
- This study explores the correlational relationships between reliability and congestion measures on both uninterrupted facilities and surface streets.
- This study focuses on south Florida using FHWA probe vehicle travel time data but the results are transferable to other metropolitan areas.

Measures of Effectiveness (MOEs)

- Congestion
 - Congestion Index, $CI = 1 \frac{s_a}{s_f}$ (= % speed reduction)
 - Traffic Time Index, $TTI = \frac{t_a}{t_f} = \frac{L/s_a}{L/s_f} = \frac{1}{\frac{s_a}{s_f}} = \frac{1}{1-CI}$
- Reliability
 - Buffer Index, $BI = \frac{t_{95} t_a}{t_a}$
 - Planning Time Index, $PTI = \frac{t_{95}}{t_f} = \frac{t_{95}}{t_a} \frac{t_a}{t_f} = \frac{BI+1}{1-CI}$

where $t_{95} = 95^{\text{th}}$ percentile travel time (min); t_a = average travel time (min); t_f = free-flow travel time (min); s_a = average speed (mph); s_f = free-flow speed (mph); L = distance (mi)

Methodology

- Identify correct distributional assumptions for the MOEs.
- Establish unbiased mean predictive function between the reliability and congestion measures
- Estimate the functional and distributional parameters using the maximum likelihood method (MLE)
- Construct prediction intervals (limits) and the coefficient of variation (CV), i.e., variation to mean ratio

 $CV \ge 0.3 \rightarrow Reliability-Congestion relationship is not trustworthy$

- Epidemiology study: Excellent (< 5%), Good (5-10%), Acceptable (10-15%), (Shechtman 2013) Unacceptable (> 15%)
- U.S. Census case studies: High reliability (< 15%), Medium Reliability (15-30%) & Low Reliability (> 30%) ← use with extreme caution

Data Descriptions

- Vehicle probe-based travel time data taken from National Performance Management Research Data Set (NPMRDS) INRIX source maintained by FHWA and UM CATT lab.
- More than 11,000 15-min travel time and speed statistical data were sampled from 50 major corridors, including uninterrupted facilities and surface streets, in south Florida between 6 am and 8 pm on weekdays.
- A total of 4,480 15-min travel time and speed statistical data were sampled during same time period from 20 major corridors in other metropolitan areas such as LA, Atlanta, DC and Orlando for a comparison purpose

MOE Histograms by Facilities





MOE Distributional Assumptions

- The <u>mean prediction function</u>, $\mu(x_i)$, and <u>prediction limits</u>, y_p , are state (congestion index) dependent. Only the coef. of variations, CV_i , from lognormal distribution are state dependent
- Lognormal distribution

$$\mu(x_i) = e^{cx_i + d}, y_p = e^{\mu(x_i) + z_{(1-p)}\sigma(x_i)}, CV_i = \frac{Std(y_i)}{E(y_i)} = \sqrt{e^{\sigma^2(x_i)} - 1}$$

Gamma distribution

$$\mu(x_i) = a x_i^b, y_p = \frac{\mu(x_i)}{\alpha} \gamma^{-1}(p \sqrt{\alpha}, \alpha), CV_i = \frac{1}{\sqrt{\alpha}}$$

Burr Type XII distribution

$$\mu(x_i) = \frac{ax_i^b}{1 - x_i}, y_p = \left(\frac{ax_i^b}{1 - x_i}\right) \frac{\left((1 - p)^{-\frac{1}{k}} - 1\right)^{\frac{1}{c}}}{k \operatorname{Beta}\left(1 + \frac{1}{c'}, k - \frac{1}{c}\right)}, CV_i = \sqrt{\frac{\operatorname{Beta}\left(1 + \frac{2}{c'}, k - \frac{2}{c}\right)}{k \operatorname{Beta}\left(1 + \frac{1}{c'}, k - \frac{1}{c}\right)^2} - 1}$$

TTI Fit by Different Distributions



Is BI Correlated with Congestion



Buffer Index seems not a reliable indicator for congestion

BI vs CI from South FL



PTI vs CI from South FL



BI & PTI from Other Metropolitan Areas



Findings

- PTI is a more predictable reliability measure than BI, showing less variability
- CI (or PSR) is a more effective explanatory variable than TTI for reliability measure
- Uninterrupted facilities exhibit more dispersed reliability measures than surface streets in south FL
- As indicated by CV, the reliability-congestion relationship is not trustworthy based on BI on either facility
- Trustworthy correlations between reliability & congestion measures are solely observed by PTI on surface streets

Conclusions

- The widely used Buffer Index (BI), defined as the ratio of the 95th % travel time to average travel time minus one, does not support the notion that congestion leads to unreliable systems on either freeways or surfaces streets
- Conversely, Planning Time Index (PTI), defined as the ratio of the 95th % travel time to free-flow travel time, suggests that this notion may only be valid on surface streets
- When performing trip planning, one should plan for additional travel time based on <u>free-flow travel time</u> in lieu of the average counterpart
- Selection of a more predictable reliability measure holds significant practical implications. Such measures can aid policymakers in identifying effective strategies to enhance reliability, especially in areas prone to high delay variability