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Experiences Incorporating Reliability into Planning Models

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Presentation Overview

- Background
  - What is travel time reliability?
  - Recent research (SHRP2)
- Case Studies and Other Examples
  - Tennessee
  - Other Link-Based Examples
  - Path-Level Measures
  - Southeast Florida
  - San Diego

Travel Time Reliability

- "Variation in travel time for the same trip from day to day." (SHRP2 L11)
- Why model reliability? Why not just average time?...
- Would you rather have:
  A. 100% chance of 20 min. commute
  B. 50% chance of 15 min. commute *and*
  50% chance of 25 min. commute ?
- Same average time but *Option A* is more reliable
  - Budget 20 minutes for on-time arrival (Option A)
  - Budget 25 minutes for on-time arrival (Option B)

Reliability and Travel Decisions

- **Route Choice**
  - Avoid unreliable routes
  - Managed/Priced lanes are generally reliable
- **Departure Time**
  - Leave early for on-time arrival
- **Mode Choice**
  - Transit can very (un)reliable
  - Walk is reliable (but slow)
- **Other**
  - Destination Choice
  - Trip Frequency
  - Location Choice

Barriers to Modeling Reliability

- **Methodological Challenges**
  - Reliability measures are generally non-additive across links (*vexing issue*)
- **Data Requirements**
  - Need months of observed data
  - Data quality isn't always great (historically)
- **Many Measures**
  - No obvious "best" measure
  - Just the right tail or full distribution?
  - Simple measures for non-technical audiences?

Link Non-Additivity

- $LinkA_{Reliability} + LinkB_{Reliability} <> LinkAB_{Reliability}$
- …with some exceptions
  - Adding the variance of uncorrelated links
  - Certain proxy measures, such as weighted travel time
- May necessitate tradeoffs
  - Path-based assignment,
  - No reliability in SP Route-finding
  - Inconsistency Path and Link- measures, or
  - Use proxy measure

Reliability Measure versus Assignment Type

Avoid confusing link/path assignment and link/path measures!

Reliability Measure

Assignment Type

	Link-Level	**OD/Path-Level**
Link-Based *(traditional shortest path)*	Problematic? Use in SP Routefinding	Inferred from skims Use in toll/mode choice
Path-Based/ Enumeration *(more advanced)*	Not needed! *(can be a model output)*	Flexible Use in path selection

Recent Research (SHRP 2)

SHRP 2 Research

OVERVIEW

- Major federally funded research effort (2006 to 2015)
- Four focus areas:
  - Safety
  - Renewal
  - Capacity
  - Reliability
- Wealth of material on reliability
  - Measuring
  - Modeling
  - Project programming

Downloadable Content:
http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/SHRP2FocusAreas.aspx

Relevant Reports

SELECTED REPORTS

- SHRP 2 L03 *(Cambridge Systematics, Inc. et al., 2013)*
  - Empirical analysis of reliability
  - Mean TTI and reliability measures
- SHRP 2 L04 *(Mahmassani et al., 2013)*
  - Path-level reliability measures
  - Tool for meso- and micro-simulation models
- SHRP 2 C04 *(Parsons Brinkerhoff et al., 2013)*
  - Reliability and route choice

Case Study: Tennessee

Overview

- Bernardin (RSG) et al.
- For Tennessee Statewide Model
- ***Link-Based Assignment, Link-Level Measure***
- Weighted Delay
  - Proxy measure
  - No additivity problem
  - Reduced challenge estimating/implementing
  - Unreliability closely depends on congestion/LOS

Is all travel time created equal?

20 minutes of this vs 20 minutes of this

? =

A Simple Version

Congested Time = Free-flow Time + Delay

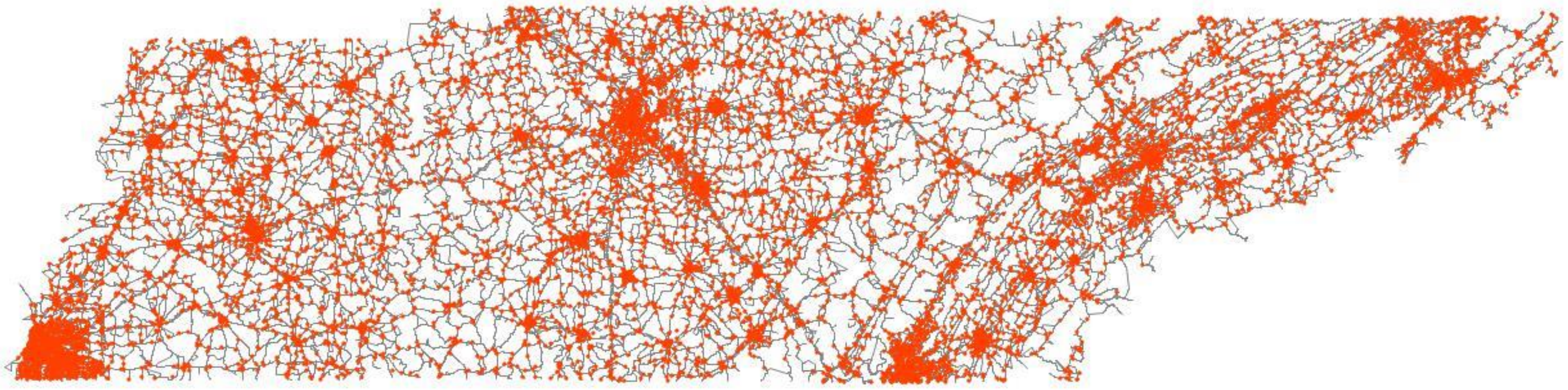
↓

Perceived Time = Free-flow Time + αDelay

Tennessee Statewide Travel Model

DATA

- 12,000+ Traffic Counts



METHOD

- Estimate α to produce Least Squared Error (LSE)

Results

FINDINGS

- Modest improvement (~1-2%) in RMSE

- Autos: α = 1.10
- SUT: α = 1.29
- MUT: α = 1.21

- Over-estimation/over-valuation of delay less than in some research, but still significant, particularly for trucks

Other Link-Based Examples

FAMPO Model

RESULTS

- Similar approach to TDOT model
- Tested $1.5 < \alpha < 1.7$
- Eventually settled on 1.5
- Closer to values in literature

LOS Weighting Scheme

LOS-BASED WEIGHTS

Travel Time Conditions	Weight	LOS	V/C
Free flow	1.00	A, B	Under 0.5
Busy	1.05	C	0.5–0.7
Light congestion	1.10	D	0.7–0.8
Heavy congestion	1.20	E	0.8–1.0
Stop start	1.40	F	1.0–1.2
Gridlock	1.80	F	1.2+

Source: (Mahmassani, et. al, 2014)

Path-Level Measures

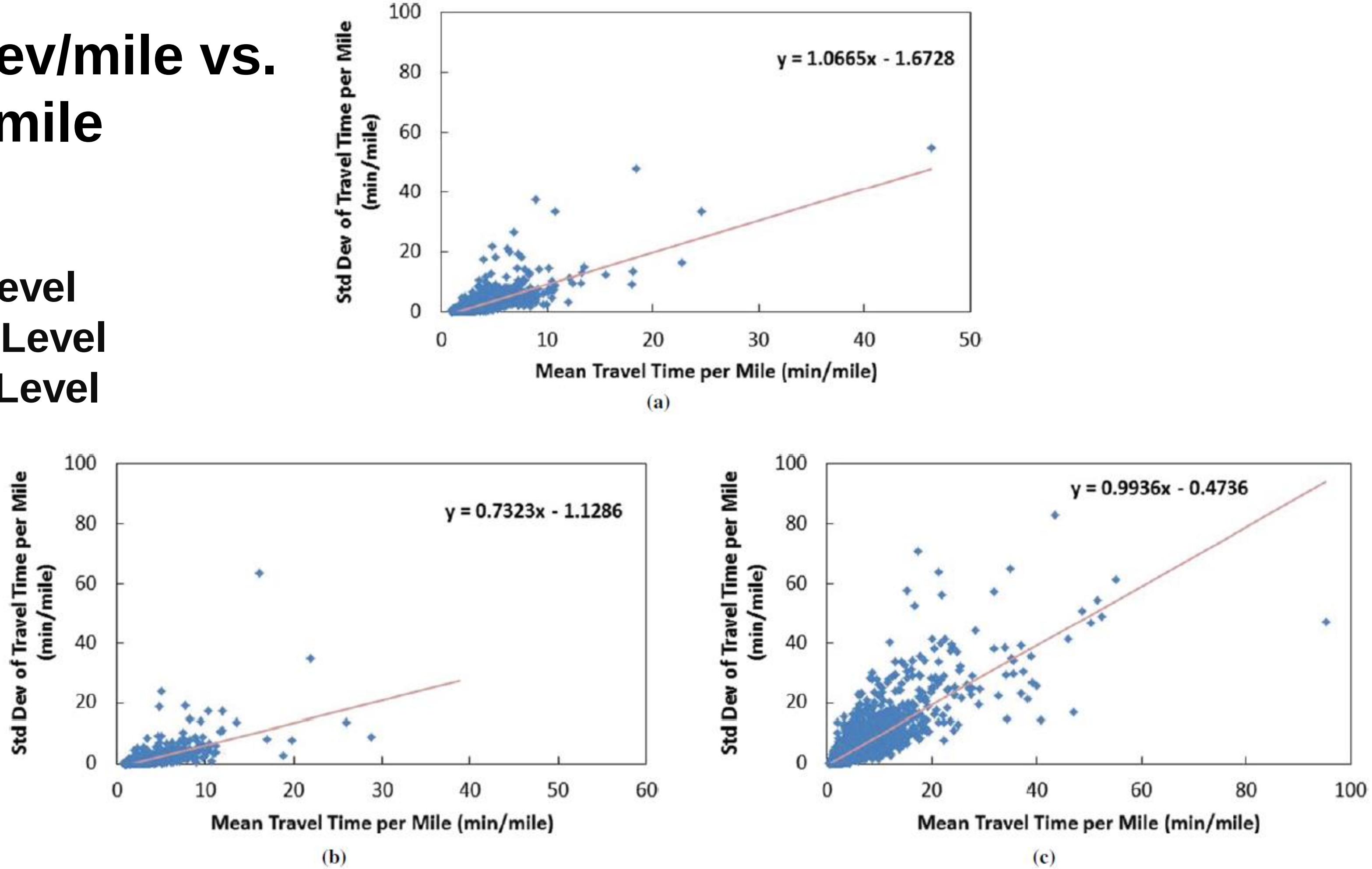
Analytic Path-Based Approaches

- Can estimate from single assignment (*instead of explicitly simulating*)
- L04: can use mean travel time per distance to predict
- L03: can use TTI to predict

Mean Travel Time Approach

Std. Dev/mile vs. Mean/mile

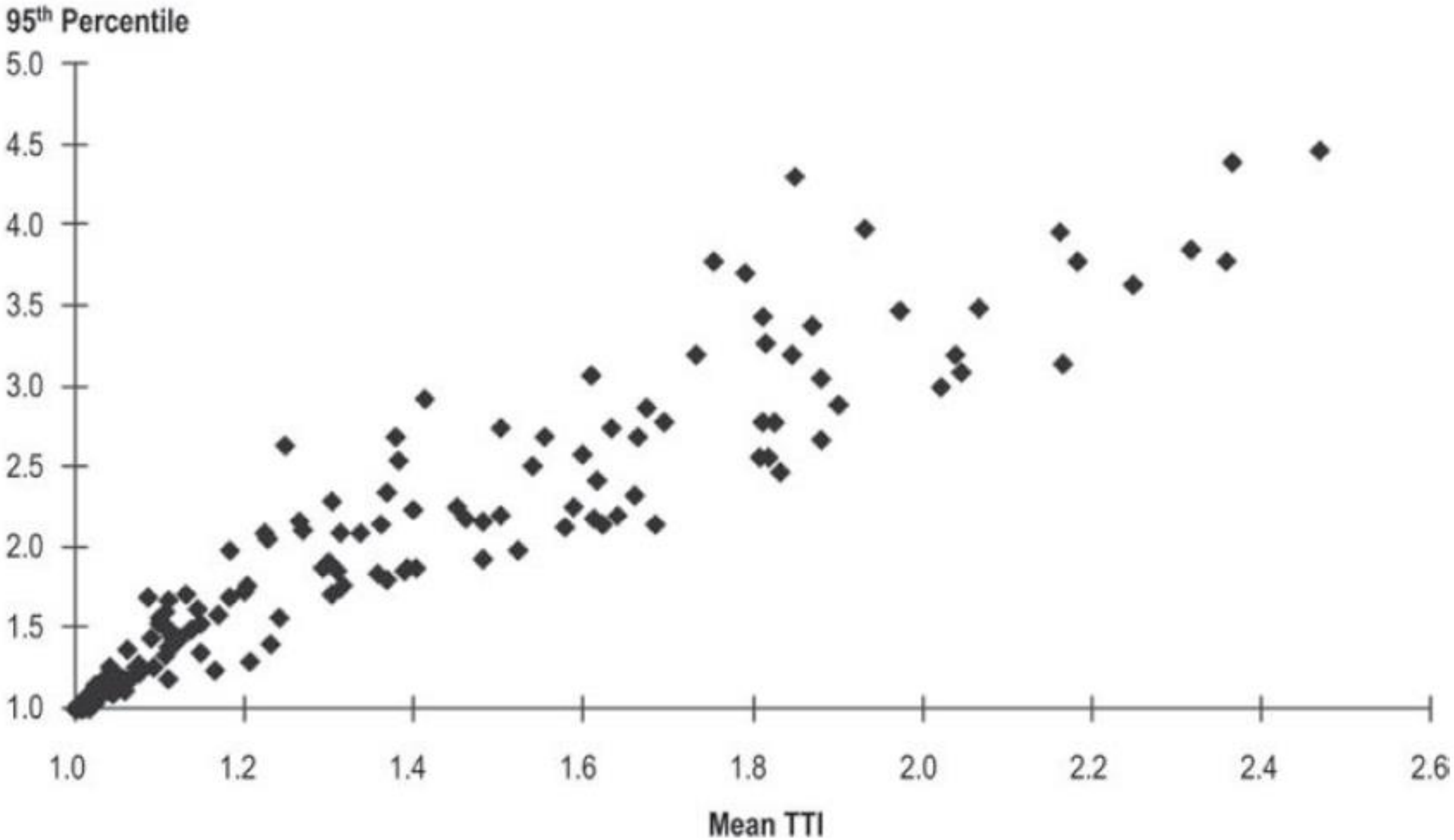
PSRC
(a) OD Level
(b) Path Level
(c) Link Level



Source: (Mahmassani, et. al, 2014)

TTI Approach

Mean TTI vs. 95th TTI for Seattle



Source: (Cambridge Systematics, et. al, 2013)

Case Study: Southeast Florida

Overview

- RSG and AECOM for Florida's Turnpike
- ***Link-Based Assignment***, ***Path-Level measure***
- Standard Deviation
  - Used in toll diversion
  - Not used for SP Route-finding
- Based on SHRP2 L04 equation considering:
  - Trip distance
  - Delay
  - Travel time correlation

Reliability Formula

ROUTE MEASURE

- Initial L04 formula:

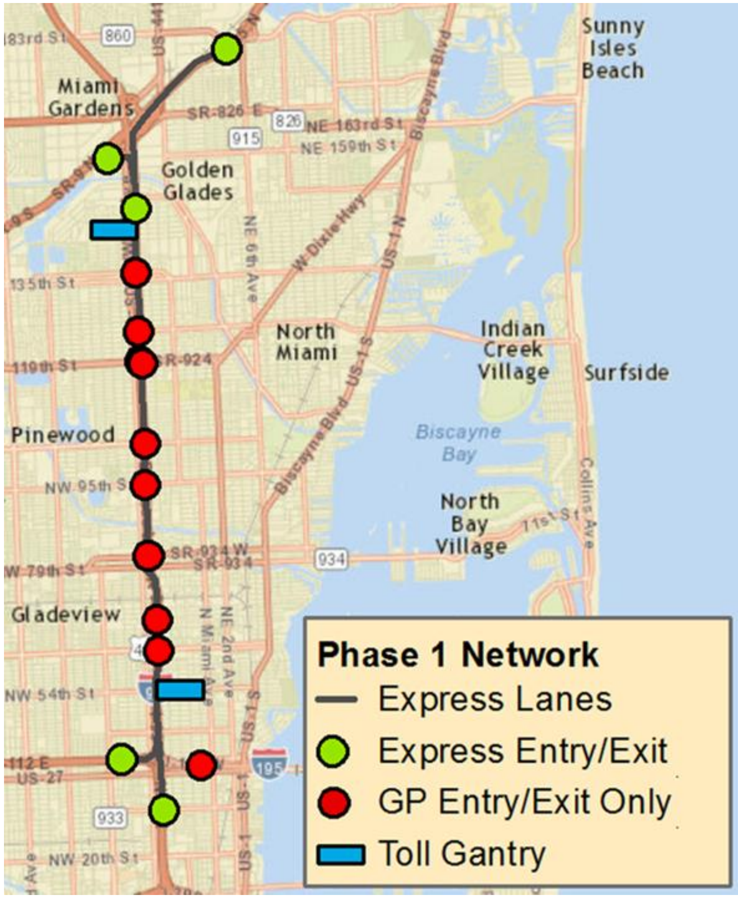
  $$StdDev = \gamma \times \left(Time_{Congested} - Time_{FreeFlow}\right) \times (Distance)^{-\eta}$$

- Grows proportionally with delay
- Decreases with distance
  - Slow/fast links cancel out
- Well-suited for corridor assignments
  - Simple pathfinding
  - Steady parameter values
- Can also be used in regional assignments

Example Corridor Analysis

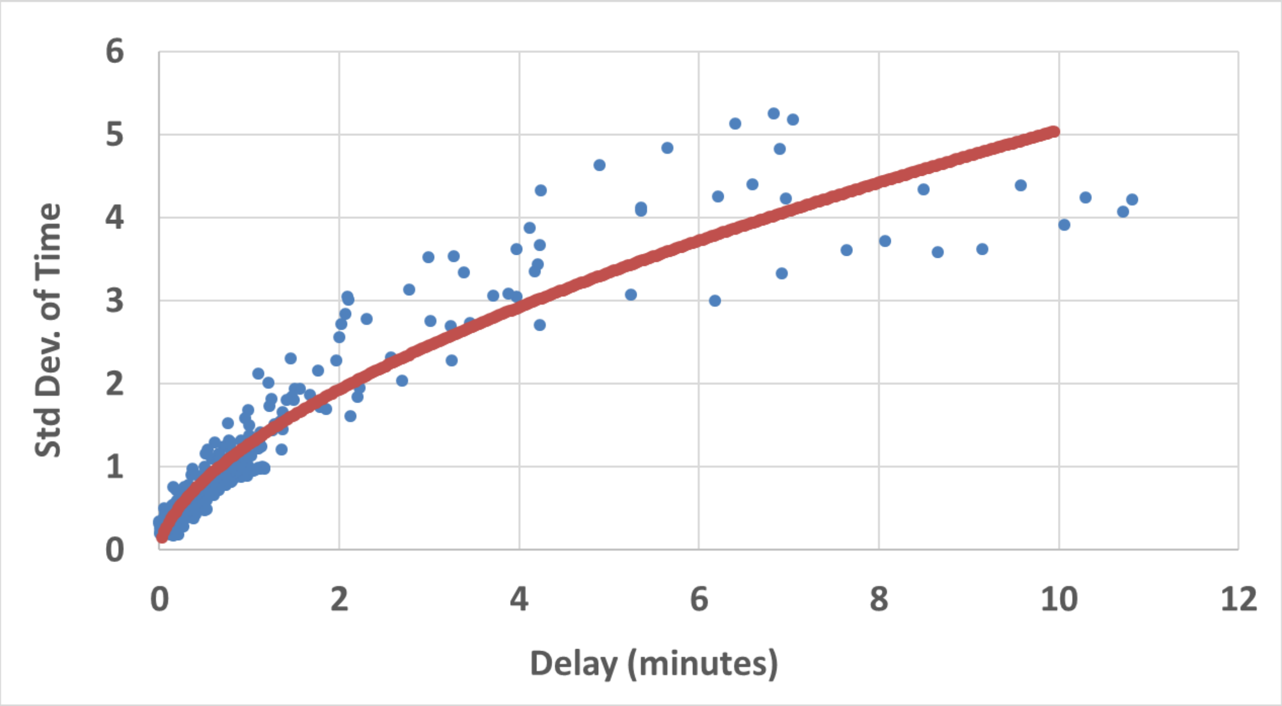
I-95 STUDY AREA

- Simple Pathfinding:
  - 1 free path
  - 1 or 0 toll paths
- Reliability not needed for pathfinding
- But used in toll choices



Reliability Equation

- One Year of data for I-95 and I-595 Corridors
- Data grouped by 15-minute period
- $StdDev = 1.28 \times \; Delay^{0.59} \; \times (Distance)^{-.1}$



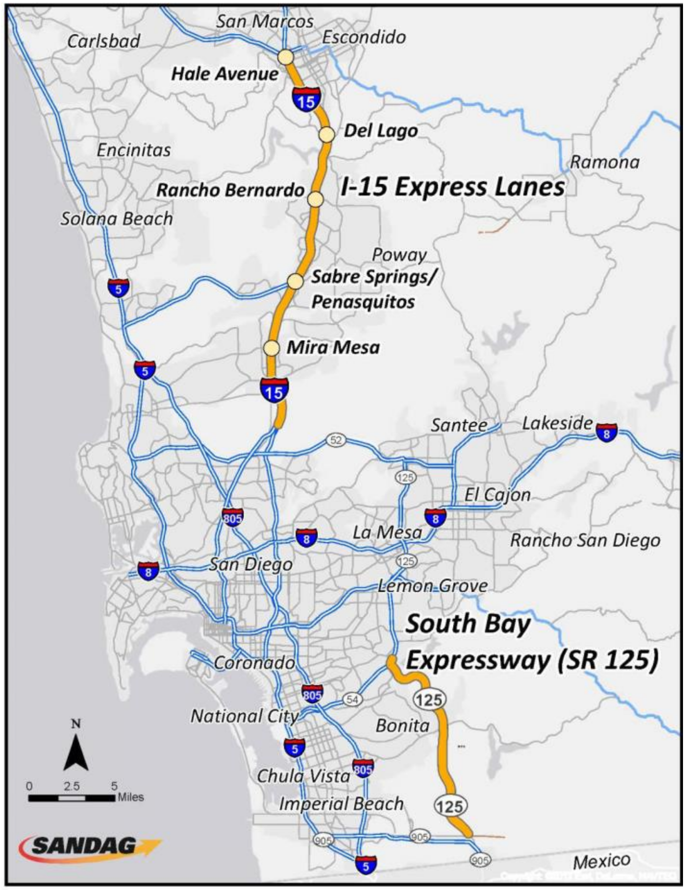
Case Study: San Diego

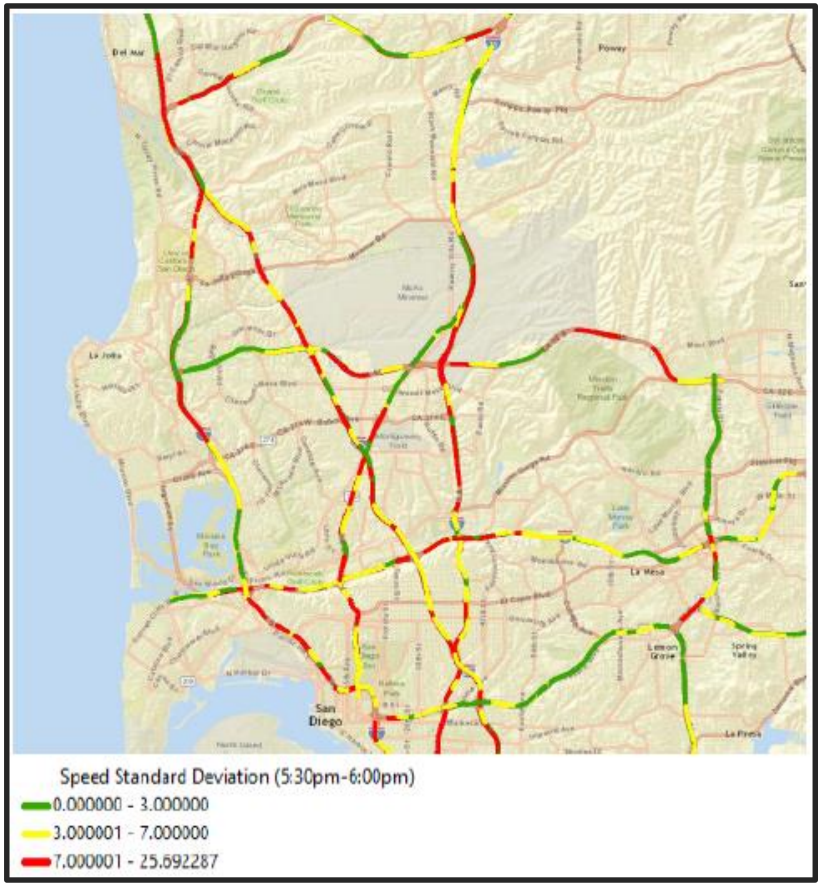
Overview

- Freedman (RSG) et al.
- For SANDAG Activity-Based Model
- ***Link-based Assignment***
- ***Link-level measure*** of Standard Deviation:
    - Depends on LOS and non-LOS Factors
    - Used in SP Route-finding
- ***Path-level measure*** of Standard Deviation:
    - Square root of summed link variances
    - Works best theoretically with no or low link time correlation
- Used in Utility equation based on SHRP2 C04

Study Area

LARGE STUDY AREA WITH TWO PRICED FACILITES





Travel Time Reliability Regression Model

$$\frac{\sigma_{min\ per\ mile}}{\mu_{\min\ per\ mile}} = f\ (speed, lanes, control\ type, distance\ to\ freeway,$$
$$time\ period, volume/capacity)$$

- Dependent variable formulated so that it can be implemented in volume-delay function
- Posted speed represents facility type variations for arterials
- (Inverse of) Distance to major freeway captures potential weaving conflicts: upstream (past) versus downstream (to)
- Control type - signalized, stop-controlled, metered, rr-xing, none)
- Time period captures time-of-day effects within broad periods
- V/C ratio captures congestion effects

Estimation Results

- Reasonable LOS effects
  - Flatter for arterials than freeways
- Significant time-of-day effects capturing within period variability
- Distance to/from major interchanges significant for freeways
- Adjusted r^2
  - 0.18 for freeways
  - 0.37 for arterials

Reliability Implementation

Original VDF Model Form

Uncongested Signal Delay

$$T_f = T_0 * \left[1 + \alpha_l * \left(\frac{V}{C_s}\right)^{\beta_l}\right] + P * \frac{c}{2} * \left(1 - \frac{g}{c}\right)^2 * \left[1 + \alpha_i * \left(\frac{V}{C_i}\right)^{\beta_i}\right]$$

Mid-link BPR function

Intersection congestion adjustment

$$C_i = S * \frac{g}{c}$$

Modified VDF Model Form

$$T_{f+r} = T_f + T_f * \left[\sum_{t=1,n} \left(\gamma_t * \frac{v}{c} - t + 0.01\right) + R\right]$$

Where:

T_{f+r} = Travel time with (un)reliability

T_f = Travel time without (un)reliability

t = v/c thresholds (C, D, E, F-low, F-high)

γ_t = Coefficients for v\c thresholds

R = non-v\c link (un) reliability

C04 Highway Utility Function (implemented)

$$Utility_{ij} =$$
$$\alpha \times Time_{ij} + \beta \times \left[Cost_{ij} / \left(I^{e} \times O^{f}\right)\right] + \gamma \times \frac{STD}{Distance_{ij}} + \delta$$

where:

α *is a log-normally distributed random parameter representing unobserved user heterogeneity with respect to travel time sensitivity*
β *is the travel cost coefficient*
γ *is the reliability coefficient*
δ *is an alternative-specific constant for toll usage*

I^{e} *captures the effect of income (I) on travel cost sensitivity*
O^{f} *captures the effect of auto occupancy on travel cost sensitivity*
STD/Distance is the standard deviation of travel time per mile

Conclusions

- Active area of research
- Several approaches, consider:
  - Model type:
    micro/meso/macro simulation?
  - Study area
    small enough for path-based assignment?
  - Study objectives
    T&R or just traffic?

References

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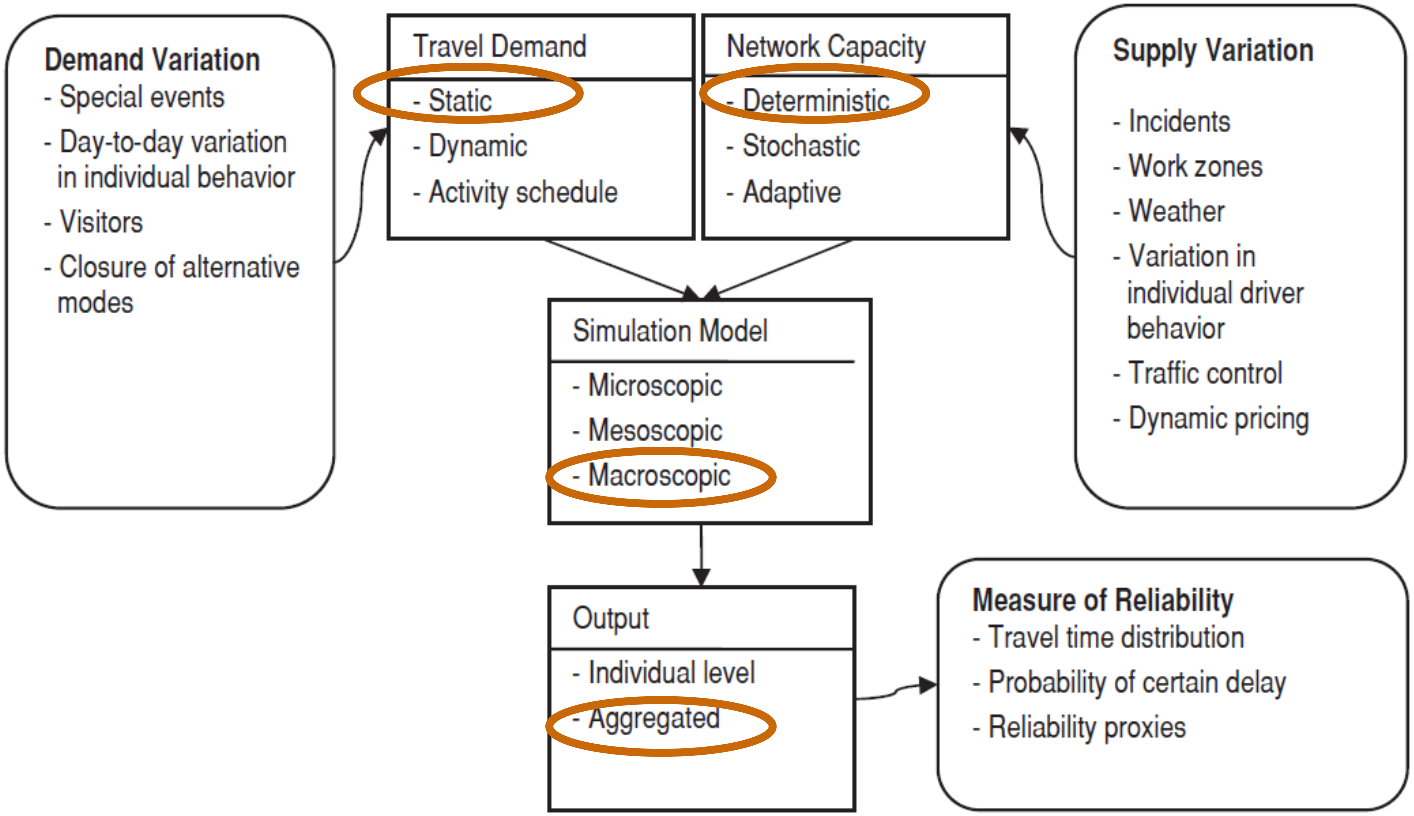
Reliability Measures by Analysis Level

		Analysis Level		
		Network	**O–D**	**Path/Segment/Link**
Characteristic	**Travel times for vehicles**	Not comparable	Comparable	Comparable
	Travel distances for vehicles	Different	Different	Identical
Applicable measures	**Distance-normalized measures** (Type A)	• **Average of travel times per mile (TTPMs)** • **Standard deviation of TTPMs** • **95th/90th/80th percentile TTPM**		
	Measures for comparable travel times (Type B)		• **Average travel time** • **Standard deviation of travel times** • **Coefficient of variation** *Standard deviation of travel times/mean travel time* • **95th/90th/80th percentile travel time** • **Buffer Index** *(95th percentile travel time – mean travel time)/(mean travel time)* • **Skew Index** *(90th percentile travel time – median travel time)/(median travel time – 10th percentile travel time)* • **Percent on-time arrival** *Percent of travel times < 1.1 median travel time*	
	Measures for the same travel distance (Type C)			• **TTI (Travel Time Index)** *Mean travel time/free-flow travel time* • **PTI (Planning Time Index)** *95th percentile travel time/free-flow travel time* • **Misery Index** *Mean of the highest 5% of travel times/free-flow travel time* • **Frequency of congestion** *Percent of travel times > 2 free-flow travel time*

Source: (Mahmassani, et. al, 2014)

Modeling Overview

OVERVIEW



Source: (Mahmassani, et. al, 2014)

Shift Variables