On the Variance of Recurrent Traffic Flow for Statistical Traffic Assignment

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Abstract

Motivation:

The origin-destination (OD) demand is a critical input to system modeling in transportation planning and management. For decades, OD demand is deterministically modeled as it's translated into deterministic link/path flow and travel cost. Recent studies on transportation network uncertainty and reliability call for modeling the stochasticity of OD demand, namely its spatio-temporal correlation and variation.

Objectives:

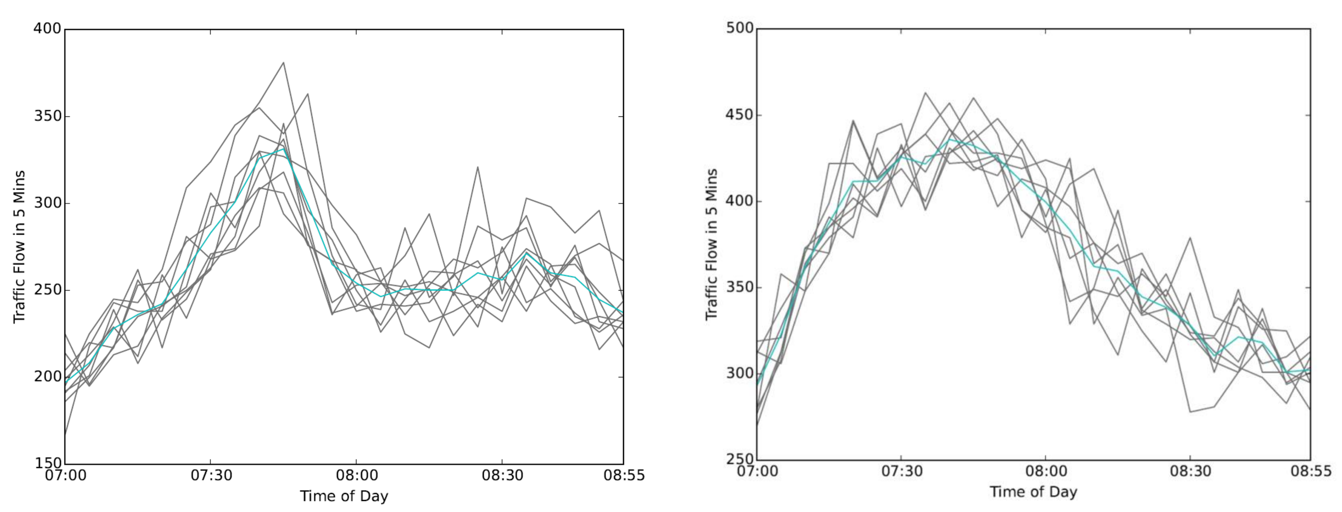
Build statistical relationship between traffic demand and network conditions (link/path flow, travel time).

Background

❑Classical traffic assignment and OD estimation methods only model the averaged condition of the traffic condition.

$$\phi: q \mapsto x, f$$

❑Real world traffic data are coupled with temporal-spatio noise.



Daily time-varying traffic counts on SR41 SB and NB

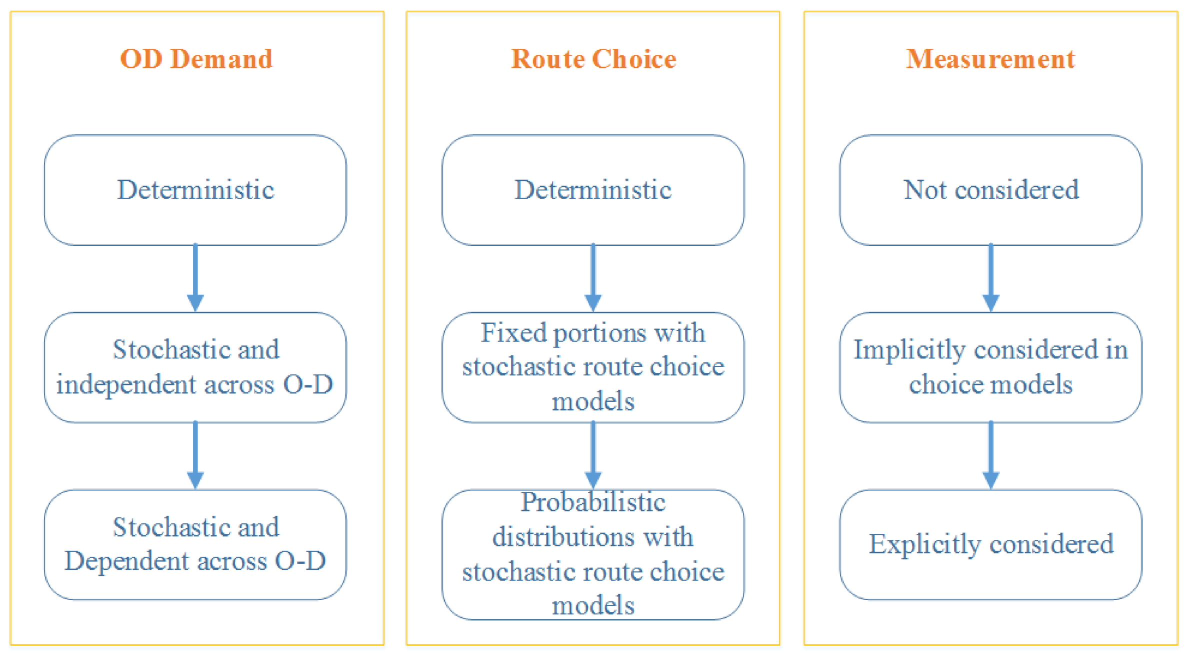
(Blue curve is the daily average. Each grey curve represents one day in May 2015)

❑Statistical traffic assignment explores the statistical features of recurrent flow patterns.

$$\phi: Q \mapsto X, F$$

❑Day to day traffic flow contains multidimensional variations.

Day-to-day flow variations



❑Traffic data include road flow, travel speed and history OD (with noise).

Model detail

OD demand

- OD demands is represented by Q_{rs}
- OD demands follow a rounded multivariate normal (MVN) distribution.

$$Q \sim N(q, \Sigma_q)$$

Individual route choice probability

- Travelers select their route by a generalized route choice model.

$$p = \Psi(c, \Sigma_c)$$

- If Random Utility Model (RUM) is used, the route choice can be represented by

$$p_{rs,k} = \Pr[C_{rs,k} \leq \min_{i \neq k} C_{rs,i}]$$

Path flow

- Each traveler independently makes identically distributed route choices on every day, which follows a multinomial distribution.

$$F_{rs}|Q_{rs} \sim MN(Q_{rs}, p_{rs})$$

- A norm approximation is adopted to find the analytical solution.

$$F_{rs}|Q_{rs} \sim N(Q_{rs}, p_{rs})$$

Link flow and cost

- Link flow is a linear transformation from the path flow.
- Link cost is a defined as a continuous function, and can be approximated by Taylor expansion.

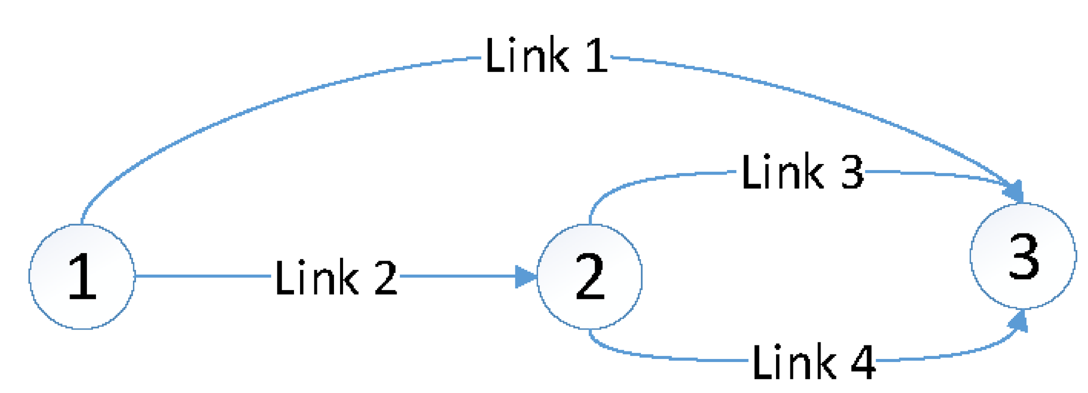
Multilevel structure

Level 1:	$X_m \sim N(X + e, \Sigma_x + \Sigma_e)$	Measurement error
Level 2:	$X \sim N(\Delta p Q, \Sigma_x)$ $F \sim N(pQ, \Sigma_f)$	Route choice variation
Level 3:	$Q \sim N(q, \Sigma_q)$	OD variation

Experiment results

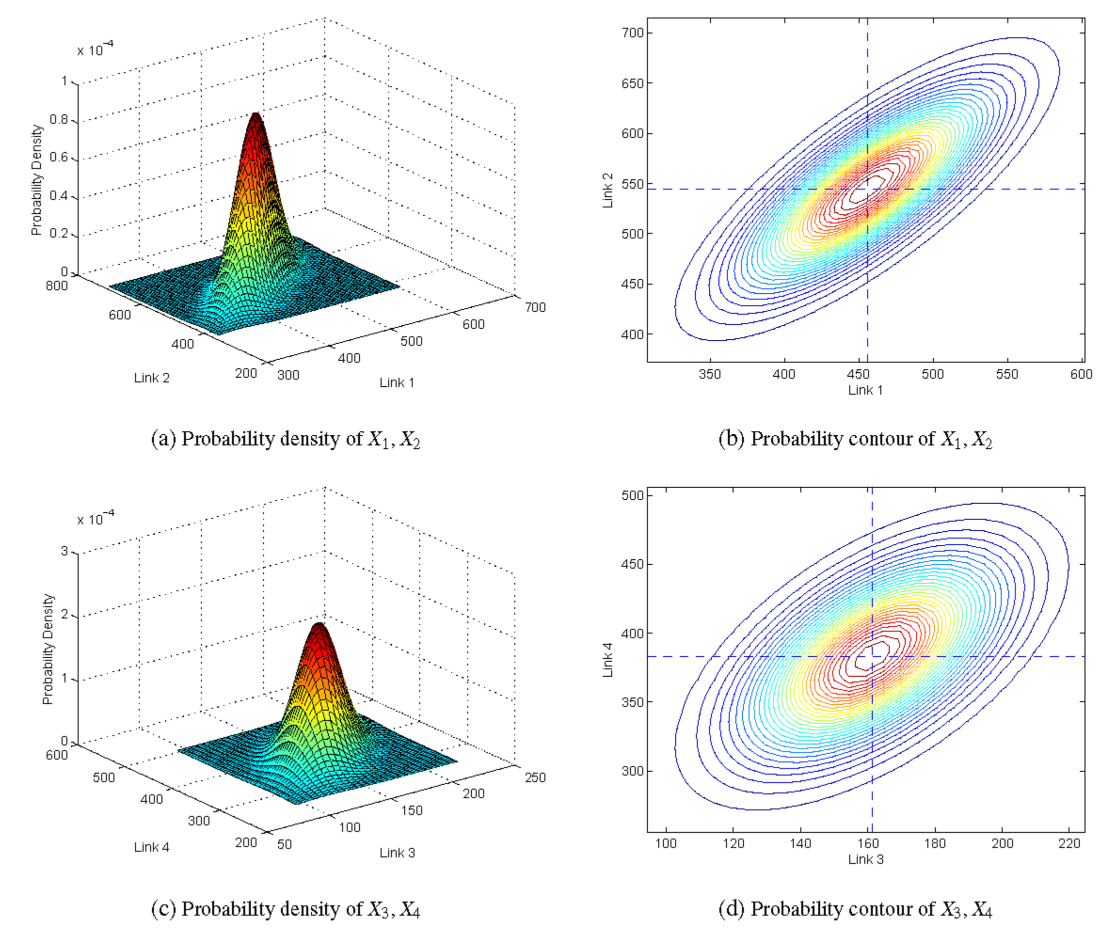
- We perform the GESTA on a small network as follows, the analytical properties of link/path flows, travel costs can be derived.

Small network: 3-path network



- BPR link travel time function is adopted, q = 1000, $\sigma_{OD}{}^2$ = 10000, $\sigma_e{}^2$ = 100, cap_a = 360

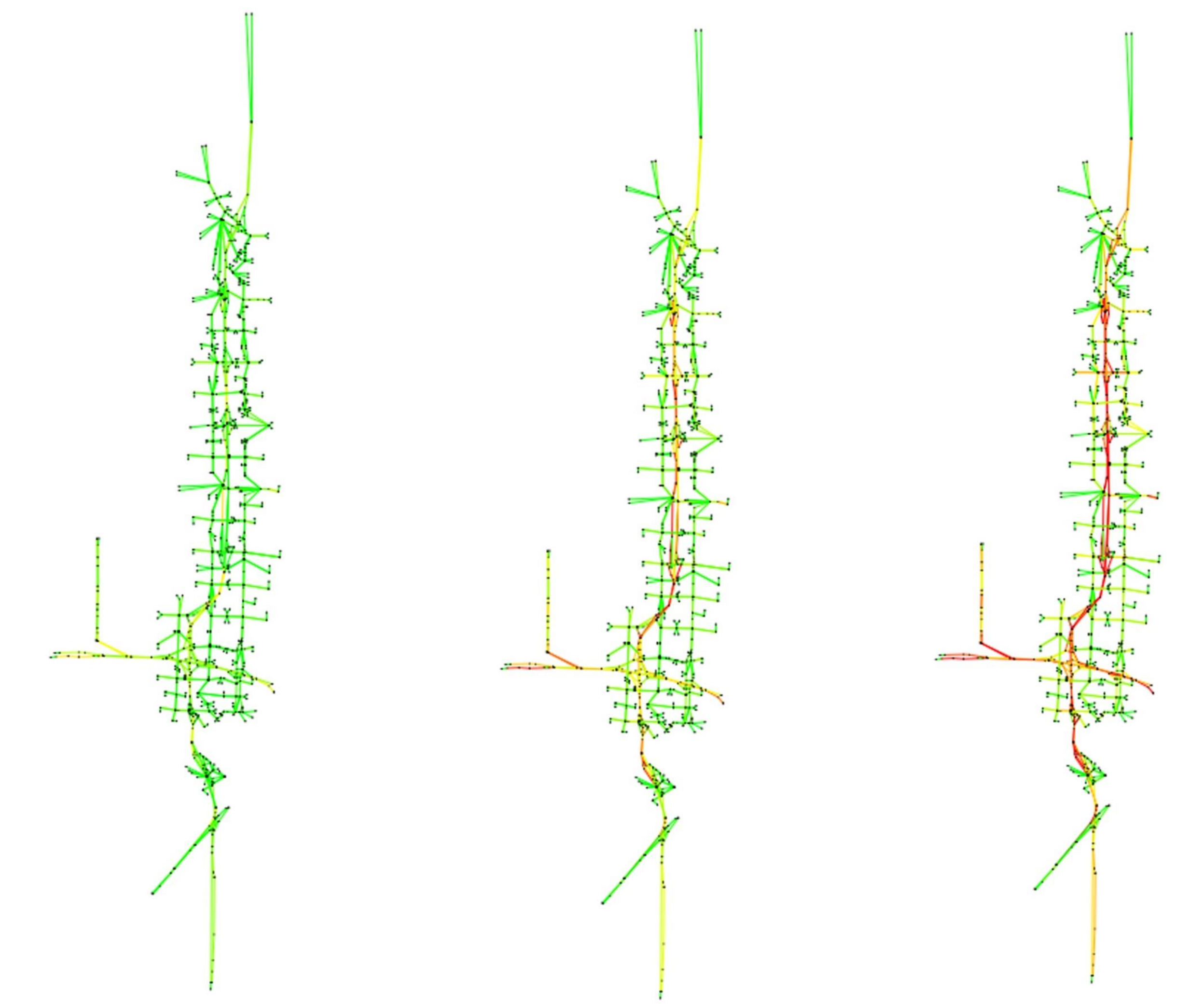
- The following figures are the probability density and contour of X_1 and X_2, X_3 and X_4. The contours can also be interpreted as confidence intervals under different confidence levels.



- Comparison with classical assignment models

Links	GESTA	Logit-SUE, $\Theta = 0.1$	Logit-SUE, $\Theta = 0.01$	UE
Link 1	$\mathcal{N}(455.6, 49.2^2)$	422.3	360.1	410.4
Link 2	$\mathcal{N}(544.4, 57.5^2)$	577.7	639.9	589.6
Link 3	$\mathcal{N}(161.4, 22.3^2)$	263.8	316.5	132.6
Link 4	$\mathcal{N}(383.0, 42.5^2)$	313.9	323.4	457.0

Large network: SR41 corridor



The 5%, 50% and 95% quantiles link flows

(Using Rectangle CI approximation. Red represents volume/capacity 1, and green represents volume/capacity=0, other colors are smoothly transitioned from green to red as volume/capacity increases from 0 to 1)