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Modeling Variability as "Expected Lateness"

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Outline

1. *Motivation/Research Questions*
   - *A Specific Problem Setting*
2. *Modeling Framework*
   - *Basing our model on scheduling theory*
3. *Brief Look at Some Data*
   - *A challenge to model consistently*
4. *Estimated Model for "Expected Lateness"*
   - *Significant, but Low Explanatory Power*
5. *Assessment, Limitations, Future Work*

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Motivation

- Transport investments & policies affect average travel times, **and** variations in travel times
  - Reliability improvements might be **worth** 10-15% that of travel time savings
- Suggests different kinds of policies, e.g. incident management, traveler information
- What is the trade-off from users' perspective?
- How can we use this in Benefit-Cost Analysis?

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How to answer these questions?

- *Need forecasts of the effects of policies on travel time distributions (supply side)*
  - *Or at least, the important features of variation*
- *How much are reliability improvements worth? (demand side)*
  - *Or, what are the important preference paremeters?*
- *My focus:*
  - ***Can we predict "mean lateness"*** *(which seems to be important from a scheduling perspective)****, and use it for benefits assessments?***

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Problem Setting

- We Have:
  - User Preferences (vis-a-vis the Scheduling Model)
  - Observations of Today's Travel Time Distributions
  - Model Predictions of Travel Times, etc., for Future Scenarios
- We Want:
  - Value of Reliability Benefits (or losses) in Future Scenarios
  - *Relative* Valuations for Different Policy Alternatives
- We'll Need:
  - Estimates of **mean lateness** for Future Scenarios

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Problem Setting

- Estimating Reliability Measures for Future Scenarios
  – **Standard Deviation** (e.g. *Eliasson, 2006; other examples*): statistical model (log-log) on (mean time / freeflow time), scaled by link length, queuing phase, and speed limit.
  – **Expected Lateness** (*this work*): similar form to Eliasson's model

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Modeling Framework: Two Approaches

1) Variability as Standard Deviation

$$U = \underbrace{\gamma C}_{\text{Cost}} + \underbrace{\omega \mu}_{\text{Mean Time}} + \underbrace{\rho \sigma}_{\text{Std. Dev. Time}}$$

- Uses Observable (and Predictable) Data
- No Behavioral Theory behind Preferences

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Modeling Framework

2) Variability as Earliness and Lateness
(Noland & Small, 1995)

$$U(t_h) = \underbrace{\gamma C}_{\text{Cost}} + \underbrace{\omega \mu}_{\text{Mean Time}} + \underbrace{\lambda SDE}_{\textbf{Early Delay}} + \underbrace{\delta SDL}_{\textbf{Late Delay}} + \underbrace{\theta I[\text{Late}]}_{\text{Indicator of Being Late}}$$

- Strong for Identifying Preferences
- Not trivial to predict "delay" statistics

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Modeling Framework

Unified Approach

- Take travel time $T = \mu + \sigma X,\ X \sim \Phi(0,1)$, in std. time
- *Noland & Small, 1995:* For specific travel time distributions, one can relate the lateness parameter (ν) to std. dev. (σ): $\nu * H * \sigma$
- *Fosgerau & Karlström, 2009:* For *any* distribution, can compute *H:*
  - Take travelers' departure time to be optimal, given travel time distribution and early/late preferences
  - *H* is actually the (standardized) expected lateness, among late arrivals

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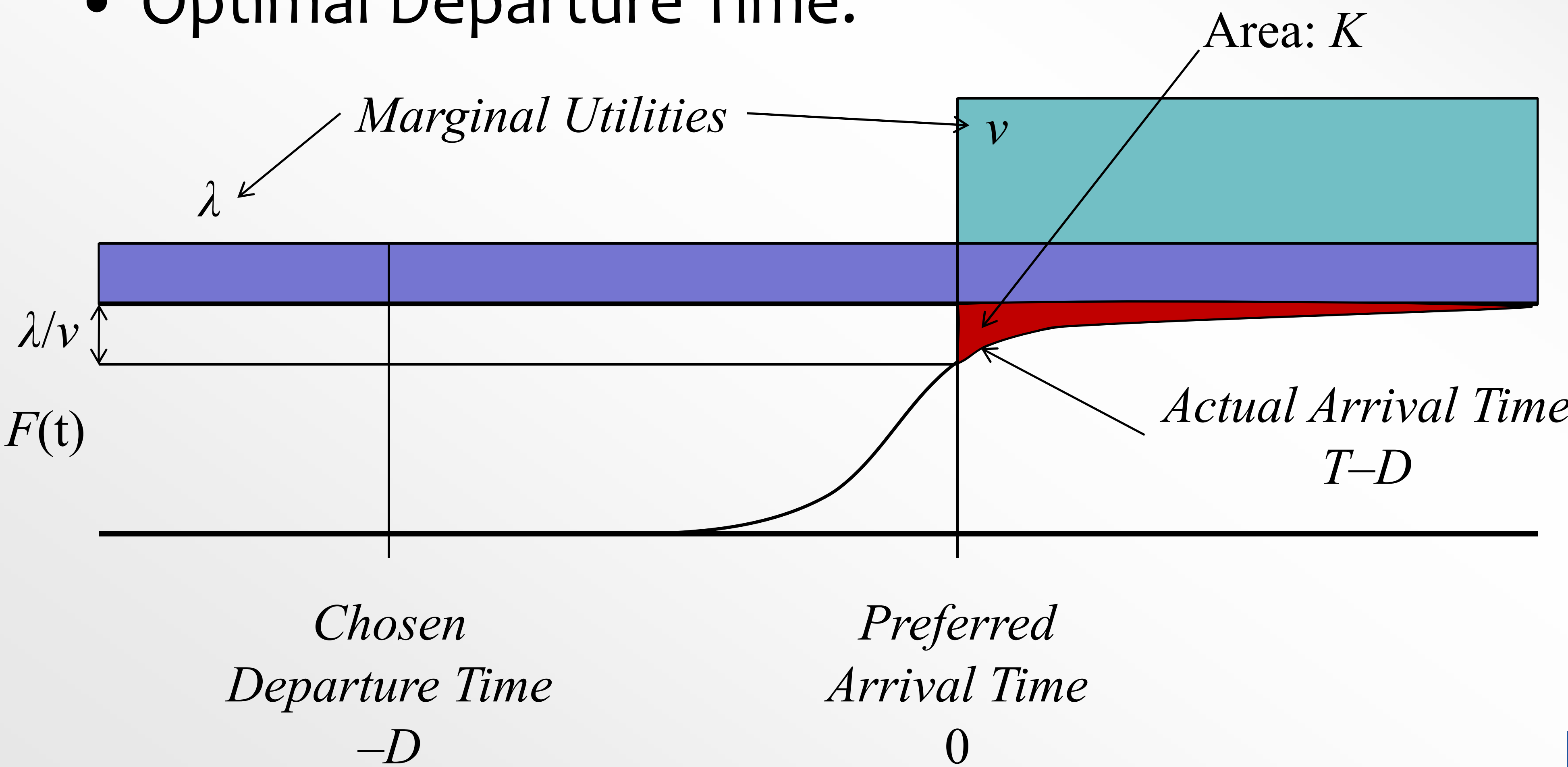
Modeling Framework
(Fosgerau & Karlström, slightly modified)

- Optimal Departure Time:



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Modeling Framework

- Take $T = \mu + X$, $X \sim F(0,\sigma)$, in *real* time units
- Utility can be expressed:

$$E(U) = \underbrace{(\lambda + \omega)}_{\text{Value of Time}}\mu + \underbrace{\nu K\left(\frac{\lambda}{\nu}, F\right)}_{\text{Value of Reliability}}$$

- Where ***K*** ("expected lateness" in *minutes*) is:

$$K\left(\frac{\lambda}{\nu}, F\right) \equiv \int_{1-\frac{\lambda}{\nu}}^{1} F^{-1}(x)\,dx = H\sigma$$

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Data

- Automatic License-Plate Matching
- 92 (One-Way) Roadway Segments in Stockholm
- Three Autumns, 2005-2007, Morning Peak
- Extensive filtering for "strange" data
  - Idiosyncratic driver behavior
  - Equipment failures
  - Major changes in roadway conditions
  - Narrowed to 58 Segments

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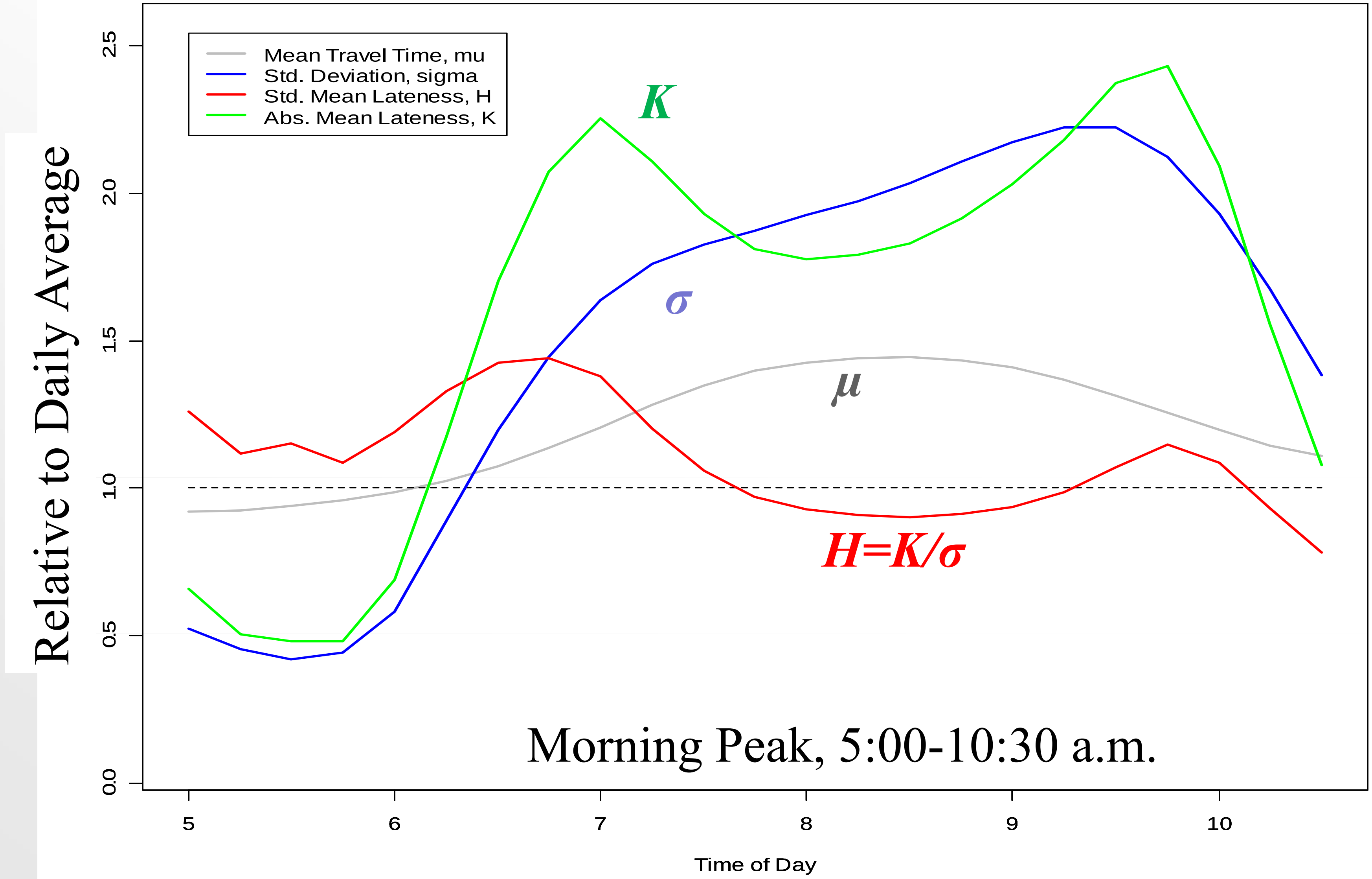
Example: Klarastrandsleden



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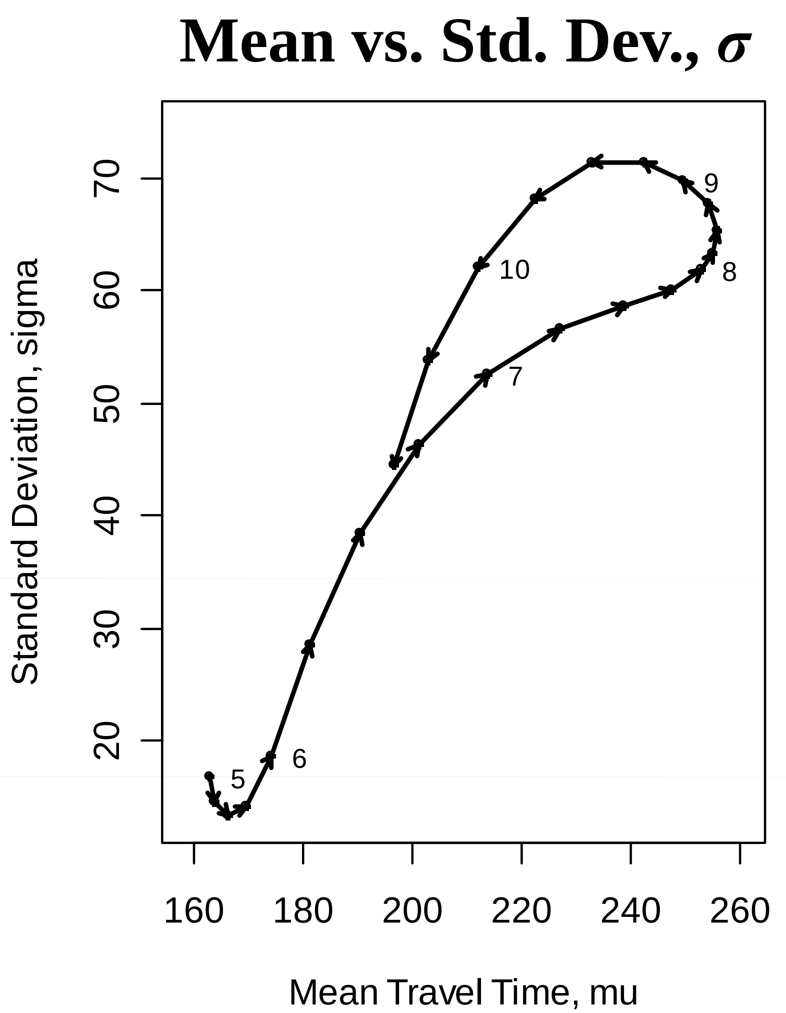
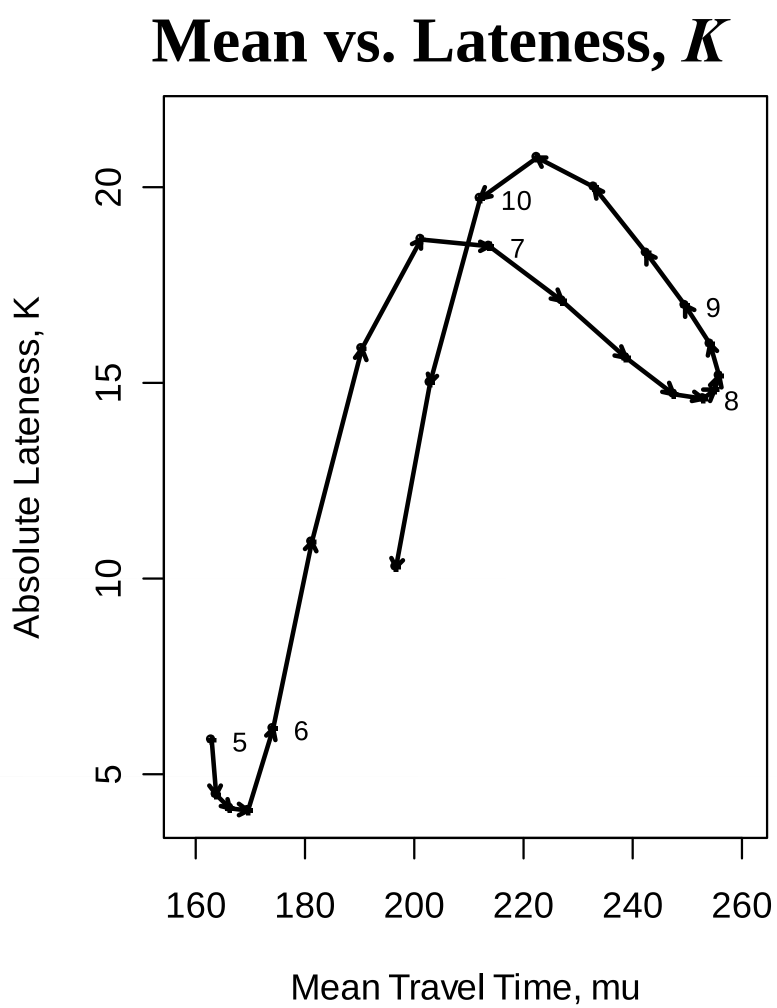
Example: Klarastrandsleden





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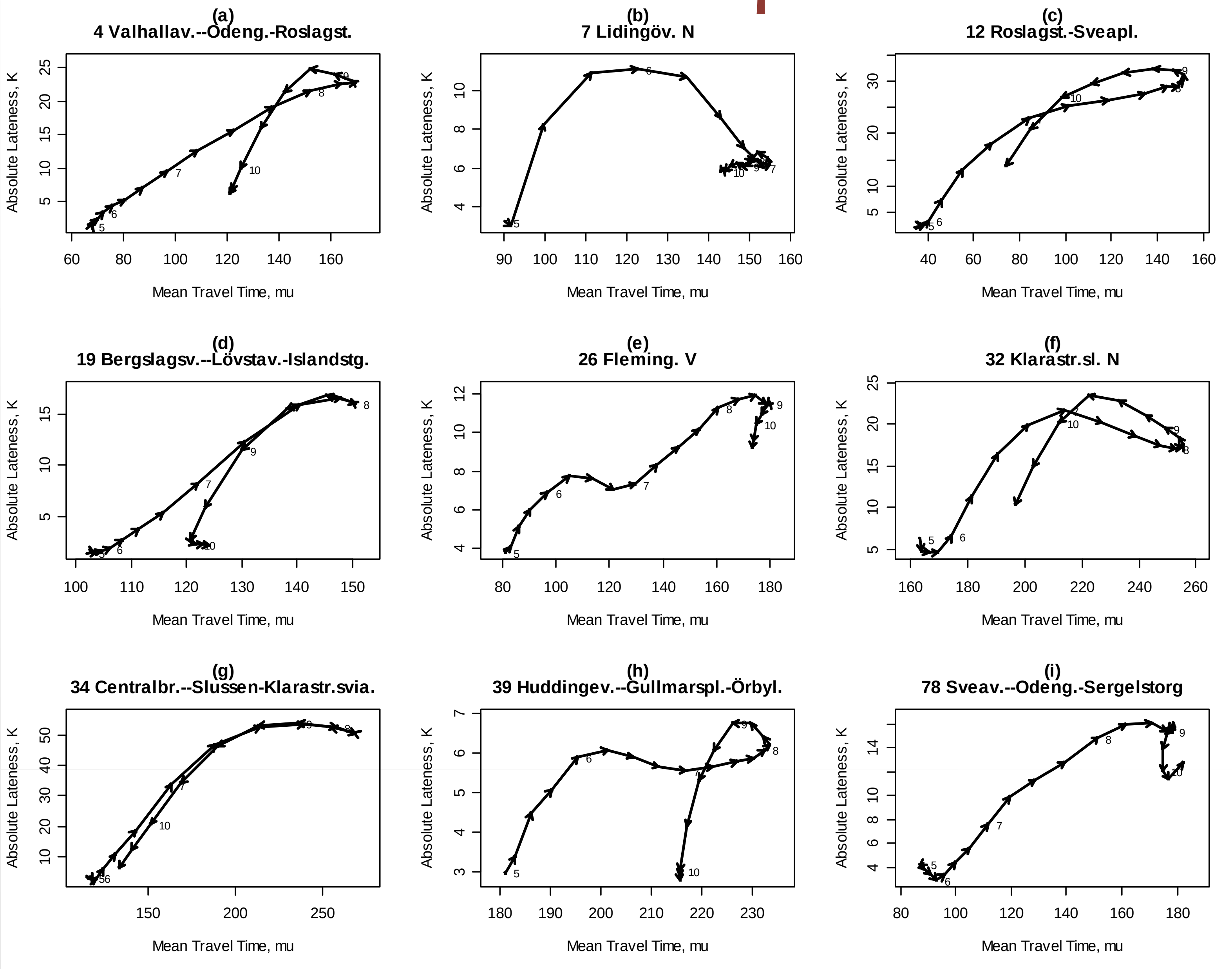
Nine Examples



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Model Specification

- Estimate a regression model that predicts "expected lateness"
- Model form *log-log*:

$$\log\left(\frac{\text{Lateness}}{\text{Freeflow Time}}\right)=\log\left(\frac{\text{Mean Time}}{\text{Freeflow Time}}\right)+\log^2\left(\frac{\text{Mean Time}}{\text{Freeflow Time}}\right)$$
$$+\left(\text{Link Attributes}\right)+\left(\text{Interactions}\right)+\varepsilon$$

- Link Attributes:
  - length, freeflow speed, location indicator
- Basic strategy: fit polynomials, scaled to link characteristics

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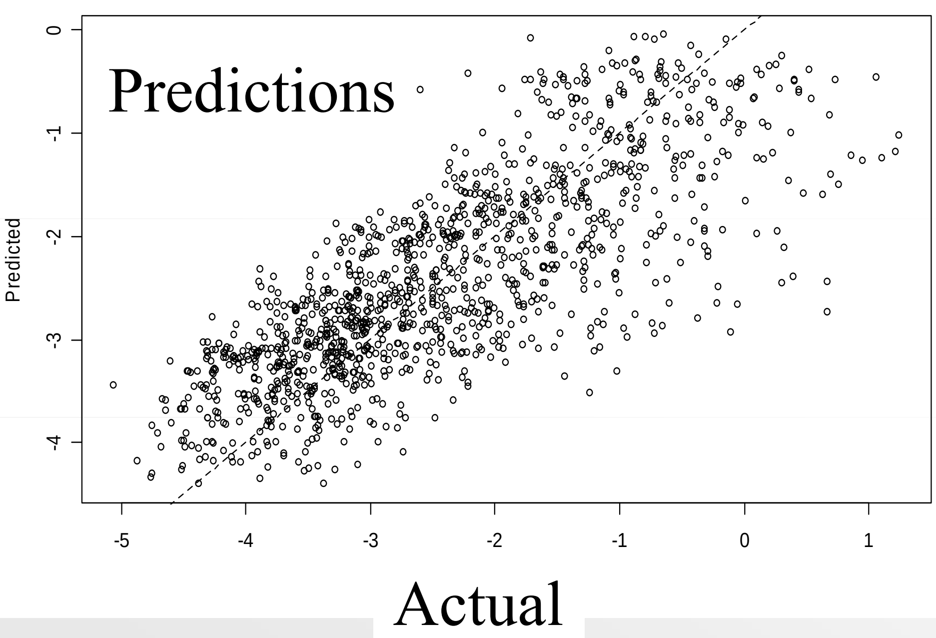
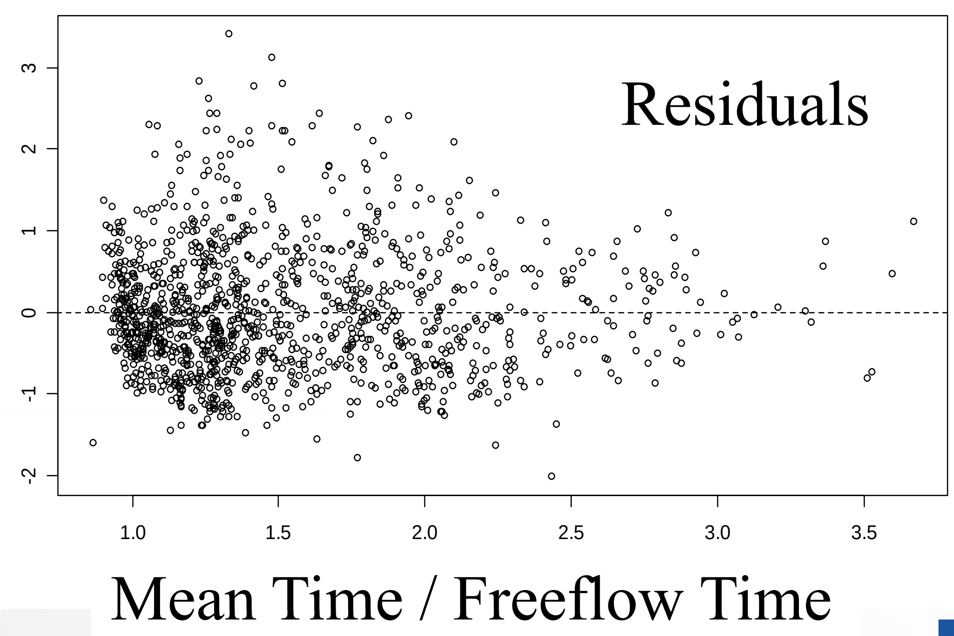
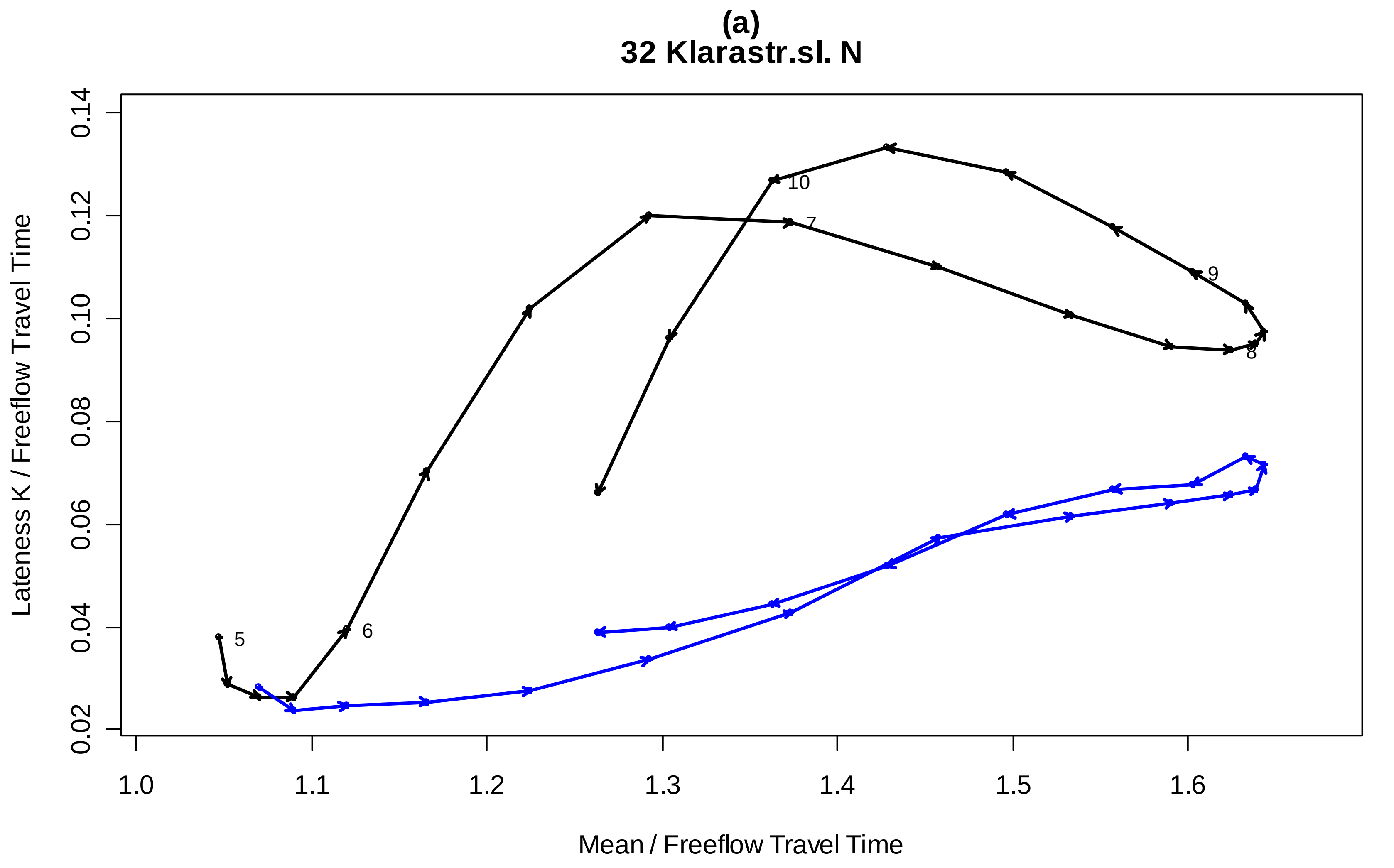
Estimated Model of Lateness Performance Statistics

Model	Para-meters	d.f.	R2	Adj. R2	F Value
Direct Statistics	10	1206	0.610	0.606	189.8*
(measured for K)	10	1206	0.175	0.168	25.07*

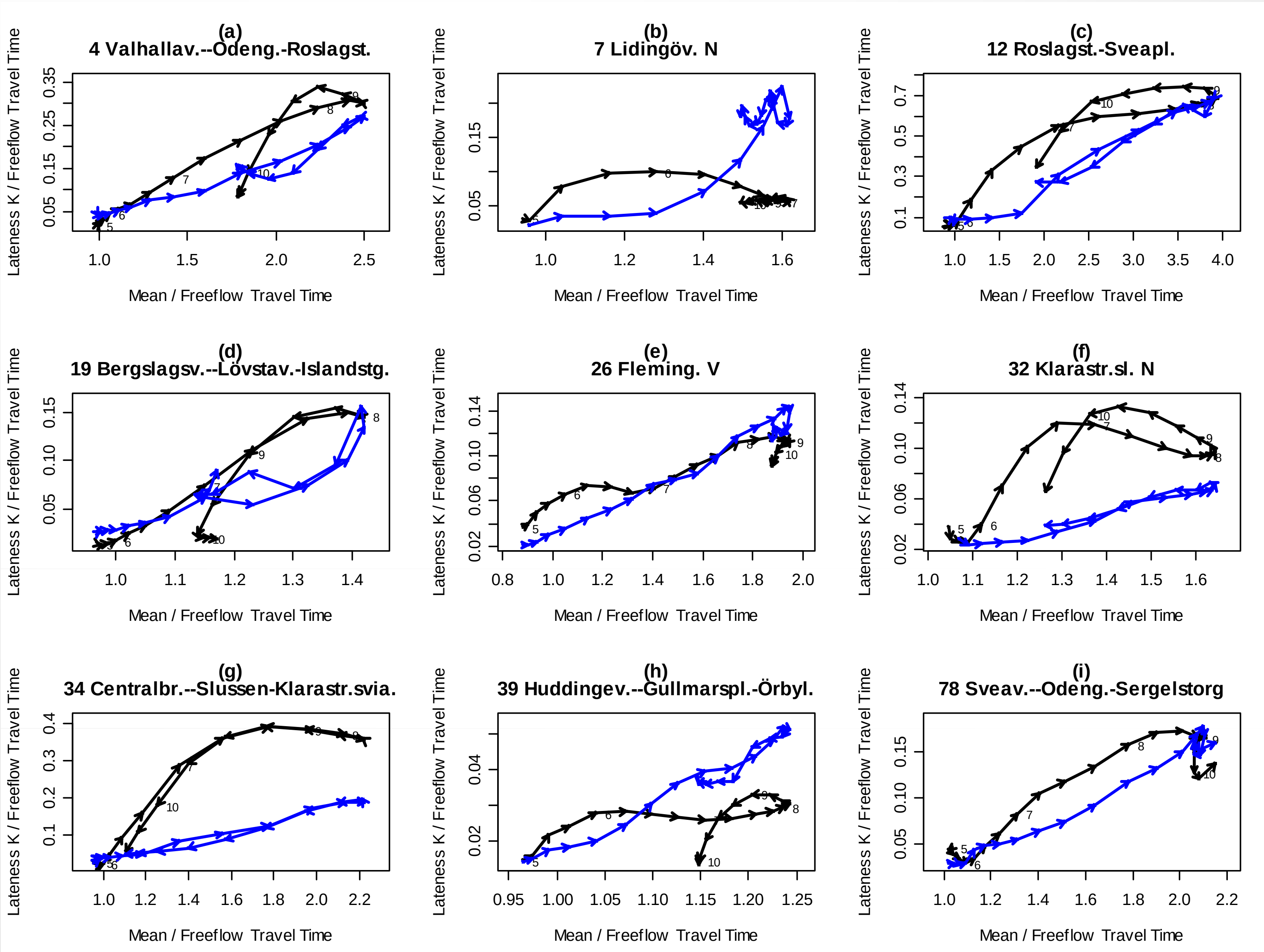




Predictions: Klarastrandsleden



Predictions for Nine Examples



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Conclusions/Main Points

- The missing component of a schedule-based approach to reliability, “expected lateness”, *can* be modeled with some significance and partial qualitative matches…
- … but *not yet* with sufficient explanatory power for benefits assessments.
- Further Refinements:
  - Phase of Queue Buildup/Dissipation
  - Periodic *Change* in Mean Travel Time
  - Controls for Serial Correlation

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Two Looming Issues

- Sequential Links:
  - Readily-available data is for short roadway segments…
  - … while scheduling theory is based on full Origin-Destination paths
- Assumption of Static Distribution:
  - Individuals optimize departure time *as if* the travel time distribution were constant…
  - … while the analysis setting here concerns a changing distribution over time

Future Directions

- Model the *causes* of travel time variation, rather than modeling variation *per se*
  - Travel times as emerging from a queuing model
  - Distinction between *supply* versus *demand* variations
- Origin-Destination travel time distributions
  - Challenge for data collection & modeling

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Questions to…

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