Travel Time Estimation for Traffic Management and Traveler Information

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Objectives

- Travel time visualizations
- Travel time fundamentals
- Previous research
- Framework for sensor spacing
- Analytical tool for sensor spacing
- Future research
- Seminar perspectives
What Can I Do With Travel Time?

- Travel time is fundamental
- Can be used to generate other things
- Travel time is multimodal
What Can I Do With Travel Time?

- Measure it
- Guess it
- Report it
- Predict it
- Forecast it
If I Get It Wrong?

- Annoy travelers
- Destroy confidence in system
- Increase congestion
- Worsen safety
- Damage air quality
- Increase fuel consumption
How Can I Affect Travel Time?

- Increase/decrease mean value
- Increase/decrease variability
- Affect comparison between modes
“Prediction is very difficult, especially about the future.”

—Niels Bohr
London Underground
London Underground

Time Travel from Elephant & Castle
2004 Tsunami

Travel Time Estimation for Traffic Management and Traveler Information

Wave Travel Time (hours)

0 - 17
Runoff Travel Time
Fire Station Response Time

Current Fire Station
Response Time from 412 E. 4th Street
Train journey times from Cambridge
Travel time difference train vs. car from Cambridge
Fundamentals

Distance

Travel Time

Time

Slope = Speed
Fundamentals

Travel Time Estimation for Traffic Management and Traveler Information

Distance

Free Flow Travel Time

Actual – Free Flow = Delay

Actual Travel Time

Time
Fundamentals – One Detector

Distance vs. Time

Travel Time

Travel Time Estimation for Traffic Management and Traveler Information
Midpoint Method

- Influence Area 4
  - Travel Time 4 (at t = 0)

- Influence Area 3
  - Travel Time 3 (at t = 0)

- Influence Area 2
  - Travel Time 2 (at t = 0)

- Influence Area 1
  - Travel Time 1

Link Travel Time (TT1 + TT2 + TT3 + TT4)
Fundamentals – Two Detectors

Travel Time Estimation for Traffic Management and Traveler Information
Measurement Parameters

- **Fixed Locations**
  - Stop Watch Method
  - Detectors (any kind)
  - RF Toll Tags
  - RF “Sign Posts”
  - Video Image (license plate)
  - Volume Based

- **Fixed Times**
  - GPS + Wireless Communication
  - Cellular Phone
Measurement: Fixed Locations

Distance

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1$</td>
<td></td>
</tr>
<tr>
<td>$x_2$</td>
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</tbody>
</table>
### Measurement: Fixed Locations

<table>
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<tbody>
<tr>
<td>$x_1$</td>
<td>$t_1$</td>
</tr>
<tr>
<td>$x_2$</td>
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</table>

Distance vs. Time

**Travel Time Estimation for Traffic Management and Traveler Information**
### Measurement: Fixed Locations

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Measurement: Fixed Times

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
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<tbody>
<tr>
<td>$t_1$</td>
<td>$x_1$</td>
</tr>
<tr>
<td>$t_2$</td>
<td></td>
</tr>
<tr>
<td>$t_3$</td>
<td></td>
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<tr>
<td>$t_4$</td>
<td></td>
</tr>
<tr>
<td>$t_5$</td>
<td></td>
</tr>
</tbody>
</table>

Distance: $x_1$  Time: $t_1$, $t_2$, $t_3$, $t_4$, $t_5$
Measurement: Fixed Times

<table>
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Distance

Time
Measurement: Fixed Times

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<td>$x_3$</td>
</tr>
<tr>
<td>$t_4$</td>
<td>$x_4$</td>
</tr>
<tr>
<td>$t_5$</td>
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</table>
Use Counts (TTI Method)
Use Counts (TTI Method)
Similar Idea Using Granular Data

![Graph showing the relationship between speed and flow (vph)](image-url)

- X-axis: Flow (vph)
- Y-axis: Speed (mph)

The graph illustrates the flow-speed relationship, with data points distributed across the graph. The trend line indicates the general trend observed in the data.
WSDOT Travel Times

Reliable Travel Times

**WSDOT - 95% Reliable Travel Times**

Where are you starting from?

Where are you going?

What time do you need to get there?

Submit

---

Your 95% Reliable Travel Time is **24 minutes**.
95% of the time you would need to leave at **7:36 AM** to arrive by **8:00 AM**.
Data Collection Was Difficult

Data Collection
Greenshields, et al., 1947

Speedometer
Greenshields, et al., 1957
Travel Time Estimation for Traffic Management and Traveler Information

Previous Research: LAFSP

AM PEAK (6:30 - 9:30) & PM PEAK (3:30 - 6:30)
32 Weekdays (June 24 to August 9, 1996) • 192 Hours

INCIDENTS
Field Logs
1560 Incidents

TACH VEHICLES
5.7 Minute Headways
3619 Runs

LOOP DETECTORS
48 Stations - 170 Controllers
240 Loops

ADDITIONAL DATA
FSP Scantrons • CHP CAD • Tow Companies • Video • Caltrans District 7

Probe travel time: 07/11/96, AM (7 cars)

Start of travel time
6 Cameras/3 Sites (1 per direction)
- US 101 north of Lincoln City
- OR-18 near Otis
- OR-18 near Grand Ronde
Mean speed = 51 mph
Previous Research: ODOT VMS I

- 15 directional freeway links
- 87 probe runs
- 516 miles/12 drivers
- 15 hours of data collected
Previous Research: ODOT VMS I

Travel Time Estimation for Traffic Management and Traveler Information

- Coifman (u/s)
- Coifman (d/s)
- Midpoint
- Coifman - Midpoint
- Coifman - Distwt
- Midpoint - Average

Probe Travel Time (min) vs. Estimated Travel Time (min)
Previous Research: ODOT VMS I
Previous Research: ODOT VMS I

- Coifman (u/s)
- Coifman (d/s)
- Midpoint
- Coifman - Midpoint
- Coifman - Distwt

Travel Time Estimation for Traffic Management and Traveler Information
Travel Time Estimation for Traffic Management and Traveler Information

- Data quality
- Congestion
- 300 ground truth runs on I-5 and OR 217
- Other algorithms
- Average error ~5-7%
- Need for more detection, but where?
Motivation

- Ongoing efforts to improve freeway travel time estimates
- Display travel time ranges for key corridors
- Desire to provide additional detection
- Need for “optimal” decision-making aid
Portland ATMS

- Freeway Surveillance
  - 502 inductive loop detectors
  - ~175 stations
    - Dual loop (act as single loop)
    - 1.2 mile average spacing
    - Upstream of on-ramps
  - 135 ramp meters
  - 98 CCTV
- ATIS
  - www.TripCheck.com
    - Real-time speed map
    - Static CCTV images
  - 18 dynamic message signs (DMS)
    - 3 display travel times
Freeway Detector Locations
Portland Speed/Travel Time Info

Travel Time Estimation for Traffic Management and Traveler Information

Updated: 4/03/2008 1:54 PM
Bus/Arterial Speeds
Hypothetical $x$-$t$ Plane

- **Extrapolated Travel Time**
- **Actual Travel Time**
- **Free Flow Travel Time**
- **Delay**
- **Over-prediction**

- **Free Flow Speed**
- **Measured Speed**
- **Extrapolated Speed**

- $x = \text{Segment Length}$
- $t_1 = \text{Time Interval}$
- $\ell = \text{Segment Length}$
Freeway Corridor Example

Travel Time Estimation for Traffic Management and Traveler Information

Northbound I-5

VMS
305.67 Columbia
302.22 Rose Qtr.
298.48 Iowa
291.00 Carman
285.26 Wilsonville

02/08/07
02/08/07

Northbound I-5
Traffic Flow Relation and Dynamics

Aassumptions:

- 1 mile segment
- \( s \sim 0.1-1.0 \) mile
- \( q_A = 2000 \) vph
- \( q_C = 1800 \) vph
- \( v_f = 60 \) mph
- \( v_c = 30 \) mph
- \( v_{CD} = -17.1 \) mph
- \( v_{AC} = -7.5 \) mph
Travel Time Estimation for Traffic Management and Traveler Information

Flow (veh/hr)

Density (veh/mi)

$q_A = 2000$
$q_C = 1800$
$v_f = 60$
$v_c = 30$
$v_{CD} = -17.1$
Travel Time Estimation for Traffic Management and Traveler Information

Real data
I-5 Macadam 2/8/07
Types of Transitions

Frontal stationary

Backward recovery

Forward forming

Backward forming

Rear stationary

Travel Time Estimation for Traffic Management and Traveler Information
Types of Transitions

- Frontal stationary
- Backward recovery
- Forward forming
- Backward forming
- Rear stationary

Travel Time Estimation for Traffic Management and Traveler Information
Travel Time Estimation for Traffic Management and Traveler Information

Estimation When Homogeneous

\[ d = \frac{l}{v_f} \]

\[ t_{tf} = \frac{l}{v_f} \]

\[ t_{tc} = \frac{l}{v_c} \]

A, D, DA: uncongested

C: congested

VHT Actual = VHT Estimated
Types of Transitions

- Frontal stationary
- Backward recovery
- Forward forming
- Backward forming
- Rear stationary

Travel Time Estimation for Traffic Management and Traveler Information
Types of Transitions

- Frontal stationary
- Backward recovery
- Forward forming
- Rear stationary
- Backward forming
- Forward recovery
Types of Transitions

- Frontal stationary
- Forward forming
- Backward forming
- Rear stationary
- Forward recovery
- Backward recovery
Traffic Flow Relation and Dynamics
Transition Uncongested \rightarrow \text{Congested}

\[ v_c \]

\[ \alpha = \text{Lag Time} \]

\[ t_c \]

\[ u_{\text{max}} \]

\[ t_{tf} \]

\[ z \]

Shock

\[ s \]

\[ \ell \]
Transition Uncongested → Congested

$\ell$ s

$t_{tf}$

$\alpha = \text{Lag Time}$

$t_c$ Congestion Signal

Shock

$\alpha = \text{Lag Time}$
Transition Uncongested → Congested

\[ \alpha = \text{Lag Time} \]

\[ t_c \text{ Congestion Signal} \]

\[ vv_{AC} \]

\[ vv_f \]

\[ tt_f \]

\[ u_{max} \]

\[ zz \]

\[ jj_1 \]

\[ jj_2 \]

\[ jj_3 \]

\[ \ell \]

\[ s \]
Transition Uncongested → Congested

\[ \alpha = \text{Lag Time} \]

\[ t_c \quad \text{Congestion Signal} \]

\[ t_f \]

\[ \ell \quad s \]

\[ x \]

\[ j_1 \]

\[ j_2 \]

\[ j_3 \]

\[ v_f \]

\[ v_{AC} \]

\[ v_c \]

\[ u_{max} \]

\[ \text{Shock} \]
Transition Uncongested → Congested

\[ t \]

\[ x \]

\[ j_1 \]

\[ j_2 \]

\[ j_3 \]

\[ \ell \]

\[ s \]

\[ v_f \]

\[ v_{AC} \]

\[ \alpha = \text{Lag Time} \]

\[ t_c \]

\[ t_{tf} \]

\[ u_{max} \]

\[ \text{Congestion Signal} \]

\[ \text{Shock} \]

\[ v_c \]
Transition Uncongested → Congested
Transition Uncongested $\rightarrow$ Congested

![Graph showing transition from uncongested to congested travel time estimation](image-url)

- **Predicted VHT**
- **Actual VHT**

**Axes:**
- **X-axis:** Sensor Spacing (miles)
- **Y-axis:** VHT

**Legend:**
- Portland State University

**Title:** Travel Time Estimation for Traffic Management and Traveler Information
Travel Time Estimation for Traffic Management and Traveler Information

Transition Uncongested → Congested

Sensor Spacing (miles)

VHT Error

Error (Absolute Value)

Error (Penalty)

OVER

UNDER

Error (Additive)
Transition Uncongested → Congested

Sensor Spacing (miles)

VHT Error

Error (Absolute Value)

Predicted VHT

Error (Penalty)

Actual VHT

Error (Additive)
Traffic Flow Relation and Dynamics

Travel Time Estimation for Traffic Management and Traveler Information
Transition Congested→Uncongested

Travel Time Estimation for Traffic Management and Traveler Information
Transition Congested \rightarrow Uncongested

\[ v_c \]

\[ v_{CD} \]

\[ \alpha' = \text{Lag Time} \]

\[ t_{t c} \]

\[ t_{r} \text{ Recovery Signal} \]

\[ z \]

\[ j_1 \]

\[ j_2 \]

\[ j_3 \]

\[ \ell \]

\[ s \]
Travel Time Estimation for Traffic Management and Traveler Information

Transition Congested $\rightarrow$ Uncongested
Transition Congested $\rightarrow$ Uncongested

![Graph showing predicted and actual VHT values for sensor spacing in miles.](image-url)
Transition Congested → Uncongested

- Error (Penalty)
- Error (Absolute Value)
- Error (Additive)

VHT Error

Sensor Spacing (miles)

OVER
UNDER

Travel Time Estimation for Traffic Management and Traveler Information
Travel Time Estimation for Traffic Management and Traveler Information

Transition Congested → Uncongested

-15% -10% -5% 0% 5% 10% 15% 20% 25% 30% 35%

Sensor Spacing (miles)

VHT Error

Error (Penalty)

Error (Absolute Value)

Predicted VHT

Actual VHT

Error (Additive)

VHT

0.0 0.2 0.4 0.6 0.8 1.0

Portland State University
Underprediction Only

Sensor Spacing (miles)

VHT

Actual VHT
Predicted VHT

Travel Time Estimation for Traffic Management and Traveler Information

Portland State University
Underprediction Only

![Graph showing VHT Error vs. Sensor Spacing (miles)]

- VHT Error
- Sensor Spacing (miles)
- Error

- Underprediction Only

*Travel Time Estimation for Traffic Management and Traveler Information*
Underprediction Only

VHT Error vs. Sensor Spacing (miles)

- Actual VHT
- Predicted VHT
- Error

Sensor Spacing (miles) vs. VHT Error

15% 16% 17% 18% 19% 20% 21%

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0

VHT
Considering Both Transitions

![Graph showing travel time estimation for traffic management and traveler information considering both transitions. The graph plots sensor spacing (miles) on the x-axis and VHT on the y-axis. The predicted VHT is represented by a dashed line, while the actual VHT is represented by a solid line.](image)

*Travel Time Estimation for Traffic Management and Traveler Information*
Travel Time Estimation for Traffic Management and Traveler Information

Considering Both Transitions

Error (Absolute Value)
Error (Penalty)
Error (Additive)

Sensor Spacing (miles)

VHT Error
Travel Time Estimation for Traffic Management and Traveler Information

Considering Both Transitions

Graph showing the relationship between sensor spacing (miles) and VHT error, with lines for predicted VHT, error (absolute value), error (penalty), and actual VHT.
Detector at End of Section

\[ \text{Detector at End of Section} \]

\( x \) \( j_1 \) \( j_2 \) \( j_3 \)

\( \ell \) \( s \)

\( v_f \) \( v_{AC} \)

\( t_{tf} = \alpha \) Lag Time

\( t_c \) Congestion Signal

\( \text{Shock} \)
Travel Time Estimation for Traffic Management and Traveler Information

Detector at End of Section

\( t_{tf} = \alpha = \text{Lag Time} \)

\( t_c \text{ Congestion Signal} \)

\( z \)

\( v_f \)

\( v_{AC} \)

\( u_{max} \)

\( j_1 \)

\( j_2 \)

\( j_3 \)

\( l \)

\( s \)

\( x \)

\( t \)
### Regime AC

#### Underprediction

<table>
<thead>
<tr>
<th>Detector Location</th>
<th>$U_{\text{max}}$ (Min)</th>
<th>Lag Time (Min)</th>
<th>VHT/Mile Pred</th>
<th>VHT/Mile Act</th>
<th>Under % Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midpoint</td>
<td>0.56</td>
<td>4.00</td>
<td>2.78</td>
<td>3.55</td>
<td>22%</td>
</tr>
<tr>
<td>Downstream</td>
<td>0.11</td>
<td>0.00</td>
<td>0.56</td>
<td>0.59</td>
<td>5%</td>
</tr>
</tbody>
</table>

#### Overprediction

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<tr>
<td>Midpoint</td>
<td>0.56</td>
<td>4.00</td>
<td>4.44</td>
<td>3.95</td>
<td>-13%</td>
</tr>
<tr>
<td>Downstream</td>
<td>0.11</td>
<td>0.00</td>
<td>8.89</td>
<td>6.91</td>
<td>-29%</td>
</tr>
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The Future

- Better estimates and forecasts
- Fusion of fixed and mobile sources
- Ubiquity of integrated information
  - In-vehicle
  - In-device
  - Multimodal routing/decision-making
  - Customizable
- Better management
Inspired by Berkeley’s *Transportation Science Seminar*, originated by G.F. Newell, 1965

First seminar October 5, 2000, *Benefits of Archived ITS Data: Measuring Capacity at a Freeway Bottleneck*

200 seminars completed

Began streaming video October 2002: 165 available for download and streaming

Began podcasts (mp3) in October 2007: 30 podcasts now available

Venue for student/faculty interaction

Strong involvement of transportation community
Travel Time Estimation for Traffic Management and Traveler Information
Seminar Perspectives

- Organized by graduate students?
- More social interaction before/after?
- More point/counterpoint?
- We’re open to other ideas!
- First air transportation seminar on May 9
- Other topics we haven’t covered?
Acknowledgements

- Travel time project teams, past and present
- Kristin Tufte, Sirisha Kothuri, David Lovell, Ben Zielke, Rafael Fernandez, Ed Anderson Sutti Tantiyanugulchai, Roger Lindgren, Monica Leal
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- My colleagues Jennifer Dill, Chris Monsere and John Gliebe
- Seminar enthusiasts and participants
- Ryan Gratzer
TRANSPORTATION SEMINAR
CONGRATULATIONS
ON YOUR
200TH SEMINAR!