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SOME OBSERVED FEATURES OF FREEWAY TRAFFIC OSCILLATIONS

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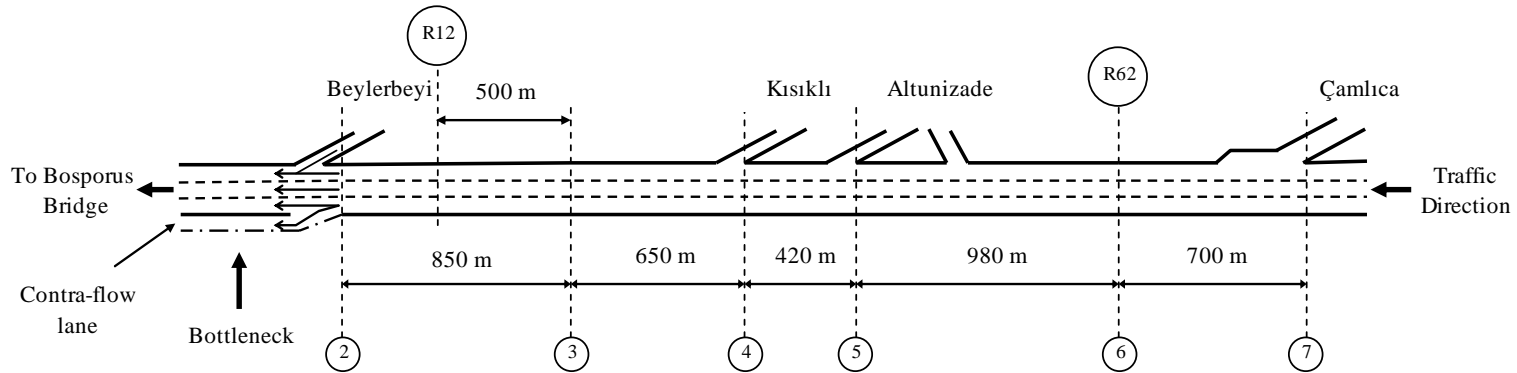
Problem Definition

Freeway oscillations

form,
propagate upstream, and
grow
in congested conditions

and may be analyzed
empirically.

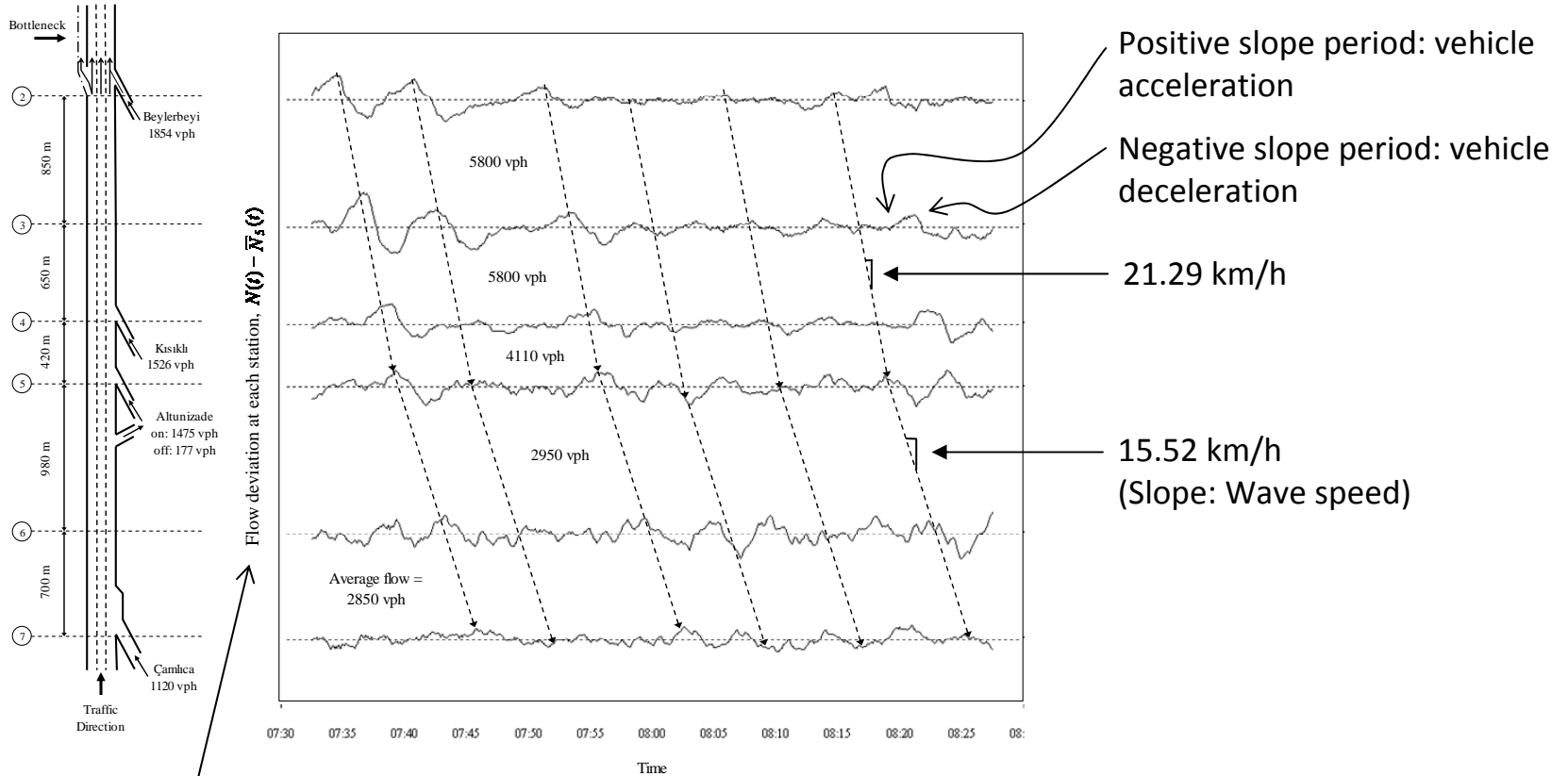
DATA



Freeway study stretch: O-1 westbound direction

- **Freeway stretch:** 3.5 km, three regular lanes in each direction
- **Manually collected data:** Measured across all travel lanes - cumulative number of vehicles at points (2 to 7) in 5-sec intervals using laptop computers during morning rush hours on 8 days in April to June of 2002 and 2003 – congested conditions prevail over the entire stretch
- **Radar data:** Collected for each individual lane - cumulative vehicle counts and average occupancies at stations (R12 and R62) in 120-sec intervals - Operated by the Greater İstanbul Municipality

Analysis Tool: Oscillation Curves



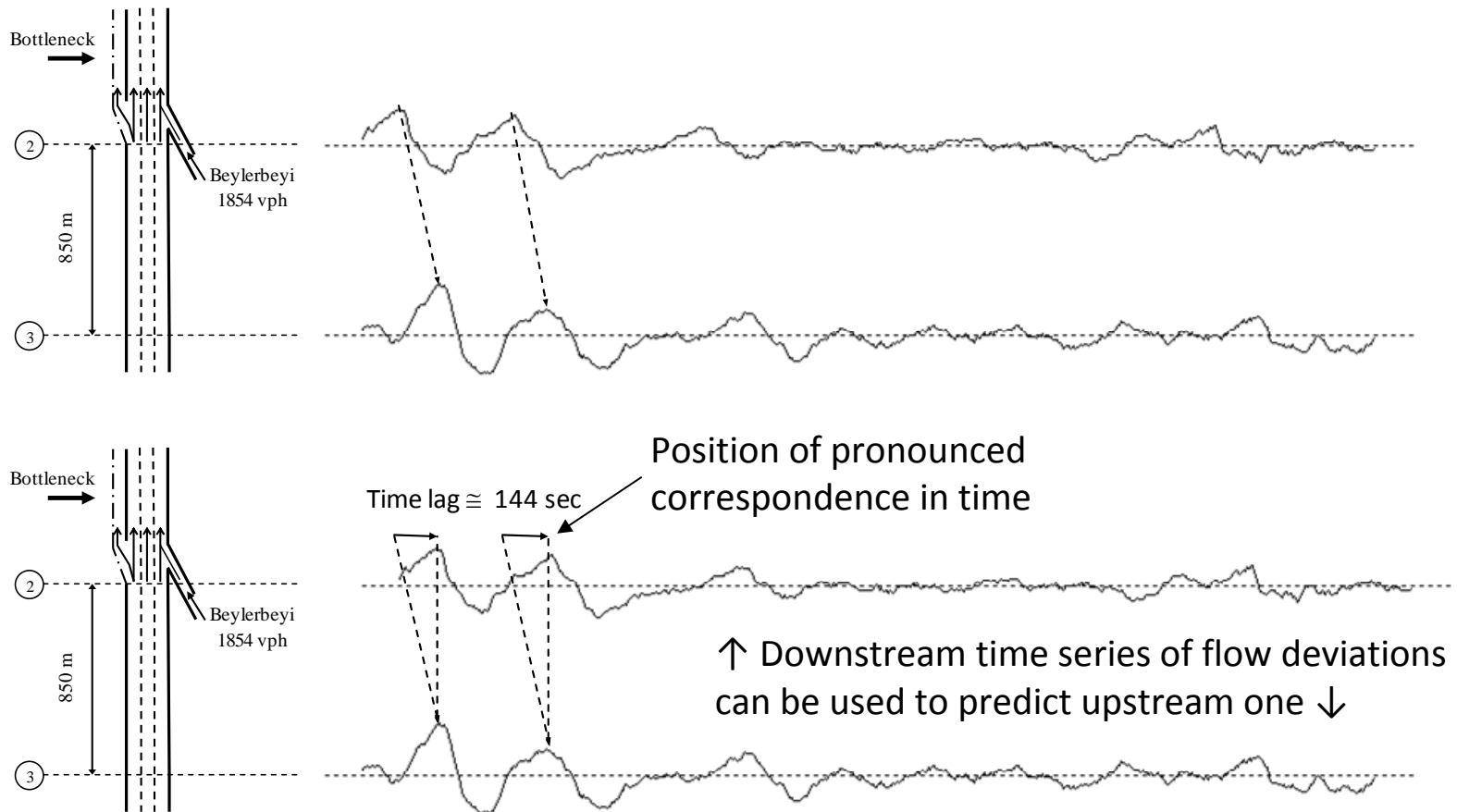
Time series of flow deviations at count stations on O-1 highway (May 9, 2002)

$$N(t) - [N(t + 2.5 \text{ min}) + N(t - 2.5 \text{ min})] / 2 = N(t) - \bar{N}_5(t)$$

Propagation Speeds of Oscillations

Cross-Correlation Method:

Comparing two time series at successive lags



Propagation Speeds of Oscillations (cont'd)

(km/h)

Count stations	April 09, 2002	April 15, 2002	May 03, 2002	May 09, 2002	May 20, 2002	June 20, 2002	June 21, 2002	May 27, 2003	Average	Standard deviation
	7:30-10:00	7:30-9:45	7:30-8:30	7:30-10:00	7:30-8:55	7:30-8:30	7:30-8:45	7:30-8:55		
2 – 3	21.1	19.13	21.86	21.1	20.4	-	22.67	21.1	21.05	1.11
3 – 4	21.27	21.27	21.27	20.35	22.29	23.4	24.63	20.35	21.85	1.50
4 – 5	18.9	23.26	21.6	21.6	20.16	20.16	20.16	21.6	20.93	1.35
5 – 6	15.34	14.4	15.68	15.34	14.7	16.04	-	-	15.25	0.61
6 – 7	16.26	15.27	15.27	16.8	14.82	16.26	-	-	15.78	0.77
Average	18.57	18.67	19.14	19.04	18.47	18.97	22.49	21.02		
Standard deviation	2.72	3.80	3.35	2.79	3.49	3.51	2.24	0.63		

Propagation Speeds of Oscillations (cont'd)

Cross-correlation coefficients

Count stations	April	April	May	May	May	June	June	May
	09, 2002	15, 2002	03, 2002	09, 2002	20, 2002	20, 2002	21, 2002	27, 2003
	7:30- 10:00	7:30- 9:45	7:30- 8:30	7:30- 10:00	7:30- 8:55	7:30- 8:30	7:30- 8:45	7:30- 8:55
2 – 3	0.73	0.70	0.33	0.73	0.59	-	0.78	0.51
3 – 4	0.86	0.70	0.82	0.81	0.89	0.92	0.90	0.88
4 – 5	0.85	0.83	0.80	0.85	0.80	0.89	0.93	0.92
5 – 6	0.76	0.78	0.76	0.78	0.67	0.88	-	-
6 – 7	0.56	0.73	0.61	0.75	0.78	0.86	-	-

Propagation Speeds of Oscillations (cont'd)

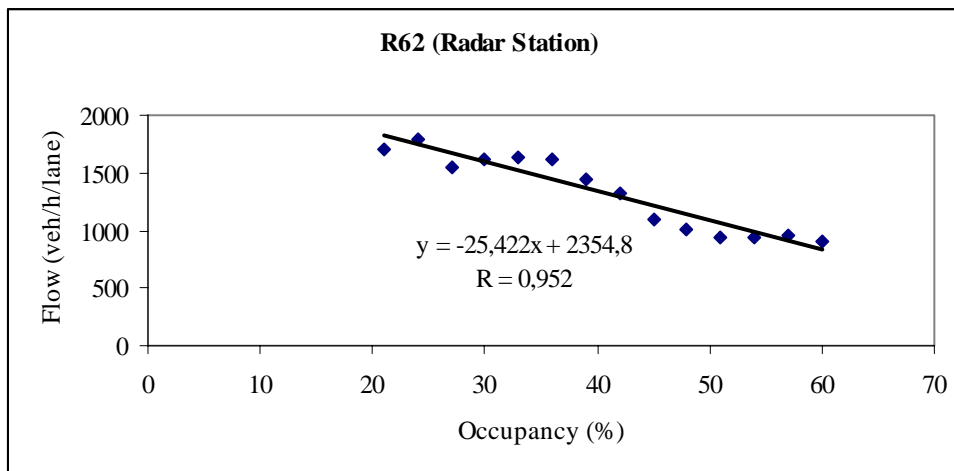
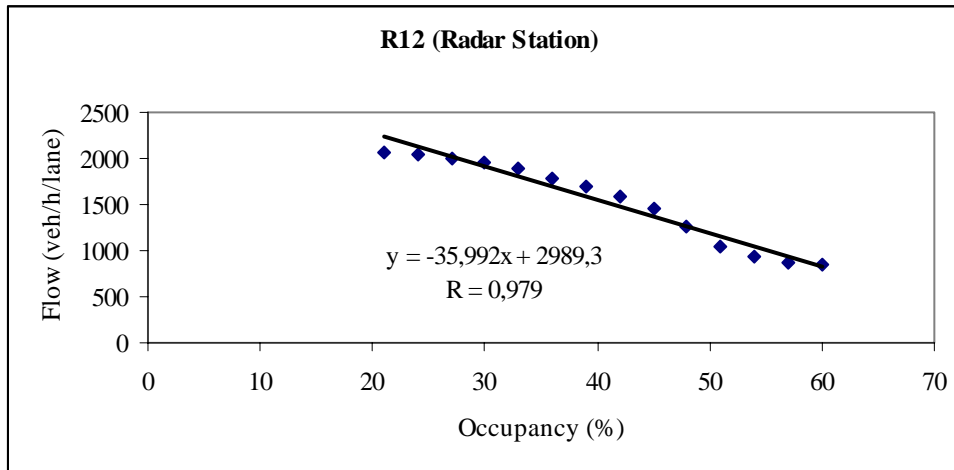
(km/h)

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2 – 3	21.1	19.13	21.86	21.1	20.4	-	22.67	21.1	21.05	1.11
3 – 4	21.27	21.27	21.27	20.35	22.29	23.4	24.63	20.35	21.85	1.50
4 – 5	18.9	23.26	21.6	21.6	20.16	20.16	20.16	21.6	20.93	1.35
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Standard deviation	2.72	3.80	3.35	2.79	3.49	3.51	2.24	0.63		

Average speed: 21.29 km/h

Average speed: 15.52 km/h

Fundamental Diagram and Oscillation (Wave) Propagation Speeds



Downstream segments 2 to 5 – R12

Average speed: 21.29 km/h

Slope in fundamental diag.: -35.99

Upstream segments 5 to 7 – R62

Average speed: 15.52 km/h

Slope in fundamental diag.: -25.42

$Speed_{2\ to\ 7} / Speed_{5\ to\ 7} = 1.37$

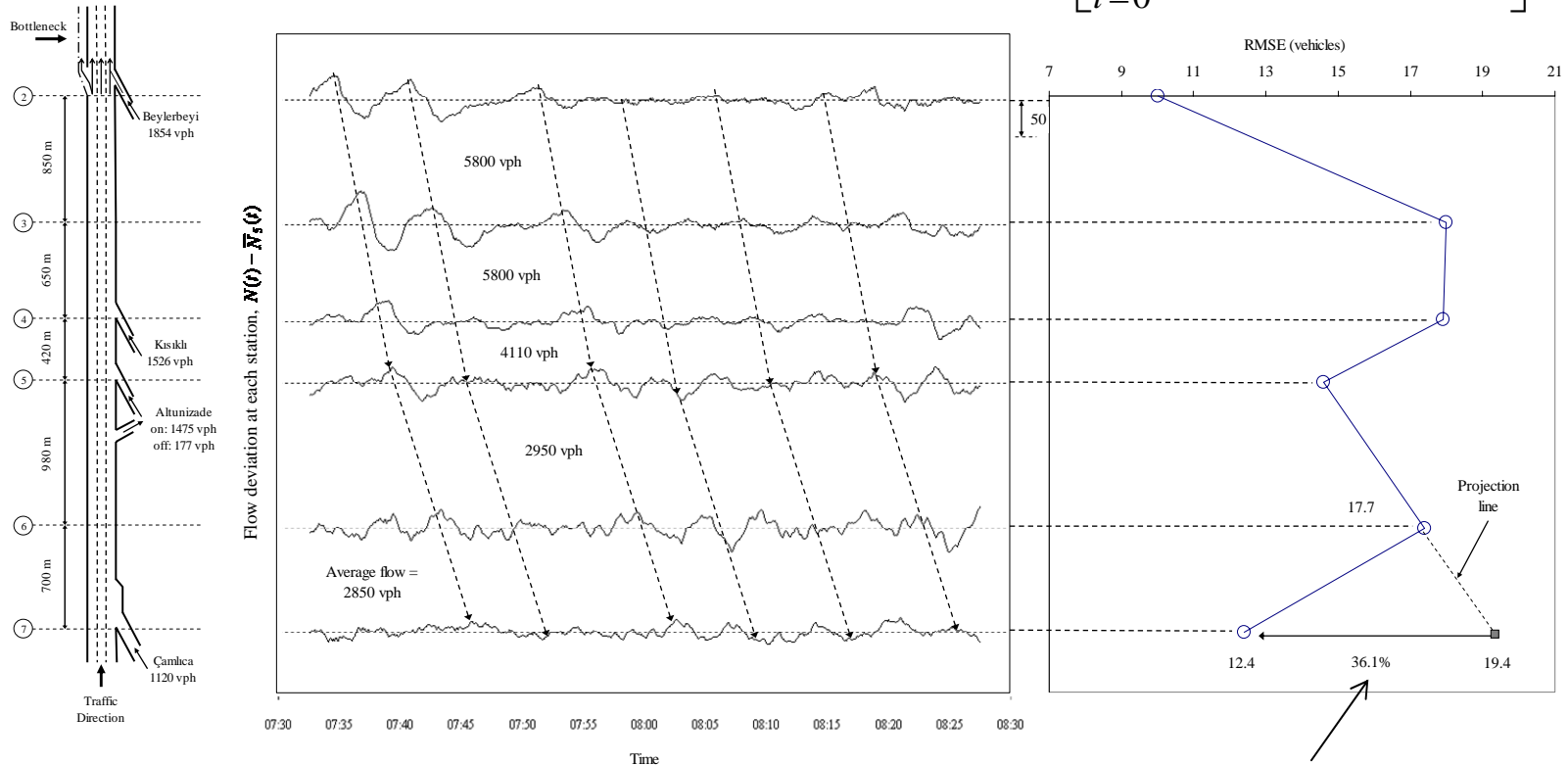
$Slope_{2\ to\ 7} / Slope_{5\ to\ 7} = 1.42$

Radar data belong to May 2007

Growth of Oscillation Amplitude

Analysis Tool: Root Mean Squared Error

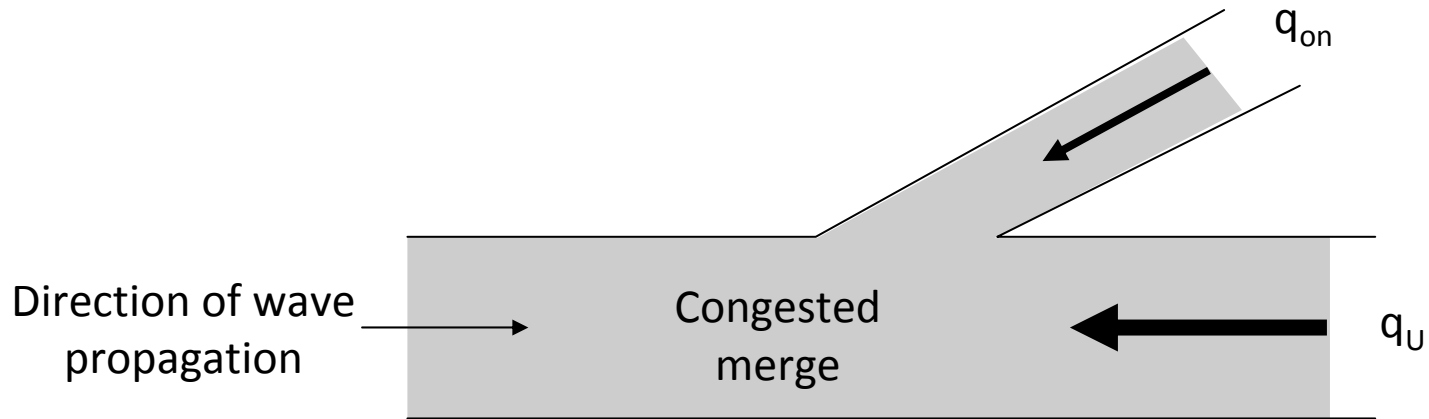
$$\text{RMSE for 5-sec flow deviations} = \left[\sum_{t=0}^{720} (N(t) - \bar{N}_5(t))^2 / 720 \right]^{1/2}$$



Merge ratio: $\alpha = 0.653$
 Predicted reduction: 39.5%

Merging Effect on Oscillation Growth

An Already Proposed Theory

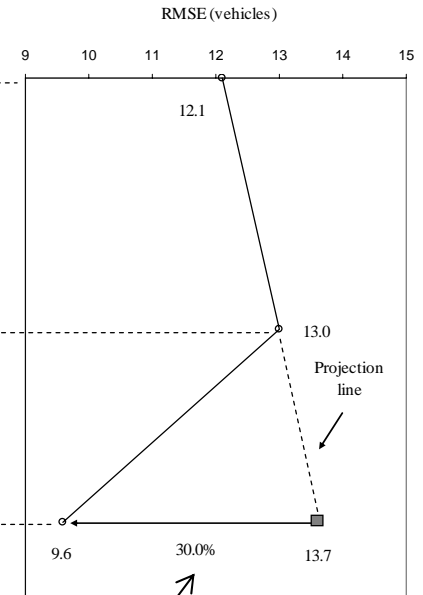
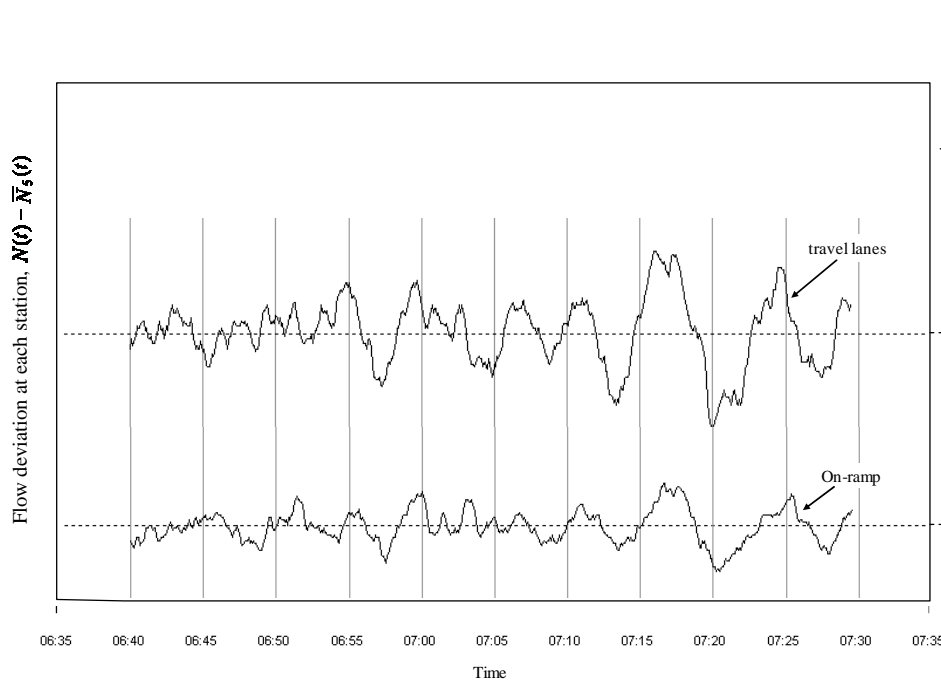
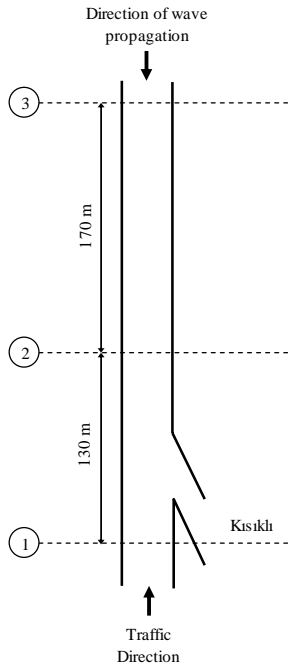


Merge ratio: $\alpha = q_{on} / q_U$

Oscillation amplitude reduction factor: $100\alpha / (1 + \alpha)$

Merging Effect on Oscillation Growth

An Empirical Evidence (April 30, 2007)



Time lag: 20 sec \rightarrow 23.4 km/h

Merging effect:
oscillation reduction (estimated)

Merge ratio: $\alpha = 0.527$
Predicted reduction: 34.5%

Conclusions

- Oscillation formation
 - Flow deviation curves help analyst visualize oscillation formation around bottleneck and merging area.
- Oscillation growth
 - RMSE's values show that oscillating waves grow in amplitude while propagating upstream.
- Merging effect: reduction of oscillation amplitude
 - Oscillation amplitudes reduce at merge sites.
 - A proposed theory predicts waves' amplitude reduction based on merging ratio in an acceptable level.
- Supporting with further empirical evidence, such findings could be used to develop new models and refine existing ones for congested flow conditions.