Using Advanced Loop Event Data Analyzer to Tune-up Dual-Loop Detectors for Improved Truck and Speed Data

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Outline

- Introduction
- Principles of Loop Detection
- Development of ALEDA
- System Testing and Discussion
- Conclusions

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Introduction

- Loop detectors serve as a primary data source
  - ATMS and ATIS
  - Other transportation applications
- Sensitivity issues affect data quality
  - Loop sensitivity is influenced by multiple factors
  - Dual-loop detectors under-count
    - More than 80% of loops
    - 10% discard criteria by WSDOT
  - Truck data misclassifications
    - 30% to 41% in non-peak hours;
    - 33% to 55% in peak hours

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Introduction

- Two main sensitivity problems
  - Sensitivity discrepancy
    - Between M loop and S Loop
  - Incorrect sensitivity levels
    - For both single loops
    - When there are no sensitivity discrepancies
- A new tool is desired:
  - Over traditional manual tune-up;
  - Identify and correct dual-loop sensitivity problems automatically

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Introduction

- Aggregated Data vs. Event Data
  - Event Data provide individual vehicle information
  - Event Data help investigate malfunction of loops
  - Event Data help increase veh. classification accuracy
- Advanced Loop Event Data Analyzer
  - To collect event data
  - To facilitate loop error correction

Principles of Loop Detection

- A vehicle's presence decreases loop's inductance
- Inductance reduction triggers the Detector Electronic Unit's (DEU) output relay
- Control cabinets scan loops at a fixed frequency (e.g. 60 Hz)

$$Ontime = \frac{SCs}{60}$$

$$Occupancy = \frac{SCs\ in\ a\ \text{20-second interval}}{1200} * 100$$

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Principles of Loop Detection

- Sensitivity level
  - Minimum relative change of loop inductance (ΔL/L) caused by a vehicle's presence
  - A threshold value signals vehicle detection

Sensitivity Level	*min ΔL/L*
7	0.01%
6	0.02%
5	0.04%
4	0.08%
3	0.16%
2	0.32%
1	0.64%
0	1.28%

Sensitivity Level	*min ΔL/L*	Sensitivity Level	*min ΔL/L*
15	0.010%	7	0.160%
14	0.014%	6	0.226%
13	0.020%	5	0.320%
12	0.028%	4	0.453%
11	0.040%	3	0.640%
10	0.057%	2	0.905%
9	0.080%	1	1.280%
8	0.113%	0	OFF

Principles of Loop Detection

$$Speed = \frac{Dist_{MS}}{(t_{s-on} - t_{m-on})}$$

$$Length = \left[Speed * \left(\frac{Ontime_M + Ontime_S}{2} \right) \right] - Loop\ Length$$

* WSDOT discards vehicles with a on-time difference larger than 10%

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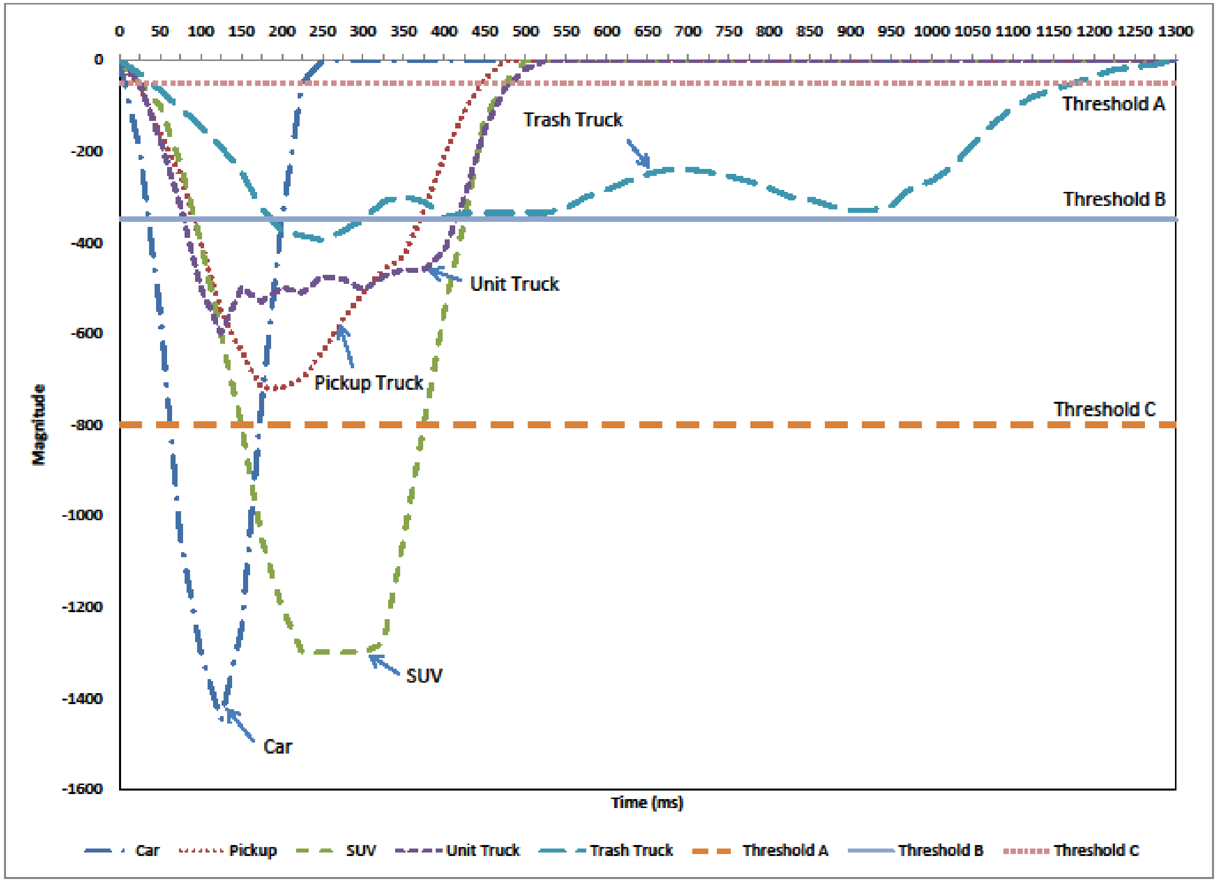
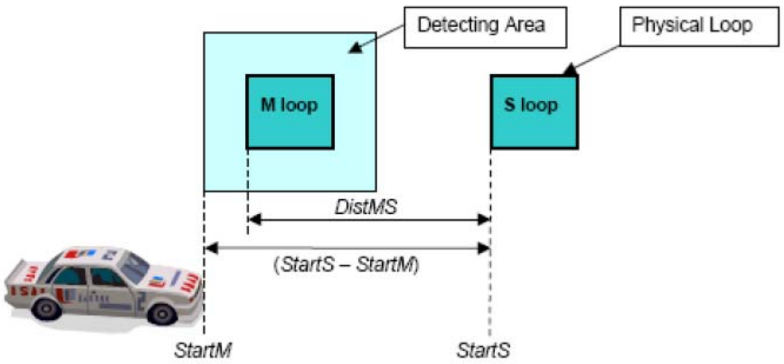
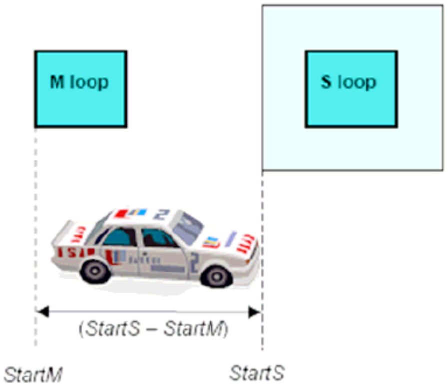
Principles of Loop Detection



Wang et al. 2009

Research Approach: Sensitivity Discrepancies





Scenarios	Impact on Speed Estimation
Over-Sensitive M Loop	Underestimate Speed
Over-Sensitive S Loop	Overestimate Speed
Under-Sensitive M Loop	Overestimate Speed
Under-Sensitive S Loop	Underestimate Speed

Research Approach: Sensitivity Discrepancies

- Causes speed estimation error
- Remedy
  - Use on-time difference as an indicator

$$On\text{-}Time\ Difference\,(\%) = \frac{(Ontime_M - Ontime_S)}{Ontime_M} * 100$$

- Implementation
  - Calculate on-time difference
  - Adjust DEU making the diff. close to zero

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Research Approach: Incorrect Sensitivity Levels

- Causes vehicle length estimation error
- Remedy
  - Compare the calculated SV length with the ground-truth SV-length distribution
- Implementation
  - Trade-off between accuracy and efficiency
  - Collect 100 SV lengths, takes less than 13 minutes

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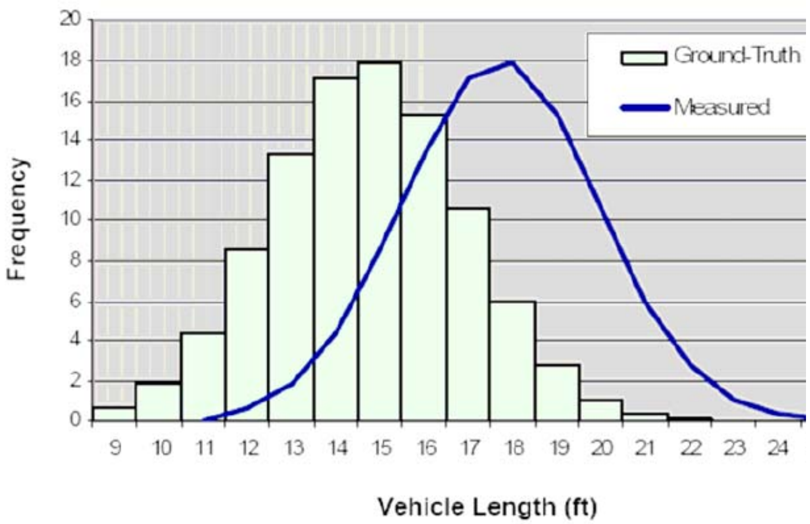
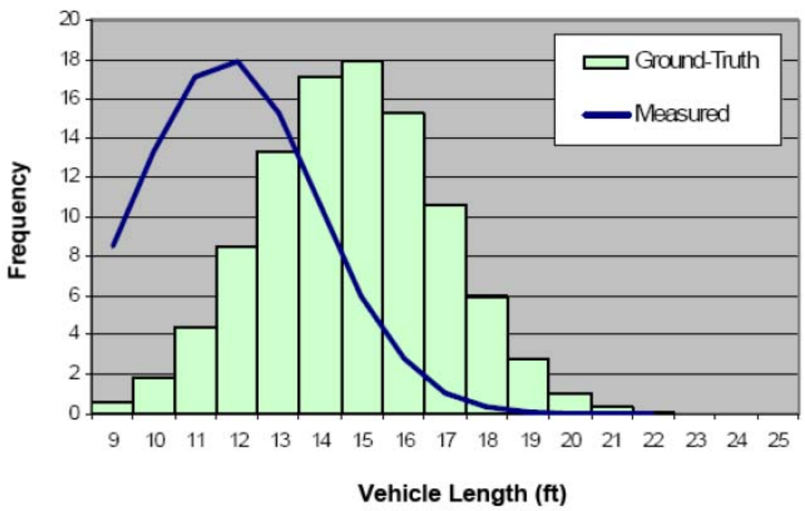
Research Approach: Incorrect Sensitivity Levels

Over-sensitive Loops

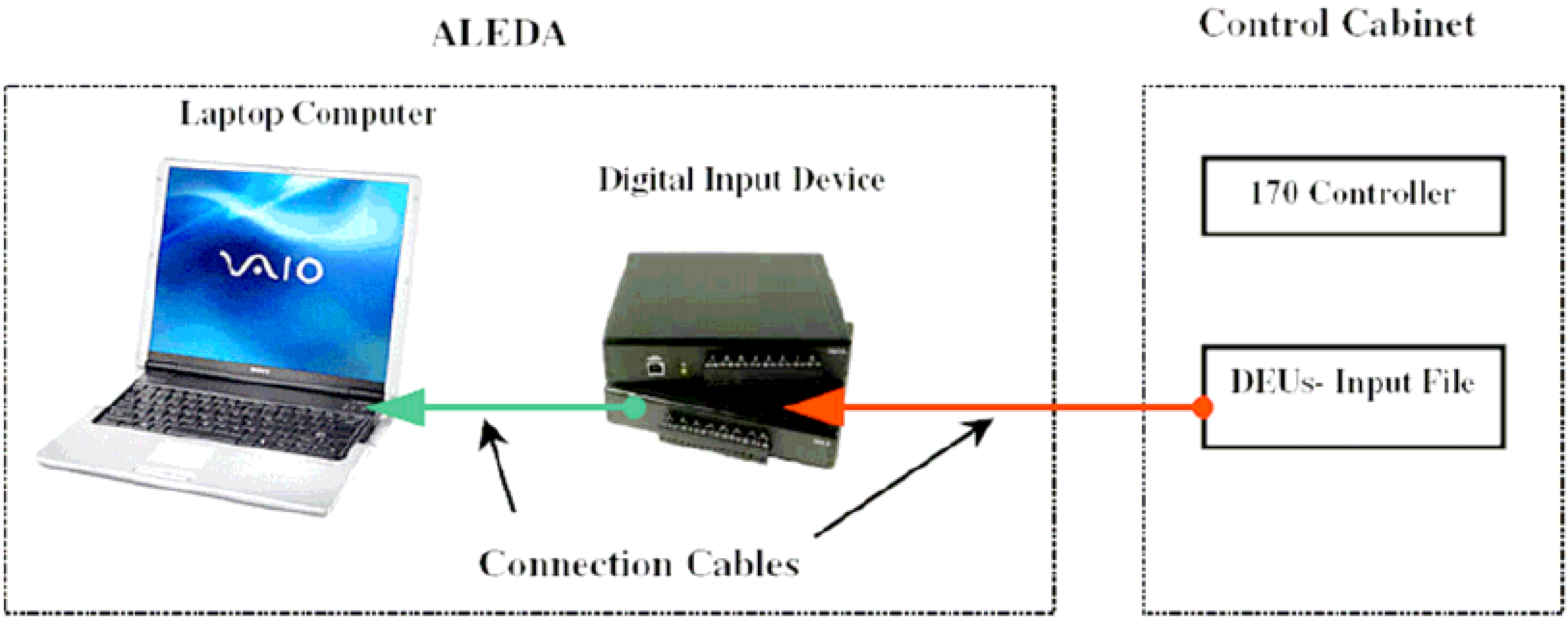


Under-sensitive Loops



Scenarios	Impact on Speed Estimation
Both Over-Sensitive	Overestimate Vehicle Length
Both Under-Sensitive	Underestimate Vehicle Length

Development of ALEDA System



- Laptop computer with Universal Serial Bus (USB) ports
- Digital input/output (I/O) adapter
- Cable connections

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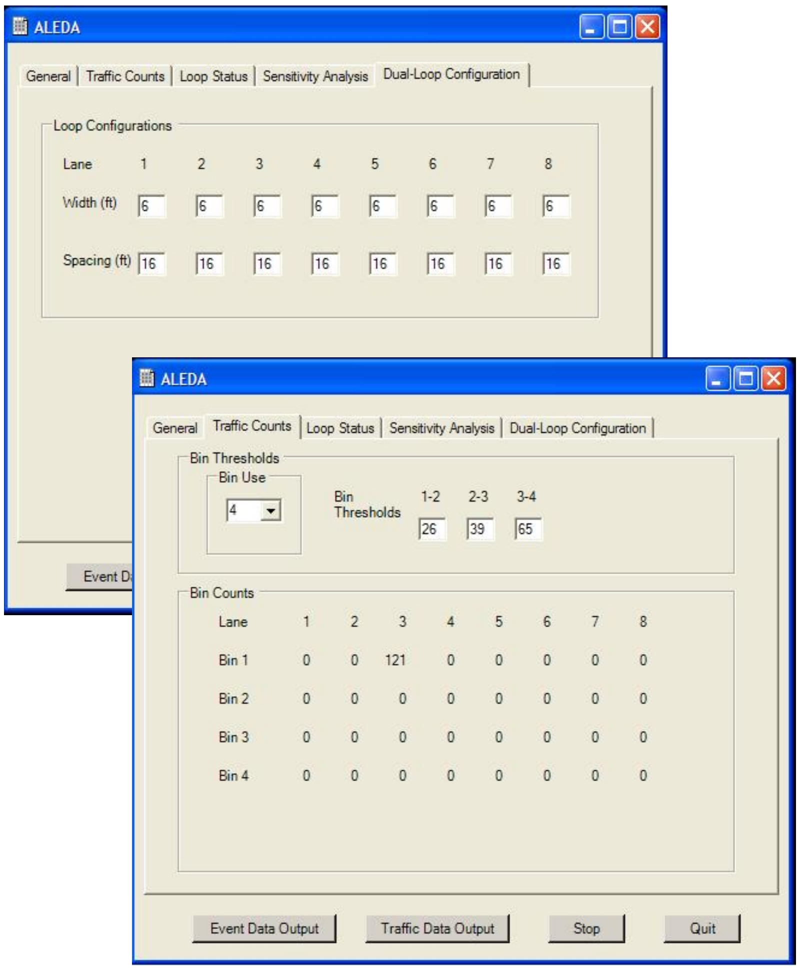
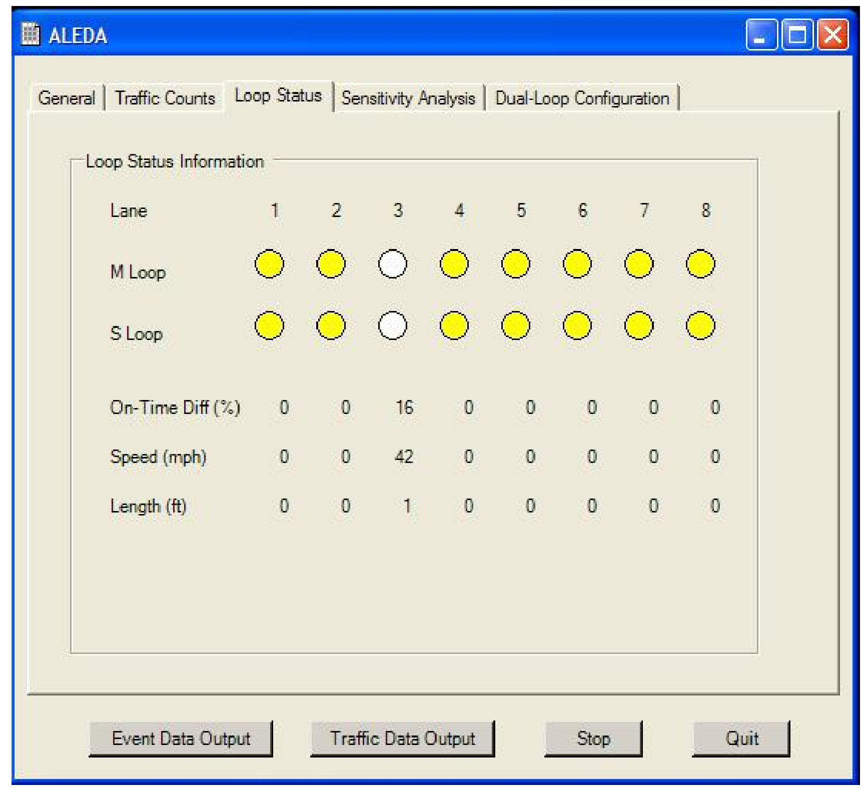
ALEDA User Interface





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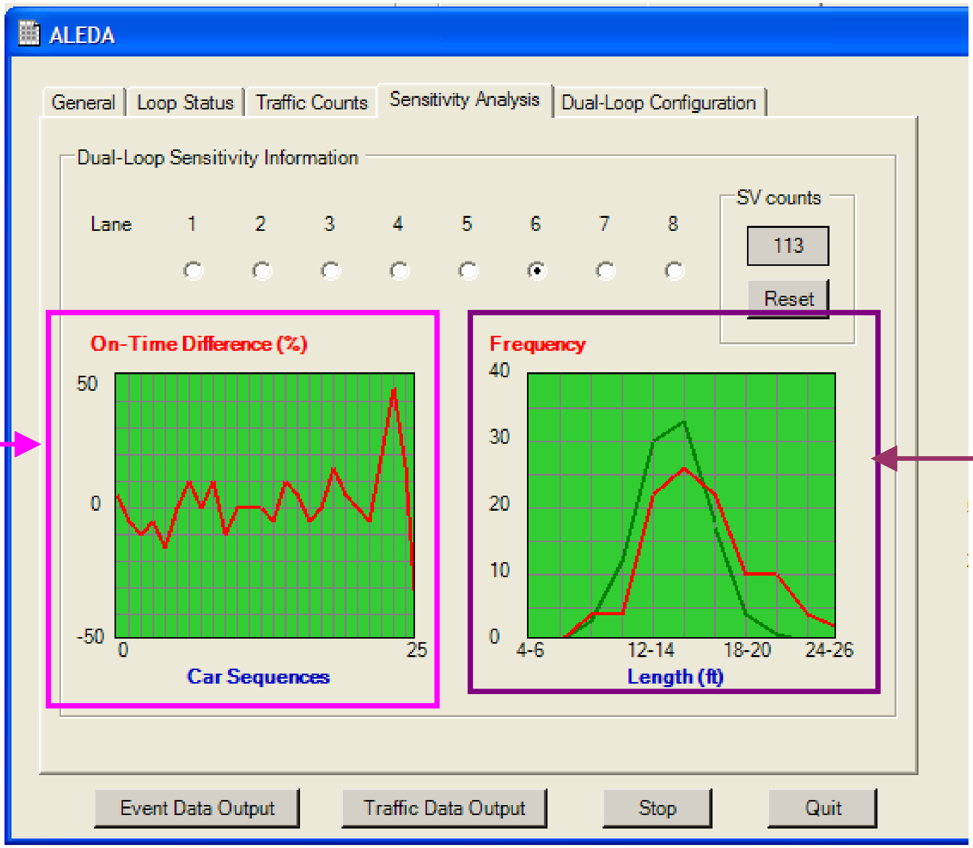
ALEDA User Interface

Check the sensitivity discrepancy



Check the correctness of dual-loop sensitivity levels

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Event Data Collected by ALEDA System

EventDataOutput1 - Notepad

File Edit Format View Help

```
*** Station Code: Insert Station Codes
*** Loop Code: Insert Loop Codes
*** Measured Date: 3/6/2005
*** Start Time: 9:04:14 PM
*** Personnel's Name :-- -- --
-M,-S,-M,-S,-M,-S,-M,-S,-M,-S,-M,-S,-M,-S,-M,-S,Hour,Minute,Second,Millisecond
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,781
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,796
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,812
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,828
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,843
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,859
0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,21,4,14,875
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```
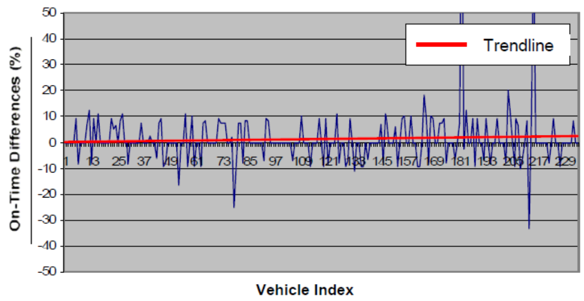

System Testing

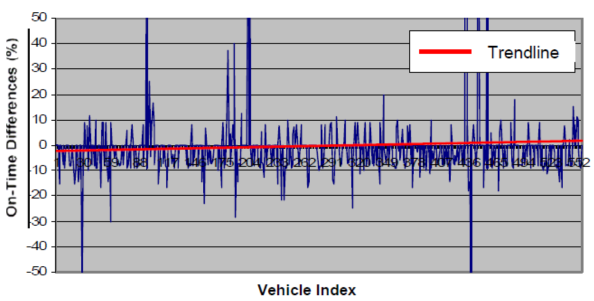
- Test Sites
  - ES-172R
    - located at I-5 northbound and Metro Base
  - ES-137R
    - located at I-5 northbound and NE 45th St.
- Use ALEDA to identify sensitivity problems
  - Sensitivity Discrepancies
  - Incorrect sensitivity levels
- Use ALEDA to correct sensitivity problems

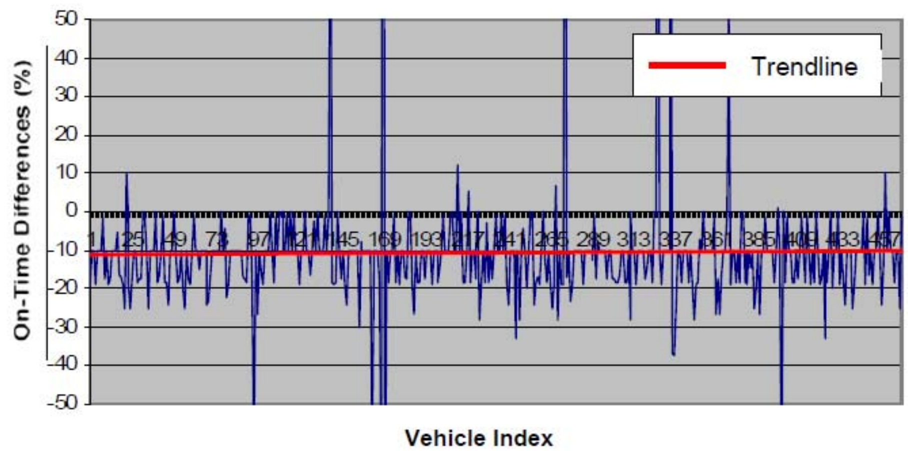
Identify Sensitivity Discrepancies

On-time Difference at ES-172R Station
(NB I-5 and Metro Base) on November 28, 2004



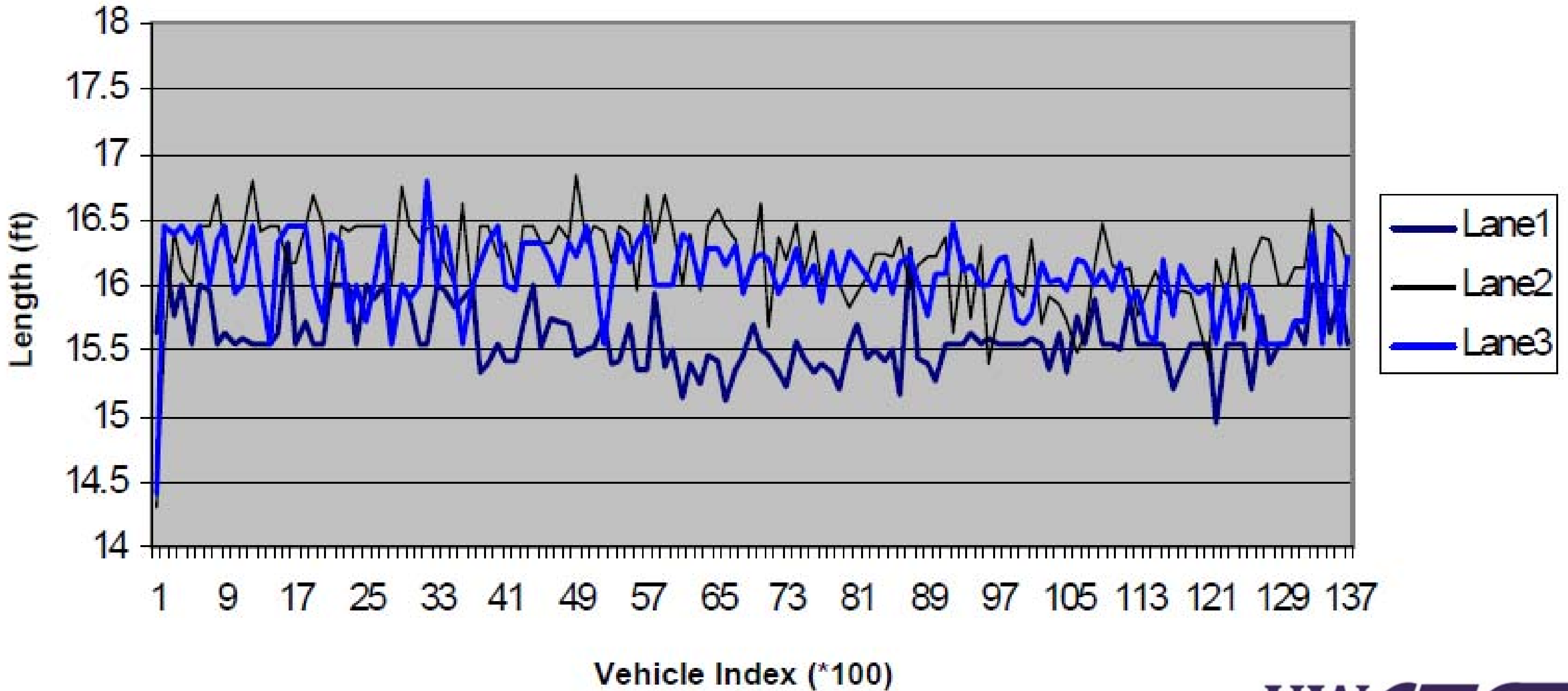
Lane	M Loop	S Loop	ST	DIFF%=(M Loop-ST)/M Loop *100
1	15778	15872	14954	5.22
2	14082	14686	12845	8.78
3	10025	11186	567	94.34



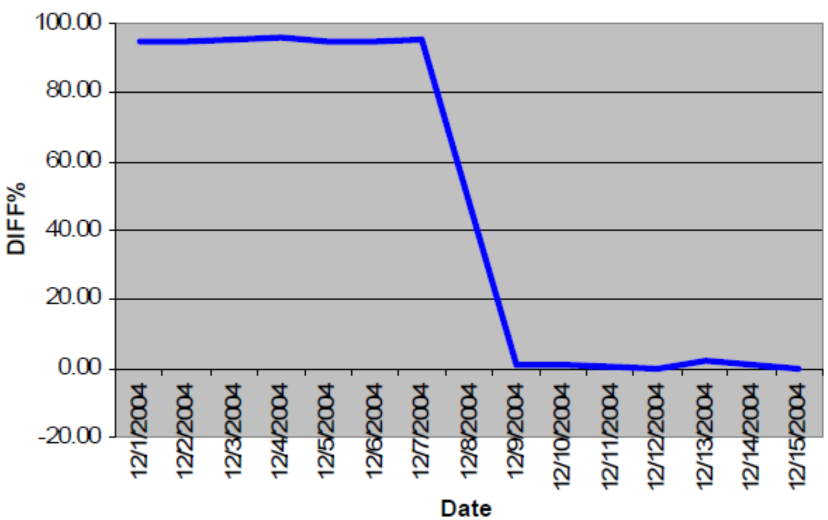


Identify Incorrect Sensitivity Levels

Estimated SV Median Length at ES-172R (SB I-5 and Metro Base)



Correct Sensitivity Discrepancies



Day	DIFF%		
	Lane 1	Lane 2	Lane 3
12/1/2004	5.06	7.31	94.90
12/2/2004	6.49	9.84	94.66
12/3/2004	6.70	8.28	95.15
12/4/2004	3.57	7.58	95.66
12/5/2004	3.88	7.27	95.02
12/6/2004	6.49	9.80	94.73
12/7/2004	7.30	10.52	95.12
12/9/2004	9.54	15.18	1.08
12/10/2004	8.71	17.29	1.22
12/11/2004	4.90	14.06	0.65
12/12/2004	4.47	13.23	-0.17
12/13/2004	7.93	15.72	1.85
12/14/2004	6.97	15.43	0.98
12/15/2004	6.57	15.84	-0.13

The ALEDA system was applied to tune ES-172R Station on December 8, 2004

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Correct Sensitivity Discrepancies

TDAD Volume Data at ES-137R Station on November 28, 2005

Lane	M Loop	S Loop	ST	DIFF%=(M Loop-ST)/M Loop *100
1	8961	8991	8013	10.58
2	14232	14283	13659	4.03
3	15738	15613	14999	4.70

The sensitivity tune-up conducted on November 30, 2005

TDAD Volume Data at ES-137R Station on December 2, 2005

Lane	M Loop	S Loop	ST	DIFF%=(M Loop-ST)/M Loop *100
1	8575	8590	8034	6.31
2	13643	13672	12803	6.16
3	14678	14527	13987	4.71

Correct Incorrect Sensitivity Level

Vehicle Count Data for Lane 1 at ES-137R BEFORE and AFTER the Sensitivity Tune-Up

	Vehicle Types	Video (VI)	TDAD (TD)	Event Data (EV)	VI-TD Error (%)	VI-EV Error (%)
BEFORE	SV	446	447	447	-0.22	-0.22
	Truck	18	13	17	27.78	5.56
	Total	464	460	464	0.86	0.00
AFTER	SV	653	651	653	0.31	0.00
	Truck	30	24	29	20.00	3.33
	Total	683	675	682	1.17	0.15

Note: VI-TD Errors (%) = (Video Data – TDAD Data) / Video Data
VI-EV Errors (%) = (Video Data – Event Data) / Video Data

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Conclusions

- ALEDA can efficiently identify and correct sensitivity discrepancies and thus improves speed estimation and volume estimation
- Incorrect sensitivity level problem can be identified and alleviated, yielding better classification/truck data

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Further Use of ALEDA

- ALEDA as a Event Data Collector
  - Provides an alternative data source
  - Provides high-resolution data
  - Provides individual vehicle information
  - With the decreasing cost for disk space, event data will play a key role in future transportation applications

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