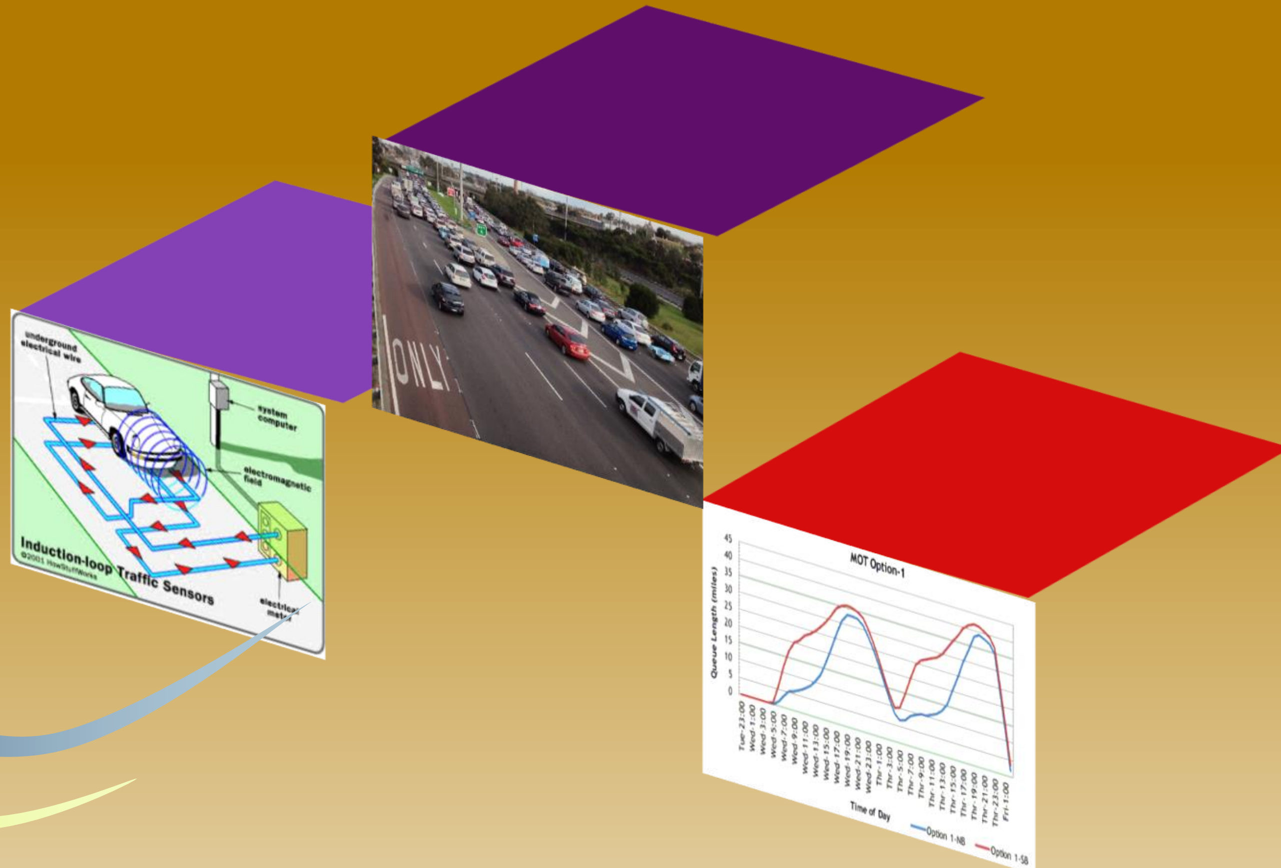

Estimation of Freeway Density Based on the Combination of Point Traffic Detector Data and Automatic Vehicle Identification Data

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University Transportation Center (UTC)
Conference for the Southeastern Region

March 27th, 2015
Birmingham



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1 INTRODUCTION

2 DATA SOURCES

3 METHODOLOGY

4 CASE STUDY

5 DATA ANALYSIS AND RESULT

6 CONCLUSION

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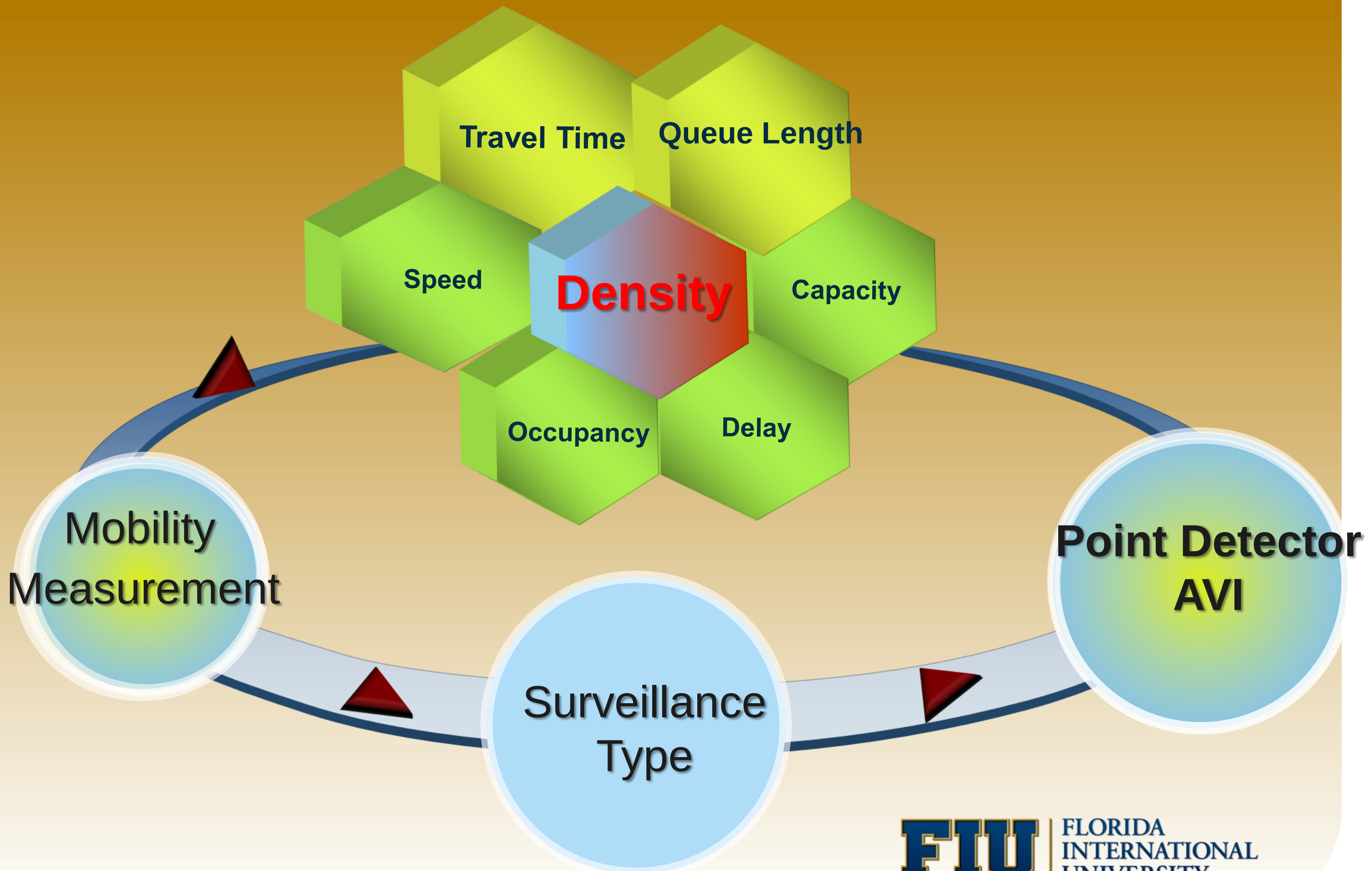
Performance Measurement



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Different Data Resources

Surveillance Type

Point detector data

- Deployed along freeway
- Speed, volume, and occupancy
- Measurement at points along the corridor
- Examples: Inductive loops, non-intrusive

Automatic Vehicle Identification

- Travel time and speed (Space Mean Speed)
- Information along the segment
- Examples: Bluetooth readers, electronic toll collection tags, license plate readers

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Benefits and Shortcomings

Benefit and Shortcoming

Point detector data

- Mature, accurate, not affected by weather
- Frequent maintenance
- Relatively short life

Automatic Vehicle Identification

- Easily installation
- Market penetration
- Error due to large detection radius

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Data Acquisition and Preprocessing

1. point detector data

- Raw detector data from FDOT traffic management software, SunGuide system
- Processed detector data from RITIS and Statewide Transportation Engineering Warehouse for Archived Regional Data(STEWARD)

2. Automatic Vehicle Identification

- Electronic toll tag readers system
- Roadside Bluetooth readers

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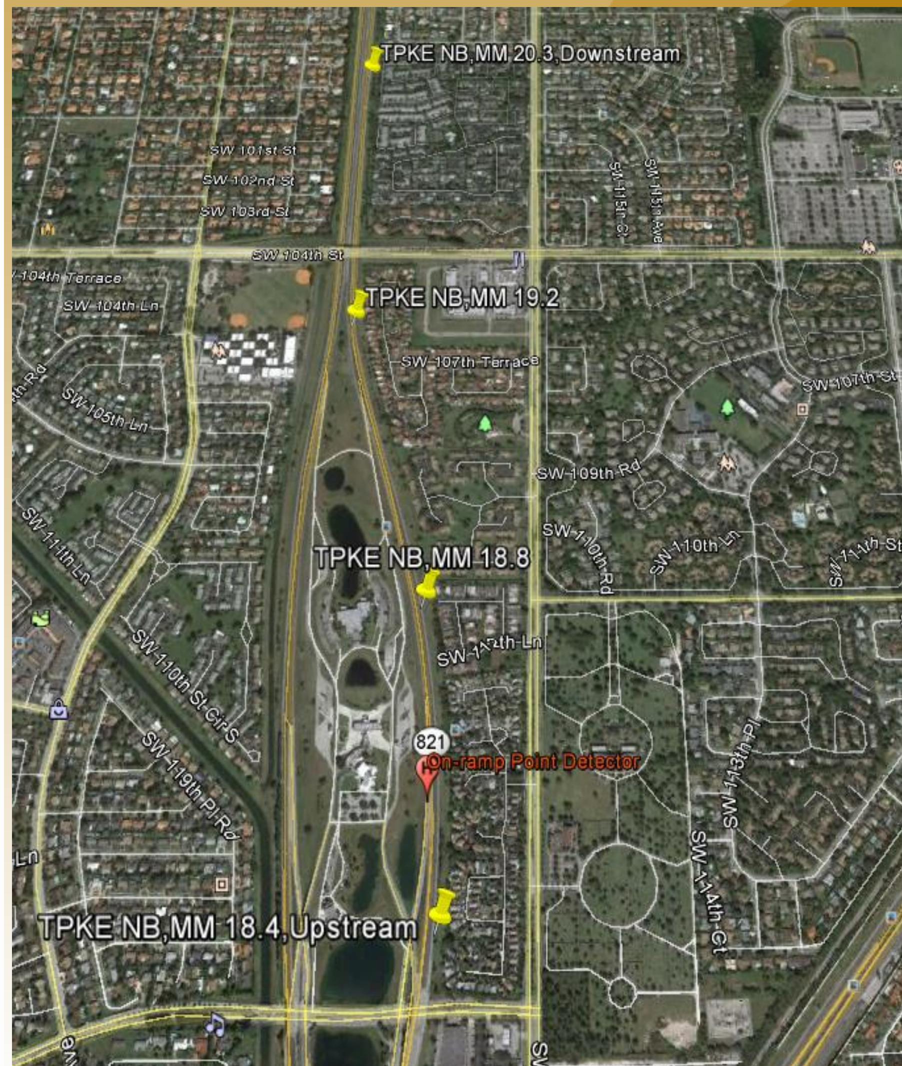
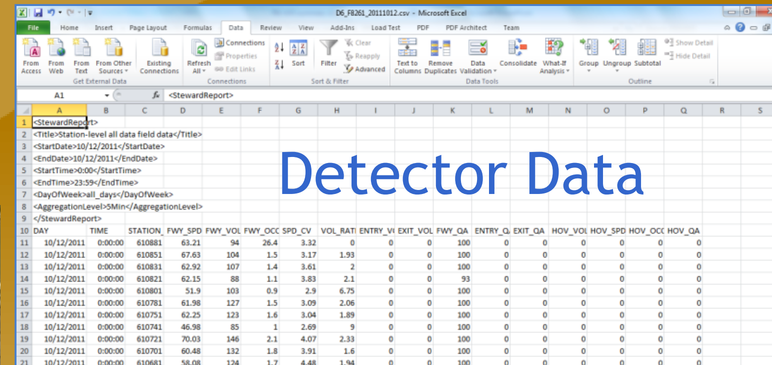
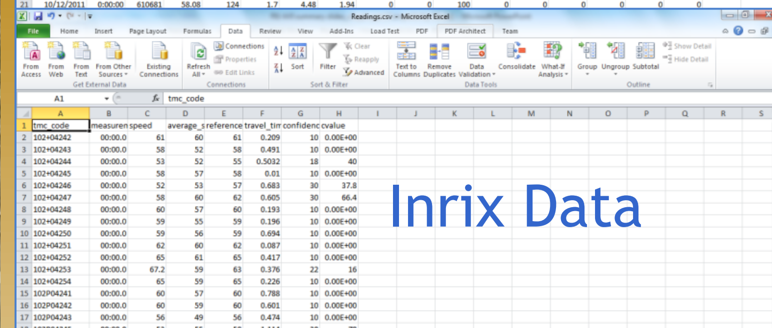
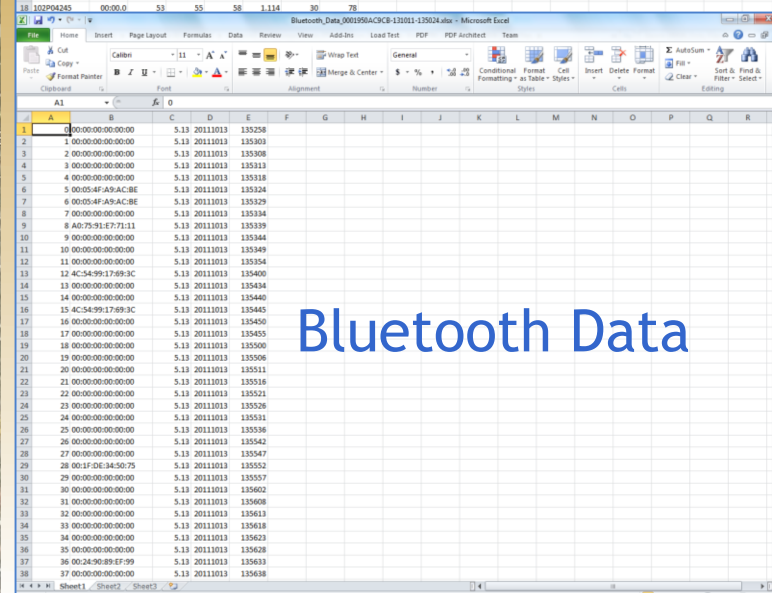
Data Capture









Density Estimation Methods

Density Estimation Methods

point detector data

- Cumulative Volume-based Method
- Occupancy-based Method
- Fundamental Relationship-based Method

Automatic Vehicle Identification ????

Density estimation is related to total volume along the segment (sample size close to100%)

Combination of AVI and Point Detector Data

Segmentation Method

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Density Estimation Based on Point Detector Data

- Cumulative Volume-based Method
- $N_i = V_{a,i} - V_{d,i} + N_{i-1}$

$$=V_{a,i} - V_{d,i} + \left(V_{a,i-1} - V_{d,i-1} + N_{i-2}\right)$$
$$= A_i - D_i + N_0$$

A_i: Cumulative arrival volumes from both mainline and on-ramps at the time period i, veh

D_i: Cumulative departure volumes from both mainline and off-ramps at the time period i, veh

N_0: Initial number of vehicles within the segment

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Density Estimation Based on Point Detector Data

- Occupancy-based Method

$$Di = \frac{5280(Occ\%)}{100(L_v + L_d)}$$

$\boldsymbol{D_i}$: Density at detector location i, veh/ mi/ln

$\boldsymbol{Occ\%}$: Occupancy in percentage

$\boldsymbol{L_v}$: Average vehicle length, ft ?

$\boldsymbol{L_d}$: Detector length, ft

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Density Estimation Based on Point Detector Data

- **Fundamental Relationship-based Method**

$$D_i = V_i / u_{S,i}$$

$\boldsymbol{D_i}$: Density at detector i, veh/mi/ln

$\boldsymbol{Vi}$: Traffic flow rate measured by detector i, veh/hr/ln

$\boldsymbol{u_{S,i}}$: Space mean speed at detector i, mi/h

$$u_T = 0.966\, u_S + 3.541$$

u_T :Time mean speed (mph)

u_S: Space mean speed (mph)

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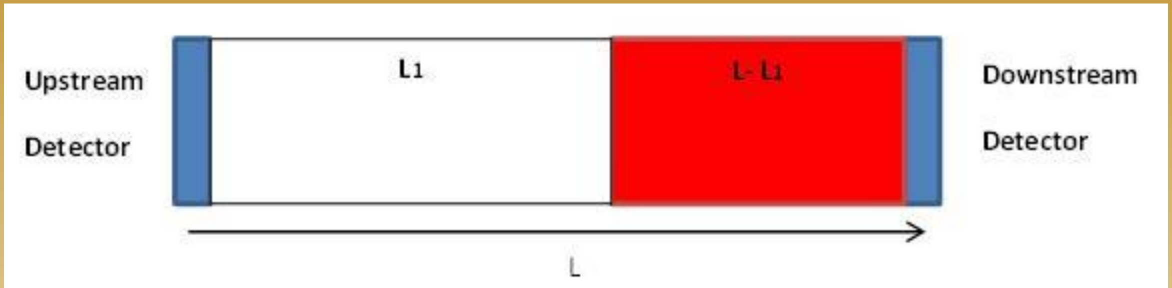
Density Estimation based Combination of AVI and Point Detector Data

- Segmentation Method

$$\frac{L}{u_{s,AVI}} = \frac{L_1}{u_{s,up}} + \frac{L-L_1}{u_{s,down}}$$



L : Total link length, mi

L_1**:** Length of the first subsegment that is assumed to have similar traffic conditions as the upstream detector, mi

L -L_1**:** Length of the second subsegment that is assumed to have similar traffic conditions as the downstream detector, mi

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Density Estimation based Combination of AVI and Point Detector Data (Segmentation Method) (Con't)

Density Estimation for The whole Segment:

- $D_f = \frac{\sum_{i=1}^{n} D_i * L_i * N_i}{\sum_{i=0}^{n} L_i * N_i}$

- Note that the quality of AVI data and detector data has a great impact on the results of this method. Thus, the AVI and point detectors have to be well calibrated and maintained

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Case Studies

Case Study 1: Comparison of density estimation based on:

- **Simulated data**
- **SR826 (0.32 mi)**
- **Virtual AVI readers, upstream and downstream detector data**

Case Study 2: Comparison of density estimation based on:

- **Real-world data**
- **Florida's Turnpike (State Road 821), Milepost (18.4-20.2)**
- **Electronic toll tag data, upstream, downstream and on-ramp historical detector data**

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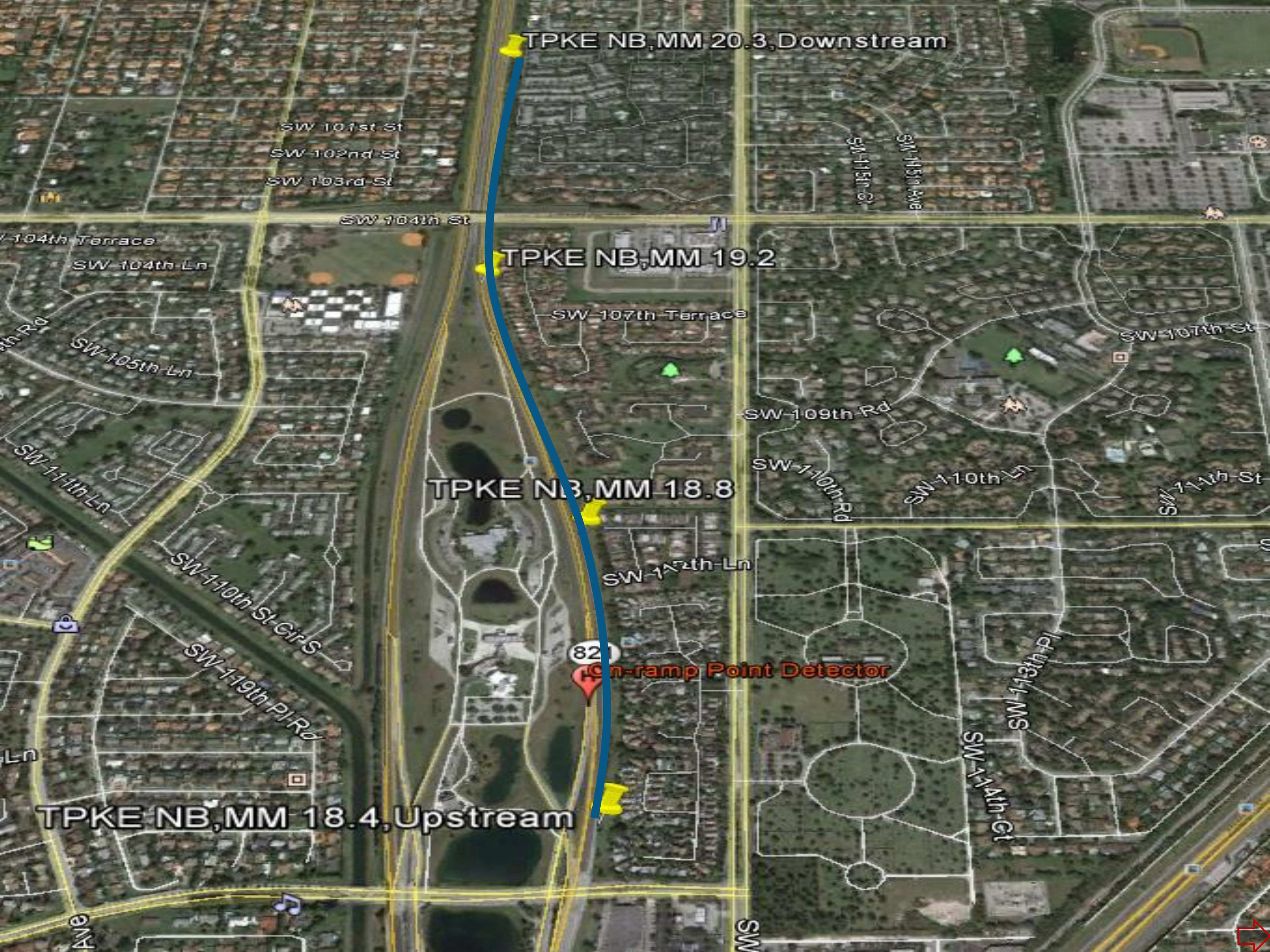
TPKE NB,MM 20.3,Downstream
SW 101st St
SW 102nd St
SW 103rd St
SW 104th St
SW 104th Terrace
SW 104th Ln
TPKE NB,MM 19.2
SW 107th Terrace
SW 107th St
SW 105th Ln
SW 109th Rd
SW 111th Ln
SW 110th Rd
SW 110th Ln
TPKE NB,MM 18.8
SW 110th St Cir S
SW 119th Pl Rd
821
On-ramp Point Detector
SW 113th Pl
SW 114th Ct
TPKE NB,MM 18.4,Upstream

HCM Method Utilizing Highway Capacity Software

- HCM procedure only requires the input of traffic flow at the mainline entrance as well as at on- and off-ramps.
- Freeway facility is **undersaturated:** speed-flow relationship for each type of segment is used to determine the segment speed.
- Freeway facility is **oversaturated:** an analysis that is similar to cell transmission model is used to estimate the number of vehicles on the segment and in turn the segment density.
- HCM 2010 procedure-based **Highway Capacity Software(HCS)** is used in this research.

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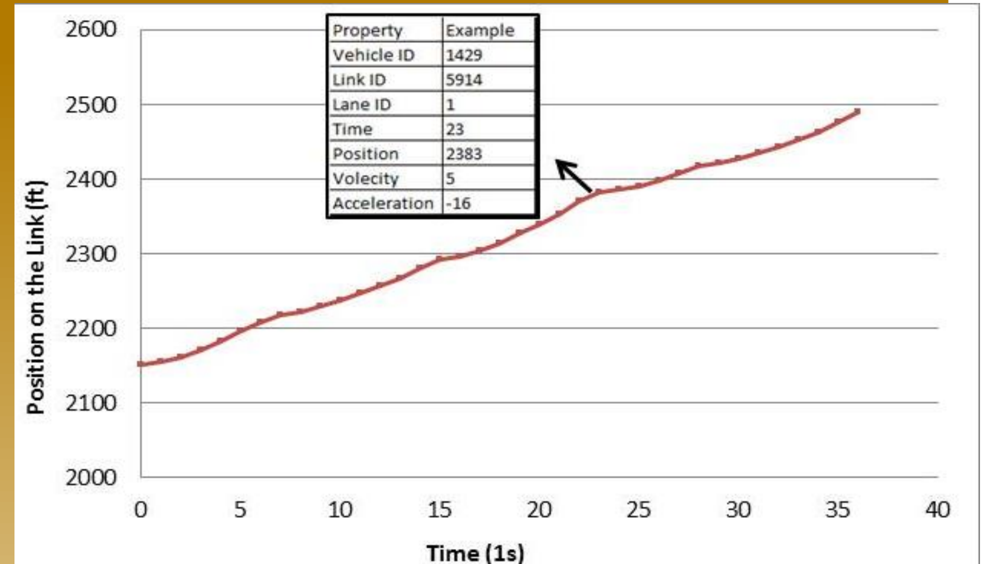
Evaluation of Performance Measurement Methods

1. Simulated data



- Vehicle trajectory data (ground Truth data)
- Reference method

2. Real world data

- Goodness of fit functions (RMSE, MAPE)

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(D_{t,e} - D_{t,a})^2}$$

$$MAPE = \frac{1}{N}\sum_{t=1}^{N}\frac{|q_{t,e} - q_{t,a}|}{q_{t,a}} * 100$$

- Maximum positive, Minimum negative differences

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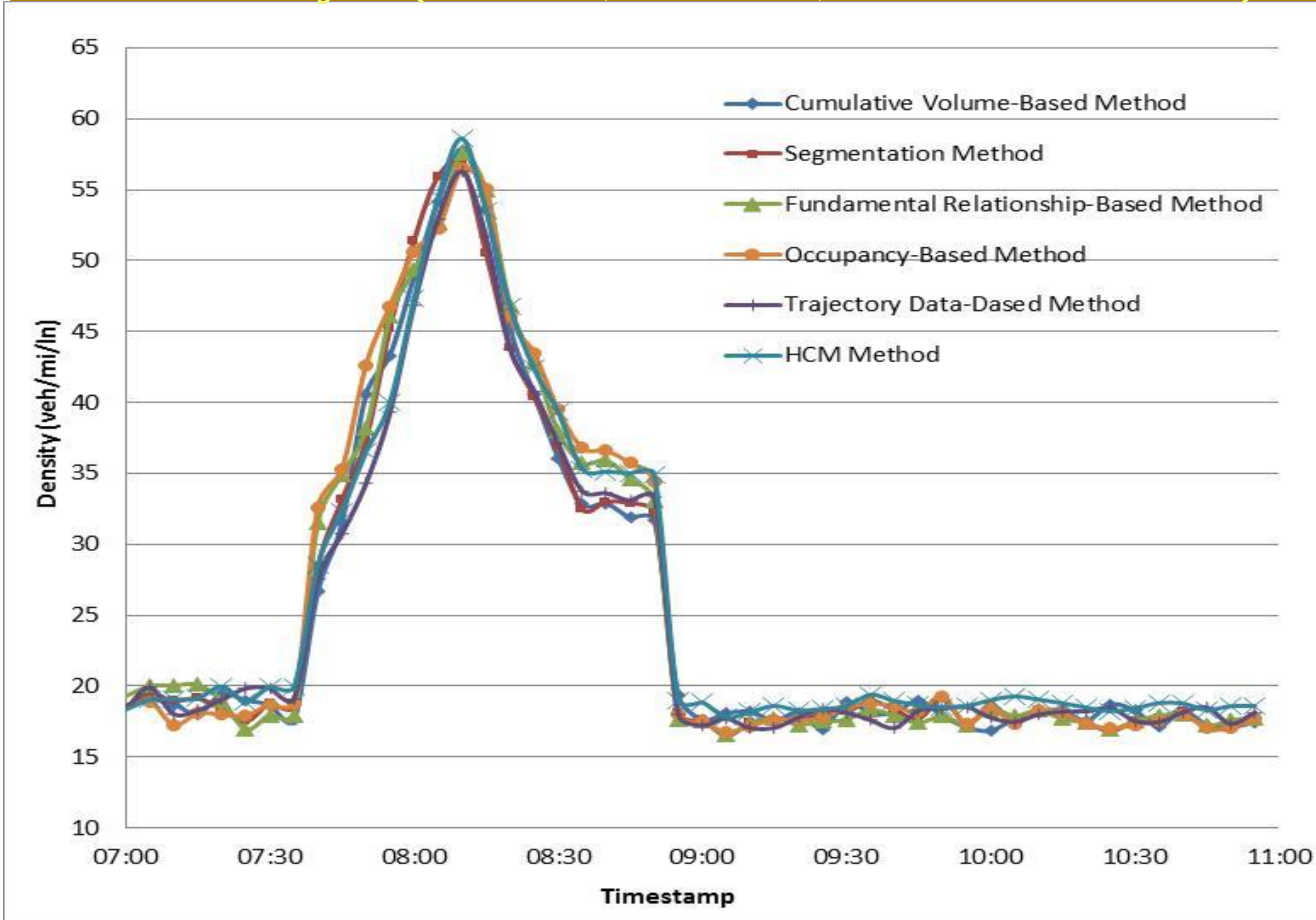
Case Study 1 (SR 826, 0.32 mi, Simulated Data)



Case Study 1 (SR 826, 0.32 mi, Simulated Data)

Comparison	Fundamental relationship-Based Method	Occupancy-Based Method	Segmentation Method	Cumulative volume-Based Method	HCM Method
RMSE (veh/mi/ln)	2	2	2	1	1
MAPE (%)	5.2	5.3	3.8	3.9	4.4
Maximum Positive Difference Compared to the Trajectory Method (veh/mi/ln) [%]	7 [12%]	8 [14.9%]	6 [10.7%]	6 [11.1%]	3 [5.3%]
Minimum Negative Difference Compared to the Trajectory Method (veh/mi/ln) [%]	-3 [-5.1%]	-2 [-3.4%]	-2 [-4.2%]	-2 [-2.9%]	-1 [-1.7%]

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Estimated LOS for Case Study 1

Time	Fundamental relationship-Based Method	Occupancy-Based Method	Segmentation Method	Cumulative volume-Based Method	HCM Method	Trajectory Data-Based Method
7:00		C	C	C	C	C
7:15	C	C	C	C	C	C
7:30	D	D	D	D	D	D
7:45	F	F	F	E	E	E
8:00	F	F	F	F	F	F
8:15	F	F	F	F	F	F
8:30	E	E	E	E	E	E
8:45	D	E	D	D	E	D
9:00	B	B	B	C	C	B
9:15	B	B	C	C	C	C
9:30	C	C	C	C	C	C
9:45	B	C	C	C	C	C
10:00	C	C	C	C	C	C
10:15	B	C	C	C	C	C
10:30	C	C	C	C	C	C
10:45	B	B	B	B	C	C

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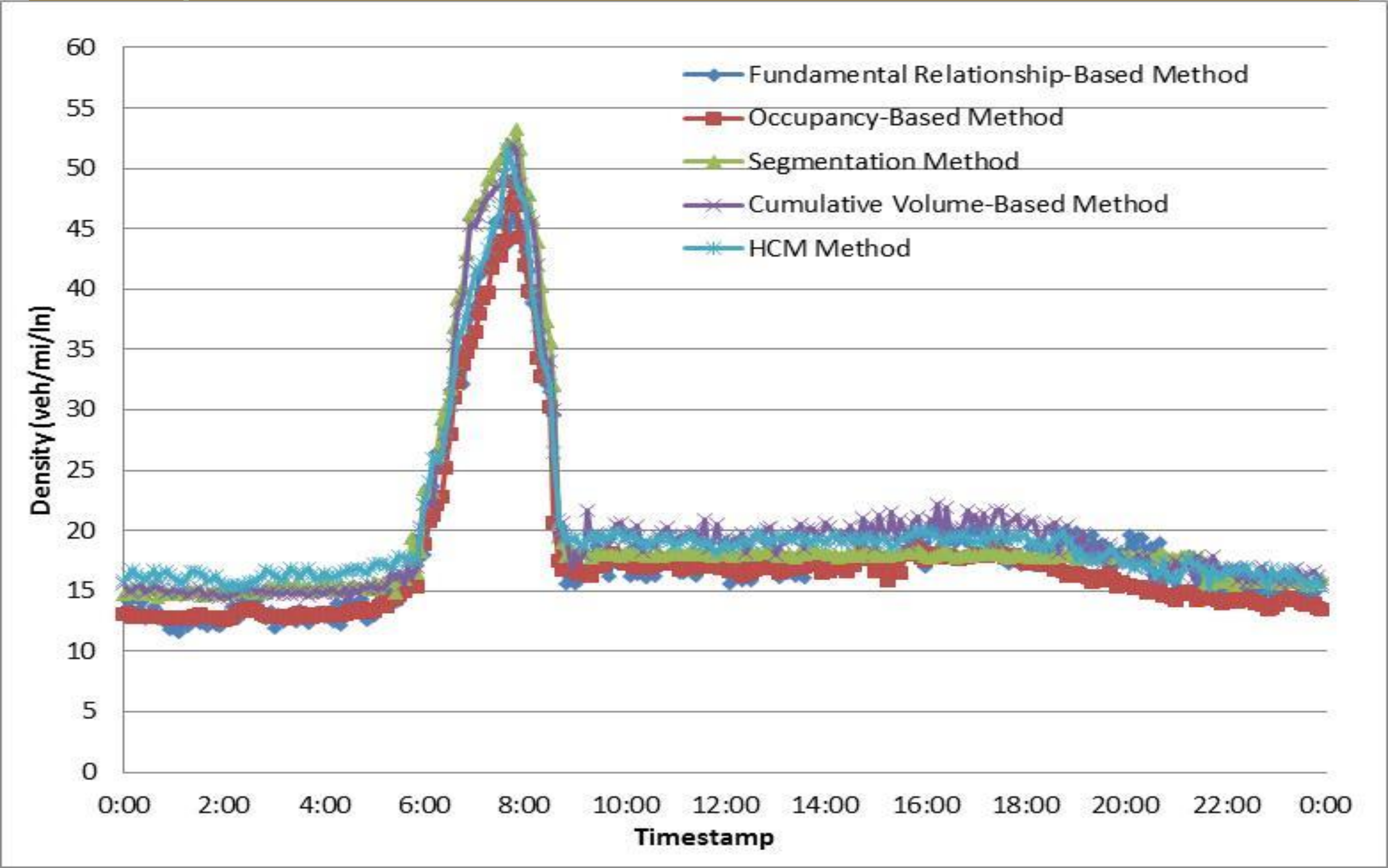
Case Study 2 (Florida's Turnpike,1.8 mi, Real-wold Data)



Case Study 2 (Florida's Turnpike,1.8 mi,Real-wold Data)

Comparison	Fundamental relationship-Based Method	Occupancy-Based Method	Segmentation Method	Cumulative Volume-Based Method
RMSE (veh/mi/ln)	2	3	2	2
MAPE (%)	10.5	12.8	6.4	5.4
Maximum Positive Difference Compared to the HCM Method (veh/mi/ln) [%]	3 [6.3%]	0.3 [0.5%]	6.9 [13.9%]	6.1 [12.2%]
Minimum Negative Difference Compared to the HCM Method (veh/mi/ln) [%]	-8 [-15.5%]	-6 [-11.6%]	-3 [-5.6%]	-4 [-7.3%]

Estimated LOS for Case Study 2

TIME		Fundamental relationship-Based Method	Occupancy-Based Method	Segmentation Method	Cumulative Volume-Based Method	HCM Method
AM Peak	6:00	C	C	C	C	C
	6:15	D	C	D	D	D
	6:30	D	D	E	E	E
	6:45	E	E	F	F	E
	7:00	E	E	F	F	E
	7:15	F	E	F	F	F
	7:30	F	F	F	F	F
	7:45	F	F	F	F	F
	8:00	E	E	F	F	F
	8:15	E	D	E	E	E
	8:30	D	D	E	D	D
	8:45	B	B	C	C	C
PM Peak	15:30	C	C	C	C	C
	15:45	C	C	C	C	C
	16:00	C	B	B	C	C
	16:15	C	C	C	C	C
	16:30	C	B	C	C	C
	16:45	C	B	C	C	C
	17:00	C	C	C	C	C
	17:15	C	C	C	C	C
	17:30	C	C	C	C	C
	17:45	C	B	B	C	C
	18:00	C	B	B	C	C
	18:15	C	B	B	C	C

Conclusion

The highest differences between the estimates from the tested methods occur during the partial queues, the transition between the uncongested and fully queued segments, on the segments.

The density estimates from proposed segmentation method, cumulative volume method, and HCM methods are also closer to density measurements obtained based on vehicle trajectories from simulation result.

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Cumulative Volume-based method using point detectors produces poor estimates(requires additional ramp detection and assumptions average vehicle length).

If ramp information is not available and AVI data is available, it would be recommended that the proposed segmentation method is applied to estimate density.

The study results indicate that the selection of density estimation method mainly affect the value of LOS during the intermediate congested conditions, in which the segment is not fully queued.

Thank You for Your Attention

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