Bluetooth as a Reliable, Cost-Efficient TDM Data Collection Method- FM Pilot Study

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Transportation Seminar Series
December 6, 2011

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Outline

* Objectives
* Need For Study
* Travel Demand Models
* TDM OD/Travel Time Data Collection Methods
* Bluetooth Technology
* Study Area
* Methodology
* Data Analysis
* Results and Conclusions

Objective

* Evaluate Bluetooth as reliable cost-efficient EI/EE OD/Travel time data collection method
* Compare Results with TDM Model
* Propose method to estimate length of time required to collect statistically valid Bluetooth OD data in relation to counts

Need for Study

* Unknown EE OD
  * Percentage of "interstate" traffic using interstate unknown
* EE OD study needed to calibrate and validate TDM and Traffic Ops Studies
  * Previous attempt at EE OD study costly and garbage

Travel Demand Models

* Forecast Traffic at Macro scale
* Trip Gen
  * Socioeconomic variables
* Trip Distribution
* Modal Split
* Traffic Assignment
  * Calibrated and validated against ground truths
* Validation of Other Modules Lacking

Travel Time Data Collection

* Travel Time
  * GPS Tracking
  * Cell Phone Geolocation
  * Toll Tags
  * Test Vehicle
* Issues
  * Privacy Concerns
  * Accuracy of Travel Time measurement
  * Availability

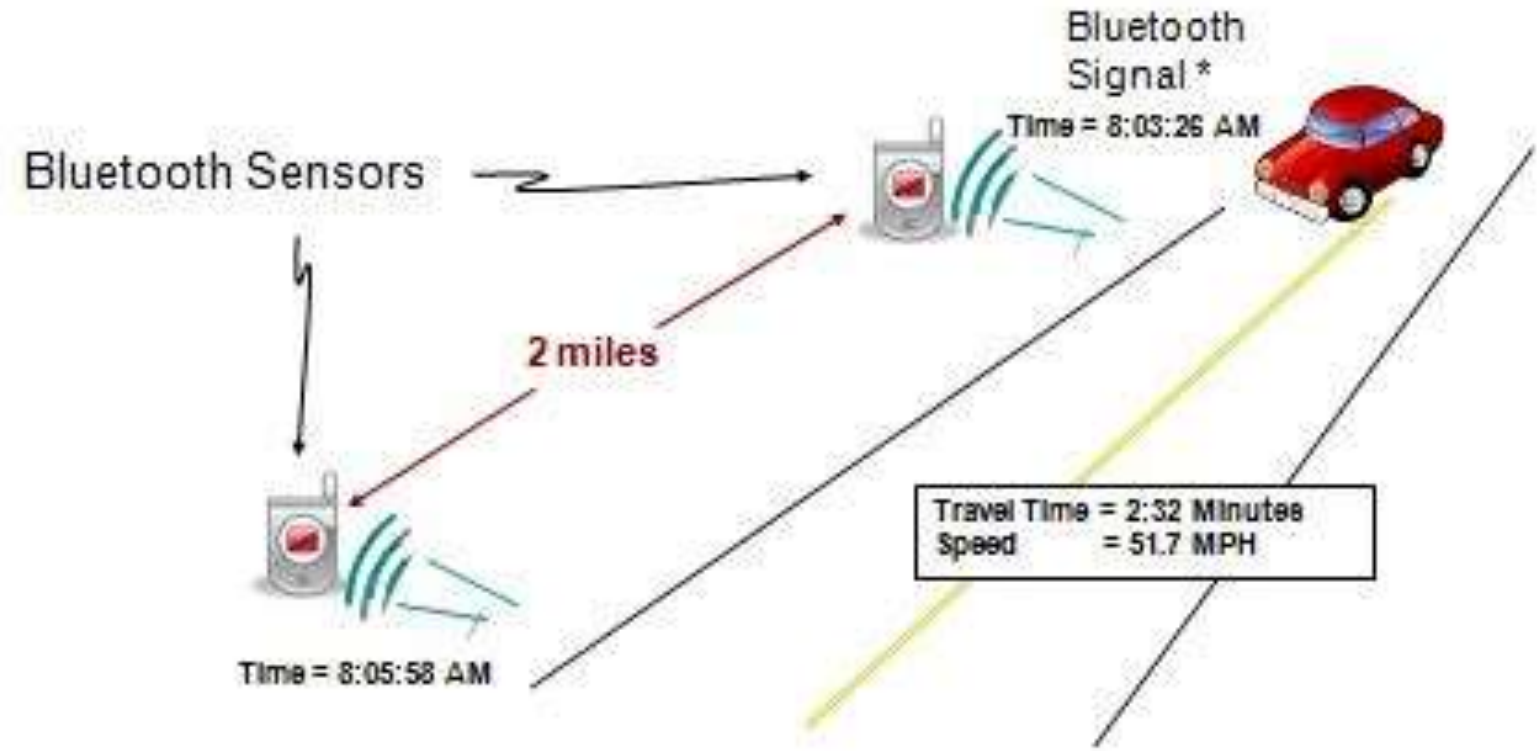
Vehicle OD Data Collection Methods

* Vehicle License Plate Recognition
  * Fargo 2008
* Intercept Surveys
  * Bismarck 2009 (URS Study)
* GPS
* Issues
  * Cost
  * Accuracy
  * Illegal in some States, ND

Bluetooth

* Industry Specification that defines how devices can be interconnect using short range wireless com

How it Works



* Bluetooth signals come from cell phones, PDAs, laptops, GPS, car radios...
** Provisional patent received

Bluetooth Equipment-BluFax

BluFax Equip Specifications

* Battery, sensor, usb card
* 50 M radius
  * Height affects detection rates
* Data not directional
* BluStats Software

Sample BluStats Processed Data

MACID	MACIDNUM	YEAR	MONTH	DAY	HOUR	MIN	SEC	HITS	SPAN_MINUTES
'00054FD88145'	2.28E+10	2011	9	17	8	51	29	2	0.08
'00136C1ACB9A'	8.34E+10	2011	9	17	8	51	39	1	0
'00054FD7B85F'	2.28E+10	2011	9	17	8	54	8	2	0.1
'00054FD85234'	2.28E+10	2011	9	17	8	56	43	1	0
'00121C1461D8'	7.78E+10	2011	9	17	8	58	41	1	0
'E83EB6C840C8'	2.55E+14	2011	9	17	9	2	17	1	0
'00121CFFB8EC'	7.78E+10	2011	9	17	9	26	36	1	0
'001EB221E20B'	1.32E+11	2011	9	17	9	30	58	1	0
'000E9F2914FF'	6.28E+10	2011	9	17	9	34	29	1	0

Bluetooth Travel Time Studies

* PennDOT, California (San Francisco), I-95 Corridor Validation Study (Washington DC Metro)
  * Compared Bluetooth to Toll Tags
  * Match Rates About 4%
  * Cost is fraction 1/3 Toll Tags
  * Easy To use
  * Tags must be present to use
  * Validates Bluetooth as a TT data collection method

Bluetooth for OD Studies

* Few Studies
* Advantages
  * Continuous Data Collection
  * Relatively Cheap
* Issues
  * Selection Bias
    * Geography, population, vehicle type, double counting etc
  * Statistical Validity
    * How long should data be collected?

Methodology

* Collect Bluetooth Data at Three External Locations In Fargo Using Blufax Inc Sensors
* Collect Traffic Count Data Using SmartSensor Radar at one Location
* Compare results with FM TDM
* Propose Model that can be used to Estimate Statistically Valid Sample Size for Bluetooth Studies

Data Collection Locations

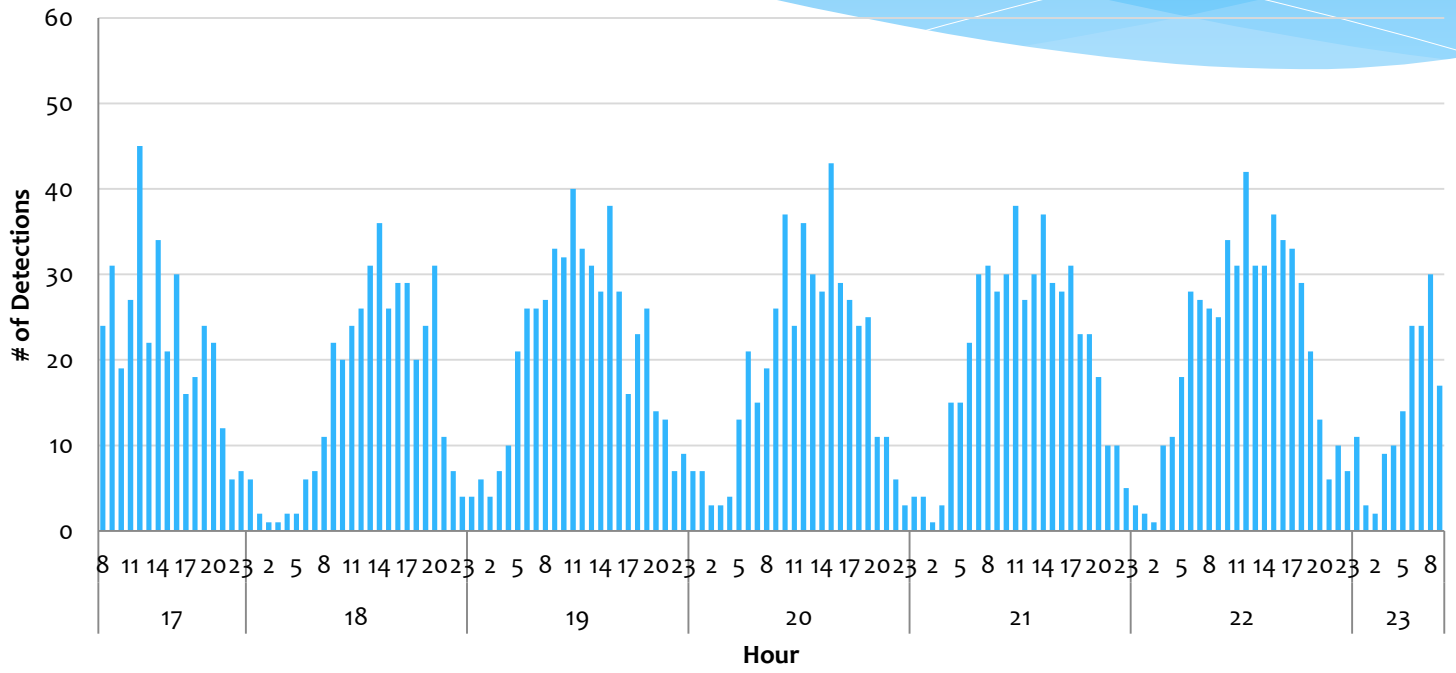
Results and Analysis

* Are we getting any data
  * Overall detection rates for each location
* Travel time analysis
  * Compare with TDM
* OD analysis
  * Compare with TDM

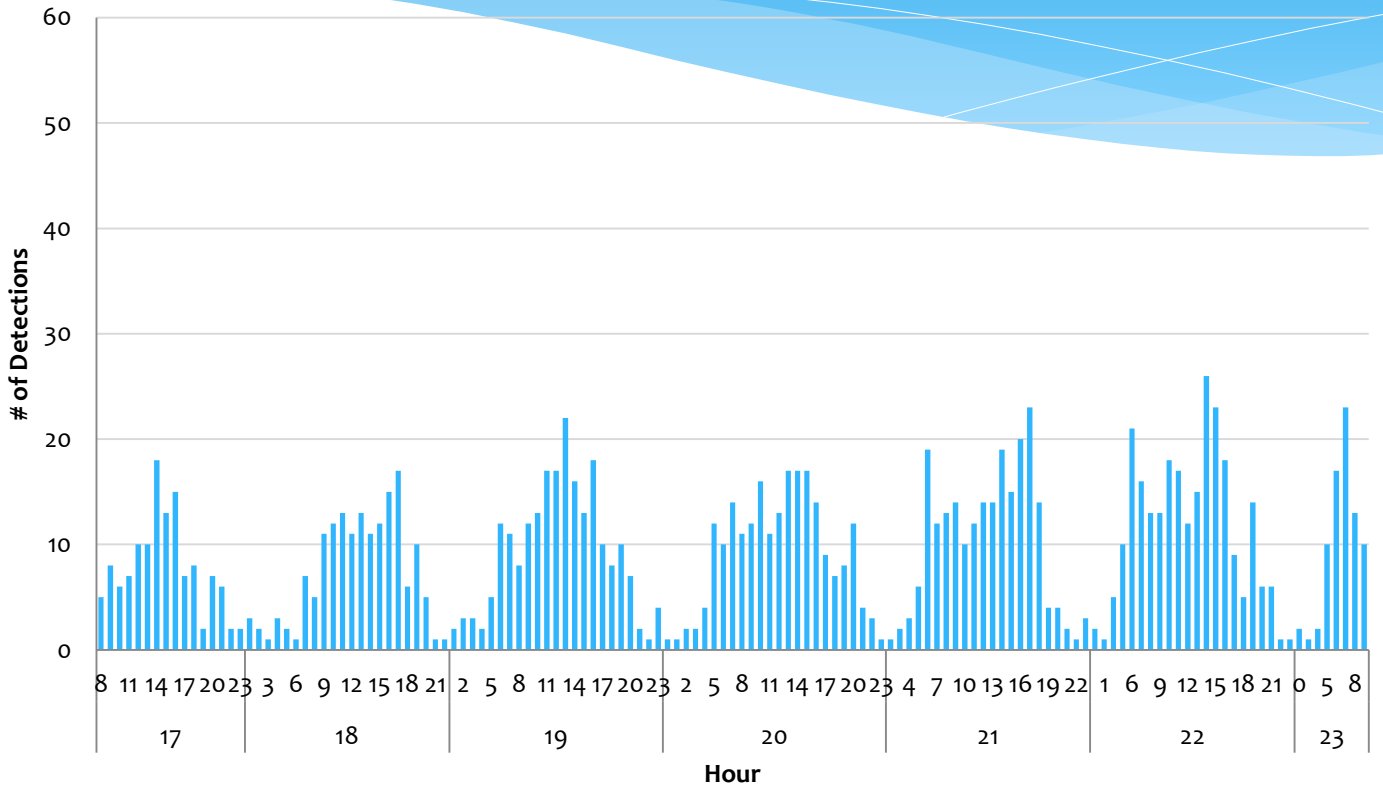
Descriptive Statistics (Detected)

Time Period	Mean	Std. Dev	Range
I-29 North			
AM Peak (7-9AM)	21.90	8.37	7-31
PM Peak (4-6PM)	28.40	4.90	16-34
AM/PM Peak	25.15	7.46	7-24
Overall Hourly	19.45	11.82	1-43
I-29 South			
AM Peak (7-9AM)	11.0	3.4	5-16
PM Peak (4-6PM)	15.3	4.8	9-23
AM/PM Peak	13.2	4.6	5-23
Overall Hourly	9.5	6.3	1-26
I-94 East			
AM Peak (7-9AM)	21.0	5.6	12-31
PM Peak (4-6PM)	34.1	5.5	12-40
AM/PM Peak	27.6	8.6	12-40
Overall Hourly	20.7	12.7	1-52

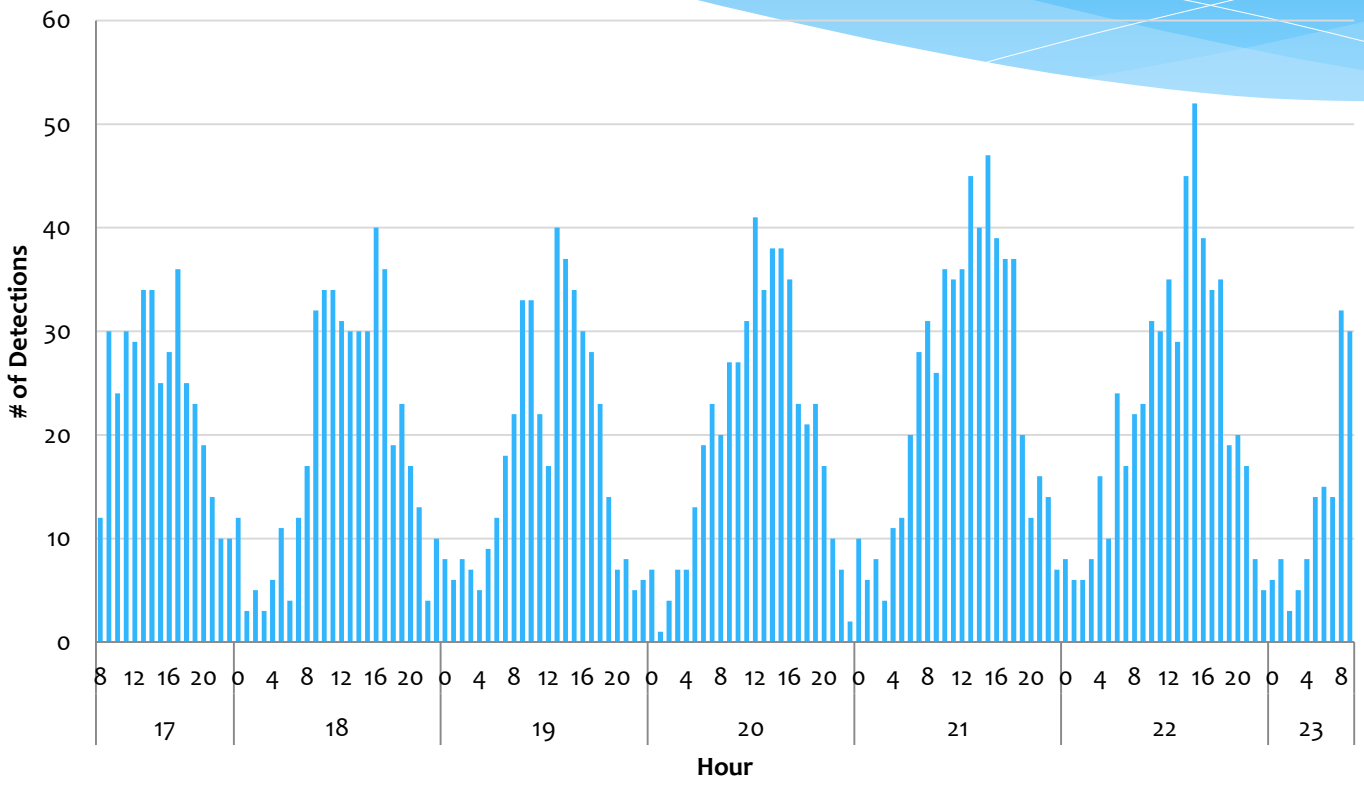
I-29 N Detections



I-29S Detections



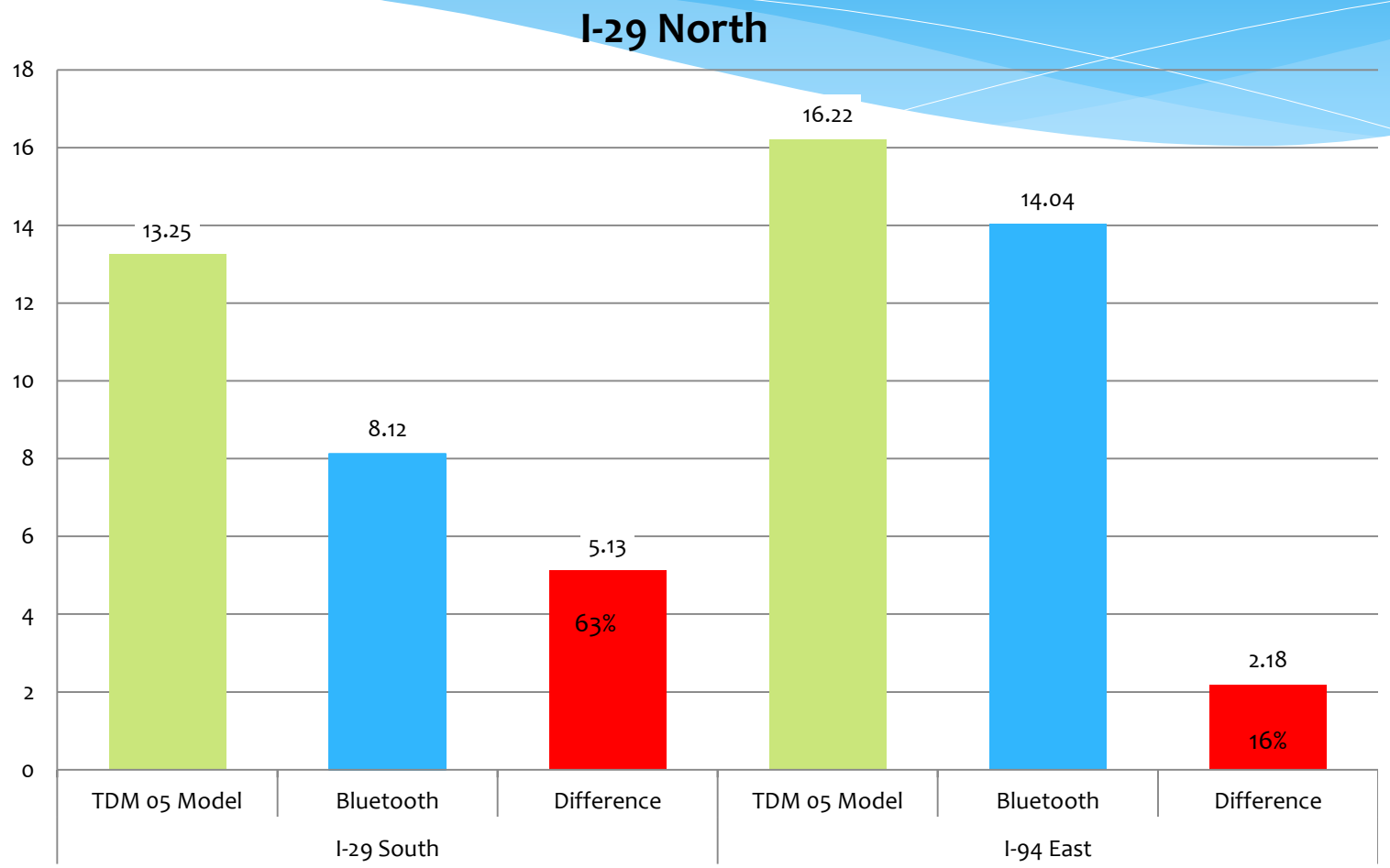
I-94 East Detections



Detection Rates

Bluetooth Sensor	Direction	Directional ADT	Detection Rate (%)
I29North	Southbound	10868	3.17
I29South	Northbound	6198	2.60
I94East	Eastbound	7553	5.09

Bluetooth / 2005 TDM Model Travel Time (Mins) Analysis



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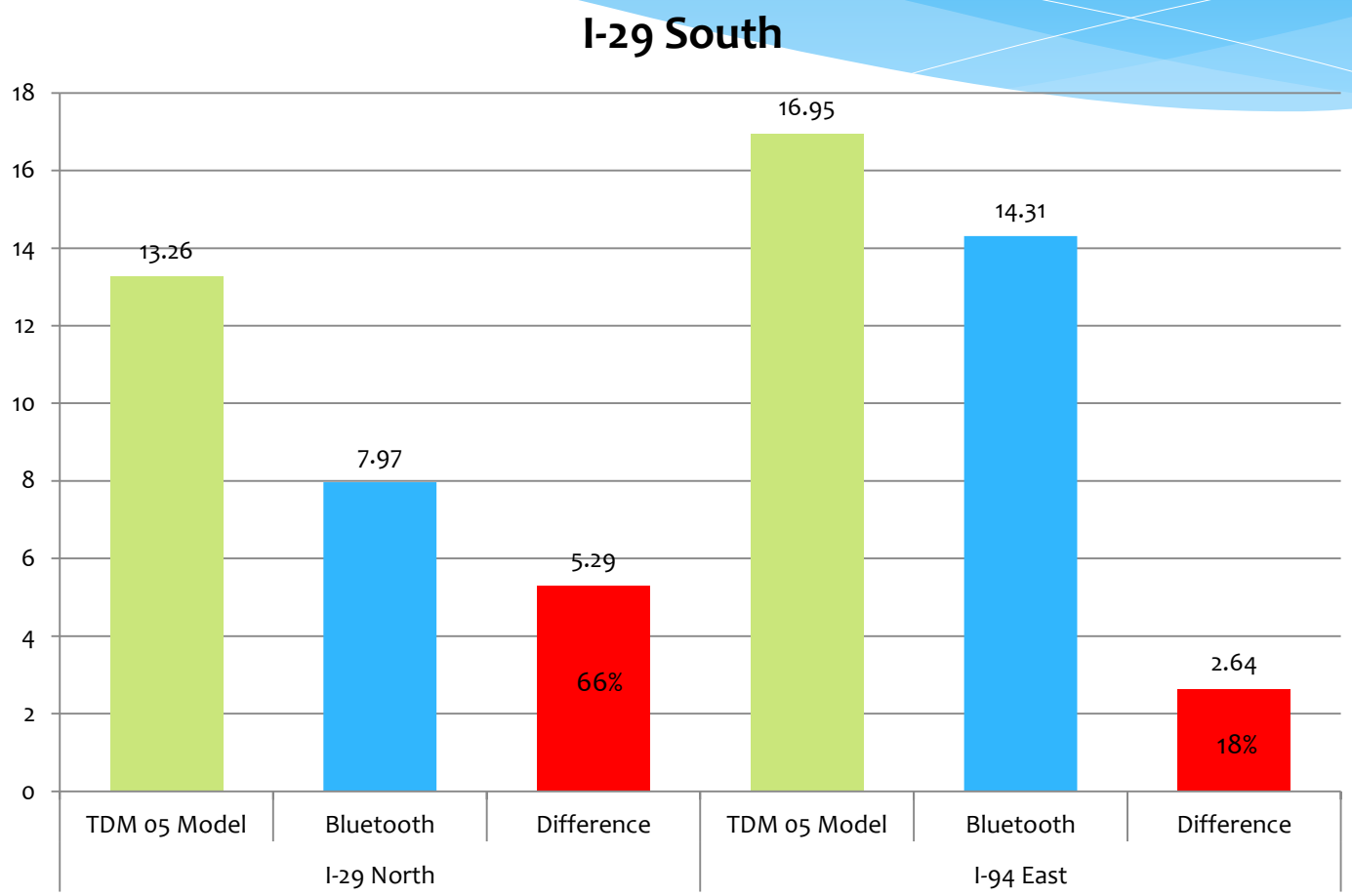

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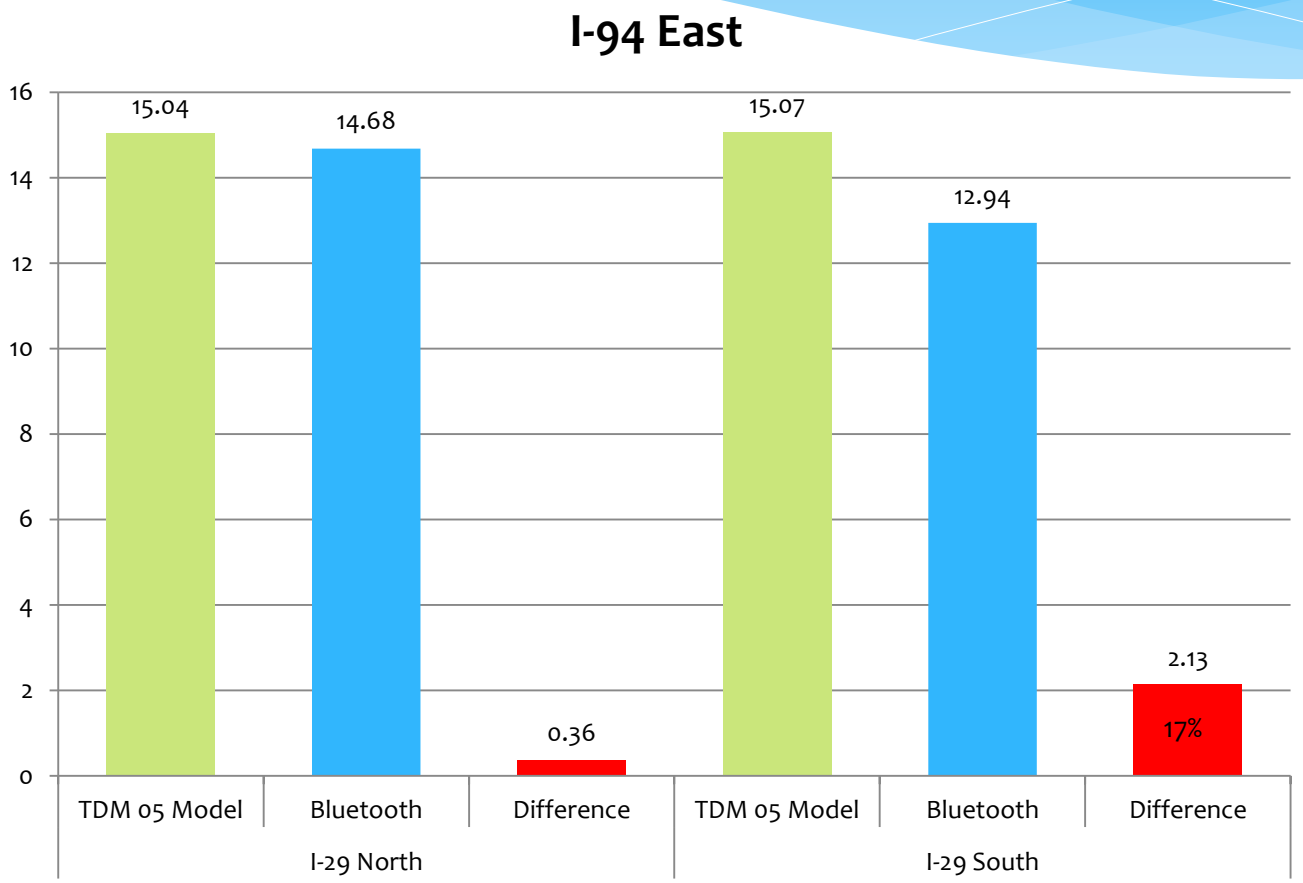

Bluetooth vs Modeled ODs

Bluetooth

Begin station	End station		
	I-29 North	I-29 South	I-94 East
I29North		45	8
I29South	31		13
I94East	56	74	

Modeled

Begin station	End station		
	I-29 North	I-29 South	I-94 East
I-29 North		94	129
I-29 South	94		82
I-94 East	129	82	

Bluetooth vs Modeled OD %

Bluetooth

Begin station	End station		
	I-29 North	I-29 South	I-94 East
I-29 North		3.34%	0.59%
I-29 South	5.17%		2.17%
I-94 East	3.91%	5.17%	

Modeled

Begin station	End station		
	I-29 North	I-29 South	I-94 East
I-29 North		1.02%	1.40%
I-29 South	1.60%		1.39%
I-94 East	1.61%	1.02%	

Sample Size Determination

* Based on counts what is appropriate number of days to collect data?
* Hajek Equation
* $r = \frac{Z^2 pq}{[(N-1)w^2 + (Z^2 pq)]}$
* r = detection rate (unknown and assumed)
* p = estimated proportion of traffic at sensor location between a particular OD pair
* q = 1-p
* w= desired accuracy in the estimates of p
* N = directional traffic count
* Z= confidence level

Number of Days to Collect Data in FM Metro at 95% Confidence

BluFAX Sensor Location	Desired Accuracy			
	±5%	±10%	±15%	±25%
I29North	74	19	**8**	3
I29South	130	32	**14**	5
I94East	107	27	**12**	4

Cost Comparison To AVLP

* Bluetooth ~ $16,000 for 14 days for 16 units
  * Fraction of AVLP five hour study done in 2008

Findings and Conclusions

* Bluetooth is efficient in collecting TT Data
* Cost effective in collecting OD data
* Low detection rates in FM area
  * Increase number of days data collected
* For OD data more studies need to be done to eliminate/reduce selection bias
  * Age groups, vehicle type, etc
* Current TDM overestimates TT and underestimates EE OD pairs

Acknowledgements

* Gom Ale (GRA ATAC who did all the work)
* BluFax Inc for providing us with test units

Questions