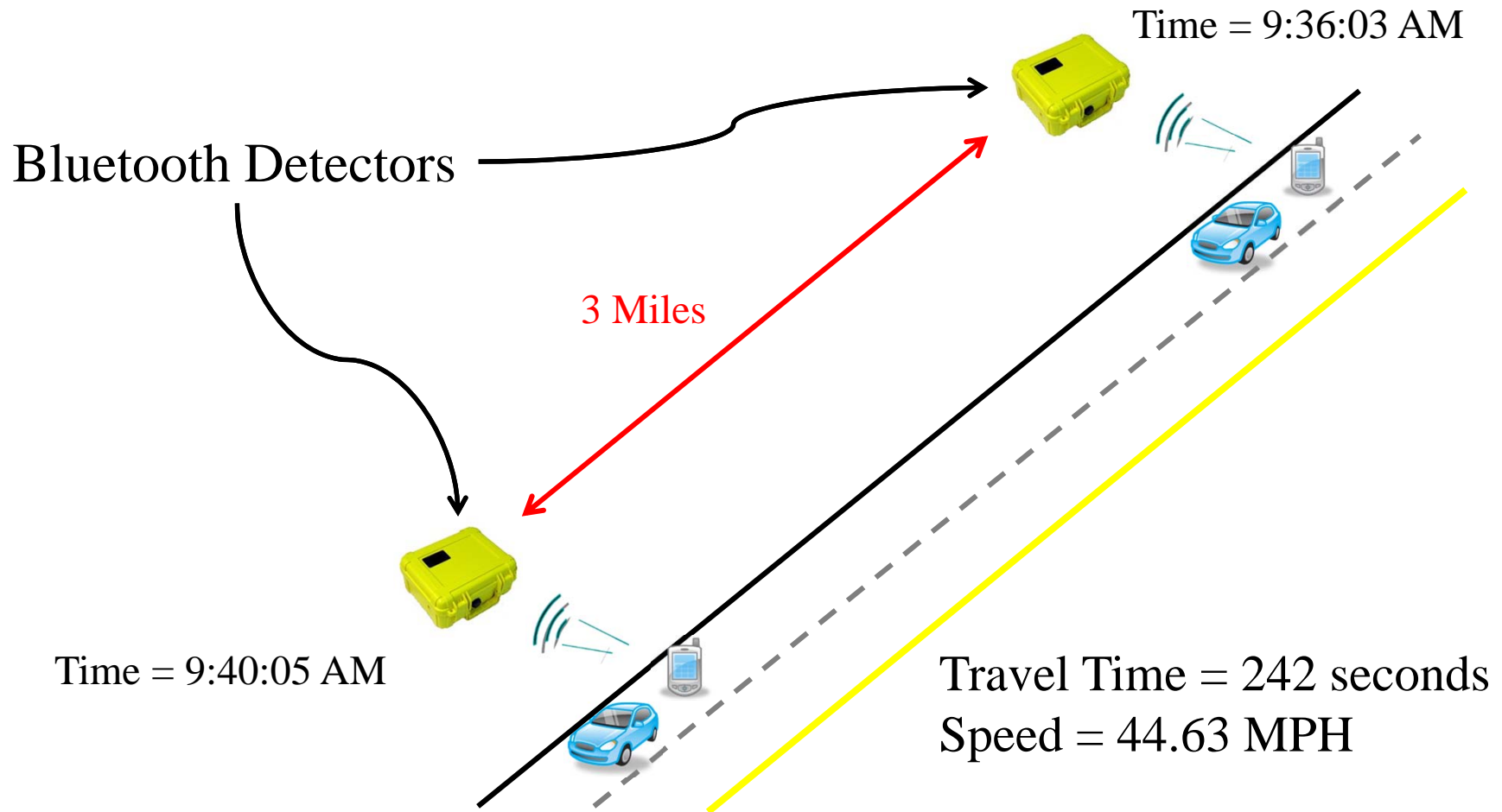


USE OF BLUETOOTH TECHNOLOGY IN TRAFFIC DATA COLLECTION & MANAGEMENT

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What is Bluetooth Technology?

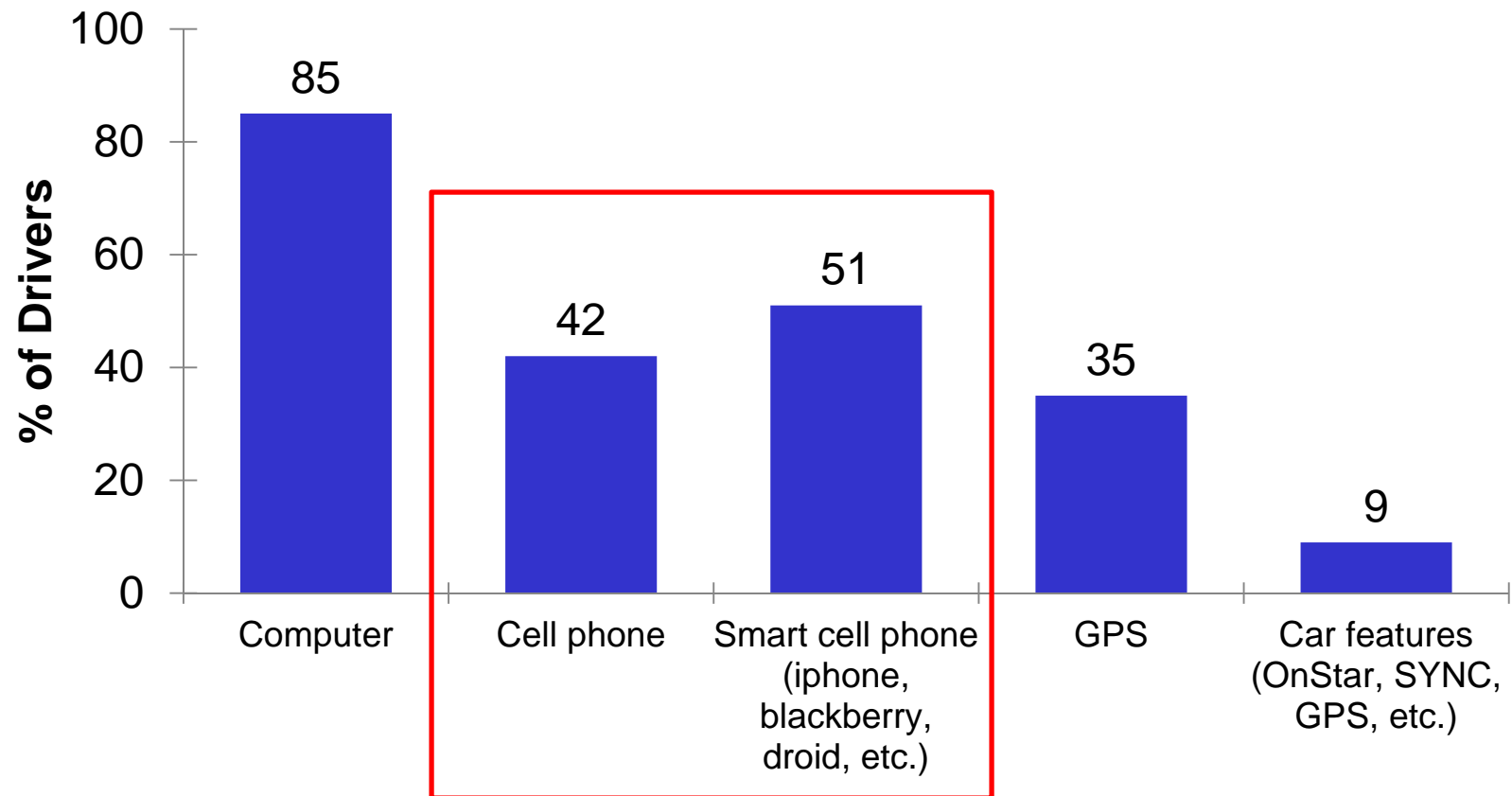


Research Background

- Bluetooth Detectors
 - Provided by TrafficCast (Leased by WisDOT)
 - <http://www.trafficcast.com>
 - Data sets were downloaded on TrafficCast's website
- Research Funding
 - Smart Work Zone Deployment Initiative
 - <http://www.intrans.iastate.edu/smartwz>
 - Wisconsin Department of Transportation

Why is Bluetooth Technology the Future?

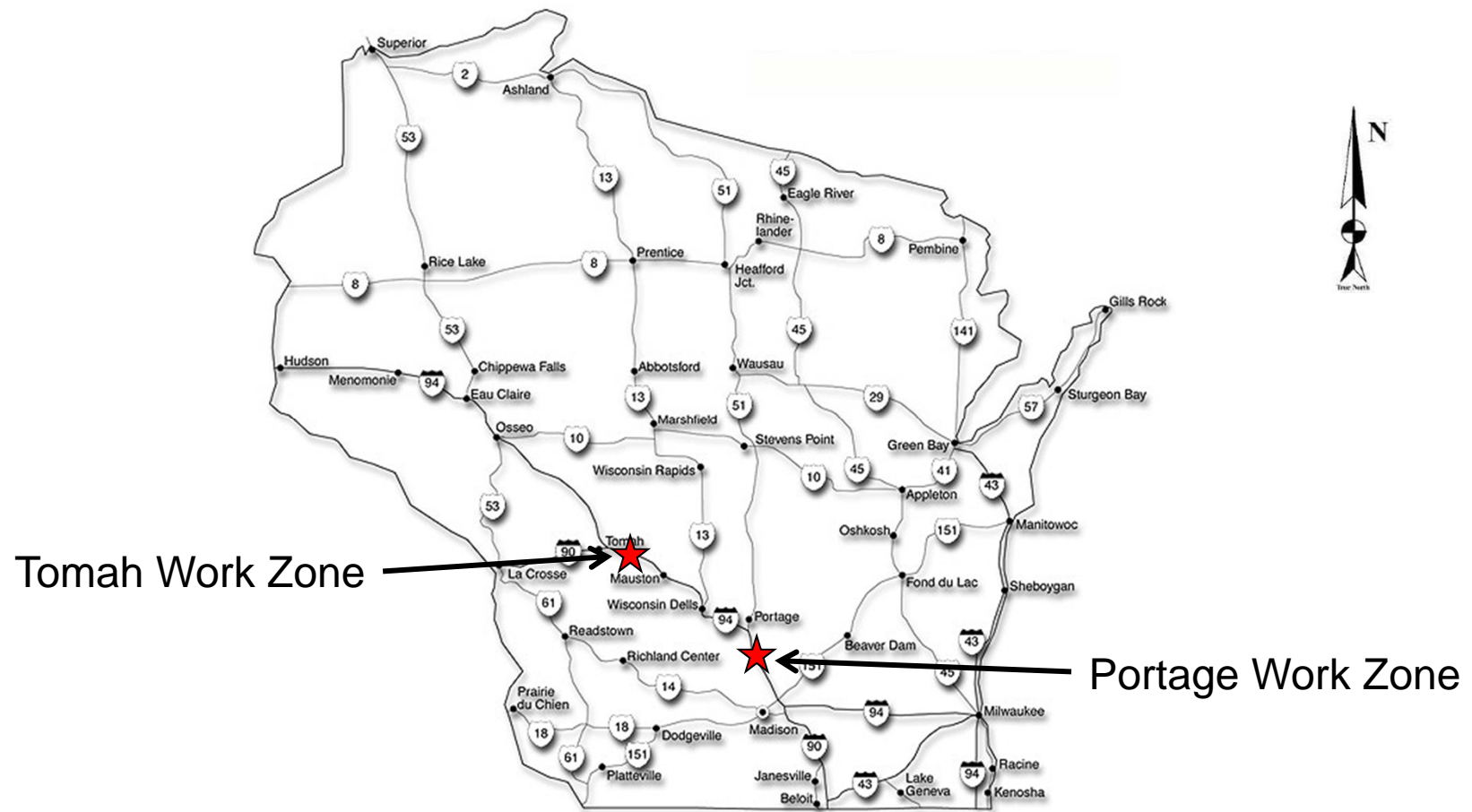
Technological Resources Available to Drivers



Current Presentation

- Discuss how we placed Bluetooth detectors for diversion analysis
- Discuss how many vehicles are really being detected
 - Taking out all of the drivers that stopped along the way
- Discuss if implementation of Bluetooth devices in urban areas is better than rural

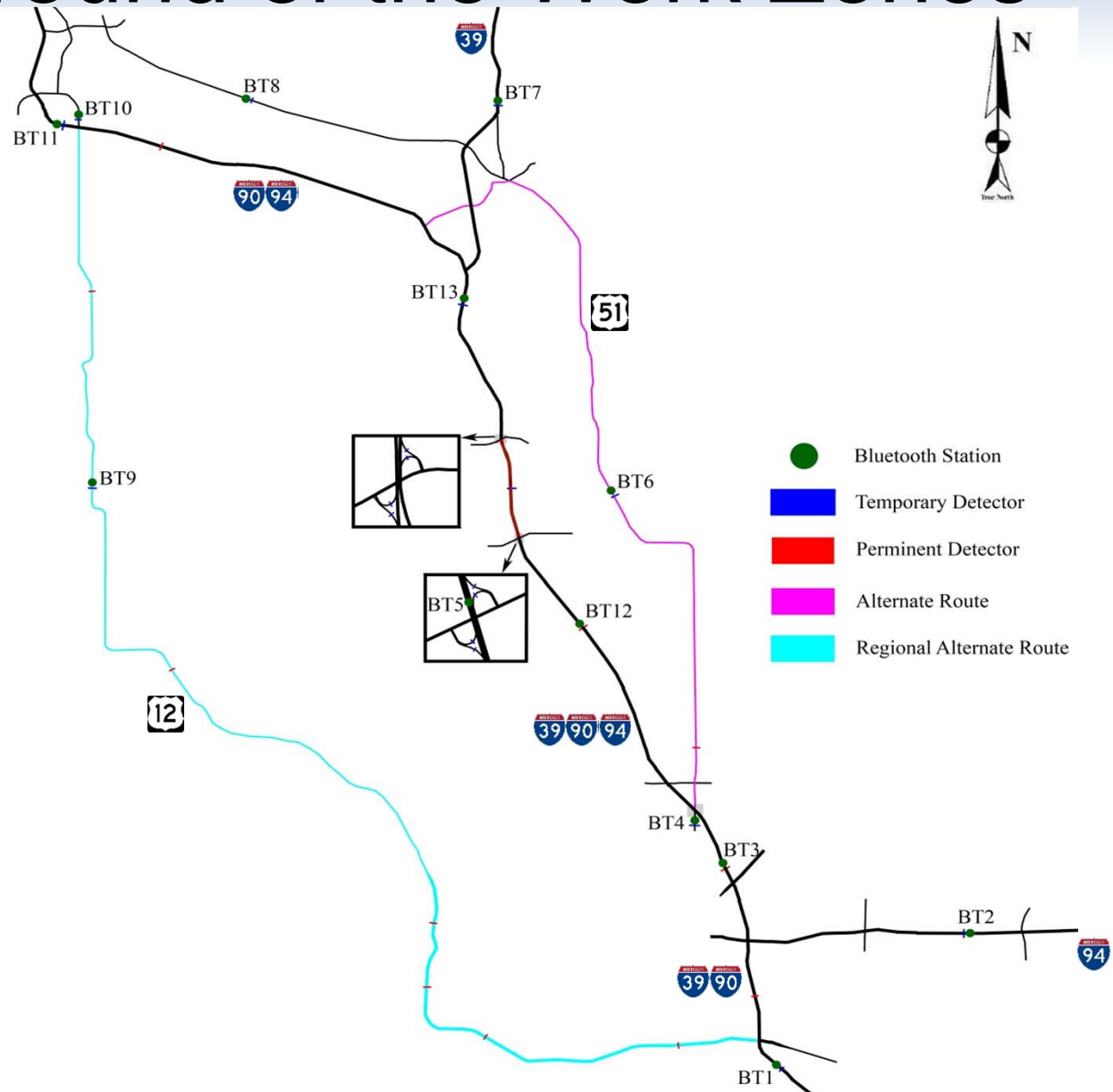
Case Study Locations



Background of the Work Zones

- Portage Work Zone
 - Rural freeway (I-39/I-90/I-94)
 - Gateway from Madison/Milwaukee/Chicago to Minneapolis or Wausau
 - Multiple alternate routes including a regional route
 - Freeway crossover (3 lanes to 2 in each direction)

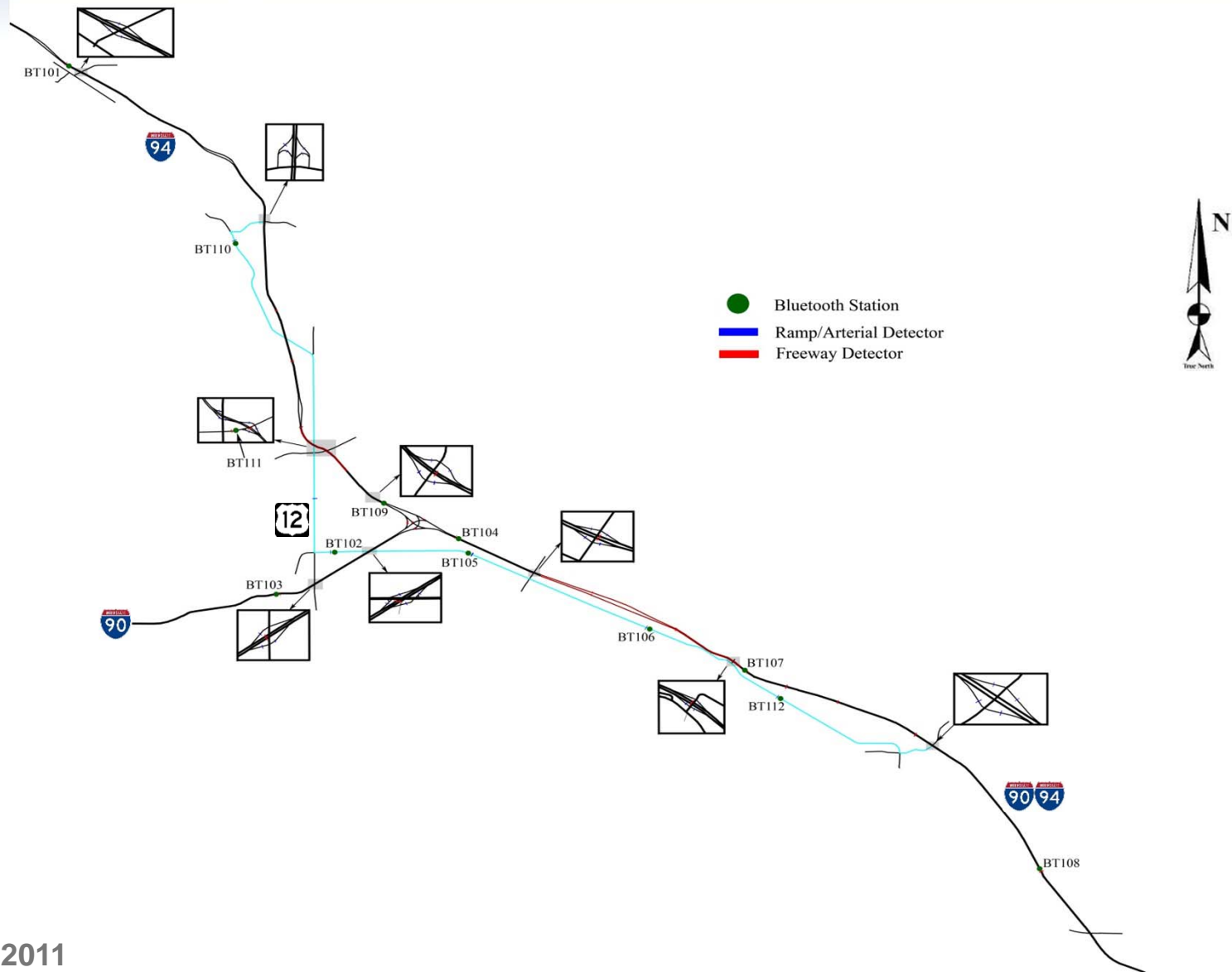
Background of the Work Zones



Background of the Work Zones

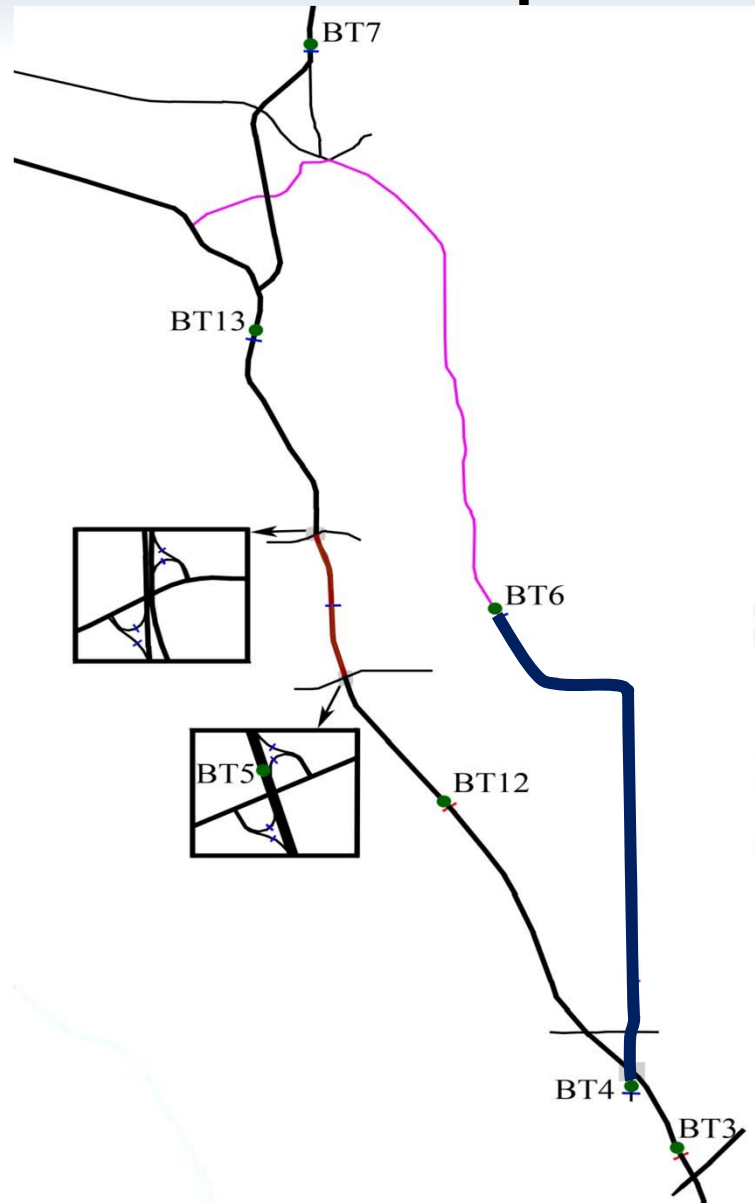
- Tomah Work Zone
 - Rural freeway (I-90/I-94)
 - Gateway from Madison/Milwaukee/Chicago to Minneapolis
 - Two construction zones
 - Only one obvious alternate route
 - Freeway crossover (2 lanes to 1 in each direction)

Background of the Work Zones



Concepts

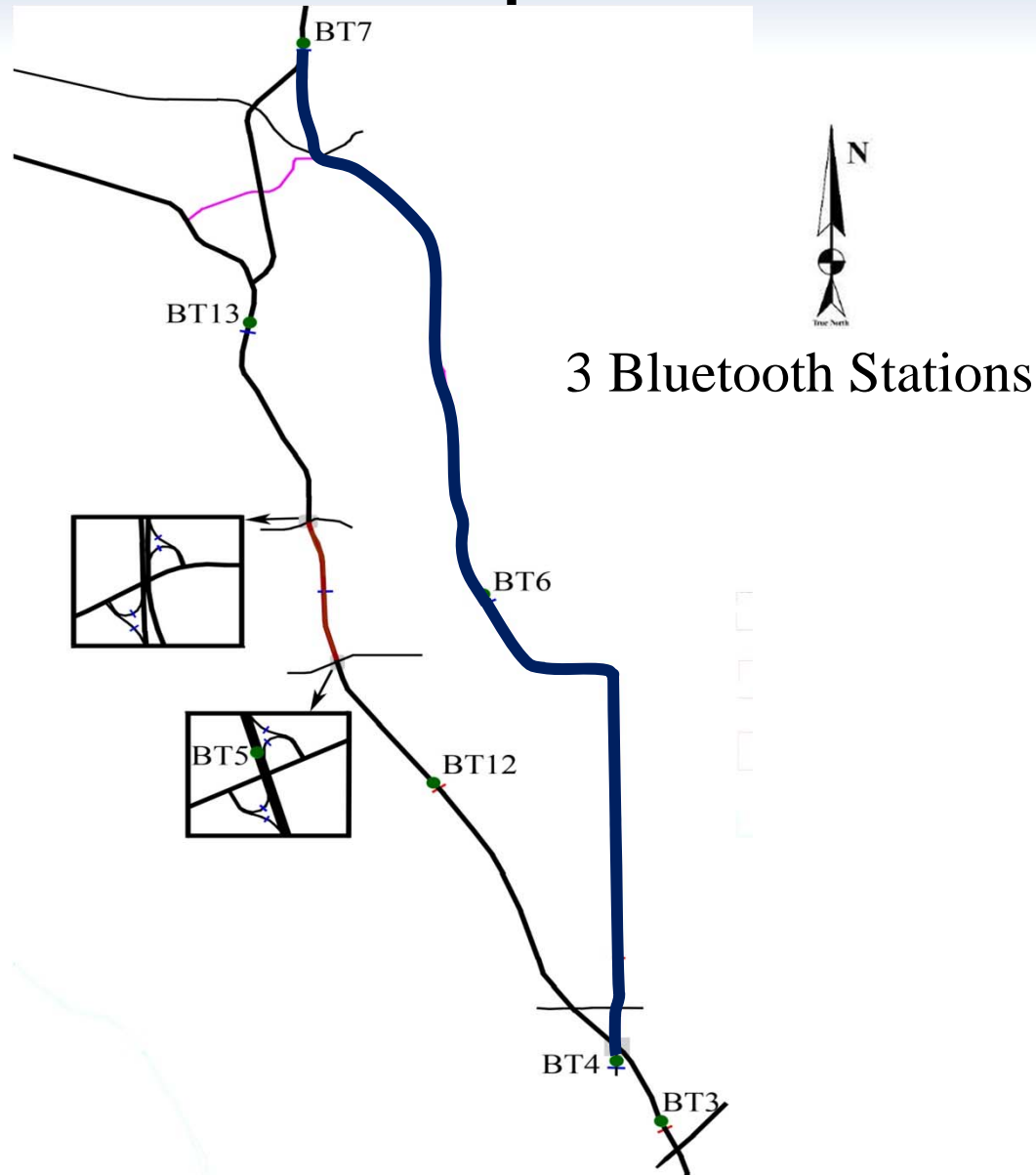
Pair



2 Bluetooth Stations

Concepts

Triple



Concepts

Number of Usable Pairs

- Total number of pairs that pass reasonable travel time filters (filtering out people that stopped and got back on)

True Capture Rate

- Ratio of the number of usable pairs to the total through volume (subtracting the exiting volume)

Bluetooth Triples & Quadruples

- Created a program to filter out unreasonable travel times
 - Created a false positive rate (varied 0% - 10%)

The screenshot shows a Windows application window titled "Find Triples from Doubles". The window has a menu bar with "File" and a toolbar with standard window controls. The main interface includes a "Route" section with radio buttons for "Triples" (selected) and "Quadruples". To the right of this is a "Low Filter" input field set to "120". Below the "Route" section are three text input fields for "Upstream BlueToad Double File", "Middle BlueToad Double File", and "Downstream BlueToad Double File". The first field contains the path "C:\Users\justin\Desktop\BlueToad\BT108 - BT112.txt", the second contains the instruction "Double-click to set file name, for quadruples only", and the third contains "C:\Users\justin\Desktop\BlueToad\BT112 - BT104.txt". To the right of these fields is a "High Filter" section with three spinners set to "1670", "7200", and "1645" respectively. Further right is a "Count" column with three input fields containing "171", "0", and "161". At the bottom left is a "Process Files" button, and at the bottom right is a "Status" field showing "Matches found: 85 (- 1)".

Field	Value
Route	Triples
Low Filter	120
Upstream BlueToad Double File	C:\Users\justin\Desktop\BlueToad\BT108 - BT112.txt
Middle BlueToad Double File	Double-click to set file name, for quadruples only
Downstream BlueToad Double File	C:\Users\justin\Desktop\BlueToad\BT112 - BT104.txt
High Filter (1)	1670
High Filter (2)	7200
High Filter (3)	1645
Count (1)	171
Count (2)	0
Count (3)	161
Status	Matches found: 85 (- 1)

True Capture Rate Modeling

- Linear programming in Excel was used to create a flow balance
 - Using volumes in the field and historical volumes

	A	B	C	D	E
1					
2		I-39/I-90/I-94 South of I-39 Split to South of US 51	Daily Volume	Balanced Vol	GEH
3		South of I-39 Split	34688	35323.27056	3.395391
4		CTH CS Exit	967	966.9997267	8.79E-06
5		CTH CS Entrance	948	947.9990443	3.1E-05
6		I-39/I-90/I-94 South of CTH CS	38046	35304.26988	14.31657
7		STH 60 Exit	1169	1169.000156	4.55E-06
8		STH 60 Entrance	2154	2154.551086	0.011873
9		I-39/I-90/I-94 South of STH 60	35654	36289.82081	3.352378
10					
11					
12		Total GEH	21.07625175		
13					
14					
15		D3 > 0	35323.27056	0	
16		D4 > 0	966.9997267	962	
17		D5 > 0	947.9990443	0	
18		D6 > 0	35304.26988	0	
19		D7 > 0	1169.000156	0	
20		D8 > 0	2154.551086	0	
21		D9 > 0	36289.82081	0	
22		D3 - D4 + D5 = D6	35304.26988	35304.26988	
23		D6 - D7 + D8 = D9	36289.82081	36289.82081	
24		D3 - D4 + D5 - D7 + D8 = D9	36289.82081	36289.82081	
25		D5 < 1010	947.9990443	1010	

Solver Parameters

Set Objective:

To: ☐ Max ☒ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

\$C\$15 >= \$D\$15

\$C\$16 >= \$D\$16

\$C\$17 >= \$D\$17

\$C\$18 >= \$D\$18

\$C\$19 >= \$D\$19

\$C\$20 >= \$D\$20

\$C\$21 >= \$D\$21

\$C\$22 = \$D\$22

\$C\$23 = \$D\$23

\$C\$24 = \$D\$24

\$C\$25 <= \$D\$25

Add
Change
Delete
Reset All
Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Results

- Portage Work Zone
 - 2 days of noticeable congestion
 - Sunday, September 19, 2010 had the most congestion (SB direction)
 - Time intervals: 11:00 AM – 8:00 PM
 - Non-closure comparison: Sunday, March 20, 2011
- Tomah Work Zone
 - 3 days of noticeable congestion
 - Sunday, April 10, 2011 was chosen for this presentation (WB direction)
 - Time Intervals: 2:30 PM – 9:00 PM
 - Non-closure comparison: Sunday, November 12, 2010

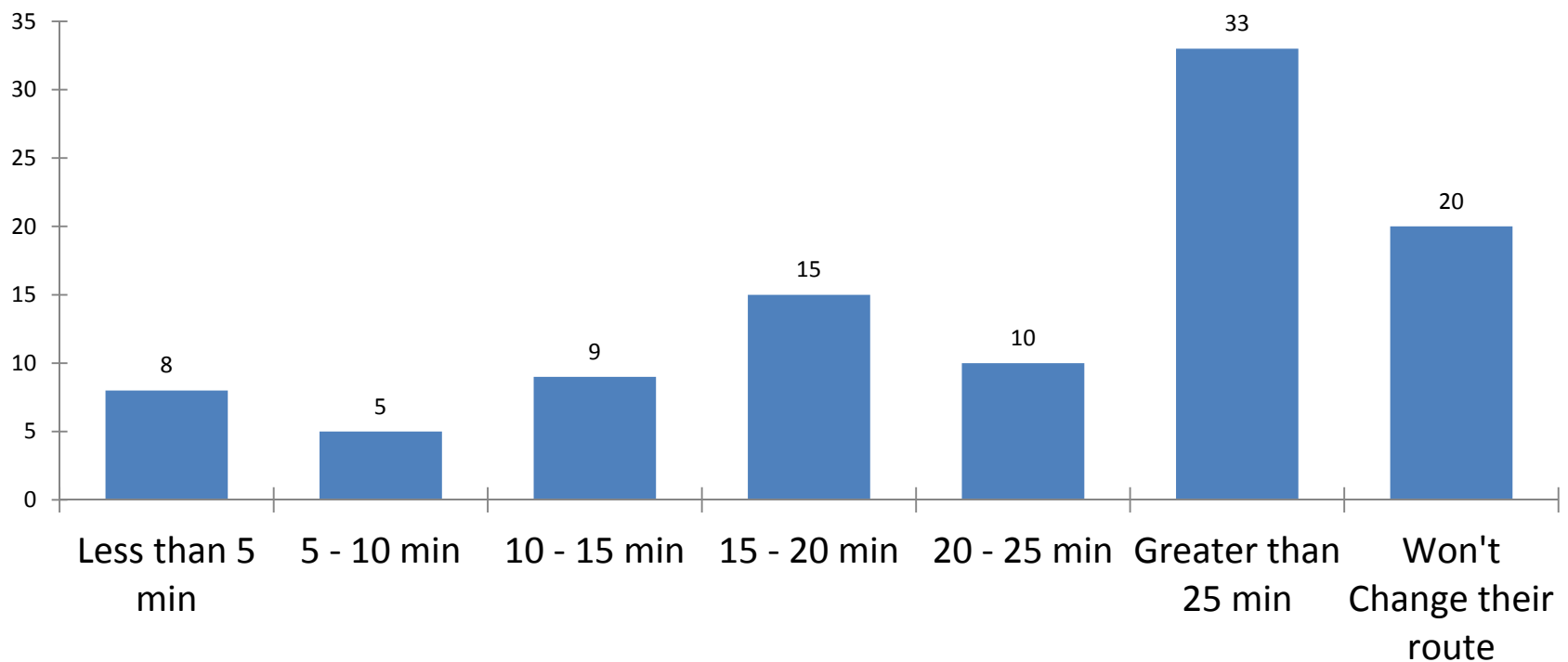
Results

- Travel Time (averaged)
 - Portage Work Zone (BT11 – BT1)
 - Through work zone: 5203 sec. (1 hr. 26 min. 43 sec.)
 - US 51: 4401 sec. (1 hr. 13 min. 21 sec.)
 - US 12: 4085 sec. (1 hr. 8 min. 5 sec.)
 - Tomah Work Zone (BT108 – BT104)
 - Through work zone: 3037 sec. (50 min. 37 sec.)
 - US 12: 2271 sec. (37 min. 51 sec.)

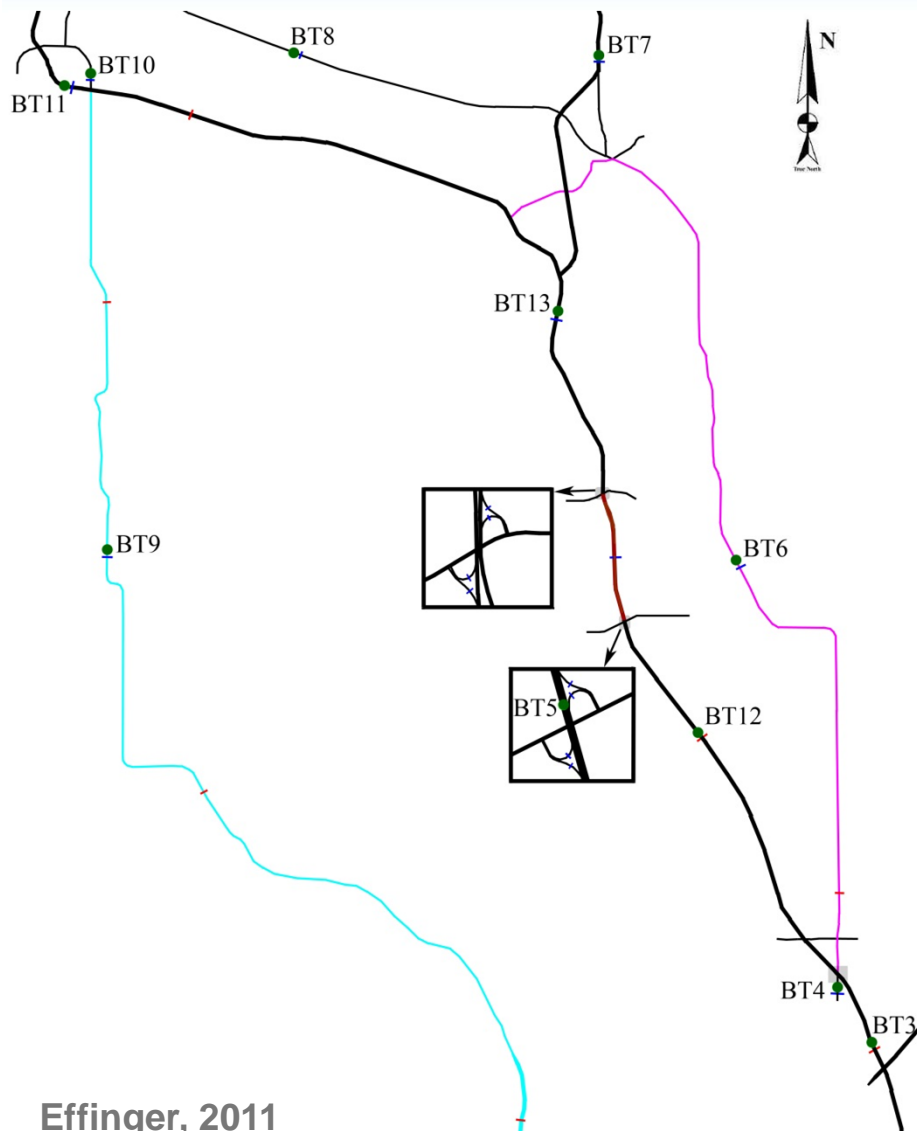
Results

- Driver Survey (464 Drivers Surveyed)

Amount of perceived travel time savings on the alternate route to divert



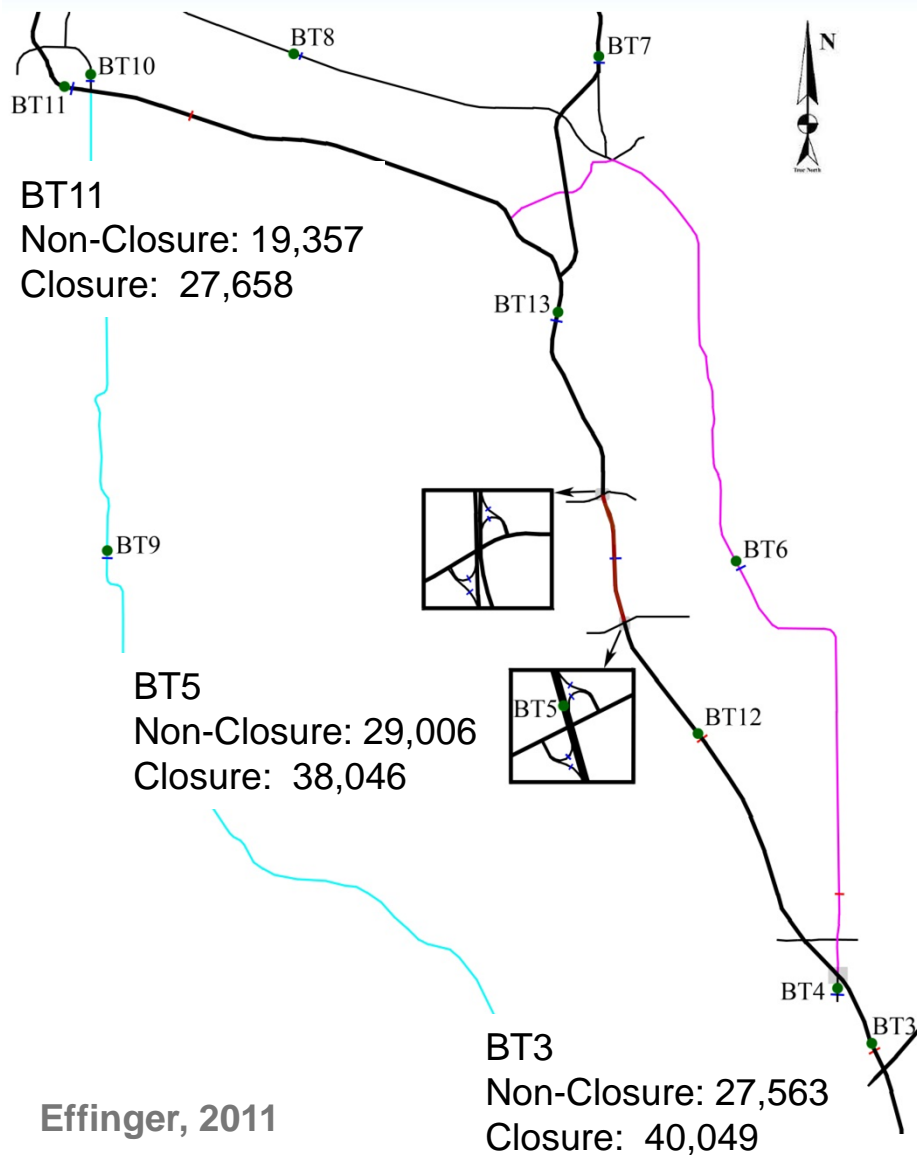
Results



- The number of usable pairs on the freeway increases during the work zone, but the increase is small (Speed might have an impact).

Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	Number of usable pairs
BT11 - BT5	3/20/2011 (Non-Closure)	27.7	210
BT11 - BT5	9/19/2011 (Closure)	27.7	246
BT5 - BT3	3/20/2011 (Non-Closure)	15.2	554
BT5 - BT3	9/19/2011 (Closure)	15.2	600
BT13 - BT5	3/20/2011 (Non-Closure)	18.5	611
BT13 - BT5	9/19/2011 (Closure)	18.5	651
BT13 - BT3	3/20/2011 (Non-Closure)	24.3	490
BT13 - BT3	9/19/2011 (Closure)	24.3	581

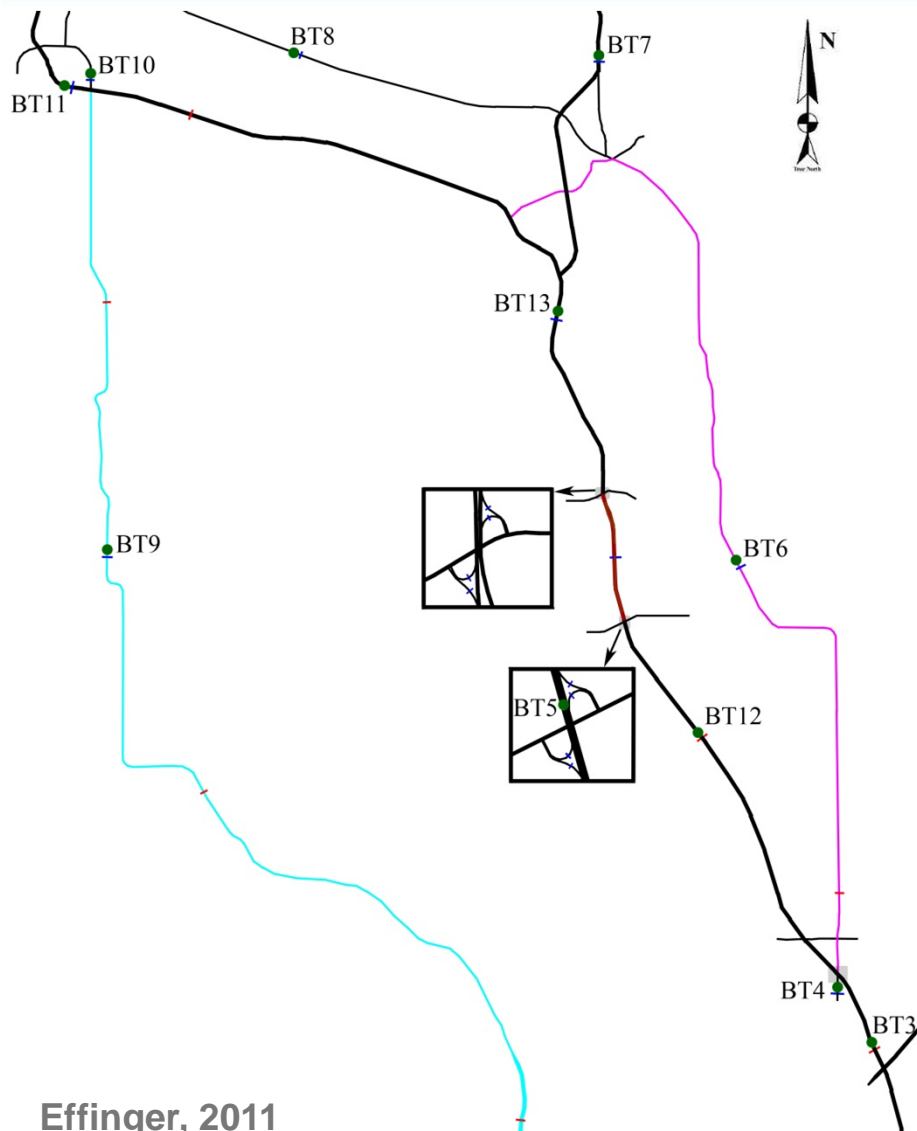
Results



- Theory: There are more Bluetooth enabled devices on the road during non-work zone conditions.

Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	Number of usable pairs
BT11 - BT5	3/20/2011 (Non-Closure)	27.7	210
BT11 - BT5	9/19/2011 (Closure)	27.7	246
BT5 - BT3	3/20/2011 (Non-Closure)	15.2	554
BT5 - BT3	9/19/2011 (Closure)	15.2	600
BT13 - BT5	3/20/2011 (Non-Closure)	18.5	611
BT13 - BT5	9/19/2011 (Closure)	18.5	651
BT13 - BT3	3/20/2011 (Non-Closure)	24.3	490
BT13 - BT3	9/19/2011 (Closure)	24.3	581

Results



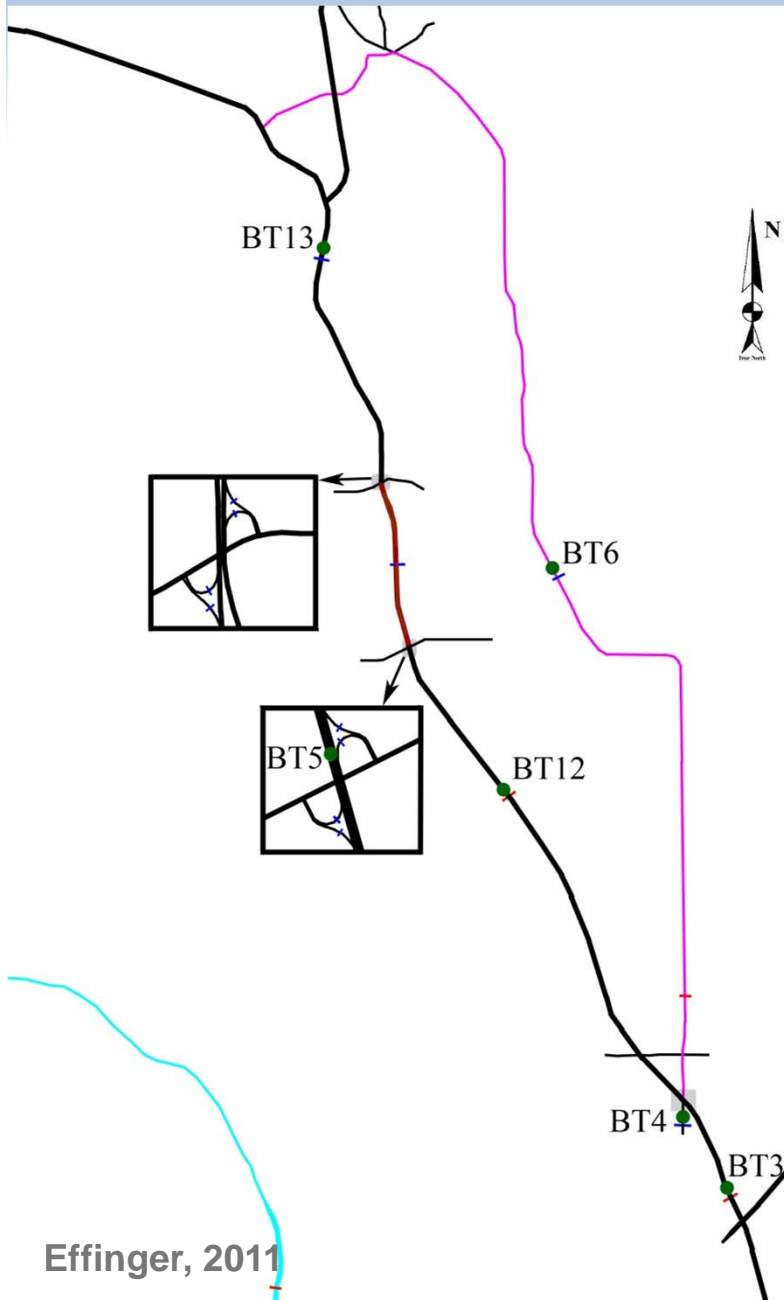
- The number of usable pairs on the arterial streets is significantly larger during work zone conditions.

Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	Number of usable pairs	Percentage occurring during congestion
BT11 - BT6	3/20/2011 (Non-Closure)	33.6	0	
BT11 - BT6	9/19/2011 (Closure)	33.6	13	100
BT10 - BT6	3/20/2011 (Non-Closure)	32.2	0	
BT10 - BT6	9/19/2011 (Closure)	32.2	5	100
BT6 - BT3	3/20/2011 (Non-Closure)	16.8	0	
BT6 - BT3	9/19/2011 (Closure)	16.8	38	94.7
BT11 - BT9	3/20/2011 (Non-Closure)	15.1	7	
BT11 - BT9	9/19/2011 (Closure)	15.1	24	91.7
BT10 - BT9	3/20/2011 (Non-Closure)	14.7	11	
BT10 - BT9	9/19/2011 (Closure)	14.7	18	77.8
BT9 - BT1	3/20/2011 (Non-Closure)	43.1	1	
BT9 - BT1	9/19/2011 (Closure)	43.1	15	80

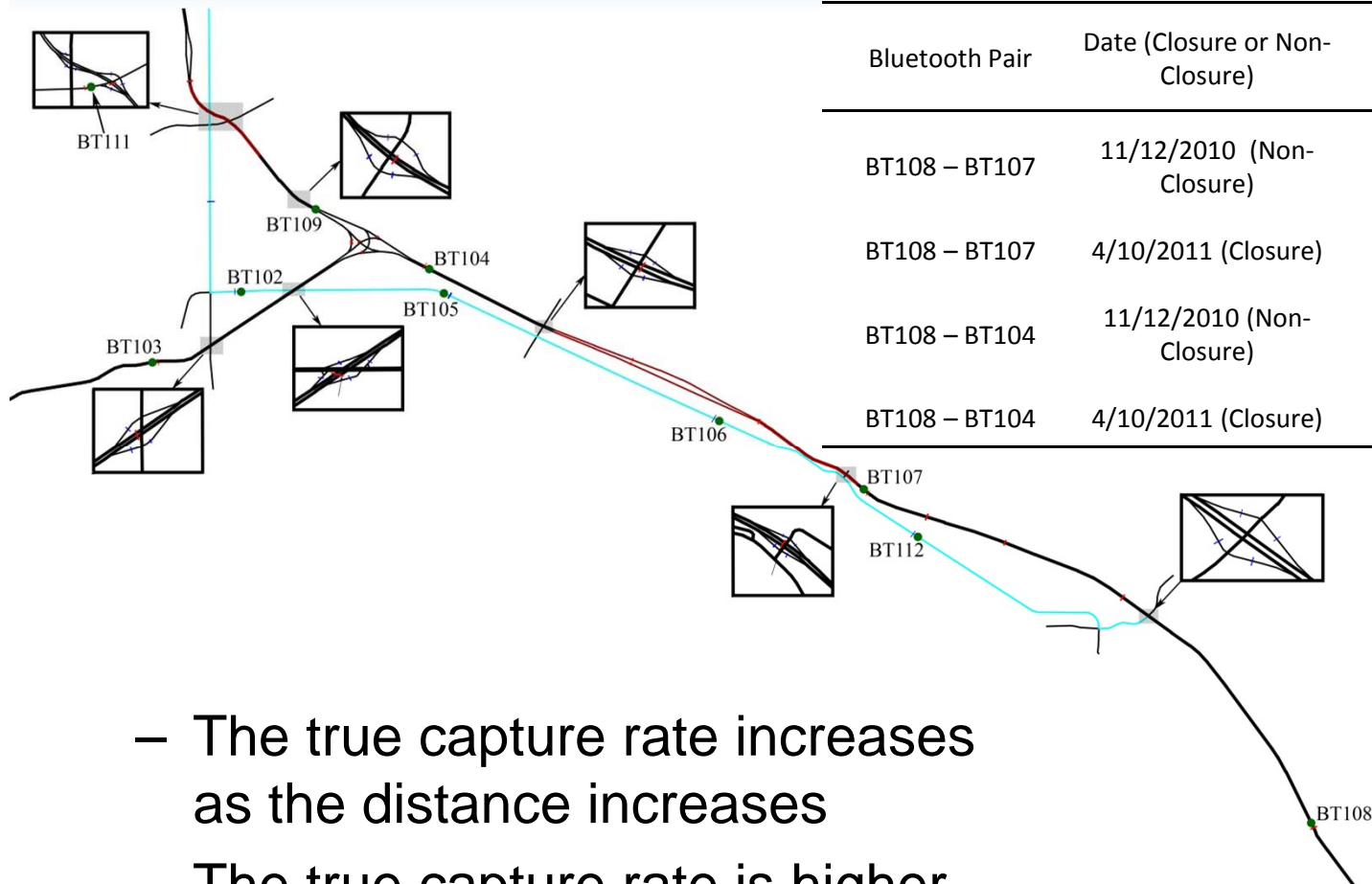
Results

- The true capture rate increases as the distance increases
- The true capture rate is higher during the non-closure weekend
 - Factors are speculation

Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	True Capture Rate
BT13 - BT5	3/20/2011 (Non-Closure)	18.5	2.3
BT13 - BT5	9/19/2011 (Closure)	18.5	1.9
BT13 - BT3	3/20/2011 (Non-Closure)	24.3	3.3
BT13 - BT3	9/19/2011 (Closure)	24.3	2.5



Results



Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	True Capture Rate
BT108 – BT107	11/12/2010 (Non-Closure)	12.5	2.8
BT108 – BT107	4/10/2011 (Closure)	12.5	2.0
BT108 – BT104	11/12/2010 (Non-Closure)	22.3	3.4
BT108 – BT104	4/10/2011 (Closure)	22.3	4.0

- The true capture rate increases as the distance increases
- The true capture rate is higher during the non-closure weekend
 - Factors are speculation

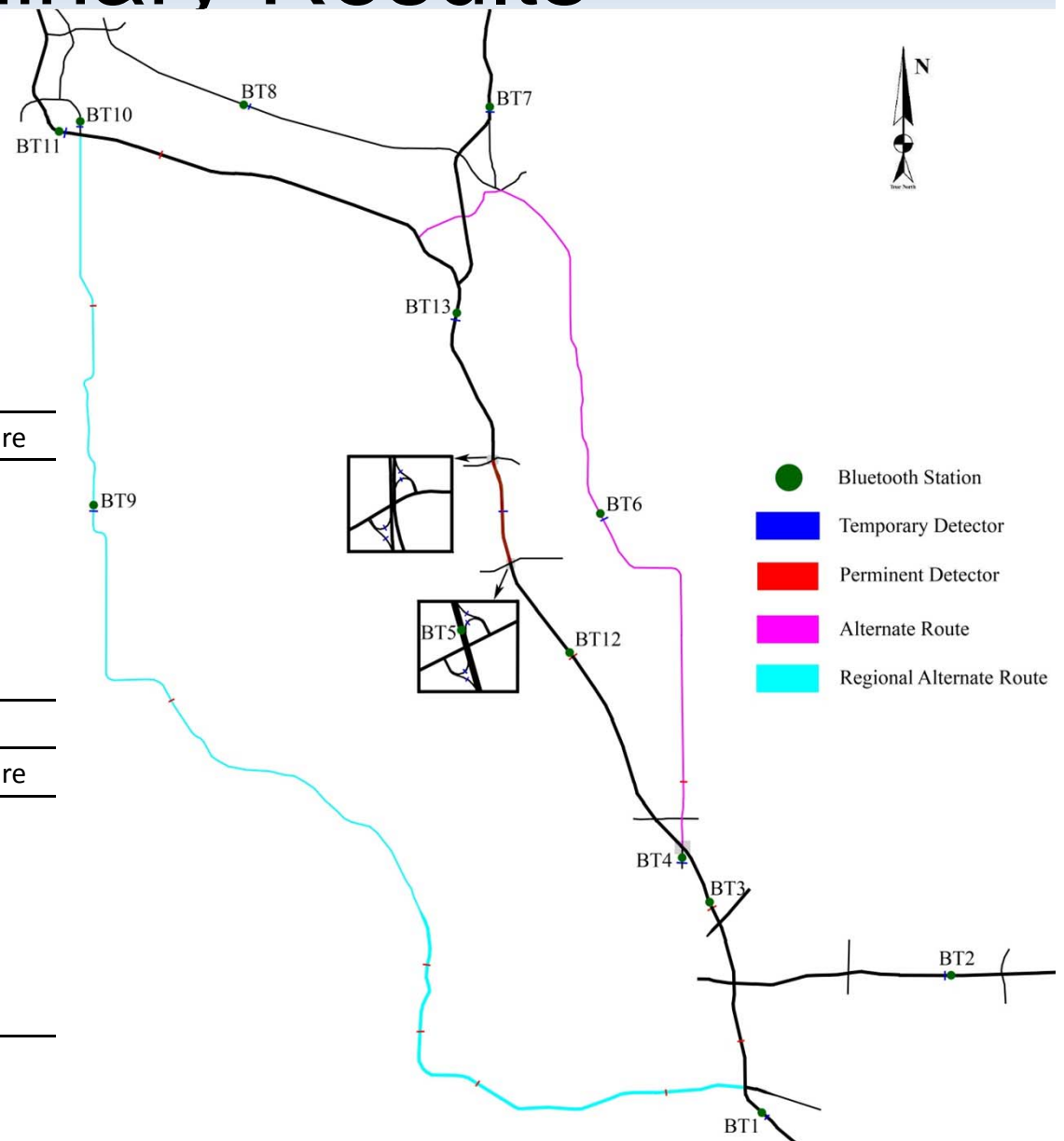
Preliminary Results

Using Bluetooth Technology for diversion

WB (NB) Triple	Closure	Non-Closure
BT1 - BT9 - BT11	7	8
BT1 - BT6 - BT11	1	0
BT2 - BT6 - BT11	1	0
BT3 - BT6 - BT11	4	0
BT4 - BT6 - BT11	1	0

EB (SB) Triple	Closure	Non-Closure
BT11 - BT9 - BT1	5	0
BT11 - BT6 - BT1	11	0
BT10 - BT6 - BT1	2	0
BT7 - BT6 - BT1	5	0
BT8 - BT6 - BT1	3	1

Effinger, 2011

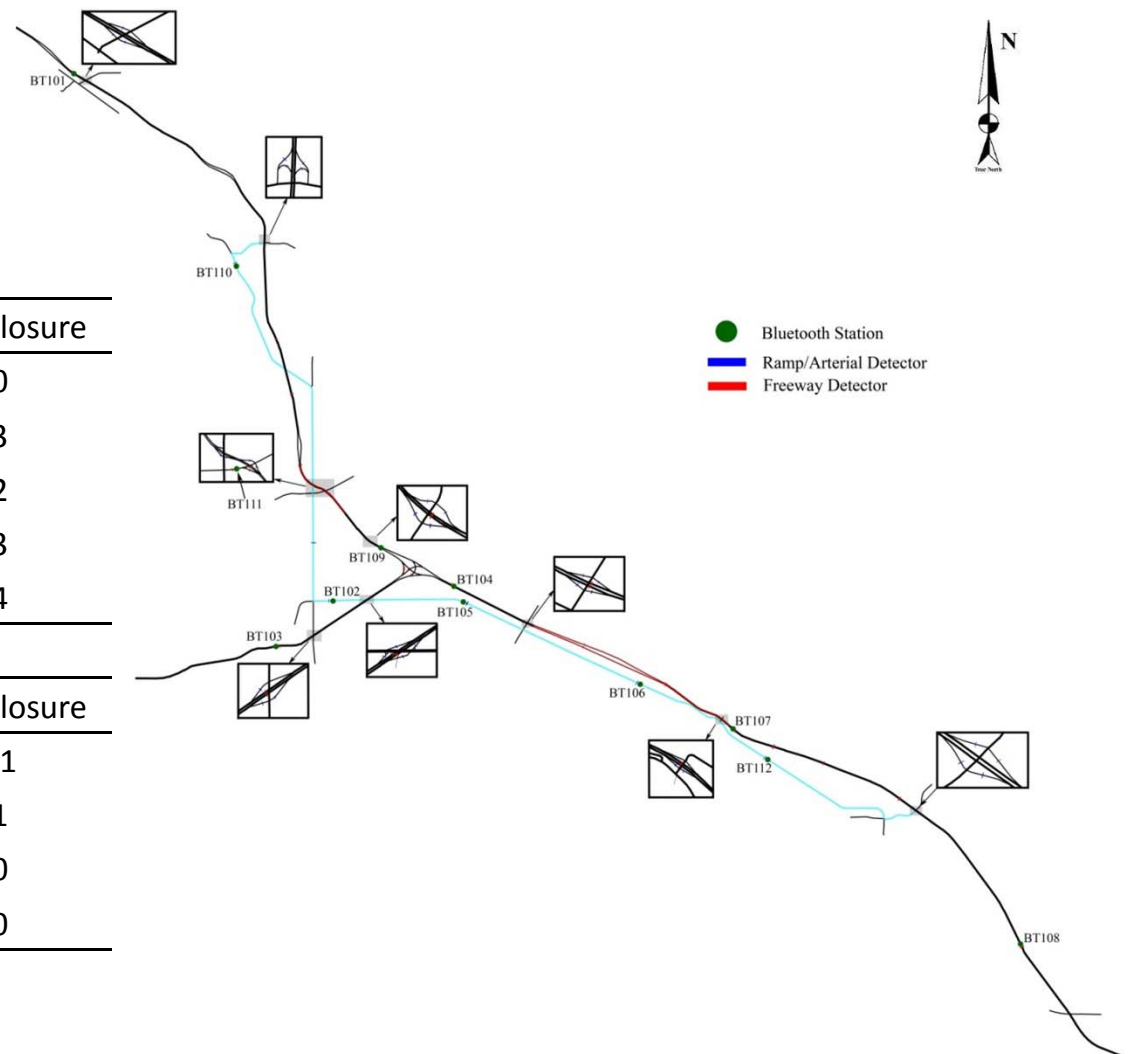


Preliminary Results

Using Bluetooth Technology for diversion

WB Triple	Closure	Non-Closure
BT108 - BT102 - BT101	13	0
BT108 - BT112 - BT104	85	3
BT108 - BT106 - BT104	64	2
BT104 - BT102 - BT101	8	3
BT108 - BT105 - BT103	21	4

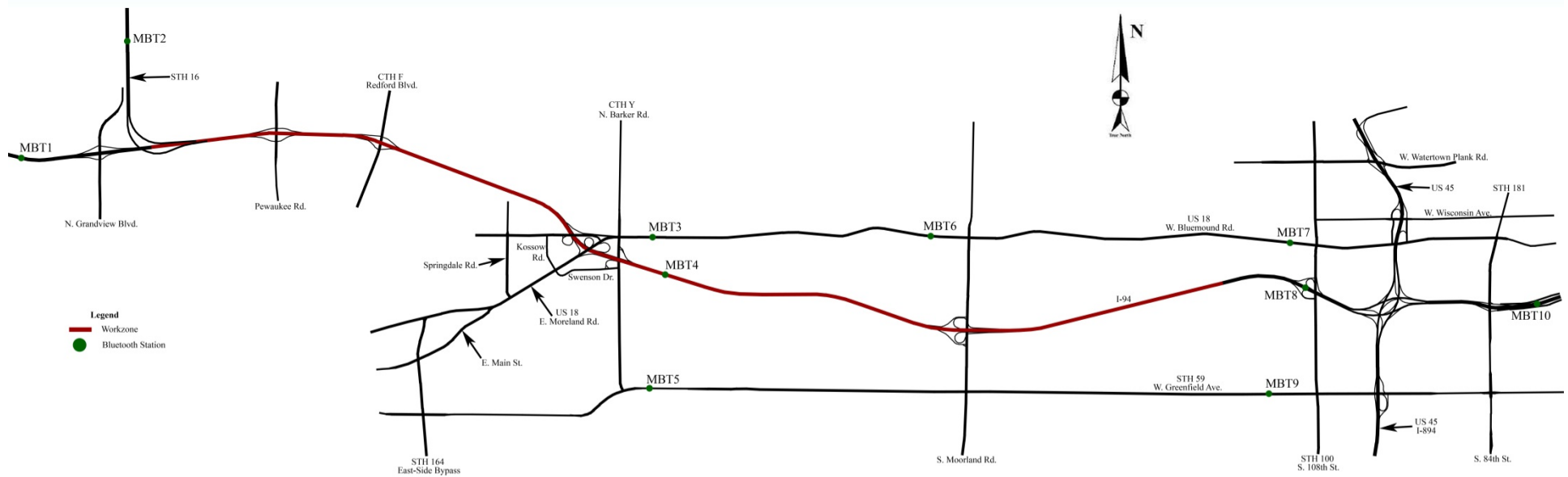
EB Triple	Closure	Non-Closure
BT101 - BT105 - BT108	47	11
BT101 - BT102 - BT104	10	1
BT103 - BT106 - BT108	59	0
BT103 - BT112 - BT108	61	0



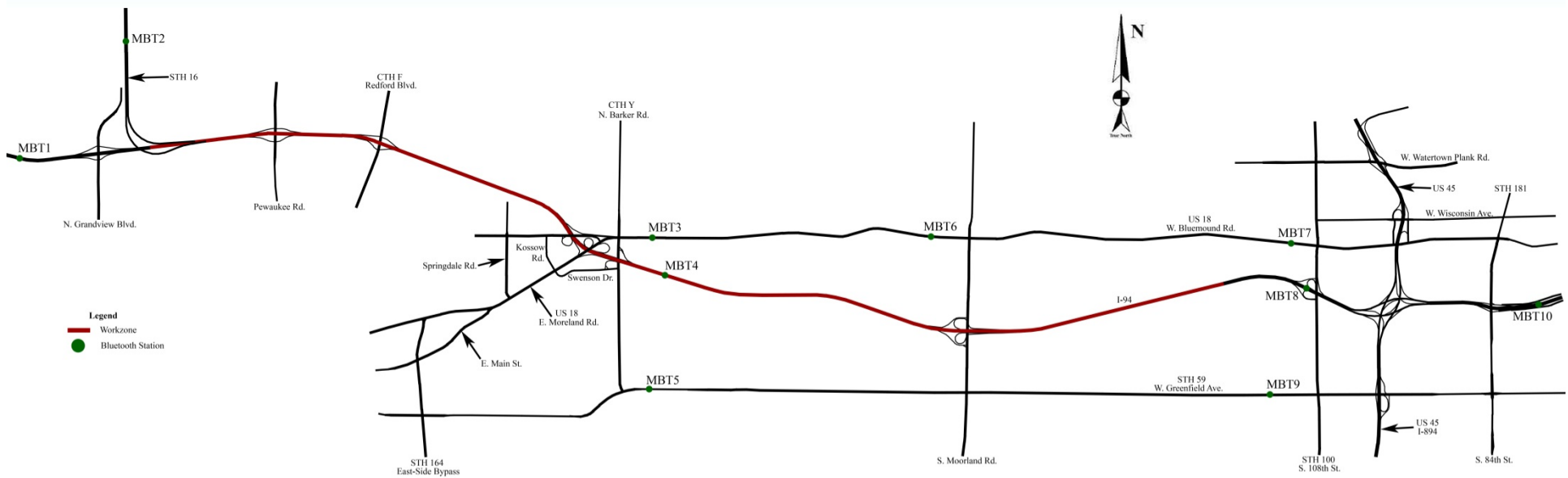
Is Urban better than Rural?

- Milwaukee Work Zone
 - 2 construction zones (I-94 E/W Corridor)
 - Waukesha County (EB & WB)
 - Milwaukee County (WB only)
 - One of the busiest stretches of freeway in Wisconsin
 - This presentation concentrates on the Waukesha County work zone.

Is Urban better than Rural?



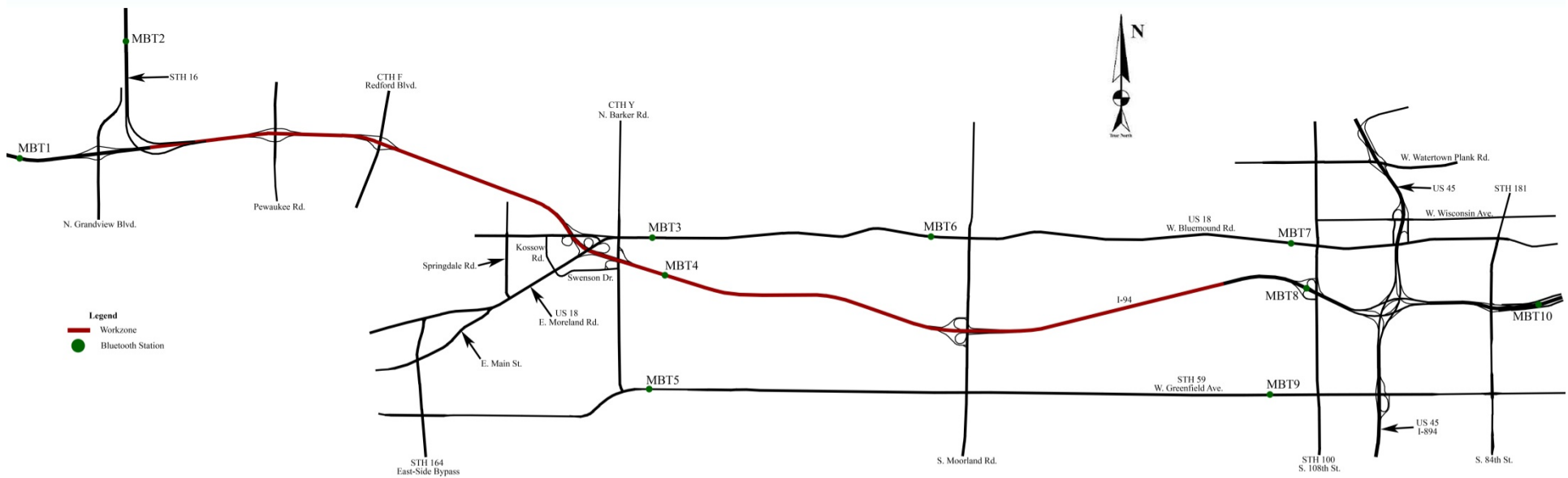
Is Urban better than Rural?



Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	Number of usable pairs
BT11 - BT5	3/20/2011 (Non-Closure)	27.7	210
BT11 - BT5	9/19/2011 (Closure)	27.7	246
BT5 - BT3	3/20/2011 (Non-Closure)	15.2	554
BT5 - BT3	9/19/2011 (Closure)	15.2	600
BT11 - BT6	3/20/2011 (Non-Closure)	33.6	0
BT11 - BT6	9/19/2011 (Closure)	33.6	13

Bluetooth Pair	Date (Closure or Non-Closure)	Distance (miles)	Number of usable pairs
MBT10 - MBT4	2/24/2011 (Non-Closure)	7.8	244
MBT10 - MBT4	5/19/2011 (Closure)	7.8	195
MBT4 - MBT1	2/24/2011 (Non-Closure)	5.9	214
MBT4 - MBT1	5/19/2011 (Closure)	5.9	270
MBT10 - MBT6	2/24/2011 (Non-Closure)	6.2	46
MBT10 - MBT6	5/19/2011 (Closure)	6.2	35

Is Urban better than Rural?



Bluetooth Pair	Date (Closure or Non-Closure)	Number of usable pairs	% of pairs being filtered out
BT11 - BT5	3/20/2011 (Non-Closure)	210	16.7
BT11 - BT5	9/19/2011 (Closure)	246	11.5
BT5 - BT3	3/20/2011 (Non-Closure)	554	8.0
BT5 - BT3	9/19/2011 (Closure)	600	12.5
BT11 - BT6	3/20/2011 (Non-Closure)	0	-
BT11 - BT6	9/19/2011 (Closure)	13	18.8

Bluetooth Pair	Date (Closure or Non-Closure)	Number of usable pairs	% of pairs being filtered out
MBT10 - MBT4	2/24/2011 (Non-Closure)	244	64.3
MBT10 - MBT4	5/19/2011 (Closure)	195	55.9
MBT4 - MBT1	2/24/2011 (Non-Closure)	214	51.6
MBT4 - MBT1	5/19/2011 (Closure)	270	42.7
MBT10 - MBT6	2/24/2011 (Non-Closure)	46	73.4
MBT10 - MBT6	5/19/2011 (Closure)	35	78.8

Conclusions

- This research is applying Bluetooth technology in diversion analysis.
 - Documenting the route of a vehicle off the freeway for long distance trips
- Tomah produced the most conclusive evidence of diversion using the Bluetooth devices.
- Urban is not necessarily considered better than rural for use of Bluetooth technology.
 - Recommend more research in this area
- Bluetooth technology is still an on-going technology.

Acknowledgements

- UW-Milwaukee
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Questions?

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