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Deriving Transportation Information from GPS Probe Vehicle Data Integrated with a GIS

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Motivation

- ④ Increase in traffic volumes deteriorate congestion in Columbus
- ④ Performance of urban traffic systems is a major concern
- ④ Accurate and reliable traffic data are needed
- ④ GPS probe vehicle techniques
 - Provide spatial and temporal information
 - Low cost
 - High accurate



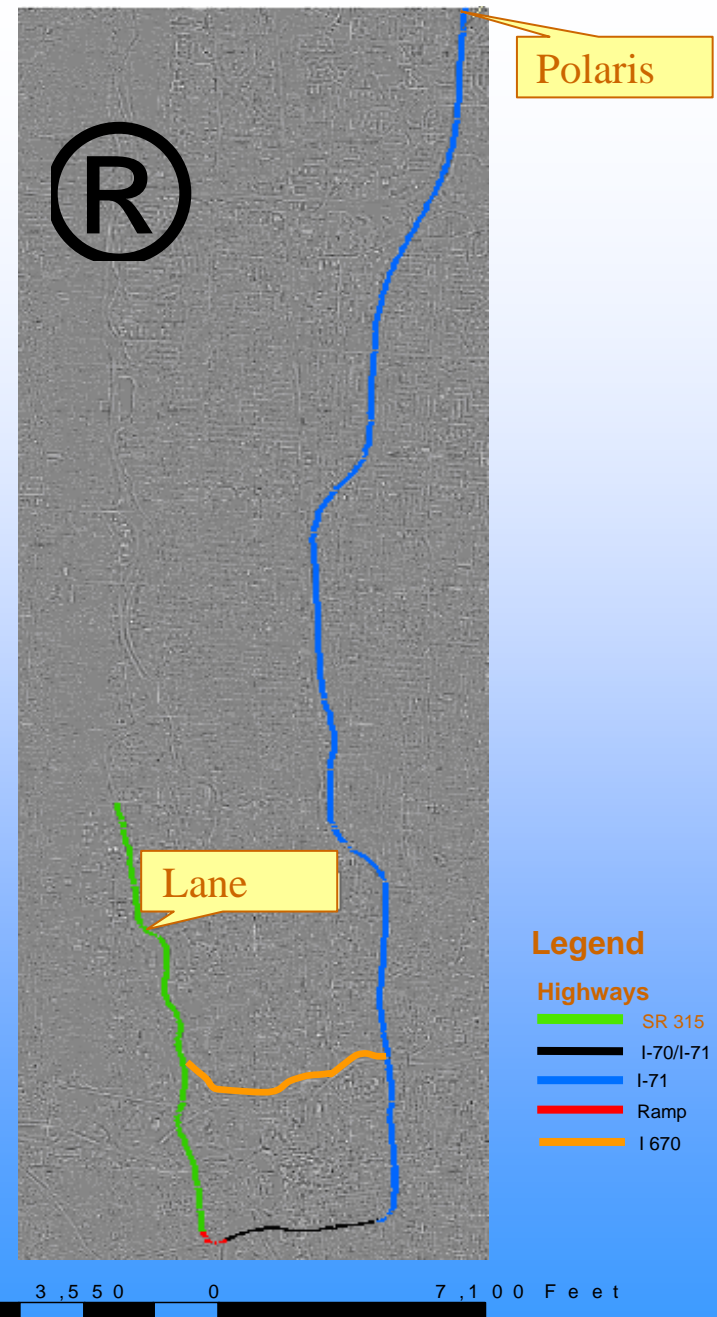
Objectives

- ② Evaluate GPS probe vehicle techniques
- ② Obtain highway spatial information integrated with GIS
 - Lane information
 - on-ramp and off-ramp exit
- ② Evaluate highway performance
 - Congestion indices (Taylor, 1992)



Study Area

- ④ South part of SR-315
- ④ I-70/I-71 overlap
- ④ I-71 north of I-70





Data Collection

- ⓐ AgGPS132 DGPS probe vehicle data
 - Sub-meter accuracy
 - Tuesday, Wednesday and Thursday in 2002 and 2003
 - AM 7:00-9:00, PM 4:00-6:00
 - North run and south run
- ⓐ Trimble 5700 RTK (real-time kinematic) data
 - Sub-centimeter accuracy
 - along with AgGPS132 receiver (apart by -2 ft)
 - Linear referencing points on highway
- ⓐ 2000 Franklin DOQQ data with 0.5 ft resolution
- ⓐ Loop detector data obtained in 2002



Highway Frame

- ④ Highway centerline digitization
 - DOQQ as a backdrop

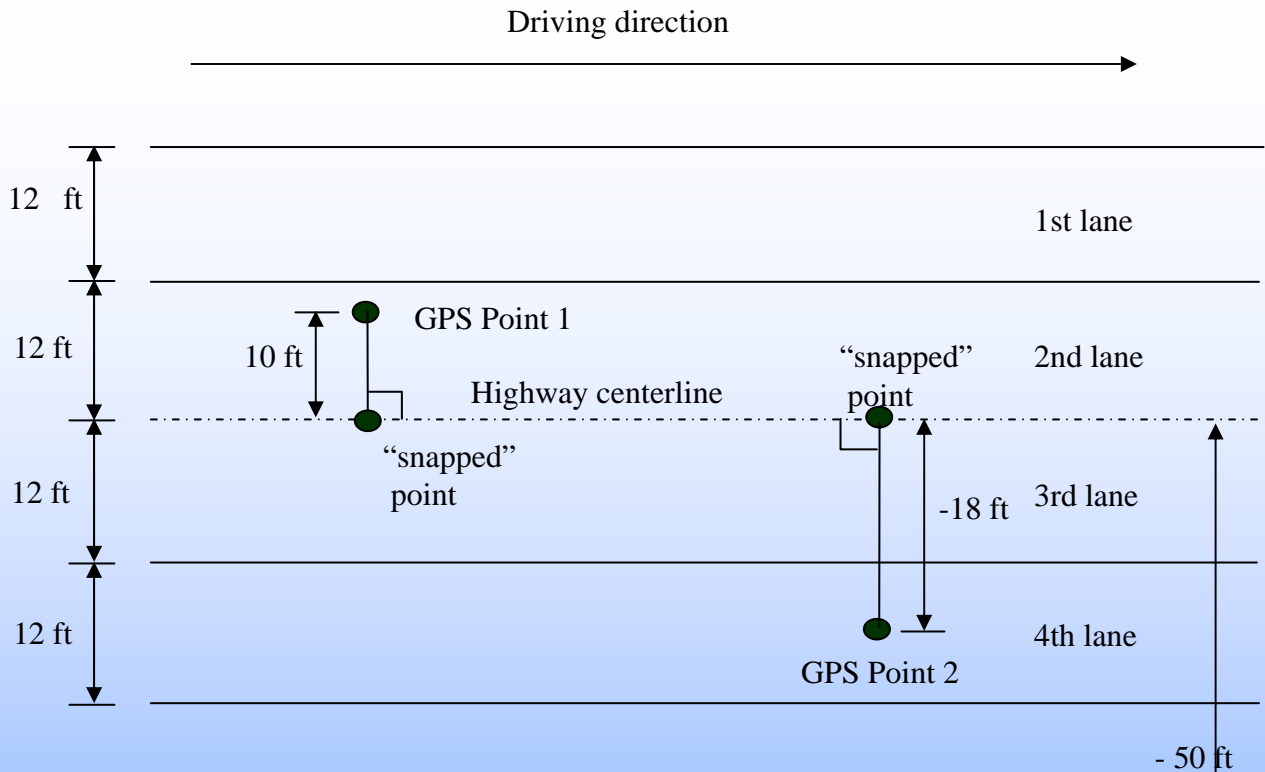
- ④ Highway linear referencing

- ④ Attaching attributes and constructing database



Map GPS Probe Vehicle Data

- ④ “Snap” GPS probe vehicle points to the centerline
 - Program input : highway centerline and GPS probe vehicle data points
 - Program logic
 - Find the perpendicular point (Closest_Point) for each GPS point
 - Record the distance between the GPS point and the Closest_Point
- ④ Segment highways to 0.5-mile segments (Quiroga and Bullock, 1999)

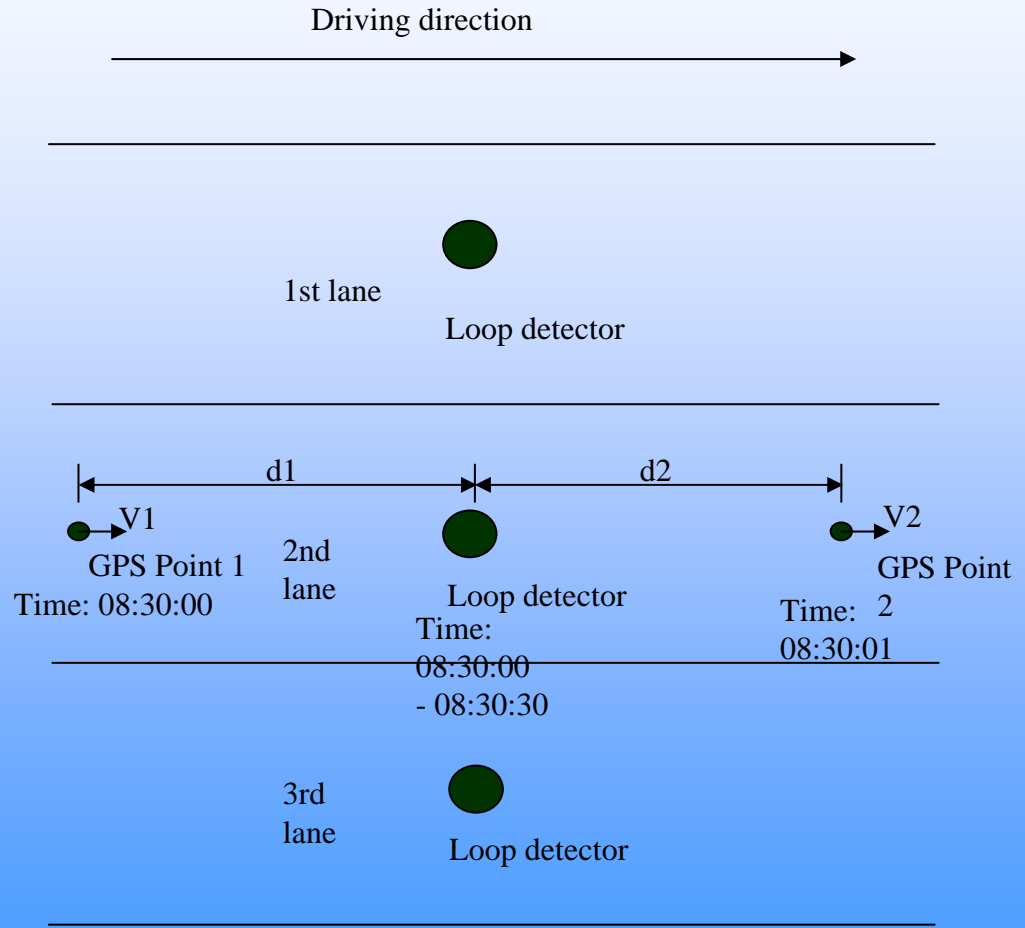


Distance between the GPS point and the highway centerline (ft)	Lane
$12 < d \leq 24$	1
$0 < d \leq 12$	2
$-12 < d \leq 0$	3
$24 \leq d \leq -12$	4



Probe Vehicle and Loop Detector

- Deriving loop detector speed data
 - 30-second speed data



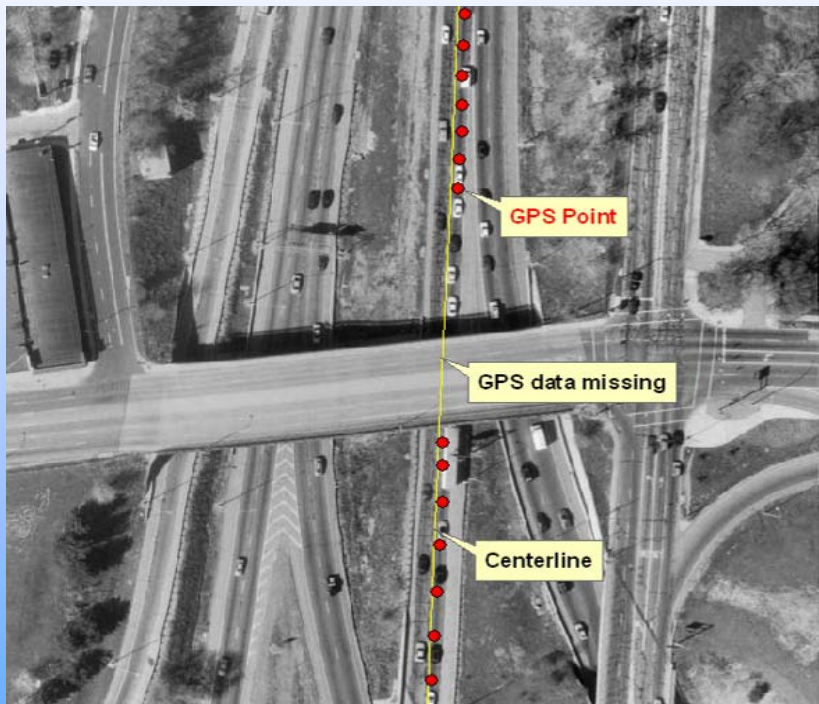
$$\text{GPS Average Speed} = (v1*d2+v2*d1) / (d1+d2)$$



GPS errors

- ⓐ Problems around downtown area: signal blockage and multipath
- ⓐ Comparison between two GPS receivers

No. of points	Mean (ft)	Standard Deviation (ft)
3525	-2.05	1.85
3678	-1.92	2.69
3607	-2.08	2.65
3296	-2.09	2.76



Signal blockage



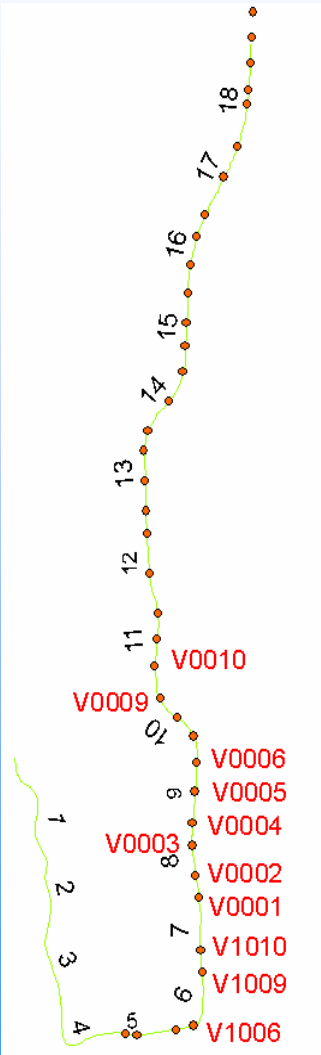
Multipath



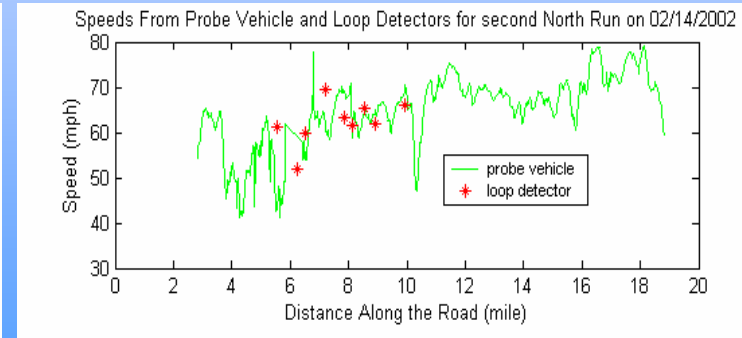
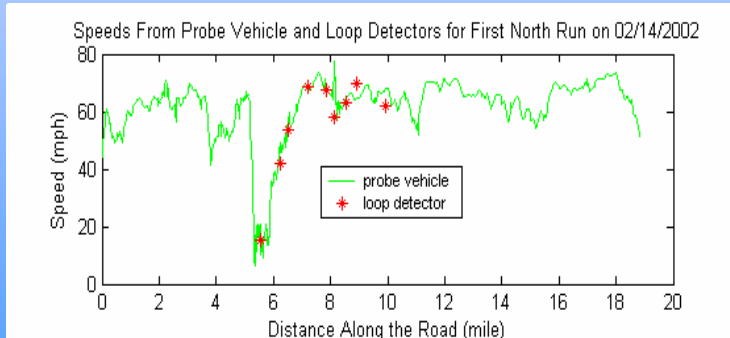
Data Comparison

Loop Detector	V1006	V1009	V1010	V0001	V0003	V0004	V0005	V0009
Average Difference (mph)	3.29	-0.32	-0.45	0.10	0.40	1.14	0.57	0.72
Stdev	6.84	2.04	2.37	2.62	1.42	5.00	3.92	3.10
No of Points	24.00	26.00	26.00	10.00	24.00	22.00	24.00	24.00

Average speed difference for the north run



North run

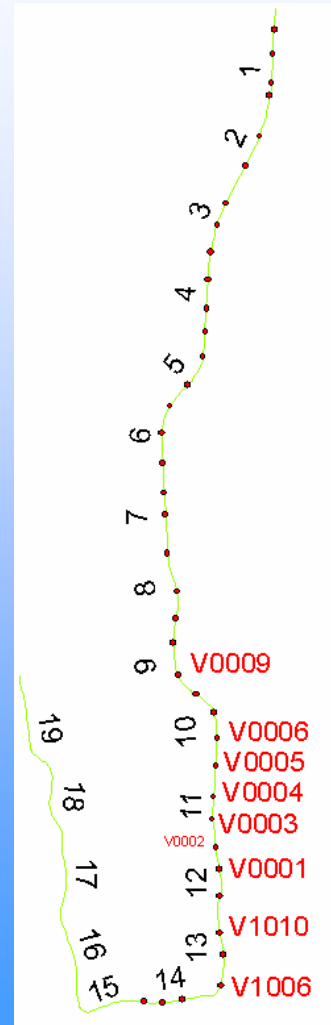




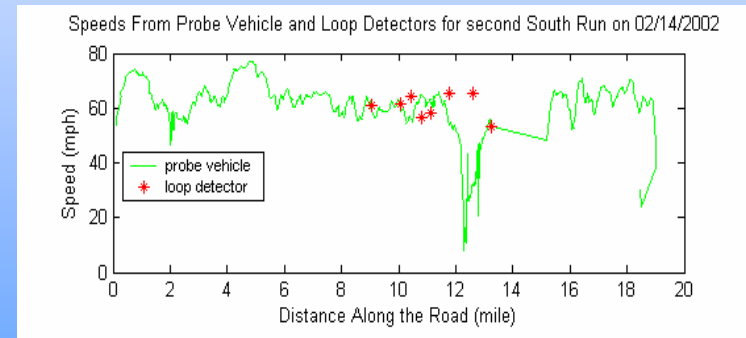
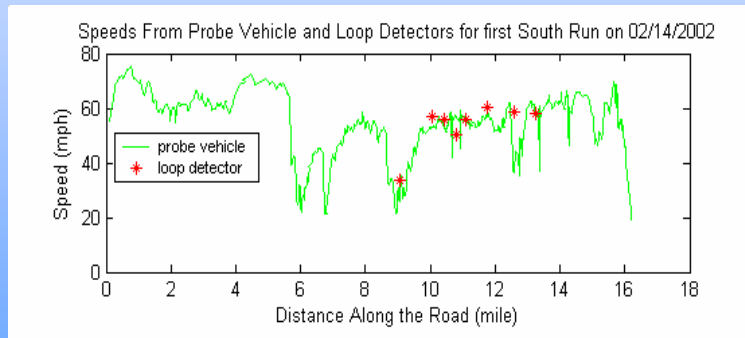
Data Comparison (cont' d)

Loop Detector	V1006	V1010	V0001	V0003	V0004	V0005	V0004	V0009
Average Difference (mph)	0.42	0.97	3.62	1.92	0.75	1.33	0.74	0.68
Stdev	2.11	5.23	5.28	4.20	3.75	2.71	1.56	3.14
No of Points	26.00	19.00	24.00	24.00	22.00	23.00	24.00	24.00

Average speed difference for the south run



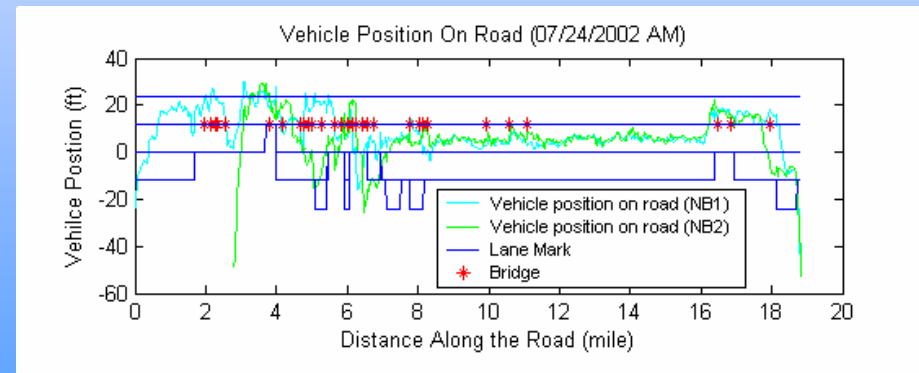
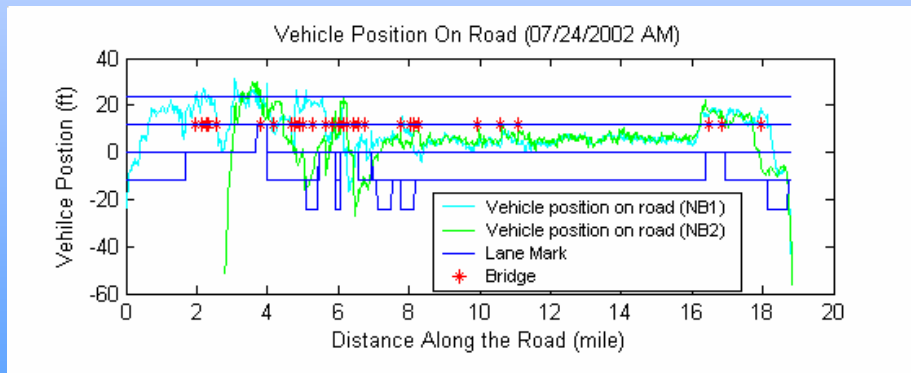
South run





Vehicle Lane Tracking

- ① Highway lane frame representation
- ② Applied low pass filter technique (3*1 window)



Vehicle position on road with respect to different lanes

Vehicle position on road with low pass filter applied



Congestion Analysis

④ Travel time and average speed

- Whole run
- Segments with 0.5-mile in length

④ Congestion index

- Congestion index = $\frac{c - c_0}{c_0}$
(C : actual travel time, C_0 : free flow travel time)
- Segments with the same speed limit
- Segments with 0.5-mile in length



Large Segments - North Run



Data collection period	Travel Time (minutes)	Speed (mph)
2002 AM	18.89	59.44
2002 PM	22.67	49.54
2003 AM	18.38	61.089
2003 PM	21.72	51.7

Travel time and speed for north run

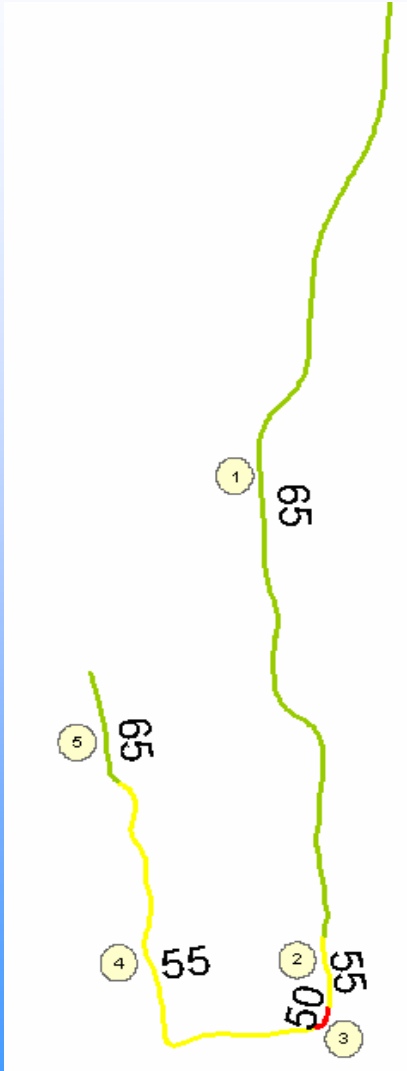
Seg No	2002AM	2002PM	2003AM	2003PM
1	0.1	0.02	0.17	0.05
2	-0.1	0.07	-0.1	0.01
3	-0.03	0.31	-0.09	0.43
4	0.22	0.66	0.04	0.64
5	0.02	0.1	0.02	0.16

Congestion index for north run

Posted speed limit for north run



Large Segments - South Run



Posted speed limit for south run

Data collection period	Travel Time (minutes)	Speed (mph)
2002 AM	19.09	50.56
2002 PM	20.2	48.57
2003 AM	16.64	57.99
2003 PM	18.37	52.54

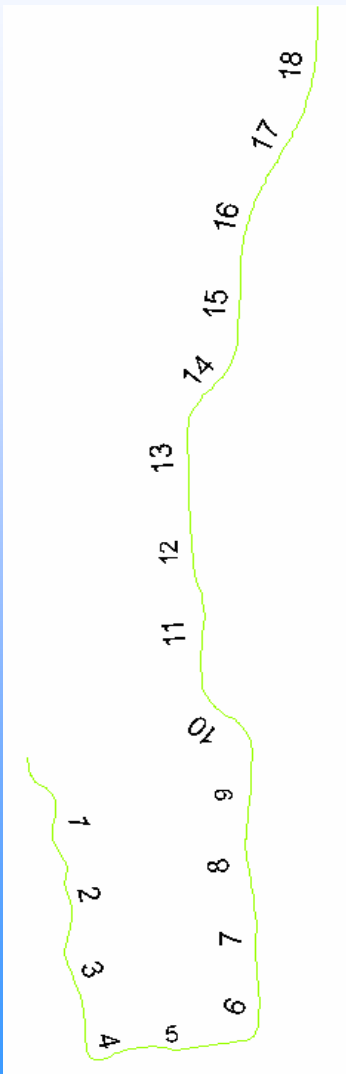
Travel time and speed for south run

Seg No	2002AM	2002PM	2003AM	2003PM
1	0.28	0.2	0.17	0.12
2	0.2	0.99	0.02	0.68
3	0.1	2.39	0.07	1.87
4	0	0.21	0	0.34

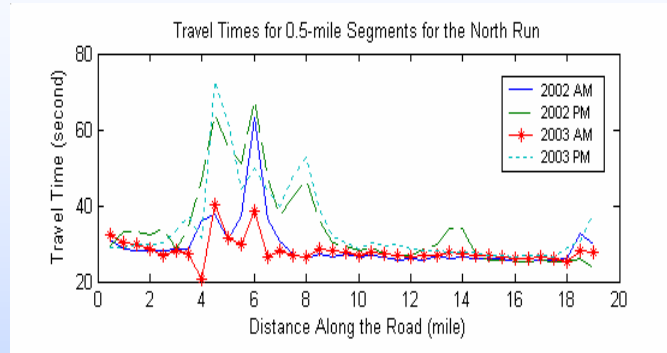
Congestion index for south run



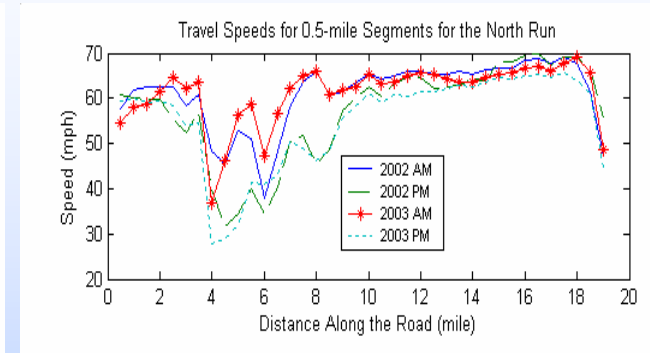
Segment with Length of 0.5 mile-North Run



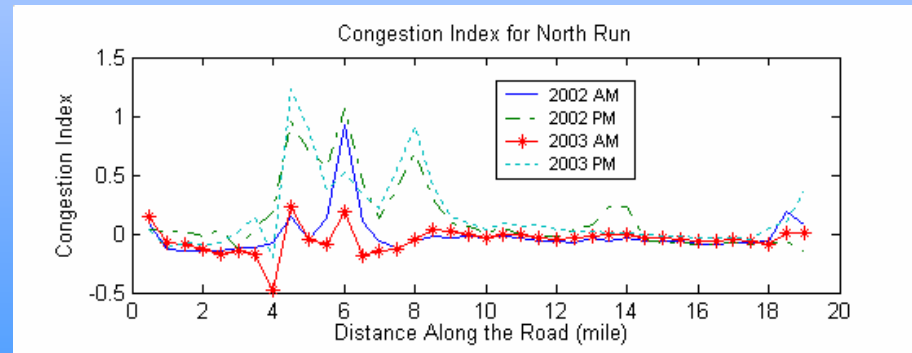
North run



Travel time



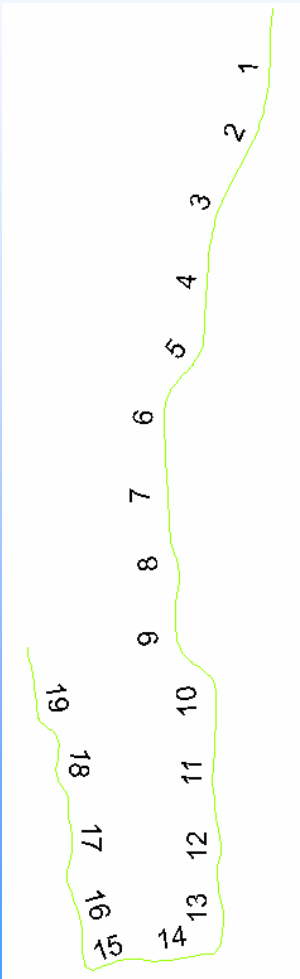
Average travel speed



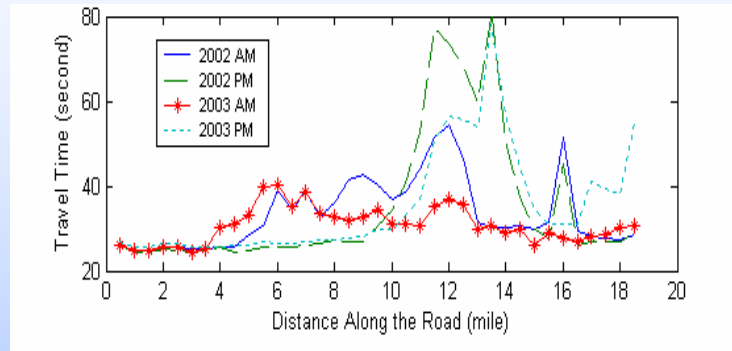
Congestion index



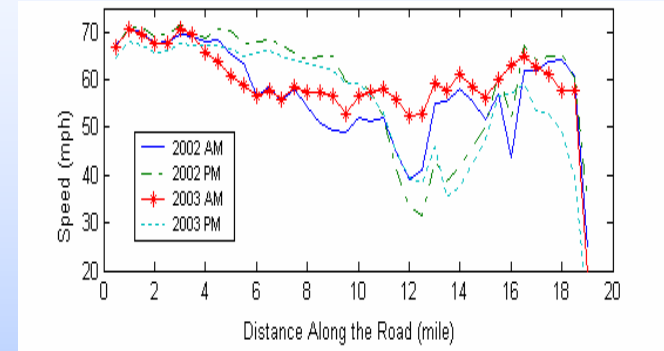
Segment with Length of 0.5 mile-South Run



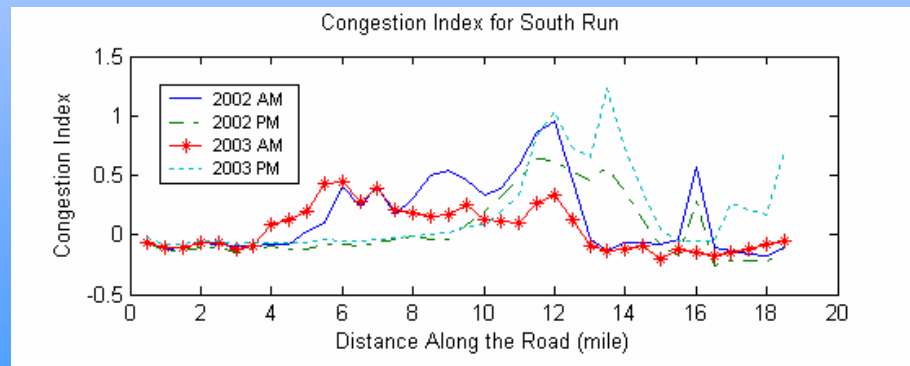
South run



Travel time



Average travel speed



Congestion index



Summary

- ④ GPS probe vehicle technique provides reasonable accurate data for analysis
- ④ GPS probe vehicle data match the loop detector data
- ④ Multipath around the downtown area degraded the GPS accuracy
- ④ Congestion analysis
 - 2002 and 2003 have similar travel pattern
 - PM peak hours have more congestion than AM peak hours
 - PM and AM have different congestion areas for south run



Conclusions

- ② High resolution imagery provide transportation data to lane level accuracy but acquiring up-to-date imagery can pose a problem
- ② GPS integrated with GIS provide simple and quick performance evaluations at the segment level for speed, travel time, and congestion
- ② GPS probe vehicle techniques are possible alternatives to loop detectors in urban areas



Future Work

- ② Reduce multipath errors
- ② Incorporate dynamic segmentation into transportation research
- ② Determine number of samples (probe vehicle runs and segments) required for large networks
- ② Integrate GPS/GIS techniques with ITS to provide real-time route and congestion monitoring



Thanks !