High-Resolution Event-Based Data at Diamond Interchanges: Performance Measures and Optimizing Ring Displacement

Alexander M. Hainen[1], Amanda L. Stevens[2], Richard S. Freije[1], Christopher M. Day[1], James R. Sturdevant[2], Darcy M. Bullock[1]

1: Purdue University; 2: Indiana Department of Transportation

Paper No. 14-0298

ABSTRACT

Signalized diamond interchanges are unique pairs of intersections characterized by interlocked left turns and relatively close spacing between ramps. A diamond interchange has four external entry points (origins) and four external exit points (destinations). To effectively operate a diamond interchange, it is critical to examine the external origin-destination paths and evaluate their impact on the interior storage and progression. This paper describes a series of performance measures derived from high-resolution signal controller data that can be used to 1) qualitatively and quantitatively assess the quality of progression of the interior movements; and 2) optimize the internal offset to improve traffic flows within the interchange. Additional performance measures for identifying internal and ramp queuing are also discussed. There is general consensus in the literature that empirical performance measures are needed by practitioners to answer the following questions:

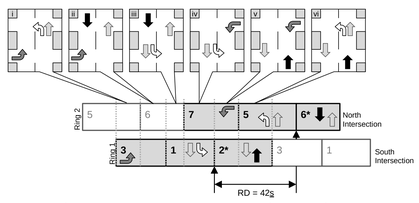
1. Are the off-ramps queuing to the point that they impede freeway traffic? (5)
2. Are the diamond interior approaches queuing to the point that they spill back and impede the adjacent intersection movements?
3. Is there reasonable progression through both signals of the diamond interchange for the four external movements?

All three items above are affected by split allocation, but items 2 and 3 also rely heavily on the offset between intersections

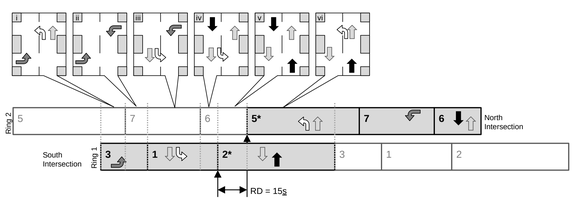
TIMING PLANS

Start	End	Pattern	Seq ID	Sequence	Cycle Length (seconds)	Ring Displacement (Seconds)	Coord. Move-ments	Notes
0000	0600	1	2	N: |7,5,6 S: |3,1,2	80	42	6 2	Off peak.
0600	0900	2	1	N: |5,7,6 S: |3,1,2	120	15	5 2	AM Peak period, heavy NB movement as traffic heads into the city. NBL is coordinated.
0900	1400	1	2	N: |7,5,6 S: |3,1,2	80	42	6 2	**THIS MID-DAY PLAN WAS USED FOR THE ANALYSIS.**
1400	1530	13	1	N: |5,7,6 S: |3,1,2	80	68	6 2	Same as pattern 3, but max recall on NBL.
1530	1900	3	1	N: |5,7,6 S: |3,1,2	80	68	6 2	PM peak period. Heavy traffic on the ramps heading south.
1900	0000	1	2	N: |5,7,6 S: |3,1,2	80	42	6 2	Off peak.

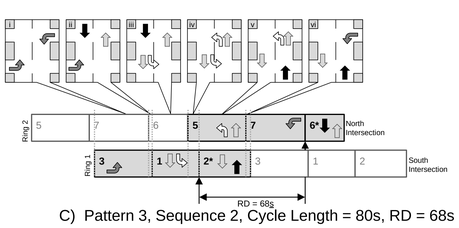
RING CONFIGURATIONS



A) Pattern 1, Sequence 2, Cycle Length = 80s, RD = 42s

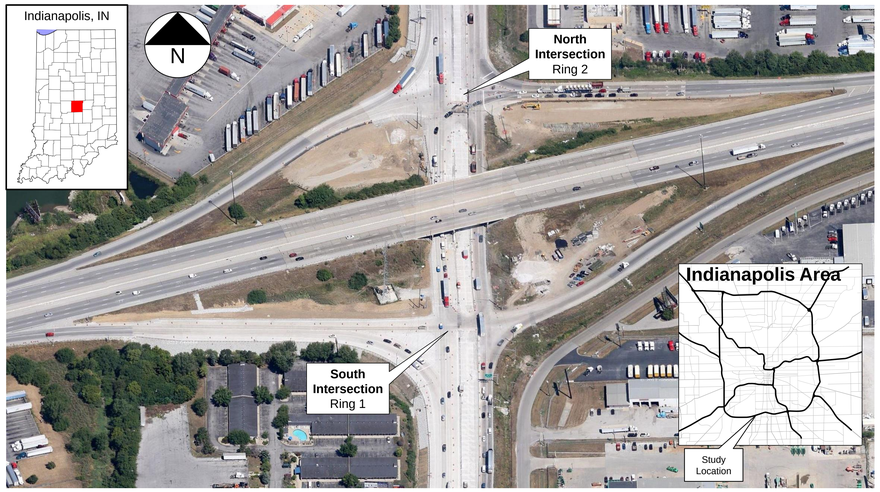


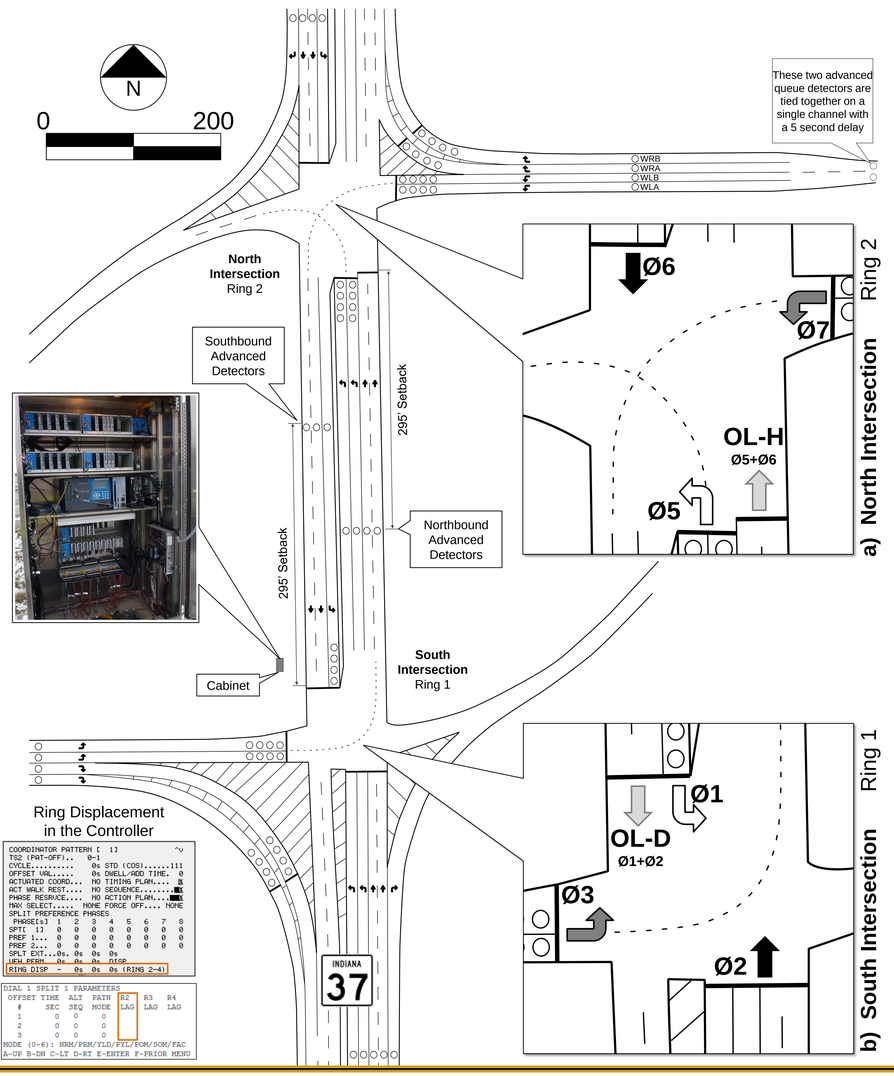
B) Pattern 2, Sequence 1, Cycle Length = 120s, RD = 15s



C) Pattern 3, Sequence 2, Cycle Length = 80s, RD = 68s

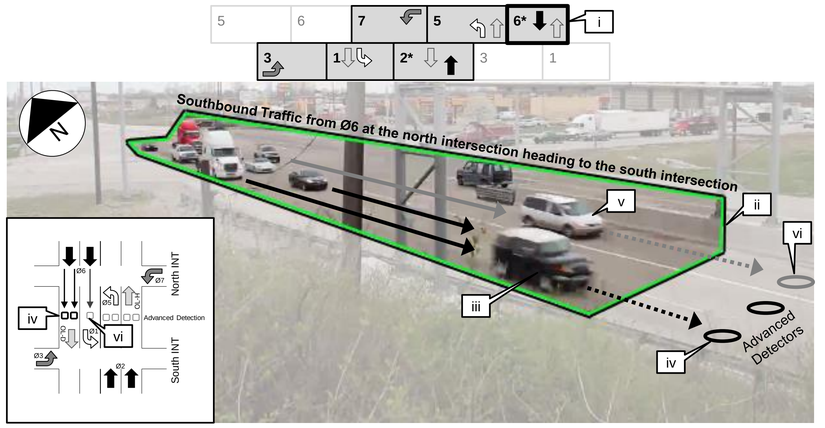
MAP & INTERCHANGE LAYOUT



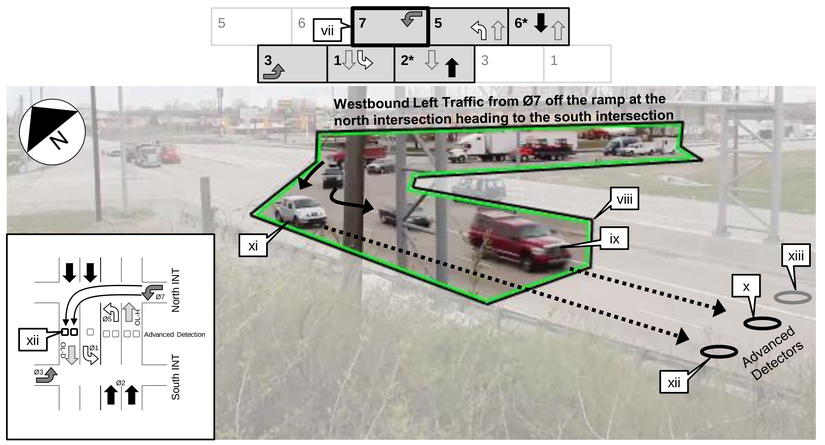


Ring Displacement in the Controller

UPSTREAM SOURCE

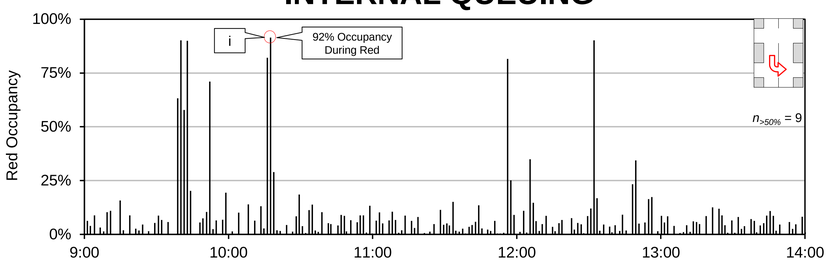


A) Southbound Thru Vehicles



B) Westbound Left Vehicles from the Ramp

INTERNAL QUEUING



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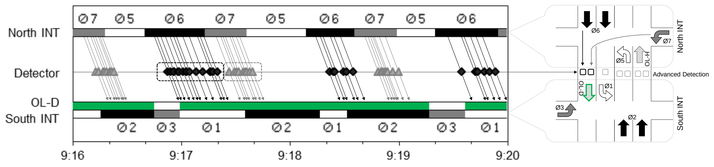
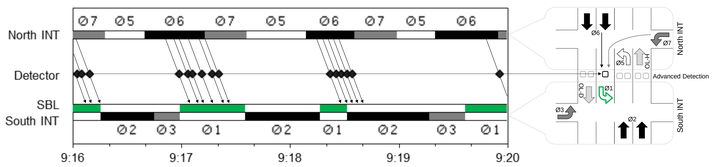
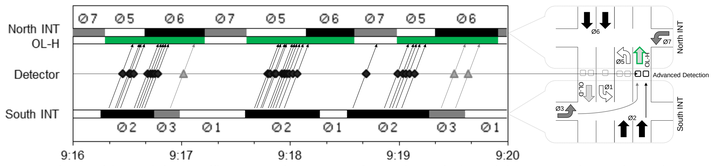
TIME-SPACE DIAGRAMS OF EACH MOVEMENT



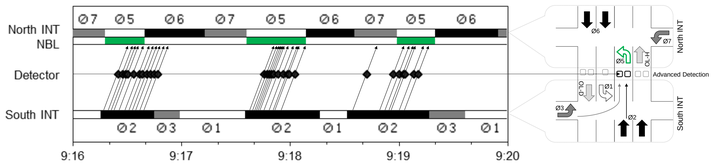
A) Southbound thru traffic sourced upstream from Ø6 and Ø7 arriving at overlap-D (OL-D)



B) Southbound left traffic sourced upstream from Ø6 and Ø7 arriving at Ø1

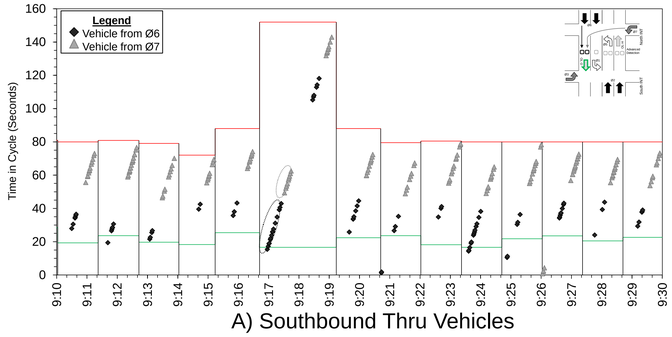


C) Northbound thru traffic sourced upstream from Ø2 and Ø3 arriving at overlap-H (OL-H)

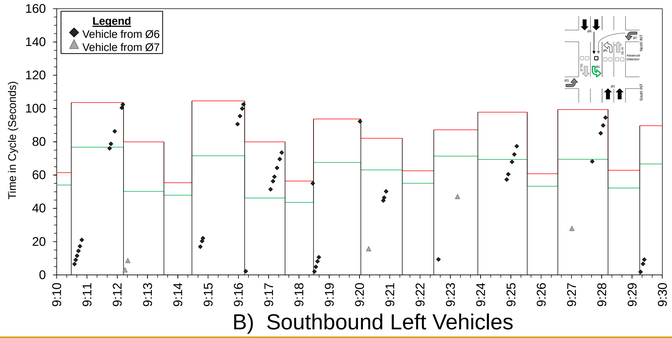


D) Northbound left traffic sourced upstream from Ø2 and Ø3 arriving at Ø5

PURDUE COORDINATION DIAGRAM (PCD)

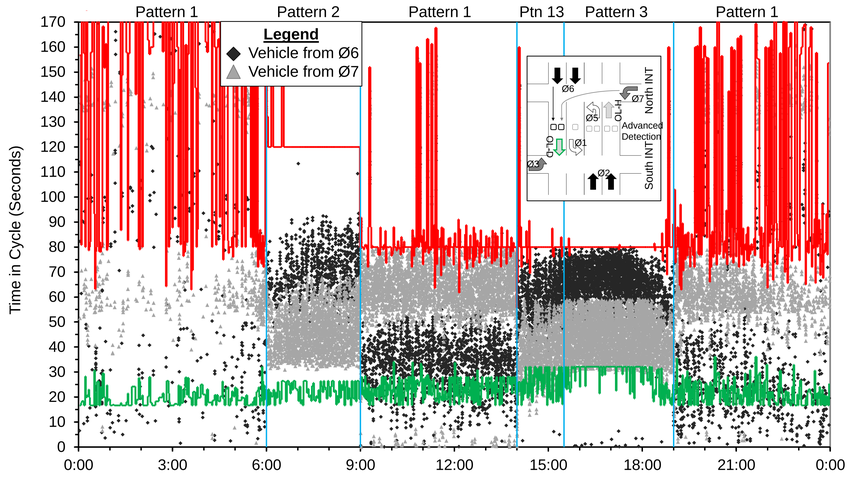


A) Southbound Thru Vehicles

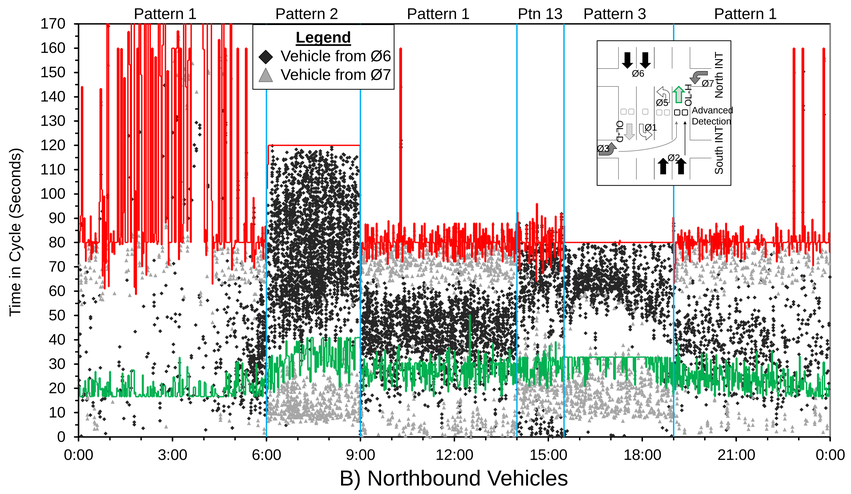


B) Southbound Left Vehicles

PURDUE COORDINATION DIAGRAM (PCD) OVER 24-HOURS

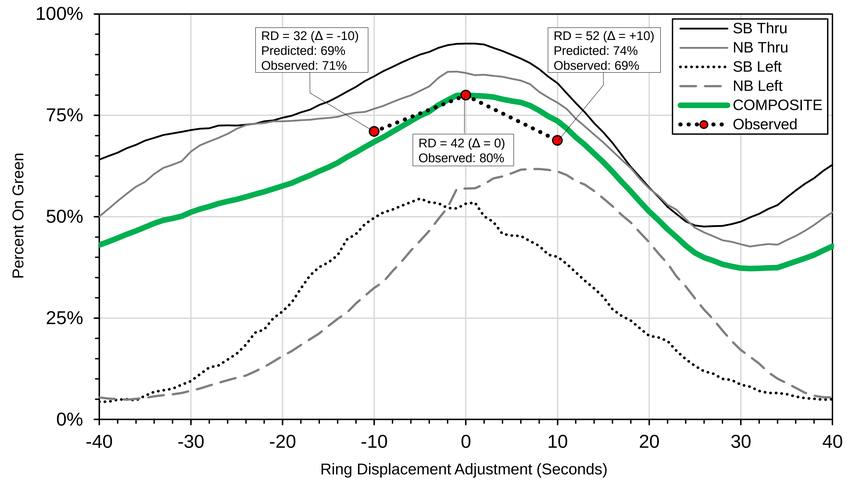


A) Southbound Vehicles

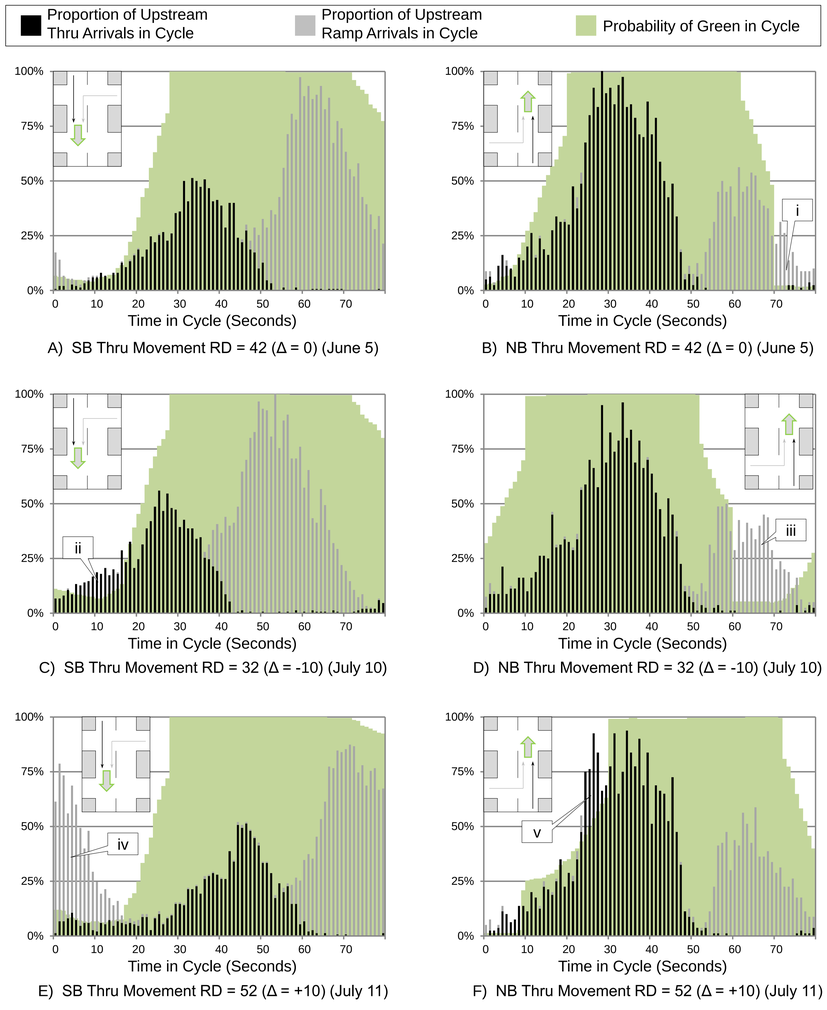


B) Northbound Vehicles

RING DISPLACEMENT SWEEP / OPTIMIZATION



FLOW PROFILE DIAGRAMS



A) SB Thru Movement RD = 42 (Δ = 0) (June 5)

B) NB Thru Movement RD = 42 (Δ = 0) (June 5)

C) SB Thru Movement RD = 32 (Δ = -10) (July 10)

D) NB Thru Movement RD = 32 (Δ = -10) (July 10)

E) SB Thru Movement RD = 52 (Δ = +10) (July 11)

F) NB Thru Movement RD = 52 (Δ = +10) (July 11)

CONCLUSIONS

High-resolution controller event data is a valuable tool in measuring and assessing performance at diamond interchanges. This study demonstrated the use of high resolution controller data in the following applications:

- Diamond operation was visualized over several hours and multiple plans. This is particularly important because it is frequently impractical to allocate staff time for that purpose, and for many large diamond interchanges, it is often difficult to find a vantage point to make high quality observations. The paper provided example PCDs and flow profiles as visualizations that would be suitable for controller front panel display or central system graphics.
- Quantitative performance measures were developed to assess the quality of progression for the four external movements, and demonstrate how those could be used to verify whether the settings are appropriate, or initiate a ring displacement parameter change. The paper also demonstrated that the predicted and observed values of POG for ring displacement adjustments were in reasonable agreement.
- Performance measures were defined for evaluating how effectively the interior of the diamond interchange was clearing. It was shown that high red occupancy ratios correlated with excessive interior queuing. These same performance measures can be used to evaluate risk of ramps queuing onto the interstate.

A final important note is that the performance measures demonstrated in this paper depend upon appropriate detection configurations. As high-resolution data and performance measures become vital engineering tools, it is critical that diamond interchange designs include advanced detection at all approaches. As the detection practices are adopted, modern controllers with graphical displays, or the ability to provide such a display on a mobile device, would be ideal platforms to convey this information to engineers in the field.