

# High-Resolution Controller Data Performance Measures for Optimizing DIVERGING DIAMOND INTERCHANGES AND OUTCOME ASSESSMENT WITH DRONE VIDEO



**PURDUE**  
UNIVERSITY

Paper No. 15-0645

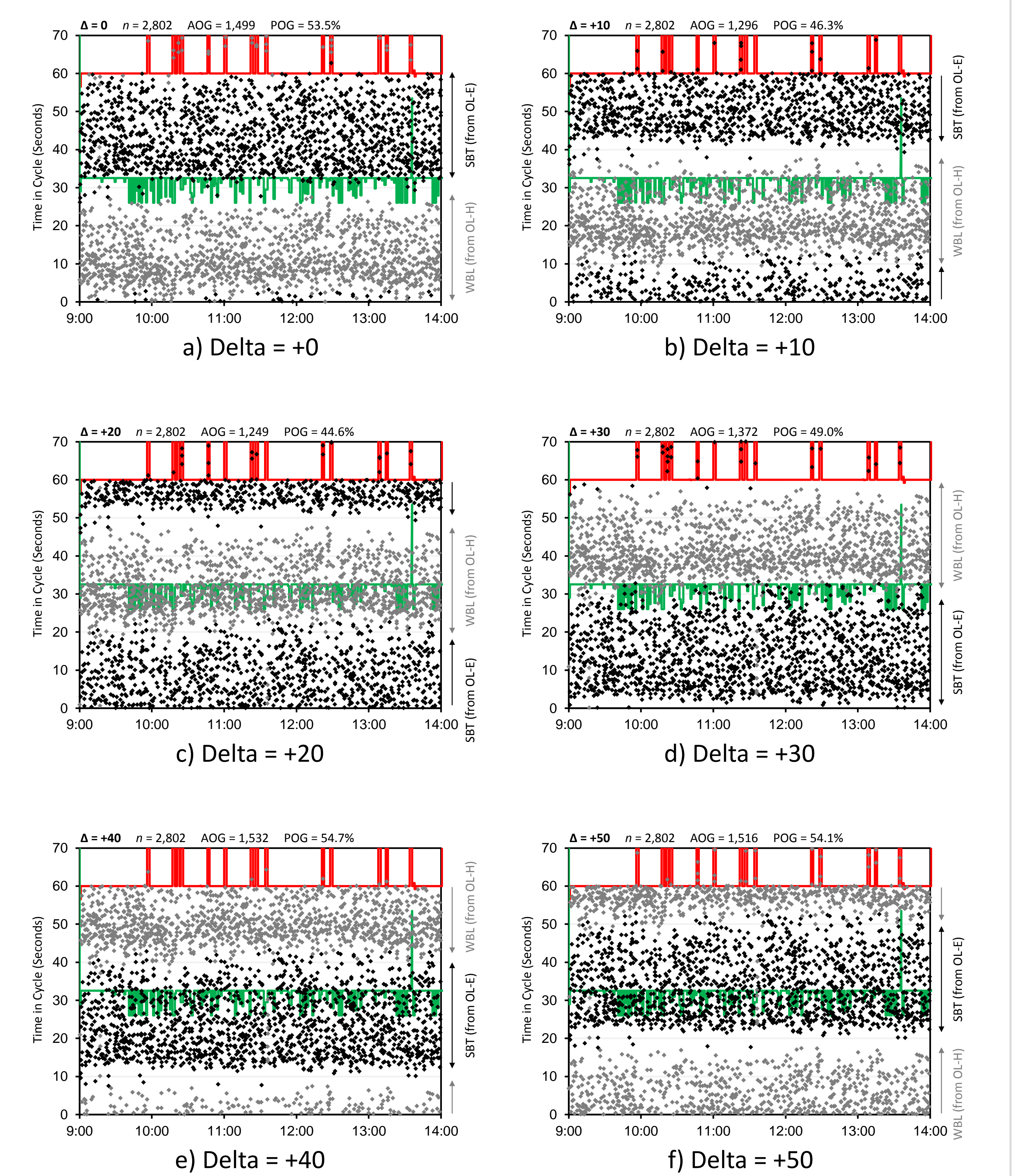
Alexander M. Hainen<sup>1</sup>, Amanda L. Stevens<sup>3</sup>, Christopher M. Day<sup>2</sup>, Howell Li<sup>2</sup>, Jamie Mackie<sup>4</sup>, Matt Luker<sup>4</sup>, Mark Taylor<sup>4</sup>, James R. Sturdevant<sup>3</sup>, Darcy M. Bullock<sup>2</sup>  
1: The University of Alabama; 2: Purdue University; 3: Indiana Department of Transportation; 4: Utah Department of Transportation

## ABSTRACT

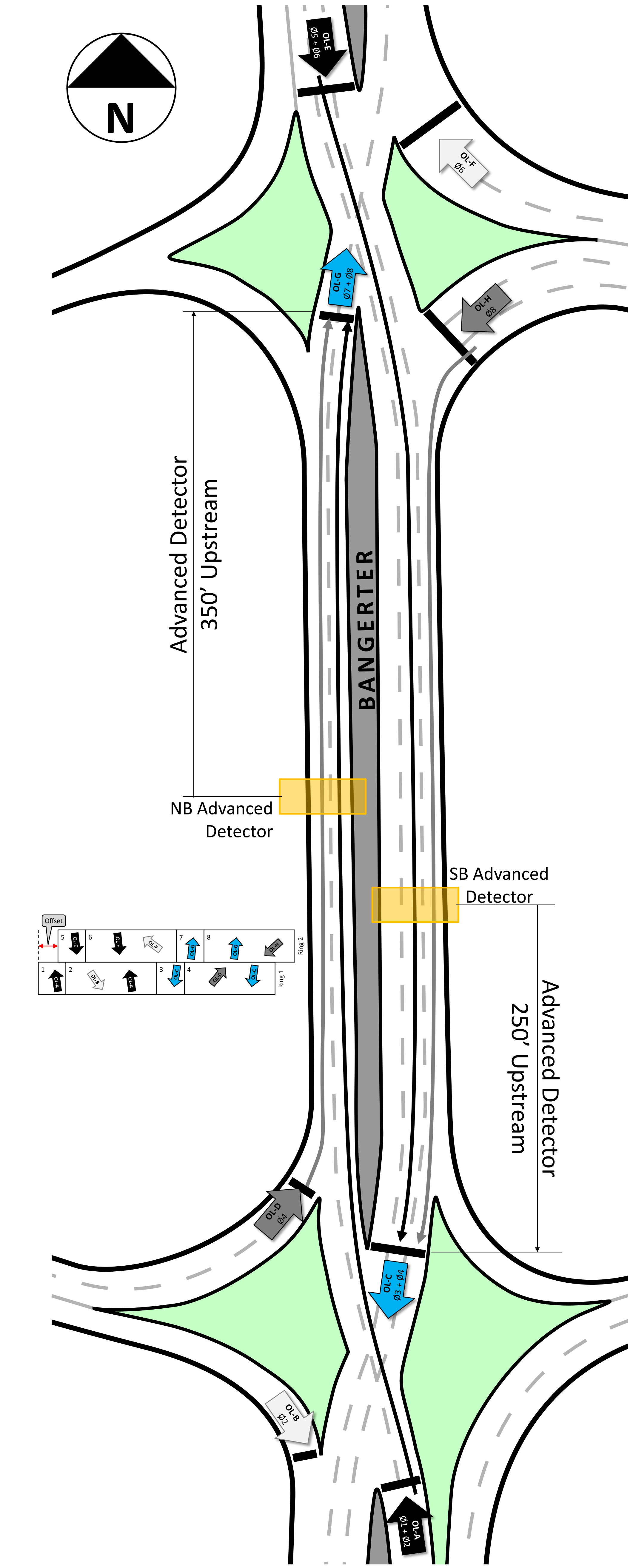
Diverging Diamond Interchanges (DDIs) are an emerging interchange configuration that eliminates the need for left-turn phases in conventional diamonds and may be less expensive to construct than some alternative geometries. This paper examines signal timing for DDIs. To date, DDI signal timing has typically used two-phase configuration reflecting the two competing movements at the cross-over points at each intersection of the DDI. This configuration inherently contains some inefficiency: i) there is potential for internal queuing under two-phase configuration, and ii) it is possible for the inflow demand to exceed outflow capacity of the interchange.

This paper uses high-resolution event data to develop performance measures to evaluate operations at a DDI in Salt Lake City, Utah. Alternatives to the existing signal timing within the two-phase configuration are modelled and tested with a field deployment. The field deployment demonstrated the ability to prioritize ramp or thru vehicles within the two-phase configuration. Additionally, a new three-phase configuration was developed and deployed to address the internal queuing that occurs with two-phase timing. Under this new configuration, the flows from one DDI intersection to the other are balanced and progression within the DDI is improved. By implementing the three-phase configuration, the percent of vehicles arriving on green at the heaviest internal movement within the DDI increased from 53% to 92%. To qualitatively illustrate these performance measures and improved DDI operation, a video from a tethered unmanned aerial vehicle (UAV) was prepared that demonstrates the vehicle arrival characteristics by overlaying vehicle detection and signal state graphics on the video.

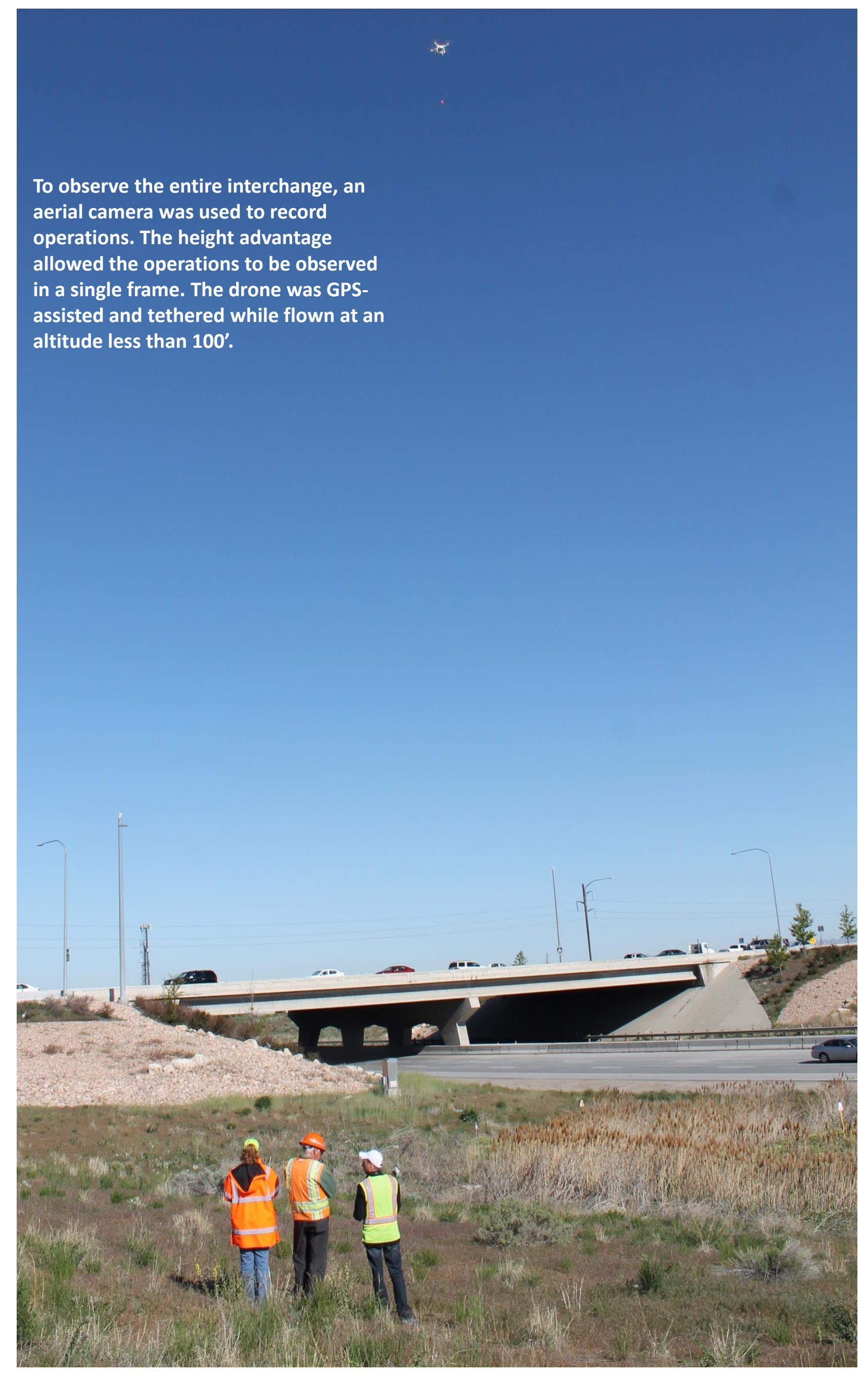
## RING DISPLACEMENT



## BANGERTER HWY, SALT LAKE CITY, UT

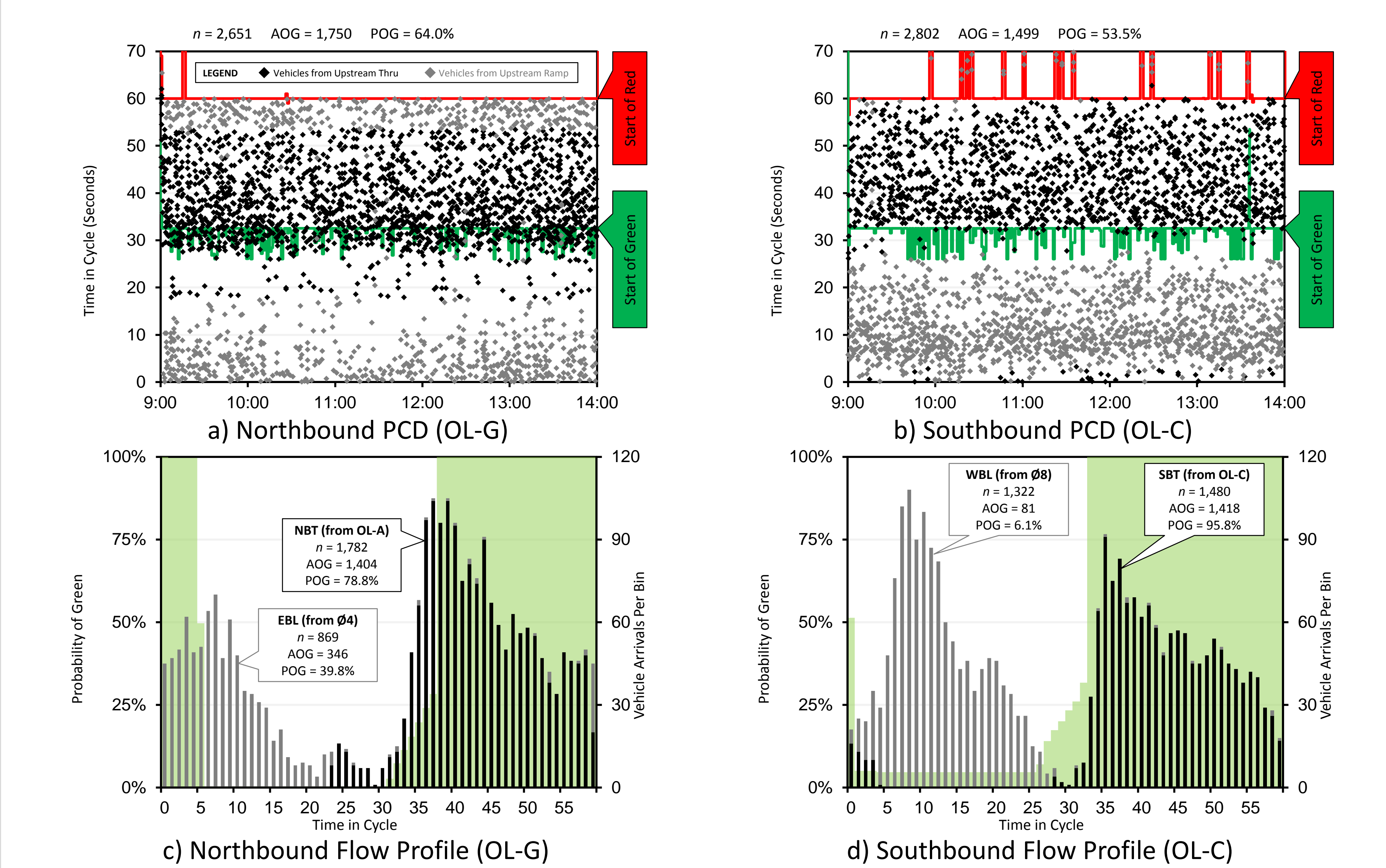


## DRONE VIDEO



To observe the entire interchange, an aerial camera was used to record operations. The height advantage allowed the operations to be observed in a single frame. The drone was GPS-assisted and tethered while flown at an altitude less than 100'.

## PURDUE COORDINATION DIAGRAM / FLOW PROFILE DIAGRAMS





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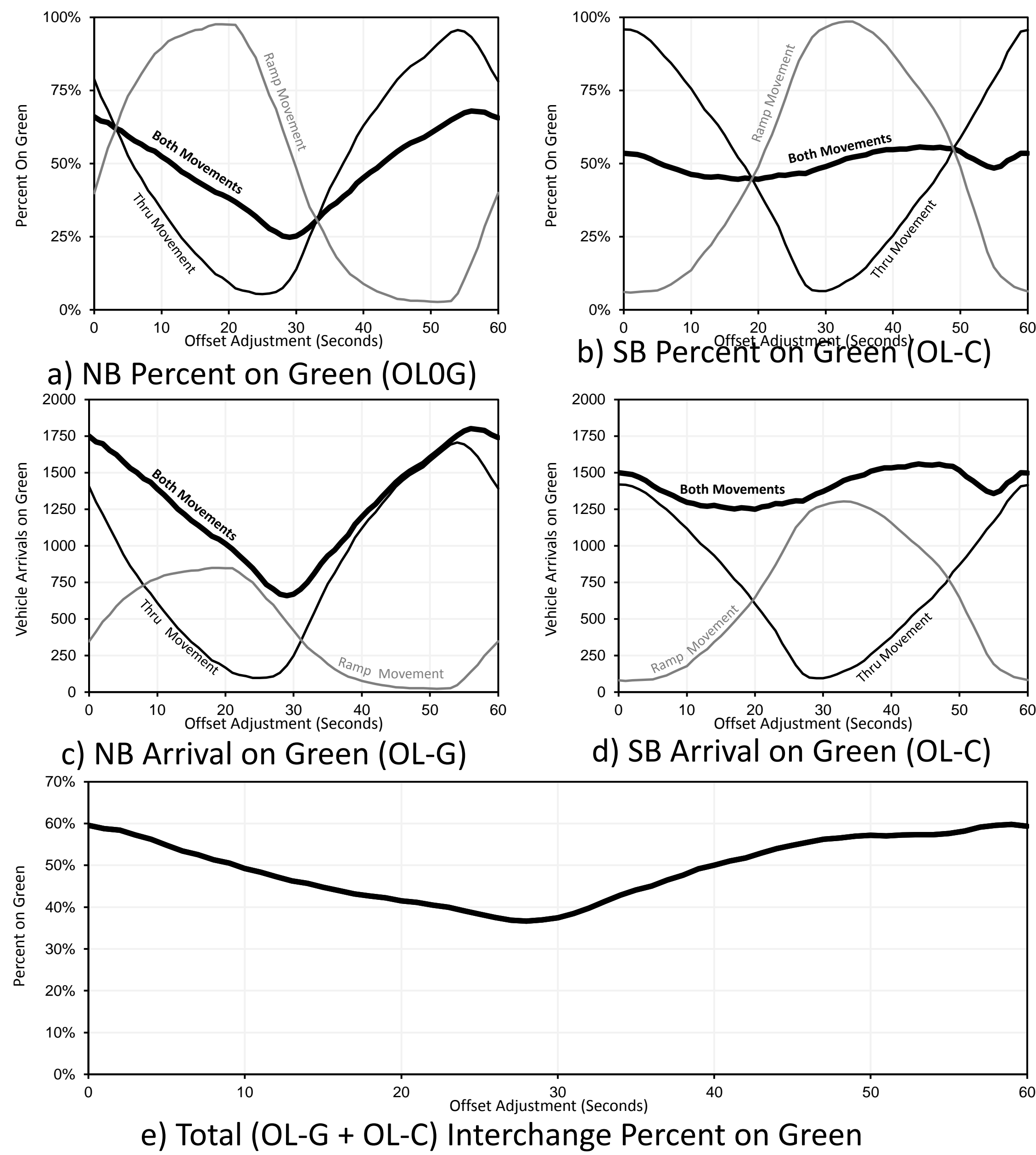


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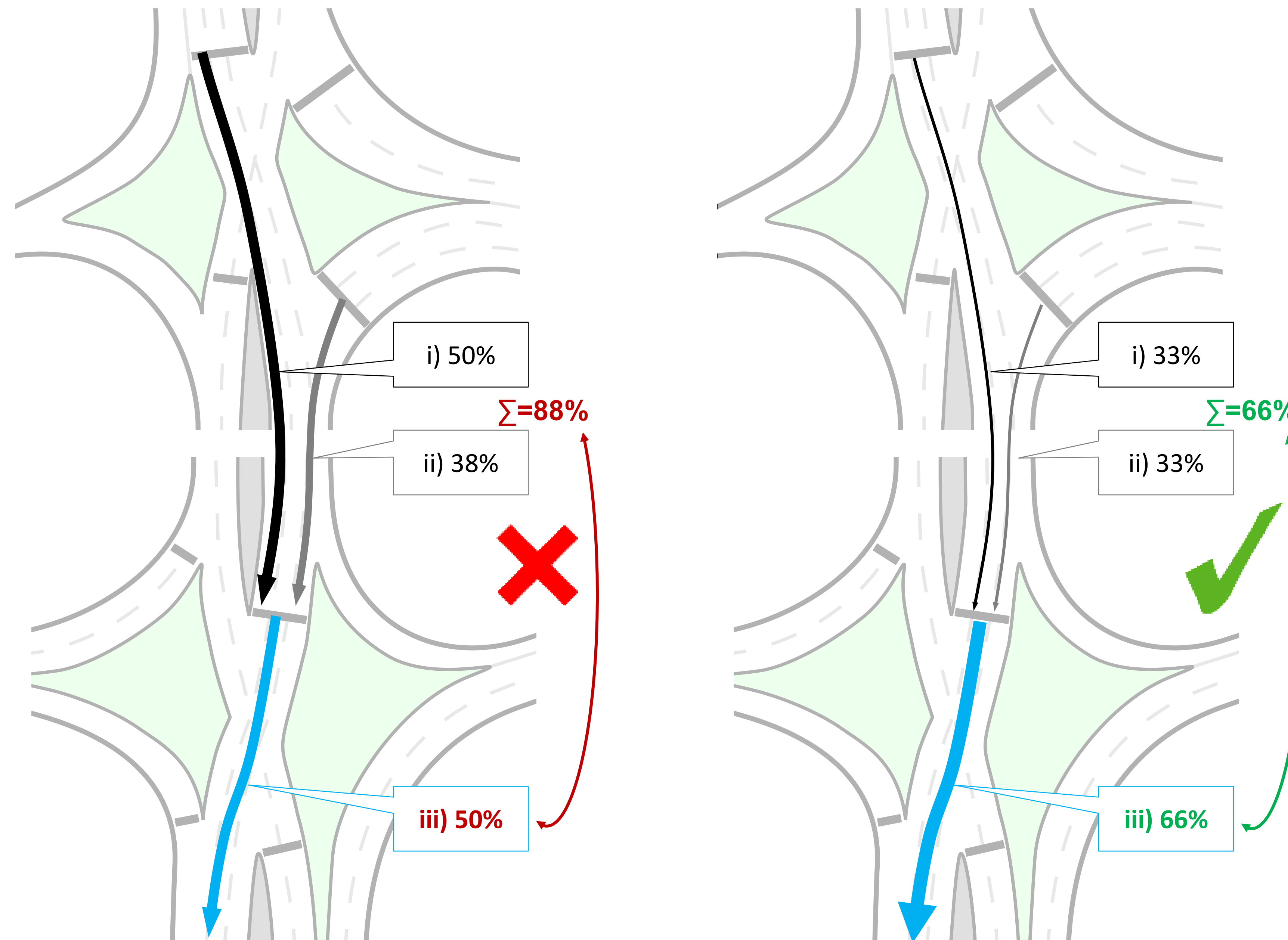
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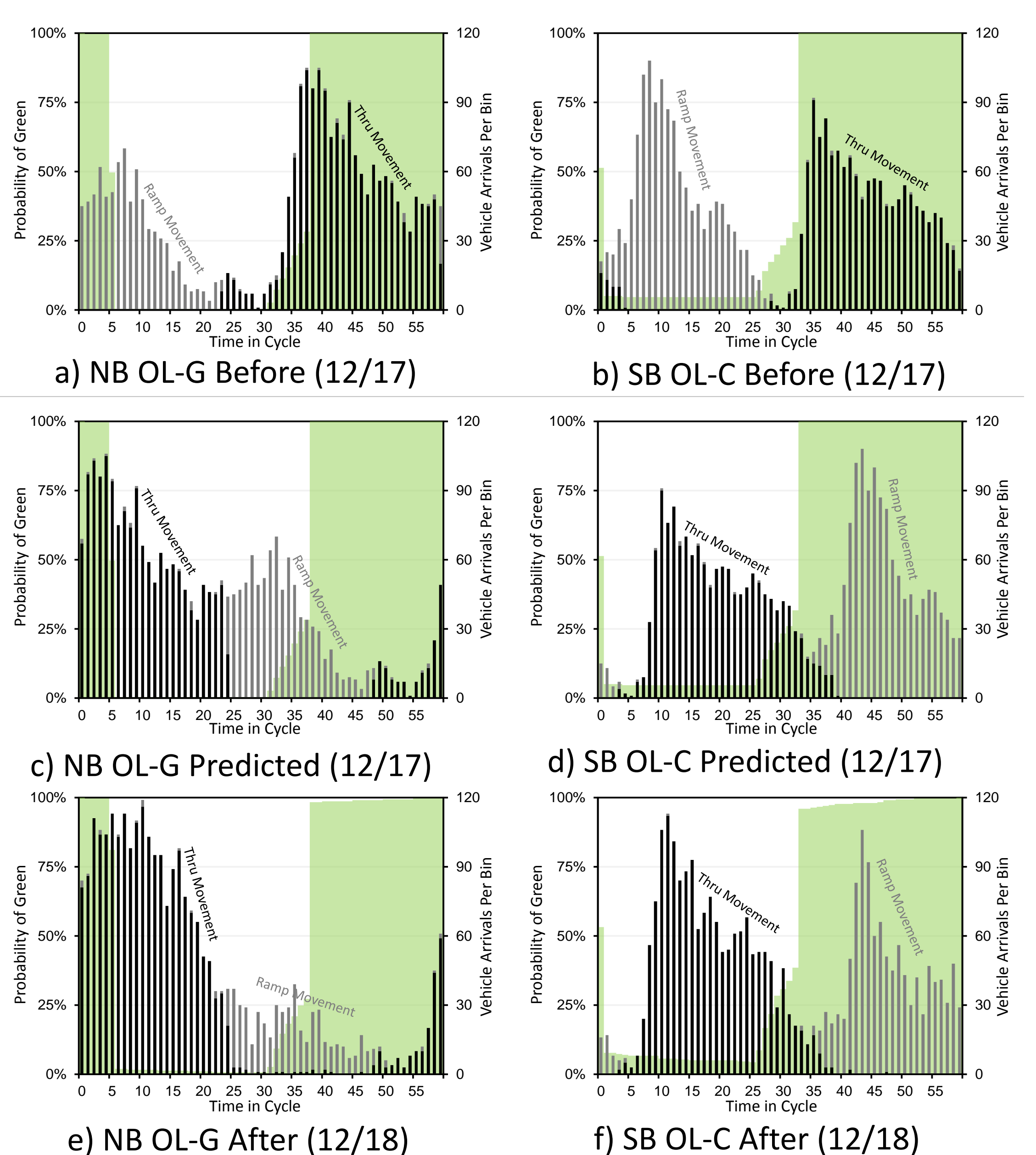
## OFFSET ADJUSTMENT PERFORMANCE



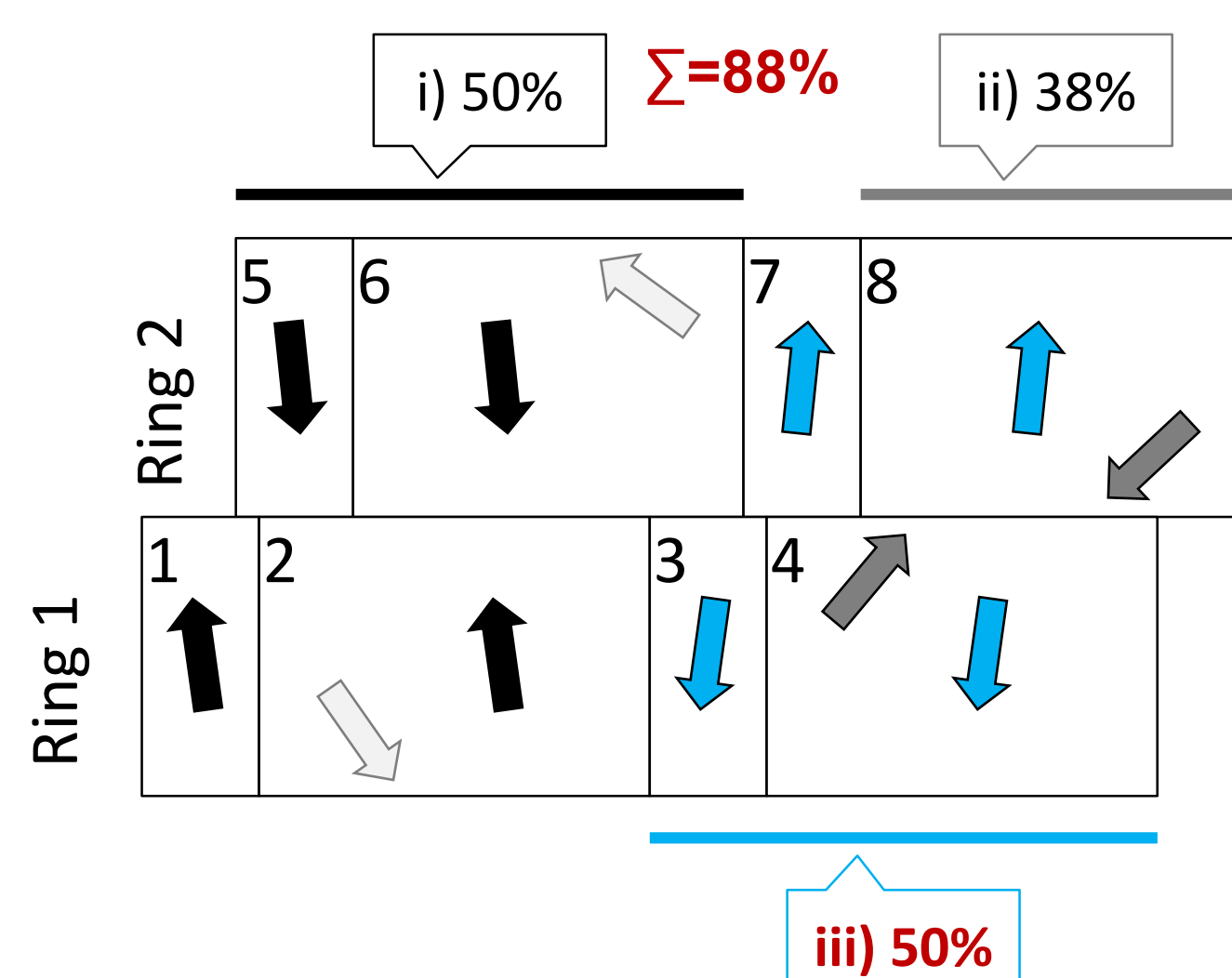
## THREE PHASE OPERATIONS & SPLIT BALANCE



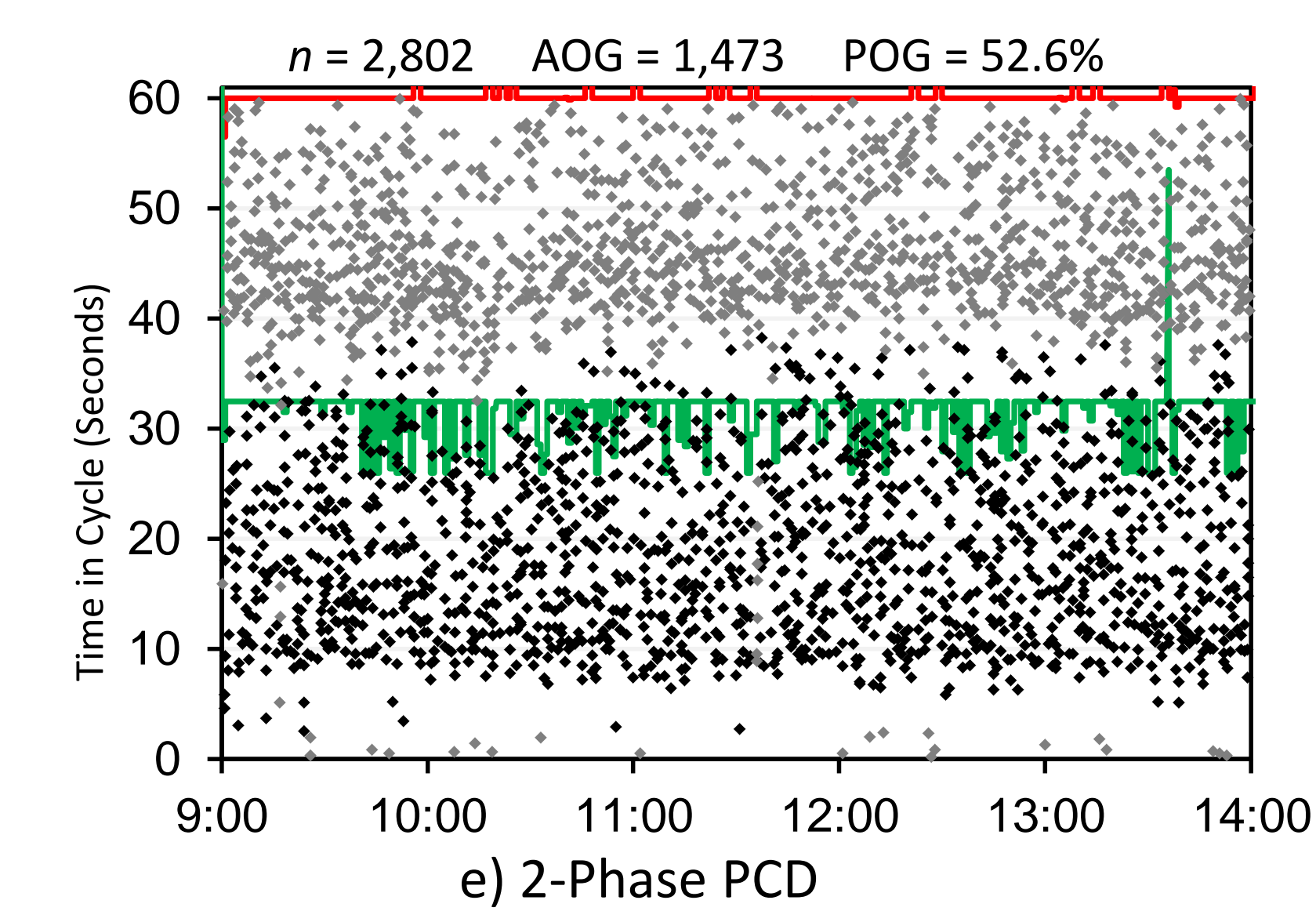
## MOVEMENT REPRIORITIZATION



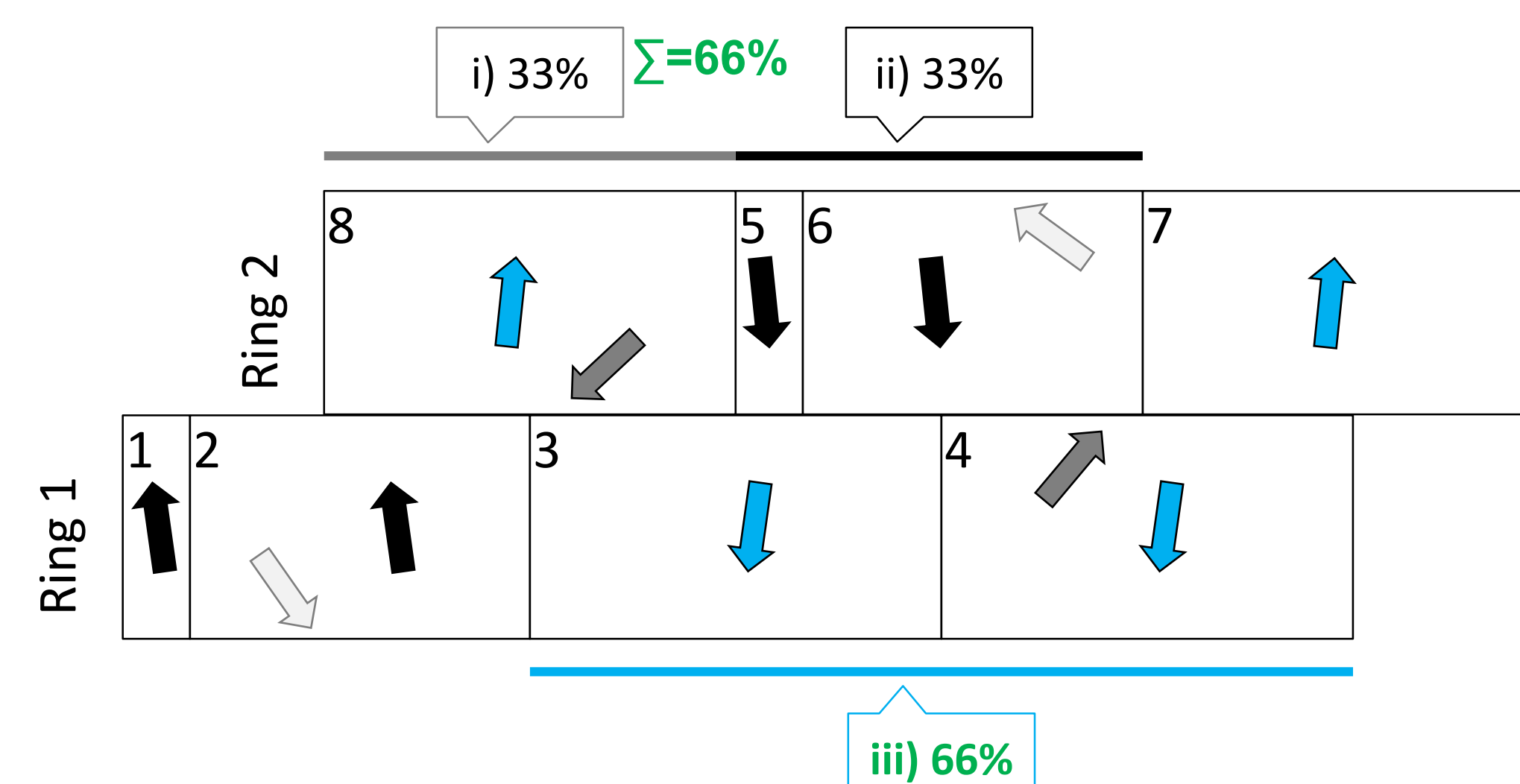
a) 2-Phase Pipe Flow Imbalance



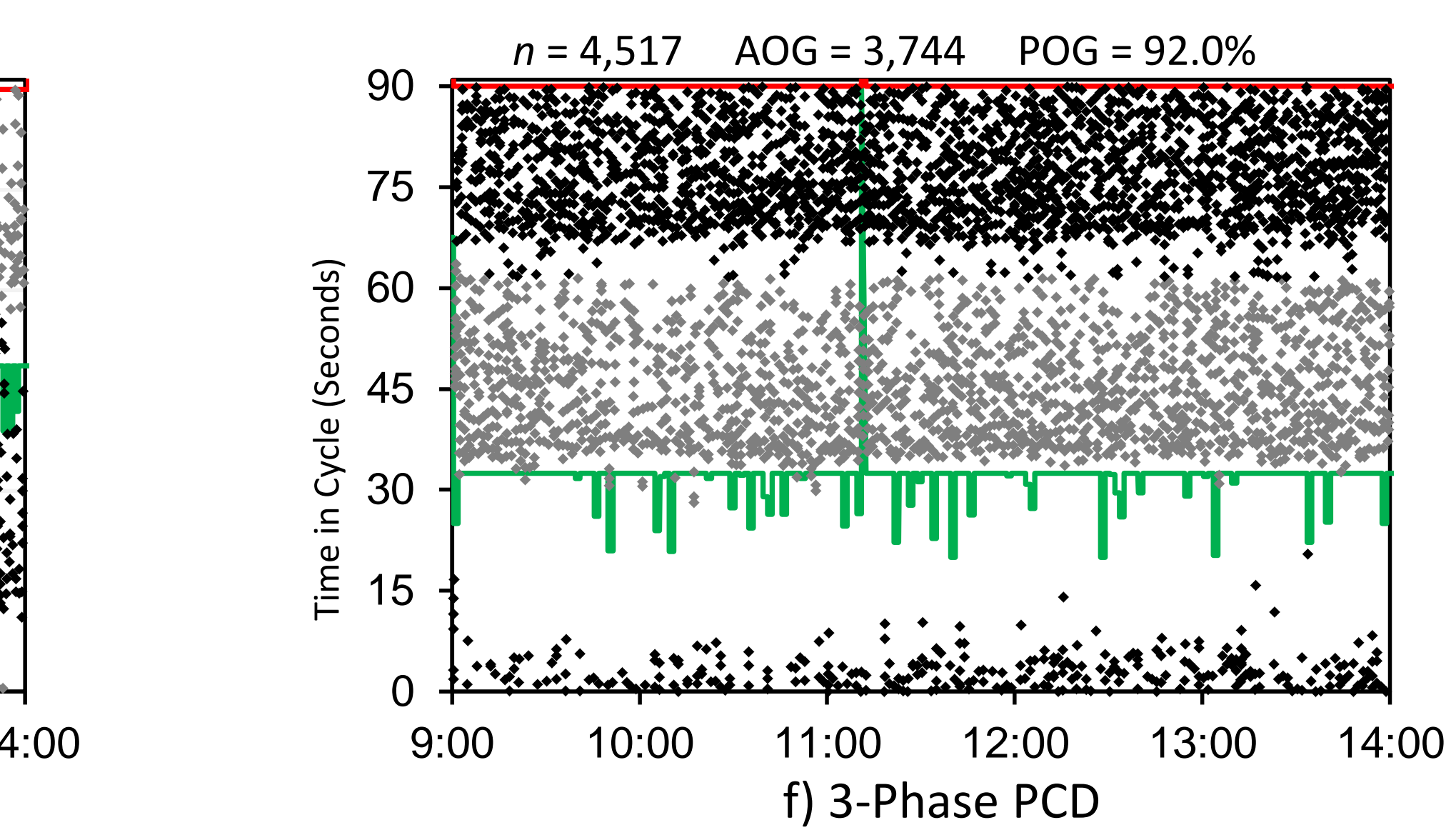
c) 2-Phase Ring Diagram  
(CL = 60s, RD = 5s)



b) 3-Phase Pipe Flow Balance



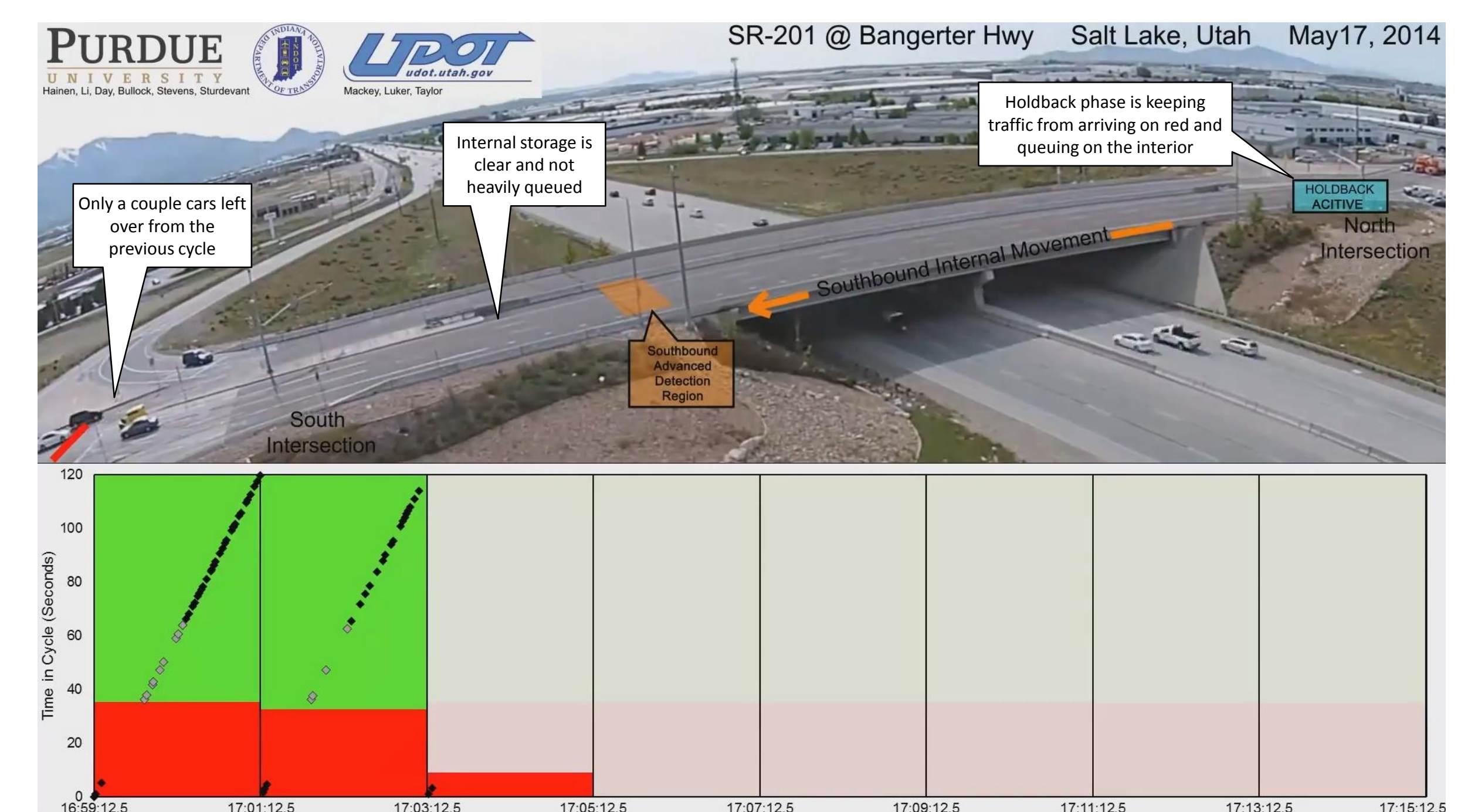
d) 3-Phase Ring Diagram  
(CL = 90s, RD = 45s)



## EMPIRICAL OUTCOME



a) 2-phase w/o Holdback (Internal Queuing)



b) 3-phase start of Holdback (No Internal Queuing)



c) 3-phase clean arrival on green

## CONCLUSIONS

DDIs are relatively rare and as agencies bring them on line it is important to have automated performance measures for characterizing their performance as well as identifying opportunities for agencies to improve timings. This paper has extended PCD and flow profile techniques to characterize DDI performance and identify operational improvements using high resolution controller data from the DDI at SR-201 and Bangerter Highway in Salt Lake City, Utah. Three-phase operation is most appropriate to consider with heavy thru movement volumes, especially when both the ramp and external thru movements are heavy. External queuing outside of the DDI and throughput through the DDI were not quantitatively measured.