Quantifying Benefits of Signal Timing Maintenance and Optimization Using both Travel Time and Travel Time Reliability Measures

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ABSTRACT

Maintaining and optimizing signal timing directly contributes to an improved end-user driving experience. With recent developments in crowd-sourced vehicle probe data, travel time improvements associated with signal re-timings can be quantitatively assessed without costly infrastructure.

This study compares the performance of three signal re-timing scenarios – 1) pre-maintenance, 2) post- time-of-day and clock maintenance, and 3) post-progression optimization – for the weekday AM peak, mid-day, and PM peak time periods. The percentage of vehicles arriving on green and vehicle travel time distributions were evaluated for each of the tasks in each period. User benefits were then quantified using the travel time data with the mean-variance method to determine the dollar savings for the tasks performed. Signal time-of-day plan maintenance and clock synchronization accounted for some of the travel time benefits, but the savings were less reliable than progression optimization, which improved both travel times and reliability.

STUDY LOCATION

INDIANA STATE ROAD 37

CLOUD-BASED DATA

Crowd-sourced probe vehicle data has become widely available on the cloud via third-party traffic data service providers such as INRIX. These data consists of *average speed* information to determine *arterial travel time* in both urban and rural areas for most times of the day. Below is an example of how travel times are computed using this data.

SIGNAL TIMING MAINTENANCE

DETECTOR RACKS AND CARDS

TIMING PLANS

Maintenance includes checking the proper operation of vehicle detection components, timing parameters (locally and relative to system), data logging, and communication at each intersection in the corridor. This insures detector actuation is functional, clocks are synchronized, and performance measures can be generated for evaluation and subsequent system optimization.

BEFORE ALIGNMENT OF TIME-OF-DAY PLANS

AFTER ALIGNMENT OF TIME-OF-DAY PLANS

- AM Plan
- Mid Day Plan
- PM Plan
- Early Evening Plan
- Overnight/Free Plan

HIGH-RESOLUTION DATA

High-resolution signal event data are digital logs of controller events, including phase indications and detector activations, to one-tenth of a second time resolution. Logs are stored in binary format, which can then be retrieved and translated. The resulting data is in a human-readable format that is mapped to a set of events of a controller.

Traffic Signal Controller

Binary Data Files
01011100 ...

Time	Code	Parameter
10:00:58.8	1	7
10:01:02.2	82	40
10:01:03.1	81	22
10:01:03.5	82	26
10:01:04.3	81	40

For more information: <http://doi.org/10.5703/1288284315333>

VEHICLE ARRIVALS ON GREEN

Using the high-resolution event data, the number of vehicles arriving during the green phase can be counted for each cycle or time-of-day period.

ARRIVALS ON RED (AOR)

Photo courtesy of Alex Hainen

ARRIVALS ON GREEN (AOG)

Photo courtesy of Alex Hainen

OFFSET OPTIMIZATION

The *link-pivot combination heuristic* was used to improve progression on the corridor by using historic arrival data to predict optimal offsets at each intersection. The objective is to maximize the total number of vehicles arriving on green. The below example shows a 17-second offset adjustment at intersection 1, visualized using the Purdue Coordination Diagram (PCD).

Quantifying Benefits of Signal Timing Maintenance and Optimization

Using both Travel Time and Travel Time Reliability Measures

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AM PEAK PERIOD RESULTS

MID DAY PERIOD RESULTS

STATISTICAL SIGNIFICANCE

CHANGES IN PERCENT VEHICLE ARRIVALS ON GREEN ($\alpha = 0.05$)

POST-MAINTENANCE

Approach	AM Peak (0600 - 0900)				Mid-Day (0900 - 1400)				PM Peak (1400 - 1900)			
	Z-Score	P-Value	Improved?	Degraded?	Z-Score	P-Value	Improved?	Degraded?	Z-Score	P-Value	Improved?	Degraded?
Pilot Gas (NB)	-1.7	0.05	No	Yes	1.5	0.06	No	No	2.2	0.02	Yes	No
I-465 WB Ramp (NB)	-0.2	0.40	No	No	-3.6	0.00	No	Yes	-10.9	0.00	No	Yes
I-465 WB Ramp (SB)	0.2	0.42	No	No	-2.1	0.02	No	Yes	-0.2	0.43	No	No
I-465 EB Ramp (NB)	3.0	0.00	Yes	No	1.2	0.12	No	No	-0.2	0.41	No	No
I-465 EB Ramp (SB)	-0.3	0.39	No	No	-1.9	0.03	No	Yes	-9.1	0.00	No	Yes
Thompson Rd. (NB)	2.9	0.00	Yes	No	1.2	0.11	No	No	2.7	0.00	Yes	No
Thompson Rd. (SB)	2.7	0.00	Yes	No	-0.6	0.27	No	No	-1.7	0.05	No	Yes
Harding St. (NB)	-1.7	0.05	No	Yes	-0.1	0.45	No	No	3.7	0.00	Yes	No
Epler Av. (NB)	1.1	0.14	No	No	-1.6	0.05	No	No	-2.3	0.01	No	Yes
Epler Av. (SB)	0.2	0.40	No	No	0.6	0.27	No	No	-8.1	0.00	Yes	No
Banta Rd. (NB)	-0.8	0.22	No	No	-3.2	0.00	No	Yes	8.5	0.00	Yes	No
Banta Rd. (SB)	0.4	0.33	No	No	-5.5	0.00	No	Yes	5.1	0.00	Yes	No
Southport Rd. (NB)	1.5	0.07	No	No	2.0	0.02	Yes	No	2.6	0.01	Yes	No
Southport Rd. (SB)	-0.1	0.47	No	No	1.5	0.06	No	No	-3.1	0.00	No	Yes
Wicker Rd. (NB)	6.3	0.00	Yes	No	2.3	0.01	Yes	No	-3.0	0.00	No	Yes
Wicker Rd. (SB)	0.0	0.49	No	No	1.5	0.07	No	No	-4.2	0.00	No	Yes
County Line Rd. (NB)	6.1	0.00	Yes	No	-2.1	0.02	No	Yes	-1.1	0.13	No	No
County Line Rd. (SB)	-0.3	0.40	No	No	0.8	0.23	No	No	-2.1	0.02	No	Yes
Fairview Rd. (NB)	-4.9	0.00	No	Yes	-2.2	0.01	No	Yes	-9.0	0.00	No	Yes
Fairview Rd. (SB)	7.4	0.00	Yes	No	2.0	0.02	Yes	No	-1.7	0.04	No	Yes
Smith Valley Rd. (NB)	13.9	0.00	Yes	No	9.9	0.00	Yes	No	24.5	0.00	Yes	No
Smith Valley Rd. (SB)	1.8	0.03	Yes	No	-0.4	0.34	No	No	3.9	0.00	Yes	No
SR 144 (SB)	4.9	0.00	Yes	No	1.7	0.04	Yes	No	-1.8	0.04	No	Yes

Most significant improvements to green arrivals due to signal timing maintenance occurred in the AM peak period, while the mid day and PM periods exhibited no overall net improvement.

POST-OPTIMIZATION

Approach	AM Peak (0600 - 0900)				Mid-Day (0900 - 1400)				PM Peak (1400 - 1900)			
	Z-Score	P-Value	Improved?	Degraded?	Z-Score	P-Value	Improved?	Degraded?	Z-Score	P-Value	Improved?	Degraded?
Pilot Gas (NB)	-0.6	0.27	No	No	-0.2	0.43	No	No	-0.2	0.41	No	No
I-465 WB Ramp (NB)	0.3	0.38	No	No	-3.2	0.00	No	Yes	-6.6	0.00	No	Yes
I-465 WB Ramp (SB)	1.0	0.16	No	No	-0.2	0.42	No	No	1.6	0.05	No	No
I-465 EB Ramp (NB)	2.3	0.01	Yes	No	1.5	0.06	No	No	-6.8	0.00	No	Yes
I-465 EB Ramp (SB)	0.5	0.33	No	No	-2.0	0.02	No	Yes	-3.9	0.00	No	Yes
Thompson Rd. (NB)	6.7	0.00	Yes	No	5.5	0.00	Yes	No	2.6	0.00	Yes	No
Thompson Rd. (SB)	0.9	0.18	No	No	0.9	0.18	No	No	8.4	0.00	Yes	No
Harding St. (NB)	2.7	0.00	Yes	No	10.4	0.00	Yes	No	5.1	0.00	Yes	No
Epler Av. (NB)	1.0	0.15	No	No	7.0	0.00	Yes	No	-14.0	0.00	No	Yes
Epler Av. (SB)	-4.5	0.00	No	Yes	1.7	0.05	Yes	No	-3.6	0.00	No	Yes
Banta Rd. (NB)	-0.8	0.23	No	No	-3.0	0.00	No	Yes	10.0	0.00	Yes	No
Banta Rd. (SB)	-1.6	0.05	No	No	-4.1	0.00	No	Yes	11.0	0.00	Yes	No
Southport Rd. (NB)	3.9	0.00	Yes	No	7.1	0.00	Yes	No	-3.2	0.00	No	Yes
Southport Rd. (SB)	8.4	0.00	Yes	No	-0.3	0.37	No	No	-0.7	0.24	No	No
Wicker Rd. (NB)	7.6	0.00	Yes	No	2.3	0.01	Yes	No	-0.2	0.44	No	No
Wicker Rd. (SB)	11.8	0.00	Yes	No	16.3	0.00	Yes	No	2.8	0.00	Yes	No
County Line Rd. (NB)	7.7	0.00	Yes	No	-4.3	0.00	No	Yes	-4.5	0.00	No	Yes
County Line Rd. (SB)	-12.2	0.00	No	Yes	-10.0	0.00	No	Yes	4.9	0.00	Yes	No
Fairview Rd. (NB)	0.9	0.17	No	No	2.8	0.00	Yes	No	23.0	0.00	Yes	No
Fairview Rd. (SB)	8.4	0.00	Yes	No	-2.7	0.00	No	Yes	-2.7	0.00	No	Yes
Smith Valley Rd. (NB)	15.6	0.00	Yes	No	9.4	0.00	Yes	No	23.9	0.00	Yes	No
Smith Valley Rd. (SB)	4.1	0.00	Yes	No	-1.4	0.07	No	No	2.6	0.01	Yes	No
SR 144 (SB)	8.8	0.00	Yes	No	3.1	0.00	Yes	No	16.2	0.00	Yes	No

Green arrivals due to optimization improved for the AM peak overall. Mid day and PM peak saw modest net improvements.

PM PEAK PERIOD RESULTS

USER BENEFITS OF RE-TIMING

COMBINED NORTHBOUND AND SOUTHBOUND, ALL PERIODS, ANNUALIZED

TRAVEL TIME SAVINGS

Monetized user benefits by reducing *mean corridor travel times*. Average volumes of all intersection approaches are used to compute benefits.

TRAVEL TIME RELIABILITY

The reduction in the *variability* of travel times monetized as a user benefit using the *mean-variance approach*.

CONCLUSION

1) Maintenance is a critical precursor for optimization.

2) Performing signal timing maintenance without immediately implementing a robust optimization scheme can itself provide a non-trivial amount of improvement to corridor performance.

3) The evaluation of costs-to-benefits can help agencies decide whether robust investments in traffic signal infrastructure are justified over simple maintenance.

2 Minutes
Improvement to NB median travel time with link-pivot optimization.

30%
Travel time savings from signal timing maintenance alone.