Appendix B. Data Reduction Procedures for Traffic Signal Systems Performance Measures

Attached document:

J. M. Ernst, C.M. Day, and D.M. Bullock. "Data Reduction Procedures for Traffic Signal Systems Performance Measures." Working paper, SPR-3409, Joint Transportation Research Program, August 2011.

Data Reduction Procedures for Traffic Signal Systems Performance Measures

by

Joseph M. Ernst
Purdue University

Christopher M. Day
Purdue University

Darcy M. Bullock
Purdue University

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INTRODUCTION

The data reduction procedures developed for this project develop a framework to link the INDOT database to a Google Maps enabled webpage that display NCHRP 3-79a performance measure graphics[1]. This webpage uses queries that exist as text files in a folder structure. The website code is structured so that new queries added to a folder will automatically be added to the website with no alterations to the rest of the website code. This allows website development, database development, and performance measure query development to be executed independently. A screenshot of the website built on this framework is shown in Figure 1.

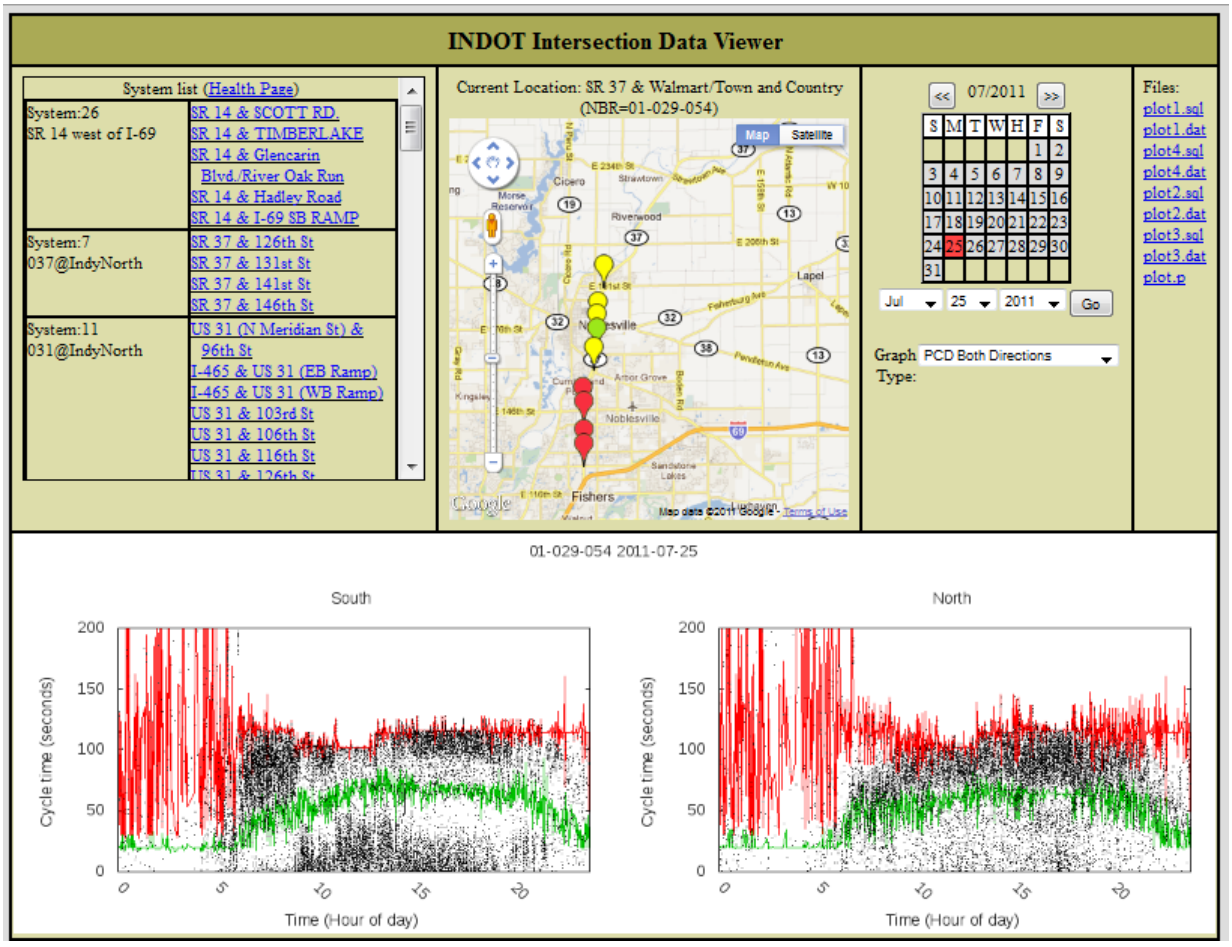


Figure 1 Screenshot of performance measures website.

[1] This paper focuses on implementation of the performance measures in dashboard. Technical details regarding the development of the performance measures is extensively documented in prior publications by the research team (1,2,3,4,5,6,7,8,9).

This following sections discuss the INDOT performance measure database infrastructure, describes each of the queries that have been developed, and then shares some conclusions including the lessons learned when developing the queries.

DATABASE STRUCTURE

The Indiana Department of Transportation (INDOT) maintains a database that stores information about deployed devices and data. This database includes the data used to generate the performance measures described in this section, but also includes many other tables. This section begins by describing the database tables that involved in the performance measures and then documents the performance measures that have been developed.

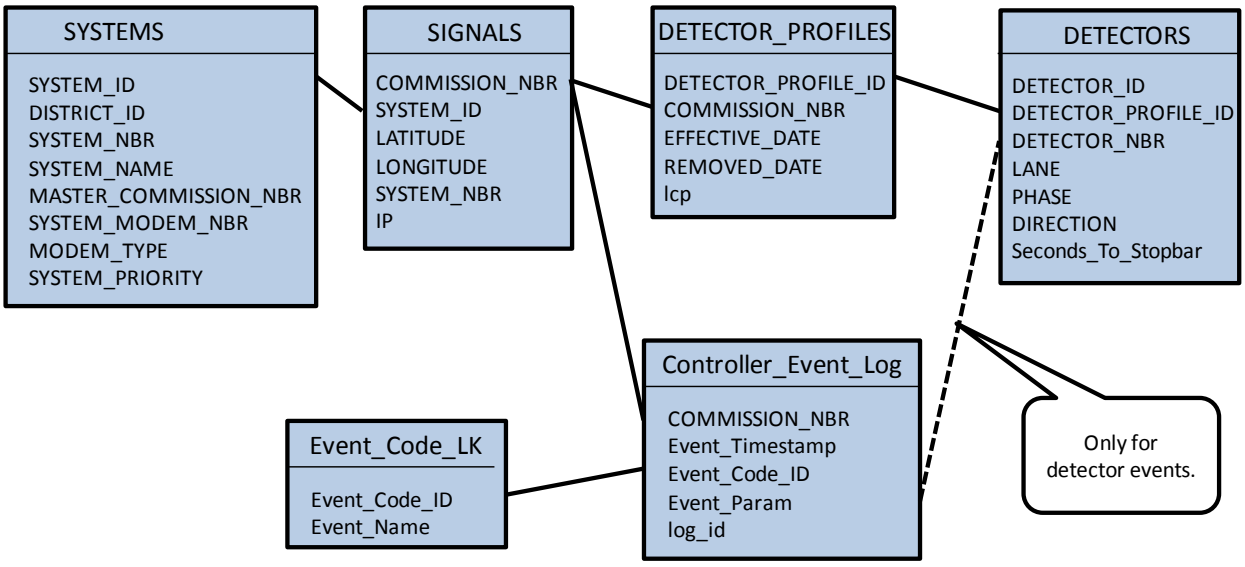


Figure 2 INDOT_Signal_Systems partial database diagram

The database diagram for the tables involved in the performance measure queries is shown in Figure 2. The "Controller_Event_Log" table is the central table for performance measures because it stores all of the collected data. The other tables linked to this table provide text based descriptions of the enuerated data items (Table 1). This structure allows the "Controller_Event_Log" to stay relatively small for the amount of data that it stores. It is important that each data point in the "Controller_Event_Log" table be as small as possible because it currently holds over 1.7 billion rows of data and is growing every day.

The "Controller_Event_Log" has four columns:

- COMMISSION_NBR
- Event_Timestamp
- Event_Code_ID
- Event_Param

The "COMMISSION_NBR" links to the "SIGNALS" table. This indicates from which intersection the data has been collected. As one would expect, the "Event_Timestamp" records the time for each data point. The "Event_Code_ID" column holds an integer that represents a type of event relating to an intersection phase or detector. These events are translated by linking to the "Event_Code_LK" table shown in Table 1. The "Event_Code_IDs" that are not used in the performance measures in this section have a gray background . The "Event_Param" column can mean one of two different things. For events that are associated with an intersection phase, the "Event_Param" is the phase number. For events that are associated with a detector, the "Event_Param" is an integer that links to the "DETECTOR_NBR" column of the "DETECTORS" table.

Table 1 Database Table: Event_Code_LK

Event_Code_ID	Event_Name
0	Phase Off
1	Phase Green
2	Phase Yellow
3	Phase Red Clear
4	Ped Off
5	Ped Walk
6	Ped Clear
8	Detector On
9	Detector Off
10	Detector Failed
11	Detector Restored
12	Overlap Off
13	Overlap Green
14	Overlap Green Extension
15	Overlap Yellow
16	Overlap Red Clear
20	Preempt Active
21	Preempt Off
24	Phase Hold Active
25	Phase Hold Released
26	Ped Call on Phase
27	Ped Call Cleared
32	Phase Min Complete
33	Phase Term Gap Out
34	Phase Term Max Out
35	Phase Term Force Off
40	Coord Pattern Change
41	Cycle Length Change
42	Offset Length Change
43	Split 1 Change
44	Split 2 Change
45	Split 3 Change
46	Split 4 Change
47	Split 5 Change
48	Split 6 Change
49	Split 7 Change
50	Split 8 Change
51	Split 9 Change
52	Split 10 Change
53	Split 11 Change
54	Split 12 Change
55	Split 13 Change
56	Split 14 Change
57	Split 15 Change
58	Split 16 Change
62	Coord cycle state change
63	Coord phase yield point

0 Grayed out cells are not used in performance
1 measures described in this section.

The "DETECTOR_PROFILES" table is used to link a detector to an intersection for a given time range. Since detection configurations change, every detector configuration must be saved so that data collected from that configuration can still be interpreted. The time range in the "DETECTOR_PROFILES" table helps to know which set of detectors was active for the data being analyzed. The last table is the systems table. This groups intersections into systems that could be coordinated. When making changes to intersections based upon the performance measures, it is necessary to look at how those changes will affect the rest of the system.

DEFINITIONS OF PHASE INSTANCE AND CYCLE

Many of the performance measures described in this section are calculated on a cycle by cycle basis. This requires the definition of a cycle boundary[2]. This section begins with an illustrative example to help describe why the definition of cycle length can be challenging. A discussion of the different definitions and the choice of cycle boundary definition follows.

The illustrative example is for a standard 8 phase intersection intersection with the phases defined in the ring diagram in Figure 3. The illustrative example focuses on the top ring (Phases: 1,2,3, and 4).

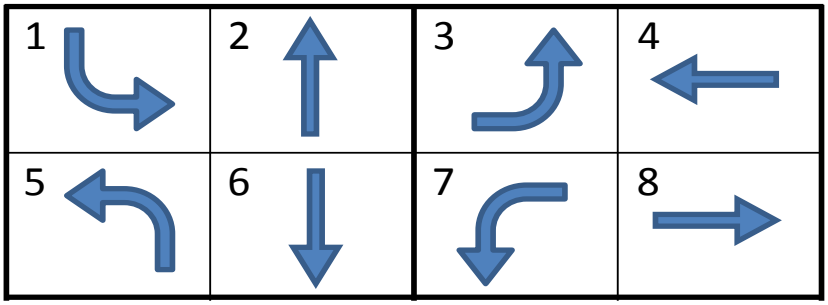
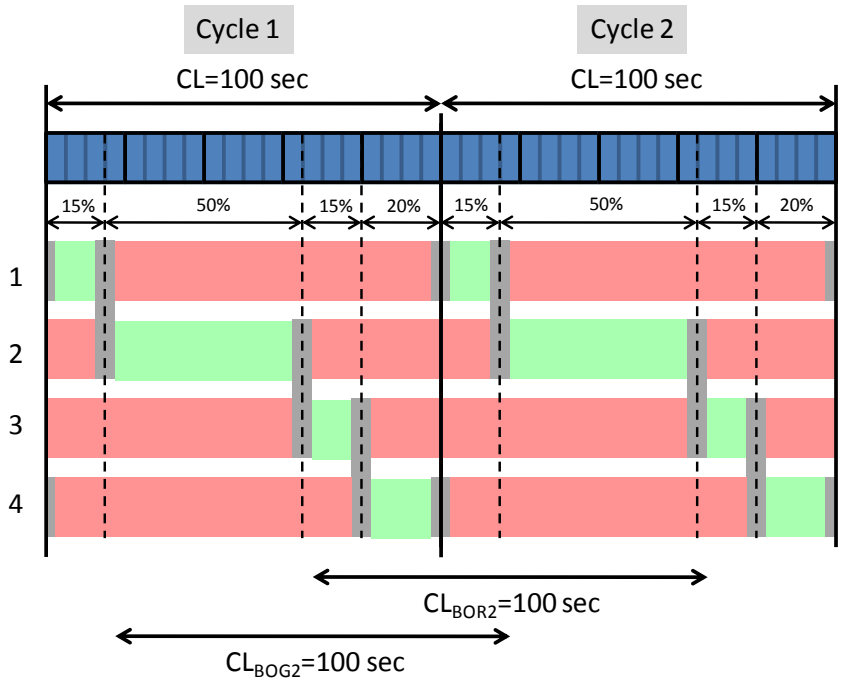


Figure 3 Standard Eight Phase Ring Diagram

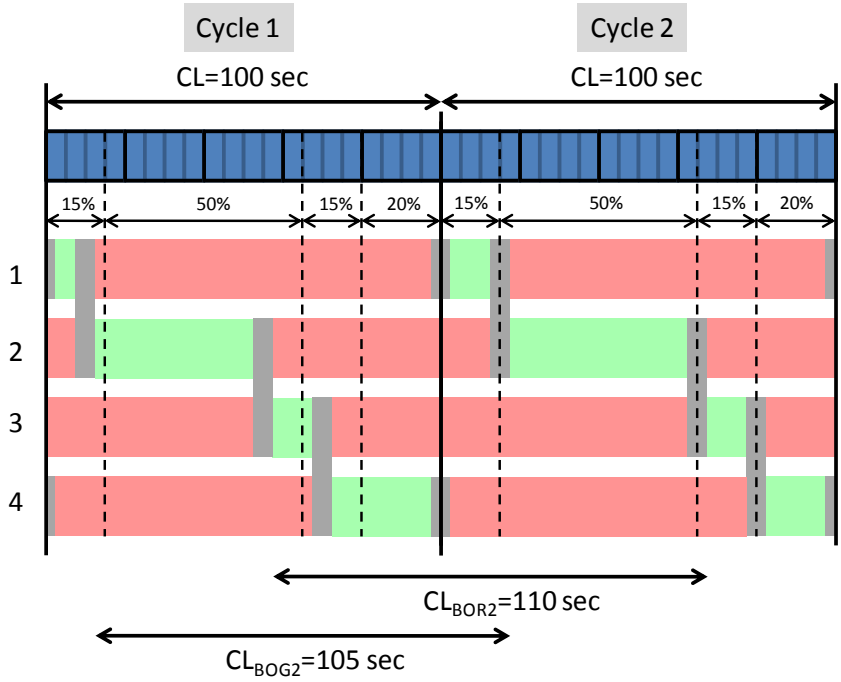
[2] For an extended discussion of cycle definitions, refer to Day *et al*. (1)

Figure 4 shows the signal head states for the phases in the top ring for two different configurations of the intersection. The diagram is red when the signal head for the corresponding phase is red, green when it is green, and gray for the yellow/all red interval. The yellow and all red have been grouped to simplify the diagram. Figure 4a shows the phase diagram for a coordinated system. The signal head states are completely determined by the split timings. For this example a 15% split is used for the left turn movements (phases 1 and 3), a 20% split is used for the cross movement (phase 4) and a 50% split is used for the coordinated movement (phase 2). In this case there is no problem measuring the cycle length because any reasonable definition of cycle length will produce 100 seconds. The phase 2 beginning of red cycle length (CL_{BOR2}) and the phase 2 beginning of green cycle length (CL_{BOG2}) are shown as two examples.

Figure 4b shows the same diagram except that the intersection is actuated/coordinated, which means that it is coordinated with split timings, but will also respond to the information from the vehicle detectors. In this example, there are only two changes from the coordinated diagram: both phase 1 and phase 2 gap out early in cycle 1. In this case the cycle length cannot be determined by measuring the time between successive changes in signal head states. Two examples are shown where the CL_{BOR2} is 110 seconds and the CL_{BOG2} is 105 seconds.



a) Coordinated



b) Actuated/Coordinated

Figure 4: Illustrative example of the complication of cycle length definitions.

With the illustrative example in mind, the options for defining cycle boundaries are now discussed. It is desirable to define performance measures using changes that are visible at the intersection. This is however in contradiction with the desire for the measured cycle length to be the same as the cycle length that is programmed in the controller.

Examples of cycle length calculations that use the changes that are visible at the intersection are limited to using the beginning or end of the red or green state of a given phase. The two examples shown in Figure 4 use the beginning of the green and red states of phase 2 (the coordinated phase in this example). There are also several choices for determining the phase from information reported in the "Controller_Event_Log". One example is the "Cycle Length Change" event (Event Code ID 41). Every time that the controller changes the cycle length that is being used, it reports this event. Another option is to use the "Coord phase yield point" event (Event Code ID 63). This event is logged once per cycle for each coordinated phase and these events are spaced at exactly the programmed cycle length. Some controllers are also configured to report a "Cycle Length Change" event at midnight every night.

The decision of which cycle boundary to use is specific to each performance measure. For performance measures that make since with either definition, the visible change of the signal head state is usually chosen. This choice is preferred because it available externally from the controller and because it is available for controllers that are not running coordinated patterns.

PERFORMANCE MEASURES

The performance measures developed in this project have been developed as a suite of database queries that generate plots on a website. Each of these queries and the code used to produce the images is presented in this section. A screenshot of the overall website is shown in Figure 1. The queries shown in this section use $$NBR$$ to represent the intersection's "COMMISSION_NBR" and $$DATE$$ to represent the date of the data selected in the following format: YYYY-MM-DD.

Communication and Detector Health

The first performance measures that must be evaluated is the health of the sensor network. If there is missing data from the system it will be difficult to determine the validity of any of the other performance measures. A first order test of system health is if the database server can communicate with the controllers. This can be accomplished through a simple "ping" test. The script that runs this test queries the database for a list of ip addresses and then attempts to ping each controller. Successful results of ping tests are stored in the database. The script that executes the ping test is shown here:

```
#!/bin/bash

psql=/usr/bin/psql
db=INDOT_Signal_Systems
nmap=/usr/bin/nmap
ping=/bin/ping
folder=/home/jernst/datamaps/scripts
query='select "IP" from "SIGNALS" where "IP" is not null';

tstamp=`date +"%Y-%m-%d %H:%M:%S"`

echo $query | $psql -At $db | while read ip; do
    echo $ip
    pnum=`ping -c 10 $ip |sed -n 's/.*transmitted, *\([0-9]*\)
*received.*/\1/p'`
    nbr=`echo "select \"COMMISSION_NBR\" from \"SIGNALS\" where
\"IP\"='$ip'" | $psql -At $db`;
    if [ "x$pnum" != "x0" ]; then
      echo "insert into health_ping_test (signal_nbr,ip,ping_time)
values ('$nbr','$ip','$tstamp')" | $psql $db
    fi
done
```

A query to see when the most recent ping test was completed is shown here, where $$maxtime$$ is the most recent attempt at a ping test and $$COMMISSION_NBR$$ is the identifier for the controller being queried:

```
select
  max(h1.ping_time) as ping_time,
  date_part('epoch','"$$maxtime$$'-max(h1.ping_time)) as diff
from
  health_ping_test as h1
where
  h1.signal_nbr='$$COMMISSION_NBR$$' group by
h1.ping_time,h1.signal_nbr order by diff"
```

A second health test finds the most recent data that has been inserted from each controller. This makes sure that the controller is not only communicating, but that it is producing data that is getting inserted correctly into the database. In this case a query is executed to find the most recent data from each controller. This is compared to the most recent system wide data. The following query finds the most recent data inserted from a given controller.

```
select
  max("Event_Timestamp") as tstamp
from
  "Controller_Event_Log"
where
  "COMMISSION_NBR" ='."'".$siginfo['nbr']."'"
```

Cycle Length

The previous section discussed the complication of calculating the cycle length. In order to make sure that all of the cycle length data is being reported and is consistent, the cycle length is calculated in several different ways. One way is to take the difference in time between consecutive "Coord Phase Yeild Point" events. These are spaced at the programmed cycle length and are reported for each coordinated phase. An example query is shown here:

```
select
  mod(date_part('epoch',log1."Event_Timestamp")::integer-
5*3600,3600*24)::float/3600,
  date_part('epoch',min(log2."Event_Timestamp")-log1."Event_Timestamp")
as cycle_length
from
  "Controller_Event_Log" as log1,
  "Controller_Event_Log" as log2
where
  log1."COMMISSION_NBR" ='$$NBR$$' and
  log1."Event_Code_ID" =63 and
  log1."Event_Timestamp" > '$$DATE$$' and
  log1."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
and
  log2."COMMISSION_NBR" ='$$NBR$$' and
  log2."Event_Code_ID" =63 and
  log2."Event_Timestamp" > '$$DATE$$' and
  log1."Event_Param"=log2."Event_Param" and
  log2."Event_Timestamp">log1."Event_Timestamp"
group by
  log1."Event_Timestamp"
order by
  log1."Event_Timestamp"
```

Another way to find the cycle length is to query for the "Cycle Length Change" event in the "Controller_Event_Log". This query is shown here:

```
select
  mod(date_part('epoch',log1."Event_Timestamp")::integer-
5*3600,3600*24)::float/3600,
  log1."Event_Param"
from
  "Controller_Event_Log" as log1
where
  log1."COMMISSION_NBR" ='$$NBR$$' and
  log1."Event_Code_ID" =41 and
  log1."Event_Timestamp" > '$$DATE$$' and
  log1."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
order by
  log1."Event_Timestamp"
```

Another way to interpret the cycle length is to take the difference between consecutive ending times for the green state of a given phase. This will not always give the programmed cycle length, but can be useful in gaining information about the variability of the effective cycle length. An example query is shown here for phase 2:

```
select
  mod(date_part('epoch',log1."Event_Timestamp")::integer-
5*3600,3600*24)::float/3600,
  date_part('epoch',min(log2."Event_Timestamp")-log1."Event_Timestamp")
as cycle_length
from
  "Controller_Event_Log" as log1,
  "Controller_Event_Log" as log2
where
  log1."COMMISSION_NBR" ='$$NBR$$' and
  log1."Event_Code_ID" =2 and
  log1."Event_Param"=2 and
  log1."Event_Timestamp" > '$$DATE$$' and
  log1."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
and
  log2."COMMISSION_NBR" ='$$NBR$$' and
  log2."Event_Code_ID" =2 and
  log2."Event_Param"=2 and
  log1."Event_Param"=log2."Event_Param" and
  log2."Event_Timestamp">log1."Event_Timestamp" and
  log2."Event_Timestamp"<log1."Event_Timestamp"+'1
second'::interval*300
group by
  log1."Event_Timestamp"
order by
  log1."Event_Timestamp"
```

A more complicated query can be used to calculate the amount of time between ring barriers. This query first creates a temporary table and then uses this temporary table to calculate the final result. This query is shown here:

```
create temp view p1256 as
(
select
  max(log1."Event_Timestamp") as t
from
  "Controller_Event_Log" as log4,
  "Controller_Event_Log" as log1
where
  log4."COMMISSION_NBR" ='$$NBR$$' and
  log1."COMMISSION_NBR" ='$$NBR$$' and
  log4."Event_Code_ID" =2 and
  log1."Event_Code_ID" =2 and
  log4."Event_Param"   =4 and
  log1."Event_Param"   in (1,2,5,6) and
```

```
  log4."Event_Timestamp" > '$$DATE$$' and
  log4."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
and
  log1."Event_Timestamp"<log4."Event_Timestamp" and
  log1."Event_Timestamp">log4."Event_Timestamp"-'1
second'::interval*500
group by
  log4."Event_Timestamp"
order by
  max(log1."Event_Timestamp")
);

select
  mod(date_part('epoch',peog.t)::integer-5*3600,3600*24)::float/3600,
  date_part('epoch',min(eog.t)-peog.t) as cycle_length
from
  p1256 as peog,
  p1256 as eog
where
  eog.t>peog.t and
  eog.t<peog.t + '1 second'::interval*300
group by
  peog.t
order by
  peog.t
```

Volumes

One useful value is the cycle-by-cycle volume of a given phase at an intersection. This volume is helpful for understanding the demand on an intersection. These numbers can also be used in a V/C calculation. This query is somewhat complicated because all of the detectors for a given phase must be indentified and included in the query. The query for the cycle-by-cycle volumes is shown here:

```
select
  (t1-4*3600-floor((t1-4*3600)/3600/24)*3600*24)/3600,
  count(*)
from
(
select
  date_part('epoch',max(t1."Event_Timestamp")) as t1,
  date_part('epoch',t2."Event_Timestamp") + det."Seconds_To_StopBar" as
t2
from
  "Controller_Event_Log" as t1,
  "Controller_Event_Log" as t2,
  (
  select
    case
      when"Seconds_To_StopBar" is NULL then '5'
      else "Seconds_To_StopBar"
```

```
    end as "Seconds_To_StopBar",
    "DETECTOR_ID",
    "DETECTOR_PROFILE_ID",
    "PHASE",
    "DIRECTION",
    "DETECTOR_NBR"
  from
    "DETECTORS"
  ) as det,

  (
    select
      "DETECTOR_PROFILE_ID" as id,
      "COMMISSION_NBR" as commission_nbr,
      "EFFECTIVE_DATE" as ed,
      case
        when "REMOVED_DATE" IS NULL then 'now'::text::timestamp without
time zone
        else "REMOVED_DATE"
      end as rd
    from
      "DETECTOR_PROFILES" as dp1
    where
      "COMMISSION_NBR"='$$NBR$$'
  ) as dp
where
  '$$DATE$$'::timestamp+'1 hour'::interval*12 between dp.ed and dp.rd
and
  t1."COMMISSION_NBR"='$$NBR$$' and
  t1."Event_Timestamp" > '$$DATE$$' and
  t1."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval and
  t2."COMMISSION_NBR"='$$NBR$$' and
  t2."Event_Timestamp" > '$$DATE$$' and
  t2."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval and

  dp.id=det."DETECTOR_PROFILE_ID" and -- use correct detectors
  det."PHASE"='1' and -- filter by intersection phase
  t2."Event_Code_ID"='9' and -- detector_on
  t2."Event_Param"=det."DETECTOR_NBR"  and -- filter log by
detector_nbr
  t1."Event_Code_ID"='2' and -- end of green
  t1."Event_Param"  ='1' and
  t2."Event_Timestamp"> t1."Event_Timestamp" and -- t2>t1
  t2."Event_Timestamp"< t1."Event_Timestamp"+'1 second'::interval*300
group by
  date_part('epoch',t2."Event_Timestamp") + det."Seconds_To_StopBar"
) as t
group by
t.t1
order by
t.t1
```

Green Time and Capacity

To determine the amount of green time in each cycle, each time that the light turns green is subtracted from the next time that the light turns red. An example of the green time query is shown here for phase 2.

```
select
  mod(date_part('epoch',log1."Event_Timestamp")::integer-
5*3600,3600*24)::float/3600,
  date_part('epoch',min(log2."Event_Timestamp")-log1."Event_Timestamp")
as cycle_length
from
  "Controller_Event_Log" as log1,
  "Controller_Event_Log" as log2
where
  log1."COMMISSION_NBR" ='$$NBR$$' and
  log1."Event_Code_ID" =1 and
  log1."Event_Param"=2 and
  log1."Event_Timestamp" > '$$DATE$$' and
  log1."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
and
  log2."COMMISSION_NBR" ='$$NBR$$' and
  log2."Event_Code_ID" =2 and
  log2."Event_Param"=2 and
  log1."Event_Param"=log2."Event_Param" and
  log2."Event_Timestamp">log1."Event_Timestamp" and
  log2."Event_Timestamp"<log1."Event_Timestamp"+'1
second'::interval*300
group by
  log1."Event_Timestamp"
order by
  log1."Event_Timestamp"
```

The capacity query is similar to the greentime query except that the green time must be multiplied by the number of lanes and the saturation flow rate. The following query uses 1900 vehicles per hour for the saturation flow rate and queries the "DETECTOR_LIST_VW" view for the number of thru lanes. These lanes are scaled by the estimate of the percentage of "thru" vehicle in each lane. The following query finds the cycle by cycle capacity for phase 2.

```
select
  mod(date_part('epoch',log1."Event_Timestamp")::integer-
5*3600,3600*24)::float/3600,
  date_part('epoch',min(log2."Event_Timestamp")-
log1."Event_Timestamp")*1900/3600*num.num as cycle_length
from
  "Controller_Event_Log" as log1,
  "Controller_Event_Log" as log2,
(
select
```

```
  sum("LANES"*"THRU_PCT"/100) as num
from
  "DETECTOR_LIST_VW"
where
  "COMMISSION_NBR"='$$NBR$$' and
  '$$DATE$$'::date>="EFFECTIVE_DATE" and
  '$$DATE$$'::date<="LAST_DATE" and
  "PHASE"='2'
) as num
where
  log1."COMMISSION_NBR" ='$$NBR$$' and
  log1."Event_Code_ID" =1 and
  log1."Event_Param"=2 and
  log1."Event_Timestamp" > '$$DATE$$' and
  log1."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
and
  log2."COMMISSION_NBR" ='$$NBR$$' and
  log2."Event_Code_ID" =2 and
  log2."Event_Param"=2 and
  log1."Event_Param"=log2."Event_Param" and
  log2."Event_Timestamp">log1."Event_Timestamp" and
  log2."Event_Timestamp"<log1."Event_Timestamp"+'1
second'::interval*300
group by
  log1."Event_Timestamp",
  num.num
order by
  log1."Event_Timestamp"
```

Volume-to-Capacity Ratio

The volume to capacitiy ratio query follows from the cycle-by-cycle volume and cycle-by-cycle capacity queries discussed above. An example of this query for phase 2 is shown here:

```
select
  t,
  volume/(green_time*1900/3600*num) as vc
from

(

select
  mod(date_part('epoch',t1)::integer-5*3600,3600*24)::float/3600 as t,
  date_part('epoch',t2-t1) as green_time,
  max(num.num) as num,
  count(*) as volume
from
(
  select
    sum("LANES") as num
  from
    "Detector_List_VW"
  where
    "COMMISSION_NBR"='$$NBR$$' and
```

```
    "PHASE"='2' and
    "Seconds_To_StopBar"='-1'
) as num,
(
  select
    log1."Event_Timestamp" as t1,
    min(log2."Event_Timestamp") as t2
  from
    "Controller_Event_Log" as log1,
    "Controller_Event_Log" as log2
  where
    log1."COMMISSION_NBR" ='$$NBR$$' and
    log1."Event_Code_ID" =1 and
    log1."Event_Param"=2 and
    log1."Event_Timestamp" > '$$DATE$$' and
    log1."Event_Timestamp" < '$$DATE$$'::timestamp + '1 day'::interval
and
    log2."COMMISSION_NBR" ='$$NBR$$' and
    log2."Event_Code_ID" =2 and
    log2."Event_Param"=2 and
    log1."Event_Param"=log2."Event_Param" and
    log2."Event_Timestamp">log1."Event_Timestamp" and
    log2."Event_Timestamp"<log1."Event_Timestamp"+'1
second'::interval*300
  group by
    log1."Event_Timestamp"
  order by
    log1."Event_Timestamp"
) as temp,
  "Detector_List_VW" as det,
  "Controller_Event_Log" as log3
where
  det."PHASE"='2' and
  det."COMMISSION_NBR"='$$NBR$$' and
  det."Seconds_To_StopBar"=-1 and
  log3."COMMISSION_NBR"='$$NBR$$' and
  log3."Event_Code_ID"='9' and -- detector_on
  log3."Event_Param"=det."DETECTOR_NBR" and
  log3."Event_Timestamp">temp.t1 and
  log3."Event_Timestamp"<temp.t2
group by
  mod(date_part('epoch',t1)::integer-5*3600,3600*24)::float/3600,
  date_part('epoch',t2-t1)
order by
  mod(date_part('epoch',t1)::integer-5*3600,3600*24)::float/3600

) as temp
```

Purdue Coordination Diagram (PCD)

The Purdue Coordination Diagram (PCD) allows all vehicle arrivals to be viewed in one image that represents all of the progression data throughout the day. This query also shows the beginning of the green interval and the beginning of the red interval. This means that there are two separate queries: detetion data points and signal head state. Because of the size of the database, temporary tables are also created in the process of generating the data for each query. The purpose of the temporary tables is to filter the enormous "Controller_Event_Log" and to create a table with just the time range and data types of interest.

There are also several minor metadata queries that must be run to figure out whether the primary movement for the intersection is North-South or East-West and to find which phase is associated with each. These queries are shown here.

North/East Direction:

```
select
  case
    when "DIRECTION"='N'
    then 'North'
    when "DIRECTION"='E'
    then 'East'
  end
from
(
select distinct
  det."DIRECTION"
from
  "Detector_List_VW" as det
where
  '$$DATE$$'::timestamp between det."EFFECTIVE_DATE" and
det."LAST_DATE"  and
  det."LANE" not in ('L','R') and
  det."DIRECTION" in('N','E') and
  det."PHASE" in ('2','6') and
  det."COMMISSION_NBR"='$$NBR$$'
) as temp
```

North/East Phase:

```
select distinct
  det."PHASE"
from
  "Detector_List_VW" as det
where
```

```
  '$$DATE$$'::timestamp between det."EFFECTIVE_DATE" and
det."LAST_DATE"  and
  det."LANE" not in ('L','R') and
  det."DIRECTION" in('N','E') and
  det."PHASE" in ('2','6') and
  det."COMMISSION_NBR"='$$NBR$$'
```

South/West Direction:

```
select
  case
    when "DIRECTION"='S'
    then 'South'
    when "DIRECTION"='W'
    then 'West'
  end
from
(
select distinct
  det."DIRECTION"
from
  "Detector_List_VW" as det
where
  '$$DATE$$'::timestamp between det."EFFECTIVE_DATE" and
det."LAST_DATE"  and
  det."LANE" not in ('L','R') and
  det."DIRECTION" in('S','W') and
  det."PHASE" in ('2','6') and
  det."COMMISSION_NBR"='$$NBR$$'
) as temp
```

South/West Phase:

```
select distinct
  det."PHASE"
from
  "Detector_List_VW" as det
where
  '$$DATE$$'::timestamp between det."EFFECTIVE_DATE" and
det."LAST_DATE"  and
  det."LANE" not in ('L','R') and
  det."DIRECTION" in('S','W') and
  det."PHASE" in ('2','6') and
  det."COMMISSION_NBR"='$$NBR$$'
```

The query for the South/West signal state information is shown here. The North/East signal state information is similar.

```
select
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp1
from
```

```
  "Controller_Event_Log" as log
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID"='2' and
  log."Event_Param"='$$SWphase$$'
order by t
;
create index temp1_ind on temp1(t);

select
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp2
from
  "Controller_Event_Log" as log
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID"='1' and
  log."Event_Param"='$$SWphase$$'
order by t
;
create index temp2_ind on temp2(t);

select
  (t1-4*3600-floor((t1-4*3600)/3600/24)*3600*24)/3600,
  t2-t1,
  t3-t1
from
(
select
  t1.t as t1,
  min(t2.t) as t2,
  min(t3.t) as t3
from
  temp1 as t1,
  temp2 as t2,
  temp1 as t3
where
  t2.t> t1.t and
  t3.t> t1.t and
  t2.t< t1.t+300 and
  t3.t< t1.t+300
group by
  t1.t
) as t
order by
  t.t1
```

The query for the South/West detector data is shown here.

```
set constraint_exclusion=on;
set enable_bitmapscan=off;

select
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp1
from
  "Controller_Event_Log" as log
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID"='2' and
  log."Event_Param"='$$SWphase$$'
order by t
;
create index temp1_ind on temp1(t);

select
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp2
from
  "Controller_Event_Log" as log,
  "Detector_List_VW" as det
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID"='9' and
  det."COMMISSION_NBR"=log."COMMISSION_NBR" and
  det."PHASE"='$$SWphase$$' and
  det."Seconds_To_StopBar" > 0 and
  log."Event_Param"=det."DETECTOR_NBR"
order by t;

create index temp2_ind on temp2(t);



select
  (t2-4*3600-floor((t2-4*3600)/3600/24)*3600*24)/3600,
  t2-t1
from
(
select
  max(temp1.t) as t1,
  temp2.t as t2
from
  temp1,
  temp2
where
  temp2.t>temp1.t and
```

```
  temp2.t<temp1.t+300
group by
  temp2.t
) as t
order by
  (t2-4*3600-floor((t2-4*3600)/3600/24)*3600*24)/3600;
```

Degree of Intersection Saturation

The degree of intersection saturation is different from most of the rest of the queries in that it is not calculated per phase. As indicated by the name, it reflects the saturation of the intersection as a whole. This query uses many of the concepts developed other queries. The cycle boundry for this query must be found in terms of a ring diagram. Therefore the boundary is at the end of phase 2 and phase 6.

The query is very complex and achieves reasonable speed by creating a series of temporary tables. This set of queries is shown here and the purpose of each temporary table is described.

The “temp_eog” temporary table selects the data for the correct day and intersection corresponding to the end of a green phase. This small chunk of the “Controller_Event_Log” is stored in a temporary table and indexed so that it can be searched quickly. The database option “constrain_exclusion” is turned on to take advantage of the “Controller_Event_Log” table partitioning and the “enable_bitmapscan” is disabled to encourage the queries to use the existing indexes on the “Controller_Event_Log” table partitions.

```
set constraint_exclusion=on;
set enable_bitmapscan=off;

select
  "Event_Param" as phase,
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp_eog
from
  "Controller_Event_Log" as log
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID" ='2';

create index temp_eog_ind on temp_eog(phase,t);
```

The “temp_bog” table is identical to the “temp_eog” table except that it stores the information for the beginning of green events instead of the end of green events. The query to create this table is shown here:

```
select
  "Event_Param" as phase,
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp_bog
from
  "Controller_Event_Log" as log
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID" ='1'
;

create index temp_bog_ind on temp_bog(phase,t);
```

The next temporary table is the “temp_detections” table. This table includes the phase and time of all vehicle detections for the specified date and intersection. The query to create this temporary table is shown here:

```
select
  det."PHASE" as phase,
  date_part('epoch',log."Event_Timestamp") as t
into
  temp table temp_detections
from
  "Controller_Event_Log" as log,
  "Detector_List_VW" as det
where
  log."COMMISSION_NBR"='$$NBR$$' and
  log."Event_Timestamp" > '$$DATE$$' and
  log."Event_Timestamp" < '$$DATE$$'::timestamp+'1 day'::interval  and
  log."Event_Code_ID"='9' and
  det."COMMISSION_NBR"=log."COMMISSION_NBR" and
  log."Event_Param"=det."DETECTOR_NBR"
order by t
;

create index temp_detections_ind on temp_detections(phase,t);
```

The next temporary table splits time by the beginning of the green interval for phase 2. This is not the cycle boundary that we are interested in; however, there will be one such cycle boundary

between each pair of t_start and t_stop times in the temporary table created by this query. This temporary table is called temp_ss2. The two is meant to indicate that it uses the phase two data.

```
select
  log1.t as t_start,
  min(log2.t) as t_stop
into
  temp table temp_ss2
from
  temp_bog as log1,
  temp_bog as log2
where
  log2.t > log1.t and
  log2.t < log1.t +500 and
  log2.phase=2 and
  log2.phase=2
group by
  log1.t
order by
  log1.t;
```

Using this table the ring barrer can be found. This is accomplished by finding the maximum end of green time for phase two and phase six between each of the phase beginning of green times found in the previous query. The query to find the ring barrier is shown here:

```
select
  case
    when log2.t > log6.t then log2.t
    else log6.t
  end as t
into
  temp table boundary
from
  temp_ss2 as ss,
  temp_eog as log2,
  temp_eog as log6
where
  log2.phase=2 and
  log6.phase=6 and
  log2.t > ss.t_start and log2.t < ss.t_stop and
  log6.t > ss.t_start and log6.t < ss.t_stop
order by
  ss.t_start
;
```

The list of ring barrier times is then reformatted into a beginning and end of cycle format. This query is shown below and creates the “boundary_ss” temporary table.

```
select
  log1.t as t_start,
  min(log2.t) as t_stop
into
  temp table boundary_ss
from
  boundary as log1,
  boundary as log2
where
  log2.t > log1.t and
  log2.t < log1.t +500
group by
  log1.t
order by
  log1.t;
```

To calculate the capacity for the v/c calculation, the number of lanes associated with the detectors in each phase must be calculated. This association between the phase and the number of effective lanes is shown below. Note that if two sensors are in the same lane, this effectively doubles the apparent capacity of the lane if both sensors are being used in the volume calculation. The temporary table that associates the phase with an apparent number of lanes is called the “temp_lanes” temporary table.

```
select
  "PHASE" as phase,
  sum("LANES") as lanes
into temp table temp_lanes
from
  "Detector_List_VW" as det
where
  "EFFECTIVE_DATE"< '$$DATE$$' and
  "LAST_DATE">'$$DATE$$' and
  "COMMISSION_NBR"='$$NBR$$'
group by
  "PHASE";
```

The “temp_cycle” temporary table defined below associates the beginning of each ring barrier cycle boundary with the start and end green time for a given phase. This query is shown here:

```
select
  ss.t_start,
  bog.phase as phase,
  bog.t as tbog,
  eog.t as teog
into temp table temp_cycle
from
  boundary_ss as ss,
  temp_bog as bog,
  temp_eog as eog
where
  bog.phase=eog.phase and
  bog.t > ss.t_start and bog.t <= ss.t_stop and
  eog.t > ss.t_start and eog.t <= ss.t_stop and
  eog.t > bog.t
order by
  ss.t_start
;
```

This next query uses the previously created temporary tables to calculate the intersection saturation. It is a set of nested queries. The innermost query calculates the v/c for each phase in each cycle. The v/c values are then summed into v/c values for each ring barrier pair (e.g., the phase 1 v/c is added to the phase 2 v/c). The max v/c for each side of the ring barrier is then found. The the sum of the vc before and after the ring barrier is calculated. The time reported is the time of day in hours. This nested query is shown here:

```
select
  (t_start-4*3600-floor((t_start-4*3600)/3600/24)*3600*24)/3600,
  sum(maxrb_vc) as xc
from
(
  select
    t_start,
    mod(rb::integer,2),
    max(rb_vc) as maxrb_vc
  from
  (
    select
      t_start,
      floor((phase+1)/2) as rb,
      sum(vc) as rb_vc
    from
    (
      select
        cycle.t_start,
        cycyle.phase,
        count(*)/(1900*lanes.lanes*(teog-tbog)/3600) as vc
```

```
      from
        temp_cycle as cycle,
        temp_lanes as lanes,
        temp_detections as det
      where
        cycle.phase::text=lanes.phase::text and
        cycle.phase::text=det.phase::text and
        det.t > cycle.tbog and det.t < cycle.teog
      group by
        cycle.t_start,
        cycle.phase,
        lanes.lanes,
        teog,
        tbog
      order by
        cycle.t_start,cycle.phase
    ) as t
    group by t_start, floor((phase+1)/2)
    order by t_start, floor((phase+1)/2)
  ) as t2
  group by t_start, mod(rb::integer,2)
  order by t_start
) as t3
group by t_start
order by t_start;
```

CONCLUSIONS

The framework developed to display performance measures on a website allow for rapid progression from the development of a query to making the resulting plots available. Many queries have been written for use with the INDOT database in order to create plots for the website. These queries have been detailed in this section.

During the development of this toolset, the size of the database size has increased and the rate of growth has also increased. Due to the size and projected size of this database, special considerations are required to make sure that the queries can be run quickly. One important step in this process is partitioning the "Controller_Event_Log" into one partition per month. This allows queries to quickly eliminate all other partitions from its query. In order to make sure that the database uses these partitions to increase the speed of the queries, the following line should be placed at the beginning of each query:

```
set constraint_exclusion=on;
```

Each of the partitions are also indexed. While developing the queries it has been noticed that the query planner is less likely to use an index search in combination with the constraint exclusion. Encouraging the query builder to use the index increases the speed of most queries to about five times the original speed. In order to do this, the following line of code should be placed at the beginning of each query:

```
set enable_bitmapscan=off;
```

Also queries that must reference the "Controller_Event_Log" more than once (which includes most of the queries documented in this section) should create a temporary table with only the relivant data from the relivant intersections and time range.

The queries developed in this section allow for quick analysis of the transportation network. The framework developed for this project will allow new queries to be quickly linked into the existing infrastructure. New queries should also run quickly, even as the database increases in size by following the query building guidelines in this section.

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