DRAFT WHITE PAPER

Portland Regional Performance Measures for the 2004 Metro Performance Measures Report

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WORK REQUESTED

After meeting with representatives of Metro about possible contributions to the Metro Performance Measures Report by the ITS Lab, three different items were requested. The first was a table of average travel times during the 4:30-5:30 PM peak period for a list of significant highway segments in the Portland area. Second was a color-coded map of average speeds for all Portland highways during the same peak period. The third item was a series of charts, one for each highway segment, showing the percentage of the time at each time of day that the segment fell below its acceptable level of service. All three of these reports were to be generated once for 2002 and again for the same days in a different year to allow comparison.

The data source for this analysis was archived ATMS data from ODOT, consisting of one report every 20 seconds from each of around 436 inductive loop detectors. Each report includes the volume of cars passing the detector, their average speed, and the percentage of the 20-second sample period when a car was over the detector (occupancy). The ITS lab is currently implementing an archive which will receive and store data of this nature continuously, but at present we have only a few large blocks of data from 2001 and 2002. Data sets covering the time periods from January 19, 2001 to January 30, 2001 and from January 21, 2002 to January 30, 2002 were chosen for the study.

METHODS

The text files containing the loop detector data were concatenated using UNIX commands, then imported as one large database table. Several data cleaning queries were then run to remove known errors. First, speed and occupancy data from 2001 were multiplied by 256 (this error was identified by the ITS lab and subsequently corrected by ODOT in 2001-2001), and then records with a volume of -1 (indicating communications errors) were deleted. Volume and occupancy were set to zero and speed to NULL (undefined) for records where the reported volume was -999, a value indicating that no cars had passed in the 20-second sample interval. Speed and occupancy were set to NULL (undefined) for detectors on ramps which do not report speed or occupancy to prevent them from affecting averages.

Next, a query was created to trim down the data set to include observations on Monday through Friday from 4:30-5:30 PM. The resulting data were aggregated across lanes, giving one reading per detector station per 20 seconds. The resulting dynamically generated peak-period table could be used as a source table for the performance measures which concentrate on this time of day.

The performance measures were expressed as SQL queries as follows: For result 1 (travel times), a table was created which associated each detector station with the appropriate highway segment from the list provided by Metro. Each line of the peak-period lane-aggregated loop detector data table was joined with relevant lines from tables describing the detector station locations and Metro study segments. The travel time for each row of data was calculated from the station length (as defined by ODOT) and average speed at that station and time of day. The rows were then grouped by highway segment and time of day, and the sum of all travel time values was calculated for each unique segment-time combination. The resulting values were then

averaged by segment to give average travel time for each segment during the peak period.

For result 2 (the speed maps) the peak-period loop data were simply grouped by station and the speeds for each group averaged. The resulting table contains the average reported speed at each detector station during the peak period. The newest version of ODOT's support tables (which describe the detectors, stations, ramps, and other ATMS components in terms of their database ID numbers) includes latitude and longitude information for ramps and stations, and the station location information is in the form of line segments which indicate the influence area for that station, i.e. the section of road represented by that station. These location data were exported to a separate table and joined to the speed results in ArcGIS to allow map visualization.

Result 3 (percentage of time congested) concerned the entire day and drew data from the original untrimmed loop data tables. The rows of the database were grouped by their Metro-assigned highway segment and the time of day, and the number of reported speeds below 46 miles per hour in each grouping was divided by the total number of reported speeds in that category. This produced for each segment at each 10-minute increment throughout the day a percentage of time that this segment is congested at this time of day. Metro provided several pages of possible criteria for determining level of service (LOS), and 46 MPH was chosen as a point below which the facilities in question were operating outside of the acceptable speed range.

All data cleaning and queries were repeated for the second data set, with the exception of the multiplication by 256, which had been rendered unnecessary by ODOT adjustments before the collection of the second year's data. After all result tables were acquired, they were exported to text files and plotted using spreadsheet or GIS software. For the actual text of the queries, please see the section 'queries' below.

QUALITY OF RESULTS

Inaccuracies were apparent in many of the results. Though the techniques that we used will produce the desired performance measures from accurate data, the relatively old data sets used in this work are known to contain errors and gaps. The correction of systematic errors in loop data is an ongoing process informed by the kinds of difficulties we find here, and we expect increases in data quality over time as hardware and software are updated. Automated error detection techniques in the regional transportation data archive will also help us to avoid the use of questionable data in the future.

The most obvious problems were observed in the travel times, where figures varied wildly or didn't seem possible intuitively. Travel time figures are computed by summing a collection of travel time figures from individual detector stations over the length of a facility. This sum is computed for each 20-second interval, and if one of the stations on a facility does not provide a reading during an interval, the summation will yield a significantly shorter travel time. This incorrect travel time will then be averaged in with the correct figures, invalidating the result. This problem was partially solved by comparing the number of stations included in each sum to the maximum number of stations included in any sum on that segment during the day. Those sums based on too few elements were rejected. These modifications can be seen in the SQL queries included below.

The problem still remains that stations may be offline during an entire day's calculations, yielding travel times that may be useful when compared to one another but do not reflect the true time required to traverse the highway segment. It is also the case that there are gaps in the sensor coverage of the freeway system that prevented us from covering the entire length of most of the requested highway segments.

Because of their unreliability, the travel time results were excluded from the final results presented to Metro. However, the core of the technique is perfectly useful and simply requires additional refinement to avoid the effects of missing data. Options for improvement include detecting error-prone data sets and avoiding their use, averaging speeds at each station over longer time periods to provide values even when gaps are present, and imputing missing data from surrounding detectors. The latter would be a very useful solution, especially if implemented systematically in a data archive.

The speed maps were quite successful by comparison, indicating lower speeds in expected locations. The most noticeable flaw of the maps is the presence of large gaps throughout the freeway system, which are simply due to incomplete coverage by ODOT loop detectors. These holes are slowly being filled in, and the older data sets represented in these maps have fewer detectors and more disabled detectors than we would expect to see today. In comparison to travel time, this performance measure is noticeably tolerant of missing data - each station is plotted independently and the missing segments do not prevent us from interpreting the neighboring areas. The reason for this is that these results are derived not from the summation of a fixed number of values over distance, but the averaging of *available* values over a sizeable time interval (5 days of peak period observations.)

The nature of the error in the third performance measure is more difficult to determine. The technique produces accurate plots of the percentage of reported speeds under 46 MPH by time of day (in 10-minute sample periods) over the entire data set. This should give a good idea of how frequently a particular location is congested at a particular time of day. Again, if the data set were complete and accurate this technique should work perfectly, and for the same reasons as the speed maps, this query should be very tolerant of missing data. However, the plots show

some strange characteristics. In many locations and over the course of the entire day, the plots show an unexpectedly high percentage of low-speed readings. This must be the result of either the systematic underestimation of speeds, the presence of a large number of individual incorrect (low) speed observations, or a mixture of both. More detailed analysis of the source data is necessary to determine which of these is to blame, but neither would be unexpected based on past studies. Speed was measured indirectly, calculated at the loop controller from occupancy and an assumed average vehicle length. The presence of long vehicles can cause systematic errors in measurement of traffic speed, and defective detectors have been known to report roughly normal-looking data mixed with a number of unbelievable speeds. Many of these errors should be resolved with the introduction of direct speed measurements and vehicle classification that will come with loop controller upgrades.

RECOMMENDATIONS

This work was intended as a proof of concept or demonstration of technique, so inaccuracies can be seen as an opportunity to seek out and correct sources of error. It is certain that an improvement in data quality or data cleaning techniques will reduce the number and variety of errors we see in the results. However, as long as errors exist in the data, we must design and select performance measures to minimize their effects.

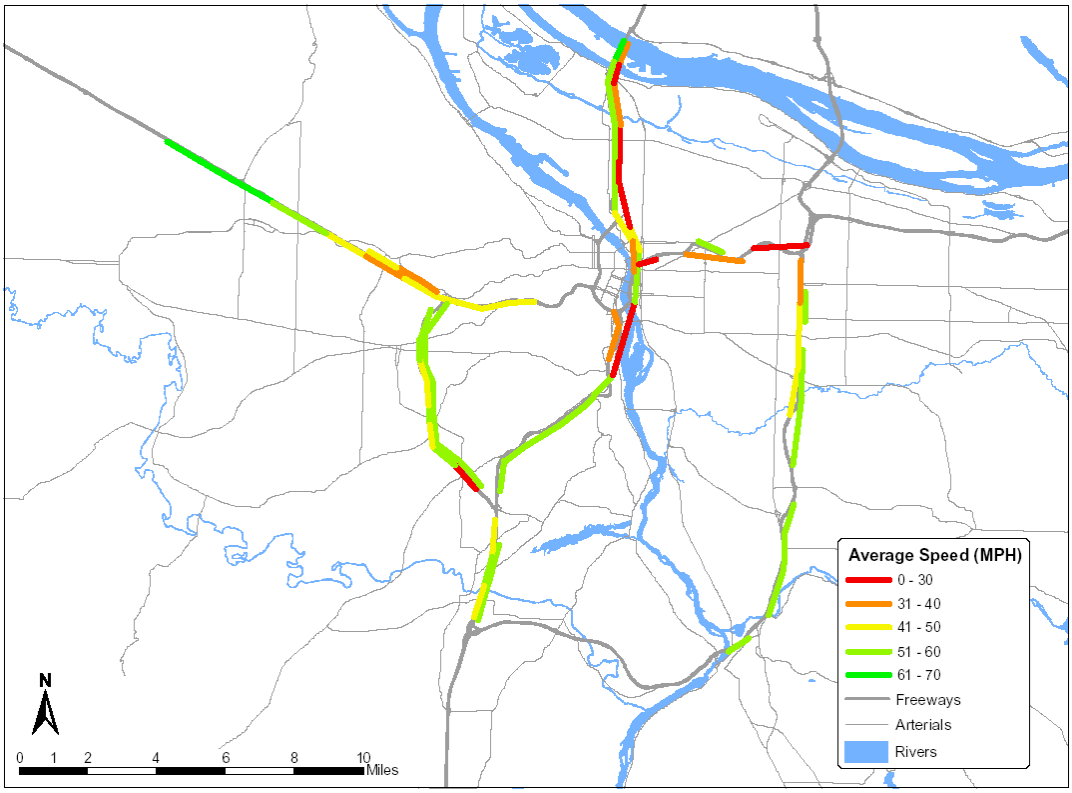
Certain performance measure calculations will naturally emphasize error, while others will average it out. Instantaneous or temporally localized values (travel time) are much more susceptible to corruption by error because inferences are made from only a few points, whereas the more global values (averages and percentages over long time intervals) tend to be forgiving of many errors. It is suggested that we favor averages over summations where missing data is

common, and choose longer term counts over instantaneous performance measures to avoid inferring too much from corrupt data points.

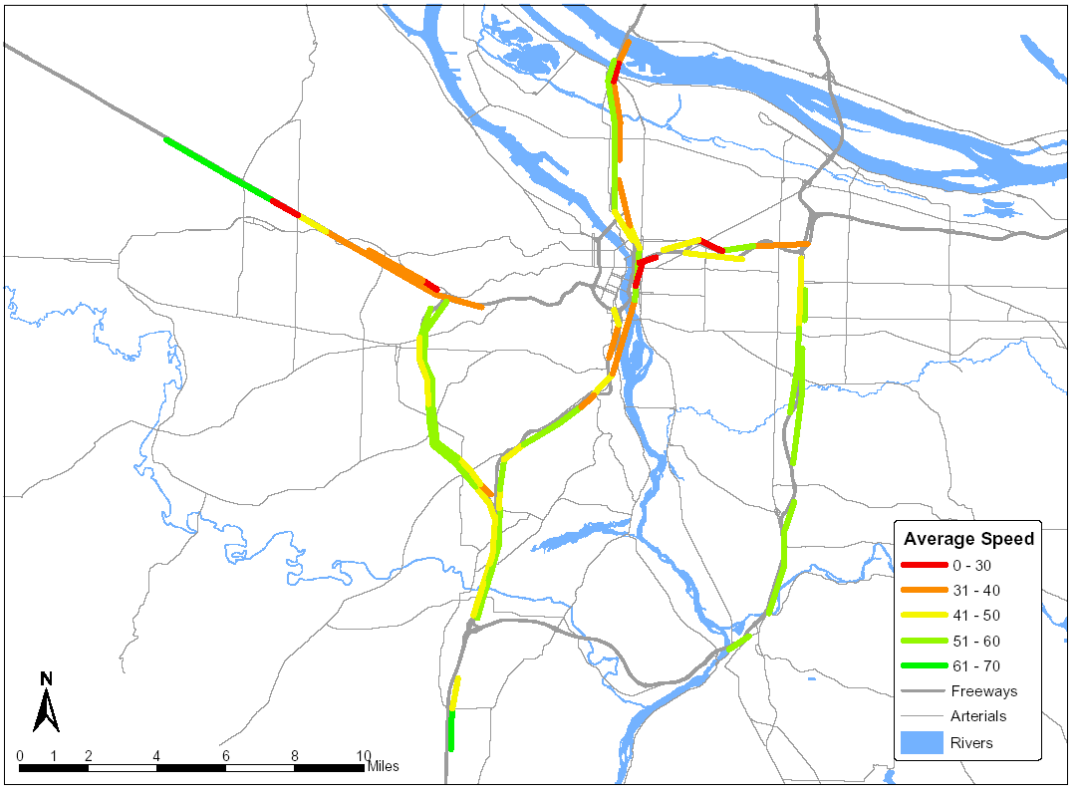
Another consideration is the quality of the criterion used to determine LOS in result 3. Speed was used simply because speed guidelines were among those provided by Metro, and speed was the only option available in the raw loop data. Because speed data is derived from occupancy, and because occupancy is often considered a good measurement of congestion, occupancy might be a better choice than speed for determining level of service.

Though travel time is a very intuitive performance measure and can theoretically be calculated from loop detector data, other performance measures which are not so sensitive to missing data will fare better as long as temporal or spatial coverage is incomplete.

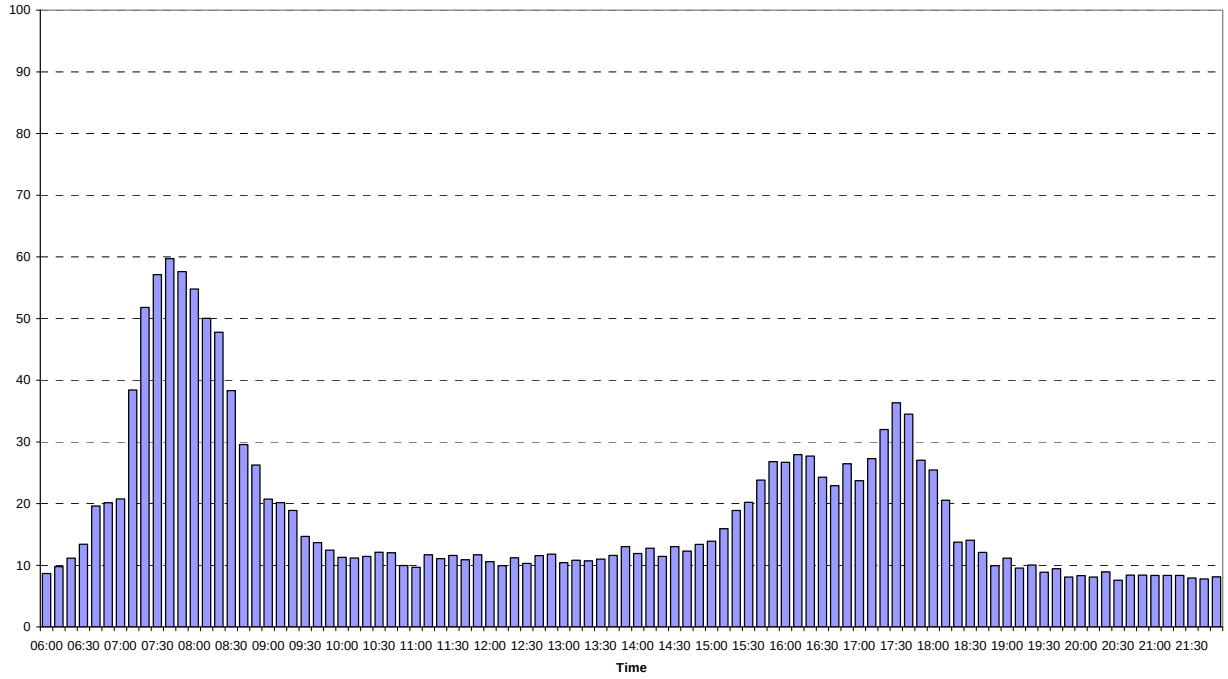
Average Speed 4:30-5:30 PM Peak January 2001



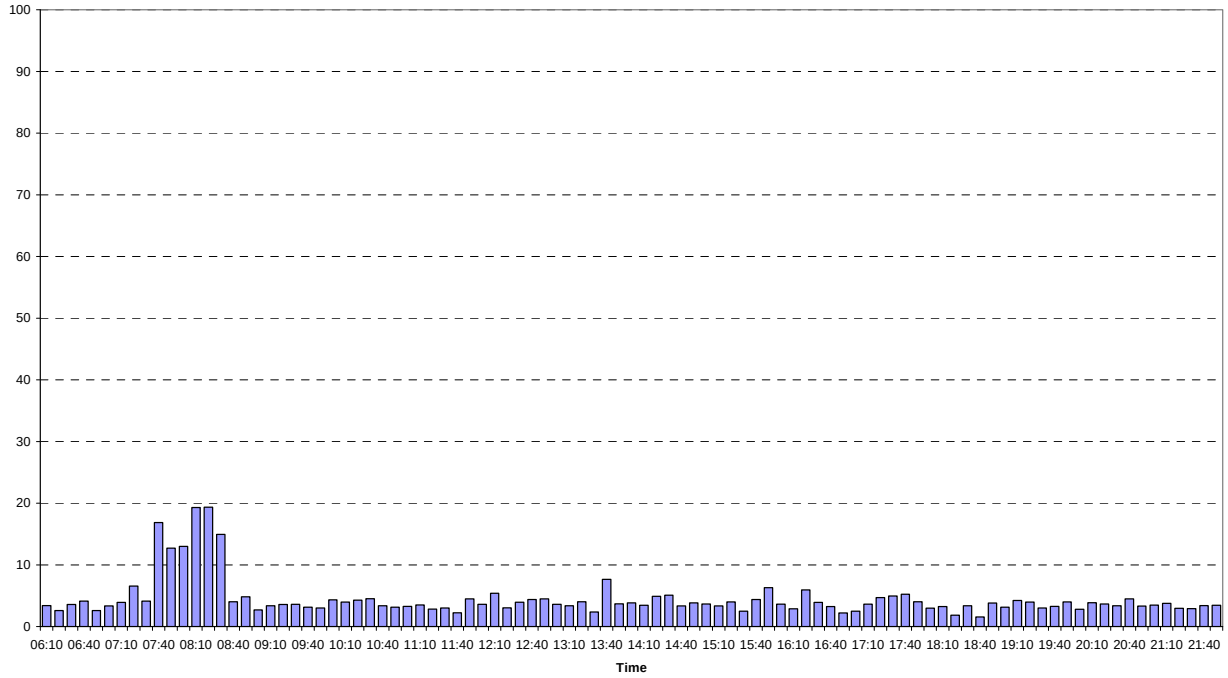
Average Speed 4:30-5:30 PM Peak January 2002



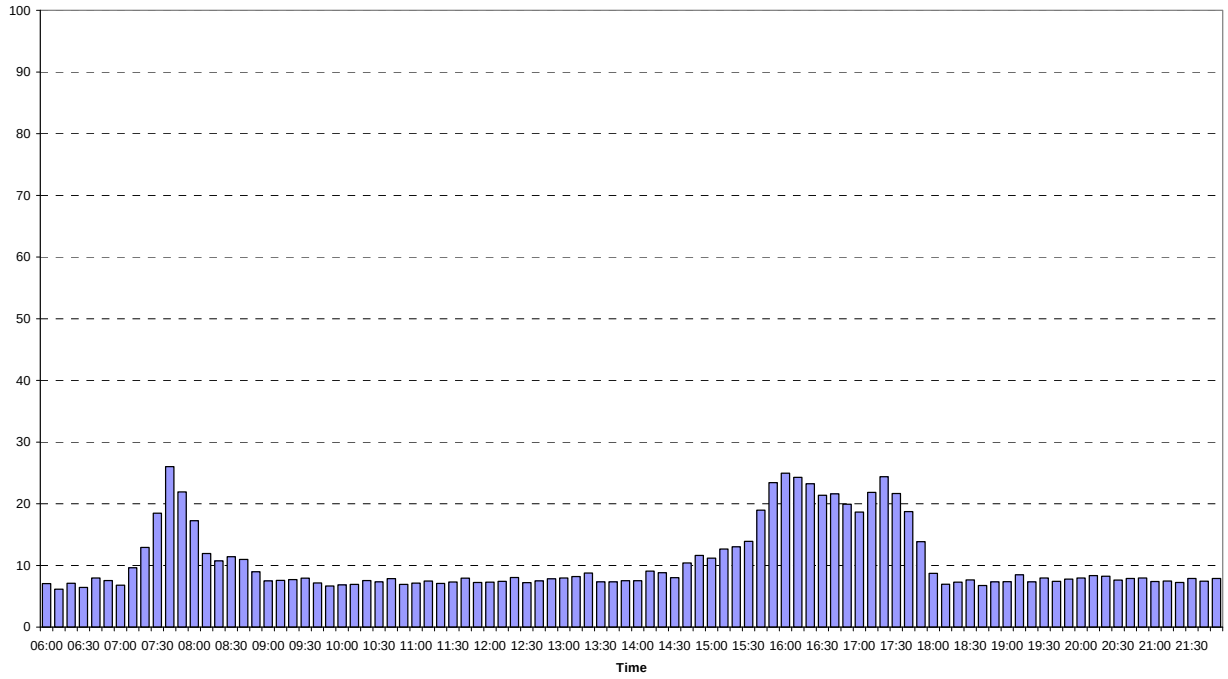
Percentage of Reported Speeds Below 30 mph (2001)
Segment 3: I-5 From Hwy 217 North to I-405 (Marquam Bridge)



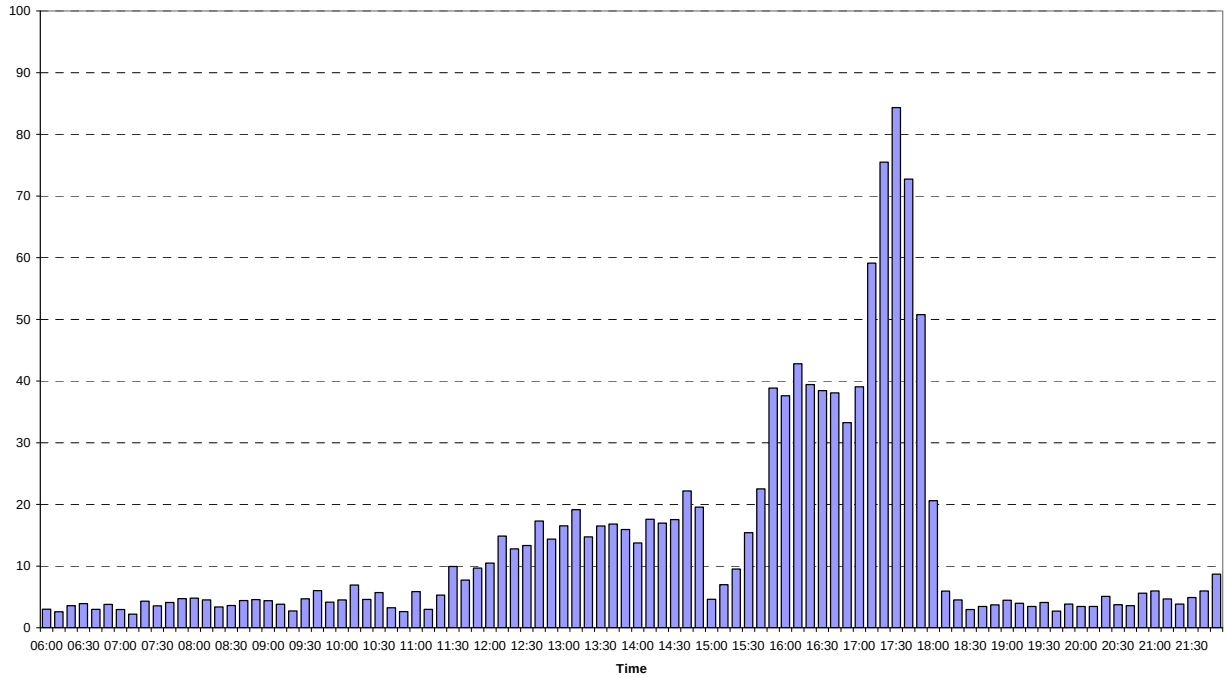
Percentage of Reported Speeds Below 30 mph (2001)
Segment 7: I-205 From I-5 East and Then North to the 212/224 Exit



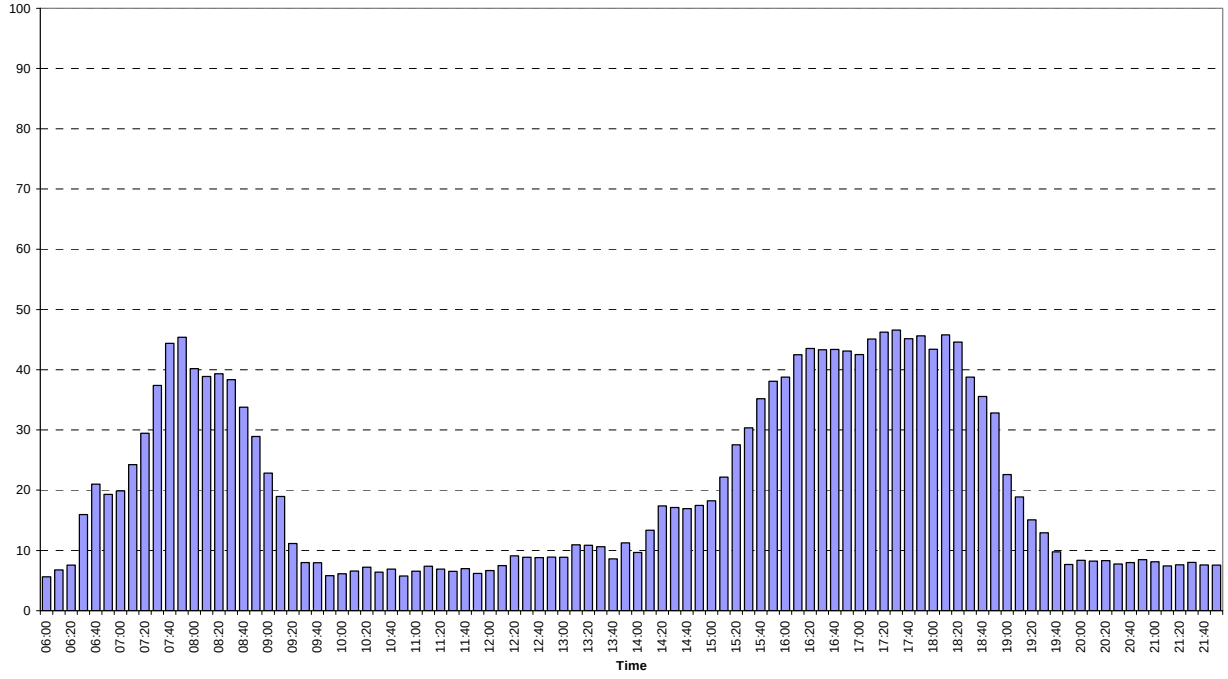
Percentage of Reported Speeds Below 30 mph (2001)
Segment 8: I-205 From Hwy 212/224 North to I-84



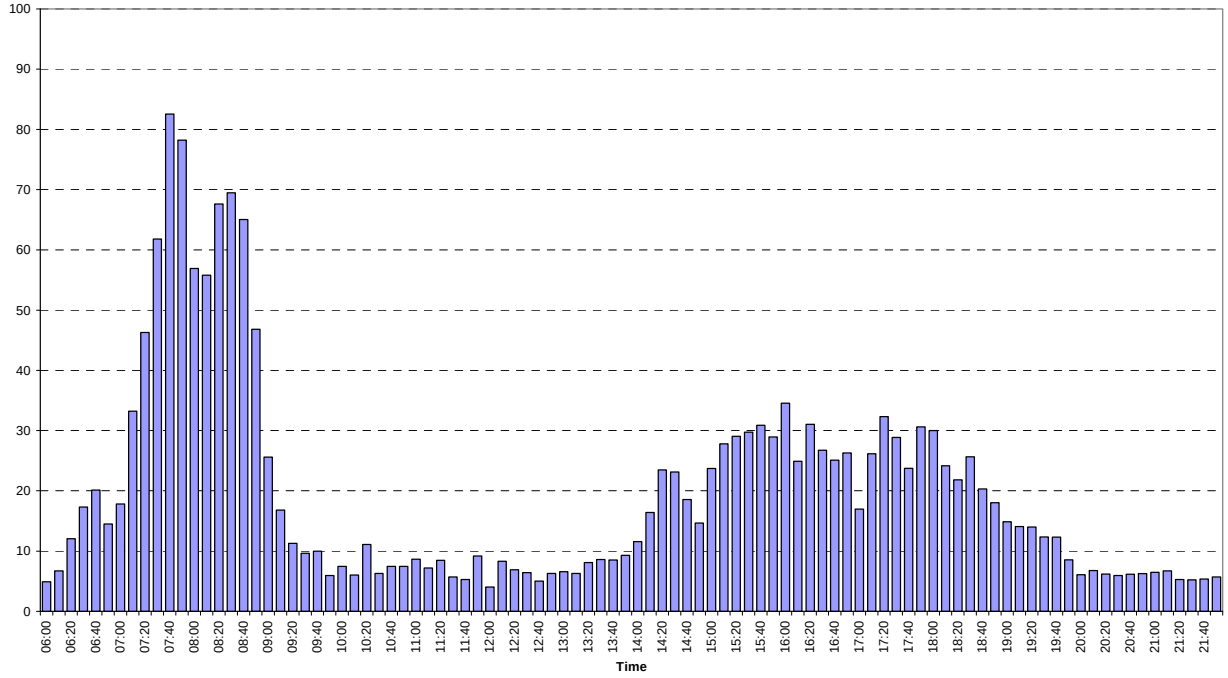
Percentage of Reported Speeds Below 30 mph (2001)
Segment 11: I-405 From Sunset Highway East to I-5



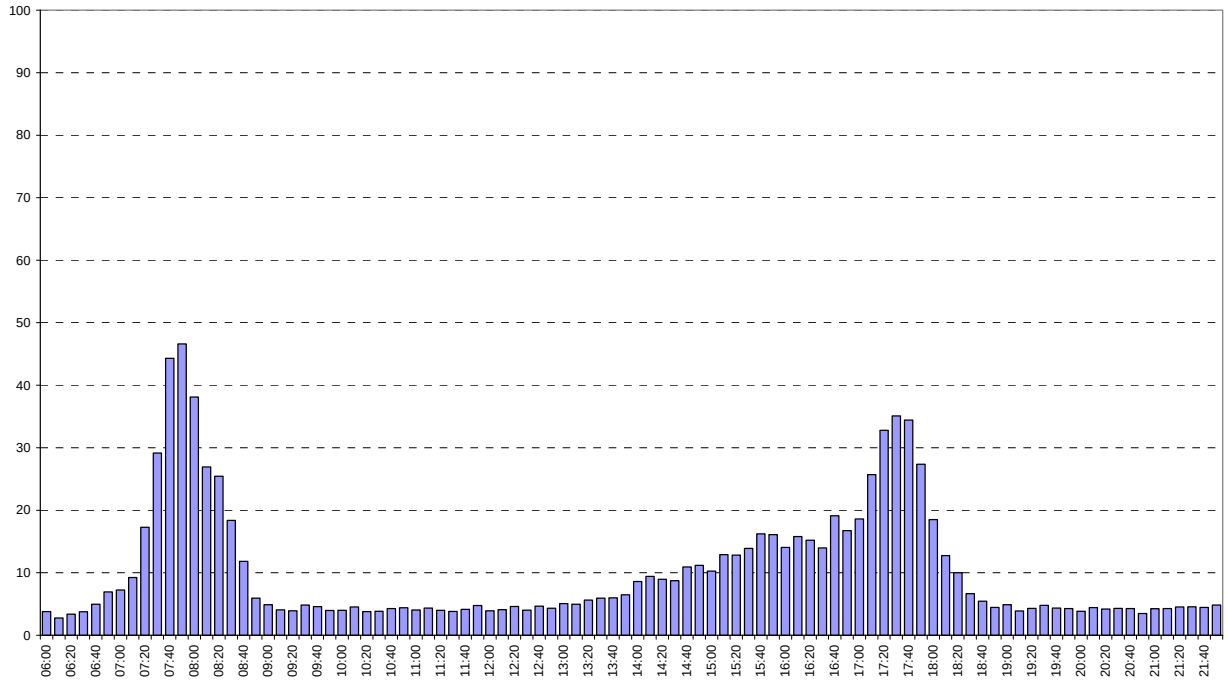
Percentage of Reported Speeds Below 30 mph (2001)
Segment 14: Sunset Hwy from Cornelius Pass Road East to Hwy 217



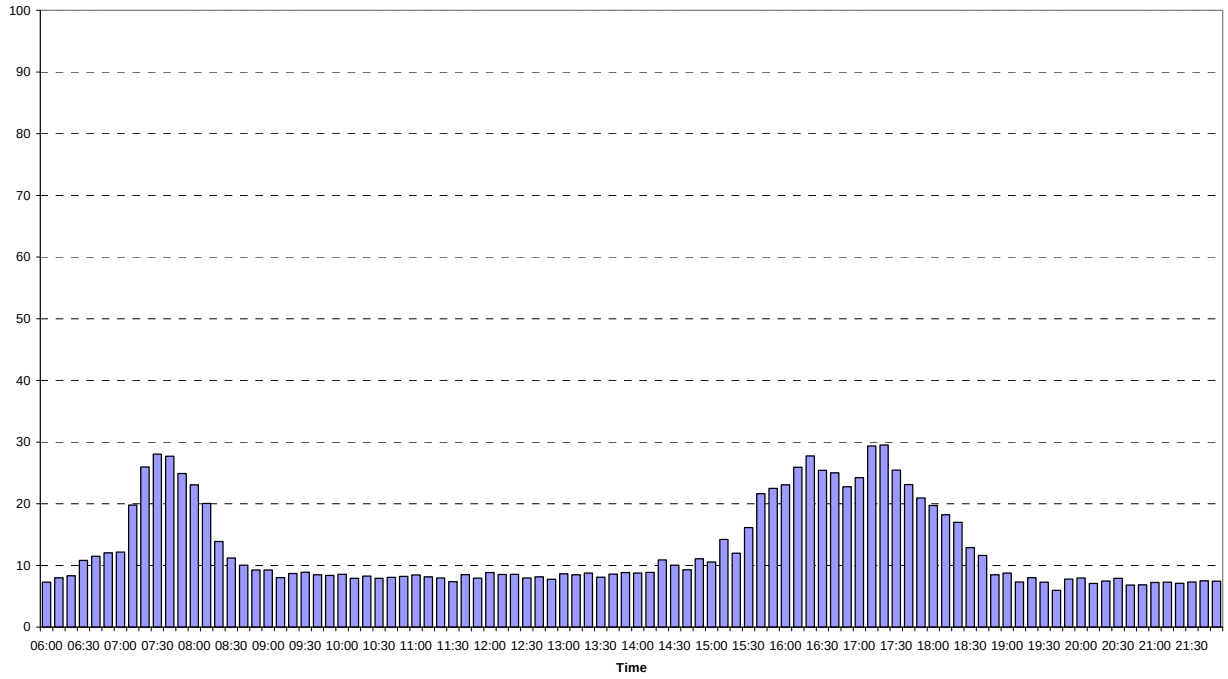
Percentage of Reported Speeds Below 30 mph (2001)
Segment 15: Sunset Hwy From Hwy 217 East to I-405



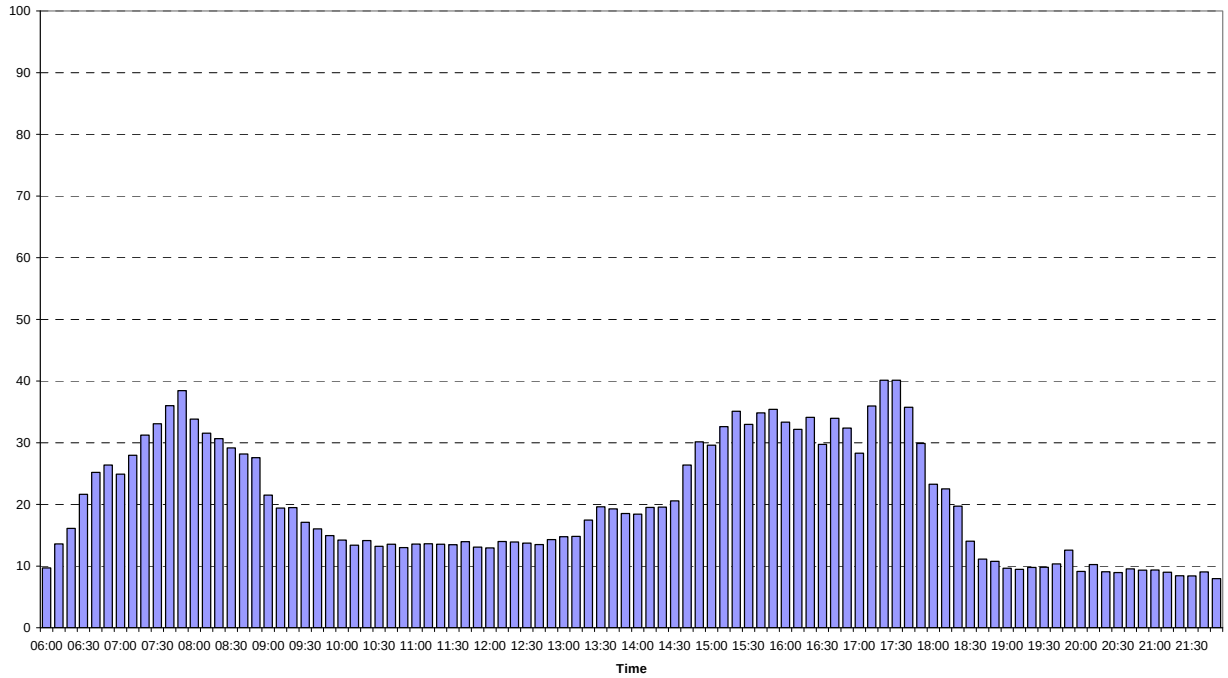
Percentage of Reported Speeds Below 30 mph (2001)
Segment 16: Hwy 217 From I-5 to Hwy 26



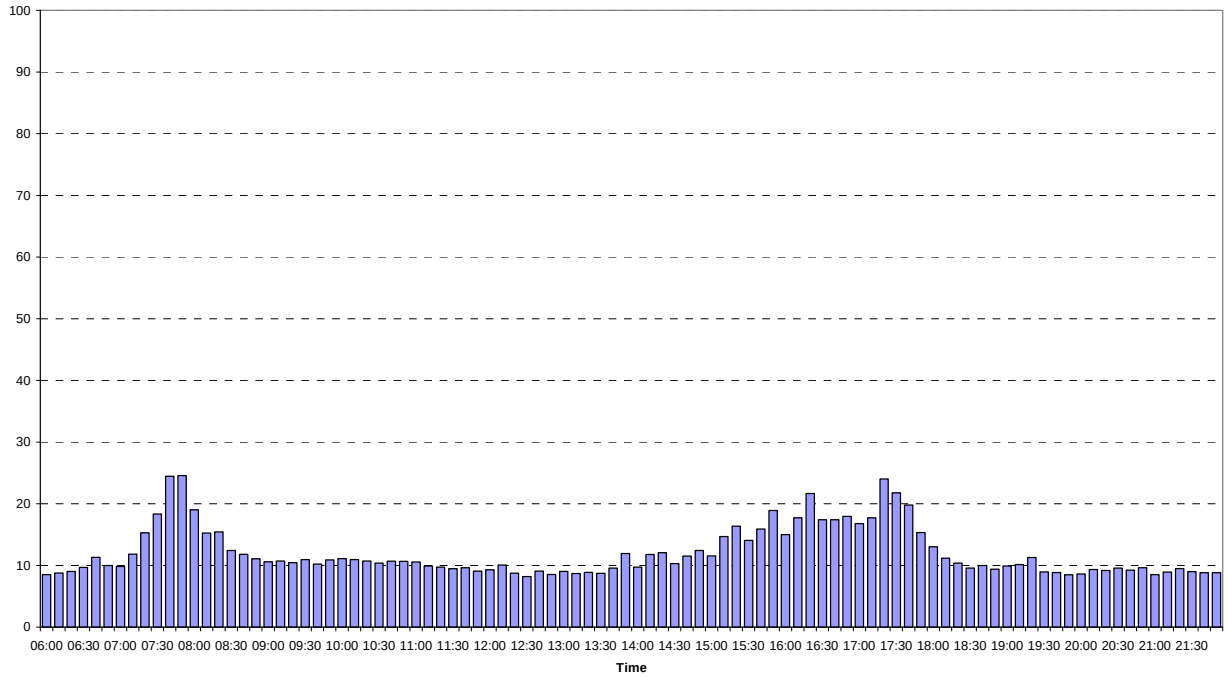
Percentage of Reported Speeds Below 30 mph (2002)
Segment 2: I-5 From I-205 North to Highway 217



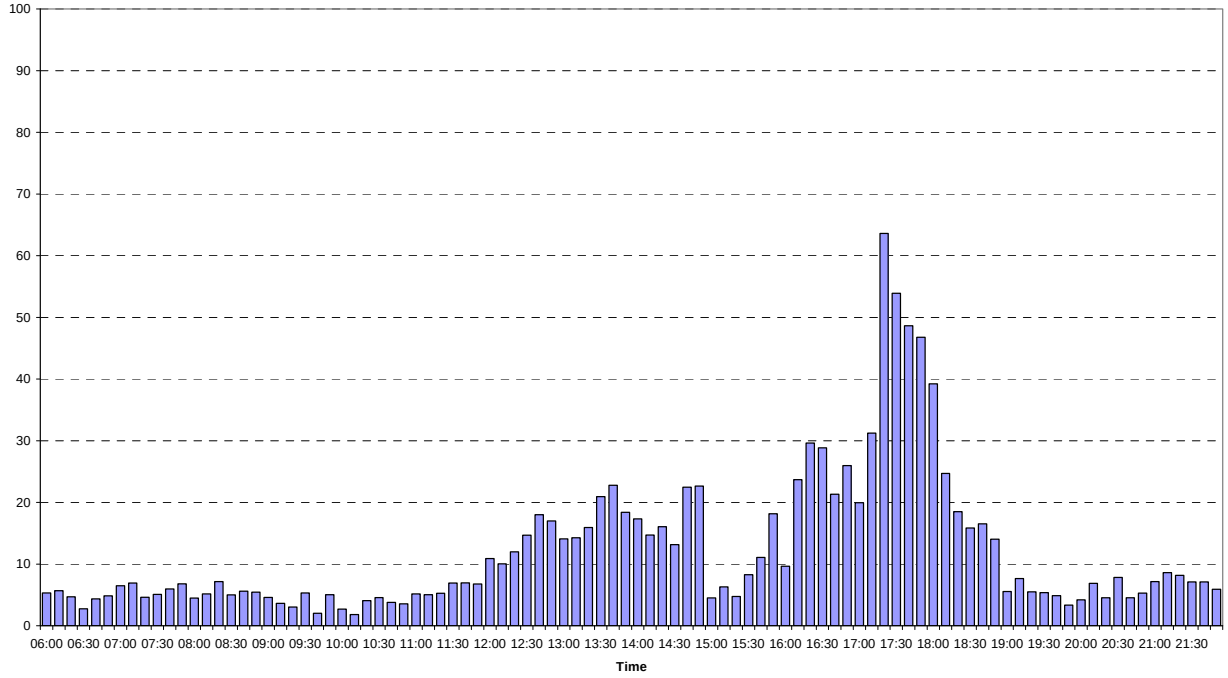
Percentage of Reported Speeds Below 30 mph (2002)
Segment 6: I-5 From I-405 to North to the Interstate Bridge



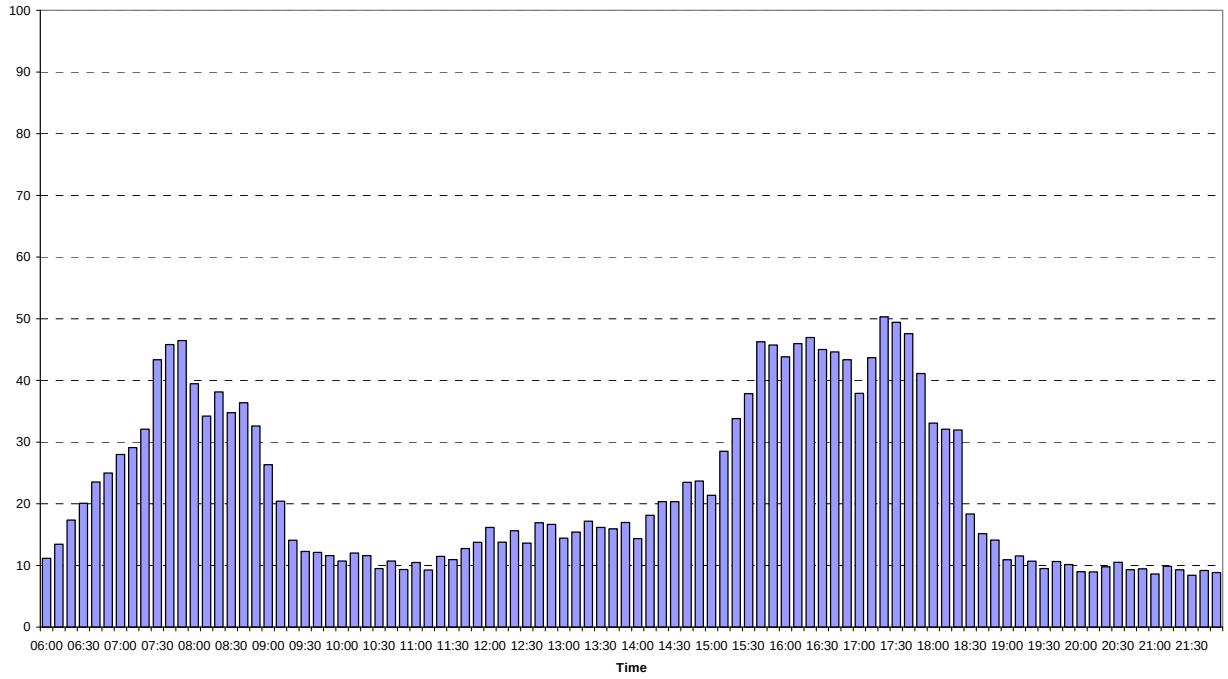
Percentage of Reported Speeds Below 30 mph (2002)
Segment 8: I-205 From Hwy 212/224 North to I-84



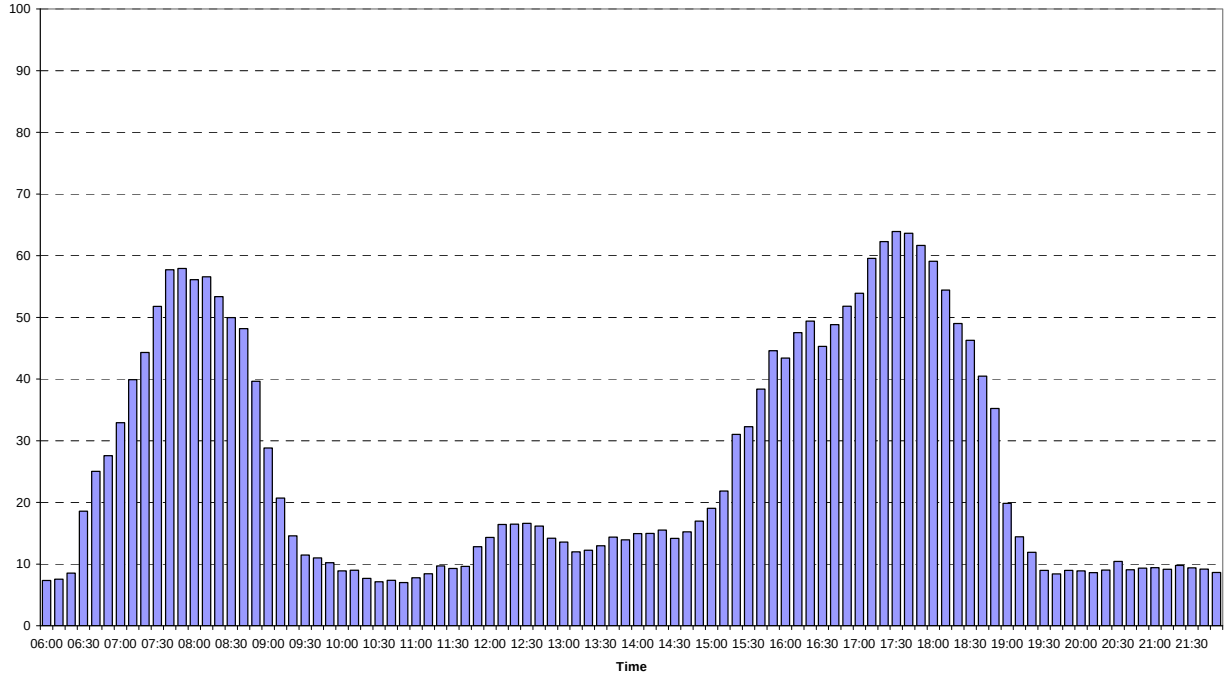
Percentage of Reported Speeds Below 30 mph (2002)
Segment 11: I-405 From the Sunset Highway East to I-5



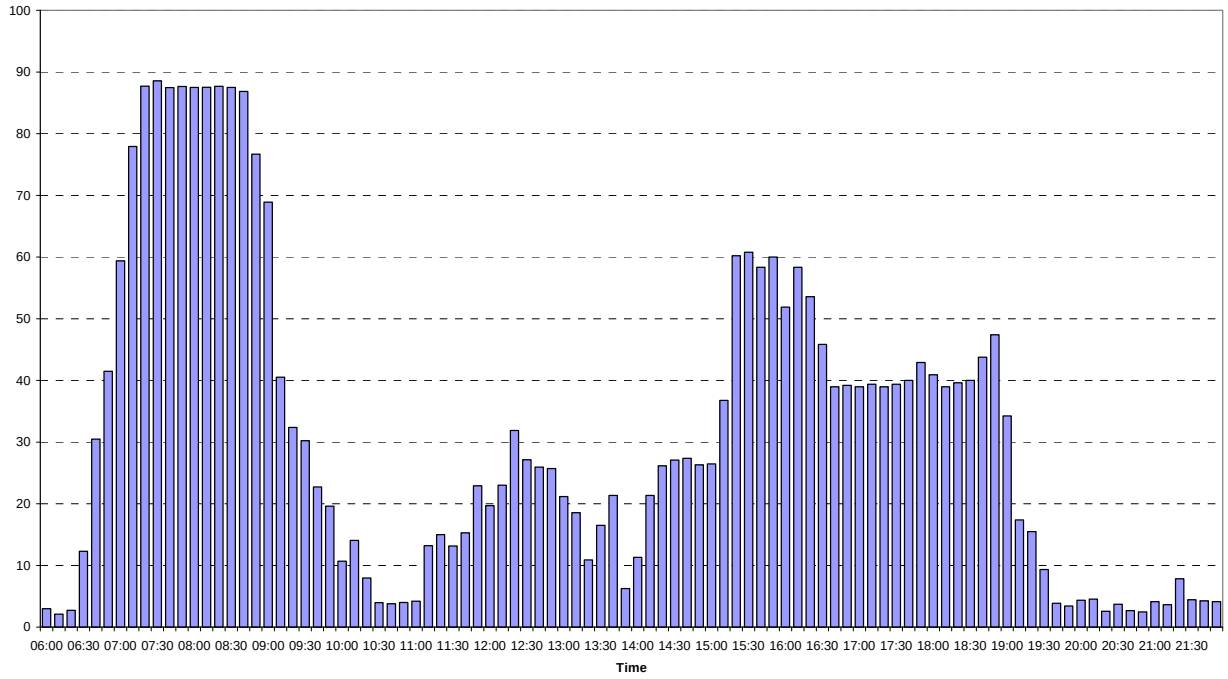
Percentage of Reported Speeds Below 30 mph (2002)
Segment 13: I-84 From I-205 West to I-5



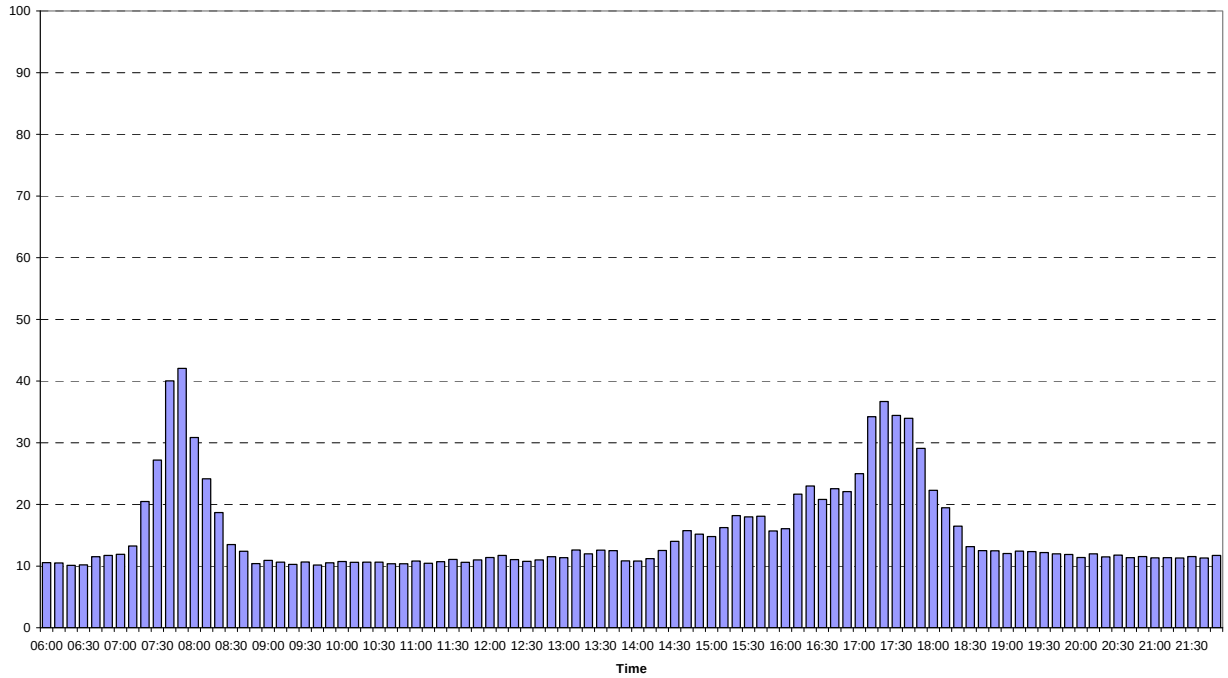
Percentage of Reported Speeds Below 30 mph (2002)
Segment 14: Sunset Highway (US 26) From Cornelius Pass Road East to Hwy 217



Percentage of Reported Speeds Below 30 mph (2002)
Segment 15: Sunset Highway (US 26) From Hwy 217 East to I-405



Percentage of Reported Speeds Below 30 mph (2002)
Segment 16: Hwy 217 From I-5 North to Sunset Highway



QUERIES (MICROSOFT JET SQL)

Fix_data_256:

```
UPDATE loopdata_2001 SET speed = speed*256, occupancy = occupancy*256;
```

Clean_data_1:

```
DELETE *
FROM loopdata
WHERE volume=-1;
```

Clean_data_999:

```
UPDATE loopdata SET volume = 0, speed = NULL, occupancy = 0
WHERE volume=-999;
```

Clean_data_badocc:

```
UPDATE loopdata SET speed = NULL, occupancy = NULL
WHERE speed=0 Or occupancy=100;
```

Query result1_prelim:

```
SELECT G.segmentid, T.time, sum(S.stationlength/T.avgspeed)*60 AS traveltime,
count(T.avgspeed) AS numSummed
FROM trim_dataset AS T, stations AS S, segments AS G
WHERE T.stationid=S.stationid And T.stationid=G.stationid
```

```
GROUP BY G.segmentid, T.time;
```

Query result1:

```
SELECT P.segmentid, avg(P.traveltime) AS traveltime
FROM result1_prelim AS P
GROUP BY P.segmentid;
```

Query result2:

```
SELECT T.stationid, round(avg(T.avgspeed)) AS avgspeed
FROM trim_dataset AS T
GROUP BY T.stationid;
```

Query result2_geocoded:

```
SELECT R.stationid, R.avgspeed, s_lat, s_long, e_lat, e_long
FROM result2 AS R, stationGeocode AS G
WHERE R.stationid=G.stationid;
```

Query result3:

```
SELECT S.SEGMENTID, Left(Format(time,"hh:mm"),4)+"0" AS time_10min,
abs(Sum(speed<46))/count(speed)*100 AS percentCongested
FROM loopdata AS L, detectors AS D, segments AS S
WHERE L.detectorid=D.detectorid And D.STATIONID=S.stationid And D.STATIONID<2000
And DatePart("h",[time]) Between 6 And 21 And DatePart("w",[time]) Between 2 And 6
```

```
GROUP BY S.SEGMENTID, Left(Format(time,"hh:mm"),4)+"0";
```

Query trim_dataset:

```
SELECT stationid, time, round(avg(speed)) AS avgspeed
FROM loopdata AS L, detectors AS D
WHERE L.detectorid=D.detectorid And D.stationid<2000 And Format(time,"hh:mm") Between
"16:30" And "17:30" And datepart("w",time) Between 2 And 6
GROUP BY stationid, time;
```