PubH 5466

Final Project

Traffic Light Signal Sequences Study

5-13-04

Good example using a textbook data set which did not provide much background or study detail
Comparing the Total Unused Red Light Time for
Traffic Light Signal Sequences:
Association with Intersection, Time Period, and Signal Sequences

Background

Traffic signals are a valuable tool for ensuring smooth and safe traffic flow throughout the community. Some of the signals are timed to work with other traffic signals to allow continuous flow from one signal to another. Some are timed so that if you are driving at the posted speed limit, you will receive a green signal at each intersection as you progress down the street. When properly timed, the traffic signals can increase the traffic handling capacity of an intersection and improve the safety and efficiency of both pedestrian and vehicular traffic.

A number of research studies have been conducted to investigate new technology and methods to enhance traffic flow and reduce accident rate. The primary goal of the traffic engineer is to provide the most comfortable ride as much as possible by getting the maximum number of vehicles through the system safely with the least amount of time and fewest stops at red light. It would be ideal if every driver could drive without stopping from one destination to another.

This study was implemented to compare the total unused red light time for five different traffic light signal sequences. Unused red light time is defined as the duration of waiting time for the traffic facing the red light when there is no traffic in
the direction(s) of green light. Knowing the differences between the signal sequences, the best sequence (with minimum unused red light time) can be implemented, facilitating smooth traffic flow. Data on unused red light time in minutes were collected at various intersections at various time periods for five different traffic light signal sequences. Thus, the hypotheses to be tested are (1) are there any differences among the traffic signal sequences? (2) If so, which sequence results in minimum total unused red light time? (3) Are there any differences in total unused red light time across the time period?

Study Design/Study Population

A Latin square design was utilized in which the two blocking factors were (1) five randomly selected intersections and (2) five time periods.

Methods

The purpose of this analysis is to examine the association between intersections, time period, and signal sequences on unused red light time. Simple statistics and plots were used to explore means, spread, and normality. The least square mean was used to determine which sequence results in minimum unused red light time. Tukey Method was utilized to implement all pairwise comparisons among sequences. The model for this study is a three-way mixed ANOVA for Latin square with no replications. With only one observation per block by sequence combination, no interactions are estimable. The plots of residuals vs. fitted values and normal probability plot of
residuals were checked for constant variance and normality, respectively. All analyses were implemented in SAS Version 8.0 (SAS Institute, Inc., Cary, NC).

**Results**

Sequence C had the minimum unused red light time (mean = 20, std = 6.88), followed by sequence D (mean = 22.5, std = 7.98), sequence A (mean = 24.12, std = 7.33), sequence E (mean = 24.14, std = 8.22), and sequence B (mean = 24.88, std = 7.91).

Overall sequence differences were found (F(4,12) = 3.45, p = 0.04). Tukey’s multiple pairwise comparisons test showed that sequence C was significantly lower than sequence B (t = 3.28, one-sided adj p = 0.02), but it was not significantly lower than the other sequences (See Table 1). There were significant differences in total unused red light time across the time periods (F(4,12) = 49.44, p < 0.0001). There was no intersection-to-intersection variability in total unused red light time since the estimated variance was zero.

The model assumptions were checked with residuals diagnostics and found to be approximately satisfied.

The relative efficiency of time period blocking for the experiment is 9.85. That is, there was an estimated 98.5% gain in efficiency over the randomized complete block design in which only the intersection is used for blocking. Thus, the time period blocks effectively reduced the error variance by 98.5%. The randomized block design without the time
period blocks would require $9.85(5) = 49.25$, or 50 replications to have an estimated variance of the treatment mean equal to that from the Latin square design.

However, there is a 93% gain in efficiency with intersection blocking. Without intersection blocking, the experiment would require only $.93(5) = 4.65$ or 5 replications of each treatment in the randomized completed block design to have an estimated variance of the treatment equal to that from the current Latin square design.

### Table 1: Differences of Least Square Means for total unused red light time

<table>
<thead>
<tr>
<th>Trt</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t(12) Value</th>
<th>Tukey Adj P</th>
</tr>
</thead>
<tbody>
<tr>
<td>A−B</td>
<td>0.76</td>
<td>1.49</td>
<td>-0.51</td>
<td>0.98</td>
</tr>
<tr>
<td>A−C</td>
<td>4.12</td>
<td>1.49</td>
<td>2.77</td>
<td>0.10</td>
</tr>
<tr>
<td>A−D</td>
<td>1.62</td>
<td>1.49</td>
<td>1.09</td>
<td>0.81</td>
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<tr>
<td>A−E</td>
<td>0.02</td>
<td>1.49</td>
<td>-0.01</td>
<td>1.00</td>
</tr>
<tr>
<td>B−C</td>
<td>4.88</td>
<td>1.49</td>
<td>3.28</td>
<td>0.04</td>
</tr>
<tr>
<td>B−D</td>
<td>2.38</td>
<td>1.49</td>
<td>1.60</td>
<td>0.52</td>
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<tr>
<td>C−D</td>
<td>-2.50</td>
<td>1.49</td>
<td>-1.68</td>
<td>0.48</td>
</tr>
<tr>
<td>C−E</td>
<td>-4.14</td>
<td>1.49</td>
<td>-2.79</td>
<td>0.10</td>
</tr>
<tr>
<td>D−E</td>
<td>-1.64</td>
<td>1.49</td>
<td>-1.10</td>
<td>0.80</td>
</tr>
</tbody>
</table>

### Discussion

Sequence C resulted in the shortest total unused red light time and was significantly lower than sequence B; however, it was not significantly lower than the others.
We are limited in the assessments we can make on normality and constant variance since there are only five observations per treatment when we ignore blocks. For future study, we should consider applying replicated Latin square design. This would allow us to assess the block by treatment interaction and more degrees of freedom left for the error.

The researchers should also consider using a different technology in which each signalized intersection is operated by its own computer. Thus, the computer can monitor the amount of traffic flow and trigger the lights for cross traffic when needed instead of relying on preset timers where the signal indications will cycle for a specified time period. The results of this study cannot be generalized to any time period since the time period studied is fixed as opposed to being random.
References


http://www.sannet.gov/street-div/trflight.shtml

Last access date: May 11, 2004

http://www.itsa.org/ITSNEWS.NFS

Last access date: May 11, 2004

http://www.dot.state.az.us/ROADS/traffic/signal.htm

Last access date: May 12, 2004