Analysis of Seasonal and Day-of-Week Traffic Patterns at National Parks

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The National Park Service (NPS) is considering improvements to its traffic monitoring program in national parks. While several of the national parks within this network collect continuous vehicle data at multiple stations within each park, these continuous data have not been systematically analyzed for their suitability in factoring short-term traffic counts at other locations. Therefore, this research investigated seasonal and day-of-week traffic patterns using a sample set of five national parks, in the context of using these continuous data to factor short-term traffic counts. From the limited sample in this analysis, it was determined that the seasonal and day-of-week factors were not statistically different from 2002 to 2006 for all five national parks, allowing for adjustment of short counts to annual average daily traffic values. Therefore, the use of traditional traffic monitoring principles (e.g., use of a few continuous count locations with many short-term traffic counts that are factored to an annual average) can be considered. The NPS traffic monitoring system may also be enhanced with the use of data from nearby state highway count locations. For the small number of parks examined in this research, there was a high correlation between park traffic and data from nearby (within 20 mi) state highway automatic traffic recorders.

Traffic data provide guidance when vital transportation decisions need to be made. They form the foundation upon which the nation’s transportation system was built and support the decisions that are made when preparing for the future. Traffic data are collected across the country, but traffic-counting needs, budgets, and geographic constraints vary from one location to the next. Therefore, before data collection begins, it is important for an area to create a traffic monitoring program to make best use of all available resources. Development of such a program assists in capturing the relevant data while preparing to properly maintain it in an archived fashion for future use in a cost-effective manner.

Various agencies nationwide are required to develop traffic monitoring programs and collect traffic data with the intent of using it to develop and improve their infrastructure systems. The National Park Service (NPS), which is a network of 391 natural, recreational, and cultural areas covering more than 84 million acres, is one agency that is contemplating the implementation of such a program. Although the NPS does not currently require traffic to be monitored in all 391 areas, several of the national parks within this network collect continuous vehicle and visitation data.

This research investigates the method in which national park traffic is currently monitored and searches for potential improvements. Although traditional traffic monitoring procedures use only a limited number of continuous counts in conjunction with a large number of short-duration counts to best utilize the available resources when monitoring traffic, several of the national parks collect only continuous traffic data at multiple stations within each park in order to monitor these roadways. If this method of data collection were applied to all 391 areas that make up the NPS, traffic monitoring would be costly and would require a significant time commitment in terms of data collection, reduction, and organization. However, it has recently been suggested that improvements could be made to the current traffic monitoring program. Therefore, in an effort to reduce the amount of time and money spent on data collection within these recreational areas, research into potential improvements to the data collection process was undertaken. One potential source of efficiency may stem from determining whether the traffic within each park follows the same seasonal pattern from one year to the next. The existence of such a pattern would enable the parks to implement a sampling approach to reduce the volume and cost of data collection. It may also allow the parks to integrate the traffic data collected within the parks with data of other nearby transportation agencies. If seasonal trends do not exist when comparing the park traffic from one year to the next, then traffic must be continuously collected in several locations in order to maintain accuracy.

LITERATURE REVIEW

Measurement of traffic volumes is one of the most basic components of transportation planning and management. Collection of these volumes is the most common measure of roadway use throughout the nation. Most agencies focus on the average annual daily traffic (AADT) when monitoring a roadway network. AADT represents the average daily number of vehicles that traverse a specific point on a roadway; however, this vehicle count is not evenly distributed. Instead, traffic varies by time of day, day of week, and month (or season), and it is important to account for these fluctuations when measuring the use of a particular roadway.

Traffic Data Collection Design

A successful data collection program accounts for traffic variability and also identifies changes in traffic patterns as they occur over time. It is comprised of “a modest number of permanent, continuously operating, data collection sites and a large number of short-duration collection efforts” and includes adjustment factors that are used to better approximate traffic conditions (1). While short-duration counts
provide vast geographic coverage and contribute to the understanding of traffic characteristics on individual roadways, permanent locations assist in determining the seasonal and day-of-week trends.

**Computation of Seasonal Factors**

Seasonal factors are used to account for temporal bias when estimating AADT using short-duration counts. External factors such as weather and the availability of both staff and equipment affect the time in which an agency can conduct short-duration counts. Therefore, adjustment factors must be developed for all times of the year. Seasonal factors can be based on the day of the week, month of the year, or any other time period. The combination of monthly and day-of-week factors is most commonly used in practice (1). To compute seasonal factors for a particular site, AADT is divided by a factor that depends on the factoring approach that was used. A typical approach is shown in Equation 1 (1).

\[
AADT_h = VOL_h \times M_h \times D_h \times A_h \times G_h
\]

where

- \( AADT_h \) = annual average daily travel at location \( i \) of factor group \( h \)
- \( VOL_h \) = 24-h axle volume at location \( i \) of factor group \( h \)
- \( M_h \) = applicable seasonal (or monthly) factor for factor group \( h \)
- \( D_h \) = applicable day-of-week factor for factor group \( h \) (if needed)
- \( A_h \) = applicable axle-correction factor for location \( i \) (if needed), and
- \( G_h \) = applicable growth factor for factor group \( h \) (if needed).

Equation 1 can be used to convert short-duration counts to AADT estimates by using the seasonal adjustment factors developed in this research. However, instead of using separate adjustment factors for the applicable month and day of the week, the factors developed in this paper are combined to yield a single adjustment factor for each day-of-week and month-of-year combination. Additionally, axle-correction factors were not needed because the short-duration volumes were vehicle counts and not axle counts. Growth factors were also not necessary because the short-duration volumes did not need to be projected into the future. For example, with the use of Equation 1 and the applicable adjustment factors, the 24-h vehicle count collected on May 1, 2006, in Yosemite National Park can be converted to an AADT estimate for 2006 as follows.

\[
AADT_{2006,Yosemite} = (VOL_{2006,Yosemite}) \times (MD_{May, Monday})
\]

\[
= (811 \text{ veh}) \times (0.74) = 599 \text{ veh}
\]

**Accuracy of AADT Estimates Using Short-Count Data**

Over the past few years, numerous studies have been conducted to assess the accuracy of AADT estimates developed by expanding short-term traffic counts. While FHWA suggests collecting short-count data with a single 48-h count every 3 years, other count durations have been studied to determine the effect that they have on the accuracy of the estimated value. A recent study in Canada examined AADT estimates that used either adjustment factors or regression analysis to expand the short-term traffic counts. For both of these expansion methods, it was determined that a minimum 8-day sample over three seasons is required to estimate AADT values within ±10%. It was also found that the more commonly used factor method of expanding one 48-h count has an accuracy that ranges from ±13 to ±25%, nine times out of 10 (2).

Another study in Canada grouped roadways prior to analysis using three different types of routes: commuter, rural, and recreational. While the commuter and rural routes were associated with low and moderate variation in monthly traffic, respectively, the recreational routes were characterized by high seasonal variation and moderate to high weekend volumes. As a result of this variability, recreational routes experienced greater AADT estimation errors than either commuter or rural routes for the same duration of short-term counts. Additionally, it was determined that longer and more frequent counts are required for recreational roadways where more accurate estimations are expected (3). Further research on this topic found AADT estimation errors to be even more sensitive to the correctness of the assignment of the sample site to an automatic traffic recorder than to the duration of the count. Results showed that "even a 6-hour count when assigned correctly can provide a much better AADT estimate than an incorrectly assigned 72-hour count" (4). Therefore, in order to ensure that the assignment is reliable, it is recommended that seasonal counts consist of at least two 1-week counts made in different months when assigning a site to a factor group (5).

Although this research did not attempt to define the exact time period in which the NPS should collect short-duration counts, it is important to recognize that accurate AADT estimates can be achieved when the short-count data are collected for an appropriate duration and when the roadway is correctly assigned to an adjustment factor group. In order to accurately assign a site to an adjustment factor group and estimate the AADT, it is suggested that several days of short-duration counts be made in different months. This recommendation supports the need for adjustment factors for all times of the year and reinforces the use of both monthly and day-of-week factors.

**Current National Park Traffic Monitoring Practices**

National park visitation and traffic volumes are currently collected under the policies and procedures found in Director’s Order 82 (DO82): Public Use Data Collecting and Reporting Program. Since as early as 1904, information concerning the public use of national parks has been collected during informal monitoring of the visitation levels, trip origins, and transportation modes used to access the parks. The NPS developed a formal system for gathering and reporting such information in the late 1960s, which is documented in DO82 (6).

DO82 requires that visitation and traffic data be collected, analyzed, and reported in a consistent manner throughout the NPS and that the parks submit accurate data to the Service-wide Public Use Data Collecting and Reporting Program in a timely manner. When determining the number of recreational visitors, vehicle counts are converted to visitation volumes using a vehicle expansion multiplier and a persons-per-vehicle multiplier that vary based on month to determine the number of vehicles and visitors, respectively. Additionally, some of the national parks include the number of persons that enter on bus, bicycle, foot, cross-country skis, snowmobile, snow coach, ferry or train depending upon the location of the park. When determining the number of nonrecreational visitors (e.g., NPS or concession employees), the national parks first estimate the number of...
nonrecreational vehicles using a predetermined proportion and then multiply this count by a persons-per-vehicle multiplier to yield the number of nonrecreational visitors. However, some parks instead use a simple count that remains constant each month when the number of nonrecreational visitors is estimated (7).

### Hourly Traffic Volumes

Hourly traffic volumes display significant variation from one hour to the next throughout the year. Traditionally, design hourly volumes (typically the 30th highest hour volume of the year) are determined by plotting the hourly traffic volumes as percentages of the AADT for the highest hourly volumes of the year. This ratio of highest hourly volume to AADT is defined as the K-factor. With this plot, the particular hour used for design is then chosen within the range that encompasses the "knee" of the curve, or the area in which the slope of the curve changes most rapidly [see Figure 1 (8)].

The typical relationship between the highest hourly volumes and their K-factors on rural arterial is shown in Figure 1. The slope of the curve to the left of the point representing the 30th highest hour volume is very steep, but to the right of this point, the curve flattens, although this is much more gradual in a rural road than in an urban facility. Therefore, while many hours exist where the volume is not much less than the 30th highest hourly volume, there are only a few hours with higher volumes (9).

According to AASHTO's *A Policy on Geometric Design of Highways and Streets*, the 30th highest hourly volume is approximately 15% of the AADT on a typical rural arterial and 10% of the AADT for urban areas. A study in Canada found that the type of road use has a significant influence on the value of the K-factor. While the lowest K-factors occur on urban commuter routes, the highest K-factors are found on routes near popular recreational areas. K-factors found between these two extremes are seen on rural routes (10). K-factor plots of traffic volumes at the national parks were examined to determine if they followed the common shape of plots on rural and urban highways.

### DATA COLLECTION

The NPS consists of 391 parks and covers more than 84 million acres. Therefore, not all of the national parks were included in this study. To narrow this to a manageable number of data sets, the 30 parks included in the NPS Annual Traffic Data Report were examined for potential research candidates. Because these 30 national parks accounted for approximately 30% of the total NPS annual visitation, it was assumed that these particular parks were areas where traffic was an issue and where the most money was spent in monitoring the traffic (7).

In determining which of the 30 parks to include in the national park sample set, the primary goal was to select national parks located in both rural and urban settings where traffic monitoring improvements were most needed. Therefore, this study examined parks that had an extremely high number of annual visitors or were large in size. The following five parks were chosen as the national park sample set:

- Acadia National Park, which is located in Maine, along the rocky shores of the Atlantic Ocean. While most of the park is situated on Mount Desert Island, a portion of the park is also located on Isle au Haut and Schoodic Peninsula.
- Big Bend National Park, which is located in southwest Texas. Southerly bounded by the Rio Grande, the river's flow to the southeast suddenly changes to the northeast and forms the "big bend" of the Rio Grande.
- George Washington Memorial Parkway, which serves as a memorial to George Washington. It is located in Maryland, Virginia, and the District of Columbia and was originally designed as the gateway to the nation's capital. It should be noted that this parkway primarily serves as an urban commuting route. Hence, it was chosen to...
serve as a control location to confirm expected seasonal and day-of-week traffic patterns.

- Yellowstone National Park, which was established in 1872 and is America’s first national park. The majority of the park is found in the northwest corner of Wyoming. However, park grounds also stretch into Idaho and Montana.
- Yosemite National Park, which is located in central California and primarily lies in Tuolumne and Mariposa Counties.

While many parks that make up the NPS had several traffic data collection stations throughout the park, only one data collection station was selected for each park due to limitations on data access from the NPS. Both geography and archived data quality were considered when determining which station was the most appropriate. In most cases, the researchers selected monitoring stations that were located at or near the main park entrances or other locations that were thought to have representative traffic patterns for the park as a whole. Future research with additional traffic data would be necessary to confirm the representativeness of the selected locations, particularly in parks with multiple entrances and multiple permanent count stations.

After the most appropriate national park sample set was determined, hourly traffic data for 2002 to 2006 were obtained directly from the NPS. After traffic data were gathered for the national park study sample, archived traffic data collected on nearby state highways were also obtained from the states surrounding these five national parks.

DATA ANALYSIS AND RESULTS

This section of the paper presents the methodology and results for three distinct questions posed by this research:

1. Do seasonal and day-of-week factors vary significantly from year to year in heavily visited national parks?
2. Are traffic count seasonal patterns and trends from state highways near national parks similar to patterns and trends within the park, such that existing state DOT traffic count data could be used to supplement short-duration counts in national parks?
3. Are the traffic-peak characteristics at national parks consistent with the values reported in the literature for rural or recreational routes?

To improve readability when these three questions are discussed, the methodology and results have been grouped together for each question in the following sections.

Seasonal and Day-of-Week Factor Analysis and Results

To determine whether national park traffic exhibits consistent seasonal patterns, traffic was compared from one year to the next for each particular park using the national park traffic data obtained for 2002 to 2006. As a means of quantifying the seasonal patterns for each park, a set of seasonal factors were computed for each of the 5 years. Although seasonal adjustment procedures can be based on any predefined time period, seasonal factors for this analysis were calculated as a ratio of AADT to the monthly average day-of-week (MADW) values, yielding a value for each day-of-week and month-of-year combination for 2002 to 2006.

The 84 seasonal factors (one value for each of the seven days of each of the 12 months) were then calculated. Daily traffic volumes were first computed for all five national parks with the summation of the hourly traffic counts across all 24 h. However, because AASHTO recommends that missing traffic data not be imputed, or estimated by using a current traffic editing program, only days that were 100% complete were used (17). Therefore, days that included even a single hour of missing data were omitted from the data set prior to analysis. All complete daily traffic volumes were then averaged for each day-of-week and month-of-year combination to yield a maximum of seven values for each of the 12 months, or 84 MADW values. Missing data was not a significant issue with these data sets, with the average completeness for all five parks at 94% (that is, 94% of the MADW values were able to be calculated). Acadia National Park had the most missing data at 82% complete (i.e., 69 of the 84 MADW values were able to be computed).

The annual average day-of-week (AADW) values were then calculated with an average of the MADW values. The conventional AASHTO averaging procedure states that the MADW values should be averaged across all 12 months to yield seven AADW values. However, a slight modification was made to this conventional approach to allow for missing MADW values in this analysis. Instead of requiring that all 12 MADW values be present to calculate an AADW value, a value that was missing could be omitted from this average. This adjustment followed that which was suggested by research at the Texas Transportation Institute when calculating annual average traffic statistics with the use of archived intelligent transportation system data (12). Therefore, in this study, the AADW values were calculated using Equation 2.

$$\text{AADW}_i = \frac{1}{m} \sum_{j=1}^{m} \text{MADW}_{ij}$$  \hspace{1cm} (2)

where

- $i$ = day of the week,
- $j$ = month of the year, and
- $m$ = number of months where MADW values were available.

A similar modification was made to allow for missing AADW values when calculating the AADT. Although the conventional AASHTO method recommends averaging the AADW values across all seven days of the week, missing values were simply omitted from the average. Therefore, the AADT values were calculated by using Equation 3.

$$\text{AADT} = \frac{1}{d} \sum_{i=1}^{d} \text{AADW}_i$$  \hspace{1cm} (3)

where $i$ equals the day of the week and $d$ equals the number of days of the week where AADW values were available.

Finally, a seasonal factor was developed for each day-of-week and month-of-year combination for 2002 to 2006 as shown in Equation 4.

$$F_{ij} = \frac{\text{AADT}}{\text{MADW}_{ij}}$$  \hspace{1cm} (4)

where

- $F$ = seasonal adjustment factor,
- $i$ = day of the week, and
- $j$ = month of the year.
TABLE 1  Seasonal and Day-of-Week Factors for Yosemite National Park in 2002

<table>
<thead>
<tr>
<th>Month</th>
<th>Sunday</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>3.04</td>
<td>5.61</td>
<td>5.23</td>
<td>5.02</td>
<td>4.54</td>
<td>2.53</td>
<td>1.91</td>
</tr>
<tr>
<td>February</td>
<td>2.34</td>
<td>3.46</td>
<td>5.34</td>
<td>4.79</td>
<td>3.98</td>
<td>2.27</td>
<td>1.54</td>
</tr>
<tr>
<td>March</td>
<td>2.33</td>
<td>2.69</td>
<td>2.89</td>
<td>2.88</td>
<td>2.56</td>
<td>1.63</td>
<td>1.40</td>
</tr>
<tr>
<td>April</td>
<td>1.12</td>
<td>1.57</td>
<td>1.74</td>
<td>1.73</td>
<td>1.54</td>
<td>0.95</td>
<td>0.84</td>
</tr>
<tr>
<td>May</td>
<td>0.57</td>
<td>0.80</td>
<td>1.05</td>
<td>1.05</td>
<td>0.94</td>
<td>0.54</td>
<td>0.48</td>
</tr>
<tr>
<td>June</td>
<td>0.55</td>
<td>0.70</td>
<td>0.80</td>
<td>0.79</td>
<td>0.71</td>
<td>0.48</td>
<td>0.46</td>
</tr>
<tr>
<td>July</td>
<td>0.51</td>
<td>0.66</td>
<td>0.71</td>
<td>0.64</td>
<td>0.51</td>
<td>0.42</td>
<td>0.40</td>
</tr>
<tr>
<td>August</td>
<td>0.49</td>
<td>0.64</td>
<td>0.70</td>
<td>0.68</td>
<td>0.61</td>
<td>0.44</td>
<td>0.39</td>
</tr>
<tr>
<td>September</td>
<td>0.62</td>
<td>0.78</td>
<td>1.00</td>
<td>1.02</td>
<td>0.83</td>
<td>0.44</td>
<td>0.52</td>
</tr>
<tr>
<td>October</td>
<td>0.88</td>
<td>1.23</td>
<td>1.41</td>
<td>1.39</td>
<td>1.24</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>November</td>
<td>1.87</td>
<td>2.68</td>
<td>3.09</td>
<td>2.67</td>
<td>2.65</td>
<td>1.33</td>
<td>1.27</td>
</tr>
<tr>
<td>December</td>
<td>3.13</td>
<td>3.68</td>
<td>4.49</td>
<td>4.50</td>
<td>4.19</td>
<td>3.18</td>
<td>2.89</td>
</tr>
</tbody>
</table>

Note: Since the AADT is divided by the monthly or daily traffic, lower numbers indicate greater traffic volumes during that time period. The same is true in Figures 2 and 3.

With these steps, a table of seasonal and day-of-week factors was developed for each of the five national parks and each of the five years. An example of such a table can be seen in Table 1 for Yosemite National Park in 2002.

The tables for Big Bend National Park, George Washington Memorial Parkway, and Yosemite National Park include seasonal and day-of-week factors for all 12 months of the year. However, because Acadia and Yellowstone National Parks experienced seasonal park closures, factors were not created for the months that the parks were closed.

To determine whether the traffic patterns were consistent from one year to the next for each of the five national parks, the Kruskal–Wallis test was used to compare the seasonal and day-of-week factors across all 5 years. Each complete daily traffic volume was expressed as a percentage of the AADT for that particular year, and the ratios were grouped according to the day of week, month, and year.

Although the Kruskal–Wallis test does not assume that the data are normally distributed, it does assume that the observations within each group come from populations with the same shape of distribution. To assess the validity of this assumption, the groups of ratios were plotted on the same figure for each particular day-of-week and month combination across all 5 years, and the shapes of the distributions were compared visually. With these plots, it was determined that the distribution of the ratios within each group is fairly consistent from one group to the next for all five national parks. An example of these plots can be seen in Figures 2 and 3 for Yosemite National Park.
Intuitively, the Kruskal–Wallis test is identical to a one-way analysis of variance where the statistic is calculated using the ranks of the data rather than the raw data values. Therefore, for this analysis, the 5 years or groups of ratios were combined for each of the five national parks, and the pooled data were ranked from 1 to \( N \), where \( N \) represented the total number of ratios across all of the groups. It should be noted that ratios of equal magnitude were given an average rank. Therefore, if four identical ratios occurred the second, third, fourth, and fifth smallest places, all four values were given a rank of 3.5. After ranking all of the ratios, the test statistic was computed for each day-of-week and month-of-year combination for all five national parks as shown in Equation 5.

\[
H = \frac{12}{N(N+1)} \sum_{i=1}^{y} n_i (\bar{R}_i - \bar{R}_y)^2
\]  

(5)

\[
\bar{R}_y = \frac{\sum_{i=1}^{y} R_i}{n_i}
\]

\[
\bar{R}_y = \frac{N+1}{2}
\]

where

\( H \) = test statistic,

\( R_y \) = rank of ratio \( j \) from year (or group) \( i \),

\( n_i \) = number of ratios in year (or group) \( i \),

\( N \) = total number of ratios across all years (or groups), and

\( y \) = number of years (or groups).

After the test statistic for each day-of-week and month-of-year combination were computed for all five national parks, the \( p \)-values were determined by using the chi-square table where the degrees of freedom were equal to the number of groups minus one. With the \( p \)-values and the significance level of 0.25, the null hypothesis was then tested for each day-of-week and month-of-year combination. However, because the Kruskal–Wallis test had to be performed 84 times for each national park, the \( p \)-value threshold was adjusted by using the Bonferroni correction. The Bonferroni correction is a multiple-comparison adjustment that is used to reduce falsely significant results when several statistical tests are performed on a set of data simultaneously. In statistics, one out of every four hypothesis tests will appear to be significant purely due to chance when a significance level of 0.25 is used. Therefore, according to the Bonferroni correction, if an experiment is testing \( n \) hypotheses on a data set, the significance level that should be used to test each hypothesis separately is \( 1/n \) times what it would be if only one hypothesis were being tested. While all 84 individual hypotheses (12 months and 7 days) were tested for Big Bend National Park, George Washington Memorial Parkway, and Yosemite National Park, only 42 (6 months and 7 days) and 56 individual hypotheses (8 months and 7 days) were tested for Acadia and Yellowstone National Parks, respectively, due to seasonal park closures. Therefore, instead of using a significance level of 0.25 to test each individual hypothesis, the following \( p \)-value thresholds were used.

\[
\text{threshold}_{\text{Big Bend/GWMP/Yosemite}} = \frac{1}{n}(0.25) = \frac{1}{84}(0.25) = 0.0030
\]

\[
\text{threshold}_{\text{Acadia}} = \frac{1}{n}(0.25) = \frac{1}{42}(0.25) = 0.0060
\]

\[
\text{threshold}_{\text{Yellowstone}} = \frac{1}{n}(0.25) = \frac{1}{56}(0.25) = 0.0045
\]

With these steps, the median was compared across all 5 years for each of the 84 day-of-week and month-of-year combinations and for each of the five national parks, theoretically yielding a total of 504 hypotheses tests. However, due to seasonal park closures in both Acadia and Yellowstone National Parks, comparisons were only performed for the months of May through October and April through November for Acadia and Yellowstone National Parks, respectively. Additional omissions were made as a result of the nature of the
TABLE 2  Correlation Values

<table>
<thead>
<tr>
<th>Distance from Park (mi)</th>
<th>Year 2002</th>
<th>Year 2003</th>
<th>Year 2004</th>
<th>Year 2005</th>
<th>Year 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>George Washington</td>
<td>5</td>
<td>0.93</td>
<td>0.92</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Memorial Parkway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acadia National Park</td>
<td>8</td>
<td>N/A</td>
<td>0.83</td>
<td>0.78</td>
<td>0.81</td>
</tr>
<tr>
<td>Yellowstone National</td>
<td>Station A-19</td>
<td>N/A</td>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Park</td>
<td>Station A-18</td>
<td>20</td>
<td>N/A</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>Yosemite National Park</td>
<td>40</td>
<td>0.77</td>
<td>0.69</td>
<td>0.73</td>
<td>0.75</td>
</tr>
<tr>
<td>Big Bend National Park</td>
<td>60</td>
<td>0.11</td>
<td>0.13</td>
<td>0.33</td>
<td>0.26</td>
</tr>
</tbody>
</table>

NOTE: N/A = not available.

Kruskal–Wallis test. To compare the medians for each day-of-week and month-of-year combination, at least two ratios were needed for every year. Years that included only a single ratio for that particular day-of-week and month-of-year combination were omitted from the data set prior to analysis.

With the Kruskal–Wallis test and the statistical software package R, a p-value was calculated for all applicable day-of-week and month-of-year combinations and for all five national parks. While the p-values ranged from 0.9966 to 0.0033 for all five national parks, each one was greater than the p-value threshold that was appropriate for that park. Therefore, it was determined that the medians were not statistically different for any of the day-of-week and month-of-year combinations, which also implies that the seasonal and day-of-week traffic patterns were not significantly different from one year to the next for all five national parks.

This analysis covered a small number of parks over a time period where most macro-level external travel factors remained relatively constant. Significant changes in any of these factors (a good example is the price of gas) may have a nonuniform impact on national park traffic over the year. Therefore, additional research would be required to determine (a) if those external factors do have a nonuniform impact and (b) if traffic at groups of parks shows similar changes due to these externalities. If so, parks where traffic fluctuates in a similar manner could be grouped together and traffic monitored year round at only one of those locations.

Nearby State Highway Traffic Analysis and Results

To determine whether the NPS could potentially share traffic monitoring efforts with various state departments of transportation (DOTS), the traffic counts collected in the five national parks for 2002 to 2006 were compared with those of the nearby automatic traffic recorder (ATR) locations. Similar to the seasonal factor calculations, only the days that were 100% complete were used in this analysis. Guidelines provided by AASHTO were used to further edit the state highway traffic data prior to performing the correlation analysis. AASHTO states that "a traffic volume of 0 for all lanes must not occur for 8 consecutive hours or 32 consecutive quarter hours." (11) After computing the daily traffic volumes for all five national parks and the corresponding state highways, correlation analyses were used to contrast the park traffic to that which was collected at nearby ATR locations. Daily national park traffic volumes were compared with those collected at the adjacent ATR location for each of the 5 years, and correlation values were calculated. A correlation value was developed for each of the six sites at the five national parks and each of the 5 years, theoretically yielding a total of 30 correlation values. However, due to missing data, only 26 correlation coefficients were developed (see Table 2).

As shown in Table 2, the correlation coefficients range from 0.97 to 0.11. Although the values are fairly consistent for a particular park across all 5 years, the coefficients significantly vary in magnitude from one national park to the next. An example plot is included in Figure 4. Not surprisingly, this correlation was generally higher where the ATR was located closer to the park. Therefore, opportunities may exist for the NPS to use ATR data from state DOTs when those ATRs are located close to the park.

HOURLY TRAFFIC VOLUME ANALYSIS AND RESULTS

Using the hourly volumes for 2002 to 2006, the K-factors of the parks were compared with those of highways found in the literature review section. For this analysis, George Washington Memorial Parkway represented an urban national park, and Acadia, Big Bend, Yellowstone, and Yosemite National Parks were classified as rural. Additionally, all hourly volumes were used for each year and for each park as this analysis did not require that each day be 100% complete.

In terms of "typical" plots, the national parks were generally consistent with those mentioned in the literature review section (see Figure 5).

The value of the K-factors for the rural parks was generally consistent with those mentioned as "typical" in the literature review section. While AASHTO states that the typical K-factor for rural arterials is 15%, the K-factors in the Highway Capacity Manual (see Figure 1) and other references (13) were larger and similar to those found at the national parks examined here (see Figure 5). Additionally, the shapes of the curves were similar to those found in the literature review section, indicating additional similarities to typical rural roads.

CONCLUSIONS

The goal of this research was to examine traffic patterns at national parks in an effort to reduce the amount of time and money that is spent on traffic data collection in these recreational areas while maintaining the quality and accuracy of the counts. This research was based on only five national parks, but the results show promise and future research could expand this sample set.
It was determined that, within a given park, the seasonal and day-of-week factors were not statistically different from 2002 to 2006. Therefore, the traffic patterns observed during each day-of-week and month-of-year combination were not statistically different from one year to the next in each of the five national parks. This allows for short-term counts to be adjusted to estimate an AADT based on historical data. Additional research will be necessary to determine if external factors (such as the price of gas) have different impacts on traffic during different times of year at different parks.

To determine whether data collection efforts can be reduced and shared among various entities, the traffic counts collected in the five national parks for 2002 to 2006 were compared with those of the nearby state highway ATR locations. Based only on the five locations examined in this study, there appears to be a good opportunity to use ATR data from nearby (less than 20 mi) highway ATRs.

The distribution of hourly traffic volume as a percentage of AADT (K-factor) was also examined. Distribution of hourly traffic volumes at the urban parks was similar to examples from the literature. The distribution of hourly traffic volumes at the rural parks had a similar shape to those found in the literature. The highest hours at the parks had much higher K-factor values than those found in AASHTO, but did match results from other literature on typical rural roadways.
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REFERENCES


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