Use of Short-term interval counts to determine K Factors

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The Question

K factors are basic traffic engineering statistics used throughout highway engineering and planning. For capacity and design purposes the design hour volume is important in representing the amount of traffic occurring at peak times. To derive the design hour volume, the engineer multiplies the average annual daily traffic (AADT) by the K factor. A K factor is the ratio between a peak hour and the ADT. This can be many different factors. The most common is typically referred to as the K-30. It is specifically the ratio between the 30^{th} highest hour and the AADT.

When looking at a graph of the highest hour volumes at a counting station, those at the highest end tend to be outliers, with a steep slope from one to the next. At some point the slope will flatten out to a more reasonable level. Through years of experience, engineers have seen that the thirtieth highest hour occurs often near that point where the slope flattens. So the K-30 is often used in applications because it does a good job of representing the reasonable peak hour. Hours above this are often special events or incidents, too large to reasonably build for.

Many other K factors are available and are used. For a jurisdiction’s own use they can choose the K-50, K-100, or simply pick the swing point on the graph. For certain applications, notably the Highway Performance Monitoring System (HPMS), a standard is needed to make it possible to compare locations, even between states. For this reason, the K-30 is mandated in HPMS. The congestion reports can be comparable only if this important factor remains standard.

After reviewing methods used by other states, the author undertook a study to show the ability of short-term counts to produce a K factor that could be used for state and federal purposes. The state of Oregon has approximately 150 Automatic Traffic Recorder (ATR) stations. Those are the only locations where a K-30 is truly measured. K-30s for all other state coverage count locations and HPMS sample locations are assigned by applying engineering judgement about local conditions using those K factors from the ATRs. If interval counts produced reasonable estimates of the K-30 statistic, it would be a good argument to use more interval counters, and have K-30 estimates that are more site-specific.

Current Applicability

Two current topics necessitate an answer to this question. The HPMS is undergoing a reassessment of what data items to collect and use. K Factors are used in the capacity and congestion calculations. A volume to capacity ratio is dependent on the K-30. Possibilities for changes in the HPMS include mixing K-30s from ATRs with short term counts at other sites used as a surrogate.

The other topic is the use of the K Factor in calculations of design hour volumes. The design hour volume is used to determine pavement and geometric aspects of highway design. It is also used in work zone analysis to determine if lanes can be closed or if the traffic will be light enough not to impact mobility.

The Method

An ATR, counting year-round, is the only location where a true K-30 is measured. To determine if short-term counts produced reasonable estimates of the K-30, data was used from fifty-seven ATRs that had no more than five days of data missing from the entire year.

To simulate the short-term counts, samples were taken from the data. Then ADT, high hour, and K factor were determined. For instance, to simulate a 48-hour count such as Oregon collects, data from 11 AM Tuesday to 11 AM Thursday could be used. The 48 hourly volumes would be summed, then the sum divided by two to produce an ADT. The high hour would be chosen. The ratio of the high hour to the ADT is the K factor estimate. The consistency of that statistic throughout the year at any particular station is impressive. The high hours tend to rise and fall with roughly the same seasonality as the volumes.

The K factor estimates were produced for six methodologies. These were three counting styles coupled with two ADT styles.

The counting styles were:

- 48-hour weekday counts. Either Monday to Wednesday, or Tuesday to Thursday. This is Oregon’s short-term count method.
- 72-hour weekday counts. Monday through Friday, with the midnight to midnight data used for Tuesday through Thursday. This is Washington’s short-term count method.
- Seven day counts. Counts started and stopped at the same hour on the same weekday. Count method included for comparison.

The two ADT styles were:

- Use the ADT from the short-term count
- Use the AADT from the station (which would not normally be available)

To create repeatability and reasonability, the counts used were restricted. The counts used these constraints:

- For the Oregon method, only start times on Monday and Tuesday between 6 AM and 7 PM were used
- For the Washington method, counts used a start of zero-hour on Tuesday
- For the seven day method, start times were noon on the five weekdays

- Used data from the week after Spring break (March 22-26, 2004) through October
- Used no statistics that included Memorial Day (May 31, 2004), 4^{th} of July, or Labor Day (September 6, 2004) or the corresponding holiday week
- No extreme incidents – very few incidents were removed from the data
- Ensured no data included any of the few missing days

The Results

Please refer to the attached table (KFactorSummary.xls) during the following explanations.

At each ATR, the table lists the ATR number, name, highway number, functional classification code, missing days, AADT, and the K-30. No station was used that had more than five days missing.

For each of the six calculation methods, there are six statistics presented from each ATR station. Starting at the top is the highest K factor calculated. Second is the average K factor, followed by the lowest K factor. Those factors that were at least as high as the actual K-30 are highlighted.

The next row of statistics is the standard deviation of the K factors computed. The fifth statistic is the corresponding K-level. Since the average K factor is not the K-30, this number shows what the average correlates to. For instance, the first ATR listed, 26-014 has a K-30 factor of 7.4. The first method shows an average K factor of 6.7. Using the list of hourly volumes for the ATR, this volume falls at the 940^{th} highest hour. So instead of a K-30, this corresponds to a K-940. The last statistic shown for each is Percent underestimated. This percentage is how much lower the estimated design hour volume would be if the average estimated K factor were used instead of the measured K-30.

In the third column are averages of the standard deviations, corresponding K-levels and the percent underestimated. Glancing at them it is readily apparent that the best performance is from the seven-day counts. Using seven-day counts raises the average K factor by one or both of two methods. The K factor is a ratio of the design hour to the ADT. That ratio will increase if either the design hour is higher and/or the ADT is lower. If the station is a commuter location with low weekend traffic, the peak hour will likely stay the same while the ADT will be lower because it includes the low weekend days. If the station is recreational, the peak hour could be quite a bit higher, while the weekends account for just two more days and so don't raise the ADT to as great a degree.

Some of the best performers in terms of percent underestimated were the higher volume locations. But these are the locations that tend to have ATRs and are typically not counted with short term tube counts because of safety concerns.

Further research might be useful to see if the better correlation is made to sites at capacity rather than simply that they are a high volume site.

Using Oregon methods, at no stations does the average measured K factor ever reach the true K-30 factor. Using Washington methods, at only one station does the average measured K factor reach the true K-30 factor, using AADT rather than the short term count ADT. The greatest success used seven-day counts. Even this method though did not perform well for most of the counts. The seven day method is also not a common practice because tubes would have a tough time staying in place for that long.

The results using the count ADT were amazingly consistent throughout the count season. They did not match the K-30 well, but repeated the statistic well. This makes sense in terms of the high hours rising and falling in roughly the same pattern as the rise and fall of the total ADT.

The Recommendation

It is the author's opinion that the short-term counts did not perform adequately at representing the K-30. The K factors produced were consistently too low to represent the K-30. For local modeling or design purposes, the short-term counts may produce a factor that is acceptable. But for standardized purposes, such as the HPMS, the short-term counts fall short of the goal.

There are two possible recommendations to make based on this data. For HPMS or other K-30 uses, sound engineering judgement, using knowledge of the local road system, could be used to apply ATR K factors to other road segments.

A K factor that is too low will result in the congestion being under-represented compared to other states that use K-30 factors derived from ATRs.

The second possible recommendation is to not use K-30 as the standard for HPMS. The K factor derived from short term counts remained consistent throughout the count season. It would represent normal peak conditions well. A typical peak could be computed from either short term counts or ATRs.

For construction purposes, the author recommends choosing one method. Mixing K-30s and short term count K factors results in alternate answers. The method should be chosen based on results from past analyses and whether they correctly gave results that did not cost the department or traffic in terms of time or money.

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