Improving Accuracy of Annual Average Daily Traffic Estimates from Short-Period Traffic Counts

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Introduction

Traffic Monitoring Program

- Federal funds for highway transportation allocated to states based on highway usage. The key parameter for determining highway usage is the annual average daily traffic (AADT).
  - AADT is the average traffic that uses a section of highway on a typical day of the year
- Every State Department of Transportation (DOT) is required to estimate the AADT for each section of roadway in their network.
- Scale of task is immense; hence, AADT estimation procedure uses statistical sampling.
- Sampling procedure results in two count programs: a permanent traffic count (PTC) program and a short-period traffic count (SPTC) program.

PTC Program

- Small number of road sections in each roadway functional class group selected
- Traffic on these sections monitored continuously all year round
- PTC volumes used to determine AADTs for development of:
  - Seasonal factors (SFs)
  - Annual growth factors (GFs)

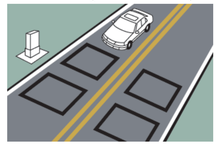

Figure 1. PTC Station

Figure 2. Inductive Loop Detector

SPTC Program

- Conducted on all other roadway sections in the state
- Counts undertaken for a short duration
  - Typically 48 hours
  - Some 24 hours
- SPTCs converted to AADT using SFs from PTC stations

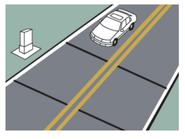

Figure 3. SPTC Station

Figure 4. Pneumatic Road Tube

Review of State Traffic Monitoring Guides and Interviews

- Key aspects of the PTC and SPTC programs were reviewed.
- Notable differences among the states in methodologies
  - Quality control checks
  - SF and GF computations
  - SPTC durations and cycles

Table 1. State SPTC Durations/Cycles

State DOT	SPTC Duration/Cycle
Tennessee	***24 hours/1 year***
California	FHWA (48 hours/3 years)
Florida	***24 or 48 hours/3 years***
Georgia	***48 hours/2 or 4-6 years***
Illinois	***24 hours/2 or 4-5 years***
Indiana	FHWA (48 hours/3 years)
Kentucky	FHWA (48 hours/3 years)
New York	***48 hours/1 year***
North Carolina	***48 hours/1 or 2 years***
Texas	***24 hours/1 or 5 years***
Utah	***48 or 72 hours/3 years***
Virginia	FHWA (48 hours/3 years)
Washington	FHWA (48 hours/3 years)

- Lack of research on count-duration/count-cycle and their relationship to accuracy of AADT estimates
- Procedure required in Tennessee for identifying outlier volumes to improve on quality of data used in estimating AADT

Research Objectives

- **Objective 1:** Develop a procedure, rooted in statistics, for identifying and deleting outlier daily volume records before the computation of SFs.
- **Objective 2:** Investigate two alternative count-duration/count-cycle schemes to determine which yields more accurate estimates of the AADT. One scheme is employed by Tennessee and the other is recommended by FHWA.
  - 24 hours every year – Tennessee Department of Transportation (TDOT)
  - 48 hours every 3 years – FHWA

Data and Methodology

Data Required and Available

- Daily traffic volumes collected by TDOT for years 2010 to 2015
  - Associated month and day-type were assigned to each volume
- 63 PTC stations (only 10 stations across 11 years, had all 365 days)
- Functional class groups
  - Recreational (2); rural interstate (5); rural non-interstate (20); urban interstate (9); urban non-interstate (27)

Calculation of AADT and SFs

- American Association of State Highway and Transportation Officials (AASHTO) method, or the average of averages method

$$AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n}V_{ijk}\right)\right]$$

- SFs were developed by indexing monthly day-types to AADT and then applied to a 24-hour volume count to estimate the AADT at a station for a given year.

$$SF_{ij} = \frac{AADT}{\bar{V}_{ij}} \qquad \widehat{AADT}^{y} = V_{24ij} * SF_{ij}$$

Outlier Identification and Removal Procedure (Objective 1)

- Quality of data resulted in atypical SFs

Major Step 1: Deletion of volume records with a magnitude of zero

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Major Step 2: Arrange volumes from oldest year to most recent year

↓

Major Step 3: Check for reasonable growth in daily volumes
Compute the ratio of previous year's AADT to each volume (except first year) $LB < \frac{AADT^{y-1}}{V_{ijk}^{y}} < UB$
**If ratio falls outside of boundaries, associated volumes are simultaneously deleted before proceeding.*

↓

Major Step 4: Flag questionable volumes for further scrutiny
(a) Compute ratio of yearly growth in average monthly day-type volume (except first year) $LB < \frac{\bar{V}_{ij}^{y}}{\bar{V}_{ij}^{y-1}} < UB$
(b) Compute ratio of yearly dispersion in average monthly day-type volume (except first year) $LB < \frac{CV_{ij}^{y}}{CV_{ij}^{y-1}} < UB$
**If either ratio falls outside of boundaries, associated volumes are flagged for further analysis.*

↓

Major Step 5: Identification of which flagged volumes in Major Step 4 are to be deleted
(a) Compute ratio of current year average monthly day-type volume to each volume in same year (Note: calculated for each volume in first year) $LB < \frac{\bar{V}_{ij}^{y}}{V_{ijk}^{y}} < UB$
(b) Compute ratio of previous year average monthly day-type volume to each volume in same year (except first year) $LB < \frac{\bar{V}_{ij}^{y-1}}{V_{ijk}^{y}} < UB$
(c) Compute the ratio of current year's AADT to each volume $LB < \frac{AADT^{y}}{V_{ijk}^{y}} < UB$
** If any of the ratios fall outside of boundaries, associated volumes are flagged and simultaneously deleted.*

Figure 5. Outlier Identification and Removal Procedure

Count Duration/Cycle/GF Analysis of SPTCs (Objective 2)

Step 1: Select PTC group with complete SFs and station with available daily volumes for years 2013 to 2015

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Step 2: Compute "true" AADT for years 1, 2, and 3

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Step 3: Select month of the year and two consecutive days
Note: Tuesday through Thursday (consistent with TDOT)

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Step 4: 24-Hour/Every Year Count Analysis
- Use 24-hour count and SF to estimate AADT for year 1
- Repeat for years 2 and 3

$\widehat{ADT}_i^{y} = V_i * SF_{ij}$

Step 5: 48-Hour/Every 3 Years Count Analysis
- Use 48-hour count and SFs to estimate AADT for year 1 (average both estimated AADTs) $\widehat{ADT}_i^{y=1} = V_i * SF_{ij}$
- Estimate GFs for years 2 and 3 $GF^{12} = \frac{AADT_T^{y=2}}{AADT_T^{y=1}}$
- Apply GFs to estimate AADT for years 2 and 3 $\widehat{AADT}_{i,i+1}^{y=2} = \widehat{AADT}_{i,i+1}^{y=1} * GF^{12}$

↓

Step 6: Repeat Step 1 through Step 5 for all Tuesday, Wednesday, and Thursday counts for all stations and PTC groups for years 2013 through 2015

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Step 7: Compare which approach gives superior AADT estimates using mean absolute percentage error (MAPE) $MAPE_i^{y} = \frac{|AADT_T^{y} - \widehat{ADT}_i^{y}|}{AADT_T^{y}} * 100\%$

Figure 6. Count Duration, Cycle, and Growth Factor Analysis of SPTCs

Results

Boundaries of Acceptable Range for Outlier Procedure

- Frequency distribution of each ratio was plotted for each functional classification group to provide a visual understanding of the central tendency of the ratio and its dispersion.
- Upper and lower bound values selected such that 99% of the data was preserved for further analysis

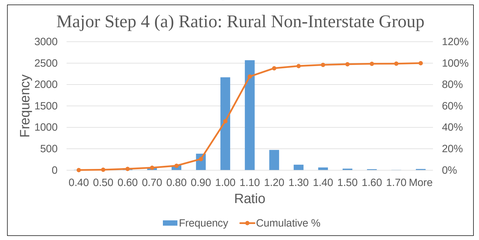

Figure 7. Frequency Distribution of Example Ratio in Outlier Procedure

Table 2. Boundaries of Acceptable Range for Computed Ratios

Acceptable Lower Bounds and Upper Bounds for Computed Ratios						
Procedural Step:	**Major Step 3**	**Major Step 4 (a)**	**Major Step 4 (b)**	**Major Step 5 (a)**	**Major Step 5 (b)**	**Major Step 5 (c)**
Ratio:	$\frac{AADT^{y-1}}{V_{ijk}^{y}}$	$\frac{\bar{V}_{ij}^{y}}{\bar{V}_{ij}^{y-1}}$	$\frac{CV_{ij}^{y}}{CV_{ij}^{y-1}}$	$\frac{\bar{V}_{ij}^{y}}{V_{ijk}^{y}}$	$\frac{\bar{V}_{ij}^{y-1}}{V_{ijk}^{y}}$	$\frac{AADT^{y}}{V_{ijk}^{y}}$
Recreational Group	0.40 - 4.00	0.90 - 1.10	0.00 - 2.25	0.25 - 2.50	0.25 - 2.50	0.40 - 4.00
Rural Interstate Group	0.40 - 2.40	0.90 - 1.10	0.00 - 2.25	0.25 - 2.50	0.25 - 2.50	0.40 - 2.40
Rural Non-Interstate Group	0.40 - 2.80	0.90 - 1.10	0.00 - 2.25	0.25 - 2.50	0.25 - 2.50	0.40 - 2.80
Urban Interstate Group	0.40 - 2.30	0.90 - 1.10	0.00 - 2.25	0.25 - 2.50	0.25 - 2.50	0.40 - 2.30
Urban Non-Interstate Group	0.40 - 3.30	0.90 - 1.10	0.00 - 2.25	0.25 - 2.50	0.25 - 2.50	0.40 - 3.30

Estimated SFs using Data after Deletion of Outliers

Table 3. Initial (Final) Computed SFs for an Example PTC Station

Month/ Day-Type	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
January	1.42 (1.58)	0.97 (1.07)	0.92 (1.02)	0.97 (1.08)	0.85 (0.95)	0.76 (0.85)	1.02 (1.13)
February	1.30 (1.45)	0.82 (0.91)	0.79 (0.88)	0.84 (0.94)	0.79 (0.88)	0.70 (0.77)	0.93 (1.03)
March	0.88 (0.98)	0.80 (0.89)	0.80 (0.89)	0.76 (0.84)	0.69 (0.77)	0.89 (0.99)	1.12 (1.24)
April							
May	26607.72 ( )	53215.44 ( )	17738.48 ( )	53215.44 ( )	33259.65 ( )	66519.30 ( )	66519.30 ( )
June	1.56 (1.38)	1.14 (1.01)	1.24 (1.03)	1.03 (1.14)	0.86 (0.96)	0.78 (0.87)	0.99 (1.10)
July	1.29 (1.43)	0.90 (1.00)	0.89 (0.99)	0.88 (0.98)	0.84 (0.93)	0.86 (0.96)	1.02 (1.13)
August	1.29 (1.43)	0.91 (1.01)	0.86 (0.96)	0.88 (0.97)	0.83 (0.92)	0.75 (0.83)	0.94 (1.05)
September	1.27 (1.41)	0.91 (1.01)	0.85 (0.94)	0.85 (0.94)	0.82 (0.91)	0.73 (0.81)	0.96 (1.06)
October	1.22 (1.35)	0.90 (1.00)	0.86 (0.96)	0.85 (0.94)	0.81 (0.90)	0.73 (0.81)	0.93 (1.03)
November	1.32 (1.46)	0.88 (0.97)	0.84 (0.94)	0.86 (0.95)	0.90 (1.00)	0.78 (0.87)	0.99 (1.10)
December	1.31 (1.46)	0.87 (0.97)	0.86 (0.96)	0.89 (0.99)	0.93 (1.03)	0.80 (0.88)	0.94 (1.04)

Alternative Growth Factor Development

- Interest in alternative GF development that is averaged across all stations in each functional classification

$$Average\ GF^{12} = \frac{\overline{AADT_T^{y=2}}}{\overline{AADT_T^{y=1}}}$$

AADT Estimation Error Results from SPTCs

Table 4. Resulting Errors for Alternative SPTC Durations and Cycles

Group-Averaged MAPE for AADT Estimates Obtained from Alternative SPTC Durations and Cycles			
Functional Classification	**24-Hour**	**48-Hour with Individual GFs**	**48-Hour with Group-Averaged GFs**
Rural Interstate	13.89%	9.77%	19.71%
Rural Non-Interstate	9.78%	8.90%	10.70%
Urban Interstate	10.04%	10.90%	15.68%
Urban Non-Interstate	9.10%	6.64%	10.51%

Discussion

- Implementing the outlier identification and deletion procedure will ensure that the PTC data used by TDOT will be of better quality and will result in more accurate estimates of AADTs and SFs at the PTC stations and therefore AADT estimates at the SPTC stations.
- Conducting SPTCs for 48 hours every 3 years, compared to TDOT's current SPTC scheme, will not only result in more accurate AADT estimates but will also lead to significant reductions in the overall number of SPTCs conducted each year and in the staff-hours required for them.

Conclusions/Recommendations

- An outlier identification and deletion procedure, rooted in statistics, is critical to a state traffic monitoring program yielding credible results. It is critical to the quality of AADTs estimated at PTC stations and to the quality of SFs obtained.
- Count duration and count cycle selected for the SPTC program of a state should be based on a thorough statistical analysis. This conclusion is motivated by the study results that show that AADT estimates based on a count duration of 48 hours on a 3-year cycle are more accurate than AADT estimates based on a count duration of 24 hours on a 1-year cycle.
- Recommendations
  - TDOT should conduct SPTCs every 3 years for 48 hours.
  - State DOTs should improve upon the quality of volume data collected at PTC stations through well designed quality assurance procedures.

Future Work

- Investigate which method of averaging multi-year SFs will produce more accurate estimates of AADTs
- Use of simple average or AASHTO method for calculating AADT when data is missing
- Micro-level analysis of outlier procedure using hourly data to identify atypical volumes before the deletion of daily volumes
  - AM/PM peak, by direction, by lane

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