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Estimation of Annual Average Daily Traffic from one-week traffic counts. A combined ANN-Fuzzy approach

Massimiliano Gastaldi *, Gregorio Gecchele, Riccardo Rossi

Department of Civil, Environmental, and Architectural Engineering, University of Padova, Via Marzolo, 9, 35131 Padova, Italy

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A B S T R A C T

This paper presents an approach to estimation of the Annual Average Daily Traffic (AADT) from a one-week seasonal traffic count (STC) of a road section. The proposed method uses fuzzy set theory to represent the fuzzy boundaries of road groups and neural networks to assign a road segment to one or more predefined road groups. The approach was tested with data obtained in the Province of Venice, Italy, for the period of the year in which STCs are taken. The method produced accurate results, which may be of interest for proper planning of monitoring and minimizing traffic count costs.

1. Introduction

Information on Annual Average Daily Traffic (AADT) is essential for such diverse fields as pavement design, fuel-tax revenue projections, and highway planning. Monitoring is necessary for accurate AADT estimates, but it is expensive for responsible transportation agencies in terms of costs and personnel.

The Federal Highway Administration Traffic Monitoring Guide (FHWA, 2012) provides transportation agencies with recommendations concerning the design of efficient monitoring programs, based on a combination of portable counters used for a few days (Short Period Traffic Counts, or SPTCs) or at least 1 week (seasonal traffic counts, or STCs) per year, and Automatic Traffic Recorders (ATRs) which give Permanent Traffic Counts (PTCs). The AADT for a given road section is estimated according to the following steps. First, road groups are determined, according to data collected by ATRs (PTCs); second, the traffic volume of the road section in question is counted for a short period (SPTCs or STCs); third, the road group to which the road section in question is similar in terms of traffic flow patterns is identified; and fourth, AADT is estimated by adjusting the SPTC (or STC) volume by an appropriate seasonal adjustment factor for the road group.

Unlike transportation agencies, traffic experts assign great value to knowledge of traffic flows for site-specific studies, sometimes at particular periods of the year. As traffic counts should be reduced as much as possible (typically one week or less), proper knowledge of the accuracy of AADT estimates, obtained at various periods of the year, becomes important for good-quality planning of counting activities in two ways:

- Identification of the best period of the year during which STCs should be taken, with the aim of maximizing the accuracy of AADT estimates;
- Checking the reliability of the resulting AADT estimates, when the period of the year cannot be chosen.

* Corresponding author. Tel.: +39 049 8275574.
E-mail addresses: massimiliano.gastaldi@dicea.unipd.it (M. Gastaldi), gregorio.gecchele@dicea.unipd.it (G. Gecchele), riccardo.rossi@unipd.it (R. Rossi).

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In this sense, it seems reasonable to integrate short counts with information from monitoring programs maintained by transportation agencies, which are commonly adopted in many countries.

Gecchele et al. (2012) recently introduced fuzzy set theory to represent fuzzy boundaries of road groups and artificial neural network, together with measures of uncertainty (non-specificity and discord) to solve the problem of identifying the group which matches the given road section. In their paper, the approach was tested by examining passenger vehicle traffic patterns as measured by SPTCs. The present paper extends analysis of the predictive capability of the approach, presenting results obtained from one-week STCs, commonly adopted by experts for their analyses (Gastaldi et al., 2013). The original structure of the approach was modified to cover the new type of input data, and is presented in detail here.

The analysis was carried out using traffic data available from twenty-five Automatic Traffic Recorder (ATR) sites of the SIRSE (Information System for Rural Road Network) monitoring program, maintained by the Transportation Office of the Province of Venice, north-east Italy.

The paper is organized as follows. Section 2 reviews the literature on the subject, and Section 3 presents the proposed approach. Section 4 demonstrates a case study, the main results of which are described and discussed in Section 5. Concluding remarks are presented in Section 6.

2. Review of past works and problems

Literature documents a wide range of methods and techniques for estimating AADT.

Some methods basically refer to the FHWA procedure provided by the Traffic Monitoring Guide (FHWA, 2012), also known as the "factor approach" (Drusch, 1966), and were designed with the aim of improving the original approach while preserving its structure. The FHWA procedure is applied in many countries to designing monitoring programs and consists of four steps:

1. Grouping ATR (Automatic Traffic Recorder) sites with similar temporal traffic volume variations;
2. Determining average seasonal adjustment factors for each road group;
3. Assigning the road section, monitored with a SPTC (or STC), to one of the groups defined in step 1;
4. Applying to the SPTC (or STC) the appropriate seasonal adjustment factor of the road group, in order to produce the AADT estimate for the road section in question.

The application of the FHWA procedure may be affected by three sources of error (Bodle, 1967):

1. Error due to day-to-day variations in traffic volumes;
2. Error in grouping road segments (ATR sites) into significant road groups;
3. Error in assigning the road segment along which SPTCs or STCs were obtained to the right road group.

Sampling error: traffic volumes fluctuate over time, and any kind of estimation in the transportation field must deal with this common problem.

Error in grouping of road segments: the FHWA "factor approach" (Drusch, 1966), suggests three ways of determining road groups according to permanent counts obtained at ATR sites: clustering analysis, geographical/functional classification, and "same road" application of adjustment factors. Each approach has some drawbacks, and analysts choose the "best" method depending on their knowledge of the road network and the availability of traffic data. Clustering analysis is the most commonly applied analytical approach and a large number of clustering methods, differing from the least-squared minimum distance algorithm proposed by TMG (Traffic Monitoring Guide), have been tested. Some of them were implemented and compared by Gecchele et al. (2011), including agglomerative hierarchical clustering (Ward's Minimum-Variance method (Sharma and Werner, 1981), average linkage method and centroid linkage method (Faghri and Hua, 1995)), partitioning (k-means (Flaherty, 1993)) and model-based clustering (Zhao et al., 2004). Other analytical methods proposed to identify road groups are regression analysis (Faghri and Hua, 1995), Genetic Algorithms (Lingras, 2001) and artificial neural networks (ANNs) (Faghri and Hua, 1995; Lingras, 1995).

Error in assignment of road segments: past studies (Gulati, 1995; Davis, 1996) noted that assigning a road section to the wrong road group can lead to large errors in the estimated AADT. To guarantee correct assignments and to minimize the risk of large errors (Davis and Guan, 1996; Davis, 1997), the TMG suggests observing traffic volumes (STCs) at different periods of the year. Linear Discriminant Analysis (Tsapakis et al., 2011) has recently been adopted to determine the group assignment of sites monitored with 24-h SPTCs, as transportation agencies wish to reduce monitoring costs by using the shortest possible traffic counts. Caceres et al. (2012) estimated the AADT of a given road section according to its attractiveness, in terms of the characteristics of nearby areas, associating the typical flow pattern of road groups (obtained by clustering ATR sites) with the location.

Lastly Gecchele et al. (2012) used artificial neural network and measures of uncertainty (non-specificity and discord) to solve the problem of identifying the group which matches the given road section, introducing fuzzy set theory to represent the fuzzy boundaries of road groups.