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RESEARCH ARTICLE

Average Vehicles Length in Two-lane Urban Roads: A Case Study in Budapest

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Abstract
The length of vehicles is one of the most important parameters in traffic flow modeling and traffic control in many aspects such as speed estimation using the outputs of single loop detectors, length based vehicle classification and density estimation. In the current study, the average length of vehicles in two-lane urban roads of Budapest, Hungary has been measured by the means of manual observation method. Having measured the average vehicles length, their relevant effective vehicles length is manually calibrated within the day that is applicable to the local operating agencies. The obtained results showed that the local operating agencies have to set different effective vehicles length during the day in order to avoid possible estimation errors. Moreover, the heterogeneity of the traffic stream in the investigation area was evident from the results.

Keywords
average vehicle length, single loop detector, manual observation method

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1 Introduction

Length of vehicles is one of the most important parameters in traffic flow modeling and traffic control in many aspects. Many of the critical parameters of the macroscopic flow-density and microscopic speed-spacing relationships depend on vehicle length (Coifman, 2015) therefore studying in vehicles length is very much important.

The vehicle length parameter might play an important role in the following topics.

1.1 Vehicle length and speed estimation

Speed is one of the most commonly used measures of performance for traffic facilities and networks (McShane et al., 1998). As an indicator of Level of Service (LOS), speed has been used in traffic operational analysis, traffic simulation models, incident detection and analysis, economic studies, and many other areas of transportation engineering and planning. Moreover, some important decision-making variables such as travel time can be further calculated based on the speed information (Ye, 2007). Data from loop detectors have been primary sources for traffic information, and single loop are the predominant loop detector type in many places. Unfortunately, neither average vehicle length nor average speed can be measured independently at a single-loop detector. Therefore, speed estimation using single loop outputs has been an important issue for decades. Speed estimation from single loop detectors is mainly based on occupancy data, a conversion factor from occupancy to density which is potentially related to the vehicle length, and the assumed relationship between flow, speed, and density. Typically, an operating agency will set average vehicle length, L_A, to a constant value and use Eq. (1) to estimate speed from single-loop detector measurements (Coifman and Kim, 2009).

$$\text{space mean speed (harmonic mean)} \approx q.LA/Occ \tag{1}$$

Where occupancy, Occ, is a fraction of time that vehicle occupies the detector.

It is also well-known that the error of the estimated speed is linearly proportional to the error of the effective vehicle length, sum of the physical vehicle length and the size of the loop's detection zone. Hence, obtaining the effective length of vehicles in the investigated area is of great importance.

1.2 Length based vehicle classification

Vehicle classification is an important traffic parameter for transportation planning and infrastructure management. Length-based vehicle classification from loop detectors is among the lowest cost technologies commonly used for collecting or estimating these data. For length based classification from loop detectors, there are three interrelated parameters that can be measured or estimated for each passing vehicle, namely effective vehicle length (L_{eff}) which is the sum of the physical vehicle length and the size of the loop's detection zone, speed (V) and the amount of time the detector is ''on'', i.e., the on-time (T_{on}). These parameters are related by the following equation (Coifman and Kim, 2009):

$$V = L_{eff} / T_{on} \tag{2}$$

At a single-loop detector, only the on-time can be measured directly, while a dual-loop detector can measure the speed from the quotient of the detector spacing and the difference in actuation times at the two loops. As such, dual-loop detectors are often employed to classify individual vehicles via Eq. (2). Since the single loop detectors are the most common tools in traffic management, having a wide survey would be worth to build an exogenous data set regarding the vehicle length to simply estimate speed and consequently classify vehicles by the single loop detector data (Hazelton, 2004).

The forthcoming subsections overviews this functionality in both loop detector types in details.

1.2.1 Dual loop detector

Dual loop detectors consist of two single inductive loop detectors placed closely together in order to measure vehicle length from the product of measured speed and detector on-time, and classify vehicles based on this measurement (Nihan et al., 2002; Cheevarunothai et al., 2007). Fig. 1 shows the effective vehicle length in a dual loop detector system where S is the space between leading edge to leading edge of the detectors, TTr and TTf are the traversal times from the rising edge and falling edge respectively. Moreover, Tu and Td are two measures dwell time over the first and second detector.

Many researchers studied on length based vehicle classification by dual loop detectors either in free flow traffic (Davies and Salter, 1983; Minge et al., 2012; Kim and Coifman, 2013) or in congested traffic (Wu and Coifman, 2014(a); Wu and Coifman, 2014 (b)). However, the deployment of dual detectors is limited compared with that of single loop detectors as in Budapest, Hungary.

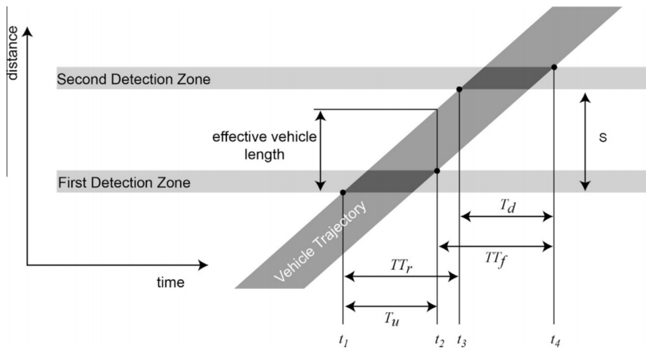

Fig. 1 Schematic of a vehicle passing over a dual loop detector (Wu and Coifman, 2014)

1.2.2 Single loop detector

Researchers have also used aggregated data with some pre-allocated intervals from single loop detector for vehicle classification (Kwon et al., 2003; Wang and Nihan, 2003; 2004). They normally considered some assumptions and classified vehicles based on their assumptions. For instance, Kwon et al. (2003) assumed existence of a truck free lane and estimated the speed of that lane using the measured volume and occupancy data from a single loop detector. The estimated speed for the truck-free lane can then be used to derive the effective vehicle length for other lanes based on speed correlation between lanes. Wang and Nihan (2003; 2004) assumed constant speed within the 5 minutes time period. They then classified vehicles by separating time intervals (20 s in their case) with long vehicles from those without in that time period. Then they used the speed estimated from those car-only intervals, in which vehicle length was known, to derive effective vehicle length and vehicle composition for those intervals with long vehicles.

Also some of the researchers used the so-called event-based data derived from single loop detectors for vehicle classification. The event-based loop detector data contains every vehicle detector actuation and de-actuation ''event'', therefore time gaps between consecutive vehicles and detector occupation time for each vehicle can be easily derived. Coifman and Kim (2009) used the event-based data from a single loop detector to identify vehicle length following a statistical based method. They studied the probability distribution of the detector occupation time (i.e., the detector on-time actuated by individual vehicles), and classified a vehicle by associating its detector actuation time with that distribution. Their method performed strongly in free flow condition and poorly during congestion since low vehicle speed also creates high actuation time. Liu and Sun (2014) used the event based loop detector data and classified vehicles based on the traffic flow theory. The proposed algorithm is based on an intuitive observation that, for a vehicle platoon, longer vehicles in the platoon will have relatively longer detector occupation time. They first grouped vehicles into platoons according to the time gaps between vehicles. They then used Newell's simplified car following theory (Newell, 2002) to describe the relation between consecutive vehicles in a platoon. Observed vehicle occupation time is compared with estimated vehicle occupation time. Discrepancy between these two is used to identify long vehicles by comparing the ratio between them with predefined critical length ratio.

1.3 Vehicle length and density estimation

Density remained a dominant variable in many traffic flow theories and most empirical fundamental relationship (between flow, density and space mean speed) studies use occupancy, occ, as a proxy for k, where: occ is the percentage of the sampling period, T, that vehicles occupy a vehicle detector. Coifman mentioned that with a homogeneous vehicle fleet Occ, occupancy, is proportional to K, density, by the average effective vehicle length, L_{eff} during T; where a given vehicle's effective length is the sum of its physical length and the size of the detection zone (2015) as shown in Eq. (3):

$$\mathrm{Occ} = k * L_{eff} \tag{3}$$

Some might think to derive the density directly via the fundamental equation of traffic flow shown in Eq. (4) to avoid the dependence on L_{eff}.

$$q = k * v \tag{4}$$

where q represents flow, k density and v space mean speed. Coifman showed that the fundamental equation of traffic flow just masks this dependency (2015) and Eq. (4) is dependent on vehicles length at the end. The main aim of this paper is to find the average vehicles length in two-lane urban roads of Budapest by the means of manual observation method.

2 Methodology

By taking a wide look at the importance of vehicles length specially in urban roads where traffic stream is much more complicated (Maghrour Zefreh et al., 2016), a traffic survey has been done by the means of manual observation method in order to find the average vehicles length in two-lane urban roads of Budapest and consequently calibrating the effective vehicles length in the investigation area manually. Having the effective vehicles length calibrated manually, the average speed of the traffic stream can be easily estimated by the outputs of the single loop detectors. This assumption is also supported by (Liu and Sun, 2014). They mentioned that if aggregated detector occupancy and volume measurements are available, then space mean traffic speed at the detector location can be estimated by using these measurements together with a manually-calibrated effective vehicle length. Fig. 2 shows this process in details.

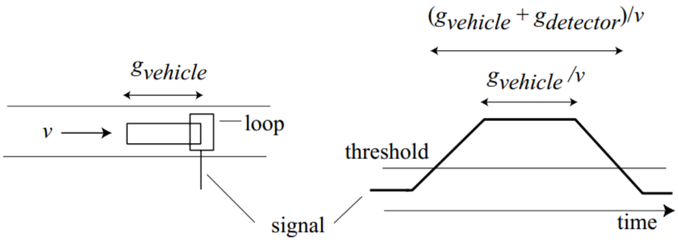

Fig. 2 A vehicle moving at speed (v) occupies a detector for time (g vehicle + g detector)/v , where g vehicle is the vehicle length, and g detector depends on the detector electronics (Zhanfeng et al., 2001).

If the correct value of g(t) is known, the effective vehicle length, then the average speed v(t) can be trivially calculated from the detector data using Eq. (5):

$$V(t) = g(t) * \left[C(t)/O(t) * T \right] \tag{5}$$

where T is the duration of the reporting period. At the end of period (t), the detector reports two numbers, c(t) and g(t). The count c(t) is the number of vehicles that crossed the detector during period (t), and the occupancy o(t) is the fraction of time during this period that the detector sensed a vehicle above it. The 'g -factor' g(t) is the effective vehicle length in this period. It cannot be directly measured at single loops, and its value must be assumed or estimated (Zhanfeng et al., 2001). In this regard, Hazelton sampled the vehicles length from an exogenous data set and assumed a simple random walk model for successive vehicle speeds and applied a Markov chain Monte Carlo approach to estimate traffic speed (2004). The main aim of this paper is to provide the exogenous vehicles length data set from two-lane urban roads of Budapest and consequently calibrate its associated effective vehicle length in order to be used in further speed, density, flow etc. estimation from the data collected by single loop detectors. As previously mentioned, the present study has been done by the so-called manual observation method. This method typically requires trained observers to collect specific information that cannot be efficiently obtained through automated means. To do so, transportation experts (MSc transportation engineering students) have been trained to videotape traffic flow separately in each hour (15 minutes per hour) within the day (7:00am to 11:59 pm) in the pre-allocated positions from both front side and back side as shown in Fig. 3. So that the tape could be counted multiple times in order to obtain the desired 95 percent confidence interval. To conduct manual observations of vehicle presence, an observer simply monitored the vehicles passed in front of the pre-allocated baseline in the investigation area.

Table 1 Average vehicles length (AVL) and effective vehicles length (EVL)

Time of day	AVL [m] (Rightmost lane)	EVL [m] (Rightmost lane)	AVL [m] (Leftmost lane)	EVL [m] (Leftmost lane)
7-8 am	4.470	6.970	4.522	7.022
8-9 am	4.490	6.990	4.830	7.330
9-10 am	4.434	6.934	4.307	6.807
10-11am	4.787	7.287	4.661	7.161
11-12am	4.530	7.030	4.910	7.410
12-13pm	4.594	7.094	5.318	7.818
13-14 pm	4.418	6.918	4.741	7.241
14-15 pm	4.651	7.151	4.477	6.977
15-16 pm	5.289	7.789	4.725	7.225
16-17 pm	5.320	7.820	4.810	7.310
17-18 pm	4.830	7.330	4.830	7.330
18-19 pm	4.645	7.145	4.975	7.475
19-20 pm	4.670	7.170	4.910	7.410
20-21 pm	4.723	7.223	4.878	7.378
21-22 pm	4.517	7.017	4.667	7.167
22-23 pm	4.515	7.015	4.640	7.140
23-24 pm	4.477	6.977	4.310	6.810
Average	4.668	7.168	4.736	7.236

Fig. 3 Sample frame of the videotaped traffic flow (front and back side)

3 Results and discussion

Having manually videotaped the traffic flow, the relevant average vehicles length was extracted manually by the trained experts. After determining the average physical vehicles length their associated effective vehicle length is calculated using Eq. (6). Effective vehicle length (L_{eff}) is the sum of the physical vehicle length and the size of the loop's detection zone, namely:

$$L_{eff} = L_{veh} + L_{det} \tag{6}$$

In the case of inductive loops there are numerous factors that can contribute to Ldet varying from one detector to another even if the design length of each loop is identical. These include variations in the buried depth of the cable, the length of the cable run from the detector to the roadside cabinet and the sensitivity of the monitoring equipment. However, at a specific site this value can be assumed constant as the value does not change significantly over time (Dodsworth et al., 2014). In this research the size of the loop's detection zone is considered as 2.5 (m) based on the on-sight vising of various loop detectors in the investigation area. The extracted average physical vehicles length (AVL) separated by time of the day (7:00am to 11:59 pm) and its associated effective vehicles length (EVL) are shown in Table 1.

Considering Table 1, this is evident that traffic composition is not similar in two lanes of the urban roads even in the same time. For instance, considering the average vehicles length in 12:00-13:00 pm in both lanes, one can see roughly 73 centimetres difference which would skew the traffic composition from homogenous to heterogeneous traffic composition.

4 Conclusions

In this study, the average vehicles length has been measured in two-way urban roads of Budapest, Hungary by the means of manual observation method. Consequently the relevant effective vehicles length has been calibrated manually using the measured average vehicles length together with the size of the loop's detection zone. The measured effective vehicle length can be used by the local operating agencies for possible application of speed, density etc. estimation. The results showed that, the local operating agencies are supposed to set different effective vehicles length within the day to avoid the large amount of error, not just setting one average effective vehicles length for the entire day. By taking a wide look at the obtained results one can find out that the traffic composition in two-lane urban roads is heterogeneous within the day.

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