Methods and models of traffic analysis

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Abstract. This article analyzes the traffic situation, and also discusses the methods of collecting data and how they are applied on the road. In addition, the advantages and disadvantages of the methods studied in the work are given. There is a separate talk about the Floating Car Data (FCD) method, what is the essence of the method, its advantages and disadvantages. In turn, the paper presents a difference in the approaches to using data collection methods, namely the Floating Car Data method on the use of the Global Positioning System in cars and the method based on telephone devices with a Global Positioning System signal. The average annual daily traffic is considered as one of the most important traffic data. Describes a way to implement the Floating Car Data method, the advantage in using and improving this method and the prospects of the method in the future.

1. Introduction

Today, for several years now, there has been a trend of increasing demand for improved traffic management, the development of new methods for collecting data, as well as the development of ways to access traffic information in real time. The use of traditional road sensors (for example, based on the use of inductive loops) for data collection is necessary but insufficient due to their limited coverage and expensive implementation and maintenance costs. In recent years, we have witnessed the emergence of alternative data sources that are promising, cost-effective solutions to overcome the limitations inherent in stationary detectors. The introduction of new methods for assessing traffic information is an important task to improve the efficiency of the use of the road network. Today, information about road accidents, traffic jams or other difficulties on the roads is often not received promptly enough. Changing the existing systems for collecting information is a way that can correct the current situation. The very essence of the FCD method is that the traffic situation is simulated in real time. Even though the idea of collecting data from devices "in the car" via mobile phones or GPS is not new, the FCD market has only recently started to develop and provide users with a wide range of applications and benefits. The main task in this work is to study data collection methods, namely the complexity of the implementation of the FCD method, with the aim of improving this method in future developments [1].

2. Intrusive data collection methods

Methods for calculating the traffic situation can be divided into two categories: intrusive (that is, requiring the physical presence of a fixed vehicle in a certain area where this fixation is performed, as well as its interaction with certain systems) and non-intrusive methods (which do not require the interaction of a vehicle with intermediate links in the transmission of location information. The
intrusive method is that the data logger and sensor are placed on or in the road. This is the most common and most important approach [2, 3].

2.1. *Pneumatic Travel Tubes*
Rubber tubes are placed across road lanes to detect vehicles by measuring pressure changes as the vehicle's tire passes through the tube. The generated air impulse is recorded and processed by a meter located on the side of the road. The main disadvantage of this technology is that it has limited lane coverage and its effectiveness is dependent on weather, temperature and road conditions. This system can also be ineffective when measuring low-speed streams [4, 5].

2.2. *Piezoelectric sensors*
The sensors are placed in a groove along the road surface. The principle is to convert mechanical energy into electrical energy. Mechanical deformation of a piezoelectric material changes the surface charge density of the material so that a potential difference arises between the electrodes. The amplitude and frequency of the signal are directly proportional to the degree of deformation. This system can be used to measure weight and speed.

2.3. *Magnetic loops*
This method is the most common technology used to collect traffic data. The hinges are embedded in roads in a square formation that generates a magnetic field. The information is then transferred to a counting device located on the side of the road. It has a generally short lifespan because it can be damaged by heavy vehicles but is not affected by bad weather conditions. Over the past decades, this technology has become widespread in Europe. However, implementation and maintenance costs are expensive [6].

In addition to the commonly used methods, recently, due to the development of technology, new, promising methods of collecting information have appeared.

2.4. *Passive magnetic method*
Magnetic sensors are mounted under or over the road surface. They count the number of vehicles, their type and speed. However, under operating conditions, the sensors have difficulty distinguishing between closely spaced vehicles. Microwave Radar: This technology can detect moving vehicles and measure their speed. The radar records counting data, speed and simple vehicle classification.

2.5. *Ultrasonic and passive acoustic methods*
These devices emit sound waves to detect vehicles by measuring the return time of the signal to the device. Ultrasonic sensors are located above the lane.

3. *Non-intrusive data collection methods*
The principle of FCD is to collect traffic data in real time by locating the vehicle's location using mobile phones or GPS across the entire road network. Data like this are sent anonymously to the central processing center [7].

After collecting and processing information, it can be transferred to drivers to obtain the traffic situation on the road. Rather, the FCD is a source of high-quality data that complements existing technologies. They will help to improve safety, the efficiency of obtaining traffic conditions and the reliability of the transport system. They become central to the development of a new transport system [8].

3.1. *Floating Car Data*
There are two main types of traffic data acquisition, namely Global Positioning System (GPS) and Cellular Systems (GSM).

Figure 1 shows an example of a GPS based network.
Figure 1. GPS based method.

Figure 2 shows an example of a cellular-based FCD network (GSM).

Although GPS is becoming more popular and affordable, only a limited number of vehicles are equipped with this system. As a rule, vehicles providing transportation services are equipped with them. The vehicle positioning accuracy is relatively high, usually less than 30 m [8, 9].
More often than not, traffic data from private vehicles or trucks is more suitable for highways and rural areas. In the case of urban traffic, taxi fleets are especially useful due to their large number and the already existing on-board communication systems. Currently, GPS sounder data is widely used as a source of real-time information by many service providers, but it suffers from a limited number of equipped vehicles and high equipment costs compared to floating cellular data [1, 9].

Currently, most vehicles are equipped with one or more mobile phones, which makes it possible to use mobile phones as anonymous traffic probes. The positioning of the mobile phone is regularly transmitted to the network using triangulation or other methods, and then, travel time and additional data can be estimated over a number of road segments before being converted into useful information by road centers [3, 10].

Unlike stationary road detectors and GPS systems, cars do not require special devices, equipment, and there is no need to build a special infrastructure along road networks. Therefore, it is cheaper than conventional detectors and offers wider coverage options. This method is easier to set up, requires less maintenance, but requires complex algorithms to retrieve and process data and therefore requires skilled personnel to predict traffic conditions and send to users.

The types of data for assessing the traffic situation provided by transport centers around the world are quite important, such as: Annual average daily traffic and Vehicle Kilometers Traveled. These two raw traffic datasets are mainly derived from fixed sensor measurements. They play a key role in traffic engineering.

Annual average daily traffic (AADT) is the average annual number of vehicles passing a point in a given section of the count every day (usually expressed in vehicles per day) [1, 11]. It simply represents the flow of vehicles along a section of road (for example, a highway) on an average day of the year. AADT is regarded as one of the most important raw traffic datasets, where it provides the necessary input for developing traffic models and calibration exercises that can be used to plan new road construction, determine the geometry of the roadway, and congestion management, road surface design and much more. AADT is generally available on most European road networks. This data is collected by traffic management centers, updated and disseminated to users by traffic information centers in most countries. On the one hand, AADT is calculated annually for all motorway or road segments. On the other hand, real-time traffic streams can be provided every minute or hour. This data is measured using the traffic recorders for some highways. AADT calculation methods are usually based on data information obtained from two types of counts: continuous automatic traffic count and short-term traffic count. A combination of these two measurements is commonly used to obtain an AADT estimate and transmit it to the user in the form of traffic conditions.

One of the most common augmentation methods for assessing AADT is the factoring method [2, 12]. In this case, the permanent sections of traffic are first manually classified into different groups (known as seasonal categories) based on the similarity of the road traffic characteristics. Each permanent station is then assigned a seasonal factor category according to the site location, assuming that the seasonal variability and movement characteristics in the short and long term are similar in the same geographic area. However, the most important questions are the optimal number of groups and the way in which short samples are assigned to groups of seasonal factors. Although this method is arguably the simplest and most used worldwide, it is still limited in terms of accuracy. More complex mathematical methods such as linear regression, neural network, genetic algorithm, etc. Have been designed to provide more accurate AADT values.

As you can see from the block diagram in Figure 3, data processing flows are a complex system.
The method considered in the study consists of two stages, namely, transferring data from vehicles (for example, via GSM) and transferring data back to drivers, as an end user. Trips made without vehicles should be filtered using pattern matching. As with GPS point data, map matching is required to map point locations to specific roads. One of the disadvantages of this technology is that the continuous transmission of a large amount of information from vehicles creates an excessive load on the transmission channels and represents a significant cost factor when using a paid communication system [1, 3]. For this reason, it would be preferable to transfer compressed data rather than individual values. For example, the average speed of a given vehicle can be transmitted to a center responsible for collecting and processing traffic data at chronological intervals. However, it would be much more efficient to filter the data according to its relevance. For example, the transmission may be limited to information about detected traffic congestion only.

4. Results and discussions

The main question about FCD is not whether the technology is an effective way of collecting traffic information in real time, but rather an assessment of what applications and benefits it can provide in the short to medium term. More accurate and up-to-date traffic information in real time can lead to significant improvements in areas such as: reduced congestion, improved O-D matrices, better monitoring of traffic conditions.

Optimizing the existing infrastructure by making better use of the existing road network will reduce driving times, thereby lowering costs for drivers and road network service providers, so it is expected that these improvements will affect all participants in the transport process, albeit to varying degrees. For example, road users will receive reliable information in real time on the best routes from their location to their destination.

The above software and hardware solutions can also be useful for identifying time dependences of traffic.

These are daily, weekly and seasonal fluctuations in traffic intensity. For example, in urban traffic conditions, the intensity of traffic flows can vary by more than 50%.
The intelligent combination of FCD with road sensors is the ideal input for dynamic traffic patterns. New data fusion algorithms will take advantage of each technology, leading to optimal solutions to traffic management problems. Thus, the traffic model can provide short-term traffic forecasting (15 to 30 minutes). For example, accidents (collisions) can be automatically detected thanks to dynamic models fed with high quality real-time data (i.e., through fusion techniques that can also include meteorological data and other parameters).

In recent years, the number of sources for collecting traffic data has increased significantly. The combination of traditional road sensors with floating vehicle data can provide high accuracy and real-time transmission of road traffic. Stationary detectors are difficult to implement for the following reasons: the need for large financial costs, the need for qualified personnel for their installation and maintenance, the dependence of such sensors on weather conditions. FCD is not aimed at replacing existing sensors, but rather to supplement their information with more accurate data. If current trends continue, transport operators can reap significant benefits from the combination of fixed and mobile traffic measurements across a wide range of areas. Due to favorable market prospects, private suppliers are currently developing all the necessary conditions for the deployment of new systems in the traffic accounting market.

5. Conclusion
This article discusses the benefits of implementing the FCD principle into existing traffic information collection systems. The advantages of this principle, its advantages and disadvantages are substantiated.

Examples of different ways to implement the FCD principle, their differences and possible implementation difficulties are given. The effectiveness of non-intrusive methods has already been proven by various road navigation systems.

The implementation of the FCD principle will significantly increase the efficiency of the use of transport infrastructure, as well as reduce the costs of end users.

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