OVERVIEW OF EMERGING ROAD TRAFFIC DATA COLLECTION METHODS

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Abstract

It is a well-known fact that the data on road traffic flow characteristics is essential for sustainable road network management. First road traffic volume counts date back to the 1950s when short-term periodic road traffic counts were carried out in cities worldwide. Manual traffic counting is one of the oldest and most technologically simple methods to obtain data on road traffic volume and its composition. Today, because of the ever-growing road transport demand, it has become clear that the development of Intelligent Transport Systems (ITS) is vital to increase safety and tackle increasing emission and congestion problems. The introduction of ITS highly depends on the quality and quantity of traffic data. Under the growing requirement of long-term traffic flow information, various traffic data collection methods have evolved. They allow systematic recording of the traffic flow volume and composition but also vehicle speed, total gross weight, number of axles, axle load and travel destination. This data, which is collected continuously over longer periods, enables a detailed analysis of traffic flows, and represents the basis for decision making in planning, designing, construction and maintenance of road infrastructure. This paper gives an overview of traditional and emerging traffic data collection methods - both fixed and mobile - and the analysis of the current road traffic data collection methods used on the Croatian road network, in terms of their potential and limitations.

Keywords: road network, traffic data, collection methods

1 Introduction

The need for the new infrastructure planning while maintaining the existing road network originates from the day-to-day population movements that affect the traffic flow. The level of success of the transport system operation depends on the organization and quality of the road network management, which includes collecting historical data on traffic load and traffic flow [1, 2]. There are two principal reasons for road managers to have accurate estimates of road traffic characteristics – to support the funding, and to optimise decision making in terms of directing resources. Increased population migration leads to higher traffic flow densities, and therefore frequent traffic accidents, shorter maintenance intervals, and lower levels of service. To mitigate these events, it is necessary to continuously collect traffic data, at least in specific locations, such as network nodes and identified black spots [3]. Following data can be collected by monitoring the traffic: the number of vehicles, the composition of traffic flow, the direction of movements and vehicle speed, and the distance between the vehicles. By analysing the collected data, it is possible to manage the road infrastructure more rationally and to plan the construction of new roads and their maintenance more efficiently.

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In general, traffic data collection methods can be divided into in-situ and on-board techniques [4]. In-situ techniques are used to obtain traffic data measured using sensors located along the road and are divided into intrusive methods and non-intrusive methods. Intrusive methods include pneumatic road tubes, piezoelectric sensors, inductive loop detectors and magnetic sensors. Non-intrusive methods obtain data by remote sensing using video cameras, manual counts, infrared sensors, microwave radar, laser radar, acoustic tracking systems and surveys [5].
The first film camera recordings of traffic flows were made in the 1930s. This led to a significant development of traffic data collecting methods, and in the 1950s the first continuous traffic monitoring was performed by automatic devices [6, 7, 8, 9]. From the 1970s, due to ever-increasing traffic volumes and the advancement of technology, traffic monitoring has shifted to more modern methods. In the 1990s, under the growing requirement of long-term traffic flow information, the rapid development of Intelligent Transport Systems (ITS) began [10]. In 2010, the framework of the deployment of ITS was defined by the EU directive 2010/40/EU [11]. ITS application improved environmental efficiency and enabled better planning, maintenance, and management of transport systems, efficient transport of passengers and goods, traffic safety, and protection of passengers and cargo, as they provide users accurate and fast information on traffic flow and road conditions. A prerequisite for ITS services is the timely collection of accurate and reliable traffic data [11, 12]. Today this process is assisted by different data collection and processing methods and devices. In ITS, data is collected on-board by using test vehicles, mobile phones, Global Positioning System (GPS) or other sensors in real-time [4].

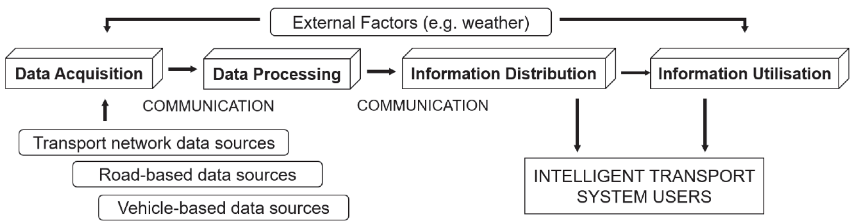

Figure 1 Intelligent Transport Systems information chain (made by Author based on [12])

The choice of appropriate road traffic data collection method depends on the type and the amount of data needed, the time interval in which the data needs to be collected, and the financial means at the disposal. ITS have received a lot of attention in the last decade, especially the issue of vehicle classification [13], which is very important information for numerous road infrastructure design and management activities. For example, the most important information in pavement structures design and maintenance management, besides the traffic volume, is the flow composition (vehicle classification), because the traffic load on the pavement is expressed by the average daily number of equivalent axles [14].
This paper provides an overview of road traffic data collection methods and lists their advantages and disadvantages. An overview of methods in use on the Croatian road network is presented, together with the different vehicle classifications they provide. Here, to present a problem in the determination of the vehicle type for the purpose of road pavement management, a systematic classification of “heavy” vehicles is given, considering their axle load.

2 Review of traffic data collection methods

In this section, six traffic data collection methods - from the oldest manual to the most recent Floating Car Data method - are presented in brief. Based on the performed literature review, the main advantages and disadvantages of each data collection method are identified (Table 1). Manual traffic data collection, performed by traffic meters, is the oldest and simplest method of collecting traffic data [15]. This method provides precise traffic data during peak hours, and it is very appropriate for counting traffic at intersections and for estimations of the average daily and annual values. The measurement itself can be performed on-site or from video, and the vehicle classification is performed based on visual observation of the counter [16].

Automatic traffic data collection is performed to determine the temporal and spatial distribution of traffic characteristics. It can be performed occasionally or continuously. Automatic devices installed on or next to the road allow obtaining data on traffic volume, vehicle speed, wheelbase, weight, and headways, and flow structure [15]. According to the mode of operation and construction, they can be divided into stationary and portable [15,17]: inductive loop, magnetic meter, microwave radar (RTMS), pneumatic meter, active infrared meter, passive infrared meter, ultrasonic meter, acoustic counter, and a video image processor (VIP).

Toll traffic data collection is based on the records of the passage of vehicles using an information card with data on the time of use and passage through the toll station, type of vehicle and location of its entry and exit. A major advantage of this method is the simplicity of determining the number of vehicles at a particular location and the composition of the traffic flow [18].

Computer image processing is becoming the go-to method for defining traffic flow characteristics from video recordings, primarily at multilane intersections and interchanges, as they allow real-time monitoring of speed, volume, queue lengths, and headways. A great advantage of such systems is adaptability to new conditions at the intersection such as the addition of traffic lanes or temporary road closure. Also, it can be used to detect accidents, which allows a shorter time for emergency reactions and provides better traffic flow [19].

Satellite traffic data collection is a method that is still in the experimental phase. New algorithms for vehicle detection are constantly being developed and perfected. To analyse the traffic, a high-resolution satellite is needed. The main limitation of this method is time discrimination because the traffic flow is constantly changing. Here, the advantage is the ability to monitor remote or difficult to access roads [20]. For automated traffic flow tracking, a complex algorithm first needs to segment the satellite image by automatically inserting road edges using vector data. Only then can the algorithm classify objects according to the maximum probability of affiliation. This method still does not replace continuous traffic counting but serves as an additional source of data [21].

Floating Car Data (FCD) method is used to collect real-time traffic data via mobile phones or GPS as sensors [12, 22]. Data such as vehicle location, speed and driving direction are sent to a central information processing centre. Practically every vehicle today has at least one mobile device on-board by which it is possible to collect traffic data or monitor the speed and traffic density. Floating Car Data is key to the further development of ITS [12].

Table 1 Advantages and disadvantages of traffic data collection methods

Method	Advantages	Disadvantages
Manual count	+ noticing traffic anomalies + good monitoring traffic at intersections + easy use of forms for further data processing + low counting costs + counting errors are less than 1% + stopping the survey to record data + a smaller number of counters	- required numerator training - high initial costs (camera acquisition) - infrastructure required to set up the camera - necessary favourable weather conditions - counter fatigue affects data accuracy - transferring data to digital format - classification errors between 4-5%
Automatic count	+ continuous recording of data over a long period + accuracy of data + does not depend on weather conditions + easy installation and removal	- high initial costs (purchase, installation) - required time for assembly and disassembly of the counter - necessary construction works on roads - an inability to monitor traffic at intersections - requires regular maintenance
Toll count	+ high data accuracy + obtaining data through the billing system + low costs of data collection and processing + weather resistance + simple determination of traffic load and traffic flow composition	- limited to infrastructure with tolls - inability to collect additional traffic parameters
Computer vision	+ availability of multiple traffic parameters data collections + the possibility of tracking the vehicle through the license plate + automatic incident detection + traffic violations detection	- high initial costs (camera acquisition) - infrastructure required to set up the camera - ideal weather conditions required - complex image processing algorithms required - large computing and memory resources required
Satellite	+ high geographical coverage	- high initial costs - necessary vehicle contrast - the object´s shadow may prevent the vehicle from being recognized - depends on favourable weather conditions
FCD	+ lower installation and maintenance cost compared to sensor or camera + high geographical coverage + fast setup	- possible bigger time delays of data transfer in case of large traffic volumes

3 The methods used on the Croatian road network

Public roads in Croatia are classified into four groups: highways, state, county, and local roads [23]. Traffic is monitored by three methods: automatic continuous, automatic occasional and toll collection method. From the data given in Table 2, which presents number of cross sections according to the traffic data collection method on the entire classified network, it can be concluded that the data collection requirements are fulfilled with a traffic monitoring system placed, on average, on every 32 km of the network. However, in each method, vehicles are classified differently. Portable meters (PM) used for automatic occasional data collection classify vehicles into five classes according to their length. Stationary meters (SM) used for automatic continuous data collection classify vehicles into nine descriptive groups. In the toll collection (TC) method, vehicles are classified into five groups according to their height, axle number and maximum permissible weight [24].

Table 2 Structure of the classified Croatian road network and number of cross sections according to the traffic data collection method

Road class	Length [10^3 km]	No. of counting cross sections by method		
		Automatic continuous	Automatic occasional	Toll
Highways & State	8.7	264	164	99
County	9.4	205	41	0
Local	8.8	27	45	0
Total	26.9	496	250	99

These differences in vehicle classification can be considered as a hindrance for more efficient management of pavement structures, as they require an extra step (vehicle load re-calculation) in the prediction of pavement maintenance needs. Table 3 shows an overview of heavy commercial vehicles considered as load in pavement structures management, created to further emphasize this issue. Their systematization was made according to the vehicles monitoring method classification, number of axles, maximum length between the axles, maximum weight, and axle load. During the systematization process, a wide range of these values has been observed even for vehicles classified in the same group by a particular monitoring method. The question being raised here is how these disparities affect the tolerable margin of error in the assessment of cumulative pavement structure load during the planning of new, and maintenance of existing road infrastructure.

Table 3 Vehicles systematization

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<tr><th>P
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C</th><th>Vehicle description</th><th>No. of axles</th><th>Max. length [m]</th><th>Max. weight [t]</th><th>Axle load [t]</th></tr>
<tr><td>3</td><td>B3</td><td rowspan="3">III.</td><td>truck without trailer</td><td rowspan="3">2</td><td>10.8</td><td>32</td><td>16</td></tr>
<tr><td>5</td><td>C1</td><td>bus</td><td>18.0</td><td>28</td><td>14</td></tr>
<tr><td>2</td><td>B2</td><td>medium trucks</td><td>6.6</td><td>26</td><td rowspan="2">13</td></tr>
<tr><td>5</td><td>B5</td><td>IV.</td><td>semi-trailer truck</td><td rowspan="4">3</td><td>18.4</td><td>40</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">B3</td><td rowspan="3">III.</td><td>heavy goods vehicles</td><td>10.6</td><td rowspan="2">32</td><td rowspan="2">11</td></tr>
<tr><td>truck without trailer</td><td>10.8</td></tr>
<tr><td rowspan="3">5</td><td>C1</td><td>bus</td><td>18.0</td><td>28</td><td rowspan="3">10</td></tr>
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<tr><td>B4</td><td>truck with 2-axle trailer</td><td>20.5</td></tr>
<tr><td>1</td><td>B1</td><td rowspan="3">III.</td><td>small trucks, vans</td><td>2</td><td>5.3</td><td>18</td><td rowspan="2">9</td></tr>
<tr><td>2</td><td>B2</td><td>medium trucks</td><td>3</td><td>6.6</td><td>26</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">B3</td><td>heavy goods vehicles</td><td rowspan="2">4</td><td>10.6</td><td rowspan="2">32</td><td rowspan="5">8</td></tr>
<tr><td rowspan="7">IV.</td><td>truck without trailer</td><td>10.8</td></tr>
<tr><td rowspan="6">5</td><td>B5</td><td>semi-trailer truck</td><td rowspan="4">5</td><td>18.4</td><td rowspan="6">40</td></tr>
<tr><td>B4</td><td>truck with 2-axle trailer</td><td>20.5</td></tr>
<tr><td>B5</td><td>semi-trailer truck + trailer</td><td>22.9</td></tr>
<tr><td>B4</td><td>truck with 3-axle trailer</td><td>30.8</td></tr>
<tr><td>B5</td><td>semi-trailer truck + trailer</td><td rowspan="2">6</td><td>22.9</td><td rowspan="2">7</td></tr>
<tr><td>B4</td><td>truck with 3-axle trailer</td><td>30.8</td></tr>
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4 Conclusion

This paper provides an overview of six methods for traffic data collection that are used to determine the traffic volume, vehicle type identification and classification. Based on the performed literature review, the main advantages and disadvantages of each method were identified. The overview showed that each method has certain shortcomings that can affect the tolerable margin of error when determining traffic volume and composition.

The choice of a particular method depends mainly on the financial possibilities of its implementation as well as on the type of data road managers want to obtain. In Croatia, three traffic data collection methods are used, and each method classifies the vehicles differently, depending on vehicle size, weight, purpose and number of axles. The more uniformed systematization of heavy vehicles could optimize the process of management of pavement structures as this process requires the determination of cumulative traffic load expressed by the number of equivalent standard axles.

Modern traffic monitoring methods that could enable more unambiguous vehicle identification should significantly contribute to the optimization of processes that use the composition and volume of traffic flow as their basic input, such as pavement maintenance planning, road traffic noise management, road network compositions and infrastructures upgrades.

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