An Overview of Different Methods Available to Observe Traffic Flows Using New Technologies

Irina Yatskiv\textsuperscript{1}, Alexander Grakovski\textsuperscript{2}, Elena Yurshevich\textsuperscript{3}

\textsuperscript{1,2,3}Transport and Telecommunication Institute
\textsuperscript{1}e-mail: ivl@tsi.lv
\textsuperscript{2}e-mail: avg@tsi.lv
\textsuperscript{3}e-mail: Jurshevicha.J@tsi.lv

Abstract

A transport planning and transport decision at all levels requires understanding of actual conditions with traffic flows. This involves the details of traffic flows, which usually consist of vehicle types and speeds, knowledge of trip length and trip purpose, trip frequency and origin/destination for trips, etc. The first group of data dealing with the characteristics of vehicle or people movement is obtained by undertaking traffic counts. All survey techniques represent a compromise between the goals of the survey, the resources available, the coverage that is feasible, and the amount of data to be collected. Authors present the comparative analysis of modern traffic flow measurement technologies, and also, existing technical devices and systems of moving transport detection for traffic flows survey in Latvia.

Keywords: surveillance, vehicle detecting, sensors

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1. Introduction

In Europe urban areas generate approximately 85\% of the EU gross domestic product, and such areas are considered to be the driving force to European economics. Cities turn out to be the crucial factor for the largest part of European citizens, who should be provided with as high living standards as possible. The need for the “correct” decision-making by solving the transport problems and trying to choose the optimal solution is a matter-of-course for any government in the world. A transport planning and transport decision at all levels requires understanding of actual conditions with traffic flows (Yurshevich and Yatskiv 2012). This involves the details of traffic flows, which usually consist of vehicle types and speeds, knowledge of trip length and frequency, trip purpose, origin/destination for trips etc. The part of data is obtained by undertaking traffic counts. But the number of data traffic application is big and transport modelling is only one of it. Intelligent transport systems (ITS) are also one of the main users of traffic data. The problem of traffic data in different aspects is a subject to be studied. In the world
there is quite a number of theoretical and experimental researches (Taylor et al. (2000), Bar-Gera (2007), Klein (2001), Frederich (2008), Hall (2001), etc.) done in the mentioned sphere. Research about population mobility includes the traffic survey technologies investigation as well (Stopher 2006). Meanwhile the discussion about the potentials and bottlenecks related to new technologies is appeared, for example Leduc (2008). This current work is the continuation of the investigation in modern traffic measurements technologies.

2. The Data Required for the Transport System Modelling

The level of performance of transportation system functioning depends on the quality of decision-making at all stage of Urban Transportation System (UTS) life cycle functioning. At the strategic level there are considered the questions of spatial planning, transportation network and its infrastructure development, detours construction, etc.; formed the plans of transportation network strategic development; considered the questions of the economic policy according the commercial and public transport; decision-making according the systematic survey of transportation systems survey and data collection, etc. At the tactical level the questions according the existing transportation network fragments reconstruction and the new construction on the base of existing strategic plan of development are considered. At that level the tasks of traffic flow coordination and control are decided as well. At the operational level there are considered the local problems of some transportation network fragments as well as the tasks of traffic control at micro level: the cycles of the light signals groups functioning regulation, public transport stop places disposition, the consideration of the lane for public transport creation, changing of the speed regime, etc.

Decision taking with regard to all aspects of UTS planning and management is a complex process which requires consideration of the current state of traffic and transportation network, its configuration, its future condition forecast, the relevance of someone or other route, weather conditions, location of zones of influence, preferences in selecting travel mode, and many other factors. The standard practice applied when managing such complicated systems is – using simulation modelling either as a part of Decision Support System (DSS) or singly. There are three approaches in the field of traffic simulation: the macro-, the meso- and the microscopic ones. They differ by the way of presentation of the traffic flow and the level of information describing transport network and road users. The macroscopic approach is meant for solving strategic problems of TS management at the city overall level; the approach presents the transportation system and the traffic flow with a very high degree of abstraction. Microscopic modelling, in its turn, is aimed mainly at tactical planning and tactical solution of operational tasks, and enables one to investigate the transport network and the properties of traffic flow (including its participants) with a high degree of particularization. The mesoscopic approach is used for modelling of some fragments of transportation network for tactical decision-making and distinguished by the fact that flow of traffic is presented as a disaggregated but without detailed description of individual vehicles behaviour.

The macroscopic and microscopic approach uses different kinds of transportation network data. These data are presented in the Table 1. Considering the modelling application as a part of DSS it is important to provide the permanent the relevant and actual data collection from the real transportation network and storing in DSS data bases. A vital role in this process may to play the ITS that
provides the set of the tools and equipment for traffic flow parameters measurement. The several procedures of traffic data collection were considered by Hall (2001). These methods cannot provide the collection of all data that are presented in the Table 1 but some of them are possible. The comparative analysis of those methods, used technologies and collected data of traffic is presented in the Table 2.

Table 1. Data necessary for macroscopic and microscopic modelling application

<table>
<thead>
<tr>
<th>The stage</th>
<th>Data</th>
<th>Macroscopic modelling</th>
<th>Microscopic modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model construction</td>
<td>The map of transportation network</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>The types of transport modes and demand on them</td>
<td>●</td>
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<tr>
<td></td>
<td>Zone division of the town</td>
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<td></td>
<td>Demand on transportation</td>
<td>●</td>
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<td></td>
<td>Rates of flow</td>
<td>●</td>
<td>●</td>
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<td></td>
<td>Traffic volumes on the fragments of network</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Public transport system schedule and routes</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>OD-matrix</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Traffic distribution by the routes at intersections</td>
<td>●</td>
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<tr>
<td></td>
<td>Light signal groups schedule</td>
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<tr>
<td></td>
<td>Traffic flow density</td>
<td>●</td>
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<tr>
<td>Model validation and calibration</td>
<td>Travel time at fragments of transportation network</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Average speed</td>
<td>●</td>
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<td></td>
<td>Speed and travel time trajectories</td>
<td>●</td>
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<td></td>
<td>Queues characteristics</td>
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<tr>
<td></td>
<td>Time delays</td>
<td>●</td>
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<tr>
<td></td>
<td>Level of emissions</td>
<td>●</td>
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<td></td>
<td>Occupancy</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Time headway between vehicles</td>
<td>●</td>
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<tr>
<td></td>
<td>Spacing or space headway between vehicles (distance per vehicle)</td>
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<tr>
<td></td>
<td>Traffic volumes on the fragments of network</td>
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<td>●</td>
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</table>

The sustainability of flow rates measures on high volume of traffic depends on from the time interval of measurement. For example, the time interval of 30 sec may give more unsustainable results than the time interval of 5, 10 or 15 minutes. The effect of different measurement intervals on the nature of resulting data was shown by Rothrock and Keefer in 1957 (Hall 2001). The sustainability of average speed estimation depends on the way of its calculation, the used parameters, the state of traffic and considered assumptions. There are distinguished several kinds of speed estimation:

- speed at point of road - instantaneous speed (radar, microwave, two closely spaced inductive loops)
- average speed over segment of the road by length $D$
  - average arithmetic speed calculated as an averaged sum of measured values of speed $v_i$ of $N$ vehicles:
    $$ \bar{v} = \frac{1}{N} \sum_{i=1}^{N} v_i, $$
  - space mean speed calculated as a distance $D$ divided on the average sum or travel times $t_i$ of $N$ vehicles:
    $$ \bar{v} = \frac{D}{N \sum_{i}^{N} t_i}. $$
In case of speed variation of vehicle on the road segment the harmonic mean of speed and average arithmetic speed gives the higher average speed than the true average, and more appropriate way of average speed over segment calculation is a space mean speed that requires only the travel time’s measure. Hall (2001) mentioned that it was shown mathematically that a distribution of speeds collected in this fashion would be identical to the true distribution of speeds, whereas speeds collected over time at one point on the road would not match the true distribution. But he assumes an "isoveloxic" model, one in which each car follows a linear trajectory in the space time diagram, and is not forced to change speed when overtaking another. Also Hall (2001) notes that for computations involving mean speeds to be theoretically correct, it is better use the space mean speed, rather than time mean speed, but the speed measurements on free flow way and on congested traffic flow (stop-and-go regime of driving) are different. Several authors proposed different ways of average speed measurement for congested traffic flow.
3. Technical Devices and Systems of Moving Transport Detection

All survey techniques represent a compromise between the goals of the survey, the resources available, the coverage that is feasible, and the amount of data to be collected. According to aims, appropriated costs, and quality requirements it can be selected one of the existing technologies for data collection. Currently, video, laser, radio frequency, induction, sound, and pressure sensors are mainly used as the engineering tools for traffic flows’ parameters (intensity, speed, direction) measurement (Kabashkin 1999).

For example, Doppler radars (mobile or static) measure the change in frequency of the signal reflected from the object as discussed by Klein (2001). By changing the frequency of the signal, the radial velocity of the object (the projection of velocity on the straight line passing through the object and the radar) is calculated with the error of ±(1÷3)km/h.

Laser radars (or lidars) use the technology of obtaining and processing information about remote objects by means of active optical systems utilizing the phenomenon of light reflection and dispersion in transparent and translucent media as discussed by Le Chevalier (2002). Its accuracy seriously depends on weather conditions (snow, rains, and dust). Both of radar and lidar technologies have a major disadvantage in the feature that the speed of one moving vehicle can be detected each time only. It has been used mainly by road policy for speed overriding fixation and safety control.

Photo (video) radar has a number of opportunities for the registration of moving vehicles. This is the best method for measuring traffic flows and speeds in static mode. This type of radar can store information in some cases to pass this information via radio to a remote mobile post. The problem of measuring at night is solved by using infrared (IR) illumination. Despite the large number of possibilities, this method has its disadvantages. To obtain a clear picture there should be moderate visibility and wet weather. Also, possible problem may be with the fixation of several vehicles simultaneously. This type of the radar can be situated above the road for the best usage as counter/speedometer or used in mobile mode if use the methods of image processing (“corner dots” analysis) for selection of vehicles from different lanes and directions as discussed previously (Grakovski and Murza 2010).

Inductive sensors (loops) are designed for detecting the moving vehicles (Kabashkin 1999). In a simplified form the inductive sensor is a wire, which is placed under the asphalt surface and is connected to the controller (Fig.1). The sensor works on the principle of inductance while driving the car through it. The disadvantage of this method is that it requires a destruction of the road surface for laying inductive loops with the special permission from road owner.

Inductive loop sensors mainly are used as traffic counters but it can classify the type of vehicle by the iron mass, select heavy hauler and trailer, but applied in pair it can detect the speed of the vehicle with the accuracy of ±1%.

An implementation of acoustic sensors (pair of two cross-directed microphones) is limited by the weather conditions, probabilistic noise, and short time of exploitation as presented by Grakovski et al. (2010). It also cannot measure the parameters of several vehicles simultaneously. The microphones situated near the road, can produce the signals proceeded by the digital signal processing methods with signal recognition in spectrum domain. Especially, acoustic sensors take the maximum of errors of measurement in “bottleneck” conditions (high density of vehicles with relatively low speed). Usually, it is used as the sensors of accident on the crossroads (frequency selection for the glass break noise).
Pressure (piezoelectric, tensor, fibre-optic cable (FOS)) sensors (Fig. 2) are composed of two screw elements, which are separated by some distance. Once the transport front wheels have crossed the first push element, the receiver gives a signal of timer start. It may become the quantity, speed, weight and direction measurement tool (Batenko et al. 2011). The accuracy of speed measurement here is less than 1%. The disadvantages of such sensors are the need to install it into the pavement, dependence on the weather conditions (temperature and ice on the strip) but, on the other hand, the time of usage of FOS more than other pressure sensors (till 20 years).

The information about vehicle’s weight can be helpful too for understanding the reasons of the trip or (for passenger transport) correlates with the number of passengers on a board.
The deployment of a network of such sensors requires significant financial resources, and sometimes also additional construction work. Installation, maintenance and protection of an expensive network of sensors and their channels of communication make the creation of full-scale ITS rather expensive, which is not affordable for all. The satellite or airborne photo, IR or microwave radar data for regional traffic flows analysis cannot fulfil permanent surveillance and satellite positioning over territory. It requires data image processing algorithms application for counting of number of vehicles on interested territories but it can give the analysis of situation at moment time simultaneously. It is an expensive tool and also it depends on the weather conditions.

Most appropriate for traffic flows data collection the Automated Vehicle Location systems (AVL) usage seems, based on Global Positioning System (GPS) technology (Fig.3). It is the main difference between usual GPS navigator (including i-phone) and AVL system receiver. The owners of navigation services mainly are private companies (excluding state special services). They offer the GPS navigation and routing based on real traffic conditions but their GPS receivers has additional transmitter function (GSM/GPRS/Wi-Fi/Bluetooth channel) let to obtain the position of each client into temporal database of the company. According to this data one can obtain the intensity of traffic in interested city’s region from on-line service. Due to relatively low representativeness of this data (small number of these companies’ clients), GPS data includes itself some differences from real situation (time delay in speed data receiving on concrete road). It’s impossible to obtain the intensity of traffic flows from these data only calculated speed of particular client’s vehicle after passing of any slot of the street. The accuracy of speed measurement by GPS navigator strongly depends on the number of GPS satellites seen at the moment of measurement by receiver (usually from 4 to 14). So, the error of positioning and, respectively, speed may be deviated on (1-10)%.

Figure 3. GPS surveillance data based on clients information (problematic roads are painted according to traffic from “lightly green” – empty till “red” – “bottlenecks”) from www.kartes.lv/sastregumi

Another way is the use of cellular mobile phone GSM data processing (Fig.4) for routes reconstruction (Kabashkin 1999, Frederich et al. 2008). There are few variants of cellular mobile phone data processing. At first, it is possible to use the billing center information data from cellular communication network. Decoding of data from the billing center database during given time period (hour, day, etc.) it is possible to
track and reconstruct the route of each subscriber by analysis of sequence of mobile
network cells (base stations) where calls of the subscriber was observed. This kind of
data has not huge volume and can be proceeded on appropriate time.

Figure 4. GSM surveillance data based on (a) cellular phone’s position triangulation,
(b) its tracking, (c) route reconstruction as well as the OD-matrix visual interpretation

The second variant consists on active mobile phone localisation inside cell using
GSM triangulation method (see Fig.4(a)), and surveillance of its route during defined
time period. This method gives the accuracy of positioning approximately 30-125
meters (depends on base stations density and weather conditions) and asks the giant
resources for representativeness, usually it is used by policy and other state special
services, and can be applied according to legislation on basis of Court solution only.
It can classify walking subscriber or moving by transport (exclude “bottleneck”
situation where the speed of pedestrian and vehicle can be the same). The deviation of
speed measurement can be significant – till 10-50%.
The third variant includes itself the data of each subscriber ID identification (Cell ID)
when base station service zone is changed. This data has a huge volume, it distributes
on a lot of cellular networks base station’s databases. Usually, the mobile phone
operator companies have not saved this data in centralised manner, and it is
problematic to assemble (copy) enough data set into common temporal database
resource as well as to analyse and reconstruct the routes of all subscribers into the so-
called “Origin-Destination” or OD-matrix (Frederich et al. 2008).
Combination of cell identification technology (Cell ID) and Round Trip Time (RTT)
together with the Forced Soft Handover (FSHO) algorithm can decrease the errors of
positioning till 16-25 meters but the errors in velocity estimation will be significant
too (Borkowski et al. 2004). It means that using GSM data one can estimate any
average speed of transportation during the route only for determination of possible
mode of transportation if need. Main complexity of this approach is in the huge data
volume processing as well as Data Mining methods application need for moving
vehicles data extracting from the mobile network data flows.
All of these three variants of GSM data application have one the same problem in
implementation. Still here we meet the restrictions of Personal Data Security and
Commercial Privacy legislation. There are some ways how to avoid it by the
exclusion of personal information from the data. The simplest and more effective way
is to replace automatically all real identificators (SIM or phone numbers) in the data
set by any conditional ID sequence directly during data copying process into common
temporal database resource for analysis and processing.
The implementation of radio frequency identification (RFID) technologies for traffic
flow analysis mostly similar to AVL/GPS system or static video, laser, radio
frequency, induction, sound, and pressure sensors systems because of need for additional equipment of vehicles by RFID markers (tags) as well as need for the roadside equipment by the network of RFID sensors (readers). Some countries actively use RFID systems for toll roads, city parking, border and custom control etc. Of course, if possible, RFID system can be involved into combined traffic data collection system, but it is also relatively expensive in design and maintenance for the role of main data source. The comparison between existing measurement technologies for traffic flow data collection is presented in Table 3.

Table 3. Traffic flow measurement technologies comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Point counter</th>
<th>Speedometer, accuracy (%)</th>
<th>Real time data</th>
<th>Additional data</th>
<th>Dependence on weather conditions</th>
<th>Data availability for public/scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human resources (counters)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>VT&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Questionnaires during annual technical inspection</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
<td>Trip purpose, VT, personal data</td>
<td>No</td>
</tr>
<tr>
<td>Pressure (piezo-, tenso-, fibre-optic &amp; air sensors)</td>
<td>Yes</td>
<td>Yes, &lt;1%</td>
<td>Yes</td>
<td>Weight, VT</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Inductive &amp; magneto-metric sensors</td>
<td>Yes</td>
<td>Yes, &lt;1%</td>
<td>Yes</td>
<td>VT</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sound &amp; ultra-sonic sensors</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>VT</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Photo/Video &amp; IR sensors</td>
<td>Yes</td>
<td>Yes, &lt;5km/h</td>
<td>Yes</td>
<td>VT, plate number</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Radar (Microwave&amp;Laser)</td>
<td>Yes</td>
<td>Yes, &lt;3km/h</td>
<td>Yes</td>
<td>VT</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology</th>
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<th>Data availability for public/scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID systems</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Client’s ID, route, weight</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>GPS navigation systems</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Client’s ID</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>GSM/GPRS triangulation</td>
<td>Average</td>
<td>Average</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Noise intensity monitoring</td>
<td>Average</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Air pollution &amp; quality (CO, CO2)</td>
<td>Average</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Airplane (photo &amp; spectr-zoned camera) surveillance</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes/No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Satellite (photo &amp; spectr-zoned camera) surveillance</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes/No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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<sup>1</sup> - VT – vehicle type.

3. Conclusion and Discussion

Under pressure on improving traffic management, collecting traffic data technologies have been evolving considerably. The main point in research – is a review of technologies that can be very useful to provide real data for calibration of historical traffic models and inputs to dynamic traffic models. Authors present the comparative analysis of modern traffic flow measurement technologies, and also, existing technical devices and systems of moving transport detection for traffic flows survey in Latvia.
It should be stressed upon that the most problematic that still here we meet the restrictions of Personal Data Security and Commercial Privacy legislation. There are some ways how to avoid it by the exclusion of personal information from the data. Main complexity of this approach is in the huge data volume processing as well as Data Mining methods application for moving vehicles data extracting from the mobile network data flows.

References


