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Road Traffic Data: Collection Methods and Applications

Guillaume Leduc

Working Papers on Energy, Transport and Climate Change
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TABLE OF CONTENTS

1 Introduction 2
2 Road traffic data collection methods: an overview 3
2.1 Conventional "in-situ" technologies 3
2.2 The Floating Car Data (FCD) 5
3 Estimation of annual traffic flow and traffic volume 9
3.1 Traffic flow – Average Annual Daily Traffic (AADT) 9
3.2 Traffic volume – Vehicle Kilometres Travelled (VKT) 12
4 FCD: from testing to marketing 15
4.1 Capabilities and limitations 15
4.2 Market development 20
4.3 Open questions 24
5 On-line available real-time traffic data 29
5.1 In Europe 29
5.2 In the United States 36
6 Conclusions 39
7 References 49

1 Introduction

The development of Intelligent Transportation Systems (ITS) requires high quality traffic information in real-time. For several years, under growing pressure for improving traffic management, collecting traffic data methods have been evolving considerably and the access to real-time traffic information is becoming routine worldwide.

The use of traditional on-road sensors (e.g. inductive loops) for collecting data is necessary but not sufficient because of their limited coverage and expensive costs of implementation and maintenance. In the last years we have been witnessing the emergence of alternative data sources. This is for example the case for methods based on the vehicle location (Floating Car Data) which are a promising cost-effective solution to cope with some limitations from fixed detectors. Even if the idea of collecting data from "in-vehicle" devices through mobile phones or GPS is not quite new, a FCD market is only now growing worldwide with a wide range of applications and benefits. This would not only improve traffic management but would also help satisfy the growing demand of drivers who are willing to pay service providers as long as they have access to relevant real-time information: will there be any congestion on my usual route today? How to avoid it? If not, how long will it last? Etc. Such questions require traffic data to be accurate, reliable, timely and as complete as possible.

Chapter 2 presents a short overview of traditional and emerging traffic data collection methods. In chapter 3 the emphasis is put on the methodology for estimating both the annual traffic flow and traffic volume mostly derived from fixed sensors measurements and largely used for traffic modelling. Chapter 4 raises a number of research questions. The objective is to assess the capabilities and limitations of the FCD technology mainly based on mobile phones. Market issues will be also addressed. Chapter 5 presents a number of sources providing real-time traffic data available on-line in Europe and beyond, mostly through the means of interactive traffic maps.

This report does not aim to provide an exhaustive review of this very dynamic field. It rather aims to make a snapshot of the recent developments and discuss the potentials and bottlenecks related to new technologies as well as some short-term perspectives.

2 Road traffic data collection methods: an overview

2.1 Conventional "in-situ" technologies

Broadly speaking, "in-situ" technologies refer to traffic data measured by the means of detectors located along the roadside. Generally, traffic count technologies can be split into two categories: the intrusive and non-intrusive methods. The intrusive methods basically consist of a data recorder and a sensor placing on or in the road. They have been employed for many years and the most important ones are briefly described hereafter:

- **Pneumatic road tubes**: rubber tubes are placed across the road lanes to detect vehicles from pressure changes that are produced when a vehicle tyre passes over the tube. The pulse of air that is created is recorded and processed by a counter located on the side of the road. The main drawback of this technology is that it has limited lane coverage and its efficiency is subject to weather, temperature and traffic conditions. This system may also not be efficient in measuring low speed flows.
- **Piezoelectric sensors**: the sensors are placed in a groove along roadway surface of the lane(s) monitored. The principle is to convert mechanical energy into electrical energy. Indeed, mechanical deformation of the piezoelectric material modifies the surface charge density of the material so that a potential difference appears between the electrodes. The amplitude and frequency of the signal is directly proportional to the degree of deformation. This system can be used to measure weight and speed.
- **Magnetic loops**: it is the most conventional technology used to collect traffic data. The loops are embedded in roadways in a square formation that generates a magnetic field. The information is then transmitted to a counting device placed on the side of the road. This has a generally short life expectancy because it can be damaged by heavy vehicles, but is not affected by bad weather conditions. This technology has been widely deployed in Europe (and elsewhere) over the last decades. However, the implementation and maintenance costs can be expensive.

Non-intrusive techniques are based on remote observations. Even if manual counting is the most used method, new technologies have recently emerged which seem very promising:

- **Manual counts**: it is the most traditional method. In this case trained observers gather traffic data that cannot be efficiently obtained through automated counts e.g. vehicle occupancy rate, pedestrians and vehicle classifications. The most common equipments used are tally sheet, mechanical count boards and electronic count board systems.
- **Passive and active infra-red**: the presence, speed and type of vehicles are detected based on the infrared energy radiating from the detection area. The main drawbacks are the performance during bad weather, and limited lane coverage.
- **Passive magnetic**: magnetic sensors are fixed under or on top of the roadbed. They count the number of vehicles, their type and speed. However, in operating conditions the sensors have difficulty differentiating between closely spaced vehicles.
- **Microwave radar**: this technology can detect moving vehicles and speed (Doppler radar). It records count data, speed and simple vehicle classification and is not affected by weather conditions.

- **Ultrasonic and passive acoustic**: these devices emit sound waves to detect vehicles by measuring the time for the signal to return to the device. The ultrasonic sensors are placed over the lane and can be affected by temperature or bad weather. The passive acoustic devices are placed alongside the road and can collect vehicle counts, speed and classification data. They can also be affected by bad weather conditions (e.g. low temperatures, snow).
- **Video image detection**: video cameras record vehicle numbers, type and speed by means of different video techniques e.g. trip line and tracking. The system can be sensitive to meteorological conditions.

Table 1 shows the type of variables provided by different type of detectors. A more complete analysis is given in Annex I along with a summary of advantages/disadvantages of each technology. This study does not detail the factors about the potentials and accuracy of each technology. For a complete review on fixed sensors (e.g. fine technology description, accuracy issues, costs) it is worth consulting the on-line available "Traffic Detector Handbook" provided by the U.S. Department of Transportation [TDH06][a]. Additional sources such as [MART03], [BENN05], [IMAG06] [SCHM05] are also quite relevant in this area.

Detector Type			Volume/Count	Speed	Classification	Occupancy	Presence
I	Inductive Loop		✓	✓ (1)	✓ (2)	✓	✓
	Magnetic		✓	✓ (3)	✓ (3)	✓	✓
	Pneumatic Road Tube		✓	✓	✓	×	×
N	Active Infrared		✓	✓	✓	×	×
	Passive Infrared		✓	✓ (4)	✓	✓	✓
	Microwave Radar	Doppler	✓	✓	✓	✓	
		True Presence	✓	✓	✓	✓	✓
	Ultrasonic		✓	×	×	×	✓
	Passive Acoustic		✓	✓	✓	✓	✓
	Video Image Processing		✓	✓	✓	✓	✓

Note: (1) Speed can be measured by dual-loops with a known distance apart, or by algorithms with a single-loop assuming the length of the detection zone and vehicle.
(2) Advanced detector cards can measure classification using "vehicle signature."
(3) Speed and classification measurement by magnetic detectors requires two units.
(4) Passive infrared detectors with multi-detection-zone capability can measure speed.
✓ - can provide the data type, × - cannot provide the data type

Table 1: Type of data provided by the count technologies
Source: [MART03]

Total costs related to roadside detectors include capital costs (purchase and installation) and operational costs (maintenance, support and day-to-day operation). Orders of magnitude of costs associated to some technologies are given in Table 5 below.

[a] See also http://www.fhwa.dot.gov/policy/ohpi/travel/travelpubs.htm

Unit Cost Element	Lifetime (years)	Capital Cost ($1000)	Cost Date	O&M Cost ($1000)	Cost Date
Inductive Loop Surveillance on Corridor	5	3-8	2001	0.4-0.6	2005
Inductive Loop Surveillance at Intersection	5	8.6-15.3	2005	0.9-1.4	2005
Machine Vision Sensor on Corridor	10	21.7-29	2003	0.2-0.4	2003
Machine Vision Sensor at Intersection	10	16-25.5	2005	0.2-1	2005
Passive Acoustic Sensor on Corridor		3.7-8	2002	0.2-0.4	1998
Passive Acoustic Sensor at Intersection		5-15	2001	0.2-0.4	2002
Remote Traffic Microwave Sensor on Corridor	10	9-13	2005	0.1-0.58	2005
Remote Traffic Microwave Sensor at Intersection	10	18	2001	0.1	2001
Infrared Sensor Active		6-7.5	2000		
Infrared Sensor Passive		0.7-12	2002		
CCTV Video Camera	10	9-19	2005	1-2.3	2004
CCTV Video Camera Tower	20	4-12	2005		

Table 2: Equipment cost of some detectors
Source: ITS Unit Costs Database (Oct. 2007), US DoT
Available at: http://www.itscosts.its.dot.gov

2.2 The Floating Car Data (FCD)

The principle of FCD is to collect real-time traffic data by locating the vehicle via mobile phones or GPS over the entire road network. This basically means that every vehicle is equipped with mobile phone or GPS which acts as a sensor for the road network. Data such as car location, speed and direction of travel are sent anonymously to a central processing centre. After being collected and extracted, useful information (e.g. status of traffic, alternative routes) can be redistributed to the drivers on the road.

FCD is an alternative or rather complement source of high quality data to existing technologies. They will help improve safety, efficiency and reliability of the transportation system. They are becoming crucial in the development of new Intelligent Transportation Systems (ITS).

In this study we focus on floating vehicle technologies based on cellular and GPS probe data. This is one category within the family of mobile traffic probes. The other category of "in-vehicle" collection methods refers to Automotive Vehicle Identification (AVI) techniques. In this case, probe vehicles are sampled at fixed location by means of electronic transponders (tags) that are read as the vehicles pass the sensors. This technology field is not discussed here but widely covered in literature (see e.g. [FHWA98]).

Basically, there are two main types of FCD[b], namely GPS and cellular-based systems:

- **GPS-based FCD**

Even though GPS is becoming more and more used and affordable, so far only a limited number of cars are equipped with this system, typically fleet management services (e.g. taxi drivers). The vehicle location precision is relatively high, typically less than 30m (note that the precision will be significantly improved thanks to the satellite Galileo, see chapter 3).

[b] FCD can also be called Floating Phone Data, Floating Cellular Data, Floating Vehicle Data, Cellular Floating Car Data, etc.

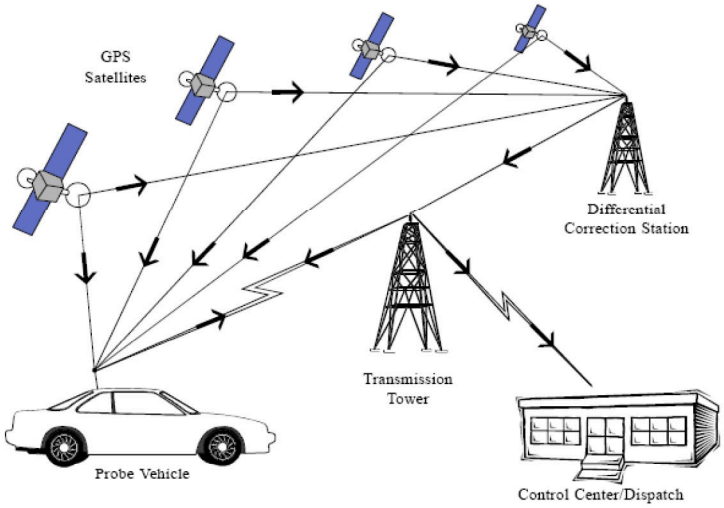


Figure 1: Communication from GPS
Source: [FHWA98]

Generally, traffic data obtained from private vehicles or trucks are more suitable for motorways and rural areas. In case of urban traffic, taxi fleets are particularly useful due to their high number and their on-board communication systems already in place. Currently, GPS probe data are widely used as a source of real-time information by many service providers but it suffers from a limited number of vehicles equipped and high equipment costs compared to floating cellular data.

- **FCD based on cellular phones[c] (e.g. CDMA[d], GSM[e], UMTS[f] and GPRS[g] networks)**

Since nowadays most of the driving vehicles are equipped with at least one or several mobile phones, it may be worth using mobile phones as anonymous traffic probes. The mobile phone positioning is regularly transmitted to the network usually by means of triangulation or by other techniques (e.g. handover) and then travel times and further data can be estimated over a series of road segments before being converted into useful information by traffic centres. Mobile phones need to be turned on, but not necessarily in use. This approach is particularly well adapted to deliver relatively accurate information in urban areas (where traffic data are most needed) due to the lower distance between antennas.

Contrary to stationary traffic detectors and GPS-based systems, no special device/hardware is necessary in cars and no specific infrastructure is to be built along the road. It is therefore less expensive than conventional detectors and offers larger coverage capabilities. Traffic data are obtained continuously instead of isolated point data. It is faster to set up, easier to install, and needs less maintenance. Note however that sophisticated algorithms are required to extract and treat high-quality data before sending them back to end-users. Even if the location precision is generally low (typically 300m), this weakness is partially compensated by the large number of devices. Note that more accurate data should be obtained from the UMTS technology (3G).

[c] Also called Floating Phone Data, Floating Cellular Data, Cellular Floating Car Data, etc.
[d] Code Division Multiple Access (most used in North America)
[e] Global System for Mobile communications (most used in Europe, China, Latin America)
[f] Universal Mobile Telecommunications System (also called 3GSM)
[g] General Packet Radio Service (also called GSM++ or GSM2+)

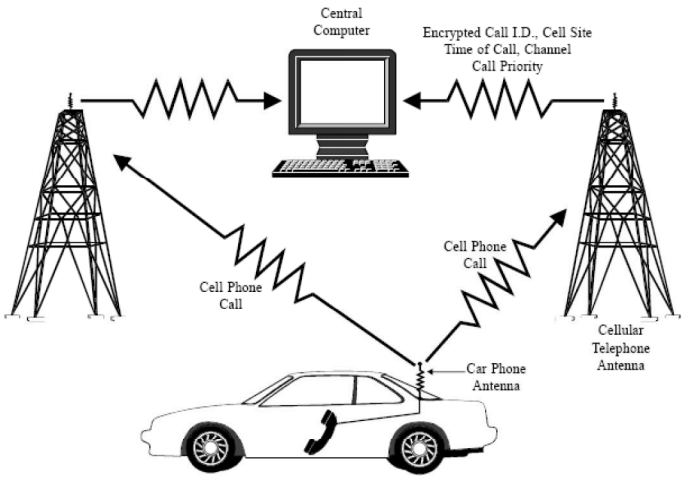


Figure 2: Communication from cellular phones
Source: [FHWA98]

Currently FCD is involved in multiple applications worldwide dealing with real-time traffic information and traffic management. In particular, the emerging commercial applications using FCD as collection method (especially based on cellular phone network) will be discussed in chapter 4.

Key messages

- After years of use and improvements, fixed sensors technologies (e.g. inductive loops) are mature and well recognised to provide precise and relevant data on the current traffic situation e.g. vehicle speed and traffic flow. New technologies (e.g. acoustics and radar) are particularly efficient.

- Public services mainly rely on these data to assess and predict the traffic situation. On-road measurements are essential and will keep on playing a key role in the future.

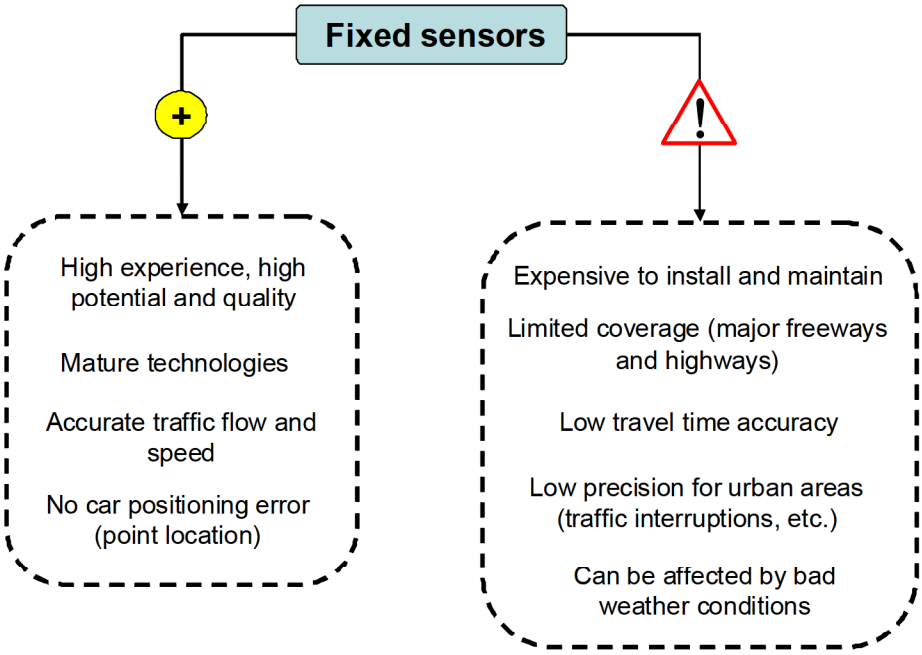


Figure 3: Pros and Cons with respect to in-situ technologies

- However, fixed sensors can generate high costs for setting up and maintaining the required infrastructure. It is also a disadvantage that such technologies, for practical reasons, have extremely limited local areas of use, so that a huge number of devices must be installed to determine the traffic situation in a wide area. Travel times are difficult to estimate with good precision, especially in urban areas.

- Over last years, alternative technologies have emerged which seem able to overcome some of these problems. Collecting real-time traffic data by tracking vehicle position is one of them.

- Floating Car Data is typically based on GPS or cellular probe data. While the first benefits from a high accuracy, it currently suffers from limited sample size and time/spatial coverage. The second however compensates its lower accuracy by relying on a large number of devices spreading all over the road network and represents a very cost-effective source of traffic data.

3 Estimation of annual traffic flow and traffic volume

Two very important types of traffic data delivered by transport centres around the world concern the Average Annual Daily Traffic (AADT) and the Vehicle Kilometres Travelled (VKT). These two raw traffic variables, mainly derived from fixed sensors measurements, play a key role in traffic engineering analysis (e.g. model calibration, determination of traffic exposure functions, etc.) and policy decisions.

3.1 Traffic flow – Average Annual Daily Traffic (AADT)

AADT is the average calculated over a year of the number of vehicles passing a point in a given counting section each day (usually expressed in vehicles per day). It simply represents the vehicle flow over a road section (e.g. highway link) on an average day of the year.

AADT is considered as one of the most important raw traffic dataset where it provides essential inputs for traffic model developments and calibration exercises that can be used for the planning of new road construction, determination of roadway geometry, congestion management, pavement design, and many others. AADT is generally available for most of the European road networks. The data is collected by traffic control centres, refined and disseminated to users by traffic information centres in most of the EU countries.

In this document, one must keep in mind two types of definition of what the "traffic flow" means, depending on the time period considered. On the one hand, AADT is calculated annually for all motorway/road segments. On the other hand, real-time traffic flows can be provided every minute or hour which are measured from traffic count recorders for some motorways links.

Methods for calculating AADT are generally based on data information resulting from two types of counts: permanent automatic traffic counts and short-period traffic counts. A combination of these two measurements is generally employed to obtain an AADT estimate over a larger road network as described below:

- First, permanent automatic traffic recording stations provide continuous counting of the traffic on selected roads (mostly on highways) for the entire year. The advantage is to offer traffic counts that are typically recorded in 15 minute or hourly intervals, 7 days a week and 365 days a year intervals. It thus enables a finer level of analysis and a more accurate annual average than short-term counts. Permanent automatic traffic recorder is the only way to provide exact AADT values (when used under perfect conditions).

- Secondly, short-term traffic counts (also called seasonal, portable or coverage counts) provide roadway segment-specific traffic count information on a cyclical basis for a large number of road segments. The collection data period typically ranges from 1 to 7 days where data are recorded in 15 min or hourly intervals. Due to differences in day-to-day variation in the traffic flow, the count duration is dependant on the road on which it is located e.g. rural or urban. In order to minimize this variation, the minimum requirements could be fixed for instance at 48-hours of continuous data for rural counts and 24-hours of continuous data for urban counts. Furthermore, special

attention must be paid to count sites locations so as to improve the data accuracy [EHLE06].

Estimation methodology

While short-term traffic counts cover a very large network in a limited time, permanent counts are required to handle temporal variations in traffic flow and their main role consists in elaborating adjustment factors to estimate annual daily volume from short duration counts.

The principle is to start with data from short-period traffic counts (generally 1-3 days sample every few years at selected points across large-scale networks). Then adjustment factors provided by permanent counts are applied to remove temporal bias by taking into account the day of week and/or seasonal variations in traffic flow. The procedure is summarized in Figure 4.

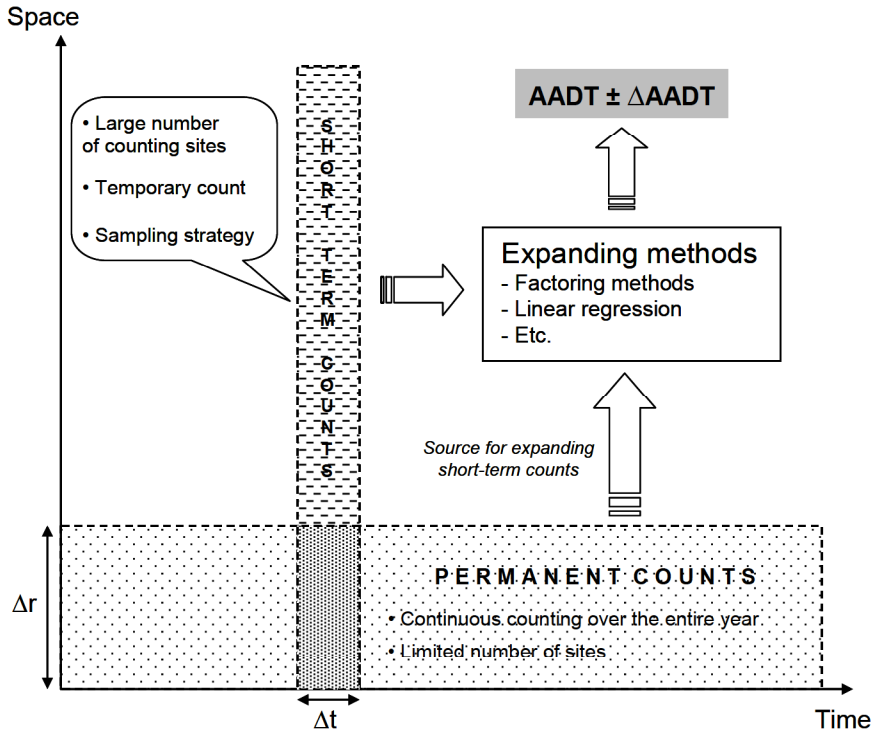


Figure 4: Schematic view of the main procedure for estimating AADT

One of the most common expanding methods for estimating AADT is the factoring method. In this case, the permanent traffic sites are first manually classified into different groups (known as seasonal categories) based on similarities in traffic characteristics of roads. A seasonal factor category is then assigned to each permanent station according to the site locations, assuming that seasonal variability and traffic characteristics at the short-term and permanent count sites are similar in the same geographic area. However, the optimal number of groups and the way of assigning short counts to the seasonal factor groups are the most critical issues.

Although this technique is maybe the simplest one and the most used worldwide, it is still limited in terms of accuracy (see e.g. [GRAN98]). More sophisticated mathematical methods

e.g. linear regression, neural network, genetic algorithm, etc. have been developed to obtain more accurate AADT values.

Accuracy issues

Due to the key role of the AADT in the calibration and validation of travel demand models, special attention is to be paid to its accuracy. Also, without precise AADT, the vehicle-kilometres travelled (VKT) cannot be accurately calculated.

As seen previously, AADT varies by day, week and month, and flow rate estimations generally involve time sampling. On the other hand, the data coverage is often limited, especially for local roads or in rural areas. Typically, when count data are unavailable, estimates are made based on comparisons to roads that are considered to be similar leading to inherent errors. Therefore, sources of uncertainties coming from duration of counts and spatial restriction should be carefully taken into account when estimating AADT.

Also, even if permanent traffic recorders can theoretically collect raw traffic data continuously over the whole year, hardware/software difficulties occur in practice leading to less than complete datasets[h], and some interpolation or more complicated estimation is necessary [TMG01].

As underlined by Gadda et al. [GADD07] there is a limited literature on how to improve AADT accuracy meaning that further research work is still needed to reduce these uncertainties.

Examples of methodologies used

In the **U.S.**, factoring method is the common methodology used to estimate AADT. This method has been adopted by transport agencies as a standard to their traffic collection procedures to match federal guidelines. Although not considered as federal standard, the Traffic Monitoring Guide [TMG01] is designed as a reference document that provides general guidance on the development of traffic monitoring programs for highway agencies. It focuses on the collection of traffic volume, vehicle classification, and weight information. Data collection agencies are then encouraged to consider the TMG methodologies in their administration of traffic data collection programs and to compare the effectiveness of this methodology to the procedures they currently use. Some interesting features are explained below, extracted from the TM guide [TMG01].

"For many years, the traditional approach to the development of AADT had consisted of three different but complementary types of traffic counts: continuous, control, and coverage.

Continuous counts are taken 365 days a year at a small number of locations. These counts provide a variety of useful information (…)

Control or seasonal counts are much more difficult to characterize because different State planning organizations perform these counts differently. These counts are usually taken from two to twelve times a year, for periods of time ranging from 24 hours to two weeks. The main purpose of control counts was to help identify traffic patterns on specific roads in order to

[h] Failure of the counting equipment regularly happens.

help place those roads into seasonal adjustment factor groups. Control counts can also be used to compute highly accurate measures of annual average daily traffic at specific locations, and are very effective in high growth or recreational areas (…)

Coverage counts are short duration counts, ranging from six hours to seven days, distributed throughout the system to provide point-specific information and area-wide coverage. Coverage count programs also vary considerably, as the diverse requirements and constraints faced by State highway agencies have translated into divergent programs. Many States have implemented coverage programs that feature relatively long (2 to 7 days) traffic counts, but where only a part of the State is counted every year. Other States have emphasized complete coverage of the highway systems each year, resulting in a large number of short duration (usually 24 or 48-hour) counts."

In **Canada** however, the situation is quite different since they have developed alternative strategies focusing for instance on the cost-effectiveness of such an evaluation [ROBI03].

In **Europe**, the UNECE [UNECE05] conducts road traffic censuses every five years. The methodology recommended for the 2005 census is available on the UNECE website[i]. They recommend three types of methods for providing AADT (for the year 2005):

- Continuous traffic counts for the entire year;
- Short-term traffic counts;
- A combination of both measurements (sampling methods).

It was also mentioned that "in certain exceptional cases, AADT may be determined without counting, based on previous counts or on counts on adjoining sections of the same road."

As an example, AADT estimates in **Finland** are based on both permanent and temporary (coverage) traffic counts. The short-term counts generally consist of two one-week counting periods. Methods for estimating AADT with such a count period as well as the related accuracy are described [LUTT07]. Also, AADT forecasting in **Lithuania** are based on methods developed by the Idaho DoT [SLIU06], etc.

3.2 Traffic volume – Vehicle Kilometres Travelled (VKT)

Vehicle-kilometres refer to the distance travelled by vehicles on roads. It is often defined as an indicator of traffic pressure[j] (or traffic demand) and is generally used to indicate mobility patterns and travel trends. It plays a key role in various important decision-makings such as air quality compliance, roadway pavement maintenance, risks of accident, etc. Due to its high impact on policy decisions, it is then critical to have an accurate estimation of VKT[k].

[i] The Working Party on Transport Statistics (WP.6) contributes to the development of a coordinated statistical system for transport in order to provide high quality data to the users. UNECE, the European Conference of Ministers of Transport (ECMT) and Eurostat have a very close cooperation within the Intersecretariat Working Group (IWG) in order to harmonise definitions, to reduce the data-reporting burden on member countries through common data collection, to exchange and disseminate data and to create methodologies.
[j] Another possible indicator of transport pressures is vehicle ownership
[k] While VKT can reflect community behaviour, VKT per capita can be used to highlight individual contributions.

Estimation methodology

The estimation of traffic volume[1] is not as straightforward as the traffic flow. Estimation procedures are well described in literature [FRIC02] and are not covered in this section. However, there are basically four methods to calculate vehicle-kilometres, which vary between Member States [UNECE05] [UNECE07].

- Odometer readings (vehicle-based method) - At regular vehicle inspections, the average distance travelled by the vehicles is determined and then multiplied by the number of road vehicles. It is mainly used by the Netherlands, Denmark, Latvia and Switzerland.

- Traffic counts (road-based method) - For one considered link, the vehicle-kilometre is calculated by multiplying the AADT by the length of the link (in km). VKT for a motorway area can then be obtained by adding up the VKT of each segment. It is the main methodology used for estimating VKT in Belgium, Finland, Estonia, Hungary, Czech Republic, Poland, Slovakia, Slovenia, the UK and Sweden (and also in the US). As a basic example of estimation, the AADT on a motorway segment can be given by:

$$AADT_s = \sum_{j=1}^{365} \frac{TF_{s,j}^{24}}{365}$$

where $TF_{s,j}^{24}$ is the 24-hour traffic flow on segment s at day j. In this case, the average daily traffic volume can be estimated as:

$$VK = \sum_{s=1}^{Ns} L_s * AADT_s$$

where L_s is the length of the segment s and N_s the total number of segments.

- Driver survey – For instance, a questionnaire is sent every year to thousands households with one or more cars which are requested to provide several information such as the number of kilometres driven by each vehicle during the whole year and unit consumption. It is generally used by some countries as a supplementary source of information.

- Fuel consumption - the volume of road traffic is estimated from information about fuel supply and fuel consumption as derived from estimates of kilometres driven per fuel litre for typical types of vehicles. It is for example used by France, Austria and Portugal.

[1] Note that in the U.S. "traffic volume" means very often AADT.

Country	Body	Odometer	Driver survey	Road counts	Fuel
Austria	Kuratorium fuer Verkehrssicherheit				●
Belgium	IBSR	×		●	×
Czech Rep.	Ministry of Transport		(×)	●	
Denmark	Danish Road Directorate	●	×	(×)	
Estonia	Estonian Road Administration		(×)	●	
Finland	Finnish Road Administration	×	×	●	×
France	Ministry of Transport		×	×	●
Germany	German Federal Highway Research Institute (BAST)		×	×	×
Greece	National Technical University of Athens		(×)		
Hungary	Institute for Transport Sciences			●	
Latvia	Latvian Road Safety Directorate	●			
Lithuania	Police Department	(×)			
The Netherlands	Statistics Netherlands	●			
Poland	General Directorate for National Roads and Motorways/Central			●	
Portugal	National Laboratory of Civil Engineering			(×)	●
Slovakia	Ministry of Transport, Post and Telecommunications Statistical Office of the Slovak Republic		(×)	●	
Slovenia	Road Directorate		×	●	×
Sweden	Statistics Sweden	×		●	

● Main source for vehicle-kilometres
× Supplementary source or research
() Do not cover all vehicle-kilometres in the country

Table 3: Methods currently used for calculating vehicle-kilometres by some EU countries
Source: [UNECE05]

Key messages

- AADT is a crucial raw traffic data for countless of applications. The estimation methodology is typically based on both continuous and temporary traffic counts that are afterwards used as inputs to sophisticated mathematical models. The AADT accuracy still requires some improvements, which may come from satellite imagery.

- The methods for estimating VKT widely differs amongst Member States. In some countries, at the moment there is no official methodology established. This issue was well addressed by the UNECE [UNECE05].

4 FCD*: from testing to marketing

4.1 Capabilities and limitations

Potential applications and benefits

The core question about FCD is not about whether this technology is an efficient way to collect real-time traffic information (which seems to be the case), but rather to assess what kind of applications and benefits it could provide in the short to medium-term. More accurate and relevant real-time traffic information could lead to a lot of improvements in many areas. Improvements such as:

- Congestion reduction
- Improved O-D matrices (commuter plans)
- Traffic queue detection
- Improved incident management
- Optimization of existing infrastructures through a better use of the current road network
- Dynamic network traffic control
- Improved information services e.g. traffic information, dynamic route guidance, road message signs, etc.
- Improved quality of information transmitted to individual drivers (real-time data) thus increasing their attractiveness to these technologies
- Improved vehicle fleet management
- Shorten driving times thus reducing costs
- Plan for future investments
- New perspectives in transport modelling: real-time data could be used to set up dynamic transport models capable to provide forecasts in a very short period of time
- Reducing fuel consumption (and thus lower CO_2 emissions) and air emissions

Therefore, these improvements are expected to affect all the transportation actors, although at different degrees (Table 4). For instance, road users will receive real-time and reliable information concerning the best routes from their location to their destination whereas road managers will have a cost-effective tool to obtain continuous/wide-covering data leading to better traffic monitoring in real time, better understanding of the traffic patterns and plans for future investments.

* It should be kept in mind that FCD is a general term defining traffic data collection from "in-vehicle" information. In the rest of this study, we focus on FCD based on mobile phones positioning which is considered as a very promising technology.

Actors	Applications
Government/public authorities	Congestion monitoring; local transport plans; journey time studies; planning studies; air pollution studies; OD matrices
Logistics and fleet operators	Vehicle fleet planning
Location based service providers	Predictive routing
Consultants	Congestion monitoring; journey time studies; planning studies; air pollution studies; transport studies
Map providers	Predictive journey times
Marketing	Optimized Traffic Systems – Static mobile sites; campaign planning; site planning
Automotive manufacturers	RDS-TMC live data for mobility portals; NavTrack GPS tracking solutions
Telecommunications	Real-time traffic information; short dial telephone traffic service

Table 4: Potential applications derived from the FCD technology
Source: ITIS Holdings (http://www.itisholdings.com/applications.asp)

Key issue: the Extended Floating Car Data (XFCD)

As seen in chapter 2, FCD usually provides information about the vehicle position, travel times and speeds. However, new types of high precision data can also be generated by the vehicles in order to get a better picture of the traffic conditions and beyond. Since a wide range of information is already recorded in a car, it would be a shame not to exploit them.
In-vehicle information can be used, for instance, to report immediately about traffic jams, detect weather conditions (e.g. data from the activation of windshield wipers, temperature sensors and headlights), road surface state (e.g. the operation of ABS system can be used to detect slippery road conditions, risk of aquaplaning or black ice) and many others (Table 5).

On-Board Sensor	Traffic Application	Weather Application	Road Management Application	Safety Application	Map Database Application
Position (latitude/ longitude)	core data	core data	core data	core data	map corrections
Vehicle heading	core data		core data	core data	core data
Speed	traffic flow status			advance notice of stopped traffic	
Ambient Temperature		icing conditions	application of de-icing	indicator of road friction	
Windshield Wiper Status	traffic slowing due to intense precipitation	precipitation	spot flooding	indicator of road friction	
Longitudinal Acceleration/ Deceleration	detect sudden slowdown indicating a traffic incident		earlier dispatch of incident response teams	advance notice of traffic incident	
Lateral Acceleration			detect hazardous ramp and road curvatures	input to Curve Speed Warning system	
Anti-Lock Brake System Activation			detection of slippery road for dispatching maintenance crews	detection of slippery road	
Traction Control System Activation			detection of slippery road for dispatching maintenance crews	detection of slippery road	
Suspension			presence of rough road or pothole		
Obstacle Detection	first indication of condition to cause a traffic jam		removal of obstacle	input to crash avoidance system	

Table 5: Examples of FCD/XFCD applications
Source: [BISH05]

The application field is immense. Huge potentials are offered to road managers and drivers based on the high quality real-time information supplying by on-board computer systems. Also, XFCD does not need any hardware into the vehicle, only software is required (but quickly installed). The data can be transmitted to the traffic centre or directly exchanged between vehicles. XFCD has become an important research area and this technology is being tested and validated in the frame of several demonstration projects worldwide. For example, the BMW Group[m] carried out a demonstration of this technology over a special test track in San Francisco, in the framework of the "Innovative Mobility Showcase". While a vehicle was driving on a slippery surface, information about the low traction was detected and immediately transmitted to the following vehicles in real-time. The data was also simultaneously forwarded to a control centre to be processed and displayed on websites.
When compared to FCD, XFCD is a more cost-effective way of collecting data since not all the data are sent to the road managers, but only the most relevant ones. Communication costs are therefore reduced while at the same data quality is improved.

Emerging FCD application: personal CO2 meter and insurance premiums

Along with traditional criteria for calculating the insurance premium such as vehicle type, bonus level, etc., information about the vehicle consumption can also be taken into account by means of high quality position tracking systems. The Italian telematics company OCTO Telematics (world leader in telematics insurance; see also chapter 4) is currently implemented such a system in Europe where the "Ecological footprint" will become a new criteria in the calculation of the premium. This approach was already adopted by the Austrian company UNIQA which awards an "ecological bonus" discount up to 25% to their clients driving less than 10 000 km annually. OCTO Telematics is about to launch a system displaying in real-time the CO2 levels of a car.

[m] Further information are available at: http://www.bmwgroup.com/

Complexity level of the process

As illustrated in Figure 5, data processing flows are somewhat complex. The communications act in two steps namely reporting data from vehicles (e.g. through GSM today and through UMTS in the near future) and transmitting data back to the drivers as the ultimate user.

Extraction methodologies (see e.g. [PAN06]) are far from being trivial since it involves the reconstruction of the road and cellular network within a digital mapping system and the handling of a large volume of information. Journeys being undertaken not using vehicles must be filtered out by means of pattern matching. As with GPS point data, map-matching is required to link point locations to specific roads.

One of the weaknesses of this technology is that the continuous transmission of the speed of a large number of vehicles generates an important heavy load on the transmission channels and therefore constitutes a significant cost factor in using a fee-based communications system. For this reason, it would be preferable to transmit compressed data rather than individual values to the centre responsible for the traffic data collection and process. For example, the average speed of a given vehicle could be transmitted to the centre at chronological intervals. However, this is still very expensive. It would be much more effective to filter data according to their relevance. For example, the transmission could be limited solely to information concerning detected traffic congestion.

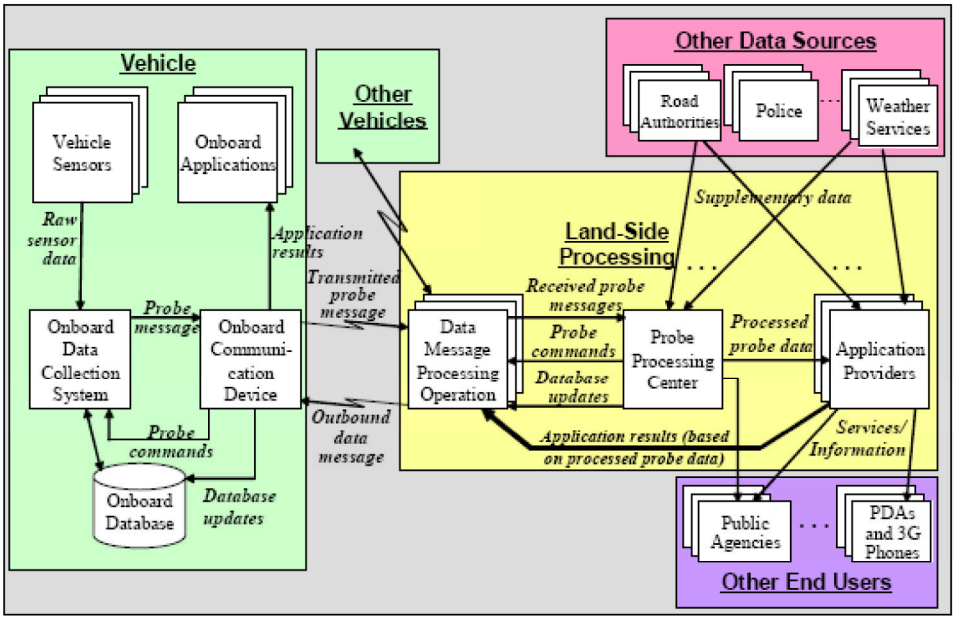


Figure 5: Typical probe data processing flows
Source: [BISH05]

Accuracy and sampling issues

It is clear that the level of accuracy expected from FCD highly depends on the level of error related to the vehicle positioning. This depends on the technology used to calculate the mobile phone location. Obviously, any errors on the location could significantly affect the speed estimates. As reviewed by Rose [ROSE06], several studies have compared speed data

measured from inductive loops (as a reference "truth" value) against speed estimates providing by mobile phones. Globally, the results showed a good correlation between the two speed measurement methods, although depending on the road section considered.

Moreover, the problem of determining the right number of vehicles tracked as well as the time intervals are critical issues to obtain reliable[n] pictures of the traffic situation. Given the level of accuracy of the technology used, typical questions are:

- How many probe vehicles and so how many sample observations are needed to provide an accurate and reliable information (sample size)? In other words, what should the minimum number of tracked vehicles be to get relevant results? This question is critical and highly depends on the technology capabilities and limitations used. As an example, a sample of 3000-5000 probe vehicles was estimated to be a reasonable range to provide reliable travel times in metropolitan areas [ROSE06].
- How often should the information be received (sampling time)?
- Last but not least, what does the transportation engineer consider as an 'acceptable' level of standard deviation (e.g. for mean speed calculations)?

In the last years, a wide number of studies [YIM01] [ZHAN07], [BARG07], [ASTA06] has addressed the accuracy and sample size/sample time issues associated with FCD (e.g. by comparing different measurements methods with regard to speed or travel times estimates, sampling time optimization, etc.). However, further R&D efforts are still needed.

Privacy concerns

When speaking about FCD, perhaps the main concern is related to privacy issues. What type of data is being collected? By whom? For how long? Although it is technically feasible to use FCD as a monitoring tool[o], the FCD service provider give assurances about the data protection ensuring that all the data collected are anonymous. This is a fundamental issue for probe vehicle systems and several technical approaches have been implemented to make FCD systems anonymous e.g. based on cryptographic mechanisms [EICH06], [SATO07]. But this concern is quite similar to other recurrent questions on mobile phones, emails and so on, that people worry about. The management of personal data related to traffic probes has to be addressed through clear policy messages to gain the people's trust. For the time being, the mobile phone operators are rather hesitant about exploiting their clients' data. Moreover, different associations worldwide are opposed to this "tracking" technology.

Questions concerning the data ownership are also of high importance. Who will own these huge databases? Should it be shared amongst the actors? This is a critical issue that has to be tackled in the short-term given the impressive deployment of the market.

For personal data protection, common operational rules must be created and respected by service providers who handle personal data. For this purpose, international standard is being developed (ISO/TC204/WG16)[p] to establish "basic principles for personal data protection in probe vehicle information services". The lack of common standard procedures to all service providers might generate public distrust in this technology.

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[n] "Accuracy refers to the level of error on average, while reliability is usually interpreted to mean the variability about the average" [ROSE06].

[o] As a recent example, Google can roughly estimate the position of the user via his mobile phone connected to internet and loading it on Google Map. Even still not very accurate (around 1km or less), this new function is under development.

[p] http://www.isotc204wg16.org/

Costs issues

The use of stationary detectors, cameras, or even helicopters can be very costly and cannot cover a large network area. Hence, given the high costs required for an efficient traffic management, the use of cellular phones as traffic probes could become an interesting alternative to cope with recurrent road congestion and difficult traffic regulation, at affordable costs. This applies even more so in large cities (e.g. North America metropolitans) which suffer from chronic high traffic density.

There is no doubt that FCD is a more cost-effective method of data collection, along with a more consistent level of accuracy, when compared to traditional measurement techniques. As order of magnitude, the U.S. public authorities have to spend more than $1 billion each year to monitor traffic for cover only 1% of the national road network (it usually costs around $100.000/mile in roadside sensors). It is widely proven that FCD can do much better for less money.

However, this technology requires the spending of a relatively large amount of money in communication costs. R&D efforts are still necessary and synergies must exist with all the actors to support the cost of the communications equipment.

4.2 Market development

Currently, several service providers worldwide have integrated floating car data from cellular phones within their raw traffic data sources. Most often, these companies rely on multiple sources coming from fixed sensors and fleet companies (e.g. taxi fleets with GPS). FCD via mobile phones represents a new cost-effective alternative that require strong partnerships amongst actors, especially with telecommunications companies. Real-time data are afterwards transmitted to users via their mobile phone and Radio Data System – Traffic Message Channel (RDS-TMC)[q].

Main service providers

- **TomTom** (http://www.mobility.tomtom.com/)

In November 2007, TomTom commercialised its "HD Traffic" (High Definition) service[r] in the Netherlands to be primarily available with a new product called TomTom One XL HD Traffic. The same operation was launched in the UK and will be extended to Germany (2008) and France (2009) through a partnership with Vodafone (as it is already the case in the UK and Netherlands). This HD technology is based on a mix of traditional data collected from fixed detectors and data generated from cellular phones via the Vodafone network (e.g. speed, direction). According to TomTom, its new HD system can cover the entire highways network plus most of the secondary roads (TomTom claims its HD Traffic covers at least ten times more roads in the Netherlands (22.000 km) than existing traffic information systems). The data are updated every 3 minutes enabling the user to anticipate/optimise his travel route in real-time.

[q] See e.g. the website http://www.tmcforum.com/ which provides a list of active TMC services worldwide.
[r] Historically, HD Traffic is based on the technology developed by Applied Generics, a Scottish start-up acquired by TomTom in 2006 whose main product was the RoDIN24 technology capable to generate real-time information (travel times) from mobile phones connected to the GSM network.

Up to now, the cost of one year subscription to the TomTom service was €399 (One XL HD Traffic). Afterwards, the subscription to the TomTom HD can be renewed for €9.95 per month in the Netherlands. TomTom is about to extend its product to other EU countries in 2008. Also, different actors (e.g. car manufacturers, traffic centres) could benefit from their high quality information and services. TomTom is certainly the first company in Europe to make this type of technology available as a consumer product.

- **Cellint** (http://www.cellint.com/)

Cellint is an Israeli company whose main activities take place in the US. It is a leading provider of cellular based detection solutions especially through the TrafficSense system which uses mobile phones to provide a real-time picture of the road traffic situation. The high quality data are sent to different algorithms that calculate accurate travel times and identify the best routes. In a second step, the information is sent back to the users. In the last years, Cellint has developed it systems over a large coverage in several countries with very good results. The TrafficSense system is very cost-effective and appears as one of the most competitive tools in the market today.

- **Airsage** (http://www.airsage.com)

Airsage is a US company created in 2000 in Atlanta. They sell real-time traffic information to local, state and federal transportation agencies (as well as to private companies for fleet management and TV and radio stations) in 46 US cities in partnership with Sprint Nextel. Especially developed for state departments of transportation, the TrafficWiSE Product Suite help them coming up with better route planning and emergency services, and also to "maximize their return on invested transportation dollars". Globally, their information seems to be cost-effective and able to estimate with a high accuracy the amount of congestion.

- **IntelliOne** (http://www.intellione.com/)

Also based in Atlanta, IntelliOne has entered the "FCD" business since 1999. They present a similar strategy as Airsage since they provide government agencies with real-time traffic data in partnership with Sprint Nextel network. IntelliOne reports real-time speeds over a large road coverage (see Live!Traffic in Figure 6) and travel times and provide high quality traffic guidance to the users through the TrafficAid system (no prices are given though). A pilot program was set up in Tampa (Florida) and further programs have been launched recently e.g. in Canada.

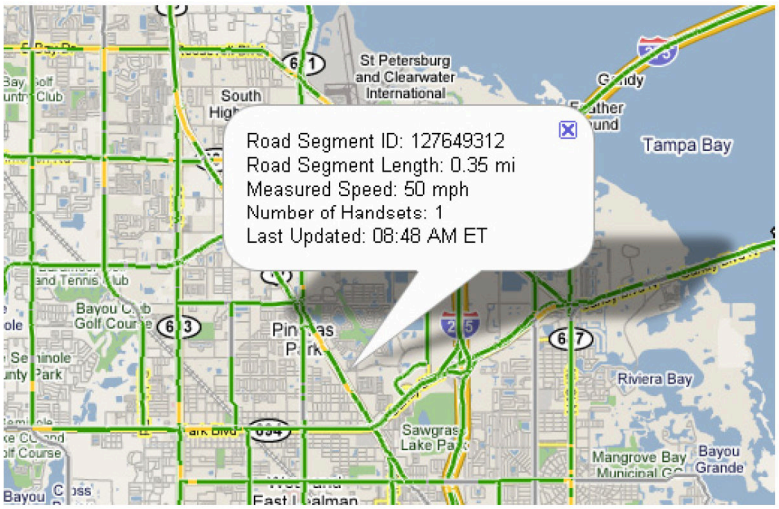


Figure 6: Real-time speed delivered by Live!Traffic (IntelliOne) on virtually all roads in the Tampa area
Source: IntelliOne (demonstration only)

- **ITIS Holdings plc** (http://www.itisholdings.com)

ITIS Holdings is the UK's leading provider of real-time traffic information services. ITIS has developed a unique system for the collection and analysis of traffic information that enables traffic flow rates to be known in real-time. Journey time forecasts are also provided. Their customers serve as both the data providers and data consumers. They have tested (and also validated, see the Antwerp case study) real-time traffic data based on cellular floating vehicle over large road networks in England, Scotland, Missouri, Baltimore, Israel, Antwerp and Australia.

- **Mediamobile** (http://www.mediamobile.com)

Mediamobile is the main operator of traffic information in France. In 2009 Mediamobile plans to improve its current system (V-Trafic) by means of 65.000 probe vehicles (partnership not yet defined).

Note that other major actors in this area are Inrix[s], Decell[t] and TrafficCast[u].

Selective pilot projects

Project intends to demonstrate the technological feasibility of a traffic data system based on cellular phone tracking. Several demonstration projects worldwide have experimented with the use of FCD to collect traffic data (see e.g. the literature review of U.S. pilot projects carried out by the Florida Department of Transport [FLOR07a] [FLOR07b] [FLOR07c] as well as the French Ministry of Transport [GEND06] who provides an interesting analysis of the FCD opportunities). Some examples are highlighted below:

The project **SINERGIT**[v] (Système d'INformation sur les dEplacements par véhicules tRaceurs avec Galileo pour l'agglomératIon Toulousaine) was launched in June 2006 by the

[s] http://mobile.inrix.com/
[t] http://www.decell.com/
[u] http://www.trafficcast.com/
[v] http://sinergit.sodit.eu/

"Pôle de compétitivité Aerospace Vallée" in Toulouse with a budget of 2.8 million euros. It is financially supported by the ANR (Agence Nationale pour la Recherche) and The Community of Agglomeration of Greater Toulouse (Grand Toulouse). Stakeholders are SODIT (coordinator), Pole Star, France Telecom R&D, INRETS, Thales Alenia Space and CETE Sud-Ouest (ASF). The objective is to integrate traffic information from cellular phones to traditional measurement systems already existing like GPS, fixed detectors or cameras. The combination of different sources of data will provide higher quality traffic information leading to a better assessment of the traffic situation. The data are collected and processed at the Sinergit platform before being spread to the different traffic information services (e.g. V-Trafic, Via Michelin). Real-time data are then distributed to users via their mobile phone or GPS and also to different operators to be analysed. It is worth mentioning that Sinergit relies on the first generation European GNSS system (EGNOS) enabling a high precision (up to 10 meter). The first tests are expected in spring 2008 on the main Bordeaux-Toulouse road.

In 2004 in **Antwerp**, the Ministry of the Flemish Government along with the mobile telephone operator Proximus and ITIS Holdings launched a project on Floating Car Data in the region of Antwerp. The objective was to assess whether data collected from mobile phones (e.g. travel times) provided accurate traffic information. The Traffic Centre of Flanders was in charge of determining their accuracy and their added value to traffic management. As a general conclusion of this project it was showed that the technology was quite able to accurately detect the traffic trends over time and per road segment. The prediction was however most accurate in the case of free traffic flow rather than congested conditions. Furthermore, a validation study was carried out by Maerivoet et al. [MAER07] by comparing traffic data stemming from cellular floating vehicles with other traffic sources such as single inductive loop detectors and GPS-equipped probe vehicle. They concluded that this technology "has a large promising potential that is ready to be cultivated upon, as a stand-alone technology or in aggregation with existing road-based detectors. At this moment, it easily outperforms the standard road-based detectors such as single loop detectors that are widely used".

The **TrafficOnline** Project in Germany (2002-2005) focused on the applicability of on-line traffic data acquisition via mobile phone networks. The project was funded by the Federal Ministry for Education and Research (BMBF) in order to develop "an innovative and worldwide portable and thus applicable system for the online detection of road traffic detection". As a result, it was showed that mobile phones can provide reliable detection of traffic congestion, depending on the area covered (better results obtained for motorways compared to cities). An analysis of some results of this project was carried out by Hopfner et al. [HOPF07].

In Kansas City (Missouri) in 2006, a contract was signed between Kansas DOT and Cellint to compare road traffic data obtained from mobile phones (via the TrafficSense system) to the existing road sensors data (via the SCOUT road sensors system[w]). The traffic data analysed were speed and traffic slowdowns over the selected roadways (note that slowdowns are defined as a decrease of speed by at least 10 mph during less than 10 minutes, where the speed before the slowdown is higher than 50 mph and the speed during the following 10 minutes drops below 50 mph). In Kansas City, sensors were placed on a 70-mile (stretch of highway) for $15 million. Cellint claimed that they could cover all of the metro area for a lot less money. Actually, TrafficSense can be cheaper than a sensor system by as much as two

[w] http://www.kcscout.com/

orders of magnitude. Several analyses were carried out within this project leading to a large set of results. Very high correlation between the cellular data and those obtained from the existing loop detectors were observed. For instance, the average latency of detecting slowdowns by TrafficSense in comparison to road sensors at sensors' location is about 4 minutes. Also, the average difference between the systems in measuring the local speed over the sensors was found to be less than 5 mph. This was the first cellular based traffic data collection system in the U.S. to be successful at a controlled pilot, with results that were verified by an independent examiner. A list of similar pilot projects in the U.S. is given in Table 6.

Geographic coverage	Provider	Client	Status
Hampton Roads, Virginia	AirSage	Virginia DOT	Pilot test
Interstate 75 (I-75) between Atlanta and Macon, Georgia	AirSage	Georgia DOT	Pilot test
State Route (SR) 400 in Atlanta	Cellint	GDOT	Deployment
Tampa, Florida	IntelliOne	Not Applicable	Pilot test
Baltimore, Maryland	ITIS Holding	Maryland DOT	Pilot test
Missouri (Statewide)	ITIS Holding	Missouri DOT	Deployment
Kansas City, Kansas	Cellint	Kansas DOT	Deployment
Kansas City, Kansas	AirSage	Traffic.com (for the Utah DOT)	Deployment (currently in testing)
Salt Lake City, Utah	AirSage	Minnesota DOT	Pilot test
Interstate 94 (I-94) between Milwaukee and Madison, Wisconsin	AirSage	Wisconsin DOT	Deployment
Interstate 95 (I-95) from Maine to Florida	To be decided	I-95 Corridor Coalition	Deployment

Table 6: Review of specific U.S. projects using cellular phone location for traffic management
Source: Florida DoT [FLOR07c] (review carried out in 2007)

In Minnesota[x] (University of Minnesota - Centre of Transport Studies) a pilot project was launched in 2007 on the evaluation of cellular phone traffic data. In this project, travel times estimated from inductive loops and probe vehicles will be compared to 'ground truth' travel times obtained by matching license plates on recorded video.

In Canada[y], a project was carried out in 2004 (until 2005) about the development and demonstration of a system using cellular phones as traffic probes in order to monitor traffic conditions. The project was led by Globis Data in partnership with Bell Mobility. It should be noted that for this project cellular phones were equipped with GPS system, leading to a precise car location. The results were quite positive.

4.3 Open questions

Market perspectives: is FCD still a concept?

The response to the above question is that FCD is clearly not a concept since it has become a real technology which is being deployed worldwide. Suppliers are present and the demand is continuously increasing (e.g. a U.S. study recently concluded that most of people are willing to pay 10 Euros per month to get accurate traffic information).

[x] http://www.cts.umn.edu/Research/ProjectDetail.html?id=2007022
[y] http://www.tc.gc.ca/tdc/summary/14300/14359e.htm

Even if further R&D and demonstration projects are still needed, the technology has been tested and validated all over the world. The FCD approach has thus evolved from a simple concept to a growing business.

However, several barriers still need to be overcome in order to achieve a mature market such as privacy concerns and standardisation. This is expected to be gradually solved.

A strong cooperation between players is growing to help the market to become mature. Each of them comes up with their own interests and would share significant profits with service providers. For instance, FCD may bring a supplement source of revenue to mobile phone operators.

Lately, a study from ABI Research[z] entitled "Traffic Information for Navigation Systems" analysed the different methods for traffic information. The report identified key market drivers, important players, and provided detailed forecasts for each major region. According to this report, traffic information services will reach more than 83 million paid or registered users worldwide by 2012.

Are there still uncertainties about the technology?

Some questions arise concerning the level of accuracy of such technology. Although the information resulting from past and current demonstration projects was found to be accurate and reliable, there is still a lack of independent evaluations regarding the quality of data. This issue is very often discussed in ITS conferences[aa] through core questions such as "How good the quality of the traffic data is? To which extent city areas with small roads can be covered? To which extent irrelevant data can be filtered out? Or how different variations of the cellular technology compare? Clear answers from service providers (if they are willing to share the information) would considerably increase the trust of potential buyers.

Another technical concern is related to the shift from current GSM-2G to GSM-3G (i.e. UMTS) network and how this change will be handled by the suppliers.

Role for policy makers?

Data collection using FCD is becoming an important business for the private sector for which the public sector is one of its best clients. Role of governments in implementing probe vehicle systems might be as follows:

- stimulate market mechanisms and initiatives, especially for medium scale pilot (>1000 cars)
- improved dialog with the actors (e.g. concerning the role of car makers)
- finance support schemes in early years to encourage the deployment of FCD technology. This would last until a sufficient mature market has emerged.
- address privacy and data ownerships issues (see e.g. the "Vehicle Infrastructure Integration" in the U.S.[bb])

[z] http://www.abiresearch.com/products/market_research/RTS
[aa] See e.g. the "European Congress and Exhibition on Intelligent Transport Systems and Services" at www.itsineurope.com
[bb] http://www.its.dot.gov/vii/

Role of the satellite Galileo[cc]?

Satellite-based technologies will offer many advantages compared to existing traditional systems [RTMS03]. Significant improvements are expected in two main areas:

- Improved AADT estimates (and so VKT if based on traffic counts, see chapter 2): high-resolution images from satellites are increasingly used as additional source of data to improve the estimation of AADT and vehicle-kilometres (see e.g. [MCOR02], [JIAN06]).

- Higher accuracy for vehicle positioning expected from Galileo may significantly improve the potential of GPS-based FCD technology. Together with its high precision, Galileo may allow FCD to become a much wider, more accepted data source to help achieve a variety of policy objectives [SCIIM05].

How will FCD improve traffic modelling?

Firstly, FCD can be very useful to provide real time calibration of historical traffic models. Secondly, the intelligent combination of FCD with on-road sensors represents the perfect inputs to dynamic traffic models. New algorithms for data fusion will take benefit of the advantages and disadvantages of each technology, resulting in an optimal solution for traffic management problems. By this mean, transportation model could provide short-term predictive traffic information (15 to 30 min). For instance accidents (e.g. collision) could be automatically detected thanks dynamic models fed by high quality real-time data (i.e. through fusion techniques[dd] which can also include meteorological data and other parameters). This faculty in anticipation will constitute a very efficient mean to reduce incidents and improve traffic conditions [FRAS07].

[cc] The EU Galileo system is expected to provide a constellation of approximately 30 satellites that will potentially allow positional accuracy in the sub-metre range. Further information is available on the EC website http://ec.europa.eu/dgs/energy_transport/galileo/index_en.htm.

[dd] Broadly speaking, the data fusion techniques take into account the qualities and weaknesses of traffic sources and combined the data to give a precise picture of the traffic.

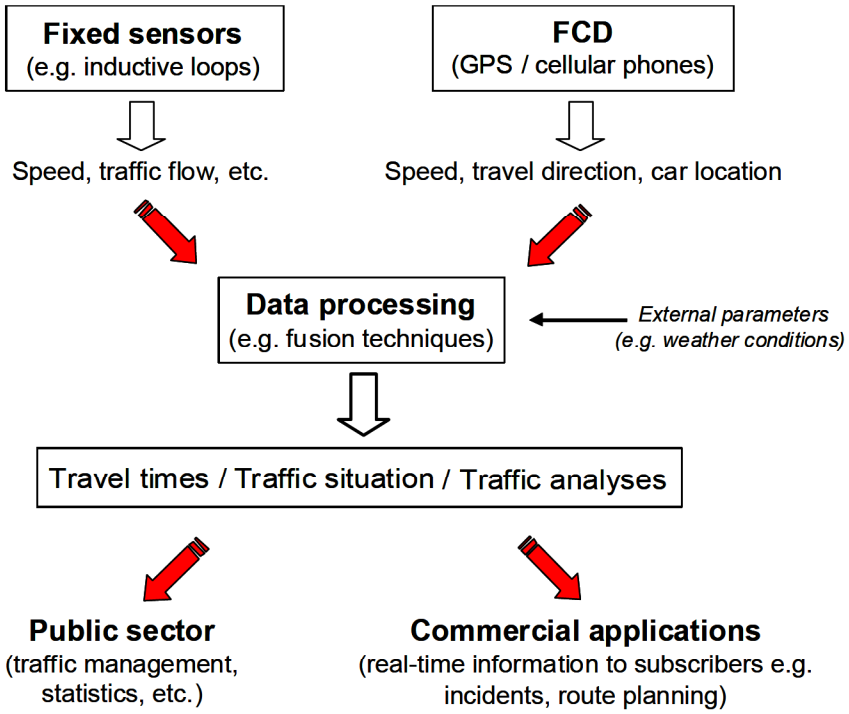


Figure 7: Schematic view of the use of traffic data

Key messages

- Knowing that in some countries there are more cellular phones than people, there is no doubt that FCD is a very promising source of real-time traffic data that will be used as a complement source to existing technologies.

- Even if R&D efforts are still required, the FCD technology is able to provide large amount of high quality traffic data over large road networks, at lower cost than traditional collection methods. Strengths of FCD comparing to traditional detectors are well identified, there are still difficulties to be overcome (Figure 8).

- Several pilot projects worldwide have demonstrated the technical feasibility of FCD (from cellular phones) with globally good results compared to traditional collection methods.

- A market of real-time traffic information with FCD as data sources is growing. Suppliers can provide new services, at competitive costs, to more and more users who are willing to pay for having precise traffic information in real-time. However, it is difficult to get a clear overview of the current status of the market.

- Major obstacles for the success of FCD deployment concern private issues, costs of communication, need for clear policy framework and standards, better transparency about the technology performance from the providers, and improving the synergy between the actors (mobile phone operators, traffic engineering, service providers).

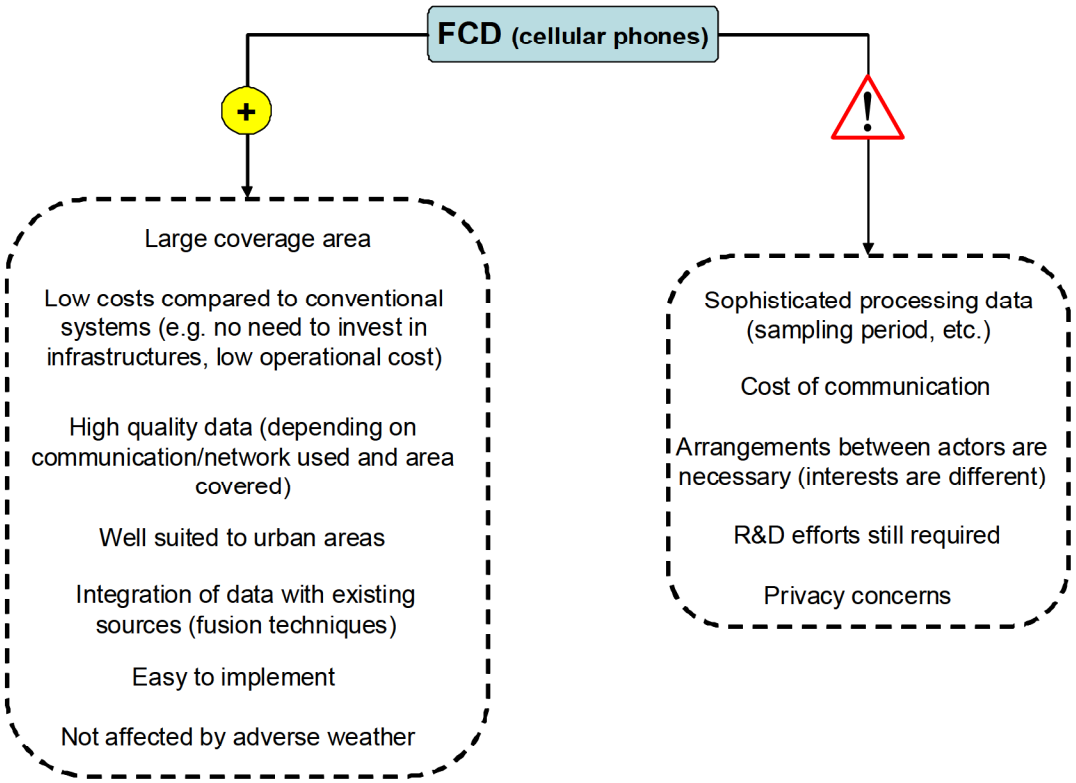


Figure 8: Pros and Cons with respect to the FCD technology

5 On-line available real-time traffic data

In this chapter we propose to identify some relevant sources providing real-time traffic data on-line. It should be noted that "real-time" traffic data is assumed here to be daily, hourly or even per minute data (typically used in the U.S.) which are generally made available by national traffic centres. Most of the examples proposed hereafter are available free on-line and most of the time provided by the national department of transports without requiring any registration access.

The traffic data are most often obtained from permanent count stations installed on major roads (generally on motorways). Therefore typical parameters are traffic flow and average speed. Further data such as occupancy rate and travel times (e.g. calculated from FCD) can also be collected. Although these raw data are implicitly collected by transport centres for many years, more and more countries are making them available on-line by means of new displaying tools (e.g. Google maps).

5.1 In Europe

Spain

Since summer 2007, the DGT (Dirección General de Trafico) of the "Ministerio del Interior de Espana"[ee] has been providing a large amount of real-time traffic data that are integrated in Google Maps. The user can then easily collect real-time traffic flow and average speed from 4000 traffic sensors located over the Spanish road network.

This tool is still at an early development stage and only a limited part of Spanish roads are covered. For instance, it is possible to collect hourly traffic flow and average speed in the surroundings of Madrid (Figure 9) from sensors located on motorways links (e.g. A6, M40, M11). These sensors provide us with 4 raw traffic parameters every hour namely traffic intensity, average speed, occupancy rate and percentage of light duty vehicles. Historical data are also available for different time periods (Figure 10).

It is probably one of the best traffic information tools that are currently freely accessible on-line in Europe.

[ee] http://infocar.dgt.es/etraffic/



Figure 9: Typical information provided by the DGT traffic map (motorways around Madrid)
Source: Dirección General de Trafico (http://infocar.dgt.es/etraffic/)

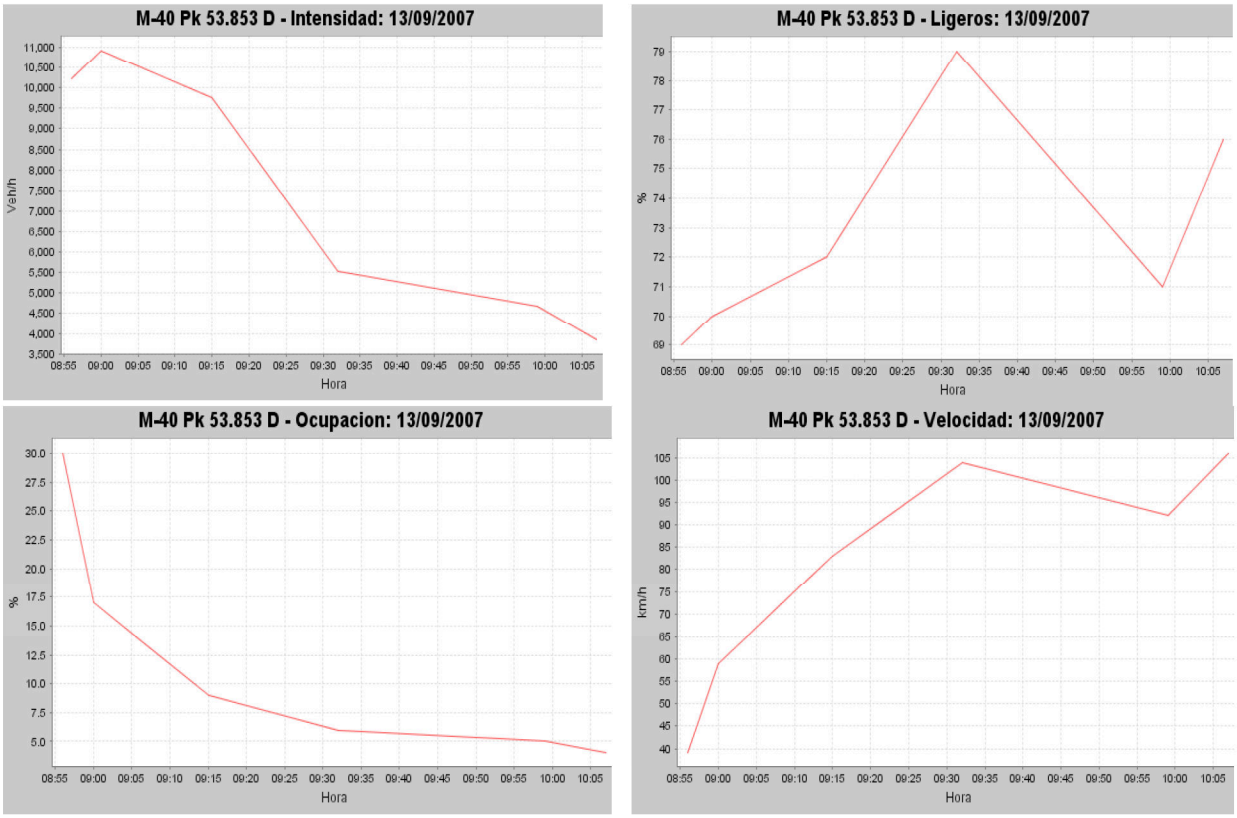


Figure 10: Example of historical values available: intensity, composition, occupation rate and average speed
Source: Dirección General de Trafico (http://infocar.dgt.es/etraffic/)
Daily values, Madrid, Motorways M40, date: 13/09/07 (weekly and monthly data are also available)

Traffic data	Unit	Time resolution	Road type
Intensity	veh/h	hour, day, week, month	Major roads
Average speed	km/h	hour, day, week, month	Major roads
Occupation rate	%	hour, day, week, month	Major roads
Light duty vehicles	%	hour, day, week, month	Major roads

Also, even not real-time data, the project called "Cascade on Wheels" proposed an original way of visualizing traffic dataset for the city of Madrid[ff]. The raw data used were daily average number of cars during the year 2006 and were visualized through the Walls Map piece (3D vertical columns emerging from streets map) and the Traffic Mixer piece (visualization combined with a sound toy).

Finland

The Finnish Road Administration provides real-time information measured from around 330 automatic counting stations placed along the Finnish road network [FRA05]. Traffic data concern traffic flows and average speed on major roads in Finland over 7 regions: Helsinki area, Tempere, Southern Finland, Jyvaskyla; Turlu, Oulu and South-Eastern Finland. Figure 11 displays an example of real-time measurements obtained from the Southern Finland region. Up to seven days historical values can also be provided displaying both the traffic flow (in veh/h) and the average speed (in km/h) as presented in Figure 12.

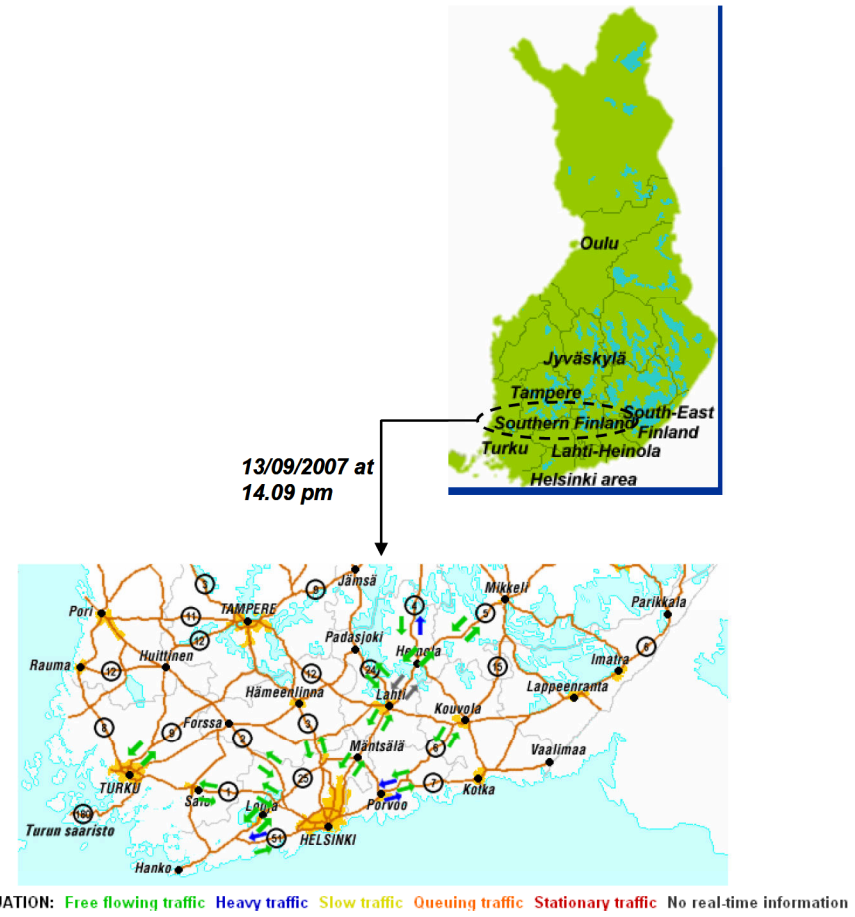


Figure 11: Example of traffic situation in Southern Finland (date: 13/09/2007 at 14.09)
Source: Finnish Road Administration (http://www.finnra.fi/alk/english/)

[ff] http://www.trsp.net/cow/.
See also http://it.infotripla.fi/fcd/open/status.do?language=en

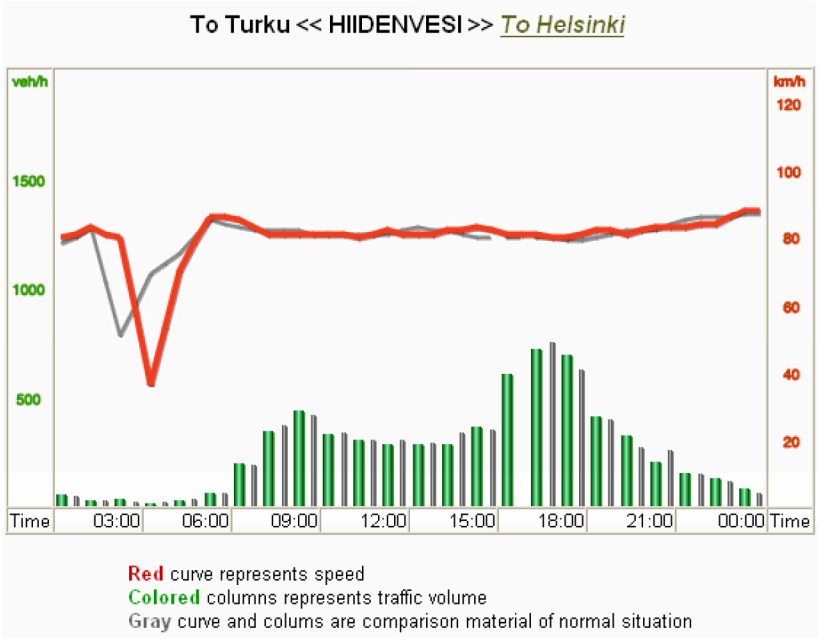


Figure 12: Example of charts plotting daily traffic flows and average speed (Southern Finland, 12/09/2007)
Source: Finnish Road Administration (http://www.finnra.fi/alk/english/)
(note that beyond 24 hours, only tables are provided)

Traffic data	Unit	Time period	Road type
Traffic flow	veh/h	hour, week	Major roads
Average speed	km/h	hour, week	Major roads

France

Strasbourg area

This case is very similar to the Spanish case but it covers only one specific zone. An interactive map of the area of Strasbourg provides the user with real-time measurements of the traffic flow, average speed and occupation rate on motorways around Strasbourg. The last version of the automatic system used (called Gutenberg[gg]) was set up in beginning of 2006. The traffic data are collected every minute from 42 traffic recording stations by means of loop sensors placed every kilometre on the road.

In addition, 50 video cameras have been installed on the road network in order to improve/complete these measurements. These data are afterwards released on the interactive map provided by the "Direction Départementale du Bas-Rhin" through their website. Unfortunately, this interactive tool does not cover the rest of the French road network.

[gg] Gestion Unifiée du Trafic ENglobant StrasBourg Et sa Région.
Note that the main goal of GUTENBERG is to reduce road accidents and provide the user with travel time.

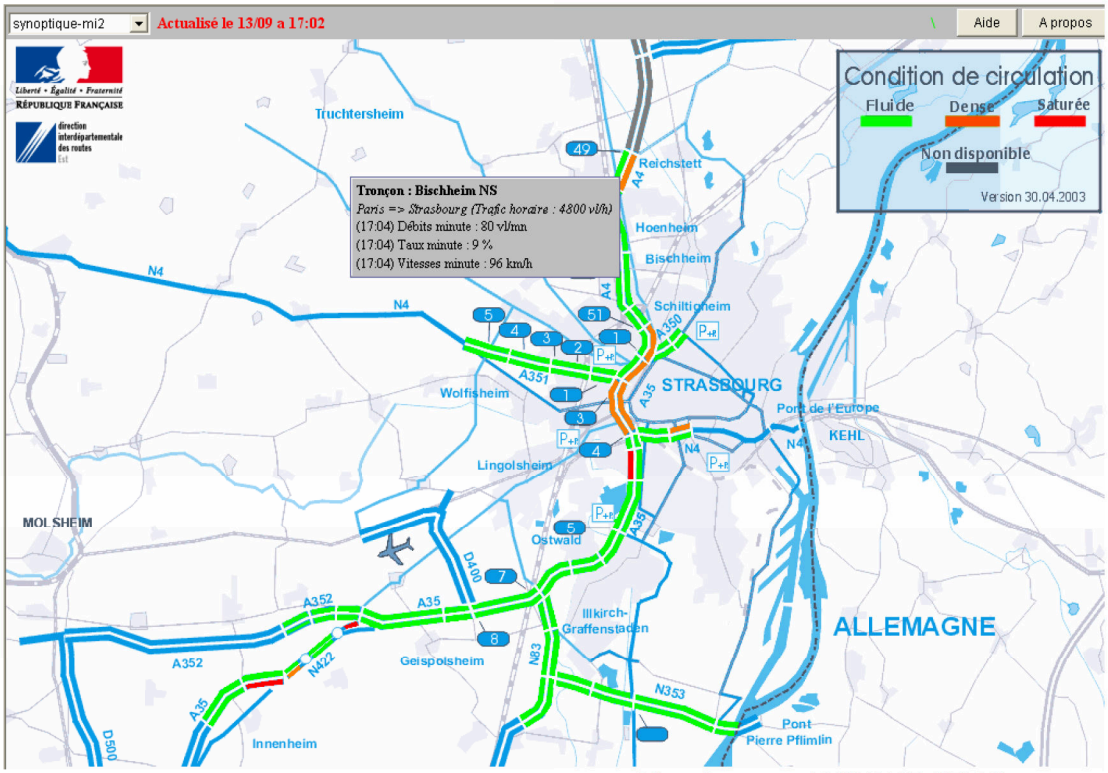


Figure 13: Real-time traffic situation in the area of Strasbourg on 13/09/2007 (17h02)
Source: French Ministry of Transport (http://www.bas-rhin.equipement.gouv.fr/mivisu/jsyn.htm)

Traffic data	Unit	Time resolution	Road type
Traffic flow	Veh/min	minute	Motorways
Occupation rate	%	minute	Motorways
Average speed	km/h	minute	Motorways

Yearly figures are also available from 2002 to 2006 (on map) at: http://www.bas-rhin.equipement.gouv.fr/DDE/comptages_routiers.htm

Paris area

Real-time traffic information in the area of Paris is provided by Sytadin[hh]. An interactive map shows the current speed and travel time on the major roads around Paris. Data is calculated from inductive loops through the SIRIUS network. (It is worth mentioning that the accuracy of travel time was compared with the Floating Car Data method. It resulted that the difference between both methods was less than 1 min for travel time up to 25 min and less than 5 min for travel time between 25 min and 45 min). This website makes also an interesting analysis of the speed and congestion situation based on different charts. Travel times in the area of Paris are also provided by V-Trafic (Mediamobile)[ii] via Google Maps.

The UK

In the UK, it is possible to get a wide number of real-time traffic data from the Highways Agency[ij]. Some of the data refer to the average speed (in mph) and traffic flow (veh/min)

[hh] http://www.sytadin.equipement.gouv.fr/
[ii] http://www.v-trafic.com/
[ij] http://www.realtime-traffic.info/index.html

measured at five selected areas which are Birmingham, Kent, Leeds, M25/London and Manchester. This service (called "Real Time Traffic Service") is being provided on a trial basis by the Highways Agency[kk].

Traffic data	Unit	Time resolution	Road type
Traffic flow	veh/min	10 min	Major roads
Average speed	km/h (or mph)	10 min	Major roads

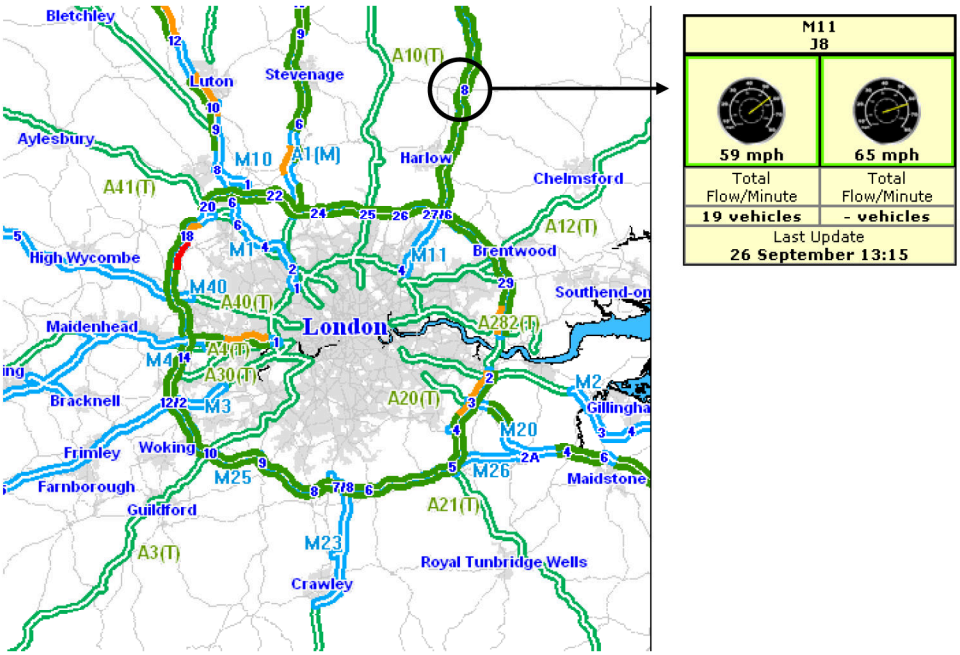


Figure 14: Real-time traffic flow and speed on M11 around London (a text version is also available)
Source: UK Department for Transport (DfT) (http://www.realtime-traffic.info/index.html)

Portugal

A large amount of traffic data are available on the website of "Estradas de Portugal" which are released by the SICIT (Sistema Integrado de Controlo e Informacao de Trafego)[ll]. It consists of a set of equipments and applications that collect and spread real-time traffic data with the aim to reinforce road security and provide a more efficient road network management. For this purpose, a specific application (called ALQUEVA) was created to guarantee the immediate and generalized access to all the traffic information. All the data are collected by more than 300 automatic count recorders installed on major Portuguese roads.

The traffic data made available are diverse (e.g. traffic flow classified by vehicle category, average speed, vehicle weight, etc.) and can be obtained for different time resolutions (annual, monthly, daily, hourly, 15 min, 5 min and 1 min) during the period 2002-2007. The results are also available in Excel format.

[kk] Note that the Highways Agency is responsible for the motorways and major roads in England. All other roads are managed by Local Authorities (www.highways.gov.uk).
[ll] Integrated Traffic Control and Information System

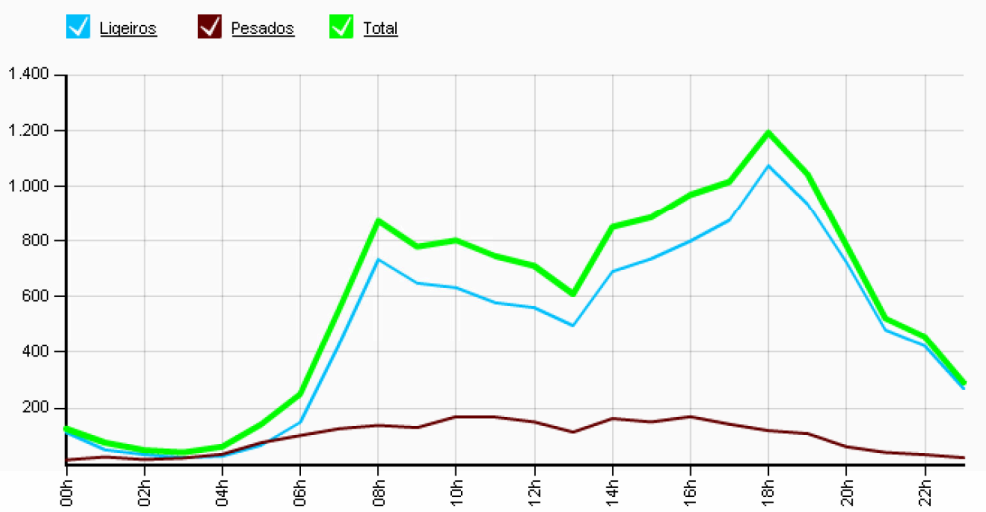


Figure 15: Evolution of traffic flow (veh/min) during a typical week day (13/09/2007)
Source: Estradas de Portugal - Gabinete de Telemática Rodoviária
http://telematica.estradasdeportugal.pt/pls/htmldb/f?p=105:2:3492511302794085::NO

Traffic data	Unit	Time resolution	Road type	Historical data
Traffic flow	veh/min	1, 5, 15 min, hour, day, month, year	Major roads	2002-2007
Average speed	km/h	1, 5, 15 min, hour, day, month, year	Major roads	2002-2007

Belgium

The Belgian Federal Government developed the START/SITTER System[mm] in order to collect real-time traffic data that are imported each minute from the three Belgian regions (http://www.start-sitter.be/).

The system provides real-time traffic variables such as flow of vehicles, average speed and occupancy rate over the whole Belgian highway network. It enables any visualisation in time and geography based on as the basic values per minute as the derived averages over 6, 15 and 60 minutes and the 6-22 and 0-24 h day values. Historical traffic data can also be downloaded from the year 1999.

Note that it is necessary to be registered before accessing the database. This tool is mainly used by the staff of the federal police and by public radio stations.

Traffic data	Unit	Time resolution	Road type
Traffic flow	veh/min	minute	Highway
Occupation rate	%	minute	Highway
Average speed	km/h	minute	Highway

Denmark

In Denmark, real-time traffic data are available for the motorway network around Copenhagen[nn]. Sensors have been placed over approximately 125 km of the Copenhagen motorway network, mostly in connection with exits and entries to the motorway. These detectors register the number of vehicles, the type of vehicle (lorry or car), and the speed at

[mm] Intelligent System about the Belgian Highway-Traffic in Real Time. See also:
http://www.tmleuven.be/project/verkeersindices/200301_paper.pdf
[nn] http://www.trafikken.dk

which the vehicles travel. On the basis of these data, the system is able to determine the traffic situation on a given section of motorway.

Italy

In Italy, OCTO Telematics[oo] makes available on-line real-time speed and number of vehicles on the Italian motorways network ("autostrade") as well as in the area of major cities. Traffic data are provided from the largest FCD fleet in Europe i.e. hundred of thousands of anonymous customers equipped with company's GPS. The dataset may afterwards be used by navigation systems (TomTom and Garmin in Italy) and contribute to the route planning optimisation. This will help end-users reduce travel times, save energy and money.

Germany

The Traffic Information System[pp] presents the current traffic situation and traffic forecasts (30 min and 60 min) on the motorway network in North Rhein Westphalia (2250 km length). The traffic simulation model is fed by real-time traffic data (vehicle speed and traffic flow) collected from 2500 automatic traffic data detection units updated every minute. This project was initiated by the Ministry of Transport, Energy and Spatial Planning of Nordrhein-Westfalen. It is one of the most relevant and reliable source of road traffic forecasts in Europe.

Also, the Bavarian Ministry of the Interior[qq] makes available real-time traffic data covering the main cities of the region. Real-time speed measurements are provided as well as traffic forecasts. Note that GPS-based FCD information from taxi fleets are used to collect traffic data.

5.2 In the United States

The **Alabama** Department of Transportation (ALDOT) provides hourly traffic flow through the Traffic Polling Data System[rr]. An interactive map enables the user to get traffic information over a wide range of road segments throughout the State. Historical data (1996-2006) are also available. Unfortunately, there is no real-time traffic flow since the last update is of January 2007.

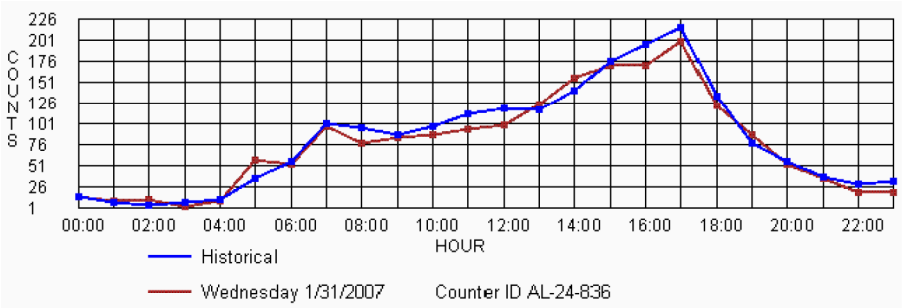


Figure 16: Example of hourly vehicle count evolution measured at one road segment in Alabama
Source: Alabama DoT (http://aldotgis.dot.state.al.us/trafficvolume/viewer.htm)

[oo] http://traffico.octotelematics.it/index.html
[pp] http://www.autobahn.nrw.de/
[qq] http://www.bayerninfo.de
[rr] http://aldotgis.dot.state.al.us/trafficvolume/viewer.htm

In **Washington** State, it is possible to obtain the daily number of cars at any traffic count recorder of the road network[ss]. The data are completed by information about the count quality, data completeness and sensor validity.

The DoT of **South Carolina** has a very user-friendly tool (the South Carolina Traffic Polling System) providing real-time traffic counts (hourly, see Figure 17) and average speed, along with historical data[tt].

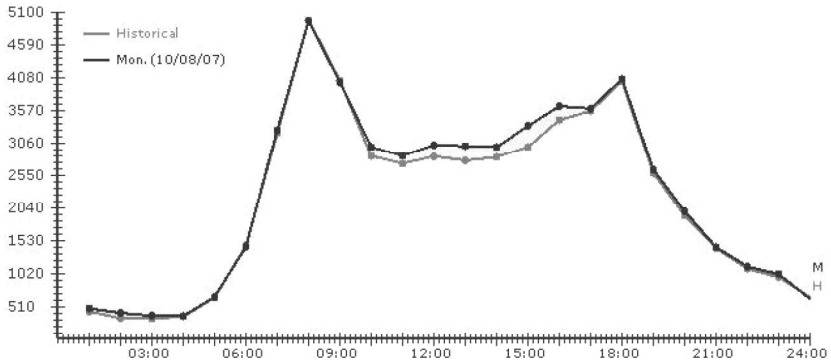


Figure 17: Example of hourly vehicle counts on South Carolina road network
Source: South Carolina DoT (http://www.scdot.org/getting/traffic_counts.shtml)

In **Maryland**, around 70 permanent sites on line are collecting traffic data along with 3700 short-term (48h) coverage count locations[uu]. The Maryland State Highway Administration provides traffic volume maps with historical counts from 1980 to the present for Maryland state roads. The website also contains traffic trends, traffic count data reports, and traffic station history (2001-2005).

In **California**, the Company Sigalert provides live traffic information (e.g. speeds, accidents) for personalized traffic reports[vv]. It covers Southern California (West/East Los Angeles County, Orange County, Ventura, Inland Empire, San Diego), Northern California (San Francisco, Sacramento), Phoenix (Arizona) plus other smaller cities. The speed data are directly collected from fixed detectors and displayed on their website in a user-friendly format, as shown in Figure 18.

[ss] http://www.its.washington.edu/tdad/
[tt] http://www.scdot.org/getting/traffic_counts.shtml and http://www.scdot.org/getting/aadt.shtml (AADT)
[uu] www.marylandroads.com/SHAServices/mapsBrochures/maps/OPPE/trafficvolumemaps/tms.asp
[vv] http://www.sigalert.com/

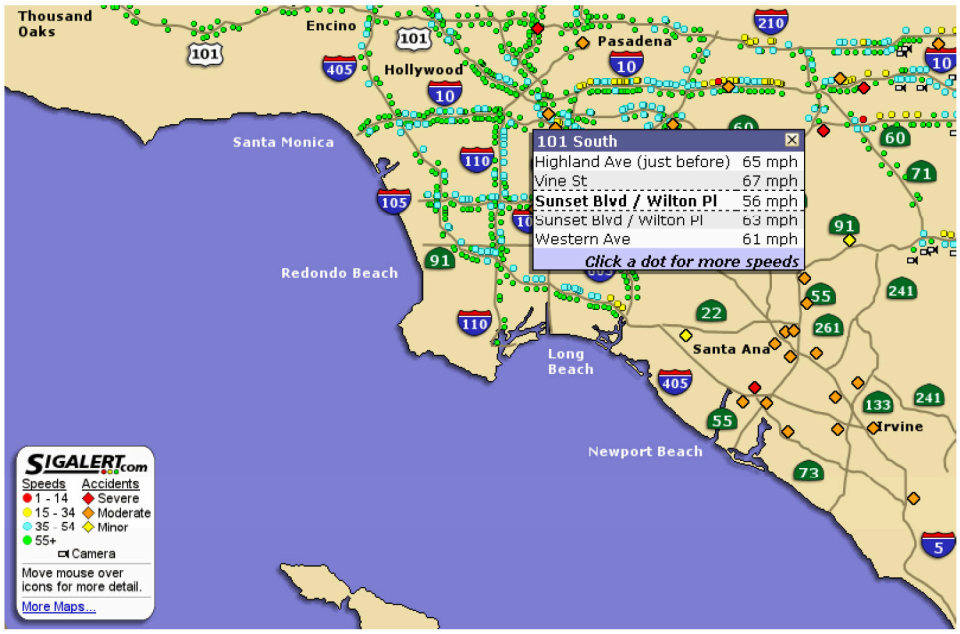


Figure 18: Speed data display on California's major roads
Source: Sigalert (http://www.sigalert.com/)

Key messages

- More and more real-time information are available on-line over Europe. Typical data are vehicle flows and speeds but travel times and occupancy rates can also be displayed. The geographical coverage mainly concerns major roads equipped with sensors.
- The novelty is that the access to this information is made possible by means of new interactive maps displaying the current status of the traffic and to a lesser extent traffic forecasts.
- One of the best applications from these maps would be the calibration of traffic historical/forecast models based on real-time information.

6 Conclusions

In the last years, the richness of road traffic data collection sources has grown substantially. The combination of traditional on-road sensors with floating car data techniques can provide high quality traffic data in real-time that can be utilised by all the transportation actors.

On the one hand, fixed detectors' capabilities are limited due to important installation and maintenance costs and their poor road network coverage which is typically restricted to well known congestion zones e.g. on highways, tunnels or bridges.

On the other hand, collecting traffic data from tracking cellular phone or GPS is technologically feasible and seems to be a very cost-effective alternative. What it was concept years ago, it is now becoming routine all over the world. The strength of this technology stems from high quality real-time data collected from thousands of vehicles over a large road network and for much less cost than traditional methods. Nevertheless, FCD is not targeted to replace the existing sensors but rather to act as a complement technology. Even if R&D and demonstration projects are still required, FCD is becoming key alternative for ITS developments. If current trends continue, the transportation actors may get huge benefits from the combination of fixed/mobile traffic measurements in a wide range of domains.

Due to promising market perspectives, private suppliers are currently developing all the required conditions to achieve a full market deployment in the near future. However, this would be possible only if public bodies invest in developing applications using them, set standards and develop a policy framework addressing key issues like privacy concerns and the protection of commercial information.

ANNEX I: Technological characteristics of road sensors

- **Current data collection techniques**

Data collection techniques	Traffic flow	Occupation rate	Vehicles categories	Speed	Travel time	O/D information	Incident detection
Magnetic loops	Yes	Yes	If speed available	With 2 consecutive loops	No (estimation by algorithms)	No (except with specific algorithms: require high number of sensors)	Yes (except with specific algorithms; response time: in minutes)
Pneumatics	Yes	Indirect (derived from axles numbers)	Partly (number of axles)	With 2 detectors, not accurate	No (not accurate)	No (not accurate)	No (not accurate)
Piezo cable	Yes	Yes	Yes (axles weight)	With 2 detectors	No (estimation by algorithms)	Not used	Not used
Video camera and image processing[ww]	Yes	Yes	Yes	Yes	No (estimation by algorithms)	Not used	Not used
Video camera and image processing with ANPR[xx]	Yes	Yes	Yes	Yes	Yes (by tracking number plates)	Yes (by tracking number plates)	Yes (if combined with incident detection algorithm)
Radar[yy]	Yes	Yes	Yes	Yes	No (except derived from local speed using specific algorithms)	No (except with specific algorithms: require high number of sensors)	Yes (by tracking moving vehicles)
Infrared sensors and other type of sensors (passive)	Yes	Yes	No	No	No	No (except with specific algorithms: require high number of sensors)	No
Active beacons and tags	Yes (if enough vehicles are equipped)	Yes (if enough vehicles are equipped)	Yes (as far as the information is on the tag)	Yes	Yes	Yes (entry exit)	Yes
FCD (existing providers GPS)	No	No	Yes	Yes	Yes	Yes	Yes (where enough vehicles are equipped)

Source: [SCHM05]

[ww] Video cameras with image processing are able to emulate one or more magnetic loops.
[xx] Automatic Number Plate Recognition.
[yy] Radar includes different technologies: radar used as a simple presence detector, radar used for speed measurement or large beam radars able to track the number of moving vehicles (many trials, but not in real use do to high implementation costs).

- **Strengths and weaknesses of commercially available sensor technologies**

Technology	Strengths	Weaknesses
Inductive Loop	• Flexible design to satisfy large variety of applications. • Mature, well understood technology. • Large experience base. • Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap). • Insensitive to inclement weather such as rain, fog, and snow. • Provides best accuracy for count data as compared with other commonly used techniques. • Common standard for obtaining accurate occupancy measurements. • High frequency excitation models provide classification data.	• Installation requires pavement cut. • Decreases pavement life. • Installation and maintenance require lane closure. • Wire loops subject to stresses of traffic and temperature. • Multiple detectors usually required to monitor a location. • Detection accuracy may decrease when design requires detection of a large variety of vehicle classes.
Magnetometer (Two-axis fluxgate magnetometer)	• Less susceptible than loops to stresses of traffic. • Insensitive to inclement weather such as snow, rain, and fog. • Some models transmit data over wireless RF link.	• Installation requires pavement cut. • Decreases pavement life. • Installation and maintenance require lane closure. • Models with small detection zones require multiple units for full lane detection.
Magnetic (Induction or search coil magnetometer)	• Can be used where loops are not feasible (e.g., bridge decks). • Some models are installed under roadway without need for pavement cuts. However, boring under roadway is required. • Insensitive to inclement weather such as snow, rain, and fog. • Less susceptible than loops to stresses of traffic.	• Installation requires pavement cut or boring under roadway. • Cannot detect stopped vehicles unless special sensor layouts and signal processing software are used.
Microwave Radar	• Typically insensitive to inclement weather at the relatively short ranges encountered in traffic management applications. • Direct measurement of speed. • Multiple lane operation available.	• CW Doppler sensors cannot detect stopped vehicles.
Active Infrared (Laser radar)	• Transmits multiple beams for accurate measurement of vehicle position, speed, and class. • Multiple lane operation available.	• Operation may be affected by fog when visibility is less than ≈20 ft (6 m) or blowing snow is present. • Installation and maintenance, including periodic lens cleaning, require lane closure.

Technology	Strengths	Weaknesses
Passive Infrared	• Multizone passive sensors measure speed.	• Passive sensor may have reduced sensitivity to vehicles in heavy rain and snow and dense fog. • Some models not recommended for presence detection.
Ultrasonic	• Multiple lane operation available. • Capable of overheight vehicle detection. • Large Japanese experience base.	• Environmental conditions such as temperature change and extreme air turbulence can affect performance. Temperature compensation is built into some models. • Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds.
Acoustic	• Passive detection. • Insensitive to precipitation. • Multiple lane operation available in some models.	• Cold temperatures may affect vehicle count accuracy. • Specific models are not recommended with slow moving vehicles in stop-and-go traffic.
Video Image Processor	• Monitors multiple lanes and multiple detection zones/lane. • Easy to add and modify detection zones. • Rich array of data available. • Provides wide-area detection when information gathered at one camera location can be linked to another.	• Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway (lane closure may not be required when camera is mounted at side of roadway) • Performance affected by inclement weather such as fog, rain, and snow; vehicle shadows; vehicle projection into adjacent lanes; occlusion; day-to-night transition; vehicle/road contrast; and water, salt grime, icicles, and cobwebs on camera lens. • Requires 30- to 50-ft (9- to 15-m) camera mounting height (in a side-mounting configuration) for optimum presence detection and speed measurement. • Some models susceptible to camera motion caused by strong winds or vibration of camera mounting structure. • Generally cost-effective when many detection zones within the field-of-view of the camera or specialized data are required. • Reliable nighttime signal actuation requires street lighting.

Sources: [VDC07], [TDH06]

ANNEX II - Sources of historical traffic data

Country	Sources	Data available/comments
Austria	• Austria's Federal State of Tyrol: www.tirol.gv.at/vde • Asfinag http://www.asfinag.at/ • Statistik Austria http://www.statistik.at/	Since 2005 Austria's Federal State of Tyrol has been using the PTV TrafficCount Management for its traffic count data and analysis. Daily traffic flows are collected from 150 automatic traffic counters that are imported and processed every day to a central traffic database. Monthly traffic count analyses and annual traffic reports are also available. "Statistik Austria" provides a permanent count traffic database.
Belgium	• Service Public Federal Mobilite et Transports www.mobilit.fgov.be	Traffic volume for the 3 regions (Flanders, Wallonie, Brussels) from 1970 to 2005. Differentiated by type of road.
Czech Rep.	• The Ministry of Interior of the Czech Republic http://www.mvcr.cz/bezpecnost/besipen.html • The Ministry of Transport http://www.mdcr.cz • Road and Motorway Directorate of the Czech Republic http://www.ceskedalnice.cz/en/d.htm	A large amount of data are available (e.g. AADT) on several road links from the Road and Motorway Directorate of the Czech Republic site. Traffic volume can be found at: http://www.udipraha.cz/rocenky/yearbk01/texty/dtjang02.htm#second
Denmark	• Danish Road Directorate http://www.vejdirektoratet.dk/ • Statistics Denmark http://www.statbank.dk	Large transport database (AADT and VKT). VKT provided by transport unit (1980-2004) and type of road (2001-2004). VKT are estimated from odometer data
Estonia	• Estonian Road Administration http://www.mnt.ee/atp/?keel=en http://www.mnt.ee/atp/failid/S03en.pdf	Traffic volume (1997-2002) for different road types. Average number of vehicles per day available in 2004 for different roads and counties.
Finland	• Finnish Road Administration http://www.tiehallinto.fi	The Finnish Road Administration (see e.g. *Road Facts 2006*) has made a large amount of historic traffic data available. The evolution of the traffic performance (VKT) and AADT (vehicles/day) are available from 1980 (or even sometimes from 1970) until 2006. Vehicle-kilometres are given by vehicle type, by road type and road regions. AADT are provided by road type and regions while the average speed is also available by vehicle type on the major Finnish road network. Note that vehicle-kilometres are most often calculated from road traffic counts.
France	• French Road Federation http://www.urf.asso.fr/ • Ministère de l'Ecologie, de l'Energie, du Développement Durable et de l'Aménagement du Territoire http://www.statistiques.developpement-durable.gouv.fr/ • Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques (CERTU) http://www.certu.fr • INRETS - Institut national de recherche sur les transports et leur sécurité http://www.inrets.fr • Comité des Constructeurs Français d'Automobiles (CCFA) http://www.ccfa.fr • Siredo http://siredo.free.fr	Historical AADT and VKT data are available for the most part of the French road network. For instance, a lot of traffic data are provided by the French Road Federation. VKT and AADT figures are generally available over the period 1990-2005. Traffic flows between France and Spain/Italy are also covered. Most of the French regions[zz] provide a map of the AADT for the last years. On these maps the segment length generally ranges from 5 to 30 km assuming the traffic variation uniform on the link. The average daily traffic data are mainly obtained from permanent count stations while temporary count stations are especially used for secondary roads.
Germany	• German Institute for Economic Research (DIW) www.diw.de/ • Federal highway Research Institute (BAST) http://www.bast.de/	The German Institute for Economic Research (DIW) provides traffic volume estimates every year for different vehicle categories.
Greece	• Egnatia Odos Observatory http://observatory.egnatia.gr/ • The Egnatia Odos Project http://www.egnatia.eu	AADT values are available on the Egnatia motorways for the years 2004 to 2006.

[zz] e.g. Region Aquitaine http://www.aquitaine.equipement.gouv.fr/rubrique.php3?id_rubrique=270
Region Poitou-Charentes: http://www.cc-parthenay.fr/parthenay/creparth/train-thouet-sevre/trafic_2005.pdf

Country	Sources	Data available/comments
Hungary	• KTI (Transport Research Institute) http://www.kti.hu/ • Technical and Information Services on National Roads (ÁKMI kht) • Magyar Kozut http://web.kozut.hu/index.php?id=135	It is difficult to get AADT values and traffic volume data.
Italy	• AISCAT (Associazione Italiana Società Concessionarie Autostrade e Trafori) http://www.aiscat.it/	The AISCAT provides historical VKT data and traffic flow from 2002 to 2006. The data are given by vehicle type and are provided in monthly or half-yearly intervals. They cover the Italian motorways network.
Latvia	• Latvian State Roads http://www.lad.lv/	The "Yearbook of Latvian State Roads 2006" provides AADT values and percentage of heavy vehicles. The "Latvian Road Administration Statistics of 2002" gives AADT from 1996 to 2002 on main state roads (plus other type of data).
Lithuania	• Lithuanian Road Administration http://www.lra.lt/en.php/traffic_safety/black_spots/107 • Vilnius Gediminas Technical University: http://www.transport.vgtu.lt/upload/tif_zur/2001-6-laurinavicius_zilioniene.pdf • Department for Statistics http://www.stat.gov.lt/	The Lithuanian Road Administration provides an interactive map displaying the average traffic flow (veh/day) on several national roads for the period 2002-2005.
Luxembourg	• Administration des ponts et chaussées http://www.pch.public.lu/trafic/comptage/index.html • CITA http://www.cita.lu/	The "Administration des ponts et chaussées" carries out permanent traffic counts from sensors (intrusive and non-intrusive technologies) installed all over the Luxembourg road network (not only on motorways).
The Netherlands	• AVV Transport Research Centre http://www.rws-avv.nl/pls/portal30/docs/11297.PDF • Institute for Road Safety Research http://www.swov.nl/ • Statistics Netherlands http://statline.cbs.nl/	The "AVV Transport Research Centre from the Ministry of Transport, Public Works and Water Management" provides the following relevant documents: - *Traffic in the Netherlands 2004*: this document gives information about traffic trends in the Netherlands. It answers to questions such as: which roads are used most heavily by trucks? Or what is the traffic speed over a particular stretch of road? This booklet is published every year under the Dutch title: 'Kerncijfers Verkeer'. - *Traffic in the Netherlands, key figures:* key figures on road traffic flows, traffic congestion and traffic speeds. The "Institute for Road Safety Research" makes available the *Passenger Traffic Statistics* containing data on traffic volume (VKT) and much more. Also, traffic density figures are given by "Statistics Netherlands".
Poland	http://www.gddkia.gov.pl	
Portugal	http://www.asecap.org/	The OTEP (Observatório Transfronteiriço Espanha-Portugal) makes available the traffic flow across the Portuguese-Spanish border.
Ireland	• National Roads Authority http://www.nra.ie/Publications/RoadTraffic/#d.en.3468	AADT refers to 24-hour 2-way flows on an average day. Differences in AADT from several areas have been highlighted. The basis for most AADT estimates is a one-day 7-hour visual count at the midpoint of the section; that 7-hour count is converted to AADT by applying an expansion factor determined from appropriate permanent traffic stations. Traffic volume is also available.
Spain	• Direccion General de Trafico http://www.dgt.es • Ministerio de Fomento http://www.fomento.es • Cintra http://www.cintra.es • Abertis http://www.abertis.com	Data are available but it is difficult to get free information. ADT figures are provided by the DGT through the general transport statistics in Spain (to be purchased).

Country	Sources	Data available/comments
Slovenia	• Ministry of Transport http://www.dc.gov.si/en/traffic/ • Statistical Office of the Republic of Slovenia http://www.stat.si/	AADT is calculated from data obtained by various manual traffic counts and automatic traffic counters in the overall territory. AADT can be provided by type of road or aggregated covering the period 1998-2002. VKT on state roads in Slovenia are also available (2000-2006).
Sweden	• Swedish Road Administration http://www.vv.se/ http://trafiken.nu/ • Statictics Sweden http://www.scb.se/	"Statistics Sweden" provides the traffic volume on Sweden roads.
Switzerland	• Federal Administration, Department of the Environment, Transport, Energy and Communications – Federal Roads Office (FEDRO) http://www.astra.admin.ch/ • Office Cantonal de la Mobilite http://www.sitg.ch/	Automatic Traffic Counts (ATC) provide average monthly and annual traffic flows, over the period 2002-2006. Results from the 2005 Swiss Road Traffic Census are available. Traffic counts are provided on-line (Geneva).
The UK	• Department for Transport (DfT) http://www.dft.gov.uk/matrix/ www.dft.gov.uk/transtat/roadtraff http://www.dft.gov.uk/pgr/statistics/ • Cambridgeshire County Council (see the *Traffic Monitoring Report 2007*) http://www.cambridgeshire.gov.uk • Transport for London http://www.tfl.gov.uk/ • The Scottish Government http://www.scotland.gov.uk/Publications/2006/12/15135954/205	The Department for Transport (DfT) provides a wide range of transport statistics through annual reports and excel workbooks. Among others, two important variables are provided: - The Annual Average Traffic Flow (AADF) measured in veh/day. They are produced using 12-hour manual data counts from a large number of sites and from permanent automatic counters at about 190 sites. - The traffic volume (VKT). VKT is derived from road counts (by multiplying the AADF by the corresponding length of road). These variables are provided by vehicle type (11 types), road type, road class, regions (local/authority) and over a large time period (1955-2005). Note that seasonally data are also provided. The DfT also proposes a GIS website which provides statistics of major road traffic flows for Great Britain. This website enables users to access AADF and VKT for each major road link in Great Britain (from 1999 to 2005). The user can search on geographic area, road class name or the unique traffic count point[aaa] number. An interactive map provides a mapped background to identify traffic flows in specific areas of the country. Relevant documents from the DfT: *Road Traffic Statistics 2005* (excel files) *Road Traffic in Great Britain 2006 data tables* (excel files) *Transport statistics Great Britain 2006* (annual DfT report) *Road Statistics 2006: Traffic, Speeds and Congestion* In London, both average daily vehicle flows and vehicle-kilometres are available by road type and/or by vehicle type in London over the period 1993-2005. Average speed and car ownership are also provided (source: *London Travel report 2006, Transport for London*). In Scotland, the Chapter 6 of the *Scottish Transport Statistics: No 25 - 2006 Ed.* provides relevant information about road traffic such as traffic volume and traffic flows at selected points on the road network. Figures are given by type of road, type of vehicle, and by council area. Historical values are given for the period 1960-2005. The monthly average daily traffic flows are recorded from 37 Automated Traffic Classifier (ATC) every month.

[aaa] Each link has a uniquely referenced Count Point (CP), where the traffic is usually counted by enumerators.

In the US

There are many sources of traffic information in the US providing the user with historical values of AADT, average speed and VKT. Most often, traffic count database are available from the Department of Transport (DoT) at State level[bbb].

State (DoT)	Traffic data	Link
California	Speed AADT	http://www.dot.ca.gov/roadsandtraffic.htm http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/2006all.htm
Illinois	AADT with GIS	http://www.dot.state.il.us/trafficmaps/table.htm
Alaska	AADT historical data	http://www.dot.state.ak.us/stwdplng/highwaydata/traffic.shtml
Wisconsin	AADT	http://www.dot.wisconsin.gov/travel/counts/
Iowa	AADT	http://www.iowadotmaps.com/msp/traffic/aadtpdf.html
Texas	Traffic flow Annual counts from 1990 to 2005	http://www.dot.state.tx.us/ http://www.dot.state.tx.us/GIS/HCRS_main/viewer.htm http://www.campotexas.org/programs_rd_traffic_counts.php http://www.nctcog.org/trans/data/tcins/
Virginia	Historical AADT	http://www.virginiadot.org/info/ct-TrafficCounts.asp www.virginiadot.org/projects/prOTIM.asp
North Carolina	Traffic flows	http://www.ncdot.org/it/img/DataDistribution/TrafficSurveyMaps/
Mississipi	Cameras (with Google Map)	http://www.mstraffic.com/#
Arkansas	Historical AADT	http://www.arkansashighways.com/Maps/TrafficCountyMaps/TrafficCount.htm
Georgia	AADT Travel times	http://www.dot.state.ga.us/DOT/plan-prog/transportation_data/traffic_counts/index.shtml http://www.georgia-navigator.com/counters/map/georgia
Massachussets	AADT	http://www.mhd.state.ma.us/default.asp?pgid=content/traffic01&sid=about#para8
Florida	AADT	http://www.dot.state.fl.us/Planning/statistics/trafficdata/default.htm
Michigan	AADT	http://webdev2.semcog.org/cgi-bin/data/att-traffic-counts.cfm

Further sources	Traffic data	Link
Traffic Count Database System	Traffic volume	http://www.trafficcountdata.com/default.aspx
AnalyGIS - Traffic Count Data:	AADT	http://www.analygis.com/Products/trafficcounts.htm

[bbb] See e.g. http://www.trb.org/trb/about/sponsorsstate.asp

ANNEX III – EU projects and other relevant sources

Traffic volume / Traffic flow

Source name	Comments
UNECE	UNECE: Census of Motor Traffic on Main International Traffic Arteries in Europe http://www.un.org/Pubs/whatsnew/e99v26.htm AADT are provided for the E-Roads of 37 European countries. Description of methodologies for calculating VKT in some countries http://www.unece.org/trans/main/wp6/transstatac5wdoc.html http://www.unece.org/trans/main/wp6/wp6.html Workshop on Statistics on the volume of road traffic (vehicle-kilometres): http://www.unece.org/trans/doc/2005/wp6/AC5-inf01e.pdf
Eurostat	VKT available but incomplete
IRTAD	IRTAD database http://cemt.org/IRTAD/IRTADPublic/weng1.html
SafetyNet (FP6) - Building the European Road Safety Observatory (ERSO) http://www.erso.eu/	See WP2 Risk Exposure Data http://www.erso.eu/safetynet/content/wp_2_risk_exposure_data_red_.htm
IMAGINE Project http://www.imagine-project.org/	Information available about traffic collection methods (see WP2)

Relevant sources about ITS and FCD

Source name	Comments
ERTICO-ITS Europe http://www.its-europe.org/ Public/private partnership to develop ITS in Europe	Examples of projects coordinated by ERTICO with FCD relevance: • EuroRoads Project http://www.euroroads.org • TMC Forum The TMC Forum is the focal point and workshop of the Traffic Message Channel (TMC) community http://www.tmcforum.com/ • GST (Global System for Telematics enabling On-line Safety Services) www.gstforum.org (see especially the GST-RESCUE subproject) • CVIS (Cooperative-vehicle-infrastructure systems) http://www.cvisproject.org/ • ISTER (Promoting the integration of satellite and terrestrial communication with Galileo for road transport) http://www.sister-project.org/
eSAFETY Support http://www.esafetysupport.org	*e*Safety is a industry/public initiative driven by the EC and co-chaired by ERTICO-ITS Europe and ACEA. The objective is to promote the development, deployment, and use of Intelligent Vehicle Safety Systems to enhance road safety throughout Europe.
European Congress and Exhibition on Intelligent Transport Systems and Services www.itsineurope.com	FCD technologies are well discussed and analysed.
TEMPO programme (Trans-European intelligent transport systeMs PrOjects) 2001-2006	Euro-regional projects: • CORVETTE (Coordination and validation of the deployment of advanced transport telematic systems in the Alpine area) http://www.corvette-mip.com/ • ARTS (Advanced Road Traffic in South-west) http://www.arts-mip.com/ • CENTRICO (Central European Region Transport Telematics Implementation Co-ordination) http://www.centrico.org/ • SERTI (Southern European Road Telematic Implementations) http://www.serti-mip.com/ • VIKING http://www.viking.ten-t.com

	http://www.travel-and-transport.com/ FCD projects in Sweden, Finland and Norway (based on GPS) • STREETWISE (Seamless Travel Information Services for the Western Isles of Europe) http://www.streetwise-info.org/ • See also the "Scottish Executive Journey Time Planner" http://scottishexecutive.itisholdings.com/ This website uses FCD to provide current estimates of journey times between major destinations in Scotland.
Traffic Euro Service.com (from SERTI project) http://tes.marketservice.at/	TrafficEuroService.com (TES.com) is a web-platform for mobile people all over Europe, for the start supported by DG TREN. TES.com provides more than 150 links to dynamic traffic and travel services on internet in 25 Member States (plus some others countries).
EASYWAY Programme (2007-2013) "Towards European sustainable mobility: increase safety, improve mobility and reduce pollution"	The deployment of ITS is expected to meet the following objectives by 2020: 25% congestion reduction 25% improved security 10% CO_2 reduction, mainly in urban areas The experiment and deployment of new data collection technologies are covered (e.g. floating car data, 3G communication, GPS/ Galileo).
TRACK&TRADE (FP6) http://www.trackandtrade.org/ "Building a data mart for floating car data"	The objective is to develop of a web-based data mart for the collection of Floating Car Data (FCD) and the provision of value-added services. The ground is prepared for new traffic services and applications based on FCD (especially from GPS and xFCD, but not from cellular phones). (see D.1.)
eMOTION (FP6) http://www.emotion-project.eu/	The objective is to investigate and specify the framework for a Europe-wide multimodal traffic information service offering real time information and special services for the road and public transport user.
INTRO (FP6) http://intro.fehrl.org/	(see WP4)
Arsenal Research	http://www.arsenal.ac.at FCD projects in Austria (e.g. FLEET, PROMOS, SAVER DATA)
European Road Information Center (ERIC) www.eric-info.com	
TNO http://www.tno.nl/	TNO is well active in the FCD research field.

Others

The Federal Highway Administration (FHWA)	http://www.fhwa.dot.gov/trafficinfo/index.htm
TrafficGroup http://www.trafficgroup.com/services/data.html	All type of traffic data (AADT, travel times, etc.)

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Title: Road Traffic Data: Collection Methods and Applications
Authors: Guillaume Leduc
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2008

Abstract

This study aims to analyse the current road traffic data collection methods - both fixed and mobile - in terms of capabilities and limitations. The development of Intelligent Transportation Systems (ITS) highly depends on the quality and quantity of road traffic data. Usually, traffic information such as vehicle speed or traffic flow is collected through fixed detectors placed along the road network at strategic points. Currently, collecting traffic data through mobile phones and In-Vehicle GPS has become an alternative source of data gathering that can provide accurate real-time information over a large road network and overcoming some problems related to fixed detectors. Even if further developments are still needed, both types of sources - fixed and mobile - are now widely used by several service providers worldwide to provide the users with high quality real-time traffic information.
Economic issues related to the emergence of this new market based on real-time information from these technologies are also discussed.

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