Simultaneous assessments of innovative traffic data collection technologies for travel times calculation on the East ring road of Lyon

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Abstract
In recent years, many innovative technologies for the travel times calculation evolved, but have never been evaluated and compared to each other at the same time. These technologies depend on the kind of implemented sensor for the traffic data collection. The purpose of this paper is to introduce an original experimentation, which will compare several recent technologies of data collection allowing travel times calculation from Bluetooth sensors, magnetometers, Floating Car Data from GPS embedded devices and even inductive loops stations for speeds interpolation. For this assessment, number plate readers (ANPR) were chosen to provide the reference travel times according to their high traffic’s identification rate (near to 90%), which is much greater than the whole of assessed systems, and also allows to reach an optimal representativeness of the traffic flow. This trial takes place in a 12 kilometres long segment of the Lyon East ring road, which DIR-CE is the road operator. The daily traffic flow is about 90,000 vehicles with around 10% of trucks. The East ring road of Lyon usually presents any kind of traffic density: free-flow, heavy traffic, regular 1 to 2 kilometres long end of day congestion. So, it will be interesting to test the swiftness of each of these new technologies for all of the various traffic conditions, especially during the fast transition phases of the traffic flow or even while the traffic is jammed and therefore when the travel times are high. There are five measurements test points along this itinerary and so four elementary segments. The installation of all the field sensors ended at the beginning of March and when all the systems will be in a nominal operating mode (actually, they are at present in a testing and settling phase), it is planned to collect data during at least three months, which will allow to build a large travel times database. Among these four road segments, one of them has neither entry nor exit, thus the penetration rate and the overall performances of each of these technologies will be able to be estimated with no disruption in travel time measurements.

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1. Introduction

1.1. Background

DIR-CE, a road operator in the Centre East of France, deployed several years ago a traffic data collection station fleet, with inductive loops to manage its road network through different traffic control centres named “Coraly”, “Hyronelle”, “Gentiane”, “Osiris” and “Moulins”.

Today, the urban freeways travel times are implemented from these inductive loops stations by speed measurements interpolation. However, on some itineraries and for several periods of the day, these travel times present important gaps compared to the real ones.

So, it has been decided to improve the reliability and the quality of the travel time information system broadcasted to the road network users. Numerous solutions exist today, based on various technologies, but few elements allow doing a sensible choice both from the expected performances and involved costs.

1.2. Goals of the experimentation

In this context, DIR-CE wishes to estimate various technical solutions allowing to enhance reliability of the travel time calculation, on one hand as for the technology of traffic data collection, and on the other hand, as for the calculation estimation methodologies and real travel times forecasting. Next, the broadcasting to the users will be done from the websites and the road network VMS (variable messages sign). In that aim, it is planned to appraise in real and known situation, various ways of evolving methods of travel times from several innovative technologies.

The objective is to estimate the metrological and functional performances of various systems and services based on these new technologies of traffic data collection, by comparison of travel times implemented by each of them according to those provided from the reference devices which are license plate readers (ANPR), and those developed from the existing inductive loops stations (cf. Figure 1).

This large-scale project deals with three main axes:

- Research for optimal algorithms of travel time development from the spatial aggregation of punctual data that are traffic flows, speeds and occupancy rate supplied by each station;
- Assessment of devices and services based on innovative technologies of traffic data collection by exit travel time measurements analysis;
- Research for improving algorithms of predictive travel times reliability with the aim of their broadcasting to the users and to the road network operators for traffic management.
2. The trial site

The choice of the testing site was operated, according to the profiles of traffic, allowing systems and sensors assessment in varied and representative situations of the typical using conditions for these technologies.

Furthermore, energy and communication networks were to be available for the operating of the systems. Finally, the site has to be equipped with traffic data collection stations allowing the traffic flow definition and the travel time calculation from flows and speeds data provided by these last ones.

The chosen experimental platform is a peri-urban freeway from the East of Lyon (N346 ring road, 2 x 2 lanes) belonging to the “Coraly” network, South towards North direction, between the interchange with A43 motorway at Manissieux as far as the interchange with A42 motorway.

The covered area is about 12 km without tunnels.

There are five vehicle recognition points (marked A, B, C, D, E), and to have so a dividing of the whole itinerary in four basic segments whose travel times can be independently analysed.

The location of the existing inductive loops stations partially influenced the choice of recognition points.

The location of these points is described as follow:

![Fig. 1. (a) Localisation of recognition points (green arrow) and inductive loops stations (yellow); (b) Mapping location.](image)

The N346 national road is a peri-urban freeway of the “Coraly” network with a high daily traffic.

This section presents a zone of regular daily congestion about 1 to 2 kilometres in the South-North direction at the end of the weekdays, caused by a slope slowing down the trucks.

The capacity of this network is about 3,500 vehicles per hour.

A typical example of hourly traffic flows for the whole of vehicles, and 6 min average speeds noticed during weekdays (except period of vacation) on the N346 road (2 lanes) is represented below:
Different kinds of traffic are defined on this road according to traffic flows and speed limits of 90 km per hour (Table 1).

Table 1. Definition of traffic flows.

<table>
<thead>
<tr>
<th>Traffic flow</th>
<th>Traffic flow (veh./h) (2 lanes)</th>
<th>6 min average speed</th>
<th>Indicative time slots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>QT &lt; 1000</td>
<td>VT &gt; 50 km/h</td>
<td>9pm – 6am</td>
</tr>
<tr>
<td>Free-flow</td>
<td>1000 ≤ QT ≤ 2500</td>
<td>VT &gt; 50 km/h</td>
<td>6am – 7am 9am – 3pm 8pm – 9pm</td>
</tr>
<tr>
<td>Heavy</td>
<td>QT &gt; 2500</td>
<td>VT &gt; 50 km/h</td>
<td>7am – 9am 3pm – 5pm 6pm – 8pm</td>
</tr>
<tr>
<td>Congested</td>
<td>∀ QT</td>
<td>VT ≤ 50 km/h</td>
<td>5pm – 6pm</td>
</tr>
</tbody>
</table>
3. Assessed technologies

This experiment deals with the estimation of performances of travel times calculation systems and services from innovative technologies of traffic data collection, or by a combination of these technologies for data fusion.

Traffic data supplied by these technologies implement the principle of vehicles recognition at one point, then the re-identification of these same ones at another point of the analysed section. Thus, the traffic informations such as speed, traffic flow and travel time can then be calculated.

Basically, it is possible to discern two approaches of these technologies :

- The ones broadcasting their position in a continuous way to an operator ;
- The others whose data are collected at the level of field sensors : the “point-to-point” systems.

Within the framework of this experiment, the continuous technologies are Floating Car Data (FCD), implementing the principle of geo-localization by satellite from various GPS devices, and the “point-to-point” systems are those using MAC address detection of various embedded devices such as mobile phones, earphones, free-hands and so on, by Bluetooth/WiFi technology, magnetic signature recognition of vehicles by magnetometers, or also a mix of these two last ones for data fusion (Table 2).

Table 2. Assessed technologies on Lyon East ring road.

<table>
<thead>
<tr>
<th>Holder or anticipated supplier</th>
<th>Technology</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOMTOM</td>
<td>Floating Car Data (FCD)</td>
<td>Geo-localization by satellite</td>
</tr>
<tr>
<td>INRIX</td>
<td>Floating Car Data (FCD)</td>
<td>Geo-localization by satellite</td>
</tr>
<tr>
<td>AUTOROUTE TRAFIC</td>
<td>Floating Car Data (FCD)</td>
<td>Geo-localization by satellite</td>
</tr>
<tr>
<td>V-TRAFFIC</td>
<td>Floating Car Data (FCD)</td>
<td>Geo-localization by satellite</td>
</tr>
<tr>
<td>BLIP Systems</td>
<td>Bluetooth / WiFi</td>
<td>MAC address detection</td>
</tr>
<tr>
<td>STERELA</td>
<td>Bluetooth / WiFi</td>
<td>MAC address detection</td>
</tr>
<tr>
<td>NEAVIA</td>
<td>Bluetooth / WiFi</td>
<td>MAC address detection</td>
</tr>
<tr>
<td>KARRUS-ITS &amp; SENSYS NETWORKS</td>
<td>Bluetooth / WiFi &amp; Magnetometers</td>
<td>MAC address detection &amp; Magnetic signature detection &amp; Data fusion</td>
</tr>
</tbody>
</table>
4. The field equipments

The setting up of the various field technical equipments and sensors has taken place from the middle of January until the end of February. All of them are power supplied by the East ring road energy network. The data transmission is achieved either by the urban freeway’s Ethernet video network, or by a 3G wireless Internet connection.

- **The reference system**: Automatic Number Plates Recognition (ANPR) devices

- **The various assessed systems**:

  - Bluetooth/WiFi sensors
  - Magnetometers
5. Implemented methodology

5.1. Reference system

Travel times analysis requires a reliable reference system, which means having a high detection rate, in any case greater than the assessed systems, and allowing a representative extraction of the statistic characteristics of the real traffic. For this experiment, ANPR devices SURVISION “Micropack” were chosen to be the reference system.

![Fig. 7. « Micropack » SURVISION ANPR](image)

ANPR devices are systems equipped with Optical Character Recognition (OCR) cameras allowing vehicle identification by its license plate. Thus, it can read any kind of license number, foreign or not. It can be settled as well at roadside or in the central reservation, as at overhang of the lane axis on a VMS gantry or a road structure such as a bridge.

These devices present a high detection rate, near to 95% of the traffic, with a variability around 3%, according to the setting-up (roadside or overhang), the brightness level (darkness, rising or setting sun), the weather conditions (rain, snow, fog) and the traffic conditions (masking of license plates between vehicles or by large vehicles).

The rate of right reading is between 85 and 90% of the detected plates. The OCR errors are mainly not attributable to ANPR, and are mostly due to a damaged or dirty license plate. The rate of recognition, product of the detection rate by the rate of right reading, is so around 80 to 85% of the traffic.

Every reading of license plate is timestamped at the second by the specific software running on the acquisition computer system on which the ANPR is connected, and stored in a text file. The installation of one license plate reader per lane in several points of the road, all of them being synchronized on the same hourly reference, allows the matching of the same vehicles in each of these positions. According to the recognition of their license plates, travel times of these vehicles on the concerned section can thus be calculated by difference of their passing times.

A other specific software also allow to record traffic video sequences timestamped at the hundredth of second. The license plate match rate is depending on the recognition rate of each entry and exit points of the analysed section. It’s also depending on the section characteristics, mainly the number of entry and exit. A closed section (here “BC” section, see figure 1(b)), without entry nor exit, thus allows to obtain an optimal representativeness of the road traffic by maximizing the match rate.
5.2. Assessment methods

In order to compare similar quantities, the period of individual data aggregation chosen for processing must be the same that the one provided by the assessed system. The optimal reference period for the analysis of the exit measured travel times is 5 or 6 min. Other multiple or submultiples periods of these can also be analysed. The statistical data extracted (average, percentiles and so on) have to be also of the same kind that those supplied by the evaluated systems, as far as these are identified. These are compared during the processing phase of collected data, so these are required in batch mode.

The sampling times will be selected to cover the different traffic flows of the trial site (see Figure 2). These ones will be defined according to the hourly aggregated data flows and the 6 minutes aggregated data speeds provided by traffic data collection stations of the experimental area.

The collection involves sampling at least 30 reference aggregated travel time sequences for each studied section.

In order that the samples would be representative of the real travel times, the aggregation period will be chosen so that their sizes should reach the expected minimum value. This one must be at least 80% of the average 6 minutes aggregated data flow, provided by the nearest data station to the exit recognition point of the studied segment. This average flow rate is considered in relation to flow rates observed over the complete duration analysis that represents these 30 travel times sequences.

Besides, to be able to introduce travel time reliability indicators, the number of individual travel times from which statistical data are calculated, on every temporal aggregation slots, will be taken into account.

An example of temporal graph of median travel times up to the 90th percentile is represented below:

![Fig. 8. Example of travel times graph on aggregation slots of 5 minutes with number of matching](image)

This kind of representation presents the main interest to compare both the temporal evolution of the reference travel times and those provided by the assessed systems, and also the scatterings of the travel times of each system.

It is thus possible to evolve a “reliability indicator” providing a clear image of the performances of each of these sections.

The definition of this indicator allows to take into account both the difference of the two scatterings of each distributions (the scattering being defined here as the distance between the 50th percentiles i.e. median travel times, and the 90th percentiles), and the absolute gaps between the reference travel times and those provided by the assessed systems.

This indicator is thus defined as follows:

\[ \text{IND}_{TT} = \frac{\min \{\overline{TT}_{90\% \text{ANPR}}; \overline{TT}_{90\% \text{A.S.}}\} - \max \{\overline{TT}_{50\% \text{ANPR}}; \overline{TT}_{50\% \text{A.S.}}\}}{\max \{|\overline{TT}_{90\%} - \overline{TT}_{50\% \text{ANPR}}|; |\overline{TT}_{90\%} - \overline{TT}_{50\% \text{A.S.}}|\}} \]  

(1)

A.S. = Assessed System
This calculation provides a measure of the covering of the two distributions, based on their maximum dispersion at one given moment. Thus, for a given aggregate range, when the two distributions are strictly identical (perfect superimposition of the two curves), this ratio reaches its maximum value equal to “1”. On the contrary, the more the distribution overlap area is low (which, in some cases, may be due to a large gap of dispersions), the more the value of this indicator tends to the value “0”, but remains positive. A negative value of this indicator means that there is not any overlap area of the two distributions. Thus, the more the gap between travel times is increasing, the more this indicator is settling to a strongly negative value, meaning a worse estimation of the assessed system.

Fig. 9. Example of travel times graph on aggregation slots of 5 minutes with reliability indicator

Overall reliability, section by section, is defined as the ratio of the duration where the indicator is positive (shown by the purple colored strip) by the total measurement time. For the example above, the travel times overall reliability is 69%, i.e. travel times are rightly estimated during 69% of the total time.
Others measurements accuracy and reliability indicators can be produced under different traffic flows, such as:

- The gaps between travel times provided by different systems and those given by the reference devices, quantified by:
  - The relative errors calculation of statistical parameters (average, median, percentiles) of the temporally aggregated data of the metrological reference and assessed system:

![Fig. 10. Definition of relative and mean relative errors of data](image)

the statistical reference value is necessarily of the same kind that the one provided by the assessed system (average, median, and so on);

  - The sharing of these errors among 4 classifications:
    - Strictly lower than 5%,
    - Between 5% and 10% not included,
    - Between 10% and 20% not included,
    - Upper or equal to 20% ;

  - The calculation of the uncertainty intervals of these gaps, achieved with a confidence level recommended by the guide [3] equal to 95%, meaning that 95% of the studied values belong to this interval (subject to these ones follow an approximately normal distribution);

- The production of others reliability indicators, such as:

  - The number of travel times compared to the real flow on the studied sequence on a section without entry nor exit;
  - The ratio of effective input data used to calculate travel times on every section against the real flow on the studied slot time;
  - The surface correlation between the reference travel times distributions and those of the assessed systems, in the case of these ones are providing (see reliability indicator (1));

- The available data rate for each technology and system throughout the whole studied period;
- The renewal and refreshment time intervals of the information provided by the various systems, in order to study their ability to develop travel times in real time.

6. Innovative administrative procedure

An innovative administrative procedure takes place in this project. In fact, the road operator decided to spend €10,000 for the cost associated with the evaluation of each sensor technology. Thereby, he wrote an administrative procedure adapted for the call for tender in this way. The principle is to assign two scores with the same weighting to each candidate: a technical mark and a financial score. Technical mark ranges from 1 to 10 and is awarded based on the nature of data and functionality offered. The financial rating is assigned based on the cost of providing, it
means 0 if the offer is free and -10 if the offer costs € 10,000 or over. The candidate is retained if its final rating is positive.

7. Conclusion

A large-scale experiment like this one is very complex to implement. Actually, a lasting installation of field sensors on an urban freeway requires to resolve lots of technical difficulties. Now, the necessary adjustment and validation phase of each system is in progress. It is planned that at the end of May-beginning of June, the data collection phase will begin to last 3 months at least. First results will be afterwards available.

This experiment will be a real opportunity to build a large travel times database developed from these various innovative technologies. Thus, the results of these assessments will allow road operators to have a better overview among the numerous existing and evolving solutions of traffic data collection for travel times calculation, and help them to take the best choice both from the point of view of the requested performances as costs to be involved.

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