Potential of using private data for public traffic management in Bavaria

Sibylle Kratzer  
TRANSVER GmbH, Maximilianstraße 45, 80538 Munich, Germany, phone: +49 - (0)89 211878-17,  
fax: +49 – (0)89 211878-29  
kratzer@transver.de

Samuel Denaes  
TRANSVER GmbH, Maximilianstraße 45, 80538 Munich, Germany, phone: +49 - (0)89 211878-19,  
denaes@transver.de

Reiner Scharrer  
Oberste Baubehörde im Bayerischen Staatsministerium des Innern, Franz-Josef-Strauß-Ring 4,  
80539 Munich, Germany, phone: +49 - (0)89 2192-3551, reiner.scharrer@stmi.bayern.de
INTRODUCTION
In recent years, additionally to traffic sensors from road operators, new data collection means operated by privately owned service providers have appeared. In Germany, the Gesellschaft fuer Verkehrsdaten mbH (DDG) holds a large network of stationary detectors. Furthermore they gather floating car data (FCD). Within data co-operation agreements, public authorities can get online access to both, data from stationary detectors and from vehicles, and use it for traffic management. To public authorities this is an opportunity to improve their knowledge base qualitatively and quantitatively. Despite the agreement the potential of this data is still unknown. Is the investment in integrating this data really worth it? What would be the added value of using this data? How could this new data be effectively integrated in existing traffic management platforms and applications?

Within CORVETTE, in a study commissioned by the OBB (road administration, subsidiary of Bavarian ministry of the interior), the potential of using private data from the DDG for improving traffic state monitoring in Bavaria has been evaluated. First, solutions for integrating the private data in the existing traffic monitoring system were designed. A new model approach was developed for merging data from different sources to estimate the traffic state. In the course of the project, a prototype was implemented for testing the models with real data. The model stability was proven and the quality of the traffic state estimation has been evaluated for different motorway sections and for different traffic scenarios. The improvement through the use of the DDG data was then quantitatively evaluated in terms of network coverage, extrapolating the results of the test scenarios to the entire Bavarian motorway network. The results of the study provide a basis for important decisions in the process of extending traffic monitoring in Bavaria.

DATA TYPES
To improve traffic monitoring without increasing the costs dramatically using private data in addition to data from publicly owned detectors has come to focus for public road operators. The public authorities in Bavaria hold stationary detectors on the motorways. These detectors, mostly induction loops, beside other values measure flow and speed of vehicles using an aggregation interval of one minute.

In addition, the privately owned corporation “Gesellschaft fuer Verkehrsdaten mbH” (DDG) holds a large network of stationary detectors (SES) on bridges. These traffic eye detectors measure speed and traffic flow on the far left-hand lane using infrared detection. Unlike the public detectors those SES send their data event-driven via short message service. Whenever the measurement values meet certain conditions the data aggregated within the last few minutes is sent to the central of the private company (DDG). This data is then made available to the Bavarian authorities due to some co-operations agreement. Depending on the level of service determined the aggregation interval of the measurements is one (heavy traffic) or seven minutes (low traffic). The data is sent no more frequently than every three minutes. The conditions that have to be met for data transmission are time triggers and changes in Level-of-Service. Each detector has its individual set of parameters setting the triggers.

The third data type that can be used by the authorities is DDG data from floating cars (FCD). Cars equipped with specialized information systems measure travel times during their journeys. Again the measured data is send to the central only when certain events are detected. These events can be time triggers or the experience of entering or leaving congestion. Whenever a condition for transmission is met a set of measurements is sent to the DDG central. Currently there is no co-operation agreement about this vehicle data. In the course of the research project CORVETTE nevertheless data of two months was made
available to the Bavarian authorities for developing and testing the models and for estimating the added value.

MODELS FOR TRAFFIC STATE RECONSTRUCTION

To integrate DDG data into traffic state monitoring in Bavaria new models were developed. The applied technique for traffic state estimation on a particular road section depends on the information available for this section. Table 1 holds an overview over the model used given certain data.

<table>
<thead>
<tr>
<th>Public detectors (less than 10 km spacing)</th>
<th>SES</th>
<th>FCD</th>
<th>Model</th>
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<tbody>
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<tr>
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<td>No</td>
<td>Not less than 3 km spacing</td>
<td>No</td>
<td>Extrapolation</td>
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</tbody>
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Table 1 – Model overview

Whenever public detectors are on the road with less than 10 km spacing sending their values every minute a flow model can be applied. This flow model is based on the Lighthill-Whitham-Richards model first order as described in [2] and [3].

When no additional data to the public data is available then the basic LWR model can be used. It was introduced in [1] where it has also been evaluated; it has been tested offline and online in various projects, e.g. INVENT and REACT. The model uses a fundamental diagram to describe the relationship between flow, density and speed. The measurement values of the detectors are used to generate boundary values. Their information is propagated deterministically to reconstruct the traffic flow. Within the project CORVETTE this model was extended to integrate SES and vehicle data when available.

When there is a stationary detector owned by the DDG between the public detectors its values will be integrated similar to the measurement values of the public detectors as boundary values. But due to the character of the SES data the following adjustments have to be applied. As the data is only available every three minutes at most the values are used for three minutes at least in the model. The SES only measures the traffic on the far left-hand lane. Therefore the flow for all lanes has to be estimated. This was done by concluding the overall flow from the fundamental diagram using the measured speed.

The vehicles send travel times and mean speeds on their traveled routes. These mean speeds are used to improve the model result. Whenever there is a vehicle measurement for a certain location the modeled speed resulting from the LWR model first order is compared to the measurement. For this a statistical test (Gaussian test) is used. If the measured vehicle speed differs too much from the modeled value, then the modeled value is replaced by the approximated values resulting from the vehicle speed. As the model first order uses the values from previous time steps to compute the following the vehicle information will propagate into the future once it was used to adjust the initially computed model values.
When both private data, SES and FCD, is available in addition to public stationary detectors, the SES data is integrated first, then the test for adjusting the model using vehicle data as described above is applied. Thus all three types of information, public detectors, private detectors and vehicle data, are used to reconstruct the traffic state.

If there are no public owned stationary detectors on the stretch or if they are too far apart but data from SES is available and those SES have a spacing of less than 3 km, then an anisotropic interpolation model as described in [4] is used to monitor the current traffic state. This interpolation model differs according to the measured speed (anisotropic: having properties that differ according to the direction of measurement). In congested traffic information travels upstream, while in free traffic information propagates downstream. Using a special filter this method removes small-scale fluctuations and adaptively uses the main propagation direction of the information flow [4]. The model had to be slightly adjusted to apply to the sporadic information from the event-driven data transfer.

If vehicle data is available within a stretch of the road where the anisotropic interpolation model can be applied, then the FCD is used as another detector not fixed to a certain location but moving over time. This results in further nodes for the interpolation caused by the vehicle information.

If the only information available is vehicle data then a simple extrapolation is used. When sending the data a sending cause is also included (“in jam”, “out jam”, “time triggered”). Depending on the current cause adequate speed values are used for a certain range up- and downstream (e.g. 1 km).

At stretches where there are only separate stationary detectors their measured speed values are used in a certain surrounding (e.g. 1 km) for traffic state monitoring.

**VALIDATION OF THE MODELS**

In the course of the project the models where implemented as prototypes using MATLAB. The LWR model variations (using SES data additionally, using FCD additionally, using SES data and FCD additionally) and the variations of the anisotropic interpolation model (using SES data, using SES data and FCD) were then validated for stability and jam detection using test scenarios.

As test scenarios real traffic data from existing roads where used. On each stretch an exclusive stationary detector owned by the Bavarian authorities was used to compare the modeled to measured values.

Each model was tested for model stability. Three criteria were evaluated:

- In case of measured low traffic with high speeds the model will not reconstruct any congestion but reconstruct the free traffic correctly.
- In case of congestion building up the model will reconstruct the decline in speed without any unusual fluctuations like heavy oscillation.
- When congestion is degenerating the model will also reconstruct the decline in traffic disturbance without any unusual fluctuations.

All types of models proved stability within the carefully chosen test scenarios and are therefore regarded to be stable.

**ADDED VALUES**

In regions with close detection through public owned detectors the integration of the private stationary and mobile detectors can still improve the accuracy of traffic state estimation in many situations. Even when the previous detection is sufficient for the models to reconstruct the congestions the additional detectors, stationary or mobile, can result in a faster reconstruction. Figure 1 (right) shows an example. The black line is the measured speed at the stationary detector used for comparison only. The blue line shows the modeled speed using
the public detectors only, the red line is the result of the model using also SES data. It can be seen that the model using the SES data reconstructs the speed drop approximately 15 minutes before the core model using only data from public detectors.

Figure 1 – Faster detection through SES data (left) and vehicle data (right)

The same result can be shown when a vehicle sends its data close to the start time of the congestion. Figure 1 (right) presents the result of a test case using real data. Again the black line is the detector measurement, the blue line the result of the core model and the red line the result of the extended model. The model using the vehicle data is able to reconstruct the breakdown some 5 minutes earlier than the basic model using stationary data only.

When shorter congestions appear that are located between two stationary detectors that are owned by the authorities they are sometimes not reconstructed using only this data. Tests have shown that data from SES or vehicles can help detect those congestions and therefore secure a better detection.

Figure 2 – Only detection through SES data (left) and vehicle data (right)

Figure 2 shows some examples on Bavarian motorways. In either case the brief congestion is not reconstructed by the model using only the public detectors. On the left figure the congestion is reconstructed using SES data, on the figure at the right-hand side vehicle data enabled the model to reconstruct the congestion.

Besides the faster and more accurate reconstruction in regions where stationary data was already available there are also regions where reconstruction is only possible due to the use of privately owned data.

To estimate the added value quantitatively the distribution of detectors on 4620 km of Bavarian motorways were evaluated. Using only data from stationary detectors owned by the public motorway authorities the traffic could be monitored on 2009 km. This corresponds to
43.5% of the overall motorway length. If SES data is used as well this can be enhanced by 475 km to 53.8% or 2484 km. Additionally, 97.8% of existing traffic monitoring on road sections that can be approximated by the LWR model can be improved by integrating SES data in the extended LWR model.

The added value of vehicle data had to be approximated analysing the distribution of vehicle measurement during the test period used in the study. Approximately 1214 vehicle measurements per day can be used to improve the traffic monitoring on sections where the LWR model can be used. At an average 210 measurements are available to improve the modelling with sections with anisotropic interpolation. And another 411 measurements are isolated and can be used to monitor the traffic state on road sections where no stationary detector data is available.

CONCLUSIONS AND OUTLOOK

Within CORVETTE, in the presented study commissioned by the OBB, the integration of private data from the DDG was designed and its potential evaluated.

It turned out that the integration of the private stationary and mobile detectors can improve the accuracy of traffic state estimation in many situations. On many stretches the data from privately owned sources is the only information available. Therefore the use of private data also results in a higher coverage of the road network for traffic state monitoring.

The results of this study provide a basis for future decisions in the process of extending traffic monitoring in Bavaria. Resulting from the added value estimation in the study, further co-operation agreements or purchasing data from private companies could be a worthy investment to get a better overall coverage of the traffic state monitoring on motorways in Bavaria.

REFERENCES