Fusion and Enrichment of Traffic Message Channel (TMC) Messages with Floating Car Data (FCD)

Anke Sauerländer-Biebl[1], David Suske, Rüdiger Ebendt, Günter Kuhns
German Aerospace Center (DLR)
Rutherfordstrasse 2, 12489 Berlin, Germany
[1] TEL: +49 30 67055 605, FAX: +49-30-67055291, Anke.Sauerlaender-Biebl@dlr.de

ABSTRACT

This paper describes an approach of DLR to fuse Traffic Message Channel (TMC) messages with urban traffic information obtained from Floating Car Data (FCD). There are two main directions for such a fusion:

1. The first direction is that of validating the TMC messages with information obtained from FCD, such as the Level of Service (LOS).
2. The second direction is that of a feature and decision fusion: the two-dimensional and time-dependent traffic situation as obtained from FCD can be completed by the more punctual information of the TMC messages that report about events like road blockings, construction sites or jammed road stretches. This information can be used directly within routing services which calculate their routes using FCD information.

The described approach for fusion has been deployed during the ongoing project SimpleFleet: FCD is collected from large fleets, and the resulting data streams are continuously delivered to a "Traffic Store". Small and medium enterprises will be able to connect to the Traffic Store via standardized APIs, enabling the use of traffic information within their fleet management solutions.

Keywords: Data Fusion, Floating Car Data, TMC Messages

1. INTRODUCTION

Traffic information can be collected from several different sources implying different quantity and quality of the received information.

To optimize the quality and completeness of the traffic information, different types of fusions are to consider [1]:

- **Complementary Fusion**: The aim is to increase the completeness of the data.
  Independent sensors regard different ranges and phenomena or they measure at different times.
- **Competitive Fusion**: Sensors regard the same section at the same time and produce data of the same type. These (often weighted) relations of such competitive data can improve the accuracy of a system.
- **Cooperative Fusion**: Often, one type of sensor alone does not deliver all needed

information. So the requested information can only be gained by combining the different types of sensors

- **Independent Fusion**: Technically speaking, this is not yet a fusion because the data of different types of sensors are not connected but they are processed in the same system.

The last type can be combined with feature and decision fusion [2], if e.g. both TMC and FCD are processed within the same routing engine, and routing decisions are based on the different features of both kinds of data.

In this paper we focus on the fusion of the two sources

- Floating Car Data (FCD) and
- Traffic Message Channel (TMC) messages

They are complemented by historical datasets and speed profiles.

Basically FCD and TMC data have absolutely different features that we want to combine gainfully.

FCD are delivered by probe vehicles which send a time-stamped position report every n seconds.

TMC messages are produced irregularly and their content is often delivered without any validation. But different from FCD, a TMC message makes a statement about the reason of the traffic impact, e.g. road closed because of road works or traffic jam because of an accident.

The information of the TMC data should be used complementary to the FCD information for routing decisions which means a *decision fusion* is done.

This approach has been developed during the ongoing project SimpleFleet: FCD is collected from large fleets and the resulting data streams are continuously delivered to a "Traffic Store". Small and medium enterprises will be able to connect to the Traffic Store via standardized APIs, enabling the use of traffic information within their fleet management solutions. The Traffic Store uses digital road maps from Open Street Map (OSM).

2. TMC MESSAGES

Traffic messages are provided directly by road authorities or via service providers. They can contain traffic data but the focus is rather on events with an impact on traffic like road works or accidents. Traffic Message Channel (TMC) is a special service of the Radio Data System (RDS). RDS is the base or the carrier medium of TMC. This system allows the transmission of additional information via the radio.

It is of particular note that there is no centrally controlled TMC registry or even a control authority. Messages of different service providers will differ much from one another in their quality. For project SimpleFleet, an important aspect is the quality of the TMC messages. Therefore, DLR conducted a detailed analysis to determine which of the sources are best in terms of quantity of emitted TMC messages (per day). Figure 1 shows how often TMC messages were received for a particular radio station. The values represent the average for one day for the month of June 2012.

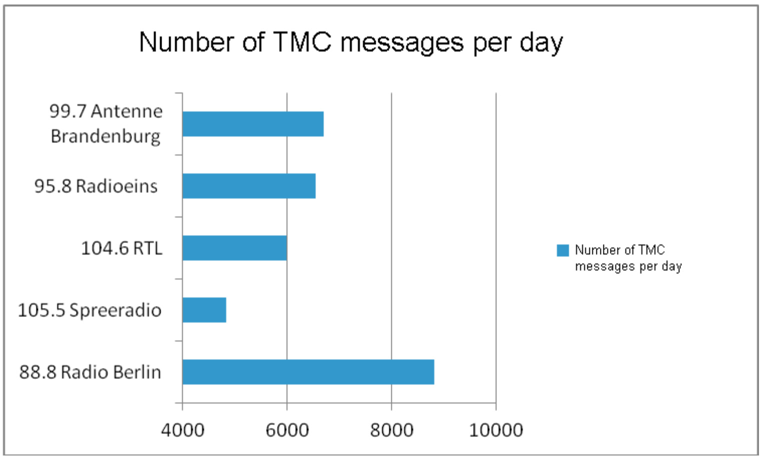


Figure 1: Number of TMC messages a day

Now we analyze the quality of the TMC messages of the different radio stations. An important aspect of quality is the truth of the TMC messages. To validate their truth, a field trial of DLR for the period of one week has been extended to also cover the (manual) identification of reported construction sites by reports of the conducting test drivers. The following diagram shows percentages of coverage and error rates. The red bar indicates how many of the construction sites have been identified as being incorrect, that is, non-existing in reality.

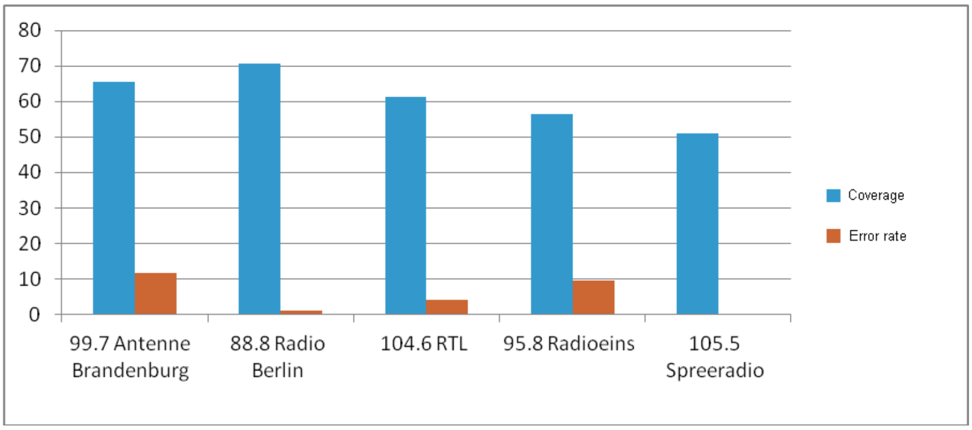


Figure 2: Quality of TMC radio stations

The quality of TMC messages makes them a very interesting source of traffic information. On the other hand, it also becomes clear that an automated mechanism of correction and enhancement, e.g. by an appropriate fusion with data from other sources is desirable. Next, we will describe the basic contents and structure of a TMC message in general.

2.1 STRUCTURE OF A TMC MESSAGE

All TMC messages consist of the same structure defined by ISO standards ISO 14819-1 to 14819-3 [3] [4] [5]. We briefly introduce the most import fields that are needed to understand the way TMC messages work.

- **wLoc2**, the location code:
  The location code specifies the location of the event. There is an extra location code list that supplies additional information like the geographical position for each TMC location. It is important to know that the location code marks the source of a traffic impact, e.g. the position of an accident itself and not the beginning of the resulting queue. The location code list is maintained by each country separately. For details we refer to [3] [4] [5].
- **wEvents**, the events:
  List of 1 to 5 event codes for each message: Each event code references an entry in the TMC event list. This list contains 1,615 different events. They can be classified roughly as accidents, congestions, closures, weather conditions and different speed regulations.
  Each TMC event is encoded in the Alert-C standard. Thus, the events of a TMC message trigger the same event code in e.g. France or England. For details, we refer to [3] [4] [5].
- **byDirection:**
  If the event affects a stretch, this shows the direction to look to from the location code: forwards or backwards.
  Every location point has at most two neighbors: one location code in direction forward and one in direction backward. The neighbor location codes are also entries in the same location list. The TMC direction is independent from the traffic direction.
- **byExtent:**
  The number of steps to follow from location point wLoc2 in the direction given by byDirection to the next location point. If byExtent is greater than 1, this means that the affected route includes n+1 neighbored location points. The traffic runs from the last extended location point towards location wLoc2, which means that a TMC message always looks against the traffic direction.

This shows that the first challenge is to map a TMC path described by the fields above onto a map, in order to compare it with the corresponding links which the FCD are mapped onto. See also chapter 4.1 for interesting side effects.

3. METHODOLOGY OF FUSION

As mentioned in chapter 2, "TMC Messages", there is no control of their quality. Therefore we try to use the second source of traffic information: the FCD.

To be able to fuse TMC data and FCD, the corresponding nodes and links of the street map, in this case OSM, have to be determined. The next step is the calculation of a LOS (Level of Service) by using current FCD and then to compare this LOS to the content of the TMC message. If the TMC message can be confirmed by the FCD LOS, further processing can be done:

- Show the information in a map and use while routing
- Observing the tendency: Is the impact on the traffic growing, decreasing or static?
- Remember the event and evaluate its repetition: Does this event occur regularly?

3.1 METHODS OF HORIZONTAL LOS CALCULATION

To have a mean to compare and validate traffic impacts we calculate LOS (Level of Service) values for affected links. The LOS is a means of evaluating the quality of the traffic flow. There are different ways of categorizing the LOS with respect to travel times or speeds.

In our approach we tried the following LOS definitions.

We start by the definition of Brilon and Schnabel [6]. The authors describe quality levels ranking from A to F, taking into account the speed limit of a road segment:

Table 1: Definition of LOS by Brilon and Schnabel [6]

Speed Limit (km/h)	50	60	70		LOS
Current Speeds	< 15	< 15	< 15		F (cyan)
	< 20	< 20	< 25		E (red)
	< 25	< 25	< 30		D (orange)
	< 30	< 35	< 40		C (yellow)
	< 40	< 50	< 60		B (light green)
	else	else	else		A (green)

The following definitions for a LOS use three or four quality levels, ranging from 0 to 2, or 0 to 3, and are due to DLR. They are derived from similar definitions in [8] and [9]: The definition in [8] gives two definitions for a LOS: one based on a mapping of mean travel speeds of passenger cars to quality levels, and the other based on a mapping of the so-called "buffer index", which is the ratio of the mean current travel time to the acceptable travel time.

The definition in [9] uses a mapping of urban street classes and average travel speeds to quality levels. The definitions of DLR aim to capture these previous ideas by mapping ratios of current mean travel speeds and the speed limit. The binning is the result of the many experiences DLR has with the maintenance of visualizations of traffic situations for big cites in Germany like e.g. Berlin or Hamburg.

Table 2: Three-level LOS definition

LOS	limit ratio = curr. mean travel speed / speed limit	Description
0 (green)	limit ratio > 0.5	free flow traffic
1 (orange)	0.25 < limit ratio <= 0.5	synchronized traffic
2 (red)	limit ratio <= 0.25	congested traffic

Table 3: Four-level LOS definition

LOS	limit ratio = curr. mean travel speed / speed limit	Description
0 (green)	limit ratio > 0.5	free flow traffic
1 (orange)	0.35 < limit ratio <= 0.5	synchronized traffic
2 (red)	0.25 < limit ratio <= 0.35	very dense traffic
3 (cyan)	limit ratio <= 0.25	congested traffic

It is of note that also [10] gives a very similar definition, albeit using a different binning, and the ratio of mean current speed and free flow speed instead. The following table gives their definition.

Table 4: LOS definition of Maier, Braun, Busch, and Mathias [10]

LOS	ratio = current mean speed / free flow speed
Green	>= 1.0
light green	0.5 < ratio < 1
Yellow	<= 0.5
Orange	<= 0.4
Cyan	<= 0.3

In the same publication [10], another possible definition of congestion is considered, using a definition of the mean delay time:

$$\Delta T = \frac{s}{v} - \frac{s}{v_0}$$

where v is the current mean travel speed, v_0 is the free flow speed, and s is the link length. Based upon this definition, DLR used a slight modification of this formula, where the actual free flow speed has been replaced by the limit speed.

In our approach a LOS is calculated for each affected link as a start. We use numbers as quality levels (0 = no impact, the higher the number, the slower the traffic). Let the TMC path be represented by the n links L_j (j = 1, …n). Then each link is weighted with its length. The resulting horizontal LOS is

$$\mathrm{LOS}_{\mathrm{Fusion}}^{\mathrm{TMCPath}(i)}(t) = \frac{\sum L_j \cdot \mathrm{LOS}_{\mathrm{Fusion}}^{\mathrm{Edge}(j)}(t)}{\sum L_j}$$

where L_j is th length of the jth link of the TMC path and $\mathrm{LOS}_{\mathrm{Fusion}}^{\mathrm{Edge}(j)}(t)$ is the LOS of the single link j at time t. For details, we refer to [7].

4 VALIDATION AND RESULTS

For the validation of a TMC message, it must be clarified which kind of TMC messages can be validated by FCD at all. Because the FCD only give information about travel times on links, only TMC messages that include impacts on the traffic flow can be validated. Messages concerning parking information, future events, weather forecasts, etc. cannot be validated with FCD data.

In principle we have to distinguish between three types of TMC messages:

- Messages that can be validated as true or false.
  Example: Traffic jam because of an accident
- Messages that could be verified but where their verification is not mandatory.
  Example: One of two lanes is closed.
  This may have an impact on the traffic or not, depending on the type of road, the time and the traffic density.
- Messages that can definitively not be verified.
  Example: Closed or additional parking lots, thunderstorm warnings for an area

This classification cannot directly be derived from the TMC event classification. Though the TMC events are grouped, some groups fit completely into one of the three categories but others contain events that fit into different categories.

If a TMC message can be validated, a horizontal LOS calculation is done by using the FCD information of the affected links. If a LOS > 0 is calculated, this indicates an impact on the traffic flow, and the TMC message will be recognized as being true. TMC messages can also include an annulment of a traffic impact. In this case the validation with FCD, of course, must validate that there is in fact "no impact" anymore.

4.1 MAP ERROR DETECTION

While mapping TMC paths to OSM links, there is the additional benefit that map errors can be detected. If the TMC location codes can be mapped on OSM points, but no connecting links can be found between the points, this might be a map error.

Example for an error that is raised because of missing links for the searched direction

An error is reported by the TMC-validation process: *No connected links for the TMC path with Location Code 32732 with one extent in direction backwards could be found.*

The TMC location code can be mapped to the crossing *Friedrichstrasse/Unter den Linden.*

The searched links are parts from crossing *Friedrichstrasse/Behrenstrasse* in direction North to *Friedrichstraße/Unter den Linden* (see screenshots of Google Maps):

Figure 3: Searched route

Figure 4: Corresponding OSM-Points (green arrows)

Table 5: OSM-points found for the searched route in the database

Latitude, Longitude	Point-ID	Description
52.51563, 13.38909	20246257	Intersection Friedrichstraße/Behrensstr.
52.51616, 13.389	26724096	
52.51683, 13.38892	25662689	
52.51698, 13.38889	968049036	Intersection Friedrichstraße/Unter den Linden

If selecting all links having one of the aforementioned OSM-points as start or end point, one can see that there is a connecting path consisting of 3 links that connect the start and the end point, but in the wrong direction (direction South):

Table 6: Result set of all links having the mapped OSM-points as end or start node

	id bigint	ext integer		startnode bigint	endnode bigint	length numeric(15,5)
1	25913	0		21487242	968049036	17.45000
2	25914	0	1	968049036	25662689	15.25000
3	25915	0	2	25662689	26724096	68.28000
4	25916	0	3	26724096	20246257	53.44000
5	25917	0		20246257	25662916	92.62000
6	36120	0		20246257	25662705	121.19000
7	38054	0		25661397	25662689	203.96000
8	38055	0		25662689	1543381919	13.08000
9	64178	0		26724096	1419121873	119.61000
10	7132	0		1206481791	20246257	14.01000

So the requested route is missing in our OSM database and missing links can now be added.

4.4 FEATURE AND DECISION FUSION

The feature and decision fusion used in the SimpleFleet project has additional benefits for the users:

- Roadblocks can be considered when routing
- Visualization of the TMC messages in the map as location and with informative text.
  The user knows where the impact is, for how long and what the reason is (road works, roadblocks, accident, etc.). FCD alone does not deliver this information.

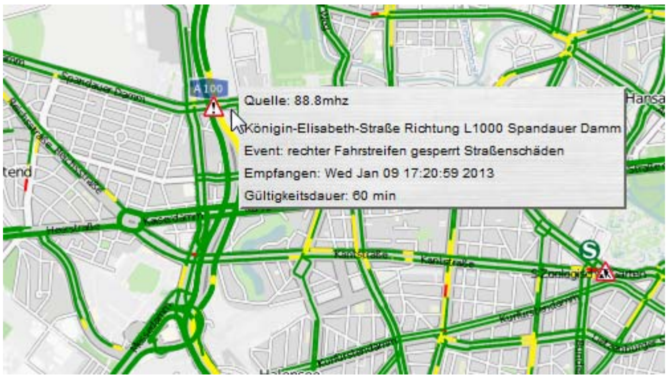


Figure 5: Visualization of fused information for Berlin

The streets colored green, yellow and red reflect information of FCD, and the danger signs represent the TMC messages with informative text when the user touches them with the mouse pointer.

- Gaining information about the typical appearance of recurring traffic jams.
  This can be shown graphically by using a traffic heat map, e.g. with OpenHeatMap (www.openheatmap.com):

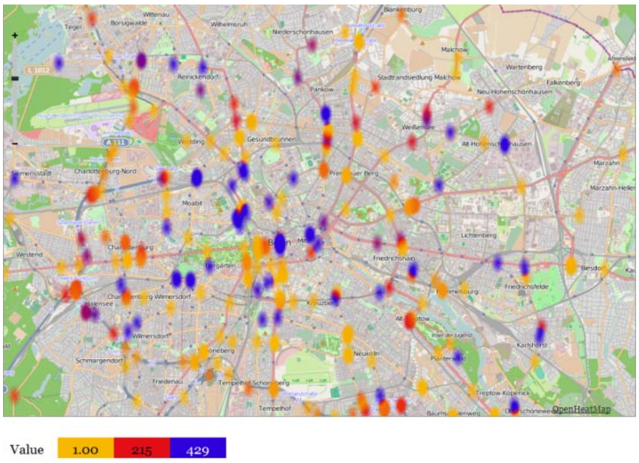


Figure 6: Visualization of all TMC messages of November 2012 for Berlin

4.4.1 Enrichment of FCD with a Spatio-Temporal Tendency of a Congestion

If a TMC message has been successfully validated, we observe its behavior: An observation period is started in which every 10 minutes a new LOS calculation is done for each link of the affected TMC path. We decided to use the 6-level LOS of Brilon and Schnabel, see chapter 3.1 and [6].

The following illustrations have been created by the help of Keyhole Markup Language (KML), and Google Earth. Figure 7 shows the results of the route "Karl-Marx-Allee" in Berlin. It shoes a decreasing traffic jam after the initiating TMC message had been received, resulting in a space-time LOS matrix. The vertical lines mark the begin and end of the involved links on the given TMC path. The width of the cells corresponds to the length of the respective links. Each horizontal line represents the LOS state of the links at a fixed time. The colors of the lines are chosen according to the color schema given in Section 3.1, Table 1. The abscissa represents the time dimension, and each horizontal line corresponds to a time slice of ten minutes. The lower the line, the more recent is the information, that is, the top lines show the traffic condition on the stretch of road for the time when the TMC message had been announced.

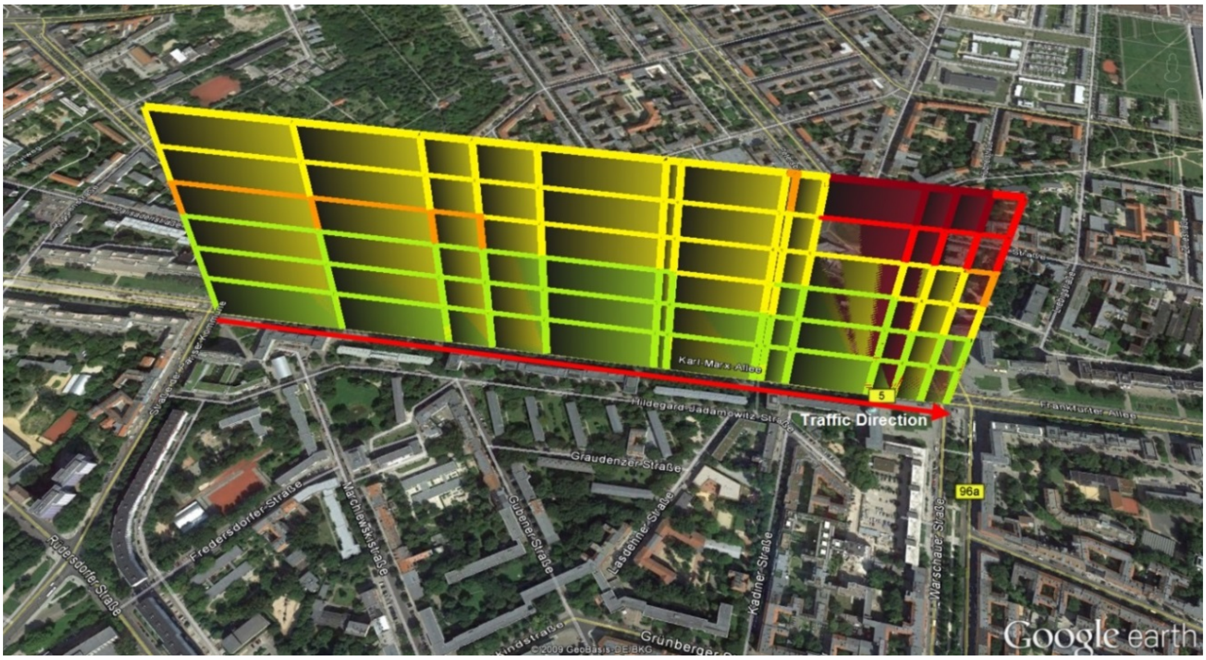


Figure 7: Space-time LOS matrix, using the LOS definition of Brilon and Schnabel[6]

We see that the traffic jam dissipates within 40 minutes and also that the recent traffic conditions are that of free flow.

To get a tendency, the previous and the current measurements of LOS values of the relevant links are compared every ten minutes. For this purpose, a numeric value is assigned to each LOS, e.g. for the Brilon/Schnabel LOS we use: A = 0, B = 1, …, F = 5. The calculated LOS is then multiplied with the length in meters of its corresponding link and these values are summed up for all links of the path. If the sum becomes 0, there is free flow traffic again. In addition, we also calculated the delay times measured in seconds every 10 minutes.

Further examples:

Figure 8 Dissolving traffic jam

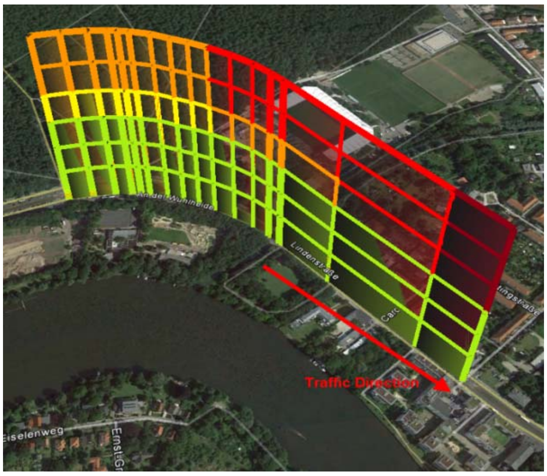
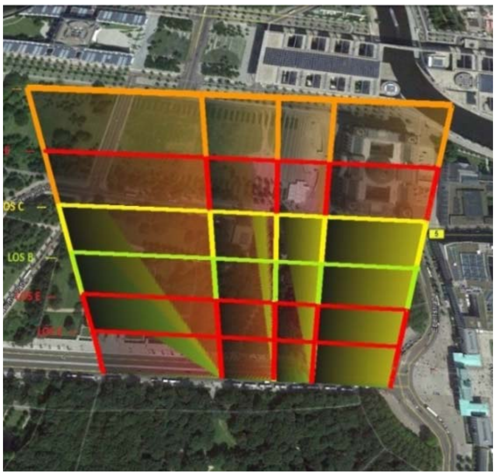


Figure 9: Instable behavior



5 ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Union Seventh Framework Programme “SimpleFleet” (http://www.simplefleet.eu, grant agreement No. FP7-ICT-2011-SME-DCL-296423).

6 REFERENCES

[1] Brooks, Richard R. and Iyengar, Sundararaja S., *Multi-Sensor Fusion: Fundamentals and Applications with Software*, Prentice Hall PTR, 1997

[2] Hall, D. L. und Llinas, J., “An introduction to multisensor data fusion", *Proceedings of IEEE Bd. 85*, 1997, pp. 6-23

[3] ISO 14819-1. Available at URL http://www.sirim.my/iscg/tc_g_3/14819-1.pdf

[4] ISO 14819-2. Available at URL http://elearning.zhaw.ch/moodle/file.php/749/Spezifikationen/14819-2.pdf

[5] ISO 14819-3. Available at URL http://www.sirim.my/iscg/tc_g_3/ISO14819_3.pdf.pdf

[6] Brilon,W. and Schnabel,W., "Bewertung der Qualität des Verkehrsablaufs auf Hauptverkehrsstraßen, *Straßenverkehrstechnik*, Heft1/2003, pp. 21-26

[7] Touko Tcheumadjeu, L.C. and Neumann, T. and Brockfeld, E. "Level of Service (LOS) based Data Fusion to enhance the Quality of Traffic Information" in *Proceedings CD ROM 19th ITS World Congress 2012 Wien, Österreich*, 2012

[8] Spangler, M. "Monitoring der Verkehrsqualität für innerstädtische Hauptverkehrsstraßen", *München – AP 1 Definition von Verkehrsqualität für die Roten Routen München – Endbericht,* Lehrstuhl für Verkehrstechnik, TU München, Munich, 2007

[9] *Highway Capacity Manual*, TRB, National Research Council, Washington, D.C., 2000

[10] F. Maier, Braun, R., Busch, F. and Mathias, P. "Musterbasierte Kurzfristprognose der innerörtlichen Störungsausbreitung und automatische Maßnahmenempfehlung", *Straßenverkehrstechnik*, 9.2008, 2008, pp. 556-563