Qualität von on-trip Verkehrsinformationen im Straßenverkehr

Quality of on-trip road traffic information

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BASt-Kolloquium 23. und 24.03.2011

Wissenschaftliche Betreuung des Kolloquiums
Scientific concept of the colloquium

Christine Lotz
Malte Luks

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Kurzfassung – Abstract

Kolloquium zur
Qualität von on-trip Verkehrsinformationen im Straßenverkehr

Die positive Wirkung von Verkehrsinformationen auf die Verkehrssicherheit sowie die Effizienz des Straßennetzes können nur dann erreicht werden, wenn die Fahrer verlässliche Informationen erhalten und ihnen folgen. Diese wesentliche Akzeptanz des Fahrers hängt jedoch stark von der Aktualität, Verlässlichkeit und Richtigkeit der empfangenen Informationen ab. Darüber hinaus ist der persönlich empfundene Nutzen von Verkehrsinformationen unabdingbare Voraussetzung für den Erfolg kommerzieller Verkehrsinformationsdienste.

Aus diesem Grund ist die Verbesserung der Qualität von Verkehrsinformationen eine große Herausforderung für die Serviceanbieter in den nächsten Jahren. Gegenwärtig gibt es eine Reihe von Projekten und Initiativen, die sich der Frage der Qualität von Verkehrsinformationen annehmen.

Am 23. und 24. März 2011 veranstaltete die Bundesanstalt für Straßenwesen ein Kolloquium zur “Qualität von on-trip Verkehrsinformationen”, um die Ergebnisse der erwähnten Projekte und Initiativen präsentieren zu lassen und mit anderen Experten zu diskutieren. Der vorliegende Tagungsband des Kolloquiums fasst die Ergebnisse dieser Veranstaltung zusammen.

Die Bereitstellung von Verkehrsinformationen ist geprägt von vielen Akteuren. Die Wertschöpfungskette beginnt bei der Sammlung grundlegender Verkehrsdaten zur Erstellung von Verkehrsinformationen und setzt sich mit der Datenverarbeitung und -interpretation bis hin zur Meldungserstellung fort. Die Weitergabe kann über verschiedene Übertragungsmedien erfolgen und beim Nutzer (z.B. im Navigationsgerät) empfangen werden. Jeder einzelne Schritt der Wertschöpfungskette kann sowohl von unterschiedlichen Partnern (privat oder öffentlich) übernommen werden als auch in der Hand eines Partners liegen. Diese Komplexität der Zusammenarbeit spiegelt sich demzufolge auch in Qualitätsmanagementprozessen wider.

Im Rahmen des Kolloquiums wurden zwei wesentliche Qualitätsaspekte näher betrachtet:

- die Datenqualität mit dem Focus auf Aktualität, Stimmigkeit der Daten verglichen mit einer gemessenen Realität sowohl zu Beginn der Wertschöpfungskette als auch an jeglichen Schnittstellen,

- die Prozessqualität, welche sich insbesondere mit der reibungslosen Datenübergabe an den Schnittstellen der Wertschöpfungskette beschäftigt.

Beide Qualitätsaspekte helfen zu verstehen, worin die heutigen Qualitätsprobleme bestehen und welche Maßnahmen im Einzelnen ergriffen werden müssten, um eine nachhaltige Verbesserung zu erreichen.

Einerseits kann es vorkommen, dass die Information über ein Verkehrsereignis an einer oder mehreren Stellen der Wertschöpfungskette korrekt vorliegt, jedoch durch ungenügende technische oder organisatorische Schnittstellen im Prozessablauf wieder verloren geht und dem Nutzer folglich nicht zur Verfügung steht. Prominentes Beispiel eines solchen Problems in der Prozessqualität ist die fehlerhafte Interpretation der Meldung im Navigationsgerät, denkbar sind solche Informationsverluste jedoch an jeder Stelle der Wertschöpfungskette. Eine wichtige Maßnahme zur Verbesserung der Prozessqualität ist die Standardisierung sowie die Überprüfung, ob die definierten Standards an jeder Stelle der Wertschöpfungskette eingehalten werden.

Andererseits kann es vorkommen, dass die Datenqualität in Bezug auf ihre Genauigkeit von Anfang an so schlecht ist, dass der Nutzer eine fehlerhafte oder gar keine Nachricht übermittelt bekommt. Beispiel hierfür ist die Vielzahl von Stauereignissen, die entweder nicht gesendet wurden oder gesendet wurden, obwohl sie nicht vorhanden waren. Eine wichtige Maßnahme zur Verbesserung dieser Situation ist die Verbesserung der Ereignisdetektion.

Der Tagungsband enthält Präsentationen, die den Status Quo analysieren, Methoden zur verbesserten Datenerfassung vorschlagen und Möglichkeiten zur Verbesserung von Daten- und Prozessqualität vorstellen.

Offen geblieben sind darüber hinaus folgende Fragestellungen:

- Wie kann die Prozessqualität der gesamten Wertschöpfungskette bei der Vielzahl der Partner kontrolliert werden? Wer überwacht die Wertschöpfungskette? Wird hierfür überhaupt eine zentrale Stelle benötigt? Oder ist es ausreichend, wenn jeder Partner eine angemessene Eingangs- bzw. Ausgangskontrolle durchführt?
- Obwohl es nur eine Realität gibt, entsteht doch Wettbewerb über die (Qualität der) Information zu dieser Realität. Wie kann Konsistenz zwischen allen Anbietern von sicherheitsrelevanten Informationen erreicht werden? Wo sollte der Wettbewerb enden und wie kann dies technisch, organisatorisch und wirtschaftlich realisiert werden?
- Welche Prozesse sollten geschaffen werden, um Partner zu integrieren, die sich nicht an geschaffene Qualitätsstandards halten (z.B. kommerzielle Diensteanbieter, die nicht mit der Verkehrsinformationsszene vernetzt sind)?
- Und nicht zuletzt, wie kann die Wahrnehmung des Nutzers über verschiedene Qualitätslevel unterschiedlicher Produkte verbessert werden? Ist der Nutzer in der Lage, die unterschiedlichen Qualitätsstufen von Verkehrssystemen zu unterscheiden? Falls nicht, welche Art von Unterstützung braucht der Kunde? Ein „European Information Services Assessment Programme“ – vergleichbar zu Euro NCAP für Fahrzeuge?

Die Ergebnisse des Kolloquiums sollen die laufende Diskussion um die Verbesserung der Qualität von Verkehrsinformationen unterstützen.

Colloquium for
Quality of on-trip road traffic information

The positive impact of road traffic information on traffic safety and on the efficiency of the road traffic system can only be achieved when drivers do believe and follow the information sent. This essential driver's acceptance of the service is tightly linked to the continuous positive experience with the up-to-dateness, liability and correctness of the received traffic information. Furthermore, the individually felt benefit of the driver is a major prerequisite for the economic success of commercial traffic information services.

Therefore the improvement of the quality is one of the major challenges for traffic information services in the upcoming years. A number of projects and initiatives are currently dealing with the questions of quality of road traffic information.

On 23 and 24 March 2011 the Bundesanstalt für Straßenwesen (BASt), the Federal Highway Research Institute, has organised a colloquium „Quality of on-trip road traffic information" to have these current studies and initiatives presented and discussed with other experts. These present proceedings summarize the contributions and results of the colloquium.

Many stakeholders are involved in the provision of traffic information. The value chain of traffic information starts with the collection of necessary data on events and continues via the data processing and interpretation to the generation of the message itself. The messages are transmitted through various media and received by the end user e.g. in a navigation device. Each of the steps of a value chain can be performed by different partners – public and private ones – as well as by the same partner, too. The complexity of interaction between the partners can therefore be very high – as of the quality management process.

During the colloquium two different views on quality have been presented:

- the data quality that proves the correctness and up-to-dateness of information compared to a ground truth, either at the very last point of the value chain or at interfaces between the partners.
- the process quality that focuses on the loss-free performance of all involved partners along the whole value chain.

Both viewpoints help to understand what today's problems of quality are and how different measures for its improvement should be arranged.

On the one hand, there might be accurate information about a traffic related incident at one or more steps of the value chain but there are losses in quality due to an insufficient technical and organisational interface between two partners so that the end user does not receive the correct information. A prominent example of this is a wrong interpretation of the received information by the navigation device, but such a lack of process quality can happen at every step of the process chain, too. One important measure for the improvement of process quality is standardisation – plus the assessment that the standards are likewise interpreted and implemented on each step of the value chain.

On the other hand, the data quality (in terms of accuracy) might be poor from the very beginning of the value chain so that the end user does not get the right information if none at all. Prominent examples are all the traffic jams that are not announced or announced but non-existent. One important measure to improve these situations is the improvement of incident and event detection.

In the proceedings there are presentations that analyse the current state, propose methods to measure data quality and identify possible ways to improve data and process quality.

Open questions still are

- How can the process quality of the whole value chain be controlled if many different partners are involved? Who is monitoring the whole chain? Is there a need for such a central entity at all? Or is it sufficient if each partner does a proper “incoming goods” and “outgoing goods inspection”?
- There is only one ground truth but there is competition on the (quality of) information about ground truth. How can consistency between all providers be achieved of safety relevant information? Where should competition end and how can this been realised technically, economically and organisationally?
- Which processes do we need in order to deal with partners that will not agree on common quality standards and their necessary processes (e.g. general information brokers that are not cross-linked in the traffic information scene)?
- and, last but not least, how can the perception of the end user about the quality of different products be enhanced? Is the consumer able to distinguish the different quality levels of traffic information services? If not, what kind of help does the consumer need? A “European Traffic Information Services Assessment Programme” – compared to Euro NCAP for cars?

The results of the colloquium shall feed the ongoing discussion on the improvement of on-trip road traffic information services.

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Quality first at NDW

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For the National Databank Warehouse (NDW) quality is crucial. After all, if the quality of the source (the data) leaves something to be desired, this obviously has repercussions on all applications which draw from it. How does NDW guarantee the quality of data? NDW Quality Manager Joris Cornelissen explains.

Last year NDW has made great progress. At the moment current traffic data are being processed of 3,000 km taken from the overall 5,500 km as defined by NDW. The tender for selecting a commercial party (EDP) that will carry out additional data collection in the Northern and Eastern parts of the Netherlands has been completed successfully. This means additional traffic data collection in the area may start as well. In addition to current traffic data the first 'status data' were added to the databank: congestion notifications and information on road works and also historical traffic data have been added.
Important for NDW is that many initiatives related to quality have been taken and achievements obtained. This is crucial for our reliability. The responsibility for quality, certainly if it deals with road traffic data, is a shared one: it is the responsibility of all parties who form the NDW partnership. This consists of *Rijkswaterstaat* (Dutch Directorate-General for Public Works and Water management), the main Dutch provinces, city regions and main municipalities such as Amsterdam, Rotterdam and The Hague. The operational NDW organisation fulfils the role of co-ordinator, facilitator, and quality manager.

1. To measure is to know

In order to be able to monitor the quality of road traffic data it is important to measure its quality. However, measuring of quality is still in its infancy. Last year, NDW focused primarily on *availability* (this should be more than 97%) and *timely delivery* (after completion of every minute the traffic data are to be available for the user within 75 seconds latest). In addition to *availability* and *timely delivery* the user should be able to rely on the *quality* of traffic data (*accuracy* and *reliability*).
At NDW measuring and quality improvement is approached from different angles: from the data suppliers, from testing by NDW and via analysis of the work processes.

2. The data supplier

The data supplier is primarily responsible for the quality delivered. One of the instruments the data supplier might use is the so-called 'plausibility test'. With this test one tries try to determine whether the measurements or the sample taken are representative for the real situation on the road. Also the *Service Level Agreements* (SLAs) between NDW and the data suppliers are an important tool in discussing and improving quality standards of traffic information data and making sure quality is always on everybody's agenda.

3. Testing by NDW

The daily NDW-organization is involved in determining data quality, however, little experience is available, even at the international level. At this moment D4T - who won the tender for new data collection in Northern and Eastern Netherlands - is carrying out so-called 'typetesting' in which they have to prove that its data collection systems meet the NDW quality standards. Another initiative is the development of a 'quality reference system'. A first pilot is running with TNO and Technolution and aims to gain experience with a system that will get (close) to establishing the *ground truth* on the road (f.i. on traffic flow, traffic speed an travel times). A second pilot is running now to develop or make use of existing systems as a reference system that can be easily deployed (at low costs), but with a lower, but known quality. Based on these pilot results NDW shall decide which reference system may be used.
For that matter data providers such as ARA (a combination of ARS and Arcadis) and *Rijkswaterstaat* (Dutch Directorate-General for Public Works and Water management) are also taking initiatives to create reference systems for themselves.

4. Analysis of work process

In 2010 NDW performed audits on CNS (the central NDW system) and the processes linked to it. Also a process audit was performed at ARA. The audits have resulted in determining improvements. D_4T - the new data supplier for Northern and Eastern Netherlands - still has to submit its quality system (processes) to NDW for approval.

5. Quality differentiation

At the start of NDW high quality standards were determined to the different types of road traffic data (such as traffic flow and travel time data): the 'A-level'. The A-level was established after broad consultation of partners and scientific partners. The level was needed to make effective traffic management possible. However, the first partners that have been connected to NDW are located in areas with high volumes of traffic: mainly the Randstad-area which consists of big cities such as Amsterdam and Rotterdam.
Gradually when other regions joined NDW - mainly in less urban areas - it became apparent that in those areas somewhat lowered quality standards could also meet the need for traffic management: the B-level' was born. As an example: the accuracy of traffic flow and traffic speed data should be at least 95% for the A-level and 90% for the B-level.In the light of this 'differentiation' NDW is preparing a study by the Leuven Universiteit (Belgium) on the relationship between specific dynamic traffic management measurements (such as opening of hard shoulder lanes) and data quality. By this research NDW can offer road authorities more insight in what quality level is needed. Also, the need for more budget control by road authorities make well-founded choices for traffic data collection even more important. The results of this study are expected before July 2011.

6. To conclude

Looking back on 2010 important steps have been taken working on data quality. In 2011 the subject quality shall be a major topic on the NDW agenda. NDW shall further develop and apply plausibility tests, measurements and reference measurements. Furthermore, by means of audits NDW and its partners shall work together to optimise the fundamental processes.

Requirements for the Organization of the Traffic Information Process Chain

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Abstract

Road telematics systems make a major contribution to the safety and efficiency of road traffic. Information services also make it possible to directly influence motorists' behaviour both before and during the journey. The spectrum ranges from warning motorists about dangers, which is authorized by the authorities, to navigation including the realtime traffic situation. Members of a mobile and networked society avail of these trends in organizing their mobility behaviour. In this context, the question arises as to whether the existing and recently emerged process chains meet the requirements of an efficient total traffic system. With a total optimum in mind, it is quite possible that processes have to be adapted or even redefined.

1. Introduction

1.1. Scope

The flexible use of mobility offers provided by all modes of transport on the part of customers or motorists is strongly impacted by the time and spatially unlimited possibilities offered by modern communications. Regionally and internationally networked solutions for mobility services which embrace all modes of transport are crucial for the efficiency of the total traffic system, and are thereby affected by the rapid developments in information and communications technology as well as the related possibilities of social networks and information regardless of location. Road traffic in particular with its enormous degree of freedom can only benefit substantially from this if it is possible to orientate the changing processes in the traffic data market towards the three

- conceptual-functional,
- technical physical and
- organizational-institutional

operating levels in a systems architecture such that potential advantages can be grouped to an optimum. In the following, the organizational-institutional aspects of value creation in the traffic information process chain are dealt with.

High-quality traffic data and traffic information are a prerequisite for value creation in the traffic information process chain, and this is basically orientated on the following steps using traffic control as an example:

>> data collection

>> data processing

>> traffic control

>> information presentation

1.2. Thematisation

In addition to controlling traffic with the help of road telematics systems, the option of broadcasting on-trip traffic information is viewed as a further significant element in traffic management. Hopes of achieving this were nurtured in the 90s of the last century in the so called *Wirtschaftsforum Telematik* (Economic Forum Telematics) where politics and industry agreed to a division of responsibilities, according to which the State was to restrict itself to its original task of controlling the traffic. Services beyond that were to remain the responsibility of industry. To this end, traffic data recorded by the federal states and communities for the purpose of traffic control were to be made available to industry via data transfer agreements for a symbolic fee. This model of dividing the execution of duties never became reality for several reasons. One of these was that industry did not succeed in positioning chargeable traffic services on the market of a quantity and quality of information that would have made them superior to that of live reports from the traffic warning service. Critical constraints were and still are the absence of nationwide traffic data recording and the fact that the customer is not prepared to pay for traffic information. By implication, the said agreement precluded installing traffic recording equipment outside the network segments in which collective traffic control systems had been set up. For this reason, the traffic situation is still fragmentary even on motorways.

In the course of time, many road operators both on community and regional level have changed to making the data they generate in connection with traffic control measures and information on the traffic situation available to motorists online. Media such as the internet but also mobile communications are predominantly used in this respect. In many cases these traffic data are also the basis for the automatic generation of reports for the traffic warning service in the traffic centres of the road operators. For this reason, the quality of traffic information broadcast via TMC (Traffic Message Channel) has become increasingly better. However, this hinders the building up of privately operated traffic services, since data sources and traffic models are often identical. In principle, two value chains have emerged on the current traffic information market, one from the industry side and one on the State side (see figure 2). The user does not only have to grapple with being simultaneously presented information from two sources with potentially conflicting content, but there are also two interfaces. The data transfer or data exchange on the data recording level on the one hand, and the passing on of dynamic control data to privately operated services on the other.

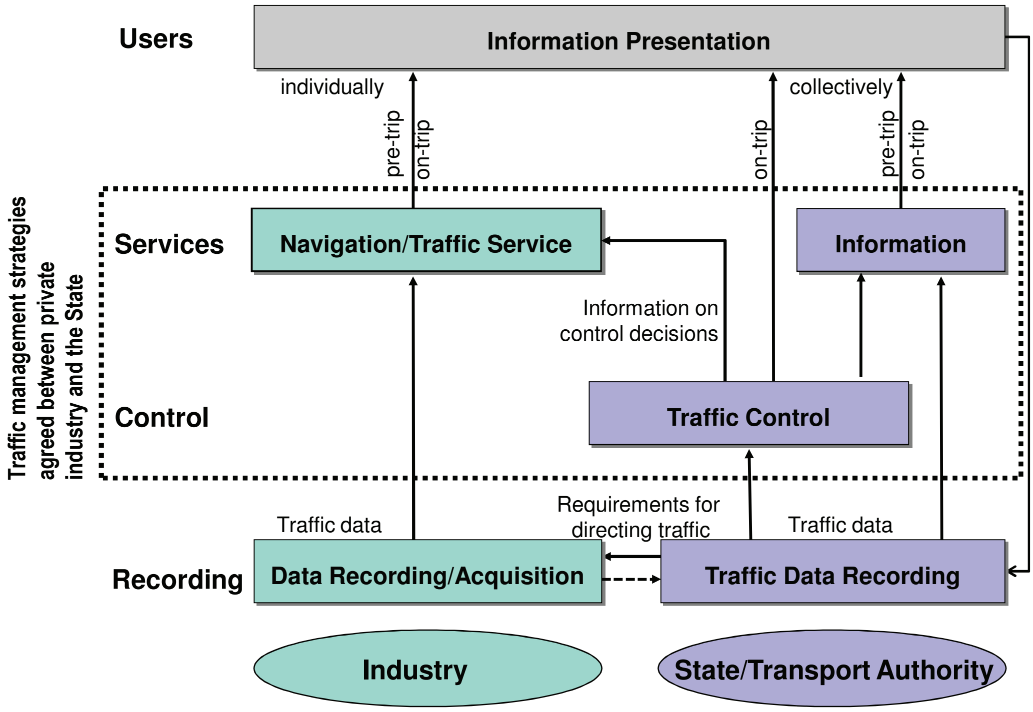

Fig. 1: Collaboration for presenting information

New methods of recording the traffic situation such as the Floating-Phone-Data-Method now enable private service providers to offer guided routes via mobile communications supported navigation devices without necessarily having to rely on purchasing traffic data from road operators. In this way, it is possible to evade the requirements imposed by traffic management in terms of dynamic guided routes by navigation, which are now part and parcel of many data transfer agreements. This might make business sense, but this is not the case when it comes to the consistency of potentially different information the motorist is offered simultaneously via navigation, radio, variable message road signs etc. On the contrary, different information on the same incidents is detrimental to road safety and efficiency.

On the other hand, the possibilities created years ago by the introduction of TMC are not being exploited by those responsible, because processes and structures have not been adapted. For this reason, the standard is still orientated towards spoken traffic radio and not on the dynamics that some traffic centres as well as TMC-based navigation devices could provide. The preparation of the TMC reports at the state reporting points is orientated towards the spoken traffic warning service. In principle, this is the correct approach, as the main objective is to warn motorists about dangerous situations. However, this means that the necessary navigation dynamics are missing if you rely on the public-sector TMC reports. Privately operated services that use mobile communications as a medium for transmitting TMC information to vehicles for a fee could provide some relief here.

On the whole, the trends iterated have neither led to quality on-trip traffic information being provided to motorists on the one hand, and nor can it be used as a further element in traffic management, for example for traffic routing in national corridors on the other.

A look at the organizational-institutional background in Germany makes it immediately clear that the division of responsibility in road traffic affairs in particular is highly fragmented on federal state and community level. In addition to the magnitude of technical problems already mentioned, this makes cooperation on both the state and semi-state side difficult. The figure below illustrates this point.

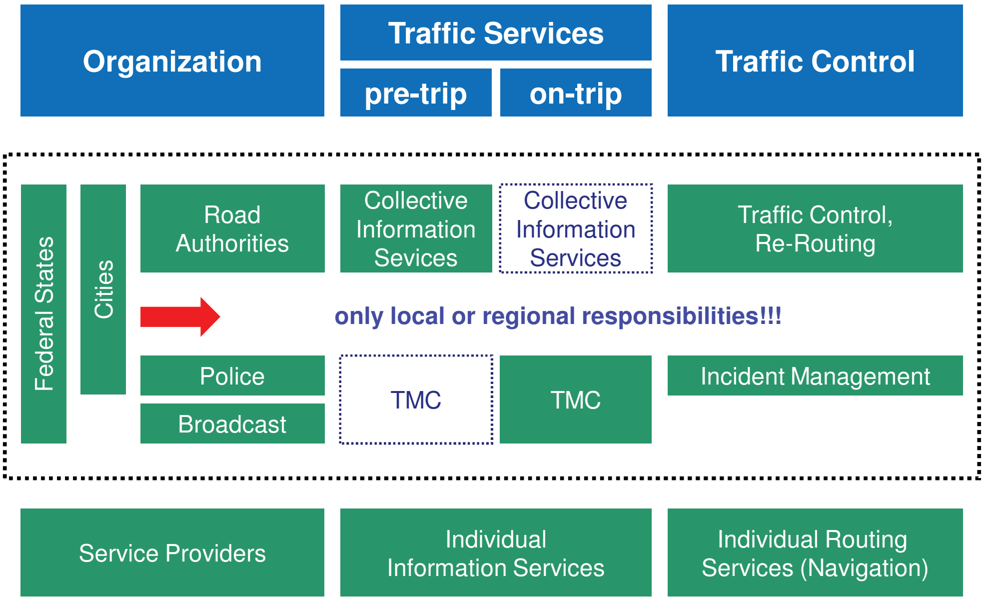

Fig. 2: Manifold responsibilities in Germany

1.3. Traffic information value chain

1.3.1. Traffic data recording

Quality-assured traffic data comprise both the basis for implementing traffic management strategies and for mobility services orientated towards the individual wishes of the customer. Local recording systems are usually installed in connection with the setting up of traffic control systems, making comprehensive, high-quality traffic data available for certain sections of the road network. In terms of network coverage, this is sufficient for the collective network and section control as it is for controlling traffic at junctions, i.e. via light signal control. It is not possible to derive nationwide traffic recording from local measuring points. And yet the question arises as to whether this should be considered for motorways in order to supply basic traffic information on the road operator side.

Companies wishing to provide tailor-made and customer-orientated mobility services do not require the level of traffic data detail needed for collective traffic control, but the data must be nationwide. Traffic data from network sections going beyond collective traffic control and the area of strategic networks or spanning priority roads are also necessary for implementing regional traffic management projects.

For some time now, industry has been endeavouring to introduce alternative data recording methods using mobile communications in order to derive nationwide traffic situations from the movement profiles of mobile telephone users, for example. Whether or not a lasting business model can be established on this basis in combination with a dynamic navigation offer will depend primarily on whether the planned standard of quality can be attained. To this end, the relevant data would have to be made transparent. In addition, traffic data from collective motorway traffic recording will be purchased from the authorities via data transfer agreements.

In conclusion, the quality and quantity of traffic data is sufficient for the purposes of collective traffic control, but fall far short of meeting the requirements for traffic management and the provision of customized traffic services. Efforts to cooperate on the part of Industry and administration in the field are perceptible; however a master plan for the utilization of synergies in particular is missing.

1.3.2. Processing traffic data

The traffic data recorded for collective traffic control are usually transmitted to traffic centres or similar institutions, and further processed there with the primary aim of closing time and spatial gaps in recordings and deriving control decisions for the operation of the collective traffic control systems. To this end, different methods, in some cases finished products and in others in-house applications, are often used. Where technically possible, automatic traffic reports are generated and transmitted to the responsible state reporting point within the framework of the traffic warning service. The traffic data are also passed on / sold unprocessed to private service providers and other institutions via data transfer agreements.

The urban and regional traffic centres as well as the motorway traffic control centres have differing levels of development with different software tools, and they do not have uniform interfaces. Some of these developments have not even been completed. A very heterogeneous picture of traffic control in Germany is thus portrayed, which can be explained by the division of responsibilities mentioned above. Everyone processes traffic data for solving the problems in their area of responsibility. In most cases, the existing traffic centres are not networked. Technical reasons are not the only critical issue here. For example, requirements must be derived from the joint implementation of traffic control strategies as already practiced in the pan-state collaboration of some federal states (LISA Project). On the whole though, what is missing in Germany is both a strategic concept and a systems architecture as the basis for the organization and scope of technical content for networking traffic centres.

The conclusion to be drawn is that due to the federal structure and the absence of a German systems architecture, analysis, if only a decentralized one, of the traffic situation is not on a uniform level, meaning that the basis for nationwide traffic control and a nationwide range of traffic services exist only to a limited extent.

1.3.3. Communications/Data transmission

The availability of communications facilities and the related cost-efficient transmission of data is affected by two applications in particular:

- the transmission of locally recorded data to the traffic centre
- the forwarding of processed information to the interface to the customer/motorist

The first point is largely responsible for traffic data recording being rare in rural areas. Whereas it is possible to transmit the data via the existing long-distance telecommunications cables, optical fibre technology on many road sections, on motorways for a reasonable price, locally recorded data in the rest of the road network and mobile recorded data in general have to be transmitted via a radio interface to the traffic centres. The costs arising from a stationary, nationwide recording of traffic data make it uneconomical. In order to minimize the communication time and thus the cost of transmission, the locally recorded data are sometimes transmitted incident-driven; this results in an incomplete picture of the traffic situation that can hardly be used for the purpose of traffic control and routing via navigation systems if at all.

In conclusion, the transmission of information to the customer is largely possible due to the development of new information and communications technologies. However, methods and procedures with which to record traffic data nationwide and to transmit locally recorded traffic data to the respective traffic centre are not available.

1.3.4. Information presentation

The transfer of information to the motorist/customer is performed by:

- collective systems for traffic control,
- collective information systems and
- individual control and information systems.

Collective traffic control systems have proven their worth. Their usefulness has been proven in several tests. Innovations such as the use of dynamic traffic information signs have established themselves on German motorways in recent years, and serve to extend the range of information content.

On the one hand, the collective information systems provide services resulting from the recycling of traffic data originally recorded for traffic control purposes. These are complemented by information on planned events such as temporary road works. On the other hand, in the case of the traffic warning service, information is specially processed on the administration side and complemented by congestion reports, and broadcast by radio. Since most of the sections of motorway prone to traffic disruption are equipped with traffic control systems, the majority of reports are generated on the basis of automatic traffic recording systems. The traffic warning service thus attains traffic service level in conurbations.

The traffic data situation described above precludes the dynamic operation of Individual route guidance systems on a nationwide basis. Nevertheless, in order to include the realtime traffic situation on motorways at least, traffic reports transmitted by radio are integrated that improve the relevant section without taking the traffic situation on the alternative routes off the motorway into consideration. This leads to a shift in traffic to traffic-sensitive networks, which is not helpful and not desired in the view of the road operators.

The following conclusion can be drawn: collective traffic control systems are part and parcel of everyday life on German roads. Individual technical systems for presenting traffic services are available. Realtime, nationwide traffic data with which to provide consistent routing and re-routing recommendations from the view of traffic management are missing. The model and systems architecture could provide the basis for the necessary harmonization between traffic control and navigation.

2. Requirements for the process chain

2.1. Cluster of topics

With respect to the further development of the traffic information process chain, it is appropriate to first concentrate on four applications to which the following central questions are pertinent:

- How can high-quality traffic data be recorded consistently and made available for the different applications?
- How can it be guaranteed that information from privately organized services and the traffic re-routing decisions made by road operators are consistent?
- Which duties will the traffic warning service assume in the future and how will the boundary to privately run service-orientated services be defined?
- Which information should remain available to motorists free of charge in the future and who is responsible for this?
- How will the future division of responsibility in the traffic warning service be defined on the one hand, and between road operators and private business on the other?
- How can dynamic information be used for realtime navigation in vehicles?

2.2. Theses for discussion

The starting situation described and the prevailing trends require thought about which direction should be taken to counteract, and how by modifying processes and structures the desired quality improvement can be achieved. In the following, several core theses are formulated, which are intended as a basis for discussion to find answers to the central questions posed above and the organizational improvements in the traffic information process chain.

- The freely available traffic warning service information may no longer be of a service nature, but must be orientated exclusively towards road safety aspects.
- Information from the traffic warning service must be free of charge as a basic service and authorised by the road operator. The police, in their role as reporting point, can provide the road operator with additional information.
- Bilateral cooperation on the part of road operator and radio station guarantees a

realtime, high-quality basic service into which operative aspects of the road operator can be integrated.

- Private service providers extract the information for the basic service from their existing data and make these available to the traffic warning service free of charge via the mobility data marketplace.
- State institutions forego the offer of value added services and make their traffic data/information available to private service providers for a fee and relevant regulations via the mobility marketplace.
- The State compels private service providers as well as radio stations to broadcast information relevant for road operation and routing traffic.
- State traffic guidance strategies and vehicle navigation routing recommendations must be synchronised. Data transfer agreements must contain relevant clauses.
- Certification required for transmitting traffic information with a routing nature or for the operation of mobile or stationary end devices ensures the conformity of state traffic guidance strategies and vehicle navigation routing recommendations.

2.3. Cooperation between road operators and radio

2.3.1. Starting situation

The primary objective of the traffic warning system is road safety. To this end, the state reporting points for the traffic warning service receive information on traffic disruptions from different sources, and summarize these into traffic warning reports which they pass on to different recipients. These are mainly radio stations which broadcast the information as part of the spoken traffic warning service or via TMC in the respective transmission area.

Reference should be made here to the exemplary cooperation existing in Hessen between the Traffic Centre Hessen and the radio stations. This points out how, starting from the theses iterated above, new forms of collaboration are suitable for improving the quality of traffic information. The process chain in the traffic warning service illustrated below is optimized such that value adding information on the radio is collected directly at the road operators.

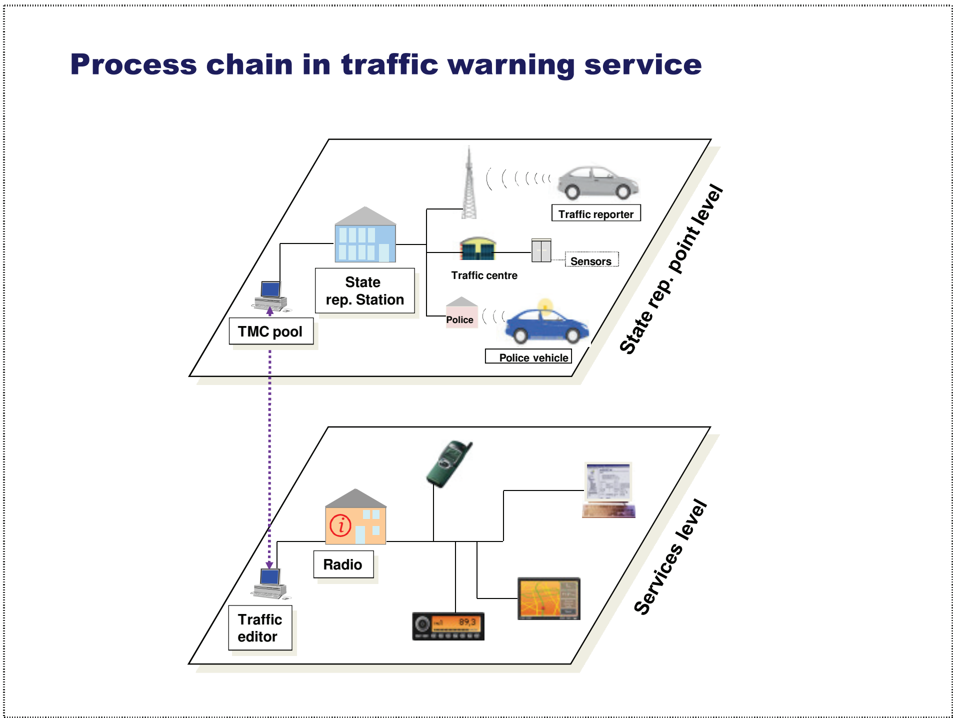

Fig. 3: Architecture of traffic warning service

2.3.2. Cooperation between Traffic Centre Hessen and radio

Comprehensive traffic data for controlling and routing traffic is recorded by the Traffic Centre Hessen. In addition, background information on traffic disruptions is available via camera pictures and reports from motorway maintenance authorities. These are suitable for considerably improving the quality of the so called reportable incidents in the traffic warning service and for generating additional traffic information. For this reason, there has been cooperation between the Traffic Centre Hessen on the one hand, and Hessen Radio as well as the private radio station FFH on the other since 2010. In practical terms, the traffic editors of both broadcasters are present in the Traffic Centre during peak traffic times as well as for special events.

Fig. 4: Radio station desks at the Traffic Centre Hessen

The collaboration gives way to a qualitative improvement of the Hessian traffic warning service, as both of the traffic editors benefit from the mentioned background information from the Traffic Centre on the one hand, enabling them to generate up-to-date traffic reports. On the other hand, it can be assured that operative information, the ad hoc broadcast of which is of great significance to the road operator, reaches the motorists. These include technical defects in traffic control systems, for example, where it is not evident to third parties whether a display is not working for operating or traffic-related reasons.

3. Conclusion and outlook

On the one hand, traffic information contributes to heightening road safety if for example motorists are warned about dangerous situations in time. On the other hand, traffic information is an instrument that can be directly used to control and route traffic. The condition in both cases is that the information is available with a high standard of quality and covering as large an area as possible. To this end, a minimum of data is required on the part of the road operators in order to be able to operate traffic control systems which have a significant effect on safety with a high level of availability. This traffic information can be a fundamental basis for building up an exclusively safety-related basic service which is free of charge to motorists. Through close cooperation between road operators and radio, high-quality and up-to-date data can be generated which can play a major role in considerably improving TMC quality. At the same time, relevant traffic guidance information could flow into TMC and thereby to the dynamic navigation in this way for the road operator. Despite this, the development of a solution for cooperation between road operators and private business is required; in fact it is required for the entire value chain in the field of traffic information/control. The development of a model and a master architecture will support this process in Germany.

Effort is not enough – and not a standard

What kind of Quality Management is needed in the Traffic Information Value Chain?

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Abstract

This contribution is neither about scientific needs nor it's about technical advise. From a more strategic point of view, the document will show the need for an awareness regarding a horizontal quality management in the travel information value chain.

1. Chinese Whispers for Travellers

Remember your childhood: it was good fun to play Chinese Whispers, wasn't it? One of your friends whispered a message to another friend, very quietly. Although the first kid gave its best, it was so difficult to understand what was said. But now your second friend was challenged to precisely pass on the information to the next in the line. So the game continued, several times. Your friends looked rather strained and you, as the very last player of "Chinese Whispers", was made the fool – because you had to present the product of multiple mishearing.

Is this just a memory of your childhood? Or do you know the new type of that game?

Usually it's called "Traffic Information Value Chain". Millions of travellers play it in daily life – without knowing it.

1.1. A Babel of technical languages

Who has ever believed in a homogeneous product called "Traffic Information"? Have a look on the German Traffic Information Service Chain – you will see immediately that this is a very fragile construction. Some dozen of players are – let's say: contributing between data collection and the display on an end user's device. Innumerable parties want to participate in that market place. That kind of activity is arising when people think that a lot of money can be made. But that makes business not easier – and a product often more complicated.

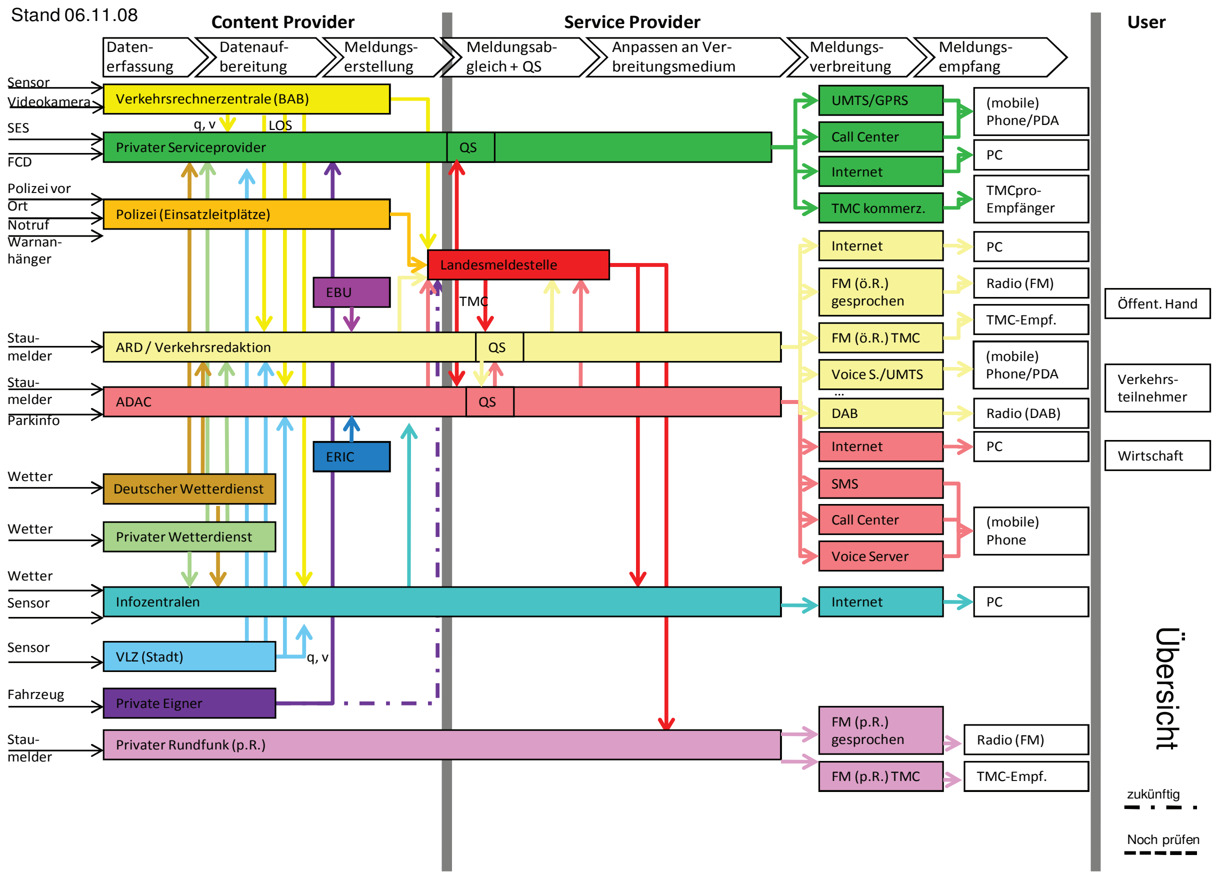

Fig.1: German Travel Information Value Chain (Chr. Lotz, BASt, 2008)

At least there are two major interfaces in the traffic information world. Between content and service provisioning and between service and end user sometimes there are worlds apart. How could that happen? Why does an existing, proven and reliable standard like TMC not guarantee a consistency of traffic information?

1.2. Just a BIT of mistake

What is the decisive argument for buying one special navigation system? Is it the design? Maybe. Is it a shiny display? Sometimes. Is it the powerful routing calculation? Very often. A free-hand option for you mobile phone? In special cases. The best Traffic Information Service? For the most part, customers even don't know that a Traffic Info is inside the device. More than 21 million navigation systems are in use in Germany only – and the user seems to know nothing about his device. It's quiet similar with mobile phones: the more features it provides the less people make use of them.
For the industry, this is a fundamental problem. They always have to develop new ideas to improve your product – although the range of varieties is quite limited in that field. Obviously some developers want their products to differ from competing devices not just by functionality – but even more by interpreting incoming messages. The *Institut für Rundfunktechnik* (IRT) has examined nine different navigation systems with RDS-TMC in 2009. They have broadcasted and analysed a set of 30 messages under laboratory conditions. Not just one single message was displayed

with the same content on the nine test devices. Different events, varying quantifiers, tremendous creativity in the interpretation of TMC messages, coded in agreement with the standard – that's what IRT had to notice.

And this error occurred just in the last link of the value chain. Therefore it should be taken as one single example – and not as an indictment.

	METAS							
1	**5 km Stau; rechter Fahrstreifen blockiert**	5 km Stau, eine Fahrbahn gesperrt	Stau	5 km Stau, rechter Fahrstreifen blockiert	5 km Stau, rechte Fahrspur blockiert	5 km Stau, Fahrbahnverengung		5 km Stau
2	**Anschlussstelle gesperrt**	Anschlussstelle gesperrt	Anschlussstelle gesperrt	Anschlussstelle gesperrt	Anschlussstelle gesperrt	Anschlussstelle gesperrt		Anschlussstelle gesperrt
3	**Unfall, stockender Verkehr**	Unfall, stockender Verkehr	Unfall, stockender Verkehr	Unfall, stockender Verkehr	Unfall, stockender Verkehr	Unfall, stockender Verkehr	Unfall	Unfall, stockender Verkehr
4	**1 km Stau; linker Fahrstreifen gesperrt**	1 km Stau; eine Fahrbahn gesperrt	Stau	1 km Stau, linker Fahrstreifen gesperrt	1 km Stau, linke Fahrspur gesperrt	1 km Stau, Fahrbahnverengung	Stau	1 km Stau
5	**Baustelle, 5 km Stau**	Baustelle, 5 km Stau	Baustelle, Stau	Baustelle, 5 km Stau	Baustelle, 5 km Stau	Baustelle, 5 km Stau	Baustelle	Baustelle, 5 km Stau
6	**schwerer Unfall, eine Umleitung ist eingerichtet**	Unfall	schwerer Unfall, eine Umleitung ist eingerichtet	schwerer Unfall	schwerer Unfall	Unfall	schwerer Unfall, eine Umleitung ist eingerichtet	Unfall
7	**gesperrt**	gesperrt	gesperrt	gesperrt	gesperrt	gesperrt	gesperrt	gesperrt
8	**3 km Stau, Stauende liegt hinter einer Kurve**	3 km Stau, Stauende liegt hinter einer Kurve	Stau	3 km Stau, stockender Verkehr, Stauende liegt im Kurvenbereich	3 km Stau, Stauende liegt hinter einer Kurve	3 km Stau, Stauende liegt hinter einer Kurve		3 km Stau, Stauende liegt hinter einer Kurve
9	**gesperrt, ortskundige Autofahrer werden gebeten, das Gebiet weiträumig zu umfahren**	gesperrt	gesperrt, ortskundige Autofahrer werden gebeten, das Gebiet weiträumig zu umfahren	gesperrt	gesperrt	gesperrt		gesperrt
10	**starker Schneefall, Sichtweiten unter 30 m**	Sichtweiten unter 50 m	starker Schneefall, Sichtweiten unter 30 m	starker Schneefall, Sichtweiten unter 30 m	eingeschränkte Sicht	Sichtbehinderung, Straßenglätte	starker Schneefall, Sichtweiten unter 30 m	starker Schneefall
11	**dichter Verkehr; linker Fahrstreifen blockiert**	dichter Verkehr; eine Fahrbahn gesperrt	Stau	dichter Verkehr; linker Fahrstreifen blockiert	dichter Verkehr; linke Fahrspur blockiert	dichter Verkehr; Fahrbahnverengung	dichter Verkehr	dichter Verkehr

Fig. 2: Examples of varying displaying of traffic messages (IRT, 2009)

Another example for a cause of a fault: In January 2011, Bosch made some field tests with WDR RDS-TMC messages. It was noticed that the full set of messages couldn't be processed properly within their nav systems – WDR transmitted the 8A groups sporadically more often than three times. We found out that we had a problem with our TMC encoding software – a component behind our internal quality system which is not permanently controlled. So we realized too late an immediate message repetition error happened sometimes after sending 3A group system information. It was not switched to the next message because the internal counter of immediate message repetition had not been reset. A slight software adaptation solved the problem once we were aware of the behaviour.

2. Everything's under control. Everything's under control?

Traffic information business more and more is seen as an important contribution to road safety. The most important statement on this was made by the European Union in 2010, when passing the *DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL laying down the framework for the deployment of Intelligent Transport Systems in the field of road transport and their interfaces with other transport modes.*

That document makes very clear that the EU wants to facilitate safety related traffic information as a tool to decrease the number of fatalities. Of course, the EU assumes this kind of information to be available ubiquitous, in "highest quality". But no definition of "quality" has been made.
What will happen if a lack of quality is detected by the responsible authorities? Do we have to be afraid to get the value chain under regulatory control?

2.1. **Traffic information service is a team play**

No one will doubt that the players within the value chain are highly ambitious. Each of them intends to improve performance and each of them wants to guarantee highest quality. But is it really enough if a road administration cares for the maintenance of loops and sensors? Is it sufficient if a service provider defines quality management for his own data processing? The traffic information value chain has so many players – but no definition for interfaces – and I am not just talking about technical interfaces. Lots of players get the best if they see themselves as a team. It's like football: We have one set of rules (called "standards") and sticking to these rules is the major principle. But remarkable success needs more: creativity, dynamic, team work – and team spirit.
Are we open enough to co-operate – or do we follow just our own interests?

2.2. **ERTICO and TISA provide a platform for Quality Management**

ERTICO and TISA, as umbrella organisations for all these issues, have considered quality management as a very important future task. It is aimed at finding a common understanding for quality management and, finally, to position Quality Traffic Information as a way to increase road safety. On 13 April 2011, the participants will try to find an approach for co-operation.

This is one small step for a marketplace, one giant leap for travellers.

If not, a chance will be forfeit to defend a strong market position and competence against other competitors.

We must learn to live together as brothers or perish together as fools.

3. Conclusion

There are a lot of responsible thinking players active in the TTI field. All of them are highly interested in quality issues. But to position the quality and safety relevance of the whole value chain, a more horizontal quality management is needed. A better understanding of the stakeholders will be the basis for a successful defending of acceptance in a more and more competitive market place with many free and uncontrollable services.

TMCplus - Improving the TMC information chain

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Abstract

TMCplus is a new approach for a professional RDS-TMC service in Austria. The main difference to other professional services in Europe is that TMCplus is not encrypted and can be used without additional costs for customer. The Austrian wide TMCplus service has officially been started on the 1st of July 2009. The goal of TMCplus is to provide the road user more precise and effective traffic information on this navigation device. Furthermore the reliability of the traffic messages was increased and the messages approval has been optimized. In addition ASFINAG and ORF have set up a conformance lab for TMC receivers where the receiver manufacturers have the possibility to test their receiver voluntary concerning compatibility with the TMCplus service. That includes pocket-navigation-devices but also in-car OEM devices

1. Introduction

In October 2002 the first nationwide RDS-TMC service operated by the Austrian public broadcaster ORF started in Austria. Henceforward the service was transmitted on three national and nine regional radio programs of ORF. The content of the TMC service was generated by the traffic editorial office of ORF based on notices from the police and rescue services, from more than 16.000 registered drivers and from the maintenance staff of the Austrian roads. With the start of the implementation of ITS systems, meaning Line Control Systems, traffic data collection and video monitoring, ORF started a co-operation with the Austrian motorway operator ASFINAG (Autobahnen- und Schnellstraßen- Finanzierungs-Aktiengesellschaft) in 2007.
ASFINAG is operating about 2.100 km motorways in Austria. On most of the motorways an area wide traffic data collection is implemented. Furthermore ASFINAG is currently operating 10 Line control and traffic management systems in high density areas. The implemented digital multicast video system of ASFINAG provides live streams from more than 2.300 cameras of the high level road network. As a result of the co-operation between ASFINAG and ORF this content is available

for Traffic information services and has been the basis for the new TMCplus service in Austria.
In the last years several professional TMC services based on data from traffic sensors for instance in Germany, France, Italy and UK have been implemented. These services have been the trigger to implement a professional TMC service in Austria too.

2. What is TMCplus?

The nationwide TMCplus service has been started officially on 1st July 2009 in Austria. The goal of TMCplus is to provide the road user more precise and more effective traffic information. Furthermore the reliability of the traffic messages was increased and the messages approval has been optimized.
The target of TMCplus to reach as much as road users as possible, TMCplus has not been encrypted. TMCplus has replaced the existing TMC service and is currently the only TMC service in Austria. With this position ASFINAG and ORF define a new way of professional TMC services within Europe. Most professional services in Europe are encrypted, which means that the information can only be received if the user has paid for the service. The Austrian TMCplus service has reached the quality level of other professional TMC services with the difference that also road users with existing TMC receivers are able to receive the service. TMCplus covers the motorway- and federal road network as well as the areas of the nine regional capital cities and the seven most traffic relevant cities in Austria.

3. Technical improvements

TMCplus fully works on the RDS-TMC specification as specified in the relevant specifications of CEN. TMCplus includes lots of technical improvements on the TMC standard which means that the quality of implementation of the service has been improved and also the quality of the TMC receivers will be checked via the introduction of a conformity testing (Chapter “User Support and Conformity Testing”).
The traditional TMC service in Austria was operated on a medium service level which means that it normally takes about 10 minutes to receive the total message queue (50 – 100 on air messages; emergency messages are transmitted with a higher priority).

With TMCplus the following technical improvements have been introduced:

- Increase of the TMC rate within the RDS data stream
- Regionalization of the TMCplus service
- Improvement of the TMC transmitters as well as the controller Hard- and Software

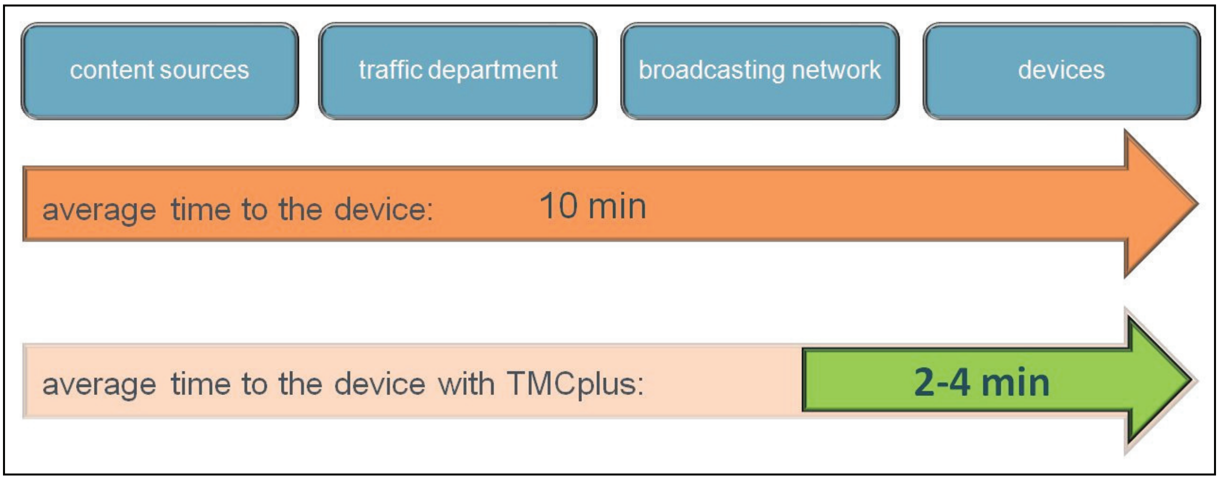

Fig. 1: TMCplus Service Chain

The target for the TMCplus service in Austria is to receive the regional message queue within 2 to 4 minutes, an increase of speed by roughly 300%. Compared with the existing RDS-TMC services in Austria the following measures have been realized with the implementation of TMCplus in Austria:

4. Optimization of the broadcasting network

The following measures for optimizing the broadcasting network have been done:

- TMC content within the RDS data stream has been doubled
- Increase of transmission rate of TMC messages
- Increase of system availability

The RDS-TMC service is creating directly four data streams. As a result of a new network interface on the coders the data streams can be sent directly by the ORF network to the program coders of Ö1, Ö2, Ö3 and FM4. With the new protocol the messages need only to be sent once to the coders instead of three times in the former RDS-TMC service which means that the data transmission rate is three times higher.

5. Regionalization of the TMCplus service

In the past all traffic messages for Austria have been transmitted area wide on all TMC transmitters. With the implementation of TMCplus in Austria the traffic messages are sorted by the regions East – Middle – West and are transmitted locally. In the overlapping areas the messages are transmitted for both regions. The result is that more messages can be transmitted per region.

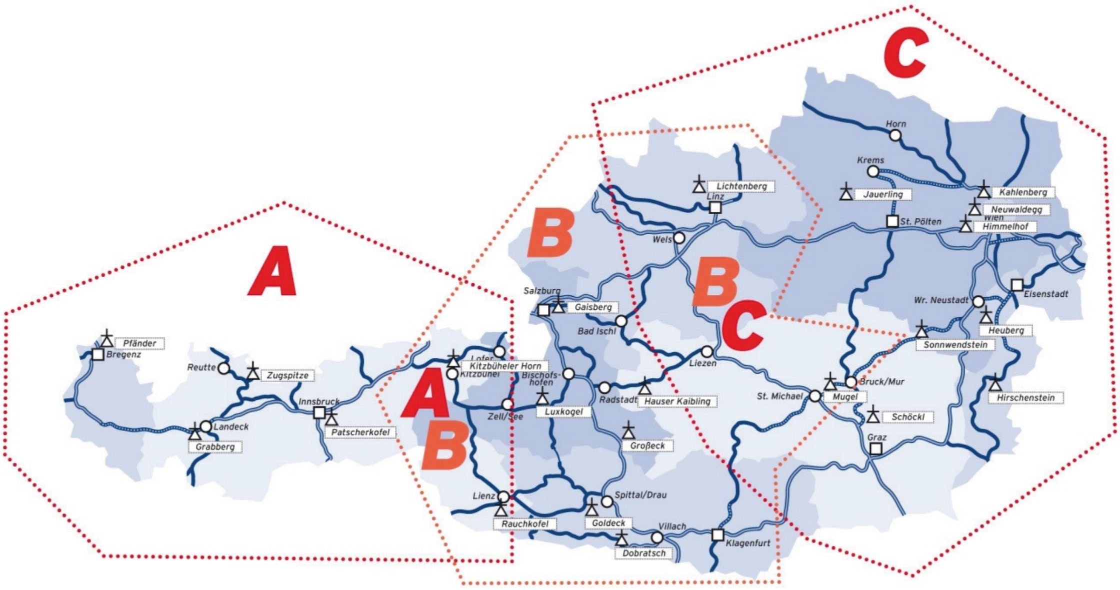

Fig. 2: Regionalization of the TMCplus signal (Regions West – Middle – East)

With the regionalization the bit rate in the regions West and East will be increased by 50% and in the region Middle it will be increased by 33%. The regionalization of the TMC signal has been done in December 2008.

6. Improvement of the content

As a result of the co-operation between ASFINAG and ORF (Hitradio Ö3) which was started in 2007 the available content for the new TMCplus service has been improved in the last years. One of the major improvements of TMCplus is the integration of the sensor-based data from the area wide data collection of the Austrian motorways from ASFINAG. The data are transmitted every minute from the sensors to the Traffic Management and Information Centre of ASFINAG. Traffic messages that result from this data are created and sent automatically to the editors from the Ö3 traffic department via DATEX interface. After validation from the traffic editor the messages are sent via TMCplus to the end users. As a consequence the messages within the TMCplus service reach the end user faster and are more precise and also the time until the messages are cancelled when the event is over will decrease.

In addition ASFINAG and Ö3 are using the anonymous data from the Austrian electronic fee collection. From this data the average travel times and Level of service for each EFC section is calculated. Furthermore warning messages from the road weather information system of ASFINAG with current weather information and forecasts for the next 72 hours are also used for TMCplus.

The editors from the Ö3 traffic department can further use more than 2.300 live video cameras from the motorways of ASFINAG.

7. TMCPLUS Conformity Testing

In order to provide an optimized service quality to the TMCplus customers, ASFINAG and Ö3 offer the receiver manufacturers and the car industry the possibility to do TMCplus conformity testing. Main focus of the conformity testing will be the correct implementation of the Austrian Location- and Event-Table as well as the decoding of the TMCplus messages. Tested devices will receive the TMCplus conformity label from ASFINAG and Hitradio Ö3. The tested manufacturer of the device is authorised to use the TMCplus certification within the selling process of the device (e.g. on the package of the device or in advertisements). The certification is branded with ASFINAG and Ö3 trademarks and end users will get information concerning the conformity testing via the TMCplus Website. The conformity testing is optional for receiver industry and the costs for the testing need to be covered by the manufacturer. The conformity testing will be done in the ASFINAG conformity lab in the Lakeside science and technology park, Lakeside B03, A-9020 Klagenfurt and has started in the 2nd quarter 2009. (see an example of a Conformity certificate on the right figure)

The current list of tested devices can be found on the TMCplus website www.tmcplus.at. Up to now more than 50 navigation devices have been tested and passed the necessary criteria. In some cases the feedback of the test results has been considered by the device manufacturers and the relevant firmware has been updated thus improving TMC decoding and interpretation.

It is not the goal of ASFINAG or ORF to earn money with the testing of TMC receivers!

Fig. 3: TMCplus logo and conformity label

The test environment includes original parts which are used in the TMCplus operation, so the test system is a real-life reference system.
The following figure shows the test environment of the TMCplus conformity testing. Based on the results of the conformity tests also firmware bugs of navigations devices has been fixed. Especially the textual description has been improved (see also figure 5)

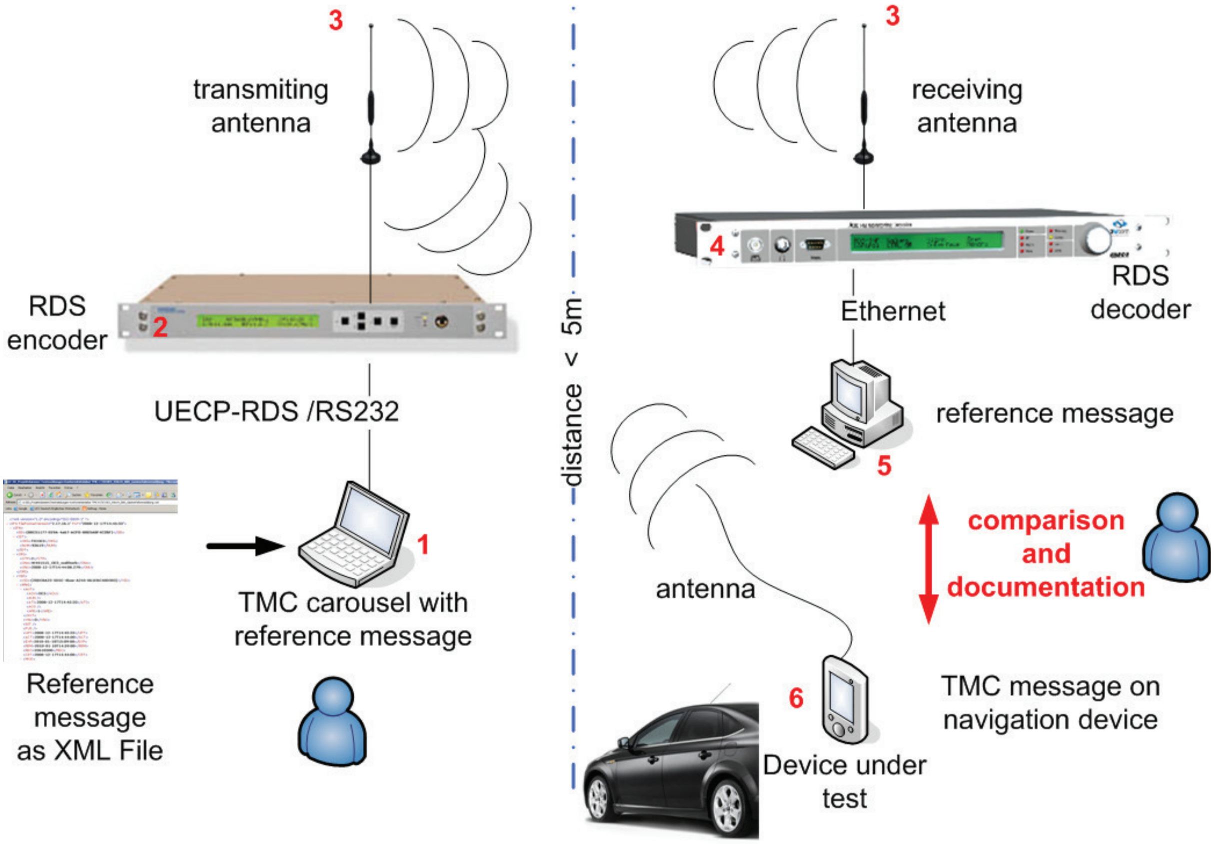

Fig. 4: Test environment of TMCplus conformity testing

Fig. 5: comparison of one message by different firmware

8. USER Support

Several market analyses have shown that most of the road users do not know RDS-TMC or its features. Therefore the user support has been an important topic within the implementation of the TMCplus service in Austria. ASFINAG and ORF are providing an information hotline to the TMCplus users in order to support the users in receiving the service.

Via the Hitradio Ö3 Hotline (0820 600 300) the user gets support on several topics of TMCplus, both about the service itself as well as information about conformity tested navigation devices. Furthermore Ö3 and ASFINAG offer the user a lot of information via the TMCplus Website on www.tmcplus.at.

Fig. 6: TMCplus website (www.tmcplus.at)

9. Summary

The TMCplus service is a new approach for future professional TMC services, operated by public service providers. TMCplus is focused on the users in order to provide them high quality traffic information on their navigation devices by using TMC without additional service costs. Up to now the test results show customer benefits regarding the human interpretation of TMC messages. At the moment Asfinag is preparing a new set of test-messages to advance the requirements. Such tests could be a pre condition for future in the field of ITS-technologies. Some of these scenarios test strategies could also be useful for future TPEG test scenarios.

Certification as Quality Assurance of Traffic Information Systems

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Abstract

NavCert is within the TÜV SÜD group dedicated to all areas of positioning, navigation and timing. As such NavCert introduced certification for traffic information systems. As there are no standards describing requirements, NavCert developed its own test plans. First step was to define Key Performance Indicators (KPI) reflecting the overall performance of traffic information systems. Then the respective ways how to measure the KPIs were described and field tests performed. In the last step the processing of data within the traffic information systems was analyzed together with the processes to validate and then finally to distribute the data. The overall goal of the work is to increase reliability and overall performance of the traffic information services.

1. Who we are

NavCert is part of the TÜV SÜD group, an international technical service provider generating with in total 14,000 employees about 1.4 Billion Euros revenues worldwide. TÜV SÜD offers testing, certification, consulting and training. NavCert is dedicated to provide validation and test in all areas in which PNT (positioning, navigation and timing) is required. As such NavCert has developed calibration schemes for area measurement equipment in agriculture together with JRC (Joint Research Centre of the European Commission) and is the only organization accredited to certify the equipment. In addition NavCert is member of the experts group of Notified Bodies for EETS (European Electronic Tolling Systems) to contribute to the definition of test and validation schemes for equipment and service providers. We have developed test and certification plans for traffic information systems and performed comparisons between traffic information systems.

2. Quality aspects

2.1. Definition of KPI

In order to improve the quality it is necessary to monitor the status and to identify if a change is increasing or decreasing the overall quality. For traffic information systems no common criteria do exist. As such we have defined KPIs (Key Performance

Indicators) to assure that the user expectation is measured. First it is important to know if a traffic jam exists or not. So the first KPI is the ***jam accuracy***. This parameter identifies the ratio between jams reported correctly and the number of all actual traffic jams. To avoid that a traffic information system is achieving a too high scoring by just indicating for all roads the existence of traffic jam the second KPI is the ***message delivery ratio***. This is defined as the ratio between correctly reported jams and number of all reports by the specific information system. From a user perspective it is not sufficient to be informed only about the existence of a traffic jam. The user expects to get guidance on his actions based on the existence of the traffic jam. A typical scenario is that due to the information – traffic jam on a highway – drivers decide to leave the highway and take a detour on cross country roads or even urban roads with the expectations to be faster than staying on the highway. However the underlying assumption is that there is no traffic jam on the intended detour as the traffic information system does not report any incident for these roads. Thus it is important to know the coverage of the traffic information system with respect to ***road coverage***. This KPI is defined as the identification of incidents for various road classes, to measure if only highways or also roads of minor classes are monitored. The most important information to the user however is the reliability of the provided information with respect to the reported length of a traffic jam and the expected delay time. This ***jam reliability*** is defined as the ratio between reported length and delay to actual length and delay.

2.2. Measurement of KPIs

The monitoring of KPIs allows the qualification of achieved results over a period of time. The challenge however in the context of traffic information systems is how to measure the KPIs as the objects to be measured are not static nor can they be evaluated inside a laboratory. The methods used should provide the same objectivity as those achieved within a laboratory. For test laboratories the standard for quality management systems, the ISO/IEC 17025:2005 defines the requirements on the competence of testing laboratories to carry out tests. Emphasis is put in this standard aside of general quality management aspects to the validation of test methods especially if the laboratory has developed its own and on the estimation of the uncertainty of measurement in order to assure the reliability of the test results. This standard refers to the ISO 5725 which deals with the accuracy (trueness and precision) of measurement results.

Looking to the measurement to the above defined KPI it is required to some extend to know the accuracy with which the measurement of an incident takes place. The measurement can be performed in two different ways, one being an observer and the other being part of the system both having its specific pros and cons. To validate the existence of a reported incidence at a given time, one has to be outside of the incident as an outside observer to confirm the existence of the incident. Being part of the system as a driver it cannot be validated if a reported incident does exist or not at the reported moment. Only at a later time arriving at the location of the reported incident, one can being part of the system identify if the information provided was correct or not, as the incident might have changed in the meantime – disappearance or new incident at the reported location.

If a traffic information system provides information (length and expected delay) of an incident, the independent observer can measure the length of the incident at the time the information was provided. As part of the system the length of an incident is

measured by passing by the incident. As such the length cannot be measured prior to being part of the incident. During the time required to pass the incident, the length might have changed resulting into deviation between measured and reported length not implying in any case a wrong reported value. However even an independent observer is not able to measure the reported duration of the delay because both measurement methods require to wait that a vehicle is passing the incident from start to end location. Again in this situation the reported duration may change due to system and measurement extrinsic factors.
The mayor disadvantage of the independent observer is that he only has a limited observation area and that this area cannot be adjusted ad hoc to allow flexible adjustments of test areas. Typically a high position like a bridge is used to monitor in real time traffic either via a camera or via a person. In best case the view allows to monitor the road for a length of one kilometre. In our approach we identified a way to cover at a given time simultaneously areas of 2 times 5 kilometres. For this it is necessary to have a view from quite a given height, in that case we are able to use an earth observation satellite. The measurements from the satellite allow identifying individual vehicles on selected roads. The speed of the vehicles can be identified individually with a resolution of about 5km/h. As such one has a snapshot available which can be used to calibrate existing equipment like road loops to assure that the provided results on the speed of the vehicle is correct. It can also be used to validate the user experience of the length of a traffic jam at a given time. The disadvantage of the satellite approach is that it provides only a snapshot at a specific time and as such is not applicable for continuous measurements.

2.3. **Processes**

We have now identified KPIs which reflect the achieved quality and based on ISO/EN 17025 a proper methodology for measurements has been identified. The next challenge is to validate that the measured values are properly processed in the process chain. Typically a lot of interfaces, system boundaries, internal and external borders have to be passed of which every connection implies a variety of reasons for errors. ISO 9001 does not provide the proper tooling to successfully manage these threats. One important aspect in the process chain is the processing of diverse inputs with the respective validation and prioritization of different levels of information. As soon as human intervention is required, another source for errors is included in the loop.
We provide an audit of all relevant processes and interfaces which is not focusing only on the quality aspects of ISO 9001, but instead we analyze that the received input will result into the expected output. We have experts looking into all aspects in the certification process. As such in all phases in which data processing takes place we analyze:

- ✓ Data collection
- ✓ Data fusion
- ✓ Data processing
- ✓ Data provided by third parties
- ✓ Integration of traffic information
- ✓ Verification of traffic information
- ✓ Qualification of traffic information
- ✓ Storage of traffic information

As a result we help to optimize the overall process by identifying critical paths and validation of (complex) processes. Weak points are identified and can be eliminated increasing the overall performance.

3. Certification

3.1. Certification process

The certification process supports to validate that the claimed features are existing. The certification process is divided in two parts, one hands on oriented and the other one desk work as depicted in Fig. 1.

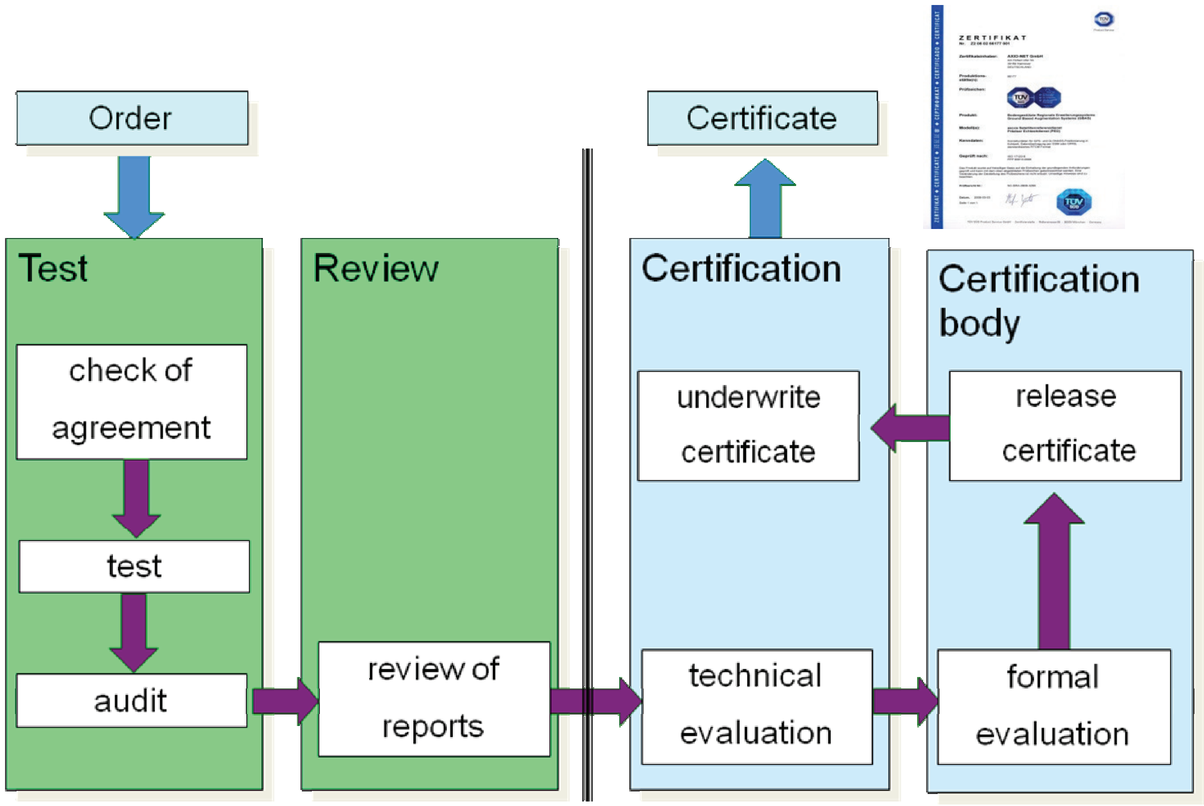

Fig. 1: Certification process

The process starts with a check of the agreement in which two important aspects have to be included to pass the first hurdle. The first one is that the agreement clearly indicates that the certification does not imply a certificate but it may also result into a test report only indicating reasons why the certification could not be completed successfully. Second the agreement has to refer to the standard which is used in the certification process as a certificate can only be issued based on a standard.

The next step is the test. Here the product or the service is tested to validate the conformance to the requirements of the underlying standard. The test is performed in accordance with the test plan which is based on the standard. In parallel or after the hands on test an examination of the processes to ensure that the results of the measurements will be achieved also in the future. Depending on the type of certification an audit or a factory inspection takes place. In this audit all relevant aspects will be evaluated with special attention to potential sources of errors like interfaces, data fusion or manual intervention. If also all results from the audit are in

line with the standard or assure that the service offered will be in line based on the back-office procedures and processing, the first phase of the certification has been successfully finished. In the next phase, the review, an independent person will review all documents produced to assure that all aspects of the test and audit plan have been completely implemented and checked. If there is any doubt, clarification questions will be asked or additional tests might be required. If the reviewer confirms the complete and correct performance of the test and audit, the first part of the certification process has been successfully completed, the hands on work. Typically one would say, a person has tested and audited, in addition an independent person has reviewed the results and as such the work is done. One can say that the evaluated product, service is in line with the standard. In the certification process however only the first part is now finished and the actual certification starts only now.
In the desk oriented second phase for the technical evaluation a technical certifier with at least the same technical knowledge as the tester and reviewer looks to the documents produced. He evaluates based on his experience if the achieved individual results based on the documentation are meaningful and in accordance with the expected results for such a product/service. If he has any doubts he will ask for clarification or for additional tests. Only if he is convinced that all aspects of the standard have been tested and the results are in line with his experience of similar certifications then he will initiate the next and last step in the certification process, the formal evaluation. In the formal evaluation the conformance with the referred standard is checked. This requires that the standard is mentioned in the agreement. In addition all people engaged must have the accreditation to work for this specific standard. Same applies to the used equipment and laboratory, that also these are accredited to be used for the respective standard. Only if this formal evaluation at the end generates a positive result, the certificate is generated and forwarded to the technical certifier. The technical certifier now underwrites the certificate to indicate that he himself accepts personal liability that all requirements are fulfilled with complete impartiality. This personal liability is expanded to the head of the certification entity and at the end to the certification body. The certificate is only now handed over to the contractor.
Due to the continuous check and balance approach not only in the certification process but also in the respective organization of the certification body complemented by periodic audits by the accreditor, the certification provides a high reliability that the validated claims and requirements are fulfilled.
The issued certificate itself is valid for a period of one year. After one year a recertification takes place which mainly focuses on some aspects of the performed tests and audits. This recertification assures that modifications in the product are not influencing the overall performance and that the processes are implemented in such a way that after a period of one year the same results are achieved. The recertification can be repeated once and after a period of three years a complete new certification has to be done.

3.2. **Certification of traffic information systems**

As for the traffic information systems no standard exists today, a private standard is used. To communicate the main claims with the certified service a test mark is used which does not only refer to the underlying standard but includes directly three main claims as a result of the certification as depicted in Fig. 2. On the left side of the octagon the name of the certified traffic information service is indicated. The second octagon on the right side is used to provide the three claims. The claim could be that the provided information is accurate and reliable. An important aspect is as described in chapter 2.1 the coverage, as an example here that motorways, cross country and important urban roads are covered. The last claim refers to the update frequency in this example every three minutes. In addition there is a reference to a WEB page where additional information on the underlying standard together with information on test plan is provided.

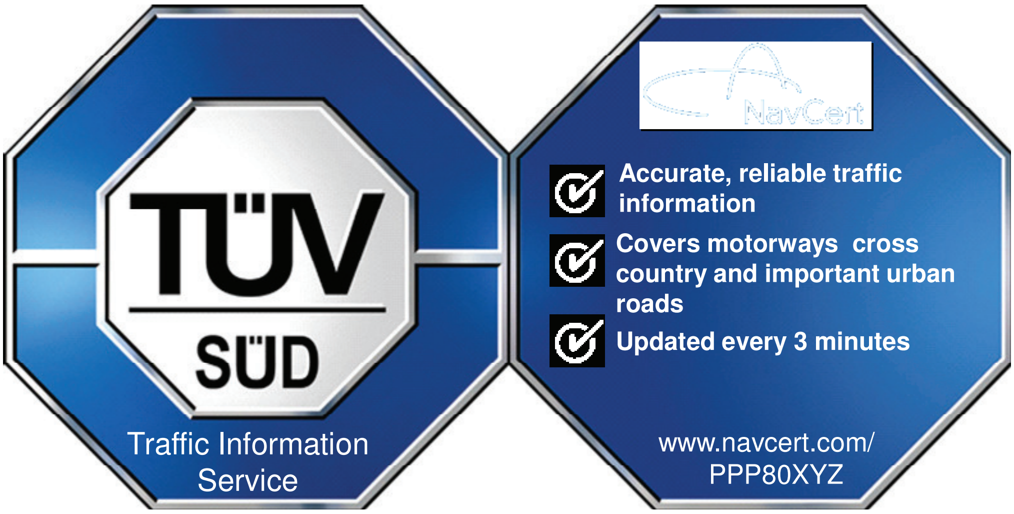

Fig. 2: Example of a test mark for Traffic Information Systems

The test mark can be used in any type of communication in the WEB, brochures or advertising as long as the certificate is valid.

4. Summary

For measurements the ISO/IEN 17025 provides excellent guidelines how to organize the field tests to measure KPIs identified as relevant for traffic information systems. We have adjusted the requirements to reflect the specific situation within roads to measure quality of offered service. An independent monitoring based on the ISO/IEN 17025 enables to monitor the quality of service and to qualify achieved improvements. The certification documents and communicates the achievements in a comprehensive format internally and to the outside.

Tests of commercial TMC-equipped navigation systems

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Abstract

The RDS-TMC specifications (ISO 14819 Series) cover the so-called "ALERT-C" protocol encoded for transmission within the RDS–TMC channel. The complete and standard-conform implementation of these specifications is a crucial issue considering the quality of traffic services and the improvement of safety on roads. The tests performed by Institut für Rundfunktechnik have clearly demonstrated that the content representation of TMC messages in commercial navigation systems currently often does not fulfill the quality and safety requirements of broadcasters and road authorities.

1. Objectives

The tests objectives were defined as follows:

- ✓ to determine the effects of an increased TMC data rate for commercial TMC-equipped navigation systems. According to the RDS-TMC specification the TMC data rate can be modified using the gap parameter (s. table below). Two TMC data rates were chosen to be tested: 0,95 groups/s and 1,90 groups/s.

Coding of gap parameter G

Binary Code	Gap (groups)	Ave 8A groups/s
00	3	2.85
01	5	1.90
10	8	1.27
11	11	0.95

- ✓ to check whether a correct representation of frequently used TMC events is obtained

2. Test description

2.1. List of tested devices

Becker Online Pro BE 7800
Blaupunkt Travelpilot 200
Garmin Nüvi 765T
Kenwood DV3200
Medion GoPal E4435
Navigon NVG 7100
TomTom ONE Classic

2.2. Test equipment

The navigation devices tests were performed at the IRT laboratory. The METAS system, a traffic messages management system of Germanys's broadcasters, was used for the generation of TMC messages and administration of a transmission loop. The transmission chain consisted of the METAS system, RDS encoder, stereo encoder and standard conform FM-RDS test transmitter.

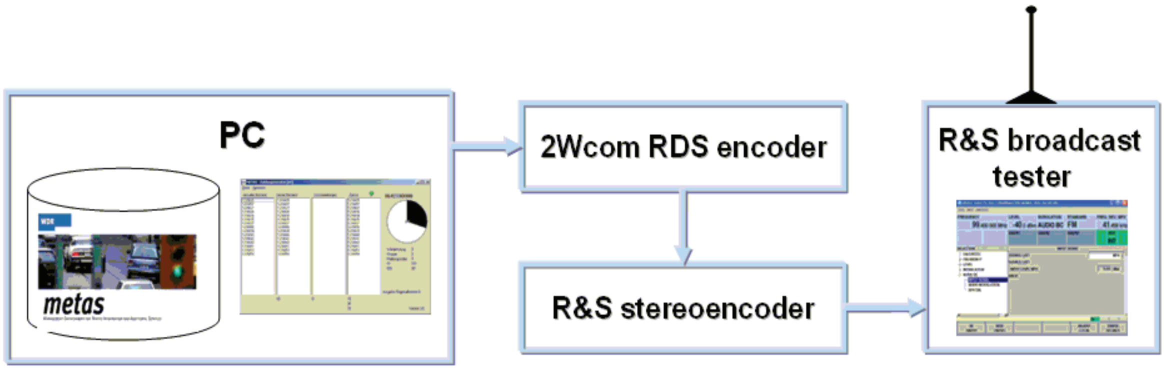


Fig.1: Transmission chain

Additionally, the GPS repeater was used to obtain the indoor GPS signal.

2.3. Test procedure

Two sets of TMC messages with frequently used events from the "ALERT-C" event list and with Bavarian TMC locations were created. The first set contained 15 (mostly one-sequence) messages, the second set contained 30 messages (with the increased rate of multi-sequence messages).

Two reference messages were selected in both sets; time intervals between service selection and arrival of reference messages were measured and averaged.

The evaluation was carried out by visual inspection. The necessary statistical precision was achieved by the multiple repetitions of the test procedure.

This procedure was a so called black-box testing, defined as a method that tests the device functionality without specific knowledge about the internal processes and algorithms in devices.

All tests were performed for two different TMC data rates. For the second set the correct representation of messages was additionally proved.

The IRT TMC decoder “Easyway” was used as reference decoder.

3. Test results

3.1. Decoding measurement

Table 1: Average time until the arrival of reference messages (sec)

device	test set 1			test set 2		
	0,95 gr/s	1,9 gr/s	impr.faktor	0,95 gr/s	1,9 gr/s	impr.faktor
1	63,1	37,0	1,71	86,0	53,4	1,61
2	53,0	29,2	1,82	67,3	36,4	1,85
3	82,0	51,4	1,60	179,2	115,0	1,56
4	129,6	92,6	1,40	138,8	113,0	1,23
5	48,9	24,3	2,01	70,8	41,0	1,73
6	146,0	85,4	1,71			*
7	94,0	53,2	1,77			*
Easyway	56,0	26,0	2,15	64,5	36,9	1,75

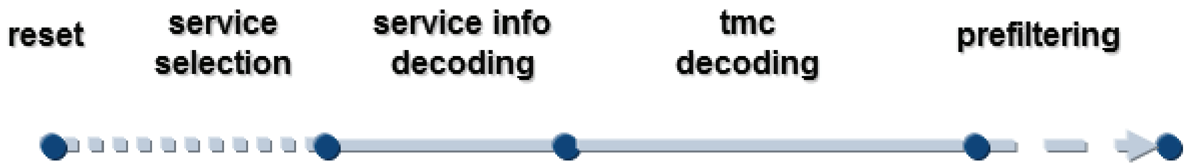
* - measurements were carried out for the test set 1 only

3.1.1. Explanation of results

As expected all tested devices demonstrated the clear improvement of the performance due to increasing of the TMC data rate.

However, time intervals between service selection and arrival of reference messages in various navigation systems are difficult to compare. The service selection procedure is implemented in different devices in different manner: using the list of available services, using the direct input of a service frequency or using step-by-step moving through the whole FM broadcast band. Therefore, for instance, the device that decodes the TMC service information parallel to the build-up of the TMC service list would have an advantage in comparison to the device that uses the direct input of a service frequency.

More generally the black-box testing offers no possibility to distinguish between the service info decoding and the TMC decoding itself. Furthermore some devices use a pre-filtering of results and present messages not immediately after arrival. At first they collect all messages and subsequently filter relevant messages out for the presentation.



3.2. Representation of messages

Table 2: Content representation of messages in tested devices

	Original message	Device 1	Device 2	Device 3	Device 4	Device 5	Device 6	Device 7
1	**stationary traffic for 5 km; right lane blocked**	stationary traffic for 5 km; one lane closed	stationary traffic	stationary traffic for 5 km; right lane blocked	stationary traffic for 5 km; right lane blocked	stationary traffic for 5 km; narrow lanes		5 km Stau
2	**slip roads closed**	slip roads closed	slip roads closed	slip roads closed	slip roads closed	slip roads closed		slip roads closed
3	**accident, queuing traffic**	accident, queuing traffic	accident, queuing traffic	accident, queuing traffic	accident, queuing traffic	accident, queuing traffic	accident	accident, queuing traffic
4	**stationary traffic for 1km; left lane closed**	stationary traffic for 1 km; one lane closed	stationary traffic	stationary traffic for 1km; left lane closed	stationary traffic for 1km; left lane closed	stationary traffic for 1 km; narrow lanes	stationary traffic	stationary traffic for 1 km
5	**roadworks; stationary traffic for 5 km**	roadworks; stationary traffic for 5 km	roadworks; stationary traffic	roadworks; stationary traffic for 5 km	roadworks; stationary traffic for 5 km	roadworks; stationary traffic for 5 km	roadworks	roadworks; stationary traffic for 5 km
6	**serious accident; diversion in operation**	accident	serious accident; diversion in operation	serious accident	serious accident	accident	serious accident; diversion in operation	accident
7	**closed**	closed	closed	closed	closed	closed	closed	closed
8	**stationary traffic for 3 km around a bend in the road**	stationary traffic for 3 km around a bend in the road	stationary traffic	stationary traffic for 3 km, queuing traffic in the bend area	stationary traffic for 3 km around a bend in the road	stationary traffic for 3 km around a bend in the road		stationary traffic for 3 km around a bend in the road

	Original message	Device 1	Device 2	Device 3	Device 4	Device 5	Device 6	Device 7
9	**closed; local drivers are recommended to avoid the area**	closed	closed; local drivers are recommended to avoid the area	closed	closed	closed		closed
10	**heavy snowfall, visibility reduced to <30 m**	visibility reduced to <50 m	heavy snowfall, visibility reduced to <30 m	heavy snowfall, visibility reduced to <30 m	restricted visibility	reduced visibility, slippery road	heavy snowfall, visibility reduced to <30 m	heavy snowfall
11	**slow traffic, left lane blocked**	slow traffic, one lane closed	stationary traffic	slow traffic, left lane blocked	slow traffic, left lane blocked	slow traffic, narrow lanes	slow traffic	slow traffic
12	**slippery road**	slippery road	slippery road	slippery road	slippery road	slippery road		slippery road
13	**queuing traffic, right lane closed**	queuing traffic, right lane closed	stationary traffic	queuing traffic, right lane closed	queuing traffic, right lane closed	queuing traffic, narrow lanes	queuing traffic	queuing traffic
14	**broken down vehicle, traffic problem**	broken down vehicle, traffic problem	broken down vehicle, traffic problem	broken down vehicle, traffic problem	broken down vehicle	broken down vehicle	broken down vehicle, traffic problem	traffic problem
15	**narrow lanes**	roadworks	narrow lanes	narrow lanes	narrow lanes	roadworks		roadworks
16	**road closed due to accident**	closed, accident	road closed due to accident	road closed due to accident	accident	road closed due to accident		closed

	Original message	Device 1	Device 2	Device 3	Device 4	Device 5	Device 6	Device 7
17	**people on roadway, traffic problem**	people on roadway, danger	people on roadway, traffic problem	people on roadway, traffic problem	people on roadway, traffic problem	people on roadway	people on roadway, traffic problem	people on roadway, danger
18	**vehicle on wrong carriageway**	vehicle on wrong carriageway	vehicle on wrong carriageway	vehicle on wrong carriageway	vehicle on wrong carriageway	vehicle on wrong carriageway	vehicle on wrong carriageway	vehicle on wrong carriagewa y
19	**carriageway closed**	closed	carriageway closed	carriageway closed	closed	road closed		
20	**5 km slow traffic, overturned vehicle**	5 km slow traffic, accident	stationary traffic	5 km slow traffic, overturned vehicle	5 km slow traffic, overturned vehicle	5 km slow traffic, accident		5 km slow traffic, accident
21	**animals on the road, danger**	animals on the road, danger	animals on the road, danger	animals on the road, danger	animals on the road, traffic problem	animals on the road	animals on the road, danger	animals on the road, danger
22	**closed, diversion in operation**	closed	closed, diversion in operation	closed	closed	road closed	closed, diversion in operation	closed
23	**construction work**	roadworks	construction work	roadworks	construction work	roadworks	construction work	roadworks
24	**exit slip road closed**	exit slip road closed	exit slip road closed	exit slip road closed	exit slip road closed	exit slip road closed		exit slip road closed
25	**objects on the road, danger**	traffic problem, obstruction	objects on the road, danger	objects on the road, danger	animals on the road, traffic problem	obstructions	objects on the road, danger	obstruction s on the road, danger

	Original message	Device 1	Device 2	Device 3	Device 4	Device 5	Device 6	Device 7
26	**exit slip road blocked**		exit slip road blocked	exit slip road blocked	exit slip road blocked	exit slip road blocked		exit slip road blocked
27	**carriageway reduced to one lane**	one lane closed	carriageway reduced to one lane	carriageway reduced to one lane	carriageway reduced to one lane	narrow lanes		
28	**vehicle fire**	accident	vehicle fire	vehicle fire	vehicle fire	accident		accident
29	**stationary traffic for 4 km; approach with care**	stationary traffic for 4 km	stationary traffic	stationary traffic for 4 km	stationary traffic for 4 km	stationary traffic for 4 km	stationary traffic for 4 km; approach with care	stationary traffic for 4 km
30	**stationary traffic for 6 km, vehicle fire**	stationary traffic for 6 km, accident	stationary traffic	stationary traffic for 6 km, vehicle fire	stationary traffic for 6 km, vehicle fire	stationary traffic for 6 km, accident	stationary traffic	stationary traffic for 6 km, accident

3.2.1. Erroneous content representation

Main issues can be summarized as follows:

Simplification: e.g. no differentiation between "burning vehicle", "overturned vehicle", "serious accident" etc. All these events are presented as "accident".

Length of traffic jam is not presented

Message reduction: in messages like "stationary traffic for 6 km, accident" or "queuing traffic, narrow lines" only the first part ("stationary traffic" or "queuing traffic") is presented

Ignoring of advices: e.g. the advice "diversion in operation" is not presented

Use of different terms for the same content, e.g. the message “objects on the road, danger” is presented as “traffic problem, obstruction”, “obstructions” or even as “animals on the road, traffic problem”.

4. Conclusions

Tested navigation systems have no difficulties with decoding of the TMC messages which are broadcasted with increased data rate. The improvement factor is between 1.4 and 1.9, the deviations can be explained by system-specific features.

The content representation of the messages vary greatly from system to system. The urgent need for standard compliant implementation of the “ALERT-C” event list in navigation systems is obvious.

How can we determine the quality of traffic information?

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Abstract

The quality of traffic information depends strongly on how we define a technical index of quality determination. Because traffic occurs in space and time, in an ideal case the quality of traffic information should be defined through spatiotemporal characteristics of traffic. In this paper, we discuss an automatic approach for the determination of the quality of spatiotemporal features of traffic with the use of the methods ASDA/FOTO based on Kerner's three-phase traffic theory. The ASDA/FOTO models allow the reconstruction of this "reality" using loop data. The reconstructed spatiotemporal traffic characteristics can be considered "Ground Truth" reality for the determination of the quality of traffic information. After the spatiotemporal features of traffic are found, they can be used for the determination of average (macroscopic) traffic parameters like travel time that is very important characteristic for traffic information services. The paper illustrates an example for one specific congestion and three different information sources. In addition, more precise traffic information beyond travel times showing real spatiotemporal congestion structures will lead to new definitions of on-trip traffic information, e.g., the quality of the reconstruction of spatiotemporal congested traffic patterns.

1. Introduction

Dynamic traffic services have an impact on the navigation systems regarding the map display, the traffic message listings and, especially, the dynamic route guidance. Therefore, from a car manufacturer's perspective the information quality of these traffic messages has to be defined and measured properly. The understanding of freeway traffic and traffic breakdown (i.e. "traffic congestion") based on Kerner's three-phase traffic theory [1-3] has lead to practical methods (called ASDA/FOTO, see [1-6]) which allow to detect and predict traffic congestions measured by various data sources. The measured reality (often called "Ground Truth") within ASDA/FOTO should be compared with different traffic service information sources by introducing a method based on travel time comparison which the key value for dynamic route guidance. For other application like jam front warnings an even more precise description, i.e., the traffic phases of a spatial-temporal congested pattern are necessary.

The travel time method has been realized in a database tool which is able to compare traffic services from different providers. An example of three content providers including TomTom's HDTraffic, Navteq's TMCPro and TMC from public broadcaster "Hessischer Rundfunk" illustrates different features of traffic services describing exactly the same traffic congestion. Independent of the traffic information protocol (like RDS/TMC, DATEX-2, TPEG and its applications, etc.) and independent of the information bearer (like FM-RDS, DAB, IP, etc.) the customer requires the highest available information quality from service providers, especially in the case of commercial services. Only a sufficient and proven quality of the content itself has the potential to open the way for economic success stories. Some examples of (public) TMC messages – if the provider will allow this - will be shown to illustrate delays and features of TMC services.

The paper will try to answer the following four questions:

- How can we understand traffic on freeways?
- How can we detect and predict congestions?
- How can we define and measure RDS/TMC product quality?
- How can we measure precise traffic information quality? (introduction with some first results)

2. How can we understand traffic on freeways?

In recent years the so-called three-phase traffic theory has been proposed by Kerner (see books [1],[2]) in addition to free flow traffic phase (F), the lower speed states of congested traffic on freeways have to be distinguished between the two traffic phases: synchronized flow (S) and wide moving jam (J) (Fig. 1). While the synchronized flow regions remain often fixed at the location of the bottleneck and the wide moving jam propagates through any kind of a bottleneck, both congested traffic phases might have similar vehicle speeds, e.g., measured by local detectors. Hence, only a spatial-temporal investigation of a congested traffic state allows the consistent congested traffic phase classification.

The definition of the wide moving jam phase [J]: A wide moving jam is a moving jam that maintains the mean velocity of the downstream jam front, even when the jam propagates through any other traffic state or a freeway bottleneck. This is the characteristic jam feature *J*.

The definition of the synchronized flow traffic phase [S]: In contrast, the downstream front of the synchronized flow phase does not show the characteristic jam feature; in particular, the downstream front of synchronized flow is often fixed at the bottleneck.

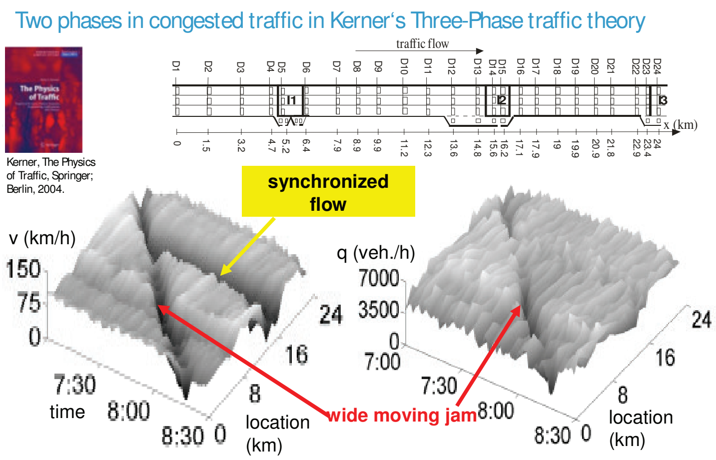

Fig. 1: Two phases of congested traffic in Kerner's three-phase traffic theory [1],[2]

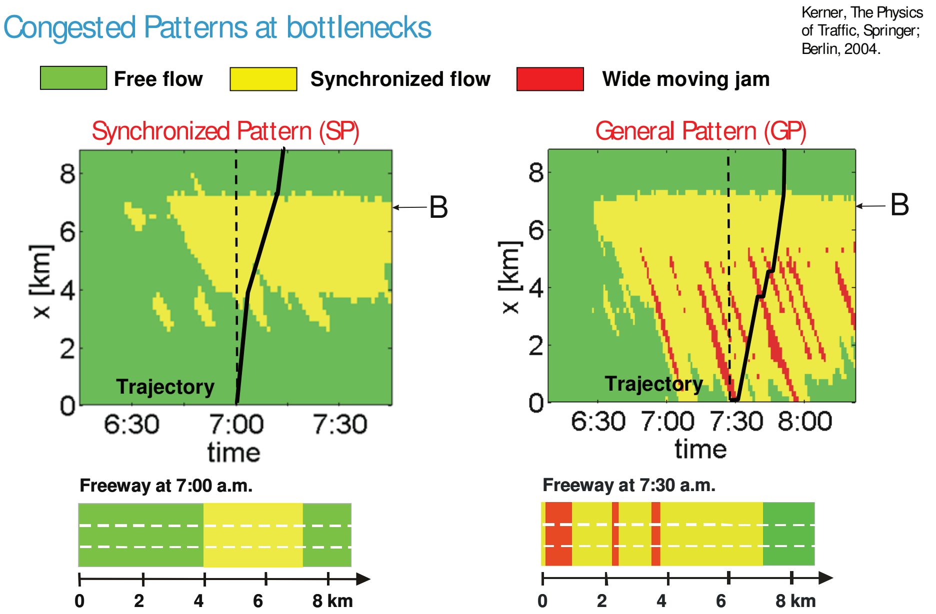

Fig. 2: Congested traffic patterns at bottlenecks [1],[2]

Considering the case of an isolated effectual bottleneck (a bottleneck, which is far enough from other bottlenecks), the following two main congested pattern types can emerge ([1],[2]):
(1) "Synchronized Pattern" (SP): this consists exclusively of an area of synchronized flow upstream of the effectual bottleneck, i.e. no wide moving jams develop in this pattern (Figure 2, left).
(2) "General Pattern" (GP): this consists of an area of synchronized flow upstream from the effectual bottleneck and wide moving jams, which develop in this synchronized flow spontaneously. GP covers thus both phases of congested traffic. It is the most frequently arising pattern at isolated bottlenecks on freeways (Figure 2, right).
The content of Kerner's book [2] is described in Figure 3.

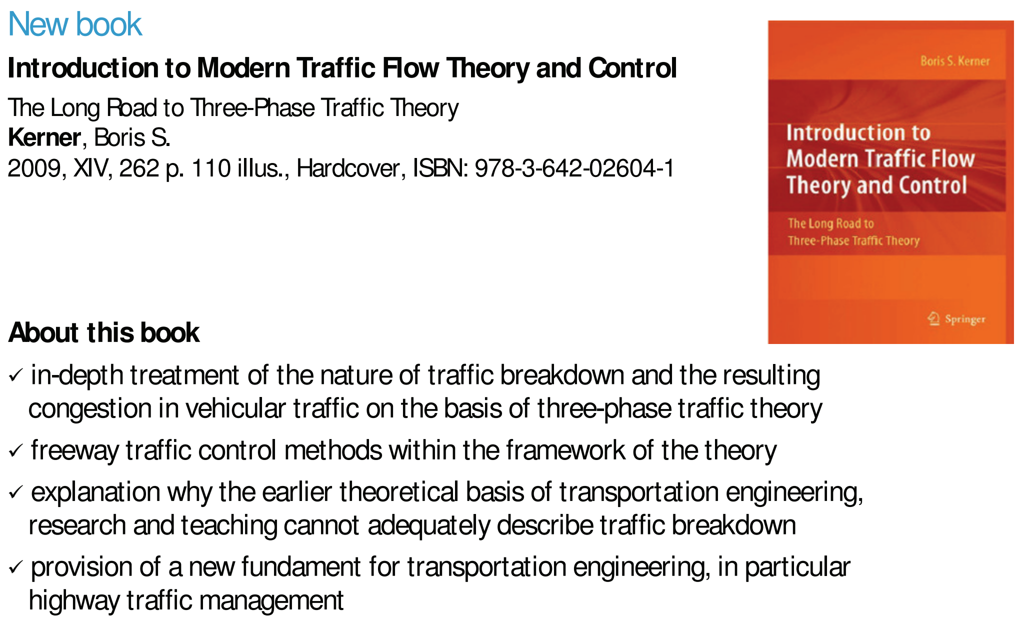

Fig. 3: Book by Kerner explaining three-phase traffic theory [2]

3. How can we detect and predict congestions ?

Figure 4 illustrates the ASDA/FOTO models based on three-phase traffic theory. The front locations $x_{up}^{(syn)}, x_{down}^{(syn)}$ and $x_{up}^{(jam)}, x_{down}^{(jam)}$ define the spatial size and location of the related “synchronized flow” and “wide moving jam” objects, respectively. The ASDA and FOTO models track these object fronts $x_{up}^{(syn)}(t), x_{dwon}^{(syn)}(t), x_{up}^{(jam)}(t), x_{dwon}^{(jam)}(t)$ in time and space (see Figure 4). Note, that through the use of the ASDA and FOTO models the tracking of congested traffic objects is also carried out between detectors, i.e., when the object fronts cannot be measured at all. Additionally, the ASDA and FOTO models work without any validation of model parameters in different environmental and traffic conditions. Model applications are not limited to stationary detector measurements which could measure the necessary flow rates and vehicle speed directly; the use of more advanced measurement technologies like floating car data (vehicles acting as moving traffic sensors) or phone probes (phones acting as moving traffic sensors) will be introduced in [9]. Figure 5 illustrates the application at the traffic control centre in Hessen while Figure 6 shows some results from Northern Bavaria.

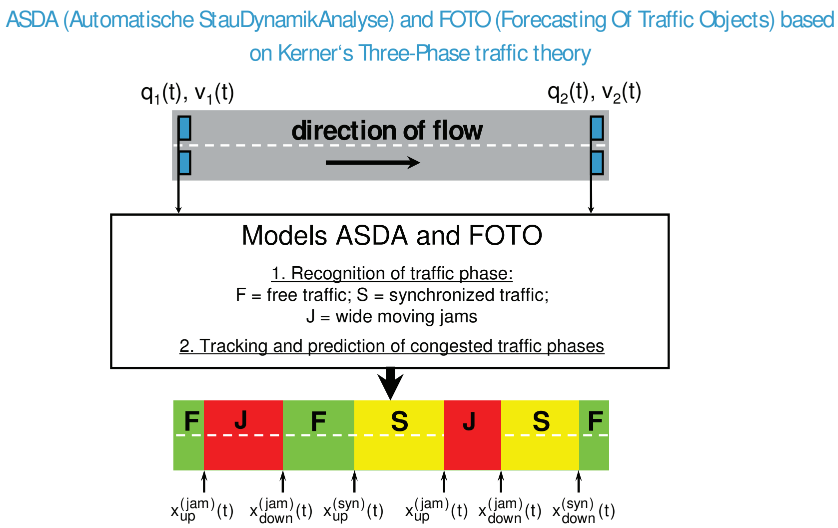

Fig. 4: ASDA/FOTO models for tracking of congested traffic patterns [1-5]

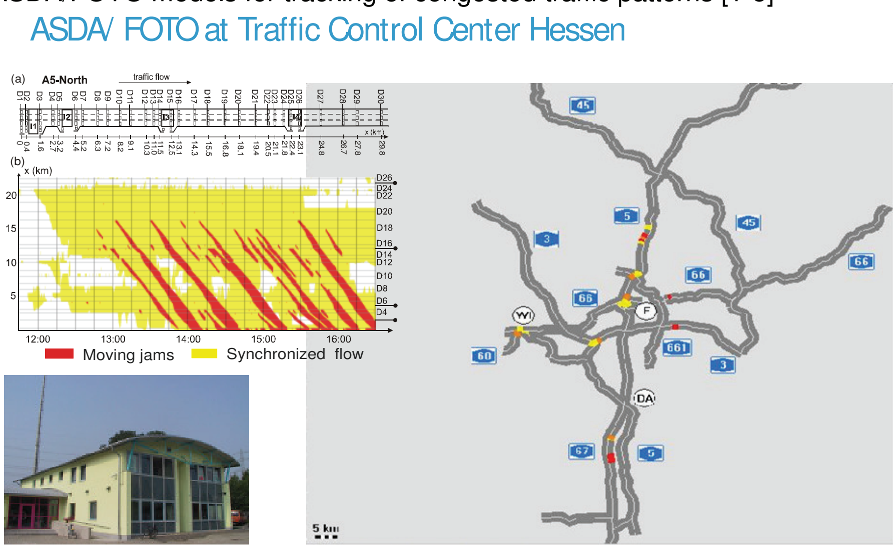

Fig. 5: ASDA/FOTO at TCC Hessen

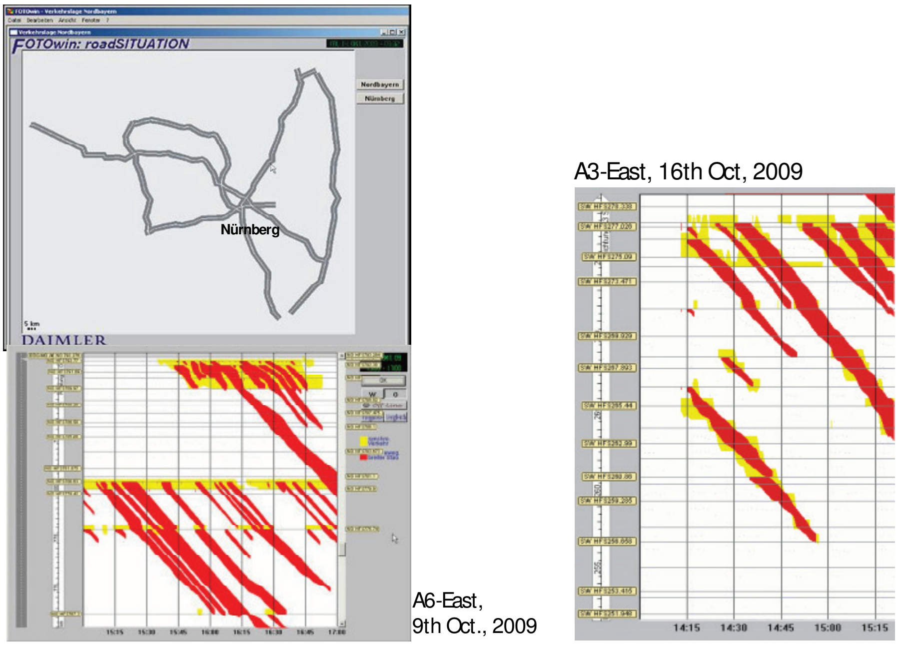

Fig. 6: ASDA/FOTO models in Northern Bavaria near Nuremberg

4. How can we define and measure RDS/TMC product quality?

The RDS/TMC product quality can be measured as follows: Fig. 7 illustrates the real "Ground Truth" travel time on a road segment as a red line (to be measured, e.g., based on vehicle date or detector data and ASD/FOTO models). RDS/TMC messages can be transformed into travel times ("stairs" like curves) if the event code is assumed to have an average speed, e.g. "stationary traffic" with an average speed of 15km/h). Then, RDS/TMC message sources from different providers can be compared based on travel time curves in congested time periods: as closer the RDS/TMC message curve to the "Ground Truth" curve as more valuable the service is. Fig. 8 gives a "Ground Truth" congestion, Fig. 9 the RDS/TMC messages and Fig. 10 integrates both real congestion (based on detector data in a dense network) and shows the delays of the RDS/TMC messages in both time and space.

Graphical example

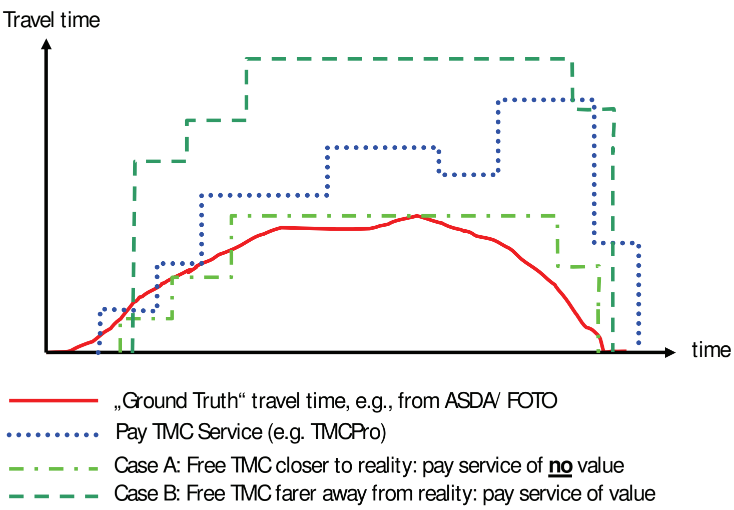

Fig. 7: Graphical example for comparing traffic services

Traffic situation over location and time of A5 in Hessen

Online application ASDA/ FOTO based on Kerner's three-phase traffic theory

Freeway A5-North, 27th, Nov. 2008; 17:30-19:30; Induction loop measurements (grey lines)

Synchronized traffic (normally fixed at the bottleneck, v=20-70km/ h)

Wide moving jam (propagates upstream, v=5-30km/ h)

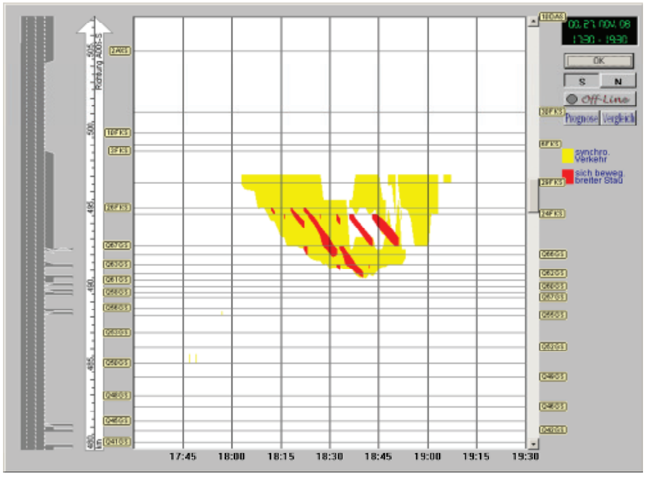

Fig. 8: ASDA/FOTO traffic situation

TMCPro messages for this traffic situation

Tag	Von	Bis	Ereignis	Länge
27.11.2008	17:14:24	17:16:06	stockend	1
27.11.2008	17:16:06	17:18:20	stockend	2
27.11.2008	17:18:20	17:20:24	stockend	3
27.11.2008	17:20:24	17:24:08	stockend	3
27.11.2008	17:24:08	17:28:08	stockend	3
27.11.2008	17:28:08	17:38:12	stockend	5
27.11.2008	17:38:12	17:55:56	stockend	6
27.11.2008	17:55:56	18:06:02	stockend	5
27.11.2008	18:06:02	18:07:54	stockend	3
27.11.2008	18:07:54	18:09:56	stockend	3
27.11.2008	18:09:56	18:11:52	stockend	2
27.11.2008	18:11:52	18:14:10	stockend	1

Event Code „queueing" — Quantifier

Fig. 9: RDS/TMC traffic messages for the situation of Figure 8

Comparison of traffic reality and TMCPro

Customer might realize both **temporal shift** (here: approx. 12 min), **spatial shift** (here: approx. 2 km) and **no detailed event description** („queueing" combines slow and moving traffic).

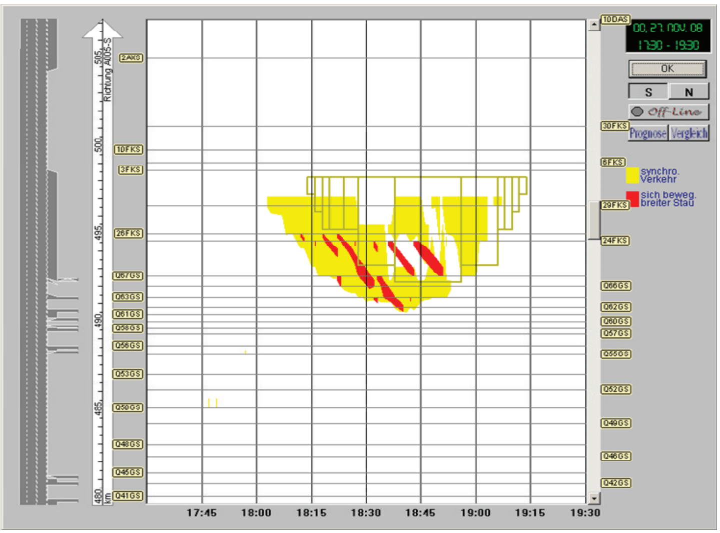

Fig. 10: Comparison of RDS/TMC traffic messages and ASDA/FOTO result

4.1. Results for different traffic service product quality

Comparison of three sources (Fig. 11: TMC provided by „Hessischer Rundfunk“; Fig. 12: TMCPro provided by „Navteq Traffic“ and Fig. 13: HD Traffic provided by „TomTom“) for one distinct traffic situation on 2nd March, 2009 on freeway A5-North (according to Hessischer Rundfunk: „accident with right lane closure“).

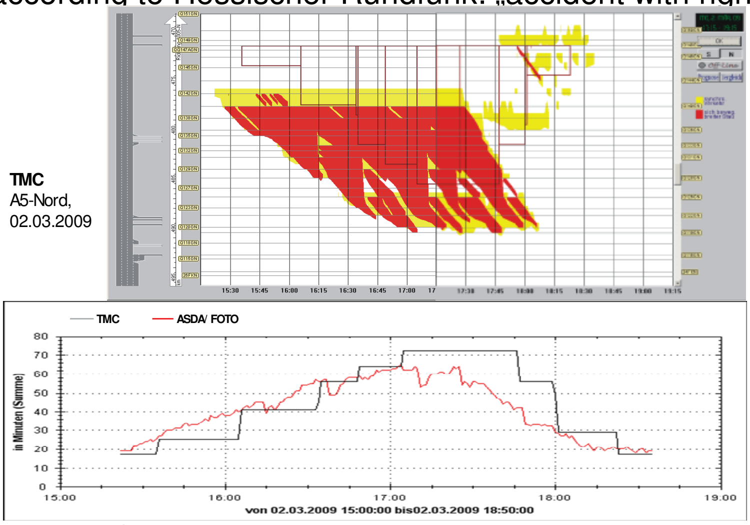

Fig. 11: TMC A5 North, 02.03.2009

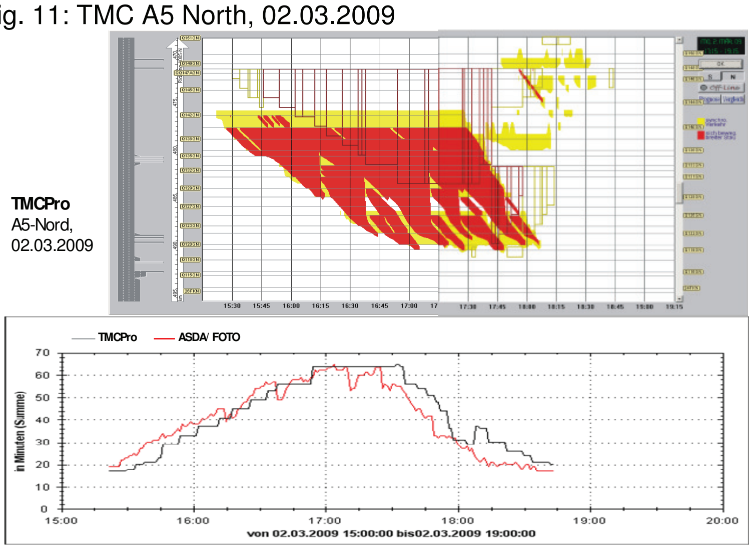

Fig. 12: Navteq TMCPro A5 North, 02.03.2009

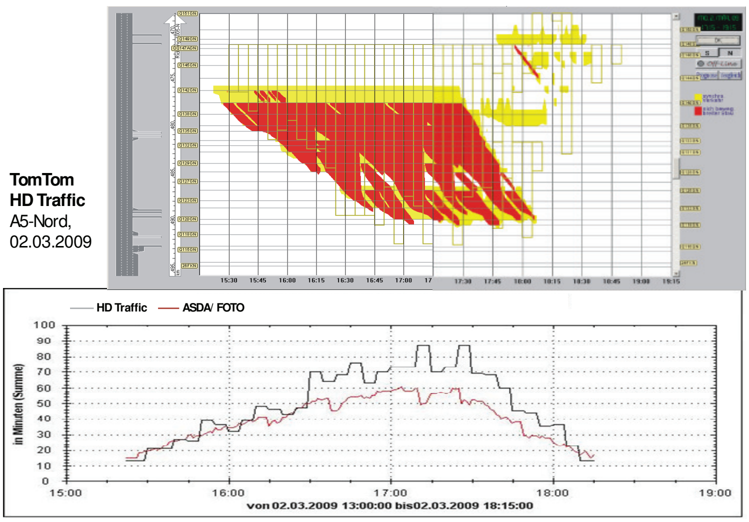

Fig. 13: TomTom HD Traffic A5 North, 02.03.2009

5. How can we measure precise traffic information quality (see [8], [9])?

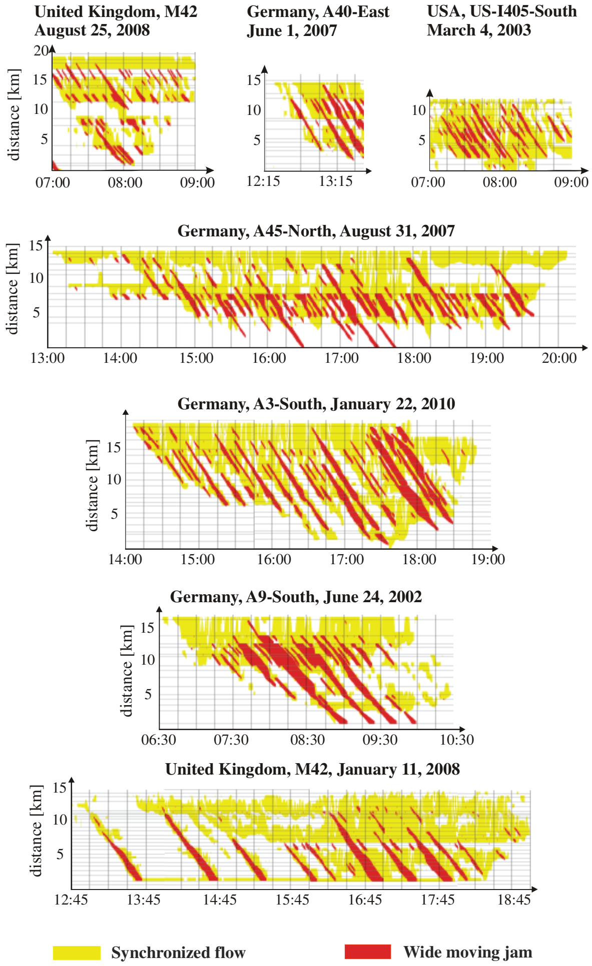

Fig. 14: Empirical examples of spatiotemporal congested patterns reconstructed and tracked by the ASDA/FOTO models using raw data measured by road detectors on different highways in the United Kingdom, Germany, and the USA [9].

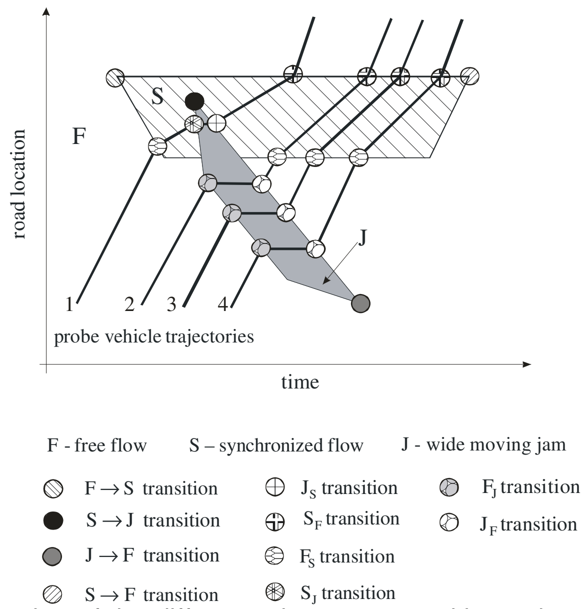

Fig. 15: Qualitative explanation of the difference between transition points for phase transitions along trajectories of four probe vehicles and phase transitions in traffic. White regions – free flow (F), a dashed region – synchronized flow (S), gray region – wide moving jam (J) [9].

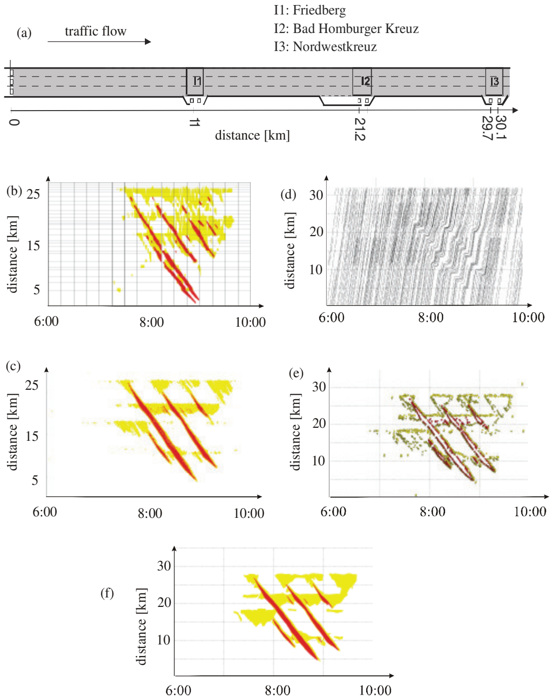

Fig. 16: Explanation of methodology used in the article: (a) A5 highway stretch. (b) ASDA/FOTO pattern reconstruction based on detector date on 10th December, 2009. (c) Simulations of the pattern in (b) with the Kerner-Klenov stochastic microscopic three-phase traffic flow model. (d) Simulated vehicle trajectories of random distributed 2% probe vehicles within the pattern in (c). (e) Detection of transition points for phase transitions along trajectories of probe vehicles in (d). (f) ASDA/FOTO traffic reconstruction based on probe vehicles in (d). [8],[9]

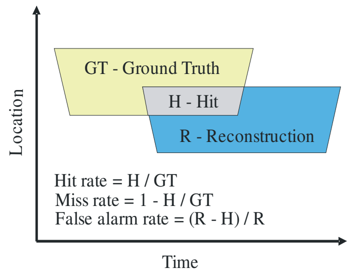

Fig. 17: Quality index used for the quality assessment of reconstructed traffic patterns.

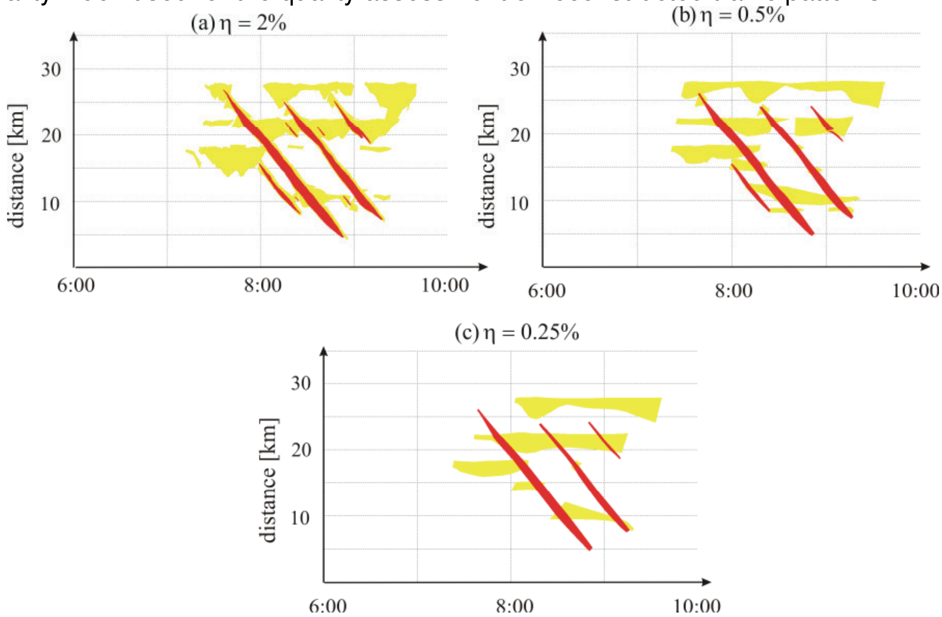

Fig. 18: Reconstruction of congested patterns with ASDA/FOTO models based on the transition points shown in Fig. 9: (a) $\eta = 2\%$,(b) $\eta = 0.5\%$,(c) $\eta = 0.25\%$. Results of microscopic simulations [9].

η	Hit [S]	False Alarm [S]	Hit [J]	False Alarm [J]
2%	0.73 +/- 0.01	0.14 +/- 0.02	0.91 +/- 0.01	0.11 +/- 0.01
0.5%	0.55 +/- 0.04	0.15 +/- 0.03	0.84 +/- 0.04	0.08 +/- 0.01
0.25%	0.39 +/- 0.07	0.16 +/- 0.03	0.69 +/- 0.09	0.08 +/- 0.02

Table 1: Quality of pattern reconstruction with the ASDA/FOTO models depending on the penetration rate η of probe vehicles. Standard deviations of quality indices are calculated for 100 different realizations of random distributions of probe vehicles moving through the same congested pattern shown in Fig. 16(c).

6. Conclusions and future proposals

- The quality of traffic information should ideally be defined based on spatiotemporal characteristics of traffic
- ASDA/FOTO based on Kerner's three-phase traffic theory reconstructs spatiotemporal traffic patterns and can be considered as one useful "Ground-Truth" determination using loop data or/and floating car data
- Found spatiotemporal features of traffic allow to determine (average) macroscopic traffic parameters like travel time / delay time
- Precise traffic information for congested patterns evolves with the higher penetration rates of GPS-based probe vehicles
- OEM navigation quality means quantified length / offsets for TMC messages
- Unified interpretation of events („stationary traffic“ means 15 km/h ?)
- Improvements regarding earlier message cancelling
- Danger messages: proof of correctness, reduction to the necessary ones
- Discussion of quality measurement methods in TISA-Forum
- Talks on quality methods with other OEM‘s (e.g., BMW) and partners

7. References

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QBench – Evaluation of Traffic Flow Quality

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Abstract

With evolving technologies and new features, car manufacturers are adding dynamic services to their products.
Consistent premium quality is mandatory for all products and where specifications exist for mechanical parts, measuring quality for services like traffic information is a challenge.
BMW has worked with their partners since many years to ensure highest quality for the offered traffic info services.
Adapting existing evaluation algorithms to latest protocols, QBENCH as a measure for traffic flow was created.

1. Basic approach Quality Measurements QKZ and QFCD

The basic approach that is used for QKZ compared Ground Truth sensor data with a TMC overlay as shown in Image 1.

[vgl.DE10246184A1:
"Verfahren zur Güteverbesserung von Verkehrsstörungsmeldeverfahren"]

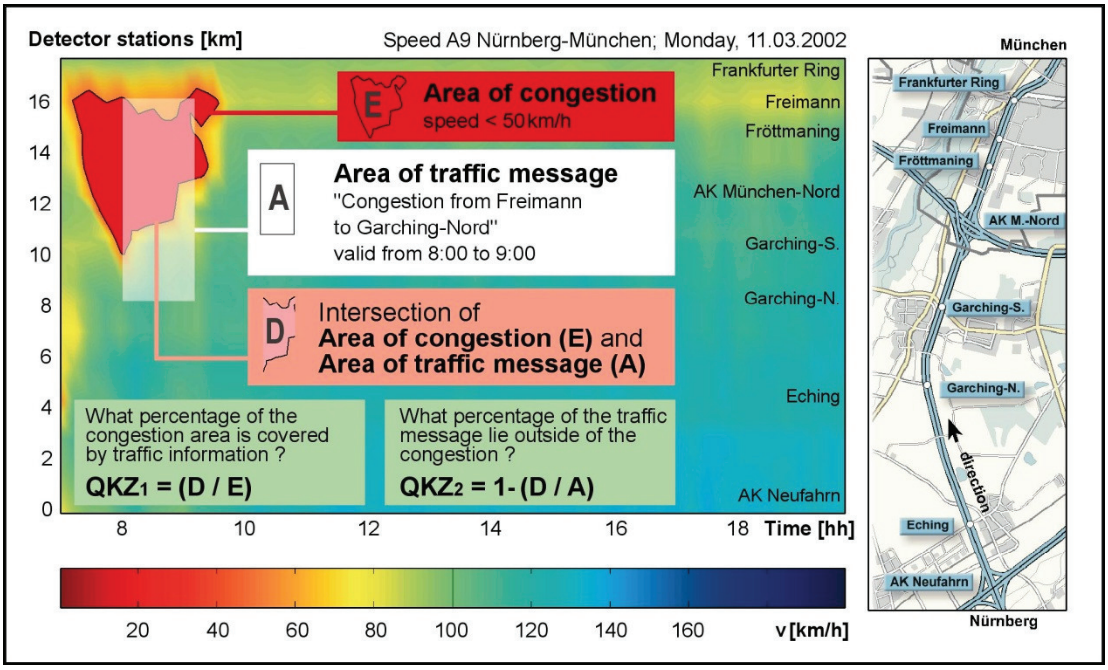

Fig. 1: Definition of Quality indices QKZ1 and QKZ2 according to the QKZ method

To have a measure that reflects the customer experience, the algorithms and rules for the quality measures must be adapted to possible limitations of the inherited protocol and transmission.

For areas and roads where no sensor data exists, the QKZ[1] system was changed to create a trajectory out of a test or customer vehicles path.

The QFCD[2] method applies to those premises. For that, GPS raw data is recorded and map- matched to the digital map. Then, average speeds are projected to the passed TMC links.

[vgl.DE102008021260A1:
"Verfahren zur Güteprüfung von Verkehrsstörungsmeldeverfahren"]
Coming from a protocol where most services use textual representation to submit traffic congestion events, the algorithm also used categories, Level Of Service, that were defined by speed ranges.

[1] "Qualitätskennzahl"; Quality indicator, describes the algorithm and the resulting figures
[2] "QKZ with Floating Car Data"

Speed bands, mostly represented by a textual event code, are often subject to interpretation or are country dependant. A fixed definition does not exist and so the quality figures are only valid with predefines intervals.

2. QBENCH approach

Having TPEG[3] applications like TFP[4], the accuracy of traffic information can be raised to a higher level, transmitting beside Level Of Service also average speeds for more granular segments.
But Level Of Service is not the primary information here and so comparison based on speed bands as in QFCD should not be used.
The distinction of Detection and False Alarm rate as in QKZ/ QFCD is not possible anymore since only travel times are used; the transitions are fluent.
Also, TFP services show traffic information at each covered link at any given time.
As in routing algorithms, a link- cost based approach was used when developing QBENCH.
The algorithm delivers one value indicating the quality directly, making interpretation and fixation of targets easy.

2.1. Adaption to cost function

Routing algorithms find the path through the digital map that fits best to the routing criteria. In most cases, the travel time and ETA [5]is the predominant criteria for the routing.
The traffic information is therefore the important meta info that is used in addition to the static map data.
Each link has a fixed minimum cost (in time) t_{ff} that is mainly dependant from the road class and speed limit.
A vehicle passing that link cannot have lower costs, as speeds are cut at the speed limit.
Traffic congestion now adds traverse time to this minimum, raising the cost of the link. This addition to the minimum time is the information which the navigation should know to calculate the fastest route.
A perfect service provider would always know exactly how big this raise is, reporting the exact speed and traverse time t_{rep}. The service would deliver the highest benefit to the customer.
The test vehicle that passes the link through the congestion records its own overhead between minimum travel time and Ground Truth time t_{gt}, creating the ideal benefit.

QBENCH compares benefits the benefits from test vehicle and service provider using a simple equation.

$$QBench = \frac{\sum_{all} B_{real}}{\sum_{all} B_{ideal}}$$

[3] Transport Protocol Expert Group
[4] Traffic Flow and Prediction
[5] Expected Time of Arrival

2.2. Congestion threshold

For most countries and markets, free flowing traffic is the predominant level of service. Taking all cases where traffic is flowing freely and the provider is reporting that correctly into account would skew the result markedly. As a result, misdetections would not be visible in the overall figure.
The congestion threshold t_{ct} defines a speed the ground truth or reported speed needs to fall below. All events where both speeds are above the threshold are left out of the equation.
Normally, the threshold should be set to a speed that is also neutral in the visualisation of the service to the customer and routing engine.

2.3. Benefits for Cost Function

The ideal benefit is calculated as the number of seconds of delay which were reported by a reference vehicle – this value is scaled by an impact factor φ.

$$B_{ideal} = \begin{cases} 0 & , t_{gt} \leq t_{ct} \\ (\varphi - 1)(t_{gt} - t_{ff}) & , t_{gt} > t_{ct} \end{cases}$$

The real benefit is based on the traffic information.
If the expected speed is outside a defined tolerance area, it is reduced.
The loss of benefit is different for overstating or understating the congestion.

$$B_{loss} = \begin{cases} (\varphi - 1)(t_{gt} - t_{rep}) & , t_{rep} < t_{gt} \\ 0 & , t_{rep} = t_{gt} \\ t_{rep} - t_{gt} & , t_{rep} > t_{gt} \end{cases}$$

If the reported speed is free flow, the real Benefit is set to zero.

$$B_{real} = \begin{cases} \left(\frac{B_{ideal}}{B_{lower}}\right)(B_{ideal} - B_{loss}) & , t_{rep} < t_{gt} \\ B_{ideal} & , t_{rep} = t_{gt} \\ (B_{ideal} - B_{loss}) + (B_{ideal} - B_{upper}) & , t_{rep} > t_{gt} \end{cases}$$

2.4. Tolerances and windowing

To ensure fair measures, tolerances define an area around the ground truth speed where no loss of benefits is applied.
Also, speeds within congestion events are not static. Window functions that combine larger stretches of roads smoothen travel times.

Tolerance and windowing must take care of:

- Impacts due to infrastructure (e.g. traffic lights, lane dependant traverse speeds)
- Speed waves in congestion

Outside the tolerance area, a jump in B_{loss} would occur, resulting in a discontinuity. To prevent this, the borders of the tolerance are newly defined by changing the ground truth speed v_{gt} to a traverse time t_{lower} and t_{upper} respectively.

$$B_{lower} = B_{ideal} - (\varphi - 1)(t_{gt} - t_{lower})$$
$$B_{upper} = B_{ideal} - (t_{upper} - t_{gt})$$

Traverse times recorded by test vehicles are usually subject to variation, especially on smaller links. Still, the highest possible granularity should be used to have a representative result of the algorithm.
A rolling window function is used to combine links to create a minimum trip length of a predefined size. Their reported ground truth speeds are then used in the QBENCH equation.
Larger windows however also reduce the significance of the QBENCH result.
Therefore, the windows are not shifted by their size, but only a percentage of their size, e.g. 2500m are shifted by only 500m (see Image 2).

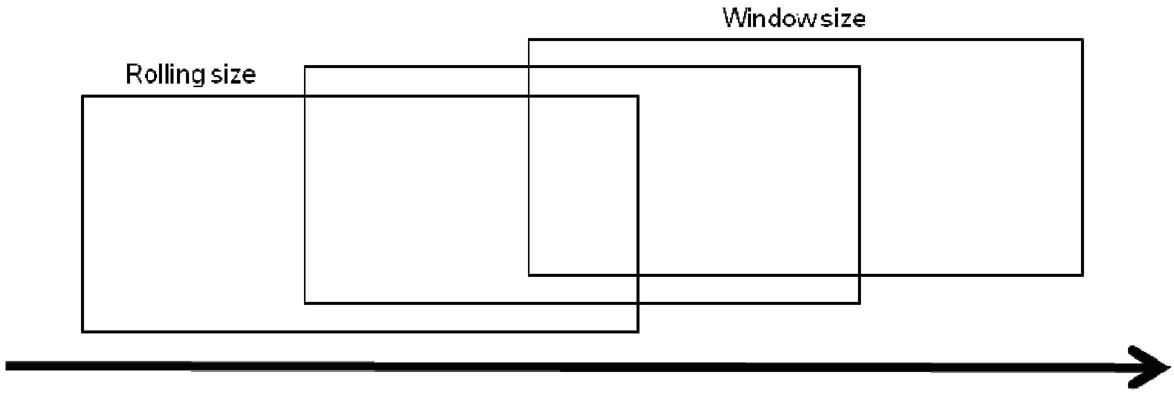

Fig. 2: Windowing method to reduce unwanted variances

2.5. Impact factor Phi φ

The focus of QBENCH is to have a figure that represents the traffic information quality. However, using the tool and its algorithm for contractual relevant quality targets, the service provider can optimize their service to meet the requirements.
Since quality is calculated out of the difference between ground truth travel time and reported travel time, for each situation the same quality index applies to two reported speeds; lower or higher than the optimum.
The impact of those two imperfect results is very different. Falsely understating congestion leads to unexpected raises in travel time while overstating leads to unnecessary detours with possibly even higher travel times than the original route with traffic.
The effect of those cases is different for specific road classes. Inner city routes usually have a lot of alternatives that are quite close in regards of travel time.
On motorways, possible detours prove to be much longer and slower. Providers using QBENCH might tend to underestimate the congestions to limit penalties.

The impact factor Phi can reduce the amount of loss in benefit for specific road classes. For arterials, e.g. the effect of overstating congestion might be reduced by setting $\varphi=3$.
For motorways, having $\varphi=2$ does not reduce impact on the result.

2.6. **Minimum congestion time and capping**

Travel times do not have a linear behaviour. Especially for lower traverse speeds, the impact of single events might be extreme for the overall result.
In order to reduce the maximum loss and gain a single event may generate it is recommended to limit both benefits B_{ideal} and B_{real} to a specific amount.

The capped value B_{cap} can be defined as

$$B_{cap} = \lambda * (\varphi - 1) * (\frac{100}{\delta} - 1) * t_{ff}$$

Where δ is the percentage of free flow speed for a segment below which it is considered congested, and λ is the number of times the minimum congestion would have to be reported correctly in order to counter the effect of missing the worst case congestion. These values differ for motorways and non-motorways and have to be defined according to local conditions.

Additionally, another requirement for a fair and representative measure is to set a minimum congestion time, which is a lower boundary for the benefit $B_{ideal}$for the overall analysis.
Since TPEG like service always report speed at any place, reaching enough congestion to have a stable result may not be very complicated in most areas.

2.7. **Congestion threshold**

For most countries and markets, free flowing traffic is the predominant level of service. Taking all cases where traffic is flowing freely and the provider is reporting that correctly into account would skew the result markedly. As a result, misdetections would not be visible in the overall figure.
The congestion threshold t_{ct} defines a speed the ground truth or reported speed needs to fall below. All events where both speeds are above the threshold are left out of the equation.
Normally, the threshold should be set to a speed that is also neutral in the visualisation of the service to the customer and routing engine.

3. Utilization

To utilize QBENCH, Ground Truth data is needed. The data must be independent from the data that was used for creation of the traffic state which lead to the traffic information.
Therefore, two possibilities can be used to collect ground truth data for the evaluation.

3.1. Using drive tracks

When using drive tracks for the quality evaluation, it is important that in addition to the requirements of minimum congestion time, that the test itself does not change the prevalent quality. Predefined routes ensure that drivers do not change their paths by following specific occurrences like major jams or false alarms.

3.2. Using sampling technology

As an alternative to the GPS tracks, also sampling techniques can be used to calculate traffic info quality using QBENCH.
Many service providers use exclusively or as an addition probe data. Those vehicles send their trajectories as single point or as point chains to their operation centre. Since those paths are distinguishable by a unique, anonymized identifier, an extract of some of them can be used to check against the rest of the data sources.
By extraction of parts of the incoming data and calculating a level of service using all other probes, the extracted portion can be used as ground truth since it did not contribute to the creation of the traffic information – it is independent data.

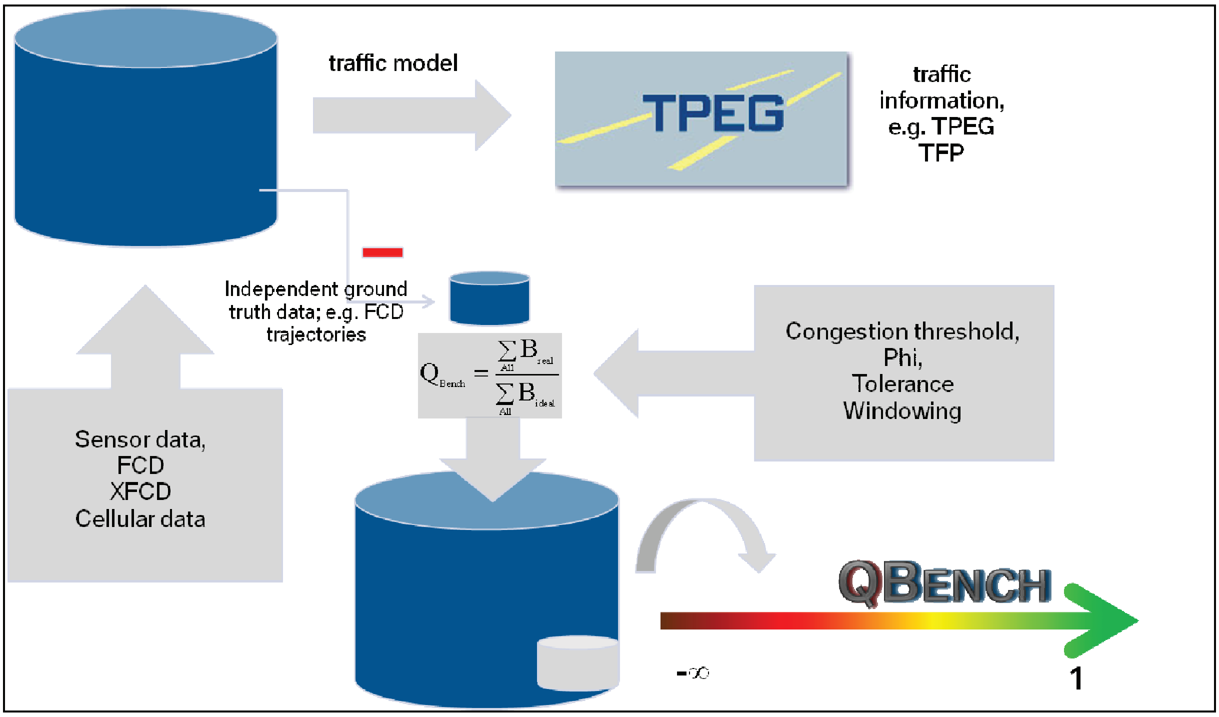

Fig. 3: Evaluation Chain for QBench

4. Conclusion

Traffic information is one of the most important dynamic services for navigation devices.
The market for traffic services is growing and the quality of the offered information is varying.
Evaluation of accuracy is needed to select the adequate provider or helps providers to show their quality compared to competitors.

QBENCH offers an algorithm that can be used for travel services that deliver specific travel time or average speeds to the customer.

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Quality of HGV Rest Area Occupation Measurements Along Long Distance Roads

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Abstract

According to an investigation conducted by the German Ministry for Transport (BMVBS) about 14.000 parking slots for HGV were missing along the country's motorways in March 2008. Both the recent economic crisis and the BMVBS' program for building new parking areas mitigated the problem, but by the end of 2010 Germany's ADAC still estimated a lack of 7,000 slots, with tendency to rise. The building and extending of parking areas is now supported by intelligent information systems which can inform the driver and potentially also his back office about available parking slots. The systematic gathering, assessment and distribution of such information are novel tasks for road administrations. The distinct characteristics and requirements are presented in this paper.

1. The Underlying Concept

Information on available parking slots does not add one single space to the lot. So why inform about them? There are two very good reasons. For one there is significant search traffic on park and rest areas by HGV drivers looking for a place to rest. On densely packed parking areas this poses risks and creates unnecessary traffic with all related adverse effects. The hypothesis for signposting: If a driver knows that a parking area is full he will not enter it.

The second and even more advantageous reason: One can indeed "create" parking places. Even if most places are filled up in one area there will always be some slots available in another. Information about available slots will guide drivers to places they may not have known of or which they know normally to be full. This provides a higher overall utilization of available parking space and effectively creates more parking options.

It is therefore assumed that information about available parking options will ease the problem. This is only the beginning, though. The more the information is made available for the logistical planning and the operation a paradigm change from reacting to acting becomes likely: Better planning will contribute to optimized timing of transports and thus result in a reduction of parking slot requirements. It is obvious that this level of elaboration requires excellent availability of reliable and comprehensive data.

2. Strategies and Technologies for the Gathering of Information

2.1. What to Count and How

It may sound simple: All we want to know is how many HGV parking slots are available at a particular installation. The basic equation is:

capacity - occupation = availability

Then again, what is “capacity”? The **nominal maximum capacity** of a parking area may be larger than the maximum at a particular time because of road works, snow deposits, etc. The number of available slots is therefore the overall **current** capacity minus the number of occupied spaces.

Then again, what is “occupation”? Vehicles may park irregularly and occupy more than one slot or block the access to slots. Thus an unoccupied slot may not be accessible and may have to be **deducted from the overall current capacity** figure.

A more realistic equation is thus:

nominal maximum capacity
- slots currently unavailable due to local constraints
- slots unavailable due to irregular usage of the parking area
= availability

The above is the foundation for understanding the advantages and pitfalls of the two principal methods available for assessing the number of empty parking slots at any point in time.

The **differential measurement** is found in most conventional parking lots with single entry and exit gates, i.e. without any bypasses. Starting with a figure for available slots at “time zero” vehicles leaving the site increment the figure and entering vehicles decrement it. Strangely enough even for fairly simple parking lots this method is not error-free. What is more, the errors accumulate over time and make it necessary for the system to be calibrated at intervals. A motorway rest area usually has more than one entry and one exit lane. Also it has no booms to help to count the vehicles in a simple and reliable fashion. In addition to that there is often a mix of passenger cars and HGVs in lorry parking areas. Counting the inbound and outbound traffic thus is insufficient to deduct how many HGVs are parking in the HGV parking area; additional vehicle classification is required to successfully determine the number of available slots.

The **single slot measurement** detects the occupation of every single slot of a parking area. It does not rely on the vehicles’ coming and going but rather measures the current occupation in real-time. As shown in the realistic equation above the problem of this method is that it cannot account for adverse situations, such as non-accessibility of slots. Generally speaking single slot measurement requires more technical equipment than the differential alternative and the effort increases more or less linearly with the number of slots to be assessed.

The above characterizations are simplified and not comprehensive but should be sufficient to show that both methods have principal disadvantages resulting in inaccurate output. A refinement can be achieved by a **full site assessment**. The aim is to gain a comprehensive picture of the situation on the parking area. It is usually achieved by using more than one technology and by applying intelligent analysis and assessment strategies and possibly human interventions. This paper does not aim at suggesting THE optimum solution and there is indeed not only one. The above elaborations rather aim at sensitising the reader of the following: It may not be possible to achieve fully correct figures for the number of available parking slots under all circumstances and with reasonable technical and manpower effort.

2.2. **A Brief View on Technologies**

Some of the available technologies can be used for both the differential and the single slot measurement strategy. Most of them, however, are only suitable for one of the two for reasons of technology and cost. Sensor technology and power of software analysis are developing so fast that no final recommendations can be given. The quality of individual sensor types and makes is relevant but it is the overall concept, the intelligent design and the analysis strategy which determine the success of an installation.

- The classical **inductive loop** is primarily used for differential measurement
- **Magnetic field sensors** (earth's field sensors) are suitable for differential measurement but best play out their advantages when used for single slot measurement
- **Light barriers** can only be used for differential measurement
- **Video detection** can be applied for both strategies and as a supporting technology for full site assessment and control and calibration purposes
- **Infrared** and **ultrasonic sensors** are used for the differential measurement
- **number plate recognition** (OCR technology) is applied in differential measurement settings
- Same for **laser scanning**
- Same for **radar detectors**

3. Strategies and Technologies for Information Distribution

3.1. **Types of Users**

The findings of the occupation measurement are of interest primarily for the following users:

1. drivers - to find a parking slot
2. back offices of drivers - to direct drivers to suitable areas
3. police forces - to direct drivers to free parking slots
4. logistical supply chain planners - to optimize route and journey planning
5. operators of parking areas along motorways and of truck stops - to assess demand and respond to it
6. planning authorities - to assess demand and to plan additional facilities and communication paths

3.2. **Communication Paths**

Clearly the users in the first three categories mentioned above require accurate real-time information, categories 5 and 6 need long-term information. Logistical planners are somewhere in-between. For strategic planning their demand is similar to categories 5 and 6, for journey or trip planning they have a time horizon of a few days.

The simplest and currently most commonly used communication is via variable message signs (VMS). The number of available parking slots is indicated a few kilometres ahead of a parking area and then again directly at the entry of it. To that end the Bundesanstalt für Straßenwesen, BASt has worked out guidelines, road signs have been adapted. Clearly this communication only reaches drivers who are in immediate demand of a place to rest. Signposting of more than one parking area ahead may be desirable. However: Areas which cannot be reached in about 15 minutes time should not be signposted as they could be full by the time the driver gets there.

Once messages have been defined TMC-RDS communication can reach drivers independent of fixed road sign installations. Drivers can thus plan ahead and adjust driving speed and routes to get to an available space more easily.

Interactive systems can direct information into the vehicles via route guidance, fleet management and on-board computer devices, potentially including road tolling systems. Interactive systems also allow booking of parking slots, where available. Internet systems can be fed with the parking data and then be used by dispatchers and planners. Last not least the information can be directly fed into planning and control systems.

4. Quality Requirements

4.1. **The Users' Side**

The categories of users (see par. 3.1 above) have different requirements. Categories 1 to 3 always demand reliable real-time data to know if a space is available or not. The credibility of a parking information system strongly depends on the accuracy of the data. The closer a driver gets to a chosen parking area the more the information has to be accurate. If a driver repeatedly experiences that he has been given wrong information about the availability of parking slots the credibility of the information system will quickly decrease.

The driver does not necessarily need to know how many slots are vacant, but the information must be trustworthy. If the information is provided at a larger distance from a parking area the number of available slots is more important for a driver.

The other user categories require long term data over as many locations as possible with reasonable granularity for easy scrutiny.
All users require some quality assurance for their work processes and for their decision making. The first three user categories have the most critical requirements:

- real-time or close to real-time information
- dependable information about the availability of parking slots

- well arranged and well readable information on road signs
- high accessibility of data for interactive systems
- high availability of interactive systems

4.2. **Operators' Options and Constraints**

As laid out in par. 2.1 we have to assume that availability information gained at parking areas will very often not be 100% correct. Any unfiltered or raw information given to the users either by road signs or electronic systems will thus be incorrect. The road operators need to consider the legal implications and the effects on users. The legal implications primarily revolve about the regulation (EC) No 561/2006 regarding the permitted work time of drivers. If free parking slots are indicated and a driver finds the area occupied who then is liable for him driving longer than he is permitted? It is not only that. Unreliable information would discredit the system and drivers would ignore it.

An obvious way out is a conservative calculation of available slots by introducing a safety margin. However, this might waste space and be counter-productive. Drivers would quickly find out about such safety margins and again the system would be discredited. The success of the information system is based on its practical value. Road administrations have to find a way to provide good, trustworthy information from the very beginning. If they fail to do so the system would be set back, potentially for years. We see two cornerstones:

1. The quality of the information has to be increased. Progress of sensor technology has to be combined with advanced software tools. The latter have to make best use of the current information provided by - preferably redundant - sensor systems. The software should also consider statistical information and contain prognosis elements. It might also suggest manual intervention and calibration if changes of the site's occupation as measured by the sensor technology appear to be unrealistic.
2. The drivers should be involved in two ways. Firstly they should learn about the quality and the constraints of occupation measuring systems. That way they will be led to tolerate initial problems and they will learn to make their own intelligent interpretations. Secondly the drivers should be led to change their behaviour in the parking areas. They should learn that by parking across two slots, in access lanes or in other wasteful ways they are contributing to the systems' problems.

By improving the quality of the system providing the information and by improving the users' understanding and contribution overall benefits can be achieved. One element is still missing, though. While the drivers and the police are directly involved and enabled to make useful deductions remote users and software systems cannot easily make intelligent assessment of the data they receive. Therefore the data providers have to attach a quality tag to their data. Remote users and automated systems need to be given an objective figure for expected accuracy of the data provided. That way the different installations along the motorways may provide data with varying accuracy and error levels as long as remote systems know about it. Clearly this advice is not applicable for road signs, but very much so for automated systems and remote users in back offices.

4.3. **Third Party Involvement**

The quality of data can either be improved and quality tagged by the road operators or third parties. Germany is currently developing a market platform for mobility data: MDM - Mobilitäts-Datenmarktplatz (see http://www.mdm-portal.de - at present only available in German language). The road operators and possibly private parties will feed the platform and other national and regional authorities may access the data, just as well as third parties. MDM sees three principal roles:

- data providers - Datenanbieter
- data improvers - Datenveredler
- data receivers - Datenabnehmer

Whether data are improved by private or governmental bodies does not matter. The platform will support both. For the sake of universal comparability and usability data have to be quality tagged. That way any source can be used for reliable output. Optimization strategies of different improvement agents using one and the same base data may come to different results. It is for the users to decide who generates the most appropriate data for their purposse.

We thus see a two-step quality approach:

1. The base data communicated by a parking site need to be better than what the underlying sensor system can provide, be it differential or single slot measurement. This job has to be done on site with software systems improving the date provided by the sensors. Already at that stage data about previous occupation patterns may be considered and provided by the road operator or data improvers. The reliability and timeliness of the resulting data have to be considered and an appropriate quality statement has to be attached to any data going to remote systems, e.g. the MDM market place.
2. Depending on the type of usage and the kind of remote end user the data should be enhanced. This may be done by the end user but more likely data will be improved by third parties having a more comprehensive view and most likely more data available for scrutiny.

5. Conclusions

HGV parking occupation information is very important for drivers, their back offices, the police forces, and various planners. Quality requirements are different for two principal groups: those directly involved in driving and in controlling it and those who are planning transport or infrastructure.

Measuring the occupation of parking is error-prone. It is risky and it may be illegal to provide wrong information to the users. Even with very high technical, organisational and manpower efforts errors cannot be avoided.

However, data can still be valuable as long as users are informed about error margins. For remote users and upstream data improvers it is necessary to add a quality tag to the data.
It would be counterproductive to prescribe one quality level for measurement systems for all parking areas in a country, let alone for the whole of Europe. This is because

- sensor technology is progressing quickly
- the quality of data assessment and improvement on site is moving on all the time

- the different layouts and topologies of parking areas make it impossible to achieve a common quality level - or the common denominator would be very low

It is not important to achieve a unified, common quality level, it is only important that the quality of data is known.

From switching and operating states of technical traffic installations to traffic information
Use of accurate and reliable real-time information in Düsseldorf

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1. Introduction

The aim of traffic information is to increase traffic safety and efficiency of the existing transport infrastructure. A high acceptance of traffic information amongst motorists as a precondition for the information's effectiveness can be achieved by a high degree of currentness, reliability and accuracy.

Traffic information can be based on a variety of different sources. This may include an event calendar, road works information and stationary detectors. But also up-to-date, reliable and accurate information about switching states and operating conditions of traffic engineering facilities are available in the traffic control centres of larger cities. It seems to be obvious to use this information as input for equally accurate and time-date traffic information.

In the following paper the example of the city of Düsseldorf shows on which sources traffic information is based and how good the quality of the resulting messages can be.

2. System Architecture

In Düsseldorf the open system architecture interface OCIT® is used for the manufacturer-independent transmission of operational messages from field devices to the traffic control centre. Field devices are both detectors and traffic lights.

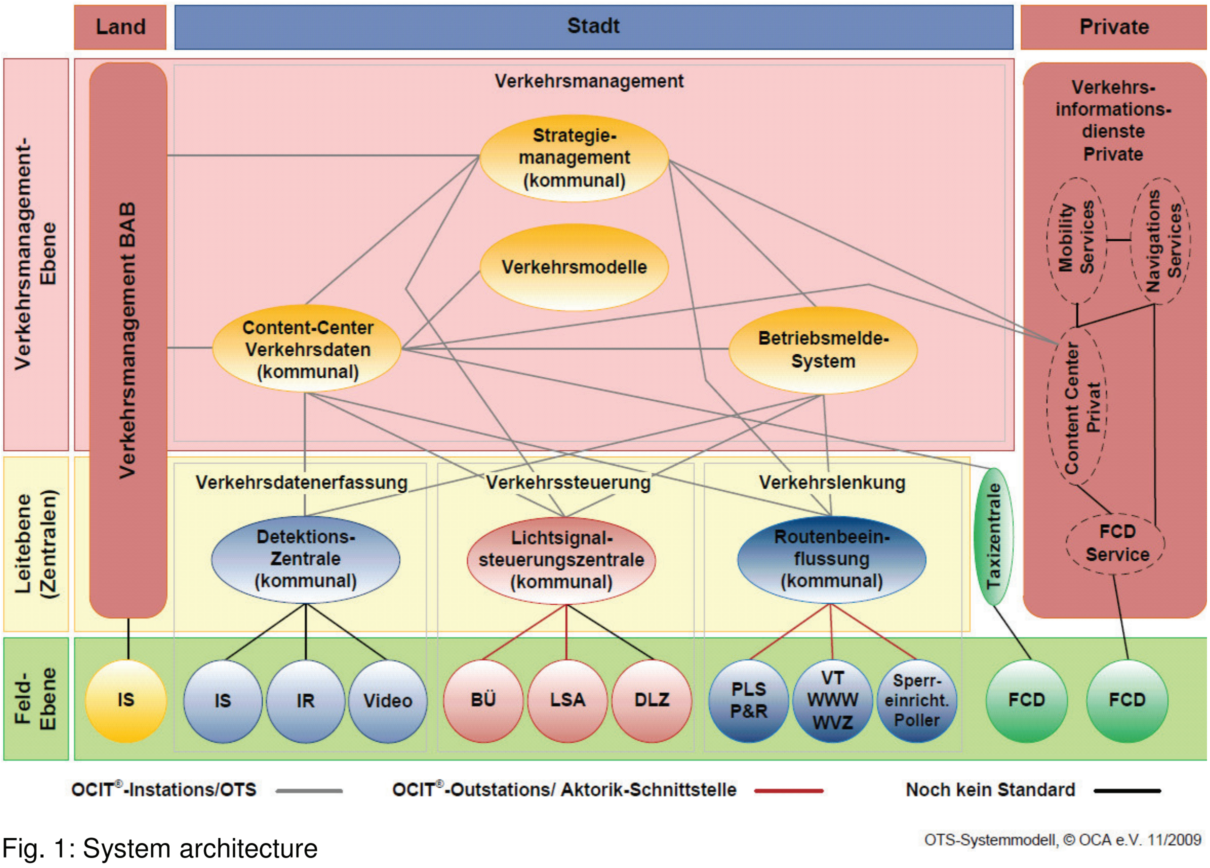

Fig. 1: System architecture

The following text shows the comprehensive, yet not extensively used potential of operating information of field devices. Düsseldorf's traffic management centre uses software solutions by GEVAS Software. *VTnet* taps the input from the traffic control centre. It processes information about current traffic conditions as well as switching states and operating conditions of the local traffic engineering facilities. The *EventManager* allows to manually generate traffic messages on road closures, road works and other incidents. Furthermore, based on the data provided by *VTnet* the *EventManager* automatically compiles traffic messages for example concerning traffic jams or emergency situations in tunnels.

Düsseldorf's *VTnet* provides the local traffic information to North Rhine-Westphalia's traffic information centre (VIZ NRW), private service providers and displays it on the city's website. In the near future it will also be linked to the national data warehouse *Mobilitätsdaten Marktplatz (MDM)*. This allows on the one hand the real-time distribution of local traffic information to various addresses like radio stations and satellite navigation services. On the other hand Düsseldorf's traffic management centre uses third party information as offered by VIZ NRW to display the current situation on highways around Düsseldorf. For the data communication both proprietary interfaces as well as OTS and Datex are used.

3. Sources used for traffic information

The following examples show which sources are used in Düsseldorf to generate traffic information.

3.1. Calendar of Events

For a profound knowledge about the various major events in a city that can have an obstructive influence on the local traffic a comprehensive calendar of events has to be set up and maintained. The input comes from the event organizers and the venue operators as well as those departments of the local police and city administration that handle the expected traffic volumes.

Event Code:	(1459) Football Match
Title:	Fortuna Düsseldorf - FC Erzgebirge Aue, 13:00 h
District:	Stockum
Address:	ESPRIT arena
Validity:	02.04.2011
Message:	Slow traffic is expected before the beginning of the football match. Visitors are recommended to use public transport. U78 serves ESPRIT arena from Düsseldorf main station. Car users reach the official parking area via A44 – Exit Messe/Arena or Rotterdamer Straße.

Fig. 2: Traffic message announcing an event

Depending on the nature of the event (e.g. sports event, music event) the expected traffic loads and their time course can be estimated and used as the basis for traffic information. However this can only offer a reference to an increased traffic volume as expected and possibly also contains travel information for visitors (e.g. information on public transport or park & ride and parking guidance). Obviously no real-time traffic information can be included in this case.

Quality characteristics of the source of information

Seeing that major events will almost never be cancelled the so created traffic information can be seen as correct and reliable in general. However, they are intentionally imprecise and hence may not reflect the actual traffic situation accurately. But they provide forecast information about an expected traffic situation around a venue that is based on experience not on current traffic data.

3.2. **Road works information**

Event Code:	(742) Road works. Single alternate line traffic.
District:	Angermund
Address:	Angermunder Straße
Validity:	03.09.2010 – 01.06.2011
Message:	Due to canal constructions at Angermunder Straße single alternate line traffic between Rahmer Straße und Am Mühlendamm.

Fig. 3: Traffic message concerning road works

Construction sites on main roads that result in obstructions must be permitted in advance by the local road administration. Copies of these permits are sent to the department for traffic management where they serve as a basis for traffic information on foreseeable obstructions due to capacity restrictions and road closures. This information is given up a week in advance so that road users can plan their journeys accordingly.

Each permit specifies a time range in which the work can be done, but does not define an obligatory start and end time. Hence, delays due to staff shortage, earlier finalisation or cancellation due to bad weather conditions cannot be foreseen. Hence, more detailed information on the actual closure of traffic lanes or road closures must be reported to the traffic management centre.

Quality characteristics of the source of information

The reliability and accuracy of traffic information on road works is increased by telephone announcements of the responsible construction manager on site at the beginning and end of a road or lane closure. This requires implementing a routine between local road administration, construction companies, traffic safety companies and the traffic operators. The larger the expected obstructions of the road works are the more important is a reliable communication between all parties involved. Since traffic information is not in the focus of the construction workers some effort is required to get real-time and reliable information on the local situation. Experience shows that the limited number of regularly subcontracted traffic safety companies in Düsseldorf has a better understanding of the operators' requirements. However since various parties are involved in the process a perfect reliability of road works information will never be achieved. Hence, the aim in Düsseldorf is to especially increase reliability of information on major road works with serious restrictions first.

3.3. Operations of fire brigade and police

Event Code:	(214) Traffic problem (507) Right lane blocked (1706) Emergency vehicles
District:	Bilk
Address:	Mecumstraße
Validity:	24.03.2011
Message:	Due to a major deployment of fire brigade constructions at Mecumstraße the inbound carriageway is reduced to one lane between Fruchtstraße und Gurlittstraße. Local drivers are recommended to avoid the area.

Fig. 4: Traffic message concerning an emergency deployment

Unforeseeable events such as heavy road accidents and major deployments of fire brigade and police can lead to significant traffic obstructions. Therefore, fire department and police in Düsseldorf announce major operations to the traffic centre. The traffic operators then compile corresponding traffic information and indicate alternative routes if available.

It is the responsibility of the traffic operators to come to the most accurate assessment of the situation at the site. At major intersections traffic monitoring cameras allow to monitor the situation. Where this is not possible, the traffic operators communicate with the appropriate control centre of fire department or police and the city's traffic safety service that usually supports firearms and police in traffic safety issues. Based on this information, traffic reports are getting more and more precise over time. Even a rough forecast of the expected duration of obstructions is possible in most cases.

Quality characteristics

Although the information status of the traffic operators is already quite good, they depend on third party information to assess unforeseeable situations like road accidents or emergencies which they then condense into a traffic report. Delays result in the fact that fire brigade and police examine and secure the situation on the spot before giving feedback to the traffic operators on the obstructive impacts of their deployment on the local traffic. Also the further development is reported via phone. Experience shows that in particular the notification sometimes is forgotten after the end of a deployment. Hence, the traffic information generated by the operators is as up-to-date as the situation allows in the beginning. Delayed clearance information seems to be tolerable to a certain extent, especially while the induced congestion is still dissolving.

3.4. Local traffic detectors

Event Code:	(101) Stationary traffic
District:	Pempelfort
Address:	Fischerstraße
Message:	Stationary traffic on inbound Fischerstraße

Fig. 5: Traffic message concerning stationary traffic

Local traffic detectors are used to detect traffic jams based on the detected Level of Service (LOS). A LOS greater or equal 5 initiates an automated traffic message reporting stationary traffic. This message will be withdrawn after an LOS smaller or equal 3 is reached.

Quality characteristics

Weaknesses of local traffic detectors can be implausible data (e.g. counts of traffic on the opposite or neighbouring lanes or neighbouring trams, double or no counts of vehicles, reflections in video detectors) or missing data (e.g. detector failure, communication breakdown). Also a bad tuned model to generate the LOS can lead to inaccurate traffic information. These kinds of malfunctioning are currently not easy to find. It is one aim of Traffic IQ[6] to monitor data quality and allows us to find implausible detector results in order to further improve them. Otherwise only obvious mistakes can be found without detailed test measurements.

Delays between stationary traffic building up and the according traffic information being sent out are small compared to those described before. Nevertheless, there is an intended delay before sending out the information. To make sure that only real stationary traffic rather than a single incident triggers the stationary traffic warning, three consecutive values in one minute intervals must deliver a LOS of 5 or worse. Further delays of a minute or two are caused by internal workflow processes. The withdrawal of the information follows without delay when the measured LOS is 3 or better.

3.5. Conclusion on the described sources for traffic information

The illustrated sources for traffic information offer a surplus value on a rather high level of currentness, reliability and accuracy. But as described there are still weaknesses that are inherent to the system.

As shown above traffic information on events, road works and emergency situations require a substantial amount of organisation and coordination between a variety of partners in and outside the department for traffic management. Furthermore the vast number of manual inputs is a source of errors and delays.

Local traffic detectors on the other hand may be faster due to automation but they can only provide local information for a single lane or street section.

[6] The City of Düsseldorf is partner in the national research project *Traffic IQ - Pilotprojekt Informationsqualität im Verkehrswesen*. For detailed information see www.traffic-iq.de.

In order to further increase the level of acceptance and satisfaction amongst motorists it is necessary to find and exploit sources that can provide reliable and accurate real-time information on the current traffic situation on an automated basis.

4. Using switching and operating states as a basis for traffic information

In the traffic control centres of larger cities a considerable amount of real-time, reliable and accurate information about switching and operating states of traffic engineering systems reflect their current status in the field. The following offers examples of how this information is used in Düsseldorf and what future utilisations are planned. The basic idea is that *VTnet* continuously polls the switching states of traffic engineering systems as the source for comprehensive real-time traffic information.

4.1. Traffic light systems

Traffic light systems report their current switch state (i.e. the running signalling programme) and operational state (i.e. whether the light signal system is in operation or not) to the traffic control centre.

Event Code:	(1804) traffic lights not working
District:	Bilk
Address:	Auf'm Hennekamp - Mecumstraße
Message:	Traffic lights not working at Auf'm Hennekamp – Mecumstraße. Road users are asked to pay attention to the road signs and pass the intersection with caution.

Fig. 6: Automated traffic message concerning traffic light breakdown

The breakdown of a traffic light is first of all a safety issue and furthermore can lead to major traffic jams not only at the respective road junction but also in a wider radius around. Therefore, permanent monitoring of the operational state is standard in traffic control centres. In Düsseldorf the information of a traffic light breakdown is also used to generate an automated traffic message when the operational state is reported as “traffic light off” for more than 15 minutes. This delay allows a quality control by the operator. If he succeeds to reactivate the traffic light during that time span no message will be send out. If not, an automated traffic message will be generated that can be fine-tuned manually according to the current situation if required.

The withdrawal of the message is initiated automatically when the operating state changes or manually in case of permanent shutdown or permanent local operation without a connection to the central traffic computer. If the traffic lights are switched off due to major road works at an intersection that also trigger a general road works message, the respective automated message can be withdrawn by the operator.

Quality characteristics

The traffic light system’s switching state in the traffic control centre supplies real-time data with high reliability and accuracy as obligatory for technical systems with high relevance for road users’ safety and a high probability for heavy traffic obstructions.

Since the reactivation of broken down traffic lights can be done from the traffic control centre within a matter of minutes a delay of 15 minutes was included to prevent traffic messages about a short-time failure that is of no matter for the network capacity.

4.2. Tunnel barrier systems

Tunnel barriers provide their current switching state to the traffic control centre. The following example of Düsseldorf's Rheinalleetunnel illustrates the utilisation of this input for traffic information.

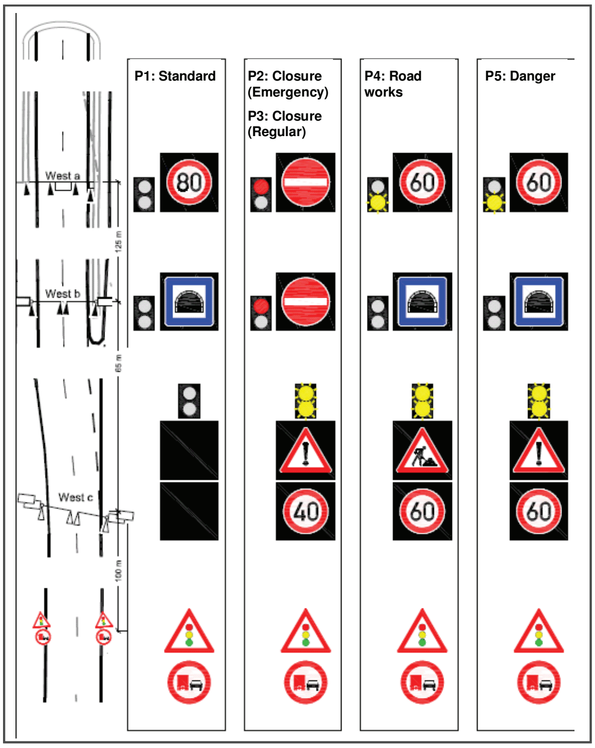

Fig. 7: Signalling programmes of tunnel barrier system at Rheinalleetunnel, west portal, inbound traffic

The tunnel barrier devices are connected to the traffic control centre using standardised light signal technology. Each switching state describes a particular signalling programme. These programmes are either activated automatically by the tunnel control centre or switched manually by the traffic operator. According to the activated signalling programme (cf. Fig. 7), both current traffic reports and alternative route strategies are triggered.

A tunnel closure due to an emergency (e.g. fire in tunnel) is achieved by switching the tunnel barrier device in program P2: emergency closure. Triggered by activating program P2 an automated traffic message about the tunnel closure is generated as shown in Fig. 8.

At the same time the tunnel closure triggers an alternative route strategy (cf. Fig. 9). This strategy activates two variable message signs (VMS) at junction Düsseldorf-Heerdt. They announce the tunnel closure and offer an alternative route. Furthermore, the capacity on the alternative route is maximised by switching the traffic lights along the route in their most powerful programmes.

Title: Closure with rerouting advices

District: Oberkassel

Address: Rheinalleetunnel

Message: Full closure of Rheinalleetunnel. Rerouting of destination Düsseldorf-Centre at junction Düsseldorf-Heerdt: Follow Brüsseler Str. (B7), Theodor-Heuss-Brücke and Kennedydamm.

Fig. 8: Traffic message in case of a closure with rerouting advices

Quality characteristics

The current tunnel barrier system's switching state in the traffic control centre can be seen as real-time data with high reliability and accuracy that is required for technical systems with high relevance for road users' safety. Delays in the automated process are a matter of one or two minutes due to electronic data processing.

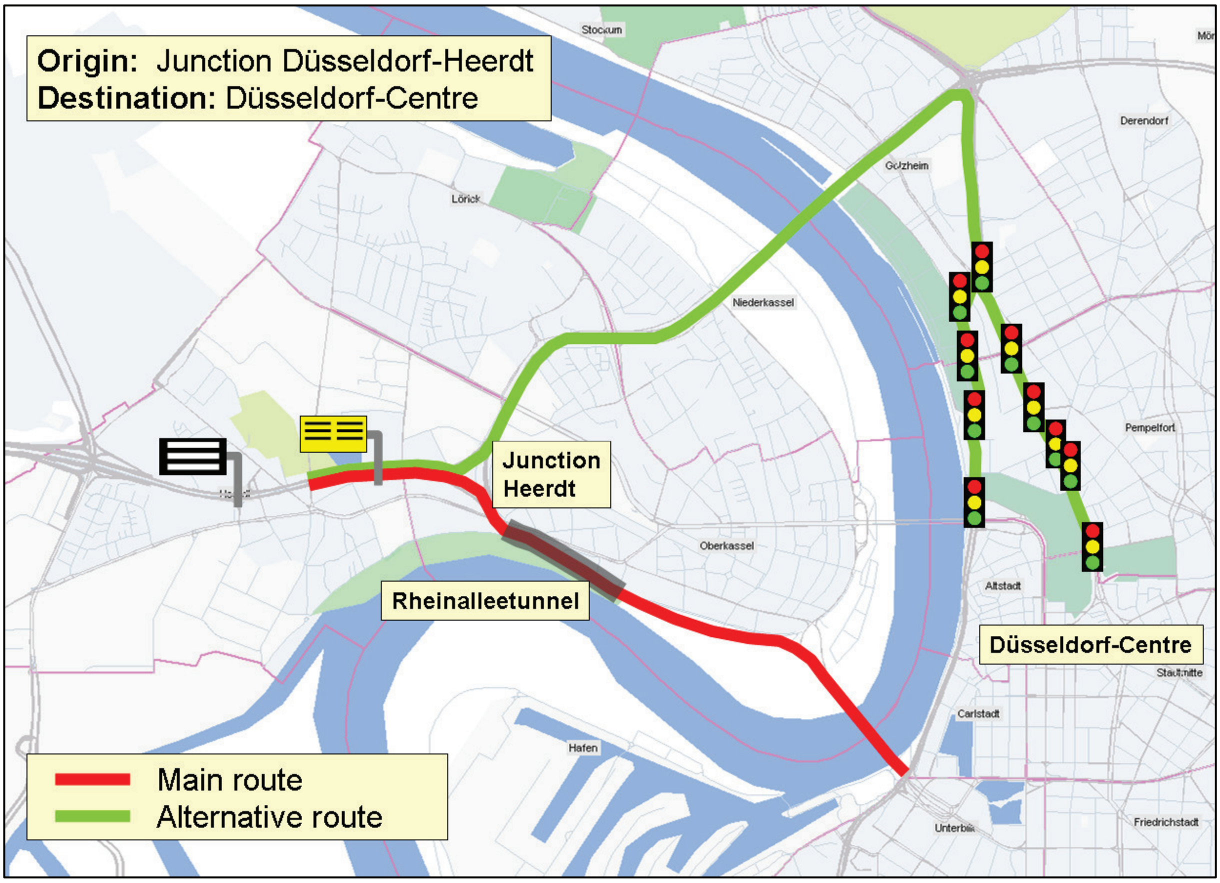

Fig. 9: Alternative route strategy for the closure of the inbound Rheinalleetunnel

4.3. Permanent lane signalling

Title:	Roger Waters - The Wall
Event Code:	(1501) Event
District:	Stockum
Address:	ESPRIT arena
Validity:	18.06.2011
Message:	Prior to Roger Waters - The Wall an increased traffic volume is expected in the area of the ESPRIT arena. Local public transport use is recommended. U78 provides a direct connection between Düsseldorf main station and the ESPRIT arena. Visitors, who can not use public transport, should use parking area P1.

Fig. 10: Preview traffic message announcing an event

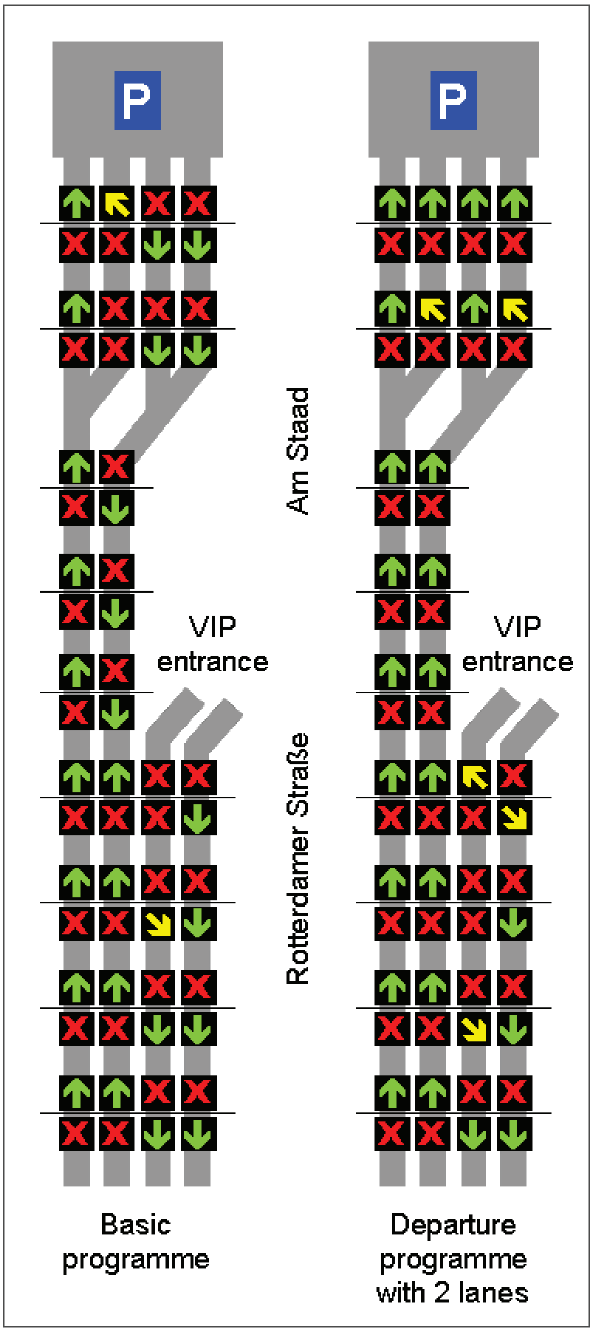

Fig. 11: Permanent lane signalling for departure

Systems for permanent lane signalling on access roads to large venues continuously report their current switching and operational states to the traffic control centre. From these states conclusions can be drawn on the restrictions due to the signalling state at the event's beginning (access signalling) and its ending (departure signalling). Information on traffic obstructions due to the current signalling state and heavy traffic can easily be used to generate reliable real-time traffic information.

This approach is illustrated in the example of a major event in Düsseldorf's ESPRIT arena. Major events and the expected heavy traffic are already announced in preview traffic reports (cf. Fig. 10). Based on the date and expected time of the beginning and end of the event the preview traffic information is generated several weeks in advance. Due to the preview character obviously no accurate real-time information about the current traffic conditions or traffic obstructions can be given.

More precise information on the current situation around a major event can be drawn from the switching states of the line signalling system. The traffic situation around the venue is closely monitored by police forces in situ. When heavy visitor traffic develops around the arena before and after a major event, they do request via telephone the traffic operator's manual switching of the appropriate access or exit programme. Based on confirmation of local police forces and own observation using traffic surveillance cameras the operator switches the lane signalling system back to the basic programme after the heavy traffic wears off.

Fig. 11 shows a simplified illustration of the signal lanes on the access road to the ESPRIT arena parking area. The *departure programme with 2 lanes* blocks the road Am Staad for all northbound traffic reserving two lanes for the departing southbound traffic. The respective switching state of the lane signalling system does serve as a reliable basis for automated traffic information that complements the rather general preview information (cf. Fig. 10) in an up-to-date and reliable manner (cf. Fig. 12).

Event Code:	(1501) Event (1854) traffic regulations have been changed (664) carriageway closed
District:	Stockum
Address:	ESPRIT arena
Message:	Due to the end of an event at ESPRIT arena all northbound traffic is blocked on Am Staad. The traffic routing on the Rotterdamer Straße is changed through the permanent lane signs. In the area trade fair/arena increased traffic volumes should be expected.

Fig. 12: Traffic message at end of event in ESPRIT arena

Quality characteristics

The current lane signalling system's switching state in the traffic control centre provides real-time data with high reliability and accuracy. Traffic information based on these states does reflect precisely the actual traffic situation and the currently available lanes as defined by the switching states. It is nevertheless a decision of experienced professionals in situ to give order to switch and switch back the lane signalling state. Delays in the process to send out automated information are a matter of a minute or two due to electronic data processing.

4.4. Traffic lights

For accurate traffic information referring to traffic obstructions in connection with major events lane signalling systems are not mandatory. When certain traffic light programmes in the neighbourhood of a venue are only used at the beginning or end of an event, reliable traffic information can also be based on the switching state of these traffic lights.

Event Code:	(1501) Event
District:	Oberbilk
Address:	Siegburger Straße
Message:	Due to the end of an event in Mitsubishi Electric HALLE increased traffic volumes should be expected on Siegburger Straße.

Fig. 13: Traffic message at end of event in Mitsubishi Electric Halle

Mitsubishi Electric Halle Düsseldorf offers a good example here. Based on a telephone request from the organiser at the end of an event the traffic operator manually switches a group of traffic lights to the exit programme for this venue. This programme prioritises the runoff from the parking area against the main road traffic causing traffic obstructions for the latter. Seeing that this signalling programme is only used at the end of an event with a high number of visitors leaving at the same time this programme is used as trigger for automated reliable real-time traffic information (cf. Fig. 13). The local situation is monitored by the organiser and the traffic operator using a traffic surveillance camera so that after the peak of the departing traffic the traffic lights can be switched back to the routine programme in real-time.

Quality characteristics

Traffic obstructions for the main road are caused by the signalling programme that is optimised for the visitors. The respective traffic lights' switching state can be seen as real-time data with high reliability and accuracy. It is nevertheless a decision of the organiser in situ and the traffic operator to switch and switch back the traffic light programmes. Delays in the process to send out automated information are a matter of one or two minutes due to electronic data processing.

4.5. Park Control System

Switching states of the parking management system offer two general types of real-time information.

Event Code:	(1501) Event
District:	Rath
Address:	Theodorstraße
Message:	Due to an event at the ISS Dome heavy traffic is expected around Theodorstraße. Visitors should follow the parking guidance system and instructions of the police. Currently parking lots P3 and P4 are open.

Fig. 14: Traffic message and parking information at ISS Dome

The parking guidance system offers the road users a highly accurate and reliable picture of where he can find a free parking space in the next minutes. It includes the current parking situation on parking garages, underground parking and temporary open event parking sites.

Furthermore, situation based parking guidance can be derived from the switching states of the parking guidance system. In Düsseldorf the opening states of parking sites and garages around the venue ISS Dome are planned to be passed to the traffic control centre. The larger the current traffic volume is, the more parking spaces are provided. According to the currently available parking areas the parking management system activates the appropriate feeding programme to guide the visitors. In addition, each feeding programme generates automated traffic information that offer real-time information on the current local traffic situation and guides the visitors to the currently available parking areas (cf. Fig. 14).

Quality characteristics

The current parking management system's switching state in the traffic control centre provides real-time data with high reliability and accuracy. It is the decision of the event organiser in situ to open and close parking areas as required. The electronic contacts at the gates allow the parking management system to react in real-time. Delays in the process to send out automated information are a matter of a minute or two due to electronic data processing.

5. Conclusions

The utilisation of operating and switching states of technical traffic installations can result in reliable and accurate real-time traffic information. Since the necessary data is in general available in the traffic control centre setting up the relevant detection and observation infrastructure to capture new data on complex traffic conditions is not required. It is simply a question of making use of the existing data and interpreting them accordingly in order to provide such high-quality traffic information.

Quality assurance of new or modified technical traffic installations is given by the usual technical acceptance tests. Automated traffic information based on data available from the traffic control centre requires further testing and approval before implementation. After implementation constant monitoring and fine tuning of the running routines is done by traffic engineers based on every day experience and feed back from operators and road users.

In Düsseldorf the described traffic information is currently provided in the internet (www.duesseldorf.de/verkehr) and to North Rhine-Westphalia’s traffic information centre (VIZ NRW) that distributes it to radio stations and private service providers and will also be distributed via the future national data warehouse *Mobilitätsdaten Marktplatz (MDM)*.

Quality Assessment of Travel Time Measurements at the Test Site Munich

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Abstract

In this paper the use of the automatic number plate recognition system for travel time measurement at the test site in Munich is illustrated and the methods how the quality of such a system can be assessed are shown. Various quality indicators for the manual analysis of the quality of number plate recognition as well as the automatic monitoring of the whole system are presented. Based on the expert knowledge obtained within the German research project *wiki,* it is described how these results can be integrated into the continuous monitoring approach within the quality monitoring concepts of the *Traffic IQ* research project.

1. Introduction

In order to be accepted, traffic information provided to the road user has to be reliable, up-to-date and, of course, in agreement with the real traffic situation it's related to. The traffic state, which serves as a basis for traffic management and traffic information, relies on traffic data, collected from different sources. To ensure a high quality level throughout the whole value chain, beginning with raw data collection and ending with the presentation to the road users, data quality must be assessed continuously.

Within the German research project *wiki*[7] funded by the German Federal Ministry of Economics and Technology (BMWi), a large set of traffic data was collected in a time span of about eight months in order to analyze route choice behavior of road users. The urban traffic state presented to road users via smartphones was calculated using travel times. To ensure the correct functionality of the system, the travel time calculation had to be monitored which will be described in this paper.

Section 2 presents the architecture of the underlying automatic number plate recognition (ANPR) system as well as a simple description of how travel time measurements can be performed. In section 3 the test site is described. The detailed quality assessment of the system as well as how travel time data is filtered in is

[7] *wiki*: „Wirkungen von individueller und kollektiver ontrip Verkehrsbeeinflussung auf den Verkehr in Ballungsräumen“ (effects of individual and collective ontrip measures to influence traffic on traffic in urban areas)

explained section 4. Section 5 gives an outlook on how the experiences gathered within the *wiki* project can affect the quality monitoring specification in the ongoing research project *Traffic IQ*[8]. The paper ends with a conclusion in section 6.

2. ANPR-based Travel Time System Description

For measuring the travel time that one vehicle needs to cover the distance of a selected route via stationary detection devices, its re-identification at a following measurement point is crucial. A so-called ANPR system uses number plate strings as unique vehicle identifiers that can be used for this purpose.

The identification of number plate strings itself is realized by using camera systems that consist of a standard video camera, an infrared camera and a corresponding light emitting LED array as well as an attached computer for image processing. The whole ANPR system can be mounted on gantries, bridges, traffic light poles or by the roadside to detect vehicles from front or behind.

By using the generated color image as well as the corresponding infrared image optical character recognition algorithms are able to determine the number plate strings of passing vehicles in real-time. Assuming optimal boundary conditions detection rates of 85%-95% are possible [Friedrich, 2008].

The overall system architecture is shown in Fig. 1. The camera systems are connected to a computer (measurement point sub-station) that collects data from the attached cameras and sends it – after processing – to the travel time server via GPRS. There, the data containing the timestamps, measurement point and camera IDs as well as the encrypted (according to data privacy issues) number plate strings – can be used to match data sets, i.e. to calculate corresponding route travel times by subtracting their corresponding timestamps (see section 4.3).

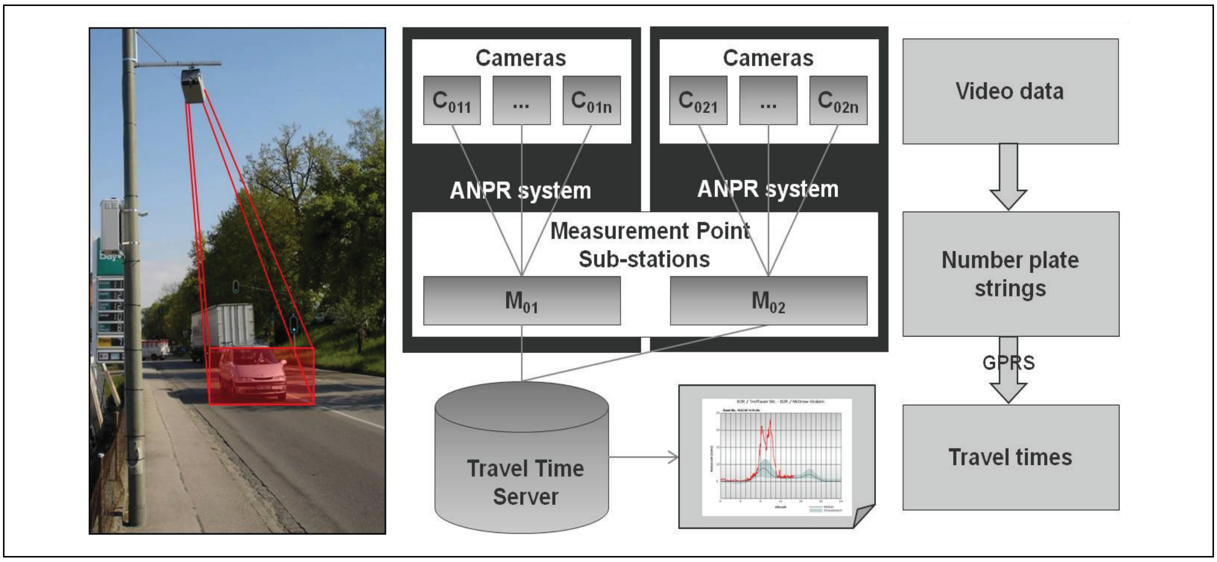

Fig. 1: Travel time measurement with ANPR systems

[8] Traffic IQ: “Informationsqualität im Verkehrswesen” (information quality in traffic engineering) Website: http://www.traffic-iq.de

3. Test Site Munich

In 2004, BMW started to install the first ANPR systems in Munich [Grüber, Röhr, 2007]. Four years later, within the research project *wiki* BMW and the South Bavarian Highway Authority (ABDS) extended the camera network. By now, the test site contains 51 cameras, installed at 22 different measurement points that detect passing vehicles from above (overhead detection). 28 cameras are installed at gantries on motorways. As can be seen in Fig. 2, the cameras are located in urban as well as in interurban areas along important in- and outbound routes.

Usually, a camera is installed to be able to detect vehicles driving on one single lane. Due to the fact that the ANPR systems are primarily used for measuring travel times a complete detection of measurement points is not realized at the test site yet.

Currently, travel time measurements which serve as a basis for traffic state analysis are possible for about 90 routes within the network shown. Travel times of vehicles are calculated for predefined routes between two successive measurement points per driving direction.

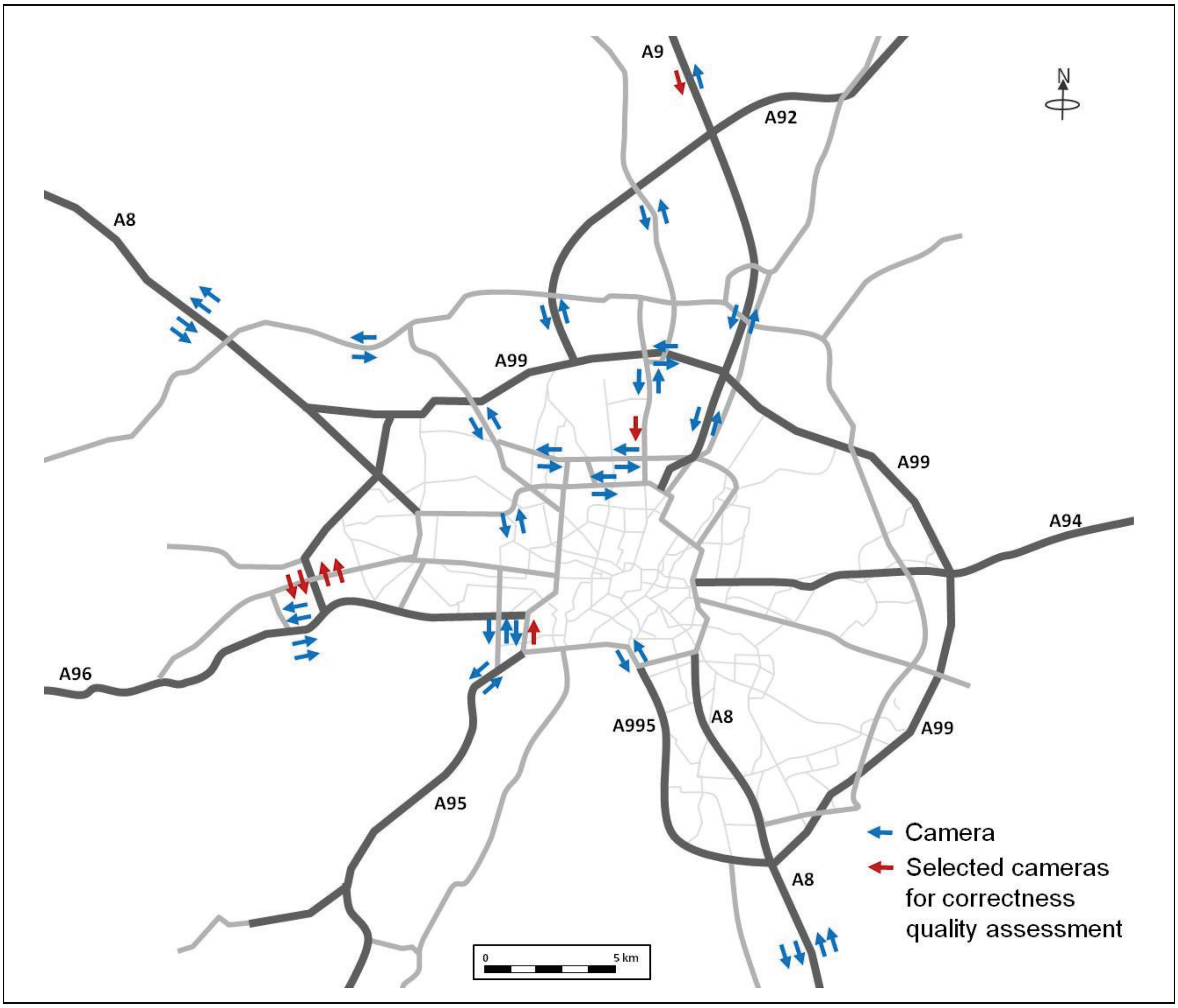

Fig. 2: Cameras of the test site Munich

4. Quality Assessment

The studies concerning route choice behavior that were carried out within the *wiki* project are based on a large set of data. In order to get reliable results a high quality level of raw as well as processed data has to be ensured. Moreover, the cameras' operational status was checked during data collection and traffic state evaluation. Therefore, various offline quality assessments in particular with regard to the indicators completeness and correctness were performed manually or semi-automatically.

4.1. Correctness

4.1.1. Definitions

Correctness was defined as the compliance of data with reality. With the assumption that cameras are installed as well as possible, detection rates are different because they are influenced by various limiting factors.

The following three indicators were established:

- Data recording rate
- Detection rate
- Successful detection rate

The *data recording rate* specifies the ratio of the number of data records received by the server to the number of passing vehicles. Whether the number plate string is successfully recognized is not relevant. A value of 100% indicates that the number of data records equals the number of passing vehicles. Multiple detection of a single number plate string would lead to a rate > 100%.

The *detection rate* is defined as the ratio of detected vehicles to the number of passing vehicles. It is important that a number plate of a passing vehicle is only read once. Whether the number plate string is successfully recognized is not relevant, too. A rate of 100% indicates that each number plate is detected once.

The *successful detection rate* specifies the ratio of successfully recognized number plates to the number of passing vehicles. A rate of 100% indicates that the camera detects correctly the number plates of all passing vehicles [Recker, 2008].

4.1.2. Analysis Results

This section shows the findings of the correctness analysis. Seven cameras installed in the urban areas and on motorways were selected for the investigations (see Fig. 2). The investigations were performed at normal weather conditions in the morning on weekdays.

One camera that is installed at a signalized intersection and detects vehicles stopping during red time has had a data recording rate of more than 100% [Recker, 2008]. This was caused by wind or problems in recognizing number plates.

The detection rate and the successful detection rate of this camera of more than 90% were also very high.

The data recording rate was equal the detection rate for a camera installed on a bridge. The successful detection rate of this camera was lower than at the other camera. This could be caused by the higher lane width in combination with lane changing vehicles because a detailed analysis of error causes showed that some detected number plates were only recognized partially [Recker, 2008].

The detailed investigation of two other cameras which detect right-hand lanes on a motorway showed that a small amount of multiple detection of one number plate can also appear on motorways. The detection rate and successful detection rate are also very high with these cameras. The successful detection rates are lower at cameras which detect only left-hand lanes of a motorway. Usually, this is due to higher speeds of the vehicles. In addition, the detection rate decreases in case of cameras installed at an angle that detect number plates of the opposite driving direction.

An investigation of the errors in recognizing number plates of all cameras showed that a single character was skipped in 37% to 74% of the cases. Another reason for errors is that only a portion of one number plate string is recognized in case of a wide lane in combination with lane changing vehicles. This was the case in 20% to 40% of the errors. Other error causes were characters recognized wrongly or an additional character read. Typically, these errors were caused by dirty or damaged number plates.

The above mentioned quality assessments concerning correctness have to be performed manually. Automation is difficult since the real situation must be taken into account.

4.2. **Completeness**

The *completeness* according to [FGSV, 2006] is defined as percentage of time intervals with current data related to a fixed duration.

Although the measurement point sub-stations of the investigated system buffer their data for two minutes, data is only sent when a number plate was detected within that time span. This poses a particular challenge for the completeness assessment for the situation where no data is sent within one of these fixed intervals. In this case, it is unknown if no number plates were detected, or if a processing or camera problem exists. Therefore, completeness of ANPR data was analyzed with plausibility checks.

The completeness of ANPR-data was checked with three different kinds of plausibility checks. One possibility is to compare the number of detected number plates with the number of vehicles detected by an inductive loop detector. Time series analysis gives a good overview of the ANPR system's operational status. A detailed analysis checks whether current data is sent to the server within the fixed time intervals.

4.2.1. Comparison with Inductive Loop Detector Data

In the case of an inductive loop detector that is located on the same lane close to the ANPR system, the number of detected number plate strings can be compared with the number of detected vehicles. Assuming a high-quality loop detector, the traffic count difference between detected number plates and detected vehicles gives information about the completeness of the ANPR data.

4.2.2. Time Series Analysis

The periodic determination of time series with data records per day turned out to be very useful to check the system's operational status. As can be seen in Fig. a breakdown of a camera is obvious because of the data gap. If all the cameras of a measurement point sub-station weren't sending any data, it was concluded that the computer or the GPRS-module of the measurement point sub-station had broken down or the power supply had been interrupted.

Furthermore, with time series analysis a decreasing detection rate of one camera can be identified. A decreasing amount of data records can, for example, be caused by rotation due to wind or pollution. In winter a low amount of data was sometimes caused by snow-covered number plates.

The analysis of decreasing detection rates can be facilitated by calculating arithmetic means. A meaningful arithmetic mean value can be calculated for weekdays in the week(s) directly after installation. Afterwards it can be compared with the arithmetic mean of data record volume sent by a camera per weekday. An increasing difference of the mean values can indicate a decreasing detection rate. However, holidays and vacations need also to be considered.

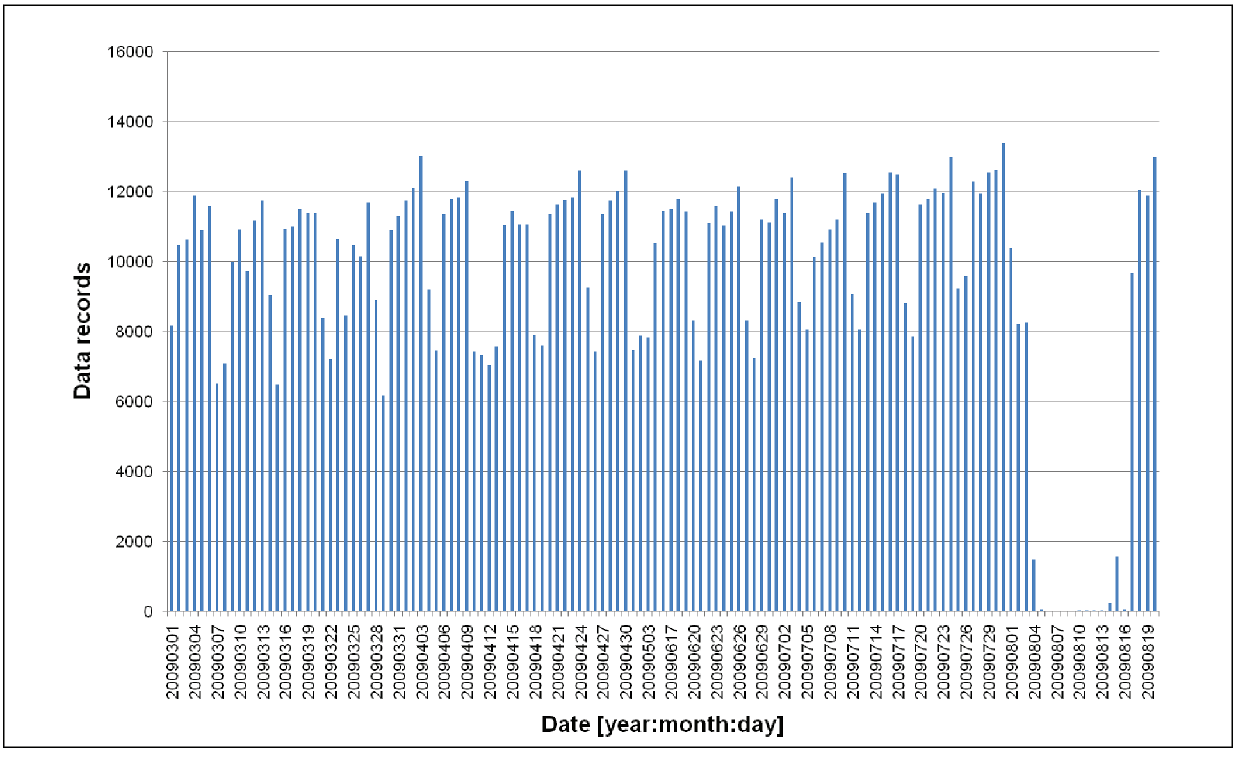

Fig. 3: Time series of a camera

4.2.3. Time Interval analysis

The data records were aggregated per camera and in intervals of 15 minutes in order to assess completeness in detail. These time intervals were chosen because the probability that no vehicle is present in the detected lane increases with smaller time intervals especially in left-hand lanes. Moreover, this check was only performed on weekdays between 7a.m. and 8p.m., excluding holidays because of minor traffic volume. Winter days with snowfall were also excluded from the analysis, because of minor detection rates due to snow-covered number plates.

4.3. Travel Time Measurement

To measure travel times, an encrypted number plate has to be identified at two successive measurement points. The difference of the detection time stamps equals the travel time of a single vehicle between the two measurement points. Assuming that the time stamps of detection are exact and globally synchronized, the resulting single vehicle travel time is of high accuracy. Nevertheless, not every single vehicle travel time should be used as representative for all vehicles as it might have behaved in a special way:

- Vehicles stopping en route due to non traffic reasons (shopping, making telephone calls etc.)
- Vehicles making detours or using other routes than the one to be examined
- Special vehicles with reduced maximum speeds (such as tractors, high load trucks etc.)
- Special vehicles with very high speeds (e.g. emergency vehicles)
- Vehicles exceeding speed limits

The single travel times of such vehicles have to be filtered out, before aggregating them.

There are several algorithms available that identify and eliminate outliers from the data. Those filtering algorithms may use statistical approaches or may analyze consecutive travel times in a serial way [Spangler, 2009].

Fig. shows the results of applying a serial filter to travel time data of an urban ring road in Munich. All the single vehicle travel times colored in yellow and orange are identified as outliers and are filtered out, whereas the grey dots remain as representative travel times. The data also shows a rise in travel times between 1 p.m. and 3 p.m., which is due to an incident. Of course, such information must not be filtered out.

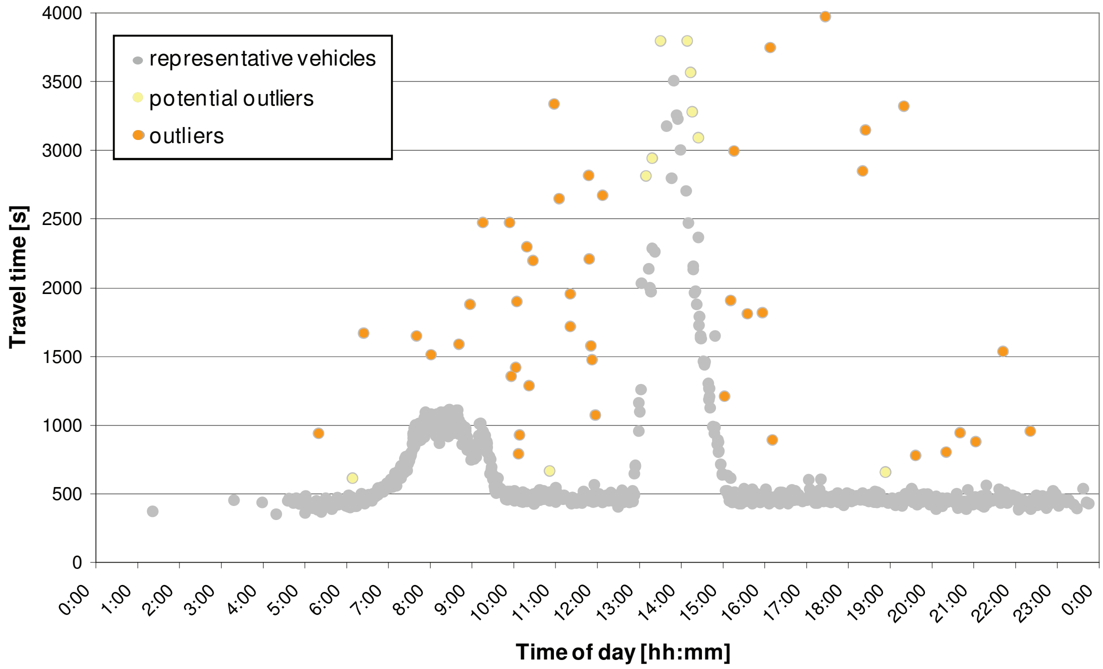

Fig. 4: Serial filter applied to travel time data on a ring road in Munich

After filtering the data, the travel times can be aggregated to 1- or 5-minute intervals and are ready to be interpreted for traffic state information.

5. Outlook

For the automation of the quality assessments that were performed manually or semi-automatically until now, the authors are developing so-called quality monitors within the ongoing research project *Traffic IQ*. These monitors will integrate and pursue the experiences and practical results of the *wiki* project as well as these of the research projects *Benchmarking* [BASt, 2006] and *Aktiv* [Lüßmann, 2011].

By using these monitors the data collected and processed by the ANPR system on the interurban highways of the test site can be checked along the whole value chain in real-time as well as backdated based on selected quality criteria.

The following three types of monitors [Ruhren, 2011] each having different foci within the value chain are specified for the system to calculate travel times by using ANPR systems:

- Device monitor
- Data monitor
- Plausibility monitor

The device monitor is used to check the quality and correct behavior of the (attached) hardware devices including cameras and measurement points. It checks if vehicles and related number plate information are identified by the cameras and if data is recorded and transmitted periodically to the travel time server for further processing.

The data monitor examines in detail the content of the transmitted data. It is primarily based on a knowledge base that contains historic data values and continuously adjusted time variation curves classified by day types. Consequently, different thresholding techniques and error benchmark algorithms allow for in-depth quality assessment.

Finally, the plausibility monitor provides algorithms to extend the functionality of the data monitor to use traffic data from other sources, e. g. inductive loop detector or environmental data, to reveal possible inconsistencies and calculate confidence indices for the different measurements.

To assess the quality within these monitors in detail and for being able to describe the quality of the whole system four meaningful quality indicators were identified:

- Availability
- Currentness
- Completeness
- Correctness

The *availability* specifies the degree of availability of information at a fixed point in time at fixed location [Wiltschko, 2001]. By using a fixed set of percentiles periods of latency are used to describe whether and when information is available for further processing.

The currentness is used to measure the degree of compliance of information with the temporally changing conceptional reality [Wiltschko, 2001]. This is realized by inspecting the delay that consists of three time fractions (aggregation, processing and intrinsic time fraction).

The *completeness* measures the degree of information that is needed to describe the reality in total [Wiltschko, 2001].

The *correctness* gives the degree of compliance of information with the reality assuming that the data is provided in time [Wiltschko, 2001]. Within the *Traffic IQ* project it is defined as the probability of reaching the metric accuracy.

With these quality indicators the quality level of the ANPR system can be assessed altogether.

6. Conclusion

In this paper the authors illustrated the use of the ANPR test site in Munich for travel time measurement and showed how the quality of such a system can be assessed. The detection rates of the ANPR system strongly depend on the camera installation parameters (vehicle speeds, detection angle, lane width and lane change behavior etc.). The higher the detections rates, the higher the validity of the calculated travel times can be.

It's indicated that there are quality indicators that can be analyzed during system installation and operation trials (ex ante analysis) and (global) indicators that are mainly applicable while operation.

The checks while operation can be performed automatically which is the aim of the *Traffic IQ* project. By performing quality checks automatically a continuous evaluation of the system's quality is possible.

Acknowledgements

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Supervising the quality of published traffic information

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Abstract

Increasing extent and complexity of measured and processed traffic data, the use of new technologies and the steadily growing demand for detailed and precise traffic information drive highway authorities and traffic information providers to expand and to improve the range of offered information. The result is that the quality of the published traffic information has to meet higher demands, too. In the following chapters an approach is described to establish a continuous monitoring system for provided traffic information (primarily regarding refined traffic data like level of service information). The description of approved system structures and some representative examples give insight into a recently concluded project.

Notice

All charts shown in this publication are based on data which was either modified substantially or generated in experimental setups. The charts reproduce facts observed during operating experiences.

1. Introduction

Timeliness and accuracy are essential parameters which should be observed well when you publish information and data. The dissemination of incomprehensible, outdated or even incorrect information may cause a significant loss of reputation and can lead to economic damage to the provider. For this reason, a regular review of published data is particularly important.

Together with ASFINAG, owner and operator of the Austrian motorway and expressway network, our company implemented a prototype to continuously monitor and ensure the quality of dynamic (constantly changing) traffic information. This action seeks to identify apparent inconsistencies and errors in the published information and therefore to enable actions to solve these problems. At the beginning of the operation no guidelines regarding the problems or the surveys existed. For this reason an approach to detect inconsistencies and errors had to be found.

2. Proceedings

In the above-mentioned project, measurements (traffic volume and speed from induction loops), traffic data (Level Of Service, LOS) and traffic information messages (TMC) were studied from different sources. The data were provided by the traffic information centre (VIZ) in 5-minute intervals. The quality monitoring system has taken over the data and processed immediately upon receipt. Tests were carried out

continuously. In addition, further reports were conducted on a daily, weekly and monthly basis. In this way, medium-and long-term effects were also studied. The results of the treatment and the tests were provided in the form of tables and charts on a web portal. In addition, selected results were forwarded to a fault management system.
As already mentioned, the scope of inspection was not clearly defined at the beginning because there was no concrete evidence of substantive problems with the published data. The challenge was therefore to develop appropriate methods to detect errors not known so far. The data included measurements from more than 1000 sensors and more than 2000 traffic segments (LOS segments) – updated in 5-minute intervals (288 times per day). Taking this amount of data into account a detailed examination of each individual value seemed not suitable. Procedures had to be developed, which could check many information at the same time.
Another task was to exclude systematic failures by the development and execution of simple tests to ensure that the data affected were not further investigated.

2.1. Data-Warehouse

To store the provided data a very compact and for the use optimized data warehouse was set up. This allowed the implementation of independent processes to import new data, execute different test and output results of numerous reports and charts. These processes were carried out in a fixed sequence.
An advantage of this architecture was that the creation of new tables and charts was associated with less work. Numerous variants were tested and compared to find the optimal representation. To make the processed data and results for users available a Web server was set up, so that an easy access to current and archived reports and charts was enabled.

2.2. Graphical representation

The graphical presentation of data is one of the most effective and powerful tools to detect inconsistencies in larger amounts of data. Using appropriate representations, amounts, conditions and trends are visualized and outliers are identified quickly. Following are some examples of charts which delivered helpful consolidated findings during the examination and monitoring of different data.

2.2.1. Representing configuration data

The following example illustrates that consistent quality monitoring can begin with the questioning of configuration data. In the present case, the underlying road network for calculating traffic data (LOS) was supplied by a list of sections (LOS segments).
For each section, the street number and the serial kilometer from the beginning and end of each LOS segment were deposited. The following chart shows the total length of each road in comparison to the sum of the assigned LOS segments lengths.

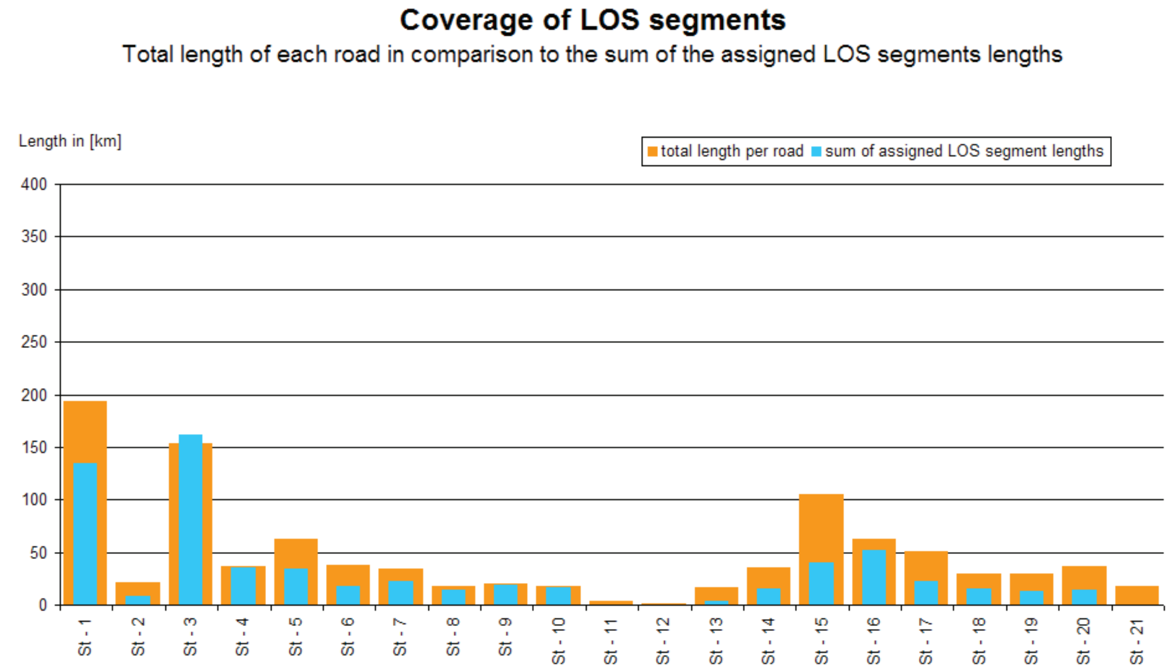

Fig. 1: Total length of each road in comparison to the sum of the assigned LOS segments lengths

In this chart, the coverage of the underlying road network with LOS segments is displayed (apparently not all roads are covered to a 100% degree). Also a supply error is visible: in the case of road St 3 is the sum of all LOS segments is larger than the total length of the road.
Another chart shows the average length of the LOS segments. This representation was not used to examine acute disorders and problems but the lengths of the LOS segments give (at least in this case) conclusion on the average distances of sensors and in the further consequence on the accuracy of the determined traffic situation.

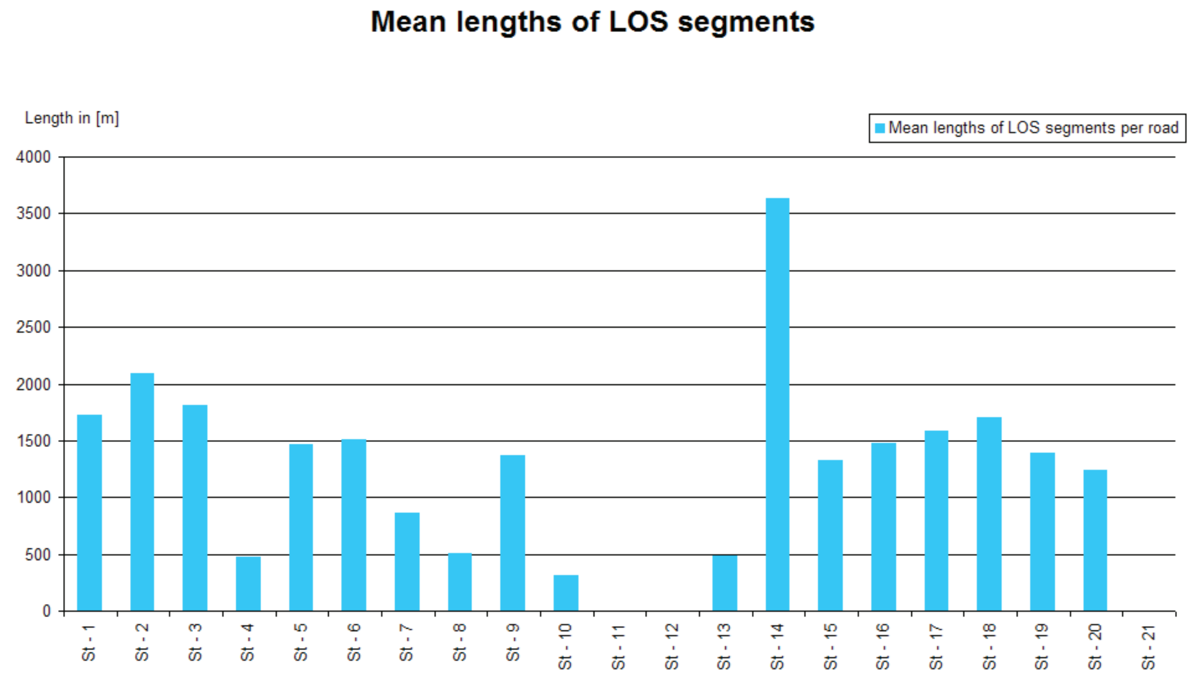

Fig. 2: Mean lengths of LOS segments per road

2.2.2. Chronological approach

A variety of evidence could be obtained from charts, which represent one or more information over time. The advantage of such representations is that large amount of data can be displayed simultaneously. It also allows the enhancement of discontinuities and irregularities.
The following chart shows LOS values over a period of one day (with an update interval of 5 minutes). Specific at this presentation is that all LOS values (obtained from more than 2000 LOS segments – that means more than 500.000 individual values) are displayed and grouped by each level:

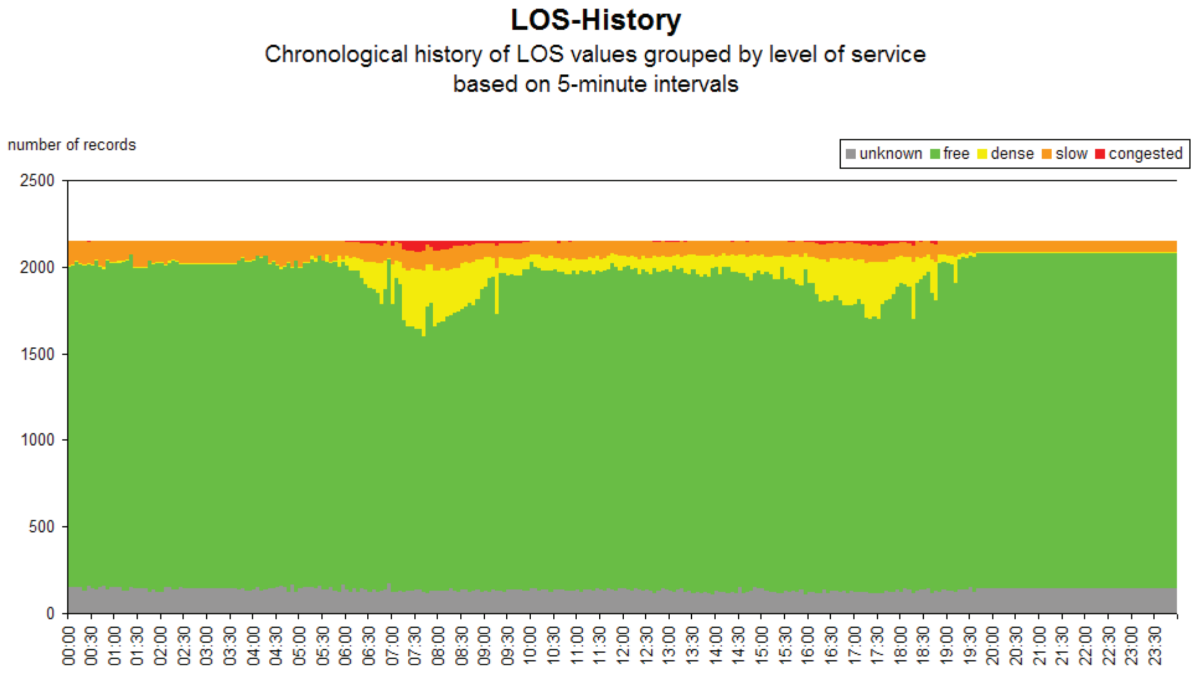

Fig. 3: Chronological history of LOS values grouped by level of service

Clearly visible in this chart is the increase in dense traffic in the morning hours (between 6 – 10 am) and in the afternoon (between 4 - 7 pm). In addition, there are a few traffic jams during this period. Striking is the almost constant proportion of slow-moving traffic throughout the day. This may be an indication of incorrect parameterized traffic detection or traffic situation calculations for example on motorway entrances and exits.
The chart also provides hints on system faults as a reasonably steady but not 100% constant progress can be expected but is not observed at all times. To address this issue further, an additional chart was prepared (Fig. 4). It contains the differences between LOS timestamps (the last change of each LOS value) and the time of data preparation. Again the data is displayed chronologically over a period of one day, to enable a direct comparison with the last chart. Moreover, the differences were classified (see legend) which supports an appropriate grouping and coloring of the data.
Notice: The chart shown below is based on the same data that were used to create Fig. 3.

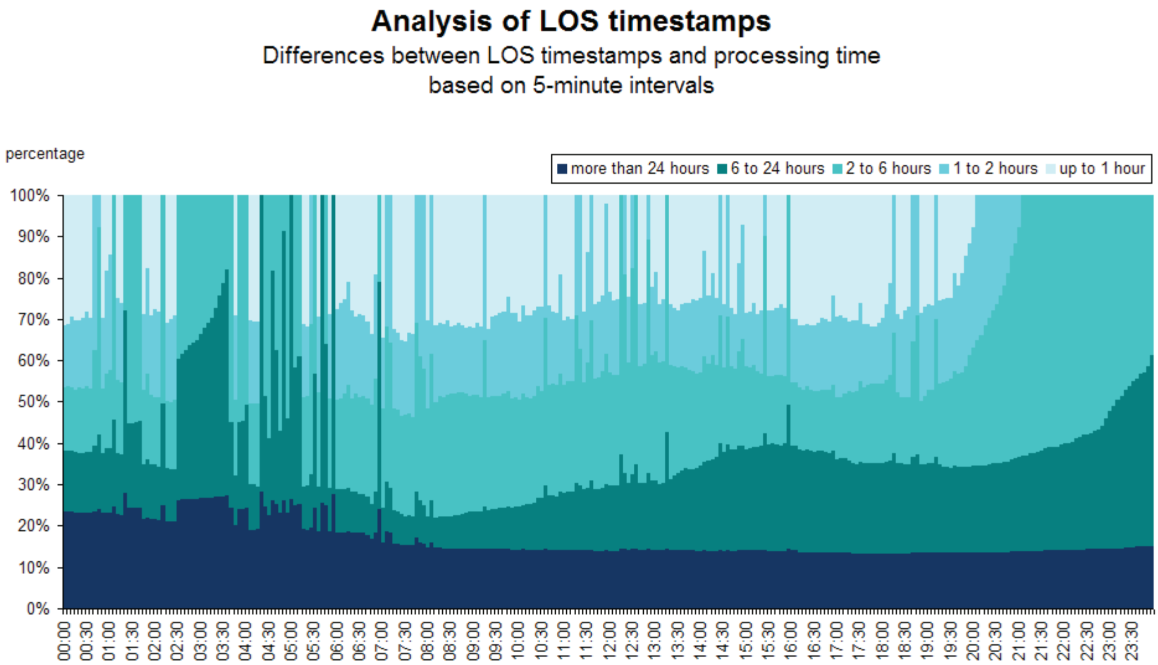

Fig. 4: Differences between LOS timestamps and processing time during one day

The above-mentioned discontinuities are even more evident in this graph. Vertical lines indicate a singular delivery of outdated data (at the time of data delivery, all processed data is older than one hour). The continuous increase of dark areas marks the beginning of a system failure (no update of data over a longer time). Without a graphical support these problems would probably not have been discovered.

2.3. **Continuous monitoring**

It is not unusual to have detailed analysis of specific problem situations being triggered in the context of an interpretation of graphically prepared data (similar to Chapter 2.2). This helps to identify and eliminate common disorders. For continuous quality monitoring, it is also important to find metrics and characteristics that indicate potential problems or in the opposite case assure the correct function of certain systems. The calculation of characteristics is needed to enable a translation from quantitative to qualitative information. The characteristics and indicators must be calculated and monitored continuously.
In the present case the existence of the Data-Warehouse helped a lot to calculate the needed characteristics, since all needed information was stored within the same system. In some cases, specific aggregations (sums, averages, maximum values, etc.) had to be calculated. However the development of complex metrics and algorithms was not necessary in this context. This allowed a relatively lean implementation.

2.4. **Message creation and transmission**

If characteristics and indicators are provided, the generation of messages is usually quite easy. These messages (qualitative information) can then be forwarded to a monitoring system (in some cases the translation from quantitative to qualitative information can also per performed by the monitoring system so that forwarding the characteristics is sufficient). In our case the messages were transmitted via SNMP (a network protocol which is usually used to monitor computer hardware). In addition, the current and historical reports were provided on a Web page.

3. Conclusion

The extent of measured and processed traffic data and related information is steadily increasing while the use of new technologies and new processes allows more complex applications. Motivated by the increasing demand of detailed and precise information (as a result of the information age) highway authorities and traffic information providers have to constantly expand and improve the range of offered information. The publication of data which until now was used mainly to control and monitor traffic systems plays an increasingly important role. It should be noted that the dissemination of false information may have unpleasant implications for the provider. Therefore, a continuous quality monitoring of provided traffic information is inevitable.

The presented methods and examples of specific test cases are not sufficient to implement a comprehensive system covering all aspects for monitoring the quality of published traffic information. The extent and complexity of the matter should not be underestimated. However the presented approach (building a Data-Warehouse, graphical representation, continuous monitoring up to Message creation and transmission) has been proven and is followed up by further development beyond a prototype phase.

For ASFINAG the developed prototype was in use over a period of 2 ½ years. To our knowledge, the developed metrics and procedures will be re-implemented to establish a system that will systematically monitor various aspects of traffic information quality.

Quality of Traffic Messages
- The Austrian A12 Example -

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Abstract

ASFINAG is operating about 2.175 km motorways in Austria. On most of the motorways an area wide traffic data collection is implemented. Furthermore, ASFINAG is currently operating 14 line control and traffic management systems in high density areas. As a result of the cooperation between ASFINAG and ORF (the Austrian public broadcaster) this content is additionally available for traffic information. The content of the TMC^{plus} service is generated by the traffic editorial office of ORF based on notices from the police and rescue services, from more than 16.000 registered drivers, from the traffic data collection and from the maintenance staff of the Austrian roads. In order to provide optimized information quality to the TMC^{plus} customers, ASFINAG has installed a system for systematic evaluation of these traffic messages. The objective is to monitor and analyze the TMC^{plus} traffic message quality of the entire Austrian motorway and expressway network, on a daily basis. The fully automated system reconstructs the real traffic situation (based on detector data and/or on travel time data from toll system) and analyzes the broadcasted messages. A first test series was carried out for a single motorway to assess the quality of traffic information reporting. The so called “QKZ-method” was therefore applied. Two indices QKZ_1 (spatial-temporal false alarm rate) and QKZ_2 (spatial-temporal detection rate) are defined to describe quality. This process, which is derived from the area of signal detection theory, offers the possibility of continuously measuring the quality with which traffic information is reported and comparing traffic information services objectively.

1. Introduction

Most drivers are familiar and have experiences, both positive and negative, with radio traffic information messages. Radio is regarded as having been the only source of up-to-date traffic information in previous years. However, modern communication and information technology as well as ever-increasing traffic problems have led to major changes in the traffic information market.

In addition to handling audio messages delivered by radio, navigation devices or navigation software on smart phones now possess alternative means of processing up-to-date traffic information. The information is first transmitted to the device in encoded form via a data channel (e.g., TMC=Traffic Message Channel) and is then automatically processed for dynamic navigation. The information can also be displayed as a text message or on a map, which allows drivers the freedom to decide for themselves the information's relevancy and its effect on their choice of route.

Irrespective of the type of traffic information used, the actual benefit obtained depends on the information's quality, which is a decisive factor in determining the economic potential of a traffic information service. The free market in general works to everybody's advantage when the user is able to evaluate a purchase based on its cost/benefit ratio. In this instance, apart from visible characteristics, an individual is rarely able to assess for himself the qualities of a dynamic traffic information service that is relevant to his needs, especially prior to purchase. Relying on the reputation of the ultimate supplier does not help solve the problem. Objective quality assessment is therefore just as relevant for traffic information services as it is for traditional automobile features such as fuel consumption and engine torques.

Objective assessment criteria already play a role with traffic information suppliers. Quality, however, was defined predominantly in terms of quantitative or technical characteristics that relate almost exclusively to the broadcasting of the information. Although this ensures minimum standards for the supply of traffic information to the customer in terms of time and space, e.g. field strength, coverage as a proportion of the overall road network etc., it does not pay enough attention to the traffic messages content and conformity with the actual situation experienced by the individual. Accuracy of content however is a decisive factor in customer satisfaction and acceptance.

Given these problems, this paper presents the results of a system that is currently installed in Austria to measure the quality of traffic messages and numerical results of a first field trial are presented. The applied method allows not only the assessment of an overall system but also of individual components' contributions of the system [BOGENBERGER, KATES, 2003].

2. The QKZ-Method

2.1. Reconstruction of the real traffic situation (ground truth)

Assessment of the traffic information messages' objective quality is based on reconstructing the actual traffic situation. The goal is to simulate as realistically as possible the actual situation experienced by the driver. Numerical traffic data, which should, if possible, be gathered independently of the data used to generate the traffic information, form the basis of the actual traffic situation's reproduction. There are various ways of doing this: e.g. numerical interpolation methods or filtering methods [TREIBER, HELBING; 2002], traffic flow simulations, ASDA/FOTO [KERNER, REHBORN, ET AL.; 2000] etc.

Because data acquisition in the selected test area is quite good (detector data and/or travel times), an anisotropic interpolation method (ASM=adaptive smoothing method) for a space-time speed field was chosen (see Figure 21). The ASM gives a realistic picture of the actual situation, and the transitions between different traffic conditions are accurately represented in terms of their time-space relationship.

Based on measurements of speed and/or calculated speeds out of travel time data, means are calculated for homogeneous sections of the freeway. Means are calculated in order to produce a smoothing effect within the data to prevent individual driving maneuvers from having too large of an effect on the overall analysis. These measurements are ordered into a matrix according to their spatial and temporal sequence. The cells of the time/distance matrix are then colored. Numerical anisotropic interpolation between the elements or colors gives a very intuitive representation of the actual traffic situation for a selected time on a given section of road.

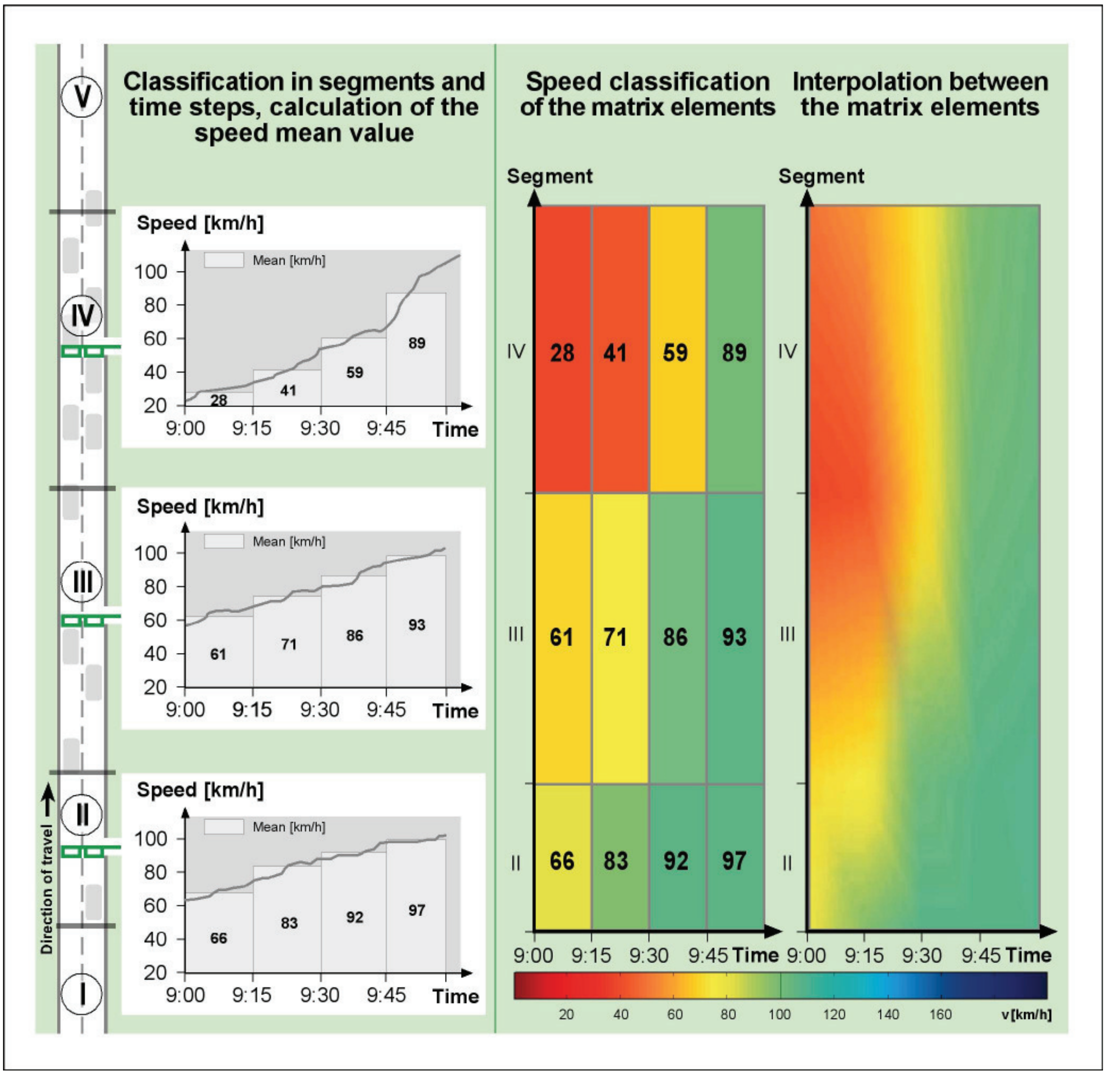

Fig. 1: Reconstruction of the actual traffic situation

2.2. **Quality Indicators**

In the reconstructed representation of the traffic situation with its distance and time axes, it is possible to identify and classify traffic conditions. There are various ways of doing this:

- A clearly delimited area can be calculated for a given level and associated with a particular traffic situation. A space-time region, in which the speed is less than 50 km/h, can be categorized as "congestion"(see Figure 2). According to the German HCM [Handbuch für die Bemessung von Straßenverkehrsanlagen (FORSCHUNGSGESELLSCHAFT FÜR STRASSEN- UND VERKEHRSWESEN; 2001)], this corresponds to quality grade F. This method is used below to derive the quality indices.

- It is of course also possible to determine additional areas for different levels or traffic situations, e.g. "congestion", "synchronized traffic", etc. and to represent them on the diagram. This is a worthwhile means of checking the generation and classification of traffic messages from content providers. However, studies have shown that drivers value traffic messages that are accurate in time and space much more than accurate in the definition of the problem (congestion, slow-moving traffic).

- Apart from clearly defined categorization of traffic situations, it is of course also possible to employ "fuzzy" classification methods. These allow traffic situations to be distinguished in a very intuitive and logical way. However, they make the process of determining quality indices somewhat more complex.

In this graphical representation of the traffic situation, congestion – defined as speeds below 50 km/h – can be represented as a surface, and its limits and areas can be calculated easily by conventional mathematical methods. The congested area is designated as an event and is abbreviated to E below.

Reconstruction of the actual traffic situation forms the basis for calculating the quality of the individual process for producing traffic information messages and the overall output. The quality indices for the overall process' outcome, namely the traffic information message in the vehicle, are derived below. The quality of the individual processes of the traffic message chain is calculated in analogous fashion and an example is given in the following Section.

A traffic report has a temporal aspect and a spatial aspect. The time reference comes from the time at which this traffic message is broadcast (see Figure 2). If the traffic messages are broadcast in encoded form, the driver's terminal can receive them more or less continuously. Only the messages broadcast continuously will be analyzed below. These messages are the most relevant for navigation devices and appear also to be the most interesting for the market situation between public and private providers. The resulting area (A) for the traffic message can thus be entered accurately in the time-space representation of the traffic situation.

The congestion event E and the report area A can be unambiguously associated with each other, and the quality of traffic messages can be objectively assessed. The intersection area of E and A is referred to as D. Here the congestion event and the traffic report match exactly in terms of both space and time. Two indices QKZ_1 and QKZ_2 are defined to describe quality. These are obtained from the relations of the different areas for the event E, the report A and their intersection D.

$$QKZ_1 = D/E$$

Quality index one (QKZ_1), the detection rate, describes the degree to which the traffic message coincides with the actual congestion event and is calculated from the ratio of the area of the intersection (between the congestion and the message) to the area of the congestion event.

$$QKZ_2 = 1 - (D/A)$$

Quality index two (QKZ_2), the false alarm rate, describes the proportion of the traffic message that is not relevant to the congestion, i.e. the proportion of the area of the message that lies outside the congestion area. This index is calculated by subtracting the ratio of the intersection to the area of the message from 1.

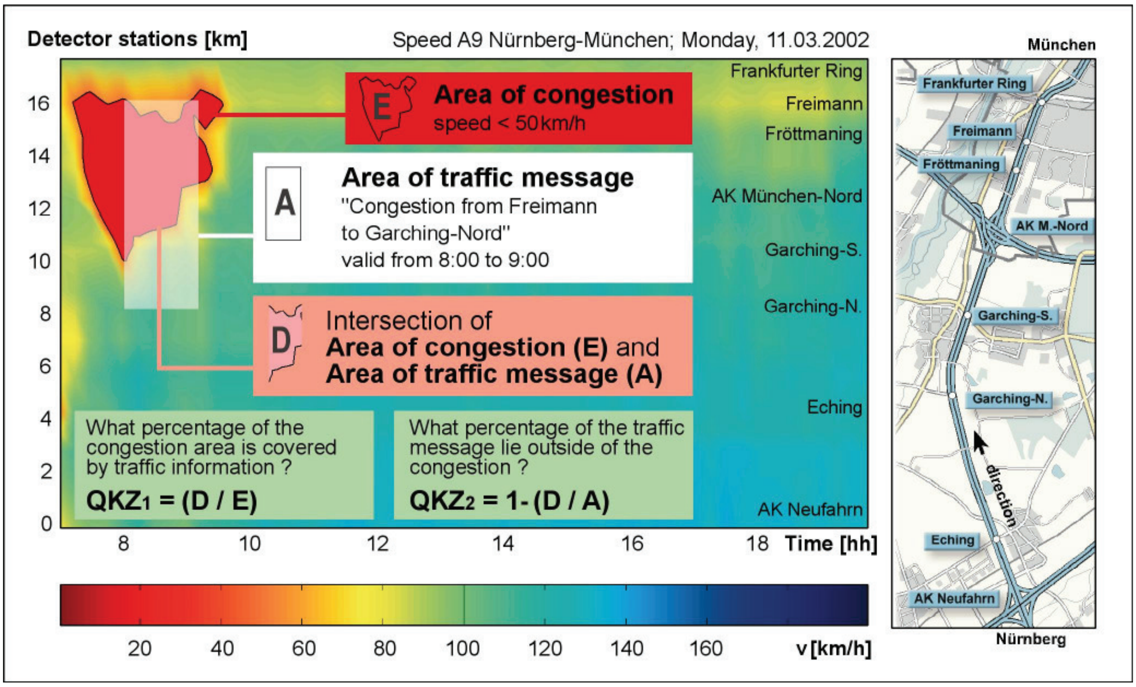

Fig. 2: Quality indices QKZ1 and QKZ2

The two indices are solid means of assessing the quality level of traffic information on the basis of objective data. When quality index one is high and quality index two is low, the quality of reporting is high. The values of quality index one and quality index two can each vary from 0 to 1 or from 0% to 100%.

To make the two-dimensional description of quality easier to interpret, categorization from A (very good) to F (poor) in a similar manner to the HBS system can be implemented. To do this, the two indices are entered on a QKZ_2-QKZ_1 diagram. The proposed quality grades from A to F are likewise entered and an unambiguous classification is obtained for each message (see Figure 4). The quality grades A, B, C, D, E and F appear as concentric ring segments. The quality grading and its extreme values will be explained below by distinguishing between different cases.

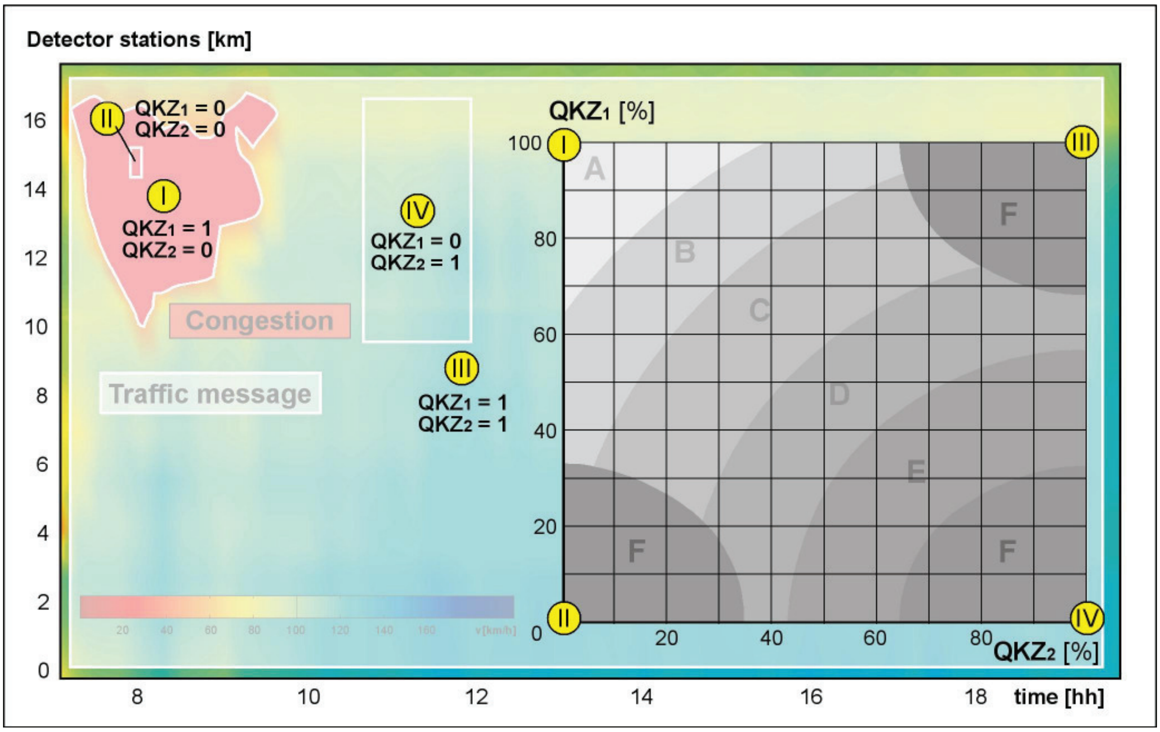

Fig. 3: Quality diagram and representation of the extreme values

Case I

- The area of the congestion event E and traffic information message A are identical. The intersection D is thus the same as E and A and QKZ_1 is 1 or 100%. None of the area of the traffic information message lies outside the congestion area thus QKZ_2 is 0. This traffic information represents the positive extreme of quality and lies at the optimum point of quality grade A in the quality diagram.

Case II

- The traffic information message is infinitesimally small ($A \rightarrow 0$) but is within the congestion event E. The intersection area D thus approaches 0. QKZ_1 and QKZ_2 are thus 0. There is virtually no traffic information pertaining to the congestion event for the driver. This is one of the three qualitatively negative extreme values and lies at the origin of the quality diagram, being categorized as grade F.

- The congestion area is very large and E thus approaches infinity. However, the traffic report indicates much too small a space and time zone for the congestion. D is thus 0 and the two quality indices are thus likewise 0.

Case III

- The traffic information message is infinitely large ($A \rightarrow \infty$). A traffic information message is broadcast all day for an entire freeway, for example (0.00-24.00: "A9 congestion between Nuremberg and Munich"). However, the congestion area is much smaller in terms of space and time. The intersection between E and D is equal to E. QKZ_1 is thus 1. However, since A is very large, QKZ_2 is also 1. The overall quality grade obtained is F, which is in the top right-hand corner of the quality diagram.

- The congestion area is infinitesimally small ($E \rightarrow 0$). D is the same as E and QKZ_1 is thus 1. Since virtually the entire message area (a) is outside the congestion area, QKZ_2 is likewise 1

Case IV

- The third of the negative extreme quality values is obtained when the congestion area (E) and the traffic information message (A) do not match in area D (D = 0). The driver obtains a “phantom” message of congestion for a traffic jam that does not actually exist. On the other hand, he does not obtain a message about real congestion into which he is actually driving. QKZ_1 is 0, while QKZ_2 is 100% irrelevant to the congestion. The quality of such a traffic information message is described by the quality grade F.

3. Test Site and Evaluation Results

The test site for a first quality evaluation study of the ASFINAG traffic messages (TMC[plus]) is the A12 between the border crossing “Kiefersfelden” and “Zams”. Half way it passes Innsbruck. The test side has a total length of 145 km. The motorway test site has 29 on- and off-ramps. It is a very heavy loaded freeway with lots of tourist traffic since it connects northern Europe with Italy.

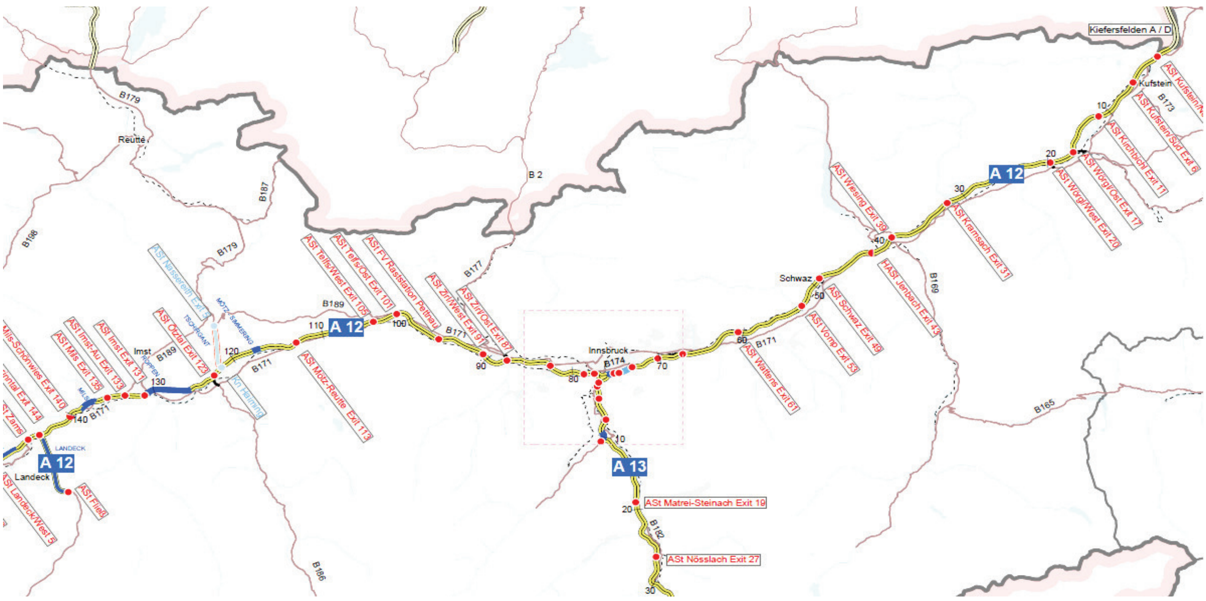

Fig. 4: Test side A12 Kiefersfelden → Zams

As an example it is shown the 2.1.2011 (Sunday) on the motorway A 12. It was a day with heavy holiday traffic. The following contour-plot (see Figure 5) shows a congested situation between 11am and 8pm. The congestion was between intersection “Wörgl” and “Wiesing/Achensee”.

The first traffic messages started at about 13:30. This was the time when the congestion was increasing. The message ends at about 20:15.

So most of the congestion was covered by a traffic message and only small pieces of the messages occurred on times without congestion.

Evaluated with the method as described above it means, that the QKZ_1 quality indicator is 0.72. That means that 72% of all congested situations where covered by a traffic message. The QKZ_2 quality indicator is only 0.18, which means that only 18% of the congestion message matched a situation with free traffic flow.

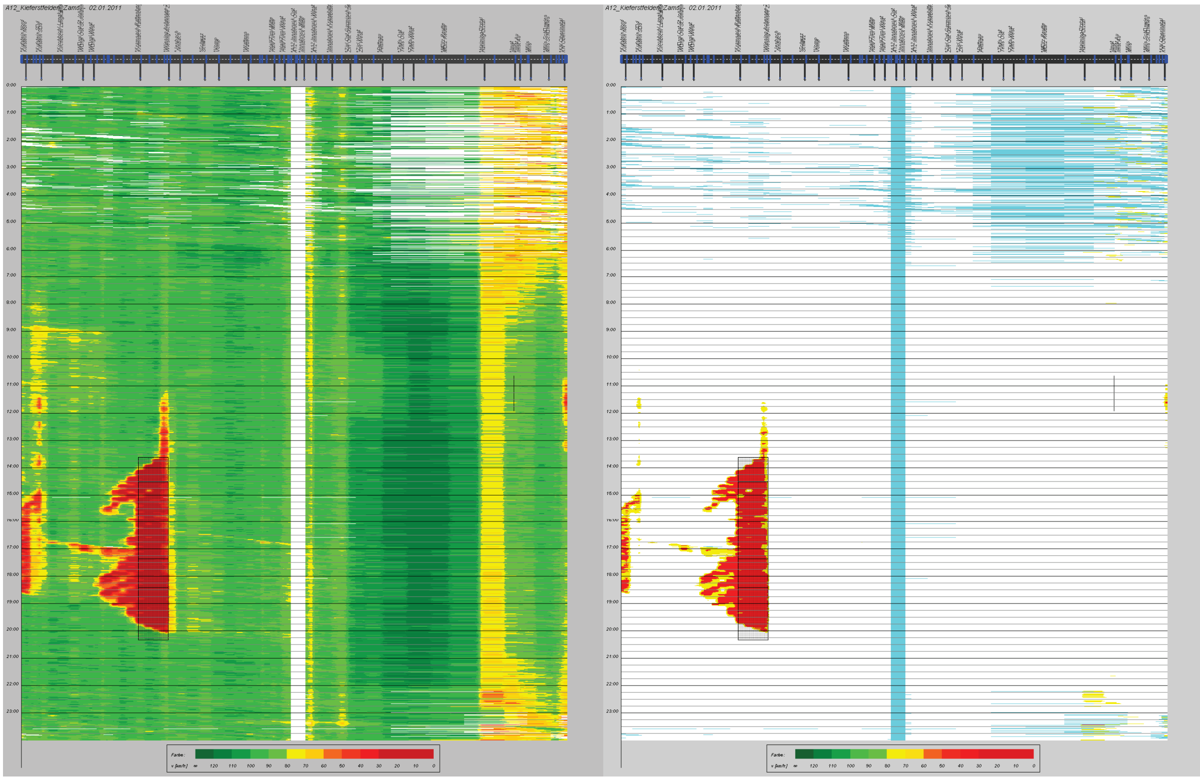

Fig. 5: Left: contour plot with messages – right: reduced contour plot with traffic states stationary and queuing traffic and messages (02.01.2011)

The overall performance of the messages was B, which means that the drivers were mostly very well informed about the current traffic situation on the A12 by the TMC^{plus} messages.

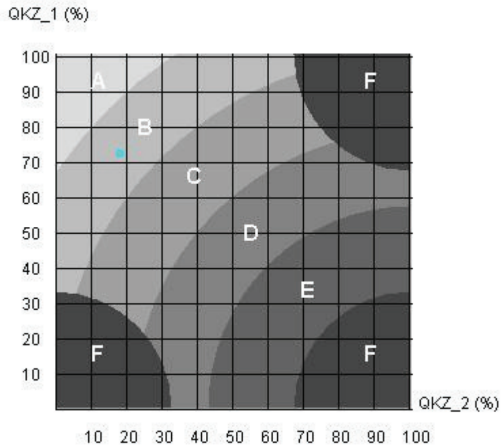

Fig. 6: Quality-diagram (02.01.2011)

Additionally to the “QKZ-method” several new indicators have been developd and are also applied for measuring the quality. Two very important ones are the “sign in” and “sign off” of the messages (temporal delay).

The delay of the messages sign in was 2 minutes and the delay of the message sign off was 19 minutes in the described test case.

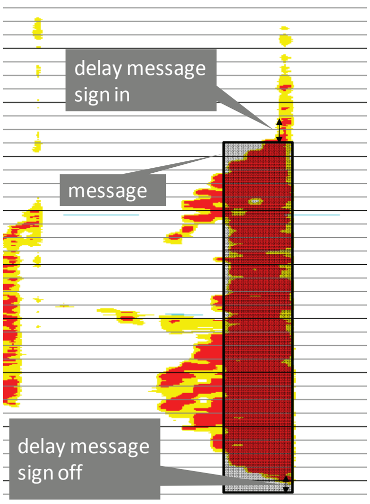

Fig. 7: Delay message sign in and sign off

4. Conclusions

Currently a system for the systematic quality evaluation of the ASFINAG traffic messages is installed. The ground truth is reconstructed by detector data and travel time data, for the superimposed traffic messages two quality indicators based on the so-called „QKZ-method“ are calculated. Several further quality indicators are also enumerated, one example is the temporal message delay.

In this paper, first results for the A12 freeway are demonstrated and already showed very promising results.

5. References

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[5] Treiber M.; Helbing D.; Reconstructing the Spatio-Temporal Traffic Dynamics from Stationary Detector Data; www.trafficforum.org; 2002.

Heterogeneous approaches to quality management for traffic information – do we need them all?

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Abstract

Bringing examples from practical experiences and projects this article shows how many different approaches towards quality measures in ITS systems already appear within a few concrete projects. While all approaches contribute to Quality Assurance (QA), the motivations and targets why they were introduced vary and respectively the approaches do so, too.

The number and difference of approaches suggest to raise the question, if there shouldn't be any guidance to assure easier understanding. Are all approaches needed? Is there a possibility for simplification? At least a common understanding scheme of the different motivations and targets for quality and maybe even a common approach to some of these targets may be useful to be developed.

1. Practical examples

The examples described in the following sub-chapters are characterised by the following structure:

a) **Subject**: The subject of examination describes what the approach is looking at. It is determined by the goal or motivation why a quality assurance method was introduced in this case.
b) **Space and Time**: The special extent of the examined information and its time extent is described. It may be
   - The *complete network*, composed by its links in a routing-graph. Usually the spatial extent is evaluated for a single point in time (e.g. how good is a network status in a single point in time).
   - *Dedicated routes*, selected because of their significance or importance to the contractor of the ITS system. Usually the information quality is observed over a time period (e.g. one day).
   - *Single location* (either a point or one single network link - edge in a network graph). Usually the information quality is observed over a time period (e.g. one day).
c) **Reference**: the reference describes against which other information the quality of the subject is assessed. In some approaches this is also quoted as the 'ground truth' while other approaches avoid the 'truth' statement since it

cannot be determined in an objective reliable way in the real world (in simulated worlds this is feasible).

According to this schema the following examples are provided from real projects and products:

1.1. Floating car data validating traffic forecast model in Vienna

Subject: "measurement propagation and data completion"-model (urban)
Using single spot on-line detector data in an urban road network a traffic model based approach called 'data completion' is determining the current traffic situation. The target was to show, how well the model depicts the real situation in the respecitve road-network in terms of travel times.

Space and Time: Routes at 24 hours
For inner-city tests, approximately 20 major routes through the city of Vienna are defined, which are divided into useful and meaningful test sections of approximately 2-3 km The model provides the current situation and forecasts for distinctive future times (+15 minutes and +30 minutes) on all network links.

Reference: Taxi FCD
Most suitable as a reference are Floating Car Data (FCD), collected by taxi or delivery fleets. The results of FCD information here are travel times computed at each link of the digital network, for each quarter of an hour

Approach and Result
The following picture shows the result for one route though the city. The upper part shows travel-times for both the taxi and forecast-results; times on the Y-axis are given in seconds.
The lower part shows the difference in percent. The difference is calculated using the following formula:

$$difference = 1 - \frac{forecast}{Taxi}$$

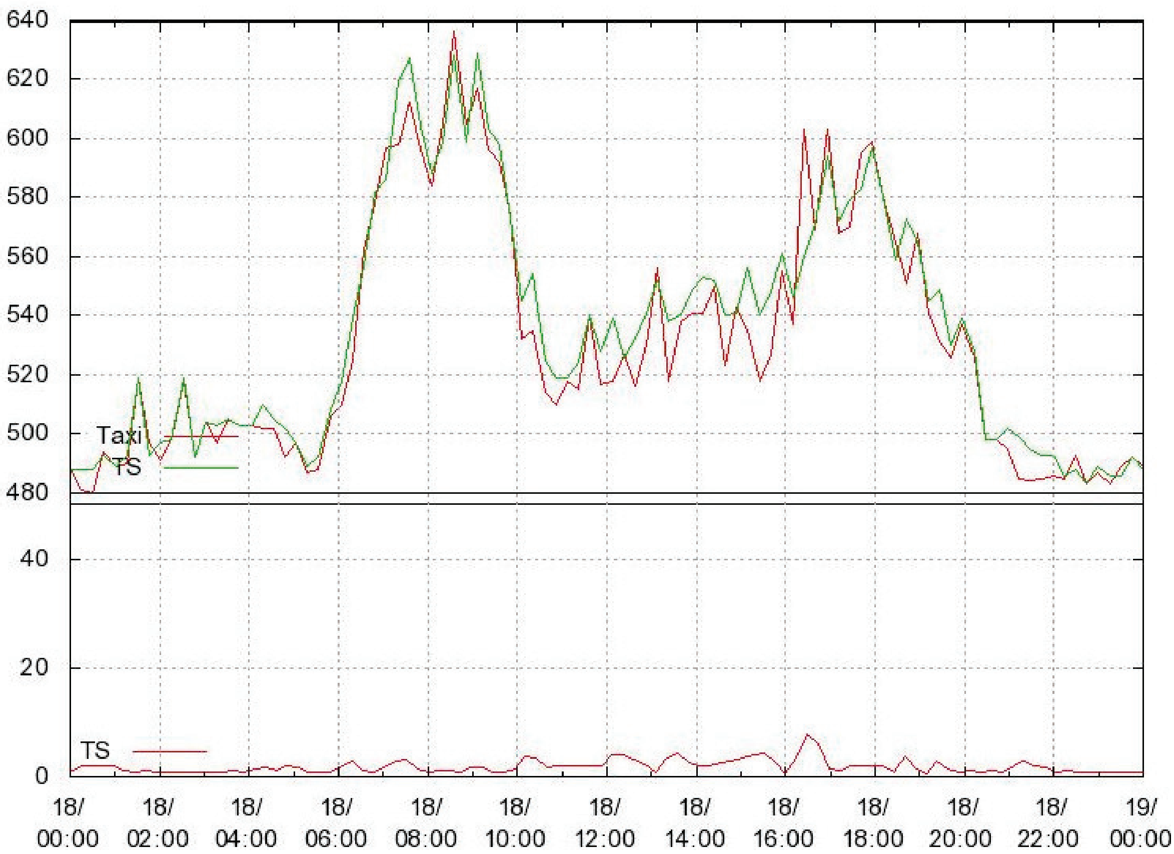

Fig.1: Travel time comparisons

Within the Vienna system [www.AnachB.at], twenty-two routes, defined on major arterial roads, are continuously and automatically tested.

1.2. **Quality Map: The Theoretical quality which can be achieved in detected road networks using measurement propagation**

Subject: "measurement propagation and data completion"-model (general)
This assessment is used to pre-analyse the level of quality which can be achieved by applying a method to a road network, which is utilising online data on single network locations and a traffic model to determine the traffic parameters volume and speed in the entire network (for current or predicted points in time).
The quality map approach shall identify systematically 'weak' spots, i.e. spots where real online detection does not contributes significantly to the estimated traffic parameters. This shall support decision making where to place additional detection in order to achieve a better traffic status analysis or forecast.

Space and Time: all network, any time
The method is analysing the entire network's ‚coverage' of detection. Each detector is contributung to downstream road section's dection, according to the amount and distribution of vehicles, passing the detector ('propagation of a measured detection value across the adjacent network').

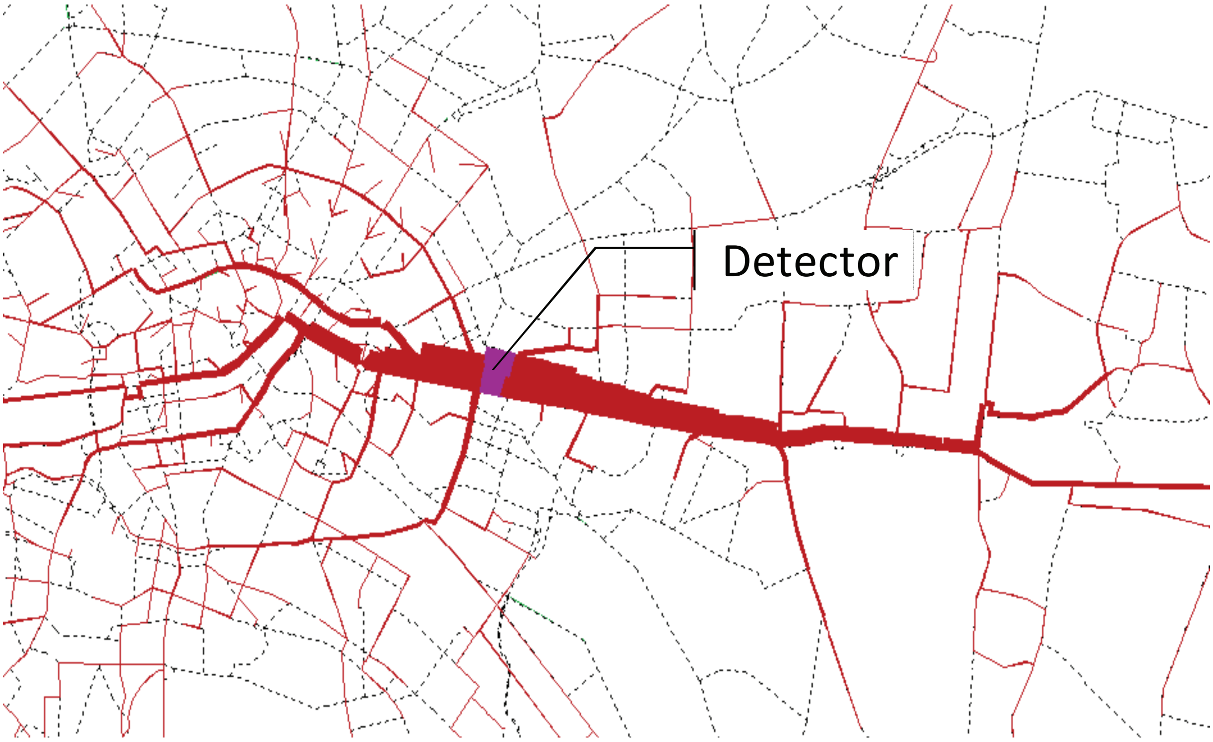

Fig. 2: Routes of vehicles passing a detector (width indicates number of vehicles)

Reference: not applicable / approach inherent
This approach does not compare to any reference. Its states plausibility of the estimation which is site setup inherent.

Approach and Result
Following all routes in the system the approach indicates the coverage of road sections which are well detected and those which are not well detected according to the measurement propagation. For each link a quality index is deduced, showing how likely it is, that the model results will be influenced by detection.

This approach is currently developed further in the project TrafficIQ [NN], where the correctness (plausibility) of model based results shall be estimated in real time depending on the current detection availability and quality. The resulting quality measure could also be put in relation to an ideal correctness (plausibility), if all available detection was functioning correctly.

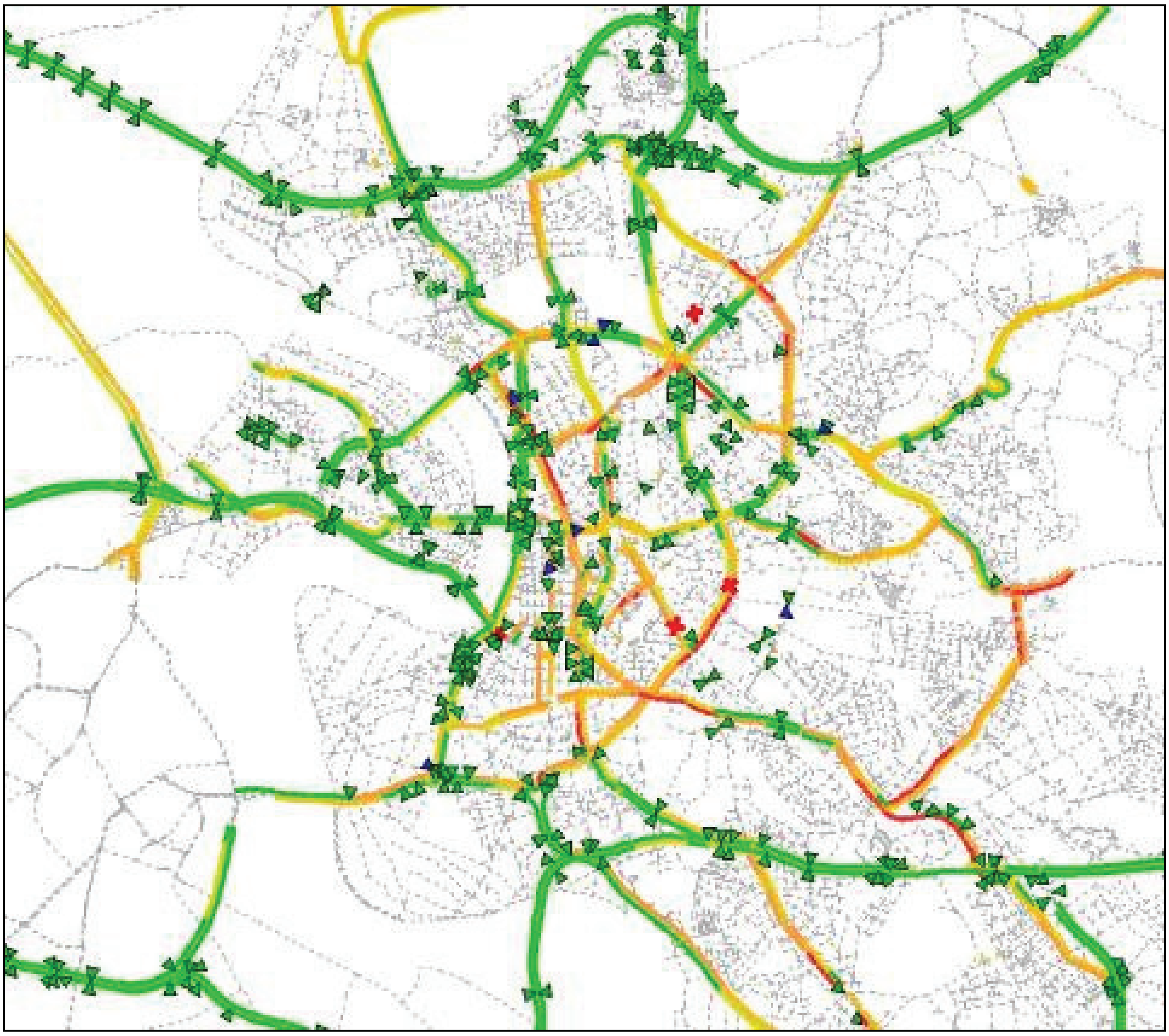

Fig. 3: Quality Map of a city main road network. Red sections are not well covered by detection.

1.3. Bayerninfo.de: Look into a multi layer forecast system

From this project two examples for quality assessment are provided. Before doing so, this introduction is provided to set the perspective and understanding, which is setting the scope for the QA actions.

The Bayerninfo services are composed of several current traffic state and forecasting systems. The reason for this is, that there does not exist a single solution, by which all types of road networks and all time horizons for prognosis can be covered.

Common motivation to all of the approaches is, to determine a full coverage traffic status (volumes and speeds) although measurements are only available on single spots. The different methods and models applied are set to estimate where no direct measurement exists: the undetected sections of a network and the future of the network status.

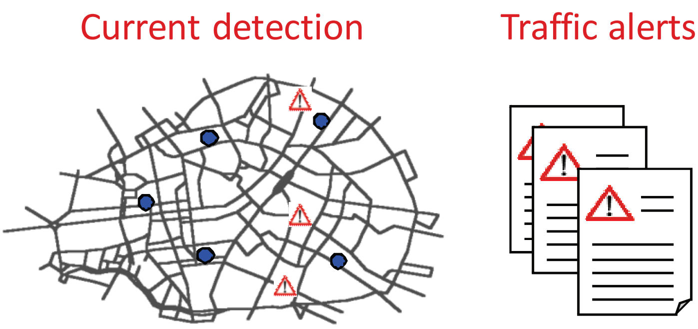

Fig. 4: What can be measured: situation on single spots

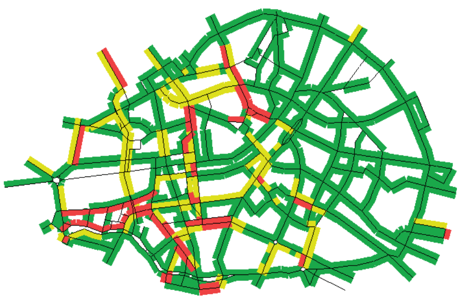

Fig. 5: What must be computed: full network status and prediction

Consequently when the computation of the current and future traffic situation has to be done using different methods and models for different time and space extensions, a fusion must finally compose all single results to one complete picture.

The following illustration shows, which different partial results need to be combined in the „multi layer forecast system“ of Bayerninfo.

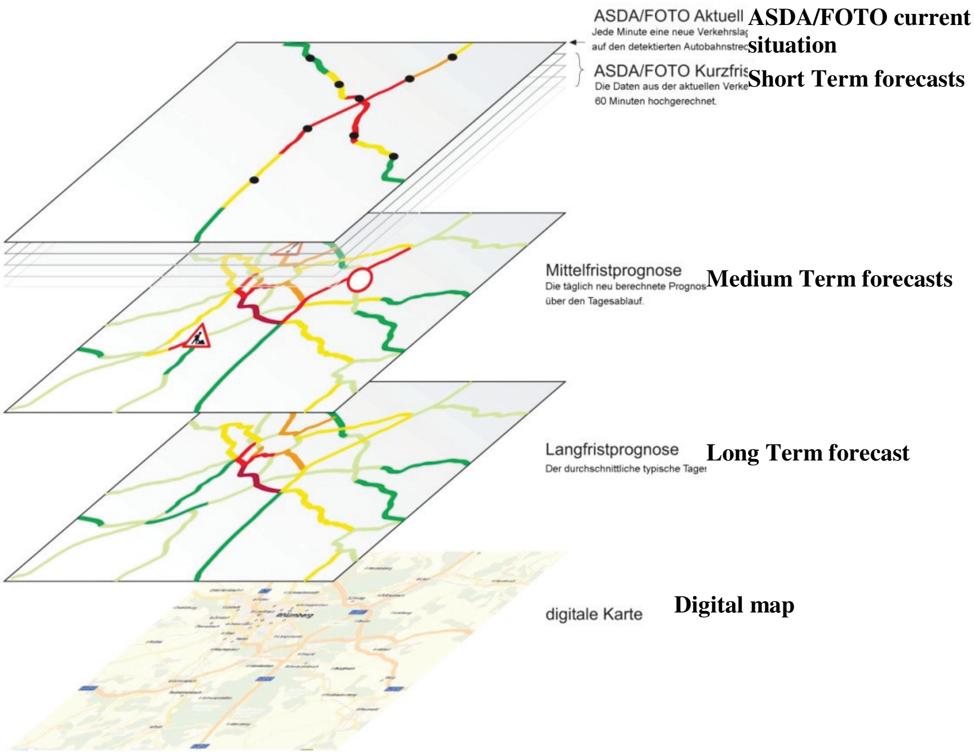

Fig. 6: Combination of (forecast-) time and space dependent models and methods in Bayerninfo to achieve a complete traffic situation overview on the network between now and up to 365 days ahead.

Only having achieved this, a real ‘dynamic’ traffic information and travel planning can be offered: When asking the system to calculate a route, the appropriate forecast layers can be utilised. While the current traffic situation is relevant for the first part of a trip beginning “now”, the forecast situation 15 minutes later or even later when the trip will be ended is relevant for all other parts. An optimisation of travel time over all this time horizons is true ‘dynamic’ routing.

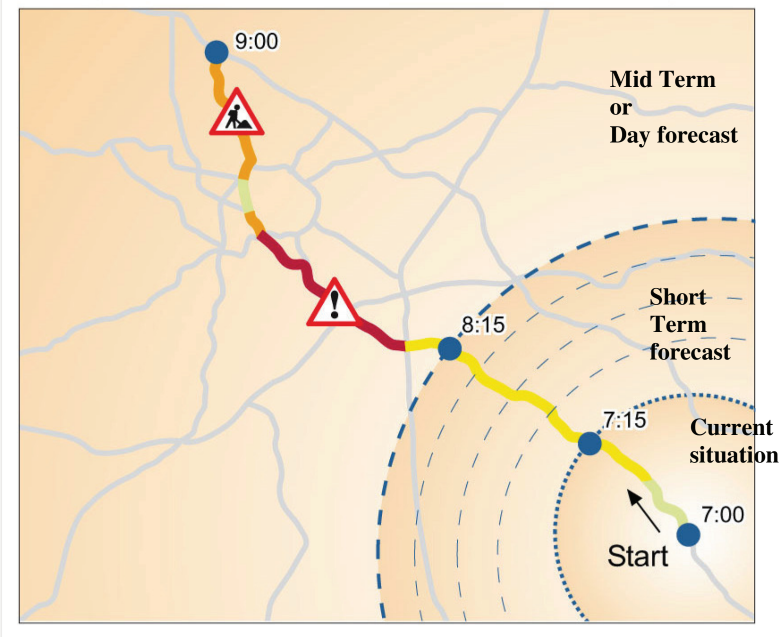

Fig. 7: True dynamic routing utilises forecast

With this definition of a multi layer forecast system, the following examples show how some aspects can be assessed in quality assurance approaches:

1.3.1. Example: Assessing current traffic situation computation (ANS Diagram)

Subject: ASDA/FOTO current traffic situation, operational system status, plausibility of different sources

On highways with regular traffic detection the ASDA/FOTO method (KERNER / Daimler Research / PTV) is using the detector measurements to determine the evolution of traffic jams – even between detectors. This process involves lane based detector data (speeds, volumes per minute), computes jam extension and movement of jam ends and it is used to produce alert messages. All these partial results on the computation chain may be subject to failures and errors. The approach shall allow to see implausible or faulty results in one glance by looking at an image.

Further the approach is used to compare other data sources with the results from this method.

Space and Time: linear road sections (routes) on highways

A time-space diagram is composed resulting in an image, showing the status of all computation steps on a regarded highway section over one day.

Reference: self (own intermediate calculation steps) or other message sources

Comparison is done between the

- Detection measured
- Jam status / extent computed
- Level of Service colour output generated
- Traffic messages generated
- Other traffic messages generated
- FCD probe dives

Approach and Result

A diagram is depicting a highway section or route in the vertical axis and is illustrating for each minute (horizontal axis) the status of the different sources or partial results. The "ASDA/FOTO Native Sciagram (ANS)" [Schmid,Epp 2010] illustrates all information in one image.

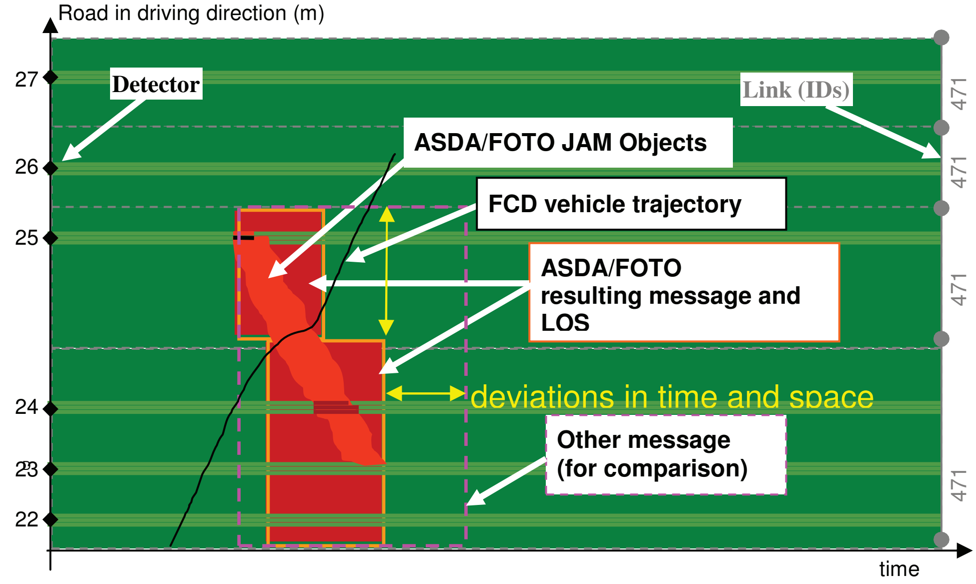

Fig. 8: ANS diagram - schema of complete view

A skilled eye may see various quality related issues on one glance by looking at the image. For example

- Is every step in the process chain running (e.g. is there a lack in the incoming detector data, has ASDA/FOTO been producing results, is the LOS colouring corresponding to the measured input or is it missing at all)
- do the results steps in the process chain fit together or are there implausible results
- how do different sources deviate

These questions address both: Operational quality and result / content quality.

The ANS approach as presented here has no automated figures which can be queried or utilised as quality indicator. Still the diagram appeared to be of very high value for human brain based QA.

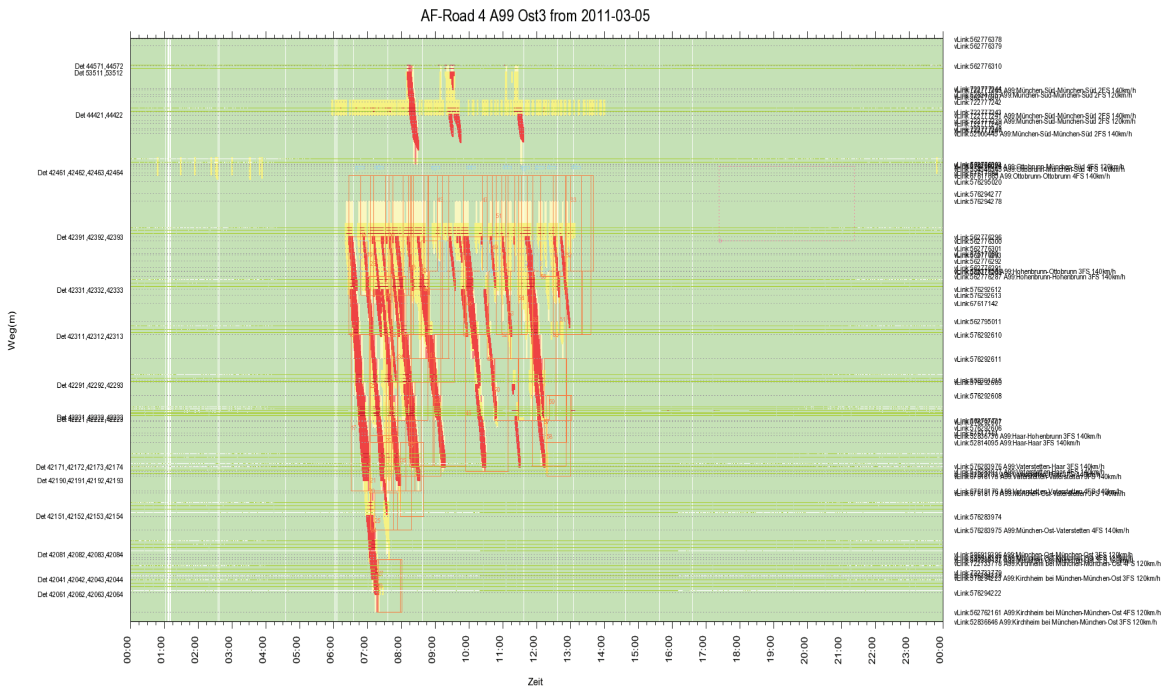

Fig. 9: A real system output of an ANS diagram on A99 from March 2011

1.3.2. Example: Assessing (short term) forecast

Subject: Short term forecast on Highways in Bavaria
On Bavarian highways with sufficient real time detection a short term forecast is computing the expected situation in the next 15, 30, 45 and 60 minutes. The road administration wants a measure to determine ex post, how precise the forecast met the situation occurring later. Measures in terms of key figures are produced automatically. In addition for single spots analysis images can be requested manually.

Space and Time: all single detected links, one day, different forecast horizons
Automatic figures show the entire system quality achieved for a single forecast horizon (+15, +30, +45, +60 minutes).
Manually requested analysis on single spots show the 4 forecasts compared to the real situation over one day.

Reference: ex post evaluation: forecast vs. real measured later
The later measured real situation is compared to the forecast situation.

Approach and Result: deviation distribution diagrams and single spot sample analysis diagrams
For the required automatic figures it was necessary to introduce metrics.
A quality index is calculated, looking at the difference between the two values. Current tests use the following approach to calculate the quality index:

$$Quality\ \ Index = \frac{|computed\ \ value\ - "truth"|}{("truth")^n}$$

In the approach the n is determined based on an empiric study.

For speed it has been decided to look at the absolute difference Δv=|predicted speed –speed occurred|. i.e. n=0 in the formula above. This results in an easy to understand dimension "[km/h] difference".

For volumes both – absolute difference (n=0) or relative deviation in % from the later occurred volume (n=1) appeared to be not reasonable to be used. Depending weather the absolute values are rather small in [veh/h] (i.e. not much traffic) or high each measure has severe disadvantages. The following table illustrates this in an example:

expected	measured	missed	
5000 veh/h	4800 veh/h	-4%	200 veh
100 veh/h	96 veh/h	-4%	4 veh
500 veh/h	300 veh/h	-67%	200 veh

Fig. 10: Relative and absolute volume deviations at high or low absolute volumes

An empiric determination of n in the range of 0,6 would provide a possible figure.
An other similar solution to this has been provided by Geoffrey E. Havers in the 1970's. The metrics is used by traffic planners (e.g. adopted in UK Highways

Agency's Design Manual for Roads and Bridges DMRB) and is here transferred to the ITS domain. He has formulated a “GEH” measure according to the equation:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

M = **M**odel Value
C = **C**ount Value

Applying this measure and the speed delta measure to all locations (links) where a counted (real occurred) value and a modelled (forecasted) value is available, the distribution of all GEH and Δv values of all ‘detected’ locations can be determined in a histogram-graph as shown below.
An other illustration of the same metric figures is to show, which percentage of the entire probe is better than a certain threshold value.
The following illustrations show both variants.

900 sec (15 minute) forecast:
Histogram
478 available measurement locations were delivering values

Fractions:
80% of all GEH did nor exceed GEH 7,04
80% of all Dv did not exceed 5,88 km/h

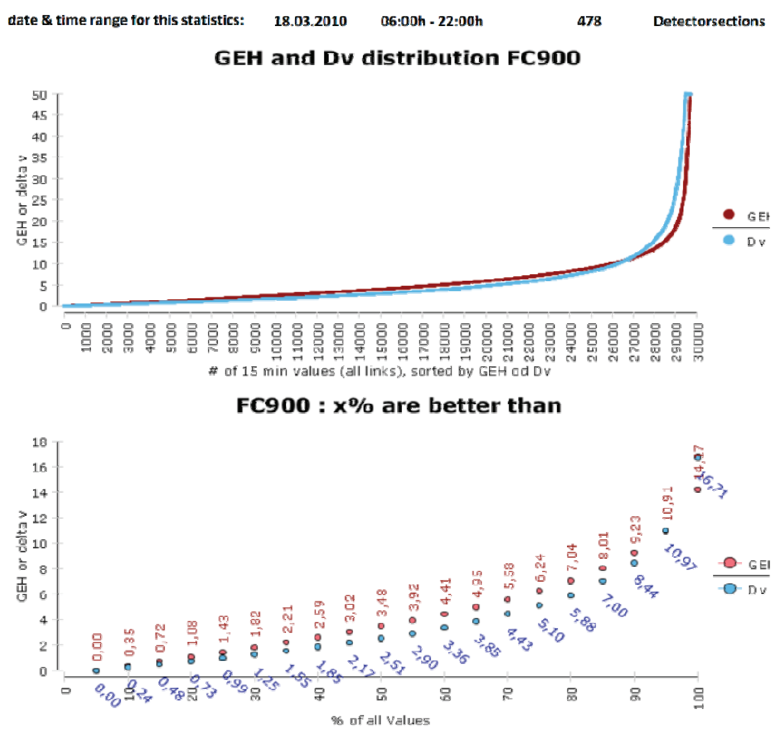

Fig. 11: Histogram and fraction illustration for GED and Δv

These figures provide an (automatic) measure for the achieved quality. They were used to determine whether changes in the algorithm lead to improvements and to what extent the improvements occurred. It could be decided which algorithm improvement was the most fruitful.

Still these figures are quite abstract. They do not show a single spot behaviour such as: how well is a forecast reacting at an unexpected speed drop?
Thus diagrams for manually selected single locations were developed on basis of the same metrics. The diagram below shows speed patterns of a single location for the different forecast horizons (lines with triangle shaped markers) and the deviation of the horizons (dashed lines and round measurement markers)

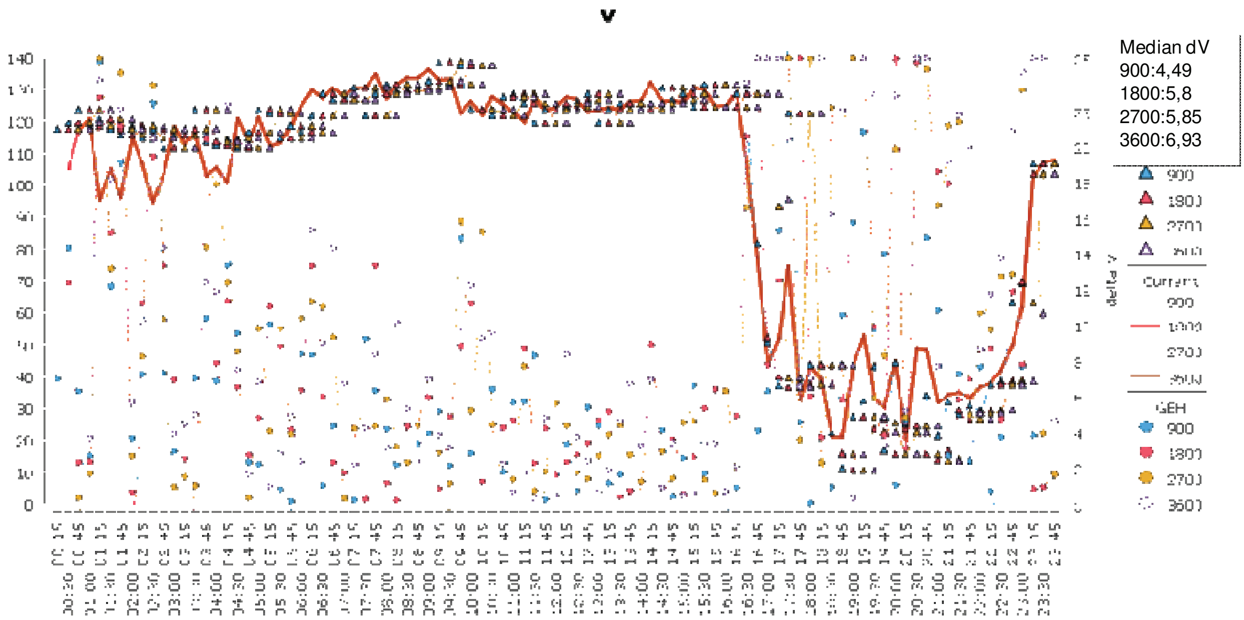

Fig. 12: Single location speed pattern – 4 forecasts vs. later measured

Finally the method of comparing different forecasts with the later measured traffic state can be applied to all ‘layers’ in the forecast system. The illustration low plots the traffic volumes computed by the different forecast runs against the measured volume as a 3D plot.

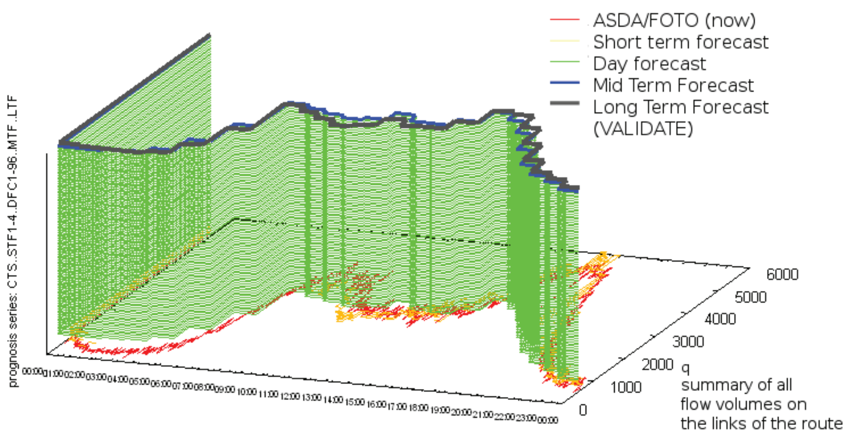

Fig. 13: 3-D prognosis diagrams

2. Synthesis

It can be observed that a great variety of approaches towards quality assurance (QA) has been set to ITS systems.

The variety emerged from the different objectives which were subject to be analysed or to be quality assured.

Orientation can be given using a common structure to describe the approaches. Still even with a similar objective for quality assurance, the approaches and methods are manifold.

In the ongoing Traffic-IQ project, a more unified description of quality is proposed across different detection and data processing approaches, which is certainly helpful. Still, itt should be discussed, whether for similar QA objectives a common measurement approach can be determined as preferable compared to others.

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