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Floating Car Data on a Larger Scale

SUMMARY

Imaginative variations of Floating Car Data (FCD) have been some traffic engineers' toys for quite a time. To apply the concept on a larger scale in the real world, however, one has to cope with a bundle of economical, political and (last but not least) technical constraints. This talk describes the way people at Mannesmann Autocom dealt with these in the process of establishing a viable FCD concept in well under a year, verifying and developing it further in what was and still is (in terms of the number of vehicles participating) Europe's largest traffic telematic field trial: VERDI (VEhicle Relayed Dynamic Information). The result is presented from the technician's as well as from the customer's point of view. We have a look at what goes on in the onboard unit of a floating car, how the traffic information center joins together the millions of FCD bits to an up-to-date approximate picture of the traffic state on any sufficiently covered German highway, and how FCD compares to stationary sources of traffic data. Furthermore, we examine quantitatively the lead of users of conventional sources of traffic information the customer had already in the field trial und will have in the future and look at the measures taken to secure her privacy. Finally, a few paths the technology of traffic telematic devices and online traffic information processing might take from here are elucidated.

INTRODUCTION

Floating Car Data (FCD) as a source of traffic data upon which your traffic information services are supposed to be built should deliver a picture as complete as possible of the traffic state of every road in the network in which you are about to offer your services.

It has to do so just in time. Nobody will pay you for being routed dynamically if this merely involves watching your remaining travel time increase when being caught in the congestion which was already there when you started your trip.

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It has to do so without excessive communication. Band width for point-to-point connections from the traffic information centre to the individual vehicle is scarce and expensive. (We ignore the case of dedicated short range communication which presupposes the availability of local infrastructure.) In one way or the other, the customer will have to pay for the FCD-related communication which he usually does not even notice to occur.

But he does know that in principle his car can transmit data about virtually every trip to some traffic information centre if it feels like that. He signed a corresponding agreement when he bought his onboard unit (OBU). FCD have to be collected in a way that he feels comfortable about this. There are even some constraints which are imposed by law.

The optimum equipment of a Floating Car from a purely technical point of view would involve something like radar detectors and video cameras, but after buying your traffic information gadget at the gas station you, the typical customer, expect to be able to plug it into your car and play with it. You are neither interested in knowing which part of the black box hides the FCD component nor are you willing to pay for it. You might even expect to get something in return for your kind readiness to deliver FCD.

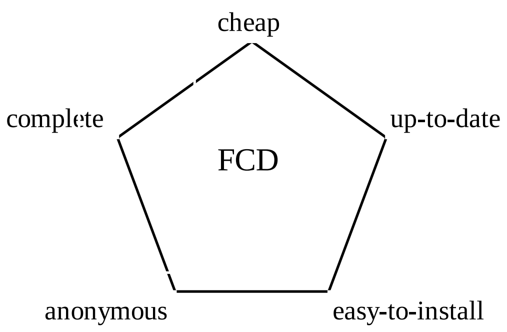

Figure 1: Conflicting requirements for a large scale FCD system

In the above we have sketched a few of the requirements you are confronted with when designing an FCD concept which is expected to work on a larger scale. When dealing with just a few Floating Cars you may pick one of these and come up with a specific solution - when being supposed to handle hundreds of thousands of them you have to satisfy all of the above and some more requirements which is virtually impossible. The FCD system is classically frustrated: whenever you pull at one corner (figure 1) to cover the corresponding requirement you uncover another one.

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In the following, we have a closer look at the FCD concept developed at Mannesmann Autocom in the GPS/GSM environment (figure 2).

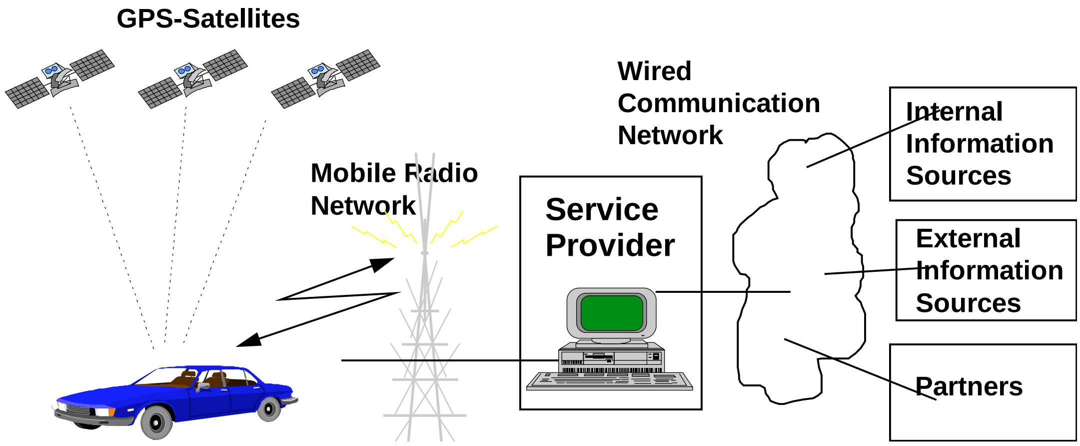

Figure 2: The Floating Car, its interfaces to the outside world, and FCD-based services

FCD-COMPONENT OF THE ONBOARD-UNIT

The availability of core competences at Mannesmann as an operator of a mobile radio network soon led to the strategic decision to offer traffic telematic services and to collect FCD at least via GSM (the former can be done in other networks as well) with localisation information provided by GPS. What remains to de done in a correspondingly equipped vehicle is to resolve the frustration induced by the three requirements of completeness, timeliness, and minimality: Information about the emergence and dissolution of every incident and congestion (plus some statistical data) has to be transmitted as fast and with as little communication as possible.

For that purpose, intelligence and expert knowledge about processing, evaluating and compressing the raw data available for the FCD component of the OBU (nothing but positions and velocities) is decentralised (put into the OBU) as far as possible resulting in a couple of functional modules as depicted in figure 3.

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FCD-OBU

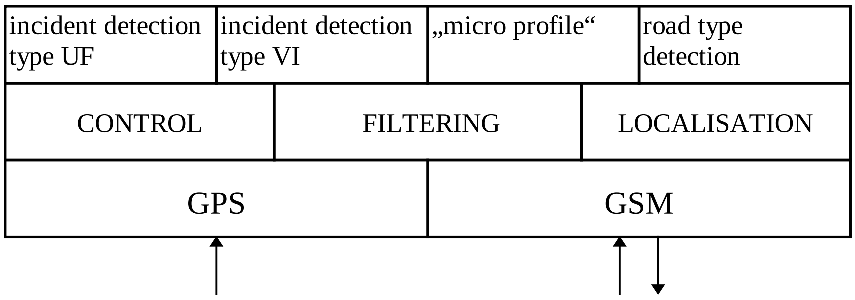

Figure 3: Functional modules of the OBU relating to FCD

Figure 3 offers a very crude and incomplete, but simple view of the functionality of the OBU as far as it relates to FCD (the lower parts of it, of course, also relate to other services). Each module is assigned to one of three layers, which we might call from top to bottom the „application layer“, the „service layer“ and the „interface layer“.

The interface layer provides access to communication and sensor data of all kinds. The two most prominent interfaces in this context are, obviously, those to GPS and GSM as can be seen from the figure. Other interfaces, especially to other onboard electronic systems, are conceivable. We do not go into any technical detail here.

The service layer provides basic services to be used be one or more application processes. These might be coding and decoding of the application data protocol (ADP), program control, filtering of incoming or outgoing data streams or answering the all-important question „where am I?“. This layer is already more complex and interesting than the previous one but we skip it anyway.

On the application layer the hard work is done. First, you need to know on which type of road you are currently going. This can be important because the traffic information centre might only be interested in FCD from urban roads or only from highways of your area. Furthermore, it will assist you in determining whether a stop was caused by congestion or merely a red traffic light. The automatic detection of the current road type from curve radii and average velocities, however, is a tough job if you can only rely on raw data like positions and headings with all sorts of device-dependent errors imposed on them. (Usually, you do not know in advance on which kind of GPS device your road type detection algorithm will run on.) It becomes easier if you have a digital road map available.

Second, you have to define events which trigger a message by the Floating Car like „I got stuck in a congestion“, „Traffic is flowing freely again“, or even „I entered an area which I was informed to be congested but it is not“. Again, this is not as easy as it seems

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to be at first glance. Obviously, you cannot simply define a threshold velocity for „heavy traffic“ or „congestion“ as velocities fluctuating around this threshold will generate a huge amount of messages, each of them adding to your communication bill. Two types of incident detection algorithms working with ensembles of virtual reference vehicles and fuzzy indicators for the traffic flexibility are taking care of that problem. They also generate a quantity called „jam classification coefficient“ (JACC) which helps to distinguish between stops intended by the driver (e.g., at a gas station) and those induced by the traffic situation.

The events triggering a message alone, however, do not do a good job in describing the local traffic situation. For one thing, they carry intrinsic delays so that the event „I got stuck in a congestion“ does not necessarily coincide with what you as a human being would define as the entry point of the congestion; for another, they simply don’t give you the important details like the remaining average flow velocity in the congestion etc. So another algorithm called the „micro profile“ crams the GSM packet with information like travel times, velocity variance etc. for dynamically chosen sections of the part of the trip immediately preceeding the trigger event. The general idea is that traffic flow consists of domains like „free traffic“, „heavy traffic“ etc. each of which grows or shrinks and slowly moves along the road, but retains its internal characteristics for some time. The „micro profile“ identifies these domains in the flow as the Floating Car proceeds in space and time.

All of the application modules described above need operative parameters and can be enabled and disabled separately. A specific combination of active modules together with their parameters is referred to as the „role“ of the Floating Car. A role may be valid globally or only within a specific area or for a limited span of time. There is a default role implanted in every Floating Car which may be overriden temporarily by manually or even automatically generated roles which satisfy the current information needs better than the default roles. Examples for roles are „jam detector“ or „full route scanner“.

GENERATING TRAFFIC INFORMATION FROM FCD

To derive high quality traffic information services from FCD you have to refine the information contained in the great many of single FCD telegrams arriving daily at your computer centre. Figure 4 highlights some of the crucial processing steps and gives an idea about the approximate order in which things are done.

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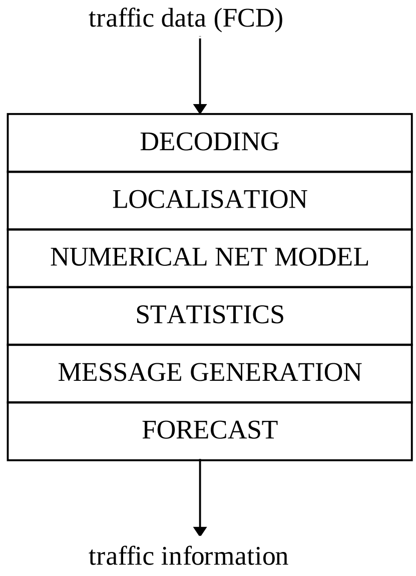

Figure 4: Central processing of FCD

Each time an FCD telegram reaches the traffic information centre a lot of trivial things have to be done first: decoding of the ADP, plausibility checks, conversion of the data to fit with various storage models, logging etc.

The first major step which is indispensable for everything that follows is the localisation on a digital road map (DRM). In case the original FCD telegram already contained this information because it was generated by a navigator which by its very nature is able to do the map matching on itself there is nothing to be done. But in case the telegram stems from a cheap device without a DRM and contains only a few imprecise GPS coordinates this step is complicated, involves squeezing and twisting a potential route over the map until it fits, and more often than not - fails. In the latter case the telegram is thrown away.

The data which successfully passed the first hurdles are used to construct a numerical model of the road network which contains primarily the velocity field as a function of space (link ID) and time, but also additional information like velocity fluctuations, transmission codes etc. This model forms the basis for statistical evaluations like the computation of the typical dependence of the travel time on a specific link on the time of the day or the estimation of time-dependent OD-flows, but also for the generation of messages describing deviations from free flow in a complete but concise form and the calculation of dynamic cost functions.

Finally, some form of forecast is needed especially to calculate time-dependent cost functions for dynamic route planning. This can be done by more or less heuristical means, by extrapolating historical data or in critical situations even by simulations

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starting from the numerical network model which for that purpose should be supported by flow measurements whereever available. Traffic forecast, however, is a topic on its own and beyond the scope of this paper.

In addition to the downward flow of information in figure 4 there is an upward flow of control which in invisible in the figure. Somewhere in your system control information has to be generated to dynamically define area-specific roles for the active Floating Cars. Of course, also communication for control purposes has to be kept at an absolute minimum. But you cannot expect an FCD system involving many different devices of quite a few manufacturers to operate entirely autonomous.

ANONYMITY AND SECURITY

Why should you as a user of traffic telematic services agree to deliver FCD? Do you have any advantage compared to those who don't? Do you have to worry Big Brother is watching you? No. First of all, the service provider receiving FCD does not get to know who you are, which mobile phone or which car you are currently using. He is not even interested in this kind of information. A device called the „A-box" (A for anonymity) located between the GSM-network and the service provider suppresses any information related to your identity, particularly your phone number.

Furthermore, it is not even possible to reconstruct the route chosen by a particular, yet unknown vehicle as start and end points of trips are never transmitted. Messages of floating cars are triggered by traffic-related events only. For the FCD operator there is no indication whatsoever about how close to the origin of a trip the location of the first message of a floating car or how close to the destination the last one is.

Of course, you can have your FCD unit turned off. But as there is no need to worry about intrusions into your private sphere you should take home your FCD deductions from the service charge and contribute a single share to the total quality of traffic information delivered.

COMPARISON WITH OTHER SOURCES OF TRAFFIC DATA

How does data from the FCD system operating in VERDI compare to conventional sources of traffic data? To which extent was it possible to satisfy the requirement of minimal communication and simultaneously to get a complete picture in time? To get a feeling for the performance of FCD already in a field trial comprising no more than 800 vehicles let us look at figures 5 and 6.

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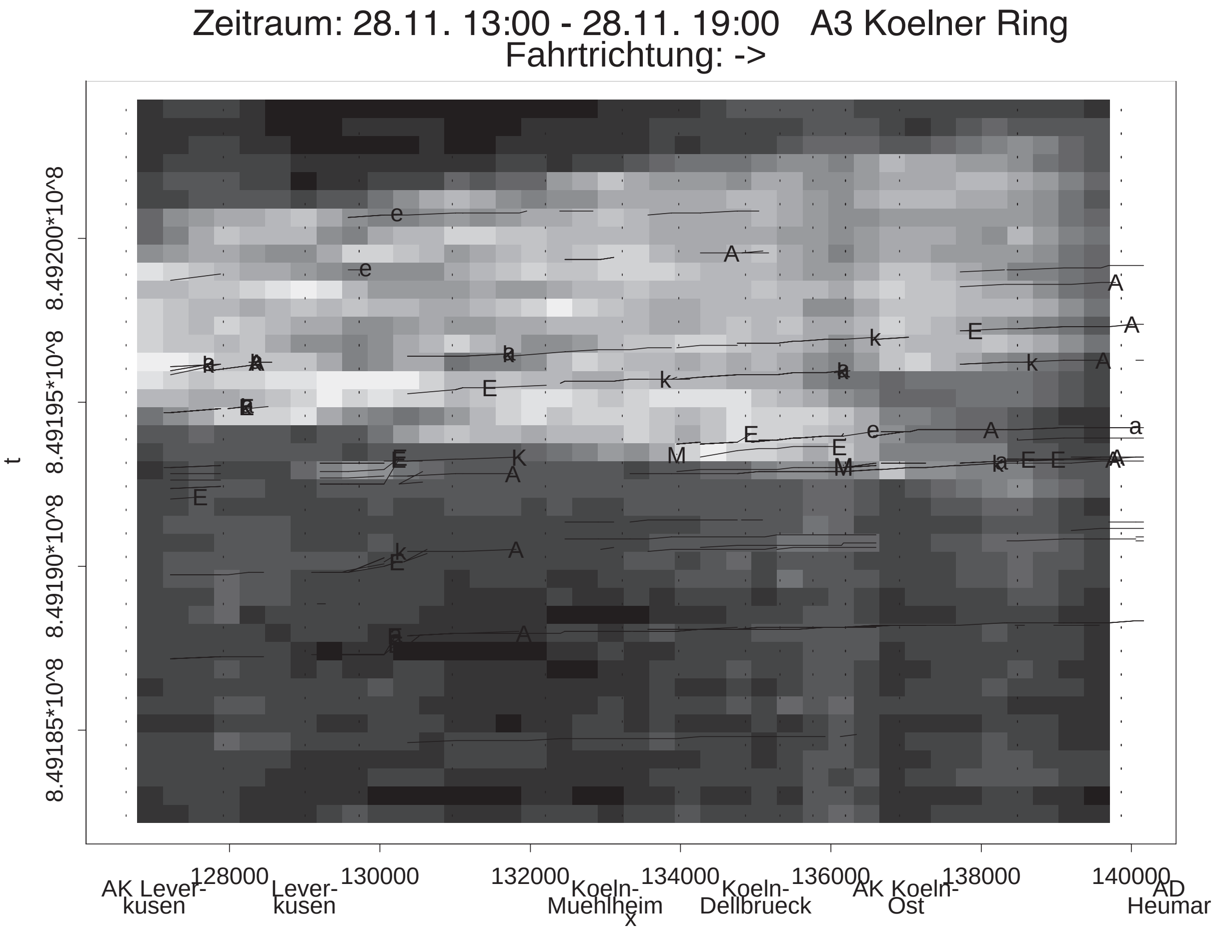

Figure 5: A congestion as seen by inductive loops

Figure 5 displays a congestion on a highway near Cologne as a grey scale plot. The highway extends along the x-axis, the t-axis represents the time of the day from 1 to 7 p.m. The velocity is coded as a grey scale, dark meaning large and light meaning small velocities. The incident lasted for about 2 ½ hours and had a maximum length of about 12 km. The picture was generated from 20000 numbers from measurements of inductive loops located at the positions marked by vertical dotted lines.

Also included in the figure (as almost horizontal lines) are the tracks of Floating Cars which got stuck in this congestion randomly. The letters denote the locations where the Floating Cars decided to send a message, each letter coding a transmission criterion. Reconstructing the velocity field from FCD alone, we get figure 6.

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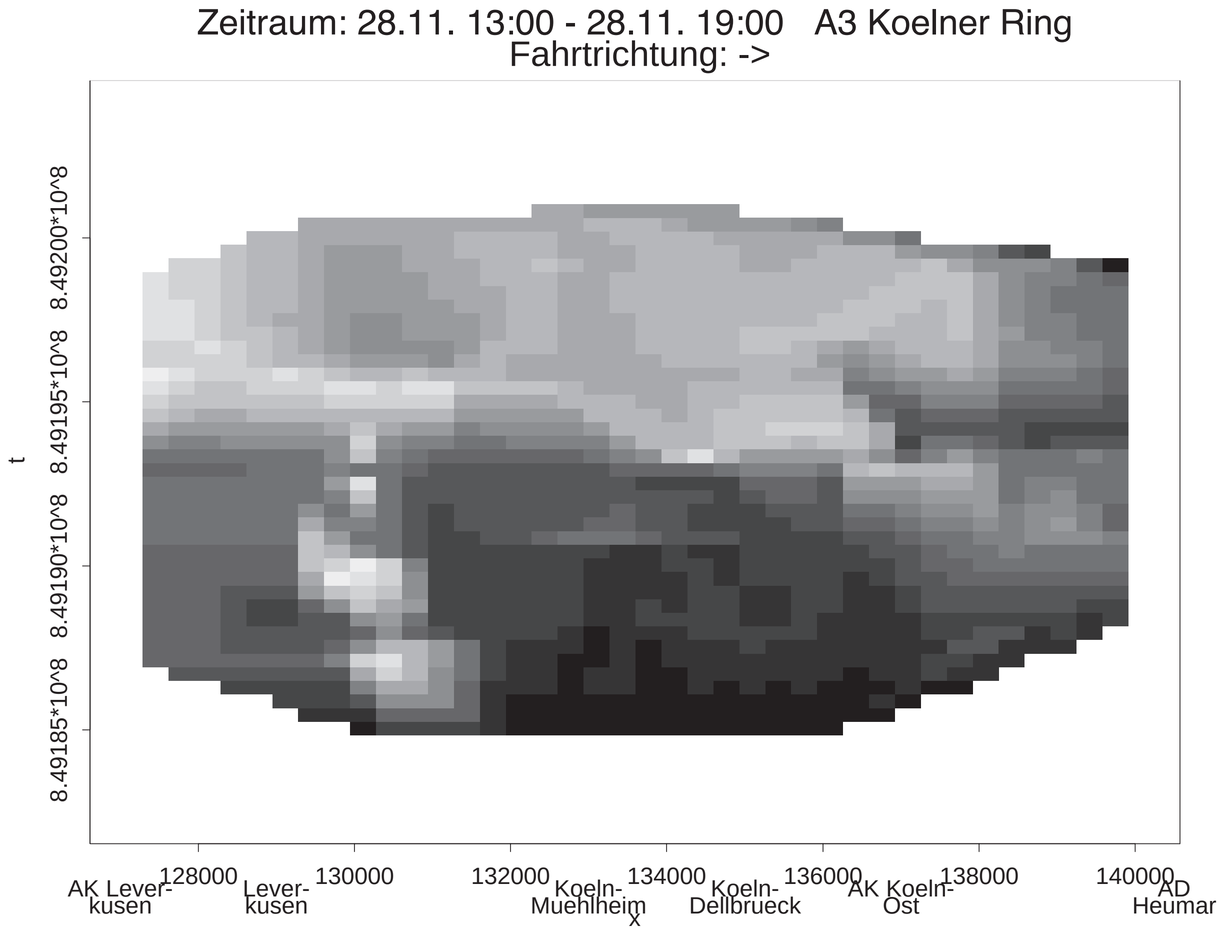

Figure 6: The same congestion as seen by Floating Cars

This figure was generated from only 200 numbers (2 orders of magnitude less than the previous one), but for all practical purposes, it contains the same information. The location, the duration and even the structure of the congestion is the same in both figures to an astonishing level of detail. The only exception seems to be a lighter structure in the lower left part of figure 6: but this one is a parking area which was used by a few Floating Cars before the congestion started. These data can be identified automatically by a small value of the JACC (see above) and the localisation information which contains clues concerning parking areas, gas stations etc. So traffic information like textual messages and travel times can easily be deduced from FCD alone. In conclusion, we get a complete picture with a minimum amount of information indeed. What about time?

Looking at all messages about traffic disturbances which were confirmed by the police in Northrhine-Westphalia from a time interval of 6 weeks we find that already the 800 VERDI vehicles detected 45% of these and - what is more - on the average a quarter of an hour earlier than you could hear the corresponding messages on the radio. (There were extreme cases in which the FCD message came unbelievable 3 hours earlier than the corresponding message from the police.) Taking into account the additional

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advantage of being informed about a congestion immediately after it becomes known (and not only half an hour later when the next news are due) we see that the VERDI participant already had a significant information lead. The FCD concept developed for VERDI proved to be a working compromise between the requirements of figure 1 but, of course, will be subject to further improvements and extensions.

THE FUTURE

Even today, however, measures have been taken to deal with those boundary conditions of the FCD system which will predictably change with time.

Obviously, the number of FCD participants will change (hopefully rise) over the years. As there is no point in collecting data from every car all the time a mechanism is needed to effectively fix the size of the sample of equipped vehicles at a value which is considered to be critical for the quality of FCD required by the traffic information services. Suitable statistical mechanisms like time slotting are well known from computer science and will be present already in the first FCD terminals commercially available.

Further complications will emerge from the diversity of devices and software versions from various manufacturers. Precautions have been taken to control and gain maximum value from a large inhomogenious fleet but these still have to stand the tests of time.

FCD will start on highways but before long the need for „city-FCD“ will arise for various reasons. First, the customer will not accept that traffic information comes to an end when he leaves the highway and enters the city. Second, traffic telematics should be a product available without any regard of national frontiers. So you have to pay attention to different traffic problems in different countries. In Germany, for example, a substantial part of the problem is located in the inter-urban network of highways whereas in France, traffic collapses usually in the large cities and not between them. Third, to achieve a sensible modal split in the long run you will need information from within the cities. City-FCD as compared to FCD on highways will result in quite a few new requirements: GPS-based localisation in dense urban networks is more difficult than on highways, detection of congestion is replaced by measurement of queue lengths at traffic lights as a central task of the FCD system and generally, urban traffic is much more stochastic making it more difficult for automatic systems to grasp the characteristics of the current traffic situation quickly.

Last but not least tools and techniques for traffic modelling, OD-estimation and related problems will have to be adapted to the gradual change of the traffic data base from point oriented data (from inductive loops or above ground detectors) over a mixture of these with FCD to route oriented data alone. FCD based traffic forecast, for example, is a topic which - due to lack of data - has not yet generated much interest in the research community. But this is about to change.

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