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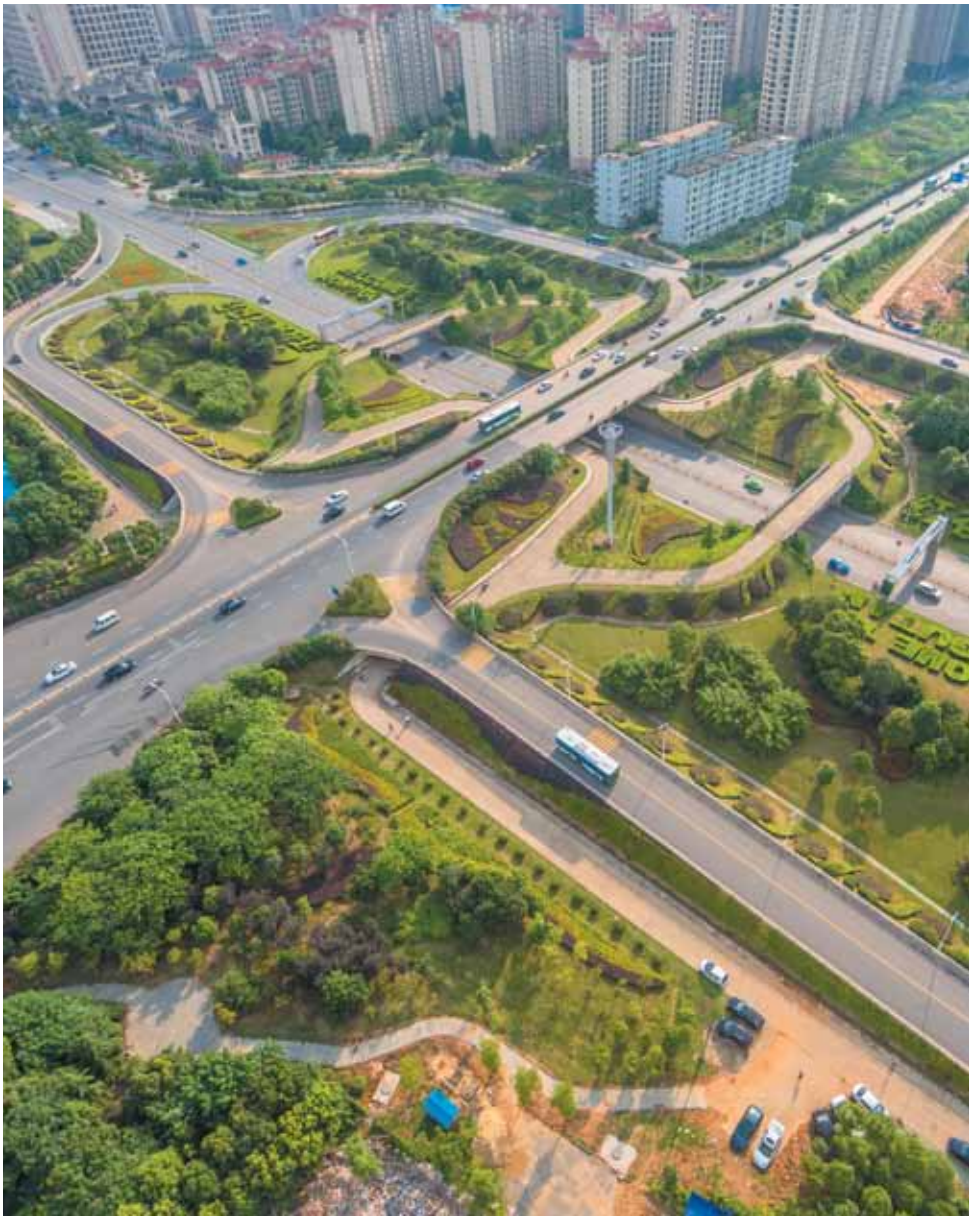
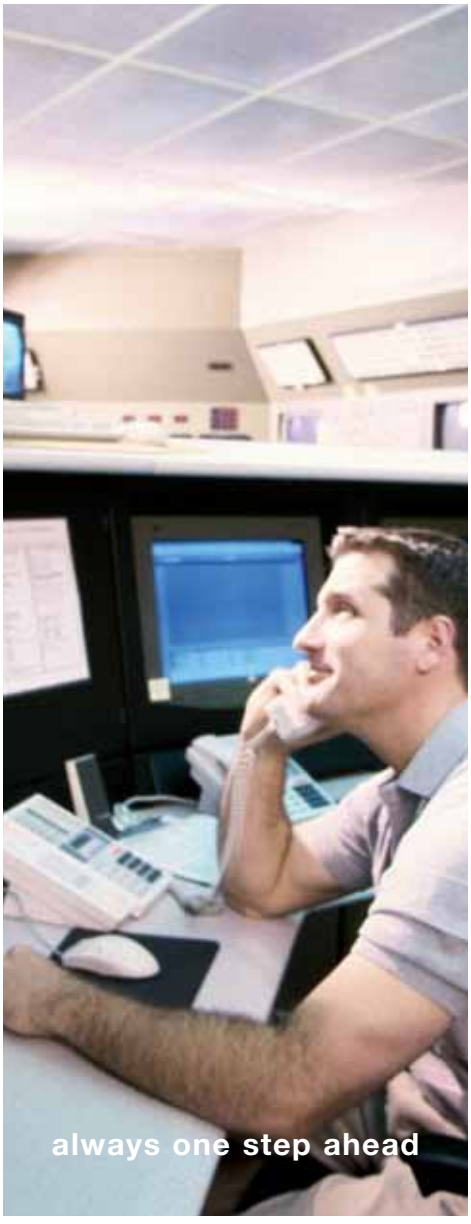
Kapsch Telematics Platform.
Traffic Data Capturing and Analysis based on Kapsch ETC Systems.





About this Document.

Electronic toll collection systems (ETC) can be used as basis for other ITS solutions allowing to reduce costs and to provide additional data that can be used for traffic management and planning purposes. This paper gives an insight to the Kapsch Telematics Platform which is a modular software system for implementing secondary telematics applications for traffic data capturing and analysis on basis of Kapsch electronic tolling systems.

Chapter 3 gives an overview how data captured by ETC systems can be used for traffic management, information, and planning purposes. Chapter 4 provides detailed information on the architecture and functionality of the Kapsch Telematics Platform and its modules for traffic monitoring, traffic data collection, traffic statistics and traffic flow analysis. Finally, chapter 5 provides a short description of the operational solution of the Kapsch Telematics Platform in the Czech Republic.

Abbreviations.

- DSRC Dedicated Short Range Communication
- ETC Electronic Toll Collection
- ITS Intelligent Transportation/Traffic System
- MLFF Multi-Lane Free-Flow
- OBU On-Board Unit
- KTP Kapsch Telematics Platform

Executive Summary.

The continual growth in road traffic increases the need for “Intelligent Transportation Systems” (ITS). Traffic management systems for example allow to control traffic helping road users bypassing congested road segments, warning road users in case of dangerous incidents, or reducing speed and thereby smoothen traffic flow in case of heavy traffic. Additionally, traffic planning tools help to optimize the road network allowing road authorities to expand the traffic infrastructure in line with demand.

Both traffic management and traffic planning require reliable and up-to-date network-wide traffic data. So far, this data is mostly being collected with a dedicated sensor network (e.g. inductive loop sensors). The erection, operation and maintenance of this infrastructure is associated with high costs, and as a result, up-to-date traffic data is frequently not sufficiently available.

The use of ETC systems for network-wide capturing of traffic data for traffic management as well as for traffic planning and the associated reduction in the number of dedicated sensor points offers major savings potential. In addition, toll systems can provide a higher data quality as they capture more information than standard traffic sensors.

Kapsch offers the Kapsch Telematics Platform as a system allowing to capture data generated by Kapsch tolling systems and transform this data into traffic data which can be used for traffic management and planning purposes. With the data traffic management centers can control traffic network-wide. The level of service can be calculated, travel time forecasts can be performed, and incidents can be detected. In addition, the data can be used by the road authority for informing road users about the current traffic situation and for planning road infrastructure projects.

The platform can be referred to as a kind of “telematics toolbox” providing pre-developed applications for the most common use cases and allowing the implementation of customer-specific solutions in addition to that. The platform provides open XML interfaces allowing to couple it with external systems like traffic management systems or traffic simulation tools allowing an easy integration with existing system environments.

Out-of-the-box applications which are currently available are a traffic monitoring application allowing to calculate travel times and level-of-service, a traffic statistics application offering a broad range of out-of-the-box traffic statistics, a traffic flow analysis application allowing to analyse routes of vehicles, as well as an application allowing to collect traffic data from enforcement stations.

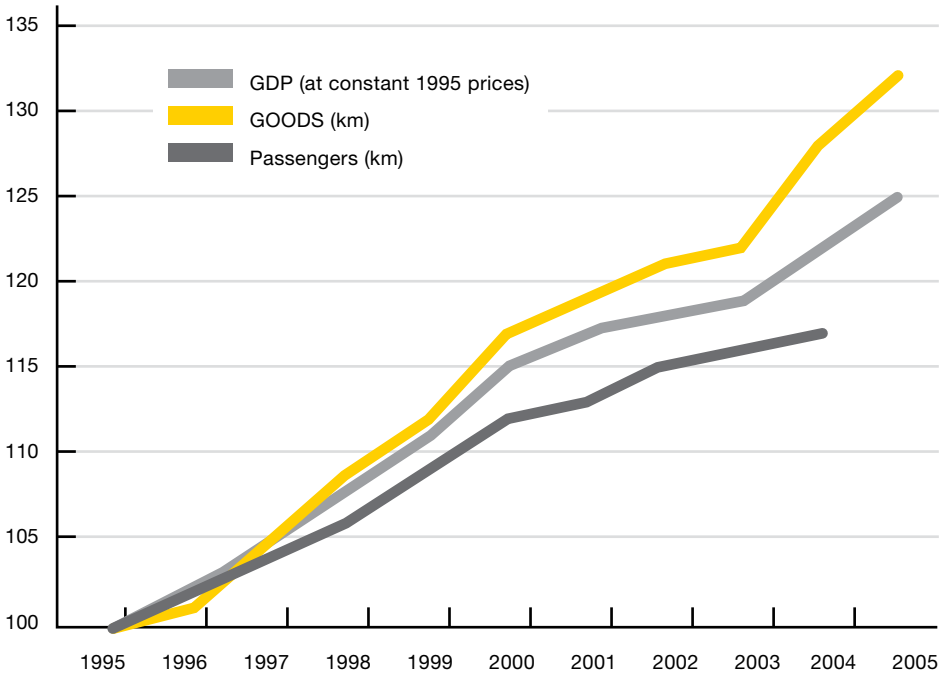
The Kapsch Telematics Platform with the four applications mentioned above is used by the Czech road authority for cost-effectively gathering real-time as well as historical traffic data as input for the national traffic management system which controls traffic on all major highways in the Czech Republic.

ETC-based **Traffic Data Capturing and Analysis.**

Traffic Management, Information and Analysis for coping with the increasing Traffic Volume.

The current traffic forecast at European level expects an average increase in the traffic performance in Europe of about 2% per year for the next 20 years. A closer look shows that the increase at major sections of the transport network (e.g. in the high-level network) will be at an even higher average growth rate of up to 4%. Especially such sections of the transport network have in many cases already reached their capacity limits today. The further expansion of these sections is difficult to finance, problematic for environmental reasons, and very often simply rejected by the population. Thus, new approaches and concepts for the optimization of the transport system will have to be found. In this context, the need for traffic management, information and planning becomes obvious.

The use of information and communication technologies helping in managing traffic and providing real time traffic information to the driver is one of the most important measures that can be taken to counter the negative effects. In addition, data from ITS applications can be used as the basis for traffic planning in order to expand the traffic infrastructure in line with demand.



Transport growth in EU 25, evolution 1995-2005 (Source: European Commission).

ETC Systems – a Cost-effective and Comprehensive Source of Traffic data.

Traffic management requires up-to-date, network-wide traffic data, which is currently collected with dedicated infrastructure (e.g. inductive loop sensors). The erection, operation and maintenance of this infrastructure is associated with high costs, and as a result, up-to-date traffic data is frequently not sufficiently available. According to the study "Telematics Applications in Road Transportation – Status and Perspectives" 1, one of the main problems in traffic control is the seamless installation of detection technology throughout the road network. According to the study, high resolution collection of traffic data is the greatest guarantee of useful results in traffic-related data processing.

In the interests of traffic planning, road authorities perform traffic counts at road cross-sections with the goal of obtaining statistics on traffic loads, traffic composition and speeds travelled. These statistics are used as the basis for determining the need for replacement and expansion of parts of the road network. The data is still frequently collected manually and requires large personnel resources, which is why the counts are often performed only in intervals of several years. Automatic road traffic counting would save costs and improve the quality and currency of the planning data.

The use of ETC systems for network-wide capturing of traffic data for traffic management as well as for traffic planning and the associated reduction in the number of dedicated sensor points offers major savings potential. In case of an all vehicle tolling system, dedicated traffic sensors can even be largely eliminated as all important traffic data can be derived directly from the toll data. Compared with conventional traffic sensors which capture traffic data at a given spot and without identifying the passing vehicles toll systems are able to provide section-based data (e.g. travel times) as well as route-specific data in addition to spot counts.

With the data traffic management centers can control traffic network-wide. The level of service can be calculated, travel time forecasts can be performed, and incidents can be detected. In addition the data can be used by the road authority for informing road users about the current traffic situation either by operating an own traffic information service or by selling the data to 3rd-parties like radio/ TV stations, internet travel portals, other telematics service providers etc. (> additional source of income). For traffic planning purposes ETC system provide comprehensive traffic statistics and allow to analyse how traffic flows through the network.

The roadside infrastructure of ETC systems (overhead bridges, power supply, data connection) can be used for the installation of further ITS equipment like installation of traffic data sensors or variable message signs, so that costs for the ETC infrastructure can be shared with other applications.

Main benefits of ETC-based traffic data capturing.

- Cost savings due to a reduced need for dedicated traffic sensors
- Better data quality (e.g. travel times for sections provide a more accurate picture about the current traffic situation than spot traffic sensors)
- New type of data available (e.g. route information of vehicles)

Overhead traffic sensors installed on existing toll station gantry (example: ASFINAG, Austria).

Available Base Data.

Depending on the technology of an ETC system there are different base data available which can be used to calculate traffic data for traffic management and planning purposes. This chapter gives an overview about the possible source data an ETC system can provide: DSRC toll data, GNSS toll data, Video/ANPR toll data, sensor data (e.g. laser scanners of enforcement stations).

DSRC

- Traffic data (current traffic situation, traffic statistics, route analysis) on tolled roads
- Vehicle tracks (station by station) on tolled roads

GNSS

- Traffic data (current traffic situation, traffic statistics, route analysis) country wide
- Vehicle tracks (permanently) country wide

ANPR

- Traffic data (current traffic situation, traffic statistics, route analysis) on tolled roads
- Vehicle tracks (station by station) on tolled roads

Sensors

- Traffic data (current traffic situation, traffic statistics)

- **DSRC toll data:** Toll data captured by DSRC roadside stations allows counting of vehicles, calculation of travel times / average speed between stations and route / flow analysis for all vehicles equipped with an OBU.

- **GNSS toll data:** Toll data captured by GNSS ETC systems can be used for generating traffic data using the Floating Car Data method. Vehicles which are equipped with an GNSS OBU can be counted for statistics purposes. Vehicle tracks can be used for tracking and flow analysis applications.

- **Video/ANPR toll data:** Video-based ETC systems as used for example in urban environments for city tolling provide raw data similar to DSRC toll data. Vehicle passages captured by video systems allow to calculate travel time between two stations, to count traffic and to do traffic flow analysis.

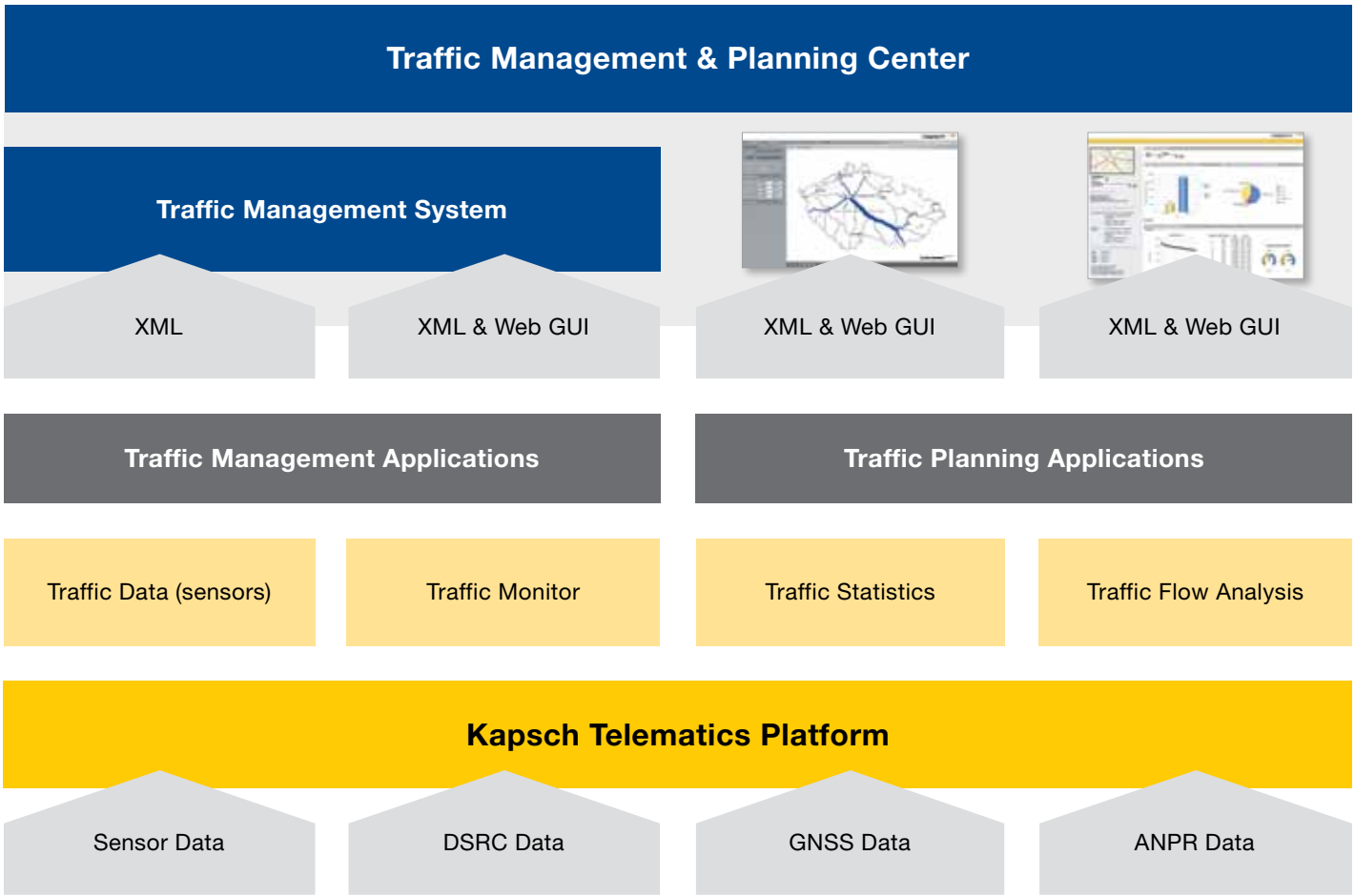
- **Sensor data:** Laser scanners of enforcement stations used for vehicle classification provide an additional source of information. The laser scanners allow to generate traffic data for all vehicles similar to conventional traffic sensors (e.g. inductive loops).

Kapsch Telematics Platform
System Description.

For implementing secondary telematics applications Kapsch offers the “Kapsch Telematics Platform” - a system allowing to collect and process data generated by Kapsch tolling systems, as well as by urban traffic, traffic law enforcement, and surveillance systems offered by Kapsch.

The platform can be referred to as a kind of “telematics toolbox” providing pre-developed applications for the most common use cases and allowing the implementation of customer-specific solutions in addition to that. The platform provides open XML interfaces allowing to couple it with external systems like traffic management centres and to integrate the ETC-based telematics applications into existing system environments.

This chapter provides an overview about the various traffic data applications of the Kapsch Telematics Platform namely a traffic monitoring application allowing to calculate travel times and level-of-service, a traffic statistics application offering a broad range of out of the box traffic statistics, a traffic flow analysis application allowing to analyse routes of vehicles, as well as an application allowing to collect traffic data from enforcement stations.



High-level system architecture of the Kapsch Telematics Platform.

Highlights and Features.

The following list summarizes highlights and features of the Kapsch Telematics Platform:

- Applications ready to use: The Kapsch Telematics Platform provides ready to use applications for traffic monitoring (average travel-time / speed calculation, level-of-service calculation), traffic statistics, traffic flow analysis, as well as for collecting traffic data provided by enforcement stations (short-term & long-term data).
- Multi-source data processing: The Kapsch Telematics Platform is able to work with various types of base data coming from Kapsch ETC systems or other ITS solutions (e.g. urban traffic solutions). Data sources can be DSRC, GNSS, ANPR, as well as sensor data.
- Dedicated data repository: The Kapsch Telematics Platform provides its own data base allowing to store, archive and analyse traffic data.
- Web front ends: The Kapsch telematics platform provides easy-to-use Web front ends for the traffic monitoring, traffic statistics, as well as the traffic flow analysis application.
- Open XML interfaces: The Kapsch Telematics Platform provides open XML web services interfaces enabling fast and easy integration into existing system environments (e.g. traffic management systems).
- User privacy: Optionally all data captured by the platform can be encrypted ensuring a maximum in user privacy.
- Scalability: The Kapsch Telematics Platform is highly scalable. The system is able to handle huge amounts of data provided by a toll system.

Following the out-of-the-box applications of the Kapsch Telematics Platform are described in more detail.

Traffic Monitor.

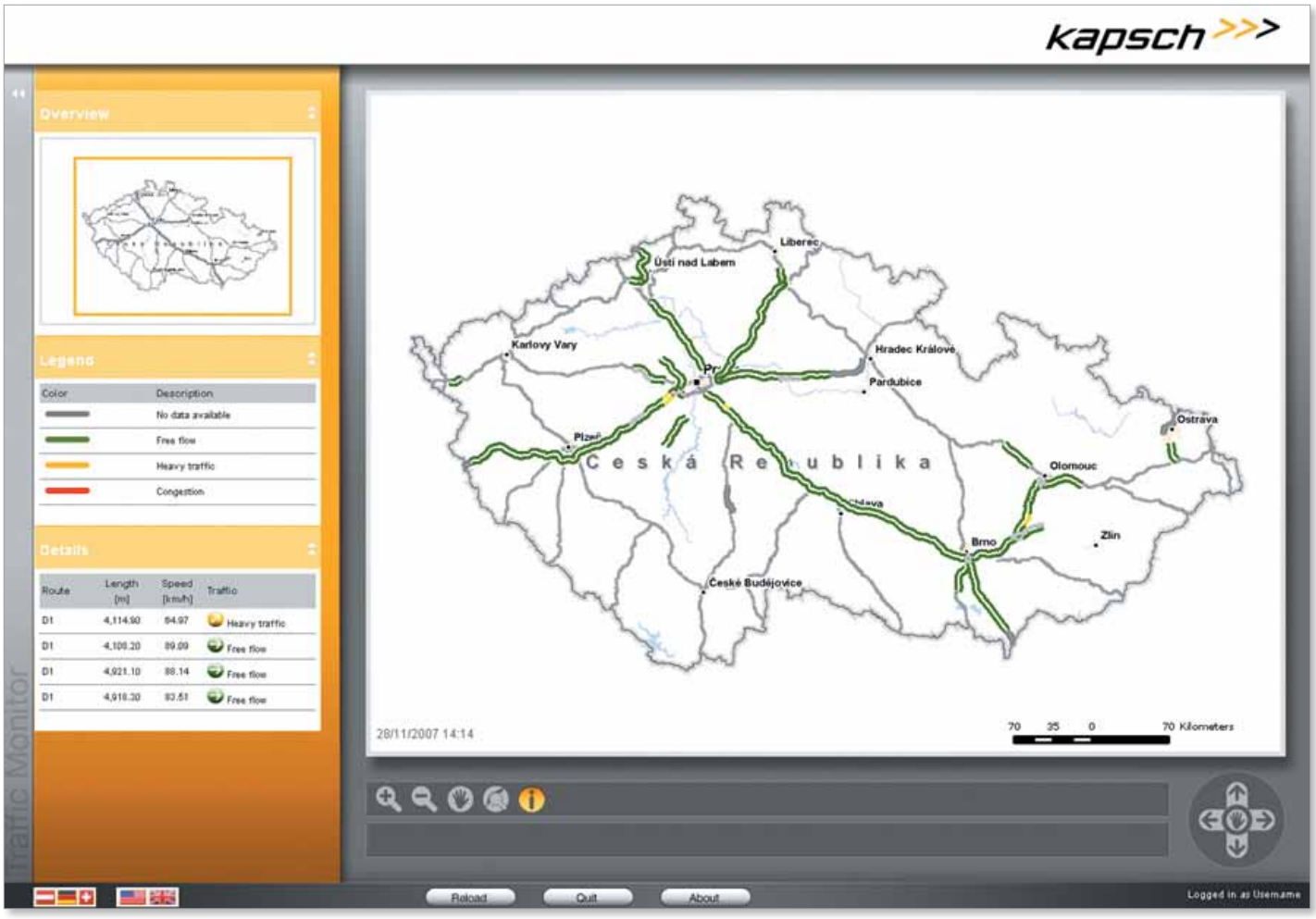
The traffic monitor is used to calculate the actual traffic situation on the road network. This application calculates actual travel times and the average speed for a dedicated road section on basis of real-time traffic data and compares these values to a base travel time. Real-time traffic data is provided by the ETC system (e.g. DSRC or video toll transactions generated by vehicles passing two subsequent toll stations). On basis of the determined travel times in relation to the base travel time the application derives level-of-service information. In addition, an extended version is able to handle data coming from Kapsch Area (GNSS toll system) using the floating car data method.

The level-of-service (LoS) is a qualitative measure describing operational conditions of a segment or traffic stream and is typically visualized as color codes representing the current status of the traffic flow on a monitored road section: Green stands for free-flow, yellow for queuing, red represents congestion. The calculation is based on the normal speed and averaged travel times.

The following levels are available:

- **Free traffic flow:** the base speed (normal speed) can be reached
- **Heavy traffic:** it is not possible at any time to reach the base speed
- **Traffic jam:** the average speed is very low, there is stop and go traffic
- **Not available:** no information available about the current situation on the road

The LoS information can be directly presented to road users via a web portal or a wireless web application. In addition, all data calculated by the application (travel times, LoS etc.) can be shared with external systems via open XML interfaces.



Sample screenshot of TrafficMonitor.

Highlights and Features.

The following table summarizes highlights and features of the Kapsch Traffic Monitor application:

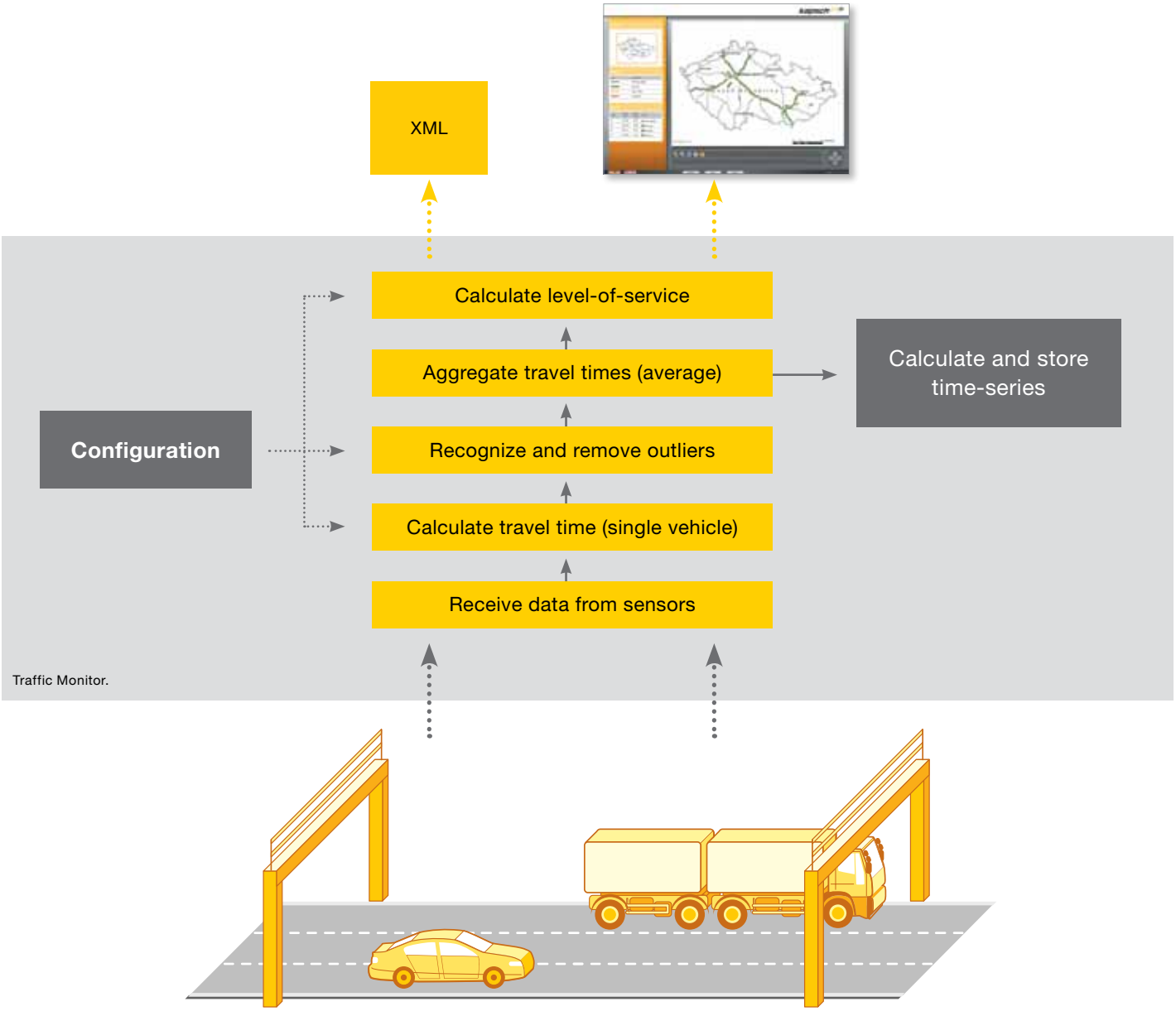
- Ready to use application for passive and active floating car data traffic monitoring
- Web GUI for provision of traffic information to road users
- XML interface for provision of traffic data to external systems (e.g. Traffic Management Centre)
- Highly configurable (e.g. monitoring interval)

Available data (per toll segment).
▪ Single travel times for all vehicles
▪ Aggregated travel times / speed (e.g. for every 5 minutes)
▪ Previous aggregated travel times to indicate trends
▪ Level of service

Technical Background.

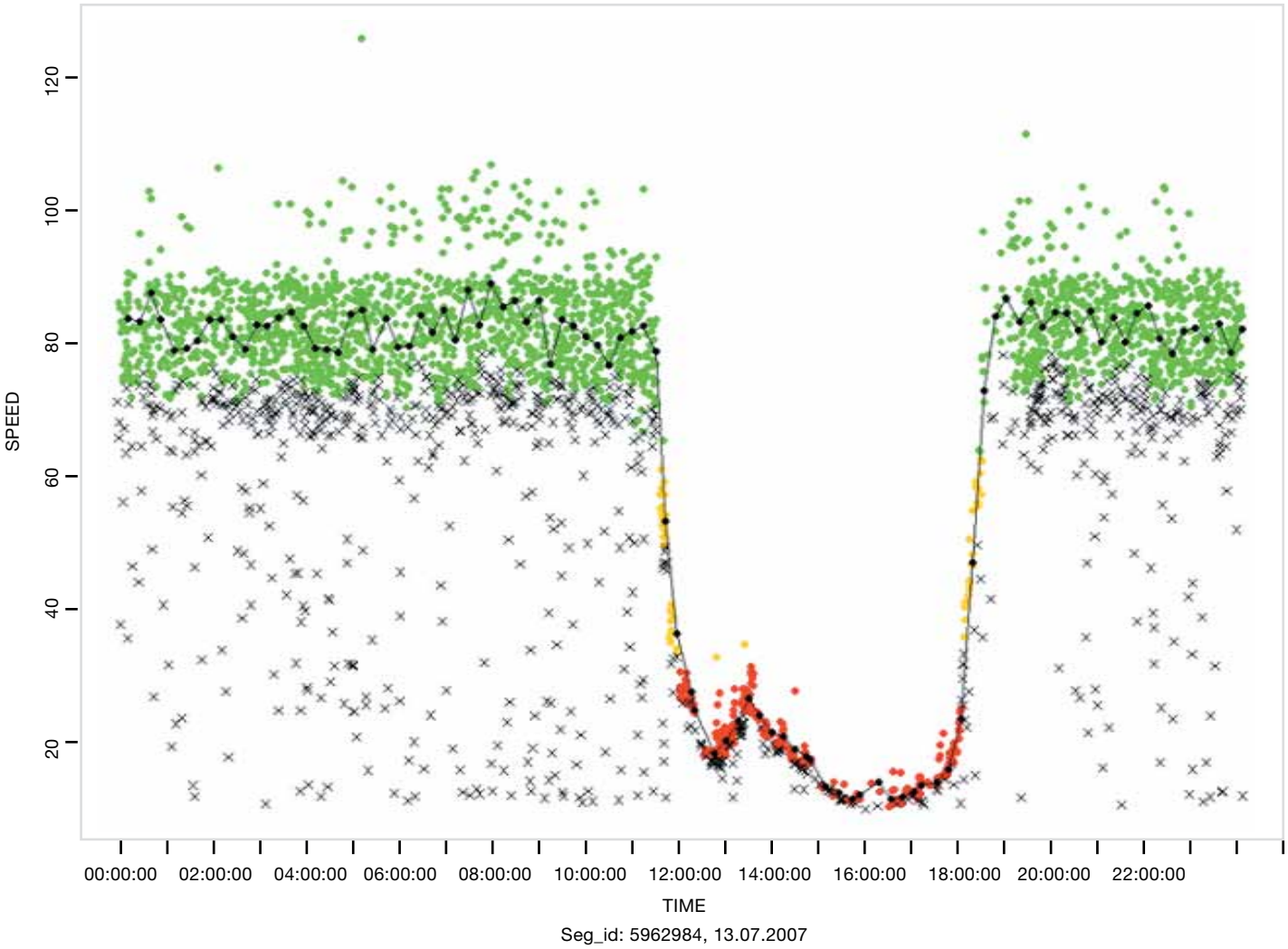
The application's design strictly follows a component model. Each component is responsible to fulfil one single step of the process cycle beginning at the data retrieval. Each processing step can be configured independently to ensure that a component can be tuned without interference of other steps. The configuration data is stored together with the application metadata in the Kapsch Telematics Platform database.

The following figure explains the processing steps of the traffic monitor system and the data flow between its components:



Traffic Monitor's processing steps.

The traffic data gained from the ETC system as traffic sensor backbone is collected continuously into a repository within the Kapsch Telematics Platform. In a pre-defined interval the data is accessed by the travel time calculation module. This module calculates the travel time between two subsequent toll stations representing one segment. A following filter mechanism detects and removes outliers and unreliable samples for "smoothing" the calculation. Then the average travel time is being calculated for the interval. Finally, the calculation module of the application derives the level-of-service for monitored road sections depending on the actual travel times compared to a pre-defined base travel time.



Time series plot of a road section in Czech Republic showing single speeds, average speed, and level of service calculated by the Traffic Monitor.

It is possible to automatically calculate the base speed on basis of historical speed data (typically these values are being captured at night time when there is little traffic and therefore an undisturbed traffic condition). If needed, the base speed of a dedicated road segment can be set manually. An individual base travel time for a segment may be predicted by traffic planners considering the geographical conditions like the road layout or base slope.

Traffic Data Collector.

An application providing data both for traffic management as well as for traffic planning purposes is the traffic data collector – a module collecting short- and long-term traffic data from enforcement stations equipped with a laser scanner for vehicle classification.

The entire application consists of a client application running on each enforcement station calculating traffic data based on raw data provided by the laser scanner. In the central back office a server application is running as part of the Kapsch Telematics Platform collecting these traffic data generated by the clients so that the data can be made available centrally to external applications like Traffic Management Centers as well as to the Traffic Statistics application of the Kapsch Telematics Platform.

Highlights and Features.

The following list summarizes highlights and features of the Kapsch Traffic Data Collector application:

- Ready to use application allowing to derive standard traffic data using the infrastructure of Kapsch enforcement stations
- Telematics Platform as central data collector
- XML interface for provision of traffic data to external systems (e.g. traffic management centre)

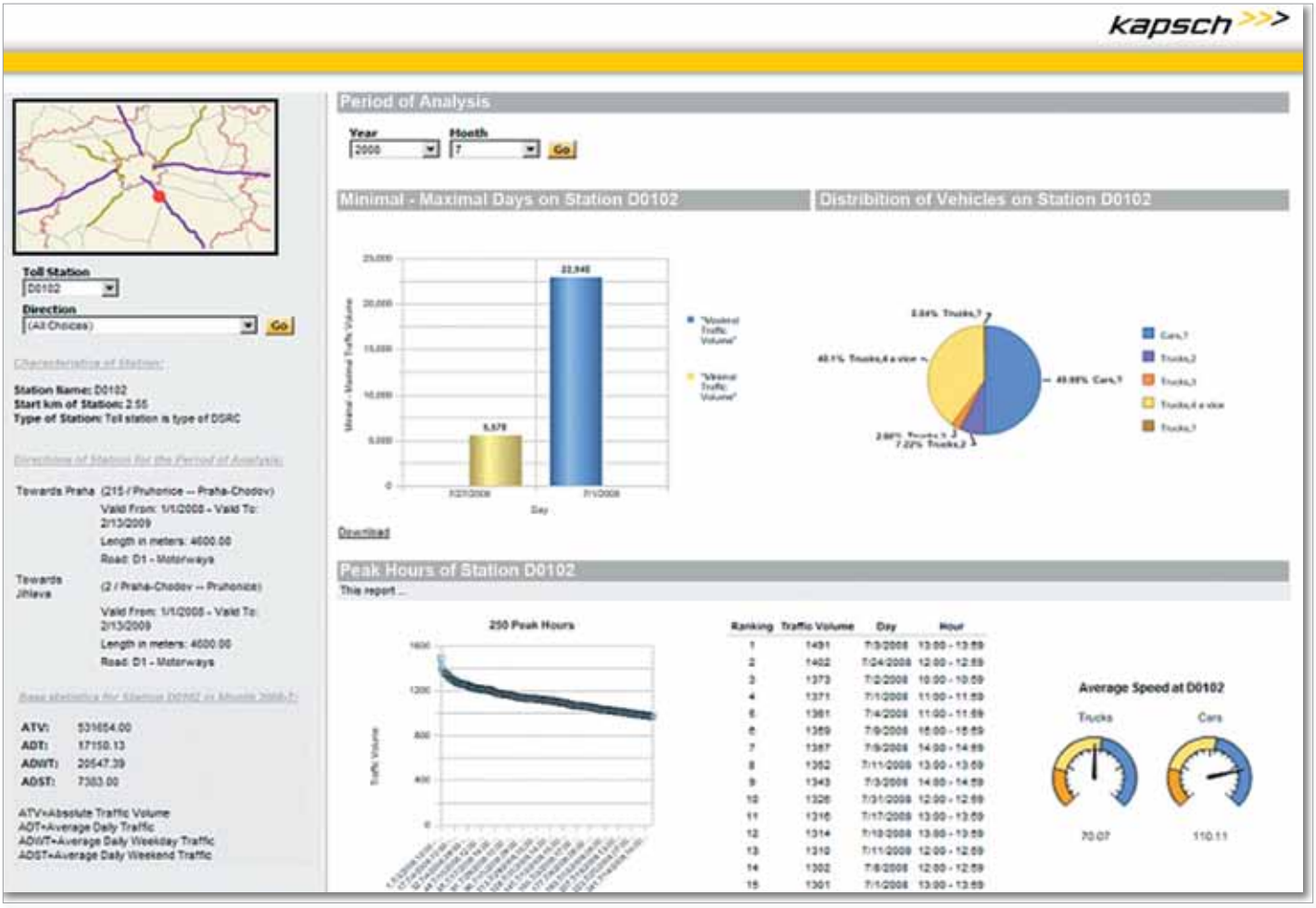
Available Data.

The client running on the enforcement stations generates both short- as well as long-term data as defined by the German TLS standard.

Available data.
Single travel times for all vehicles ▪ Traffic volume (2 classes) ▪ Mean velocity (2 classes) ▪ Smoothed mean velocity for all vehicles (1 class) ▪ Standard deviation all vehicles (1 class) ▪ Mean net time gap
Long term traffic data ▪ Traffic volume (8 classes) ▪ Mean velocity (2 classes) ▪ Standard deviation (2 classes) ▪ v85 for passenger cars (1 class)

Traffic Statistics.

This application provides statistics on the traffic volume and its development over time. The statistics form the basis for planning the transportation infrastructure and the design of traffic-controlling measures. Typical statistics are the amount of traffic per day, vehicle distributions with differentiation between passenger vehicles and trucks during peak hours and monthly peaks based on the day of the week. The statistics can be based on the DSRC, GNSS or ANPR toll data as well as on long-term data captured by the laser scanners of the enforcement stations.



Sample report of the traffic statistics application.

The Traffic Statistics application allows to generate station-based statistics (e.g. traffic volume counted at a specific station) and section-based statistics (average travel-times between two stations).

Highlights and Features.

The following list summarizes highlights and features of the Kapsch Traffic Statistics application:

- Ready to use application with Web GUI (based on Oracle BI)
- Predefined out of the box statistical reports covering the most common use cases
- Detailed traffic statistics for tolling / enforcement station
- Detailed traffic statistics for toll section
- High data quality through permanent data capturing
- Enhanced statistics through additional available data provided by toll attributes (e.g. vehicle classification, vehicle emission class, vehicle nationality)
- Dedicated data repository for statistical analysis
- XML interface for provision of traffic data to external systems (e.g. traffic simulation tools)

Available Reports.

The traffic statistics application comes with a set of pre-defined reports or the most common statistics. The following standard reports are available:

Available standard reports.

Traffic volumes
- Absolute traffic volume (emission class, axle class)
- Absolute traffic volume special hour groups (max / 6-10 /15 - 19)
- Average daily traffic (all days, working days, …)
- Minimal / maximal days
- Hourly report (min / max / Q30 / Q200 in a month)
- Traffic comparison (AWDT/AADT, ASDT/AADT per week)

Time series
- Daily time series (relative, absolute)
- Yearly time series (relative, absolute)
- Time series for special daily characters – free choose able interval (relative, absolute)
- Time series for weekly traffic (relative, absolute)

Traffic growth
- Average traffic growth rate

Sleep analysis
- Local speed distribution (hour groups)
- Momentary speed distribution (hour groups)
- Travel time comparison (to 30 night value)
- Average momentary speed (year, month, week)

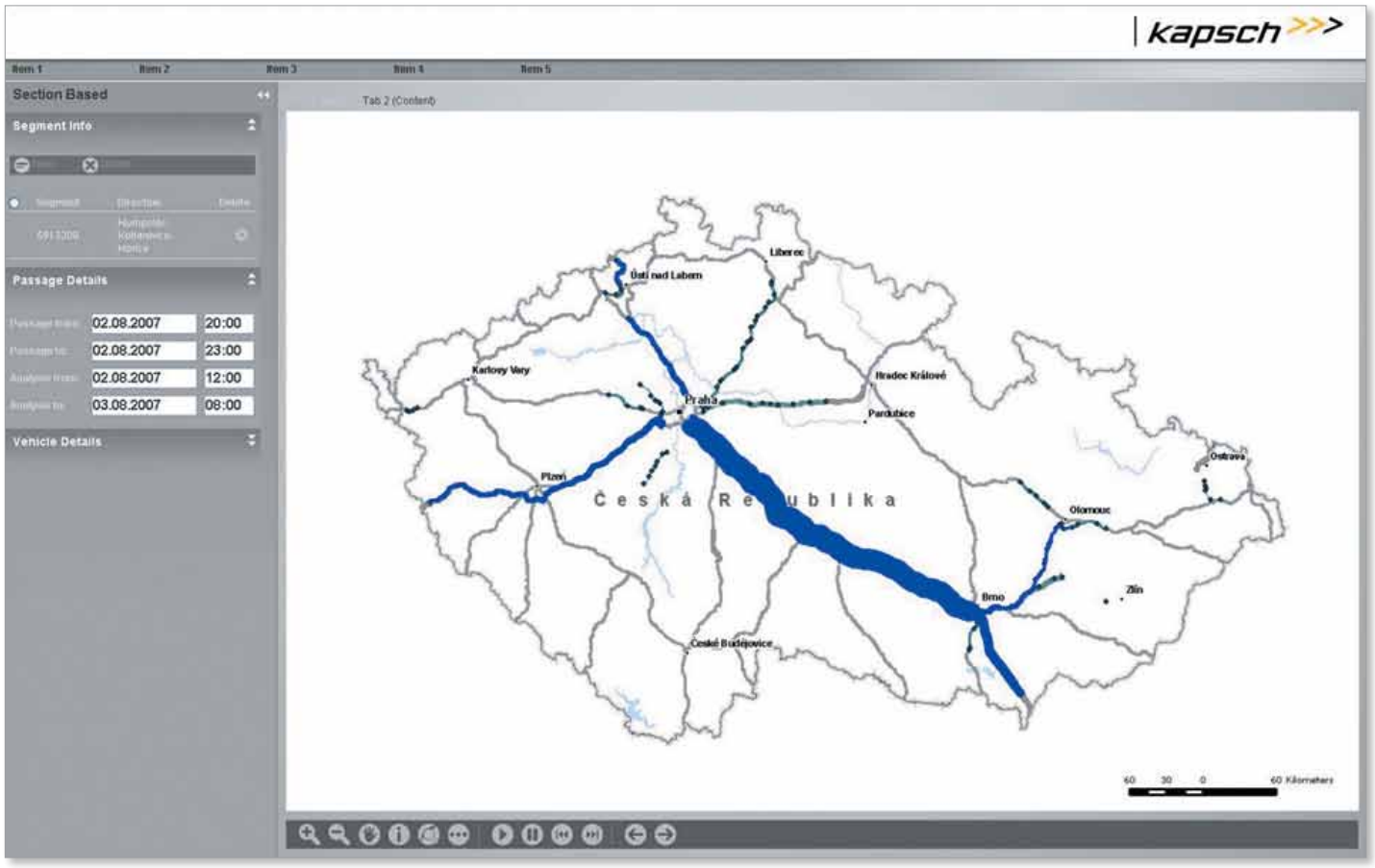
Heavy goods transports
- Ratio of heavy goods vehicle on entire traffic (1)
- Ratio of heavy goods vehicle on entire traffic (2)

Peak hours
- Ranked hourly volumes (over weeks, days, hours)
- 250 – Hours Duration Curve
- Ratio of peak hours on ADT

Traffic Flow Analysis.

This application allows to analyse the traffic flow within the tolled road network. The basis is route information of single vehicles. Routes of vehicles are determined on basis of sequences of DSRC or video toll transactions (station passages).

There is broad spectrum of use cases the application can be used for. Examples are the analysis of the traffic passing a certain station (e.g. “Where do vehicles go to after passing a station?”) or the flow between stations (e.g. “How many vehicles have driven from station A to station B and which intermediate stations have they passed?”). Based on the traffic flow analysis authorities can do road network planning and optimization or evaluation of further toll station locations for example.



Sample screenshot of a single segment based Traffic Flow Analysis.

Various types of traffic flow analyses are possible by choosing different input parameters. The three main methods for analyses are the segment-based analysis (evaluating a single toll segment), the route-based analysis (routes defined by the user by selecting multiple stations) and the detour analysis (providing the amount of vehicles which have not driven on the tolled network).

The analysis of a single segment provides information about routes of all tolled vehicles which have passed the segment in a given time (where have vehicles come from, where did they go to).

Multi-segment analysis allows to analyse routes of tolled vehicles between two or more stations. An example would be a “from-to analysis” showing routes of vehicles which have driven from A to B. A route is defined by a start station and an end station. Intermediate stations which must be passed or must not be passed can be added. Finally, the detour analysis allows to analyse possible toll detour routes. For this the user chooses toll segments asking the system to calculate the amount of vehicles which have driven on these segments (in a given timeframe) but have not used the tolled road network.

Base data for the traffic flow analysis can be DSRC, GNSS and video toll data stored in the Data Warehouse of the tolling system. Due to the very large amount of data traffic flow analysis can be performed for a maximum period of interest of 24 hours (note: these can be any 24 hours in the past for which the toll transactions are available).

Highlights and Features.

The following list summarizes highlights and features of the Kapsch TrafficFlow application:

- Ready to use application with web based GUI
- New dimension in traffic analysis through available route information
- Segment-based analysis (based on an single toll segment vehicles passing that segment in a given time frame are being analysed)
- Route-based analysis (routes defined by the user are being analysed in a given time frame (Segments can be freely combined with AND / OR / NOT operators)
- Detour analysis (analysis providing the amount of vehicles which have not driven on the tolled road network)

Examples of Traffic Flow Analyses.

The following table provides an overview about types of analysis possible with the traffic flow analysis application.

Available standard reports.
Traffic volumes ▪ Where do vehicles come from / go to which pass a certain segment (“Traffic Spider”)? ▪ How many vehicles go from A to B and which route do they take?
Transit traffic analysis ▪ What are the main transit routes in a country? ▪ How many transit vehicles are passing a certain transit route within a given time window? ▪ What vehicle classes are using certain transit routes?
Source/target traffic analysis ▪ How many vehicles are driving to a certain target / starting their trip at a certain source? ▪ Where do these vehicles come from / go to? ▪ Which highway entries/exits are most frequently used (e.g. optimal locations for gas stations, billboards etc.)?
“Refuel tourist” analysis ▪ Which border crossings are often used by refuel tourists? ▪ How many refuel tourists are passing a certain border crossing within a given time window?
Detour route analysis ▪ What are possible detour routes (detour=route on not tolled roads?) in a country? ▪ How many vehicles are using these routes?

Case Study: Kapsch Telematics Platform in **Operations in the Czech Republic.**

The Kapsch Telematics Platform is being used by RSD (Czech Road Authority) for providing input data for traffic management and traffic planning. This chapter provides a brief overview about the installation of the platform in the Czech Republic.

Czech Truck Tolling System.

On 1st January 2007 the Czech Republic's nationwide electronic toll collection system "MYTO CZ" started commercial operation. One year later the system had expanded to cover 1180 km of elected highways and motorways, while around 375.000 On-Board Units (OBUs) had been registered.

Facts & Figures.	Czech HGV tolling system.
Owner	Czech road authority
Operator	Kapsch Telematics Services CZ
Start of operations	1.1.2007
Implementation phase	9 months
Income per year	223 Mio EUR (in 2009)
Payback period	6 months
Average toll per km	0,16 EUR (in 2007)
Average toll transaction per day	650.000 (in 2007)
Vehicles subject to toll	HGV > 3,5 tons2
Toll parameters	#axles, emission class
Network length (tolled roads)	1.200 km
Road types	Highways, selected level 1 roads
Transaction performance	Above 99.7%
Toll sections	480
Toll stations	240
Enforcement stations (Stationary)	40
Mobile enforcement vehicles	30

MYTO CZ

The Czech Government also needed to safeguard and maximise return on its investment by ensuring the system could be adapted to support future developments without compromising existing functionality. This might include, for example, adding vehicle classes, and supporting wider traffic management, road safety and other telematic functions. Already the system has been augmented to extend its role as a traffic management and traffic planning tool, demonstrating the soundness of an approach based on investing in a solid, revenue-generating system.

Kapsch Telematics Platform providing data for the National Traffic Management Center.

Based on the DSRC toll data of the ETC system, traffic data are being derived by RSD cost efficiently. For traffic management and traffic planning purposes accurate real-time as well as historical traffic data is generated on basis of the electronic toll system.

For this the Kapsch Telematics Platform is being used allowing the Czech road authority to capture travel times, level-of-service, traffic statistics as well as traffic flow analysis data for the entire tolled road network in a cost efficient manner and feed that data via open XML interfaces to the Czech National Traffic Management Center located in Ostrawa. There the data is being used for controlling traffic and to plan traffic infrastructure in line with demand.

Data flow of generating traffic data based on toll data. (left side) traffic situation on CZ highways derived from toll data.

Kapsch Group.
Kapsch is one of Austria's most successful technology corporations, specialized in the future-oriented market segments of Intelligent Transportation Systems (ITS), Railway and Public Operator Telecommunications as well as Information and Communications Technology (ICT). Kapsch. Always one step ahead.

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