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Smart telematics enabling efficient rail transport – development of the ViWaS research and development project

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Abstract

Single wagonload (SWL) transport is a major component in European rail transport systems and in the logistics of different industrial sectors such as steel, chemical and automotive. However, changing framework conditions and increasingly demanding market requirements have led to dramatic losses of market share and even to complete shutdown of SWL business in some countries. As this business segment has been evaluated as an important component of the European co-modal transport system also in the future, significant improvements are needed. The ViWaS project develops and proposes solutions which contribute to a raised competitiveness of SWL in Europe.

Unlike in road transport, load tracking and tracing is still not widely used in SWL. ViWaS seeks to accelerate the introduction of communication technology in rail freight. With on-board communication technology freight operators improve the dispatching of wagons and the rescheduling processes in case of disturbances. Based on reliable on-line telematics data, the dispatchers will be able to inform their customers about changes in the transport schedule earlier than today, increasing the reliability and satisfying the stakeholders.

Cost-efficient and intelligent telematics-based information services enable real-time wagon tracking and automatically depict wagon mileage information. The telematics data service will generate the required information which is necessary for a reliable quality recording. With this additional information, the current life cycle of freight wagons of six years will be optimised. Since the accident of Viareggio, the railway authorities are requesting documentation of wagon mileage. A small electronic mile--counter with a radio link to the telematics device RodoTAG® overtakes the RU's responsibility of wheel-set individual mileage counting. Based on long term experiences with NavMaster telematics, Eureka defined a list of requirements for the system design

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“small, lightweight and cost reducing”, resulting in a completely new system concept: The ViWaS telematics PCB is very small sized and equipped with a low power multi-GNSS (GPS, GLONASS, Galileo, QZSS and SBAS) circuit. With the new GSM and GPS modules, a significant cost reduction could be achieved, interfaces for complementing sensors as e.g. shock detection, digital/analogue inputs/outputs, etc. are integrated. In addition, based on the analysis of user requirements the development of a reliable load sensing technology for freight cars has been launched. This request is a result of the fact that today most of the freight cars in railway operation do not use the full load capacity as there is no existing cost-effective possibility to measure the load especially during the filling-up process e.g. in the area of bulk freight. If the wagon would be overloaded and afterwards moved by a train, all wheel sets have to be exchanged for a costly inspection in a workshop. Thus, the freight car will not be filled to its maximum payload resulting in reduced capacity and higher costs. In order to optimise the dispatching processes wagons will transmit their load status, enabling the dispatchers to re-dispatch the wagon in short time after unloading leading to shorter standstill times and higher wagon efficiency.

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Keywords: ViWaS; rail freight traffic; aJour telematics; GPS; Galileo; tracking; RodoTAG; wheelset mileage; loading sensor; Industry 4.0

1. Background and objectives

Nomenclature

Eureka	**Eureka** Navigation Solutions AG
SWL	**S**ingle **W**agon **L**oad **T**raffic
ViWaS	**Vi**able **Wa**gonload production **S**chemes
WPAN	**W**ireless **P**rivate **A**rea **N**etwork
ECM	**E**ntity in **C**harge of **M**aintenance

1.1. Current situation of SWL rail freight transport

In road transportation approximately 85% of trucks are equipped with telematics systems that monitor the vehicle’s condition, track its position and offers direct communication to the driver via mobile phone. The fleet management gets real-time information and has even redundant ways to communicate with the transport, in case of problems. The rail freight transportation is traditionally operating their transports using infrastructure-based information sources. Therefore, the wagons are in general not equipped with wagon-based monitoring and communication equipment like telematics systems and sensors. The result is a constant loss of time critical goods to road transportation. Figure 1 compares the communication abilities of road and railroad transports assets.

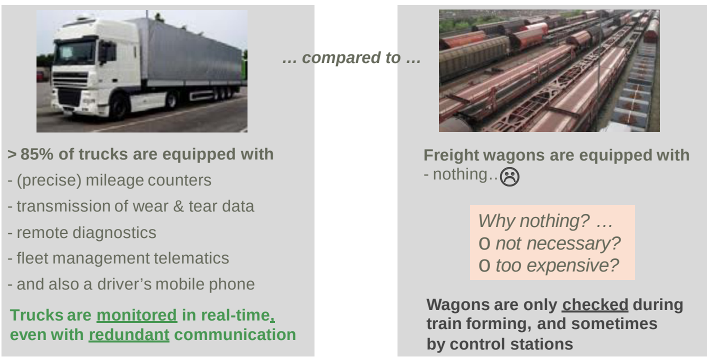

Fig. 1. Today’s communication of road and railroad transport assets (source: Eureka).

ViWaS seeks to accelerate the introduction of communication technology in rail freight. With on-board communication technology, freight operators improve the dispatching of wagons and the rescheduling processes in case of disturbances. Based on reliable on-line telematics data, the dispatchers will be able to inform their customers about changes in the transport schedule earlier than today, increasing the reliability and satisfying the stakeholders.

1.2. Eureka's contribution to the ViWaS project

Eureka's telematics team has an experience of more than 15 years in the development of telematics systems for railway applications. At the beginning of the ViWaS project in 2012, a deep analysis of the railway's demands for logistics and asset condition information has been accomplished by the team. The evaluation of several use cases and many interviews with shippers, train operators and wagon keepers have shown that there is a high interest in on--wagon telematics, but the existing systems were not practice friendly and too expensive for professional implementations. The analysis also showed the lack of a sufficient presentation and distribution of the telematics information to the different stakeholders of transport and the technical wagon management. Eureka has identified three main objectives for the ViWaS developments:

1. Development of a new telematics system with simplified installation and service.
2. Implementation of a wireless wagon network together with a smart load sensor.
3. Development of an IT platform for telematics information presentation and distribution.

A general requirement for a cost reduction of more than 50% was defined for the investment in the new telematics and also for the installation and its operation for a time period of 6 years.

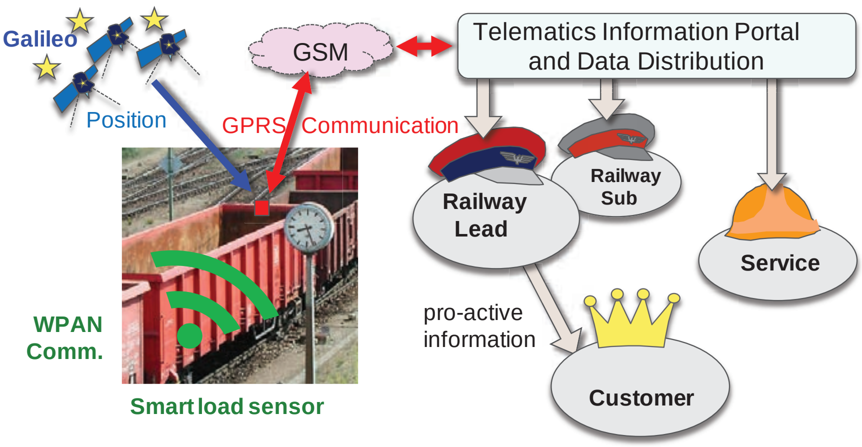

Fig. 2. Smart Wagon Telematics (source: Eureka).

2. Development of a smart wagon telematics within the ViWaS Project

2.1. The new "aJour Telematics" for freight wagons

The list of requirements for the new telematics was quite comprehensive and contained several goal conflicts. Finding the best solution was therefore typically a balancing of different characteristics like "small housing" versus "high functionality with longest battery operation". As a first step, the most optimized housing size ratio was evaluated. For the various wagon types and wagon constructions, it was clear that a universal mounting concept will require different sizes and device proportions. The requirement of a battery change by the user leads into an extended discussion of warranty issues due to possible damages of housing seals. As a result, having a complete extra housing for the battery was identified as the best solution. This construction idea was additionally beneficial as a flexible size ratio could be realised. A cable connection between battery and electronics housing allows both boxes to be arranged in different orientations. Figure 3 shows the design of the main components. This final construction resulted in a very stable and extreme watertight housing design. Condensation of humid air inside the housing is a very critical reason for corrosion of the electronics. Therefore, the sealing was designed to be gas tight, even over temperature range. This was verified by air pressure tests according to DIN 60068 2-2 in a climate chamber.

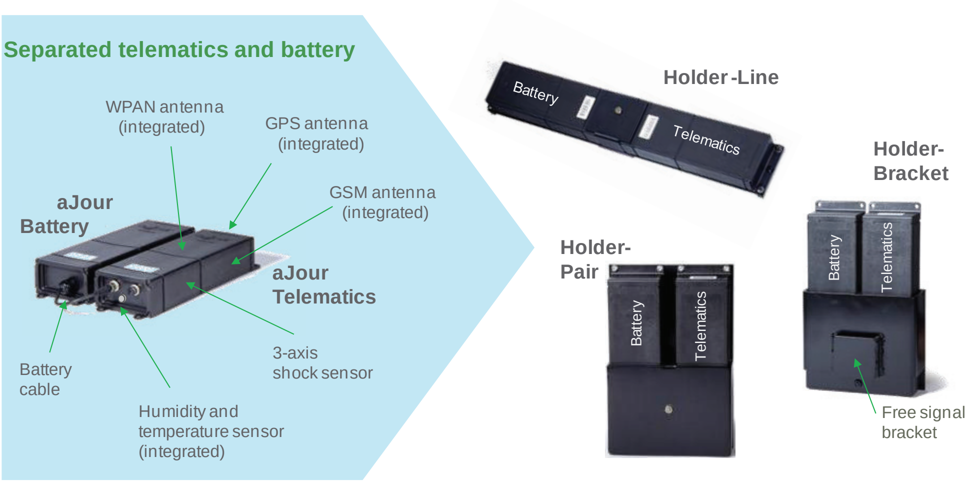

Fig. 3. Final design of aJour Telematics, aJour Battery and three different mounting holders (source: Eureka).

Within the demonstration phase of the ViWaS project, the telematics components were tested on many different wagon types and even on a flat container platform. Figure 4 gives an overview of practical evaluated applications.

Fig. 4. aJour Telematics installation examples (source: Eureka).

Workers have been trained in the installation and have given an important practical feedback about their experience with the handling of the system. As a result, all installation and service processes are optimized and well documented. The telematics mounting plate may be welded by a railway workshop, or could also be screwed to a wagon. Practical verifications proved that a mobile field service is able to mount the equipment in less than half an hour to a wagon. Such an in-field installation e.g. at a loading site avoids the effort and financial loss of a wagon downtime for several days.

2.2. Functionality of the new telematics

The new electronics design and the use of the most advanced components allowed a significant extension of the functionality and number of transmitted messages, while keeping the maintenance free operation at 6 years and more. The established standard functions of the telematics, shown in Figure 4, have been overtaken to the new system generation. The new type of motion sensor inside the telematics unit now allows an individual configuration of the sensor characteristic to the mechanical behavior of the tracked object.

Fig. 5. Telematics standard functions (source: Eureka).

Most of the railways and wagon keepers reported interest in a monitoring of the wagon and load condition. Wagon keepers mainly asked for information from their assets to reorganize the wagon maintenance form today's fixed maintenance periods (e.g. 6 years) to mileage-based periods or even condition-based maintenance. Therefore the new system is able to supply a mileage information based on GPS distances, or a wheelset monitoring with many more information using an additional RodoTAG sensor on an axle. A 3 axis shock detection was requested either from wagon keepers as well as from railways to get an automated reporting in case of mishandling of the wagon. These alarm reports include date/time, max. g value, XYZ-direction and also the GPS position where the impact occurred. Several goods, which are mainly transported on rail, have be transported within a specific temperature range like fresh products or chocolate and some products are sensitive to humidity like steel coils. Condition monitoring demands as shown in Figure 6 can now be solved with specific sensors, which can be inbuilt in the telematics or directly placed close to the goods by using the new smart sensor ConnTAG. The telematics device is able to measure these parameters and compare them with configurable thresholds. In case of a violation, the telematics measures its position and sends an alarm message.

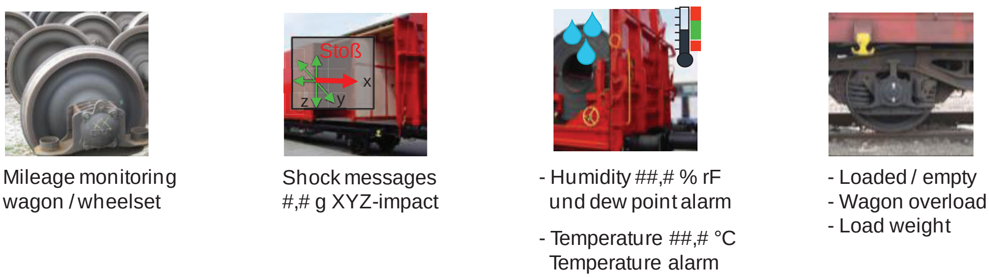

Fig. 6. Telematics extended with condition monitoring functionality (source: Eureka).

Several shippers, railway undertakers, wagon keepers and maintenance service suppliers were asked regarding benefits and consequences if a reliable load sensing technology would be available for freight cars:

- Is the wagon still loaded? When can the wagon be dispatched for the next transport?
- Is the max. axle load exceeded? May additional weight be added, or is the wagon overloaded?
- What was the transported weight of the load? This could be used in future for a billing process.

The evaluation showed that the railways and also the wagon keepers have high interest in answering these daily questions. Therefore the ViWaS Project was extended by a development of a load sensor functionality that answers the questions above.

3. Implementation of a wireless wagon network together with a smart load sensor

3.1. WPAN – wireless wagon data network

One of the design goals for the ViWaS development was to make the new system easy to install. The demand for additional sensors, which have to be separate from the telematics device e.g. mileage on the axle, load sensor on the boogie, however conflicted with a necessary cabling to connect these sensors. Moreover, cable installations on wagons have always shown that they are endangered by sabotage and theft

In a previous project, the Eureka team had developed a wireless data radio based on the public 868 MHz frequency. This WPAN (Wireless Private Area Network) was mainly used to transmit mileage data from the RodoTAG smart sensor to stationary hotspots, installed in railway yards. Practical tests showed that this technology offers a very energy efficient and reliable communication around freight cars. Based on these experiences a small WPAN module was developed that could be integrated in the ViWaS telematics.

The result is a wireless network as described in Figure 7, which is able to connect energy autonomous smart sensors to the telematics device. During the demonstration phase the reliability of this communication could be proofed under real railway conditions. The communication is stable within a range of 30 to 50 meters around the telematics device. Even sensors placed inside of sliding wall wagons where able to transmit their data to telematics units installed outside of the front wall of the wagon.

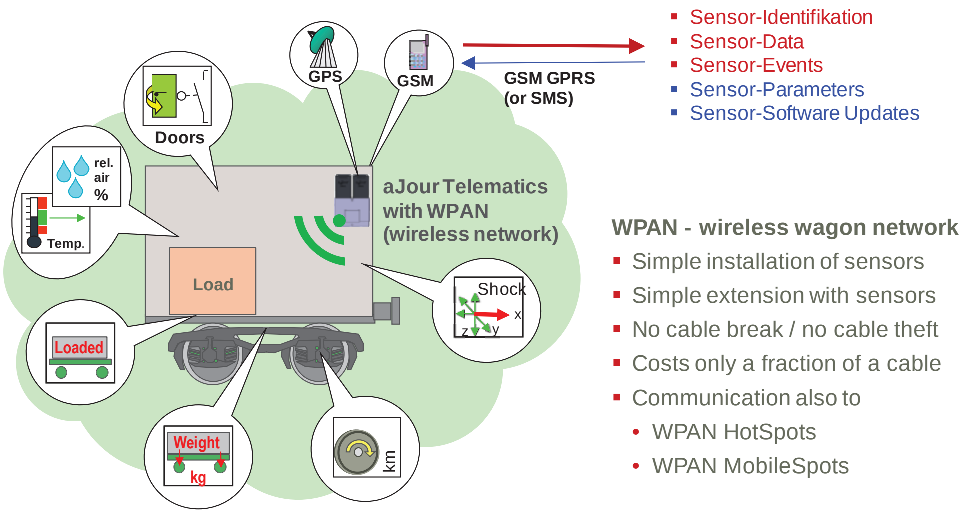

Fig. 7. WPAN (Wireless Private Area Network) enables cable free installations of sensors (source: Eureka).

3.2. What are Smart Sensors and how are they related to the "Internet of Things" and "Industry 4.0"?

Smart Sensors or also called "Intelligent Sensors" are typically tiny little devices with sensors that are able to process the measured signals according to thresholds, other mathematical functions, or logical rules. A smart sensor has the ability to communicate its results and status if a data network is in reach. The wireless communication together with an inbuilt long term battery offers a maintenance free operation for many years. Smart sensor applications using network destinations the Internet are also called "Internet of Things" or discussed as "Industry 4.0".

Eureka has already developed two types of smart sensors, both equipped with a WPAN communication and Gateways to the Internet. Figure 8 shows the main features of both smart sensors.

The wheelset monitoring sensor RodoTAG offers a precise mileage counting functionality for wheelsets and Wagons. This smart sensor is mounted on the wheelset axle and operates for 600,000 km or 8 years. Additional functions like flat wheel and wheel blocking detection are in further development.

The universal ConnTAG smart sensor can be configured for many different tasks. It is equipped with several inbuilt sensors and it offers an electrical connection to an external sensor like a pressure sensor or door contacts. The internal tilting sensor offers an angle resolution of a few degrees. Mounted on the mechanical rods behind the hand brake handle or the Empty/Loaded handle of the wagon, the smart sensor is able to detect the actual handle position by measuring its current angle compared to the center of gravity.

Fig. 8. RodoTAG and ConnTAG smart sensors (source: Eureka).

3.3. Development of a Smart Sensor to measure wagon load

During the conception of the Smart Load-Sensor the functionalities, product properties and business cases were taken into account. The final specification defined three different functionalities:

1. The wagon is "Empty" or "Loaded" information
2. The wagon has an "Overweight or "No Overweight"
3. The weight of the wagon's payload is xx.xxx kg

The goal was to develop a sensor system for reasonable cost that is able to solve the three different requirements of load related information with a saleable technology and software. The best measurement points for load information were located at the boogie structure. Therefore, the development of an extended version of the universal smart sensor ConnTAG was initiated to test a weighing of wagons within the ViWaS project. Figure 9 outlines the system concept of the load sensor.

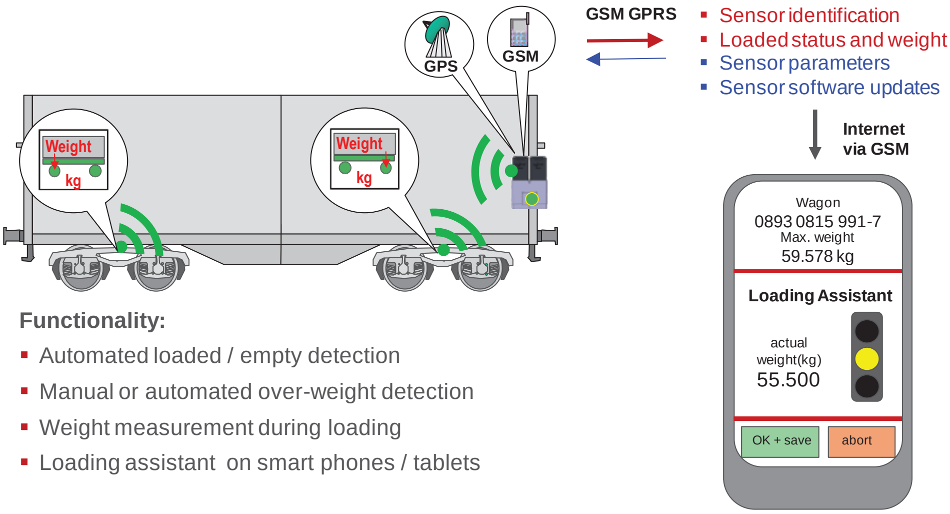

Fig. 9. System concept of smart load sensor (source: Eureka).

The practical field tests of the smart load sensor system started in summer 2015 and current results confirm that the system is working properly. Figure 10 illustrates the calibration and verification of the weighing sensor system. The detection of a "Loaded" or "Empty" condition requires one sensor only, whereas overweight detection and weighing implementations require two, or better four sensors.

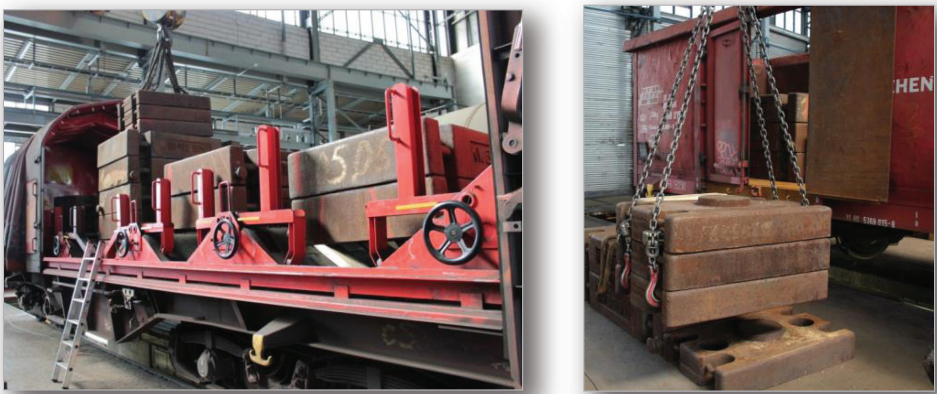

Fig. 10. Installation and intensive testing of the system (source: Eureka).

3.4. Benefits of the smart loading sensor for the different stakeholders

Shippers may have the highest benefit from the system by using the loading assistant software application. Today, most of the freight cars in railway operation do not use the full load capacity as there is no existing cost--effective possibility to measure the load during the filling-up process e.g. of bulk freight. If the wagon would be overloaded and afterwards moved by a train, all wheel sets have to be exchanged for a costly inspection in a workshop. Wagon keepers estimate cost between 4,000 and 8,000 Euro for such cases. Thus, the freight cars are typically not filled to its maximum payload resulting in reduced capacity and higher transportation costs. The loading assistant function (see Fig.9) is now able to visualize the measured weight of the wagon to the loading personnel using a tablet or a smart phone. A graphical green/yellow/red indicator on the display gives a clear signal to loader in order to add, or reduce the payload weight. The loading is finished and and the weight confirmed when the operator presses the “OK and save” button.

The railways benefit from less costly processes, as wagons with load sensor do not have to be transported via a weighing station, as well as less effort with wagons that are caught with overweight. Another benefit is the optimization of the dispatching processes with wagons that transmit their load status. The dispatcher is able to re--dispatch the wagon in short time after the wagon shows an “Empty” status. This will lead to shorter standstill times and higher wagon efficiency.

The wagon keeper or ECM benefits from wagons, which are not pulled with overweight as he is responsible for the safety of his wagons. The knowledge of the loading status or even better the weight could additionally be used to calculate the ton-kilometres performed for the wagon. This parameter is ideal for the prediction of preventive maintenance tasks.

4. Development of an IT platform for telematics information presentation and distribution

The main requirement for the new IT platform development in ViWaS was the demand for an infrastructure independent transport monitoring system, capable to serve the different stakeholders: railway operators, wagon keepers and shippers with adequate information according to their specific needs. One of the critical issues was the implementation of a rights concept that allows a high flexibility of data exchange and on the other hand a clear and strict data security with the handling of data of different customers. Therefore, the visibility of data is restricted according to the ownership of related wagons and telematics devices. Cases of a temporary relation e.g. wagon rental are also restricted to the certain time period.

The new platform offers a Web interface for three different main-roles of users: Administrators, Operators and so called Observers. These roles define in general the visibility of certain information and the right to change system settings. The Administrator for instance may add additional Operators or Observers. He has also the right to see all data of his related telematics devices and smart sensors and may even change their configuration settings by sending Configuration-Commands. The Operator sees the last telematics data and the history of his wagons like position, next railway station, speed, temperature, humidity and many more. The Observer role is restricted to view the last information, only.

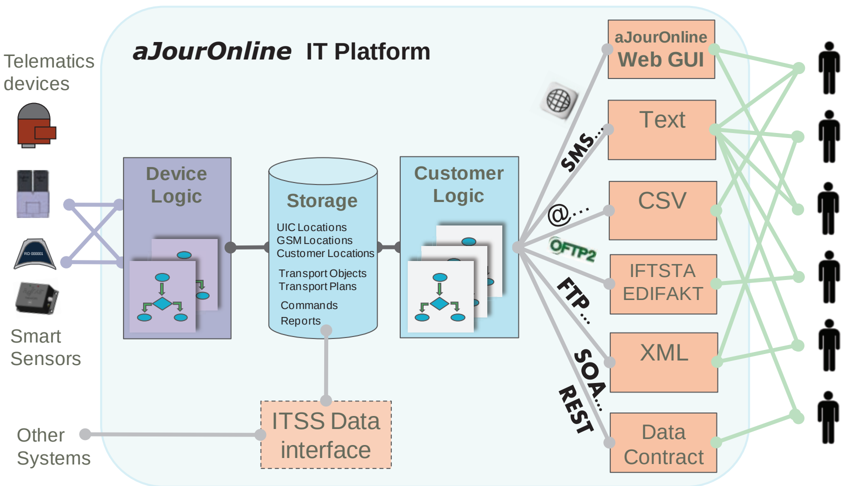

Fig. 11. System overview of the aJourOnline IT platform (source: Eureka).

The software platform, shown in Figure 11 and Figure 12, is programmed in a modular way, allowing an easy introduction of new protocols, formats and usages. It also includes interfaces to adapt it to existing software solutions on the client side.

Eureka is one of the founders of the ITSS practice group, which has defined an open, free of charge data exchange standard for telematics data of different telematics suppliers. The requirement for such a data exchange format was initiated by the TIS working group, consisting of major railway undertakers, wagon keepers and shippers. An implementation of the ITSS data interface is planned for 2016.

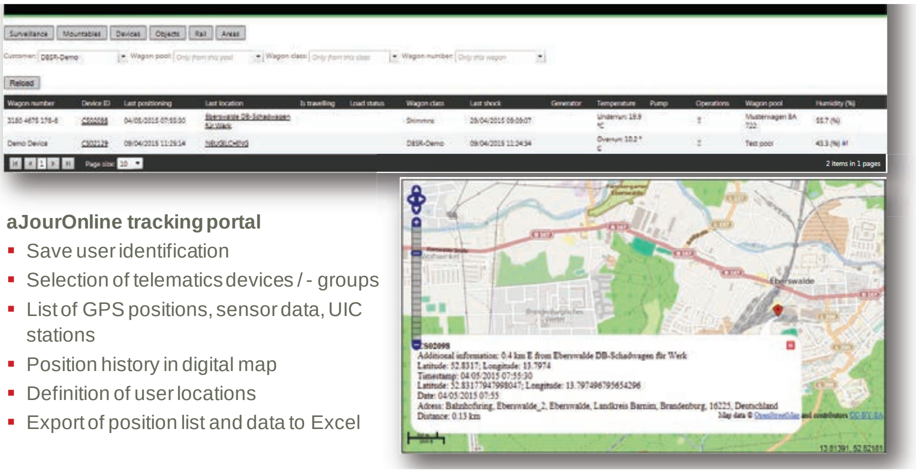

Fig. 12. Example screen of the aJourOnline IT platform (source: Eureka).

5. Final conclusion

The ViWaS project team has developped a telematics solution that fulfills all requirements and key performance indicators, which were defined together with the railway operators and wagon keepers.

These aJour Telematics systems and the RodoTAG smart sensor are now in series production. The Smart Load Sensor is installed on a fleet of wagons and will be tested for several months. The aJourOnline platform is in live operation and many railways are already using it for their daily dispatching of wagons.

The total cost of the wagon telematics including installation and the operational cost could be reduced within the ViWaS project by more than 50%.

It is of high importance that the investing party has a vital interest in the benefit of its investment. An investment in wagon telematics will lead to less cost and a higher turnover. One of the critical hints of a large implementation of wagon telematics seems to be the fact that all three parties: shipper, railway and wagon keeper will share the “less cost” benefit. But this distribution of benefits might also has lead to a “wait and see” behavior of many railway stakeholders compared to their competiors of road transportation.