Chapter 25
Intelligent Transport Systems for Road Freight Transport—An Overview

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Abstract This paper presents a state-of-the-art analysis of Intelligent Transport Systems (ITS) for road freight transport including an overview of telematics applications for road freight transport. Furthermore, an analysis on how different actors of a transport chain perceive the developments of ITS is given. The paper also presents selected examples of practical ITS usage.

Keywords Intelligent Transport Systems (ITS) · Road freight transport · Telematics

25.1 Problem Background and Research Questions

The majority of freight transport in Germany is carried out by trucks using the road network (Mondragon et al. 2009) and it is expected that this dominance will continue in the future. However, investments into road infrastructure will not increase in the future thus there is a need for technological systems which control the traffic flows on roads, try to avoid traffic disturbances, as well as to ensure increased road safety. In addition, such systems could also improve the efficiency and productivity of public and private fleets. These systems are known as Intelligent Transport Systems (ITS) or telematics and are defined by Müller (2012) as the process of data collection, processing, and output which achieves goals by using sensors, information and communication technology, and mathematical models. As ITS also allows autonomous decision making on a vehicle by vehicle basis, it is important to know how different user groups of a transport chain accept ITS and its consequences.

In this paper, we want to present a state-of-the-art analysis of the current progress in the field of road freight related ITS as well as a critical reflection on these developments from the perspective of different user groups. This includes a

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M. Freitag et al. (eds.), *Dynamics in Logistics*, Lecture Notes in Logistics,
DOI 10.1007/978-3-319-45117-6_25

presentation of the advantages and disadvantages of ITS and an elaboration into potential future developments. The paper is driven by the two following research questions, which are answered by using secondary data, as well as on the findings of three expert interviews representing the view of a transport provider, a professional truck driver, and a software programmer:

(a) What are the application areas for ITS in the field of freight road transport and which kind of systems are utilized?
(b) How do different user groups of a transport chain evaluate current ITS developments?

The remainder of the paper is as follows: After a short introduction, we present a short description of the basic set up of ITS based on the notions of Sussman (2005). Then, we show the main application areas of ITS for road freight transport including some examples of how ITS is currently used. Afterwards, we discuss these developments from the perspective of the different user groups. The paper closes with a critical reflection and an outlook for future research.

25.2 Fundamentals on ITS

Any ITS consists of several system components including a communication infrastructure, a service provider, positioning systems, end user devices, and systems for external information provision (Sussman 2005). Global navigation satellite systems (GNSS) are a fundamental part of ITS as they allow positioning while the vehicle moves. At least four satellites are required for exact positioning for route navigation (Evers 1998). The most prominent GNSS are the US-American GPS, the Russian GLONASS, and the European Galileo system. Communication systems refer to monodirectional and bidirectional communication networks based on radio, mobile, and satellite frequency (ESA 2011). Furthermore, telematics standards include Open Service Gateway initiative Alliance (OSGi Alliance), The Motor Industry Software Reliability Association (MISRA), open systems and their interfaces for electronics inside motor vehicles in cooperation with the Vehicle Distributed Executive (OSEK/VDX), and ERTICO-ITS Europe. Sussman (2005) divides ITS into the following six categories: (1) Advanced Traffic Management Systems (ATMS), (2) Advanced Traveller Information Systems (ATIS), (3) Advanced Vehicle Control System (AVCS), (4) Commercial Vehicle Operations (CVO), (5) Advanced Public Transportation Systems (APTS) and (6) Advanced Rural Transportation Systems (ARTS). For freight road transport, AVCS as well as CVO systems are of special importance. AVCS helps drivers to keep control over the vehicle while CVO systems ensure the improvement of efficiency, safety, and other controls of the transport.

25.3 ITS for Road Freight Transport

Access to current information on the traffic situation, weather, as well as cargo conditions is crucial for operating road freight transport in an efficient way. A continuous surveillance of the involved road freight transport processes further allow for a better foundation for long-term as well as short-term planning, thus leading to improved profitability as well as savings potentials due to reduced transport efforts. In the following section, we discuss eight ITS areas as suggested by Sussman (2005) and the German Research Information System (FIS) (2015). These ITS application areas for freight road transport refer to (1) fleet management, (2) toll collection and control, (3) tracking and tracing, (4) emergency and disturbance management, (5) control of public traffic systems, (6) provision of traffic information, (7) control of hazardous goods and heavy bulk transports, and (8) primary traffic control units (Baumann 2011). Most of these application areas belong to the field of Commercial Vehicle Operations (CVO) (see Sussman 2005). Fleet management can be considered to be the most prominent application area within road freight transport as it includes the processing of order and traffic information and the adequate provision of data for drivers. Permanent surveillance, securing and control of hazardous goods or heavy load transports is also an important ITS application area. The use of sensors may refer to Advanced Vehicle Control Systems (AVCS) (see Sussman 2005), which are seen as to be of major importance for road freight transport (Kortüm et al. 1998).

Maurer (2012) differentiates between conventional driver assistance systems and driver assistance systems with automatic detection. The first group includes systems which simply assist drivers in controlling their vehicles with easy to measure key performance indicators including Antilock Braking Systems (ABS) or Tire-Pressure Monitoring Systems (TPMS). The second group is also known as Advanced Driver Assistance Systems (ADAS) as they include Automated Data Processing Systems (ADAS). ADAS assists drivers in difficult traffic situations or in other unobservable situations with predetermined ranges of performance indicators. This refers to situations such as emergency brake systems, Lane Departure Warning systems (LDW), anti-drifting systems or systems which are able to recognize driver fatigue. Within the context of the European Union, CVO as well as AVCS are of increasing importance for road freight transport as many vehicles cross multiple country borders and are then confronted with different toll systems.

Given the increasing number of goods transports within urban areas, the control of such transports is becoming more important too. To date, traffic control systems have been used to stabilize, harmonize, and allocate traffic allowing for better traffic flow within an urban area. This is also relevant for road freight transport as, recently some ITS-related city logistics systems have been introduced (Anonymous 2015a; Dresdner Verkehrsbetriebe 2015).

The next section presents up-to-date examples for all ITS areas which should provide further insight into the topic matter.

25.4 Selected ITS Application Areas in Road Freight Transport

Table 25.1 presents selected examples of ITS where we identify the latest developments in fleet management, city logistics, Collaborative Adaptive Cruise Control (CACC), toll systems. The table also presents an example of an area-wide hazardous goods control.

The broad range of various examples shows that road freight transport provides for each of the identified ITS areas, adequate application possibilities. Applications for truck parking lot allocation, which is a sub area of fleet management, has progressed considerable in the past. Specific applications therefore refer to ITS-assisted compact parking (Kleine and Lehmann 2014) or the app-based parking lot search and reservation system with which the driver or his freight forwarder can book parking space for the desired truck service area. “Highway-Park” or “Systemparken” are such app-based systems. A successful utilization of ITS depends however on the acceptance of the various user groups in a transport chain. We are now going to show how different user groups assess the potentials of ITS for freight road transport. The results of this assessment are shown in the following section.

25.5 Critical Evaluation of ITS from the Perspective of Different Actors of a Transport Chain[1]

The main results of this assessment are summarized in Table 25.2. They refer to the main arguments of the various ITS user groups in regards to road freight transport.

25.5.1 A Transport Provider’s View on Using ITS

So far, transport providers cannot recognize any economic advantages by using ITS in their fleet management. In accordance to Directive EC 561/2006 of the European Parliament, transport providers are allowed to control driving, working, standby, and idle time with electronic tachographs. Based on this, transport providers are already capable of identifying delays or failures.

ITS is capable of warning drivers in good time about traffic disturbances and suggest bypasses in order to improve adherence to delivery dates. This helps the transport provider avoid any surcharges due to delays. Consequently, the risk of losses is minimized or even avoided. However, these advantages are difficult to

[1] If not else indicated, this section refers to the expert interviews: Anonymous (2015b), Gieske (2015), Warkentin (2015).

Table 25.1 ITS categories with application and characteristics

ITS	Application and characteristics	
Fleet management	**"SKEYE Fleet" (Evers 1998)**	
	Drivers exchange with the control center in a wireless manner order cargo information as well as operating conditions	Operational conditions and other information are captured by additionally implemented sensors in an electronic logbook
	A geographic information system determines the position	Car theft protection by definition of a free travel zone
	SKEYE Fleet Software allows the implementation of an individual fleet management control center	Depending on the signal, the system differs between a simple logbook entry and an alert
	Rule-based real-time control (Kapsalis et al. 2010)	
	Hub-and-Spoke-system based network architecture	Remote configuration of the vehicle system with rule-based event activities possible
	Improved assistance of transport relevant to security by vehicle-installed sensors which are linked to the systems	Safety mechanisms with three levels for sound conditions, system independent firewall, and authenticity check
	Vehicle-installed gateway for connection with fleet control center	Little programming skills for rule development required
City logistics	**Computer assisted truck guidance system (Anonymous 2015a)**	
	Discharging of inner-city traffic network by redirecting heavy bulk load transports	Reduction of energy consuming deceleration and acceleration processes by cross road prioritization
	Faster routes due to priority traffic light circuits at cross roads	Reduction of pollution and noise emissions
	No need for further road network expansion	Reduction of inner-city rat run truck traffic
	"CarGo-Tram" (Dresdner Verkehrsbetriebe 2015)	
	Relief of inner-city traffic network by intermodal transport chains	Faster routes by priority traffic light circuits at cross roads
	Allows JIT-delivery within urban areas	Only efficient if track infrastructure exists
Advanced vehicle control systems	**Collaborative adaptive cruise control (Zambou et al. 2003)**	
	Shorter vehicle space due to automatic cruise control	Stable convoy of vehicles due to adjusting engine torque of all participants of the convoy
	Three possible communication structures: direct, bus, and direct with broadcasting	The smaller the vehicle space, the more complex the programming effort
	Efficient driving with fewer deceleration and acceleration processes	Uncertain legal security in case of accident due to software failure

(continued)

Table 25.1 (continued)

ITS	Application and characteristics	
Toll system	**“Toll-Collect” (D) (Toll-Collect 2015)**	
	Established since 2005	Current Limit weight of 12 t, by October 2015–7.5 t
	Nationwide (federal road and Autobahn)	Emission dependent environmental toll
	Generation of additional income sources	Easy expandability through reprogramming
	“GO Maut” (A) (Asfinag 2015)	
	Established since 2004	Limit weight of 3.5 t
	Nationwide (highways and express ways)	Emission dependent environmental toll
	Generation of additional income sources	Expansion only by further implementation of toll bridges
	“LSVA” (CH) (Eidgenössische Zollverwaltung 2013)	
	Established since 2001	Limit weight of 3.5 t
	Nationwide (all types of roads)	Emission dependent environmental toll
	Generation of additional income sources	No expansion required as all roads are tolled
Hazardous goods control	**“SHAFT” (Zajicek and Schechtner 2005)**	
	Area-wide control of hazardous goods and heavy bulk transports	Transmission of electronic shipping notification to On Board Unit (OBU) and database system
	System components: OBU, hazardous goods server, hazardous goods database	Automatic route control in emergency situations
	GPS and wireless transmission technology for permanent positioning	Simple cross-border expansion possibilities

validate as comparison values are lacking. Another potential advantage refers to an automated truck storage space allocation by feeding the system with order information. This allows the optimal usage of time and truck storage space in relation with the picking and receiving location. However, the replacement of shippers by automated systems could lead to system breakdowns as “computers” do not consider any human interaction.

25.5.2 A Professional Truck Driver’s View on Using ITS

The job of a professional truck driver is not an easy task, and in today’s world requires ever expanding skills including planning skills and technical know-how.

Table 25.2 Perspectives on ITS

Transport provider
• Links such systems with additional financial burden • Does not see any direct benefit • Requires comparable entities to analyze the cost/benefit ratio • Fears its replacement by intelligent systems
Professional truck driver
• Fears an increase of external control, thus loosing direct responsibility • Despite partly autonomous systems, failure is always connected with the driver • Needs help with route navigation and compliance with its driving and rest periods • Approves the importance of additional safety systems
Traffic control center
• Needs such systems for controlling and influencing traffic flow due to a steady increase in traffic • Sees high potential benefit • Has to be constantly adapted to the latest safety standards
Client and receiver
• Is mainly interested in a low-cost and short delivery process • Does not want any cost sharing for increasing transportation safety • Tracking and Tracing seems to be sufficient enough, does not demand further technologies
Public authorities
Programmer
• Has to consider economy's and population's interest while applying ITS • Needs ITS for efficient control and for better law enforcing • Boosts widespread usage of ITS through bills and incentives • Has to worry about and ensure road safety
• Extends every system with additional capabilities • Is responsible for a system's portability and expandability • Is responsible for better comprehensibility of the professional program code

Although the requirements for drivers are permanently increasing, drivers additionally face more and more surveillance.

The use of ITS is justified as drivers are subject to various bills and restrictions which need to be controlled. Furthermore, the position of the vehicle needs to be known in regards to cargo control. ADAS can assist drivers along the trip, which drivers do not always consider to be a positive issue as ITS may lead to diminishing self-dependent driving thus leading to decreased job satisfaction. This further leads to potential physical as well as mental stress. ITS is not able to interpret or to foresee these effects. Despite all technical possibilities, any failure will be attributed to the driver even though the driver may not be responsible. The realization of driving and idle times is, however, a positive application area for ITS. Even though drivers are aware of the legal situation, ITS can better assist drivers in their decision making, especially when to take a break. This will lead to increased traffic safety.

25.5.3 A Traffic Control Center's View on the Use of ITS

All traffic information from different systems are fed in the traffic control center. This includes real-time recordings of inner-city traffic surveillance cameras, weather and traffic sensors on motorways and highways which help to monitor the traffic situation, and state of the technical equipment in the traffic infrastructure. Based on the data analysis, traffic control centers can intervene in current systems by, e.g., changing light signals dependent on the traffic situation, which conveys information regarding changing conditions to road users who are then able to adapt to the situation. Any modern traffic control center has integrated user software allowing all users to access required and relevant data on individual work stations. Today's increased traffic density, increased road network, and other traffic related factors require systems which are able to cope with many interactions of these factors. ITS offer many positive advantages for traffic control centers regarding traffic control and planning. However, they require perpetual systems updates in order to include and to adapt to current safety standards (Landeshauptstadt München Baureferat 2012).

25.5.4 A Client's/Receiver's View on the Use of ITS

Any client wants products to be delivered to a receiver without damages. As long as no problems occur and as long as costs are low, the whole delivery process is of very low interest. A need for information is generated if products do not arrive as promised, either because of time delays or product characteristics. Tracking and Tracing helps to monitor the position of a delivery. However, delivery costs are required to be kept to a low level. Any ITS system which helps to keep delivery costs as low as possible and simultaneously keeps promised delivery times is of interest for clients/receivers.

25.5.5 A Public Authority's View on the Use of ITS

Any state represents the interest of the public but it also has to represent economic interests. This can lead to limitations in transport policy. Public interest includes urban areas free of emissions, reduction of noise pollution, reduction of CO_2 emissions, creation of high quality living conditions, and congestion-free roads.

City logistic concepts, such as the examples as shown in Table 25.1, consider all these issues in their concept.

Decreased acceleration and deceleration processes lead to positive gains as average speed is increased and emissions are reduced. Furthermore, goods freight transports are reduced in inner-city locations. However, public authorities are required to take over the installation of such concepts due to higher costs which private organizations are not willing to cover. Therefore, it is necessary to find a balance between legal obligation and positive incentives for companies to invest into better equipped and safer trucks.

25.5.6 A Programmer's View on ITS

A programmer views ITS as a closed system with partly blurred and partly clear determined boundaries. The project description by the customer is therefore crucial for the adaptability and expansion of the system. Thus, the requirement catalog includes the minimum requirements as well as 'nice-to-have' functionalities as well as the future vision of the project. The anticipatory thinking of a programmer plays a major role for the sustained and long-term advantage of ITS. It is the programmer's responsibility to develop the program code in such a manner so that later successors can adapt it or expand it easily. These findings show that ITS can only be used for guaranteeing safe and efficient freight road transports if the various interests of the transport providers, professional drivers, traffic control centers, customers and receivers, public authorities as well as programmers are equally considered. This requires the active involvement of these groups in defining the prerequisites for ITS.

25.6 Conclusion

The purpose of this paper was to present a state-of-the-art analysis of the current progress in the field of freight road related ITS as well as a critical reflection of these developments from the perspective of different user groups. Overall, we were able to see that within the analyzed literature there is a focus on the interplay between ITS, a vehicle and its environment (e.g. road infrastructure, road conditions, parking, etc.). For further research it would be interesting to differentiate further between vehicle and load units. First attempt of this can be found in the research of the SFB 637 with the intelligent container (e.g. Lang et al. 2011) or swap bodies (e.g. Podlich et al. 2009).

Based on the presented discussion in the previous sections, we are able to answer our two research questions as follows.

What are the application areas for ITS in the field of freight road transport and which kind of systems are utilized?

Based on the systematic ITS application areas in accordance to Sussman (2005), we were able to identify fleet management, city logistics, ADAS, toll systems, and hazardous goods and heavy bulk transport controls as the most important areas. For each of these areas, we have presented at least one application system (see Table 25.1).

How do different user groups of a transport chain evaluate current ITS developments?

We have provided in Table 25.2 a summary of the various views from different actors of a transport chain. We therefore recognized the various dilemmas between user groups depending on their individual goal settings.

As the field of ITS is significantly influenced by current technology development, it is necessary to see how these developments affect these systems.

Taking the ADAS perspective, we need to consider the future development of system architectures and sensor technology which allows for more precise measuring. Currently, ADAS is operated within rigid system architecture. In the future, system borders need to be opened allowing the interaction between different ADAS systems. This will lead to even more complex systems inside the vehicles, which will require different computer nodes compared to today (Reichart and Bielefeld 2012). Another wide area for future developments is urban logistics concepts, out of which city logistics has been positively developed in larger cities. Future intelligent systems need to be able to improve the efficient utilization of fleets as well as an efficient allocation of orders amongst various actors. One example is the Internet-based combinative auction trade of transport orders.

Considering the broad range of technologies which are able to realize ITS, we recognize a huge potential for future research. New ITS for road freight transport are seen to be integrated, intermodal, Internet-based and intelligent (Giannopoulos 2009) and will require more complex methods and processing algorithms in order to allow for an appropriate utilization of collected data (Crainic et al. 2009).

Finally, it is the will and motivation of all road users and their ability to adapt and change that will promote the use of any future ITS system.

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