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LOAD TRACKING IN ROAD TRANSPORT

ABSTRACT

For the first time in history, remote monitoring and safe-keeping of the assets is now possible also during road transport. These possibilities were enabled by development of the information technology during the last decade. Whereas such development continues in a planned direction, the influence of the improved and cheaper means of information upon the transport companies could be foreseen.

This article includes the latest guidelines for truck and load monitoring systems development. On the basis of these guidelines, the role of users in the remote monitoring systems development is also presented. In order to express their problems more quickly and to respond with greater efficiency, it may be necessary for them to get basic knowledge about telecommunication and informatics.

KEY WORDS

asset tracking, load planning, mathematical models, Inmarsat C, cellular mobile telephony, satellite telecommunication nets, intelligent GPS receivers

1. INTRODUCTION

After setting up of the Inmarsat-C Service [1] it promptly took an important place in road transport, and together with the navigation GPS (Global Positioning System) receivers, enabled also monitoring of each single truck and load [2]. Trucks and load together are usually over millions of US dollars worth. On some branch roads in Asia, Africa and Latin America, the highway robbers had been so successful that they had become very serious obstacles for road traffic in those areas. The insurance companies there did not want to insure road carrying any more. As consequence of lost trucks and loads the transport companies went bankrupt, since the insurance companies refused to adjust the insurance claims.

Road cargo transport in such dangerous areas has been normalised as well by the Inmarsat-C Telecommunication Service for the remote monitoring. Such monitoring provides transport companies constant communication with each single truck, giving them the benefit of real-time vehicle tracking. They track the progress of each truck, its direction and speed, as well as the course of dispatch loads by remote measuring of all door positions and connections between the truck and the trailer. The transmission of all these data is automated and the driver has no influence on it. Inmarsat-C System is built-in the truck. It is hidden, mechanically protected and has an auxiliary stand-alone power supply system. In case of a violent entrance into a vehicle or into Inmarsat-C System itself, the built-in alarm would be activated and alert the monitoring centre in order to achieve a prompt action.

In the event that a vehicle has changed the planned routes or has not driven in compliance with an agreed schedule, the computer system in the monitoring centre will activate the alarm. Thereupon the supervisor will take adequate measures, on the basis of the available information regarding a particular vehicle. He might send just a warning to a driver or ask him a question, which needs to be answered in a precise determined way. The supervisor may take the extreme measures, such as stopping the vehicle from the monitoring centre, if the truck has abandoned an agreed route or the supervisor noticed that the truck has been broken into. The stopping may be performed by cutting off the fuel supply or by the drive motor brake operation. A supervisor must consider the safety of the driver and the participants in road traffic, before he decides on the method and the degree of braking.

In the South African Union more than ten trucks had been disappearing every day, but since the Inmarsat-C System has been introduced the number of successful robberies has decreased and in 1995 it was lower than 34%. Consequently, the insurance companies have reduced extremely the insurance premiums for trucks and loads that were remote controlled. The Optron (Pty) Ltd company, Johannesburg, is certainly among the most successful companies in that country, and it performs assets tracking/remote monitoring in road transport as well.

There are over million trucks transporting goods on roads all over the USA every day. According to the data of the American FBI (Federal Bureau of Investigation), over nine billion US dollars in goods are stolen every year. Also more than 10% of all trucks in the USA have been lost for shorter or longer periods of time [3] every year.

2. MAINTENANCE AND LOAD PLANNING

In the past, technical obstacles and prices made it impossible to apply remote measuring for tracking and safekeeping of the assets during transport. Setting up of telecommunication nets for personal cellular mobile telephony and then the satellite telecommunication nets have enabled low prices for the digital data transmission. Whereas the technology for hardware has also been developed in the last decade, the remote measurement has reached high reliability and the equipment has become small enough and the prices lower. All this together with development of the standards and the software has enabled remote monitoring and safekeeping of the assets during transport for the first time in history.

Truck and load remote monitoring enables also prediction of engine troubles and breakdowns. This is particularly important when perishables or dangerous loads are transported. When the supervisor in the monitoring centre knows the position of the vehicle, he can choose, in advance, the suitable place for safe parking of the truck. The driver may try to repair a damage there by himself, or he could wait for help.

Figure 1 - The CrossCheck GSM equipment of the American producer Trimble Navigation [5].

Transport companies which introduced truck and load tracking system, have had the opportunity to enjoy the optional advantage provided by such system. They may send to the driver additional instructions with regard to the loading of the goods during the pending route. In such a way the pending route of the truck can be organised more economically. On the basis of the news on a situation in road traffic, they may inform the driver about the changing of the route, if such changes are necessary, and reduce the freight costs consequently. The price for such message is lower than one tenth of EURO. Every hour of the delay or stoppage of a truck costs EURO 32 on the average. For example: if better organisation of load transport can prevent delays of only one hour every day it would mean a saving of EURO 9,320 per year [4].

Truck and load monitoring and tracking system enables also better planning of the following routes and schedules, as well as the performance of a scheduled vehicle maintenance. In such a way the transport company may assure better services and at the same time organise the use of their vehicles in the best way.

3. MATHEMATICAL MODELS FOR LOAD TRACKING

The fundamental three features of traffic flows are considered to be: flow, speed and its concentration. One of the basic measures of traffic flow performances is the relationship between the flow [cars/km] and the concentration [cars/hour], which is represented in the form of an equation of state. To choose and develop an adequate mathematical model one should have to be acquainted with the fundamentals of the traffic flow theory [6]. Nevertheless, there is no limitation on the number of mathematical models, each of them will be valid only if their theoretical data is compatible with the collected field data.

The first research into car following analysis was launched in America in the 1950s. At the end of the 1980s, on the basis of the extensive behaviour measurements of two-vehicle platoons (lead and following) at the General Motors (GM) Research Laboratories, a fifth model arose [7]. All the used mathematical models of car behaviour in the traffic flow are overviewed in the reference literature [7, 8]. The measuring of traffic flows has become simpler and cheaper by using the navigation receiver GPS, which determines the position and speed and has been available since the mid 1990s. With regard to the previous analytical methods for the research into car following behaviour, the navigation receiver GPS has brought an important improvement [9].

The GM model development followed the progression of increasing complexity of the model. The fifth model (1) includes: $x_1(t)$ for distance of the lead vehicle from the starting point at time t, $x_2(t)$ - distance of the following vehicle from the starting point at time t, T - time lag for the driver in the following vehicle. There are the two exponents: l is the headway exponent and m is the speed exponent. These two exponents as well as the sensitivity factor α are used to specify the psycho-physical properties of individual drivers.

$$d^2x_{n+1}(t+T)= \frac{\alpha_{l,m}[dx_{n+1}(t+T)]^m}{[x_n(t)-x_{n+1}(t)]^l}[dx_n(t)-dx_{n+1}(t)] \quad (1)$$

The less complex simulation of the movement of individual vehicles on the road has been made with the first and second models where $l = m = 0$. So, in the first and second models the relationship between the individual vehicles in the traffic flow is linear. The primary difference between the first (2) and second models (3) was in the sensitivity factors α. In the first model this factor was a constant. In the second model the change of the sensitivity factor has been taken into consideration in the form of response variation for individual drivers in the function of the traffic concentration. Namely, the manner in which the individual drivers steer their vehicle varies, as the distance between the vehicles changes.

$$d^2 x_{n+1}(t+T) = \alpha[dx_n(t) - dx_{n+1}(t)] \quad (2)$$

$$d^2 x_{n+1}(t+T) = \alpha_{1 or 2}[dx_n(t) - dx_{n+1}(t)] \quad (3)$$

The most important parameter of a vehicle in the traffic flow is its speed [ms^{-1}]. The speed for individual vehicles was measured in different times TMS (Time Mean Speed).

In the case of load tracking the speed of a vehicle is observed as speed in space - SMS (Space Mean Speed), which is determined as the relationship between the driven distance and the time needed to pass such a distance (4).

$$dx_{n+1} = [(x_{n+1}(t+dt) - x_{n+1}(t)) / dt] \quad (4)$$

In the specific cases, however, such simple model is not good enough. Therefore, the steering ability of individual drivers has to be taken into consideration. In the Laplace space G(s), the human linear transfer function for steering is represented with the first members (5). The non-linear relationship between the stimulus and response values is represented by the correction factor R, which is used to specify the driver's ability to drive in a predicted manner.

$$G(s) = K \frac{e^{-ts}(1+T_L s)}{(1+T_l s)(1+T_N s)} + R \quad (5)$$

Among all parameters in the equation (5), the measurement of the gain K, which varies from +35 dB to -12 dB, is the easiest one. The delay e^{-ts} is the response time of a driver and it is between 0.12 s and 0.3 s. All the time constants T which are used to specify psycho-physical abilities of the drivers, vary together with the variation of the terms on the road. The time constant T_L (lead) is between 0 s and 2 s, the time constant T_l (lag) is between 0.0005 s and 25 s and the time constant T_N (neuromuscular lag) is between 0 s and 0.67 s [10].

4. INTELLIGENT GPS RECEIVERS

A GPS receiver gives two basic data: precise time and position. The example of such a GPS receiver is the GPS-MS1E, which is produced by the Swiss company μ-blox AG [11]. The intelligent GPS receiver encompasses superior microprocessor, which calculates the velocity and the time of journey on the basis of these two data. It also performs additional calculations with the data received from the measuring sensors, built-in inlet tap of the fuel tank and in inlet taps of the tanks for other liquids. Such measuring provides very precise determination about the location at which the load has been poured out. Piece goods may be equipped with the labels, which can be recognised only by the radio wave reader. So, the dispatcher may follow the trucks and track the time and place of their dispatch loads.

When a tracked vehicle and its load reach the previous determined conditions, the superior microprocessor forms the message and sends it by the telecommunication system to the monitoring centre. Sending of the messages to the monitoring centre would, under determined conditions, change the truck and load remote tracking system into the AVL (Automatic Vehicle Location) system. In that case the message would be composed of the data on the vehicle position and an alarm, if there is any. Such messages reduce the price for using the AVL system because the telecommunication net expenses are reduced. At the same time a supervisor in the monitoring centre may concentrate on exceptional cases. He does not need to waste his/her time by tracking trucks that drive along the agreed route and keep in compliance with its schedule.

In the area of transport and logistics, the intelligent GPS receiver has opened new areas and new ways of using the means of information.

Figure 2 - Navigation receiver GPS-MS1E made at the Swiss company μ-blox dimension 30 x 30 mm [11].

5. FEATURES OF NEW GPS RECEIVERS

The third generation of intelligent GPS receivers is already coming up and their purpose is the assets tracking and its safekeeping during transport. Intelligent GPS receiver combines all the necessary hardware in the integrated technology and adequate built-in executive functions also without the superior microprocessor. The development of the intelligent third generation GPS receiver was affected by the three basic factors: price, power consumption and dimensions. Low power consumption enables their operation also in the state of emergency, when the power supply in the vehicle does not act. FIRST is a type of the intelligent GPS receiver, which is produced by the American company Trimble, and is distinguished by extremely low power consumption. It can be very simply built into the already existing equipment and systems, owing to the small dimensions that it may reach.

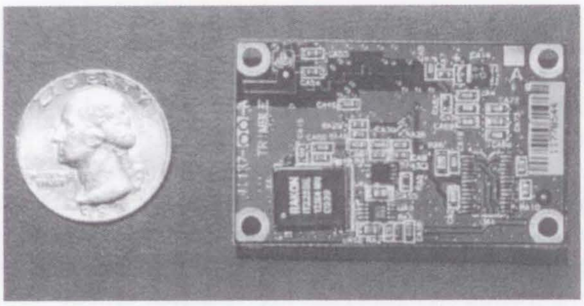

Figure 3 - Prototype of the FirstGPS navigation communicator made by the American Company Trimble Navigation [12].

Tracking and Safety System for every particular asset, requests specific adoption owing to its specific features, different geographical areas of transport, different chosen ways of data transmission and different conditions of security. A control system built in a vehicle may send the messages to the monitoring centre in regular periods of time or on request of the monitoring centre and, of course, in case of emergency. However, there are also entirely different requests with regard to the company performances as public traffic companies, taxi services, delivery companies or such international transport companies which perform long distance transport of goods.

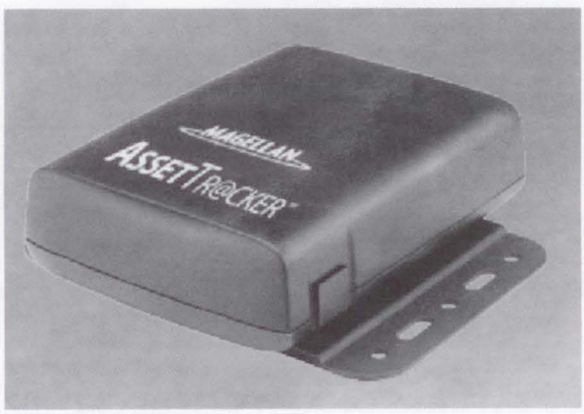

Figure 4 - AssetTr@cker produced by the American company Magellan enables communication through cellular mobile and satellite net [3].

The intelligent GPS receiver enables all these adoptions in a simple way - by changing software. Besides, the intelligent GPS receiver selects, by itself, the most suitable and reliable way of data transmission. An example of such a product is the AssetTr@cker, intelligent GPS receiver, produced by the American company Magellan, with the possibility to communicate through the cellular mobile telephony or the satellite net Orbcomm. With such selection of data transmission, enabled by AssetTr@cker, the asset tracking during its transport may be assured worldwide.

6. DEVELOPMENT OF INFORMATION TECHNOLOGIES AND TRANSPORT

The exchange of goods and the transport are directly connected with the telecommunications [13]. The development of road transport has been most affected by the cellular mobile telephony. After 1996 its application started to spread suddenly, surprising also the biggest optimists among the designers and managers of the telecommunication nets.

In September 2000, the three biggest producers of personal mobile telephony, Ericsson, Motorola and Nokia established a forum for supporting the innovative developments of the system enabling users to track the position, by means of satellite navigation system GPS (Global Positioning System) [14]. The objectives of such association - the personal mobile telephony plus the global satellite navigation system – have been to improve the spread of mobile telephony. Today, mobile telephony is used for sending messages and data between individuals, but in the future it will also take part in different systems as: trade, banking and traffic. Beside quick access to services of such systems, mobile telephony will enable a person both monitoring and management.

Satellite radio-navigation system GPS was set by the USA administration, above all for the state defence needs. However, its civil application has grown so fast that it has become the world navigation standard and the system for co-ordination and measuring of the time intervals. In 1999 started the GPS upgrading. It was to be open and adapted to civil needs. During the first phase, which will be finished in 2005, its reliability is to be increased. The European Community is about to build an independent satellite radio-navigation system Galileo, which will be under civil administration. Galileo will be part of the European integrated transport and most probably will be finished by 2008.

7. CONCLUSION

As consequence of the planned growth and development of the means of information in the following years, the users also have to prepare themselves. This is particularly important for the companies, which are involved in cargo transport. It will be obviously necessary to change the way of management in such companies and to re-organise them. Only innovative companies, which have adequate knowledge, will be able to implement such changes. It is important that the researchers and designers of new information systems for the needs of transport, at the very beginning, keep in touch with the users who should also participate in development, which is particularly important when the system is updated for the specific transport user. Whether the users participate in development or not, they would be completely dependent on their knowledge in the following two stages: within the period of introduction of new information systems and later on, when they have to use it.

The navigation communicator GPS, which tracks the position and speed of the vehicle as well, can perform the measurements of traffic flows in a much simpler and cheaper way. The equipment for GSP can be easily built into any vehicle and anybody can drive such a vehicle. The measurements can be performed in any form, for any condition of the traffic flow and on any road. As the measurement of the position is digital, it is suitable to be recorded and processed by a computer. Compared with other measurement equipment for the same purposes the price of the equipment for GPS is very low. Defining of the position is made with accuracy of 1m and in time intervals of 0.1 sec. The future researches of traffic flows are to be aimed at the common measurements of a greater number of vehicle properties and driver capabilities in the same traffic flow, and at the estimation of new mathematical models.

POVZETEK

SLEDENJE TOVOROM V CESTNEM PROMETU

Prvič v zgodovini je mogoč daljinski nadzor in varovanje lastnine tudi med prevozom po cestah. Omogočil ga je razvoj informacijske tehnologije v zadnjem desetletju. Ker pa se ta razvoj nadaljuje v načrtovano smer, se lahko tudi predvidi vpliv teh izboljšanih in cenejših informacijskih sredstev na razvoj podjetij na področju transporta.

V članku so podane najnovejše razvojne usmeritve sistemov za daljinsko spremljanje tovornjakov in njihovega tovora. Na osnovi tega je prikazana pomembnost uporabnikov pri tem razvoju. Da lahko uporabniki sodelujejo pri razvoju in nato tudi izkoriščajo to tehnologijo pa morajo nujno imeti potrebno znanje iz področja telekomunikacij in informatike.

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