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ELECTRONIC SYSTEM OF TRACKING AND MONITORING OF THE CONDITION OF RAILWAY VEHICLES. MANAGING THE OPERATION PROCESS AND DETECTING THREATS AND EMERGENCY STATES.

s. 145-155

ABSTRACT

The article presents an innovative, electronic system of tracking and monitoring of the condition of railway vehicles. Thanks to the use of electronic tools, it is possible to track vehicles and transported cargo in real time, in particular railway wagons. The author also presents the functionalities of the system, including the possibility of ongoing management of the operation process of railway vehicles and the detection of potential hazards and emergency states of monitored railway fleet. A system user, e.g. a railway undertaking, can use the System to optimize the maintenance process of railway vehicles. It can easily manage periodic inspections of vehicles, including individual levels of maintenance. Thanks to the system, the user can continuously receive information and alerts regarding the location of vehicles and their technical condition. Thanks to this, it can optimally manage their operation process, significantly increasing the level of safety in rail transport.

KEYWORDS

Monitoring, Safety, Railway vehicles, Operation, Detection

INTRODUCTION

Only a few years ago most companies providing railway services considered electronic systems of monitoring of vehicles to be a superfluous gadget. Nowadays it is hard to imagine operating a transport business without the possibility to track and monitor

company's own rolling stock and cargo in real time. Road carriers have long appreciated the invaluable benefits of the use of such systems but how far did railway enterprises go in implementing analogous IT solutions and what are the benefits of their application? Analysis of the Polish rail transport market provides insight into dynamic changes that the management process of fleet of vehicles and cargo is currently undergoing.
Both carriers as well as customers expect the continuous monitoring of vehicles and the transported cargo, which is especially important when highly processed goods are transported and in particular by means of intermodal transport. Poland as a country with a strategic location, which combines several types of transport: rail, road, maritime and land transport, faces the challenge of optimizing the entire transport process. That is the reason for the increased use of IT tools, including monitoring systems, which provide significant technical and financial benefits. It will not be possible to manage the railway activity effectively without modern IT tools, including in particular the systems that provide the possibility to manage the rolling stock in real time.

1. NATURE AND NEEDS OF THE POLISH TRANSPORT SYSTEM

Because of its geographical location, Poland may use practically all modes of transport to carry goods. However, in reality inland waterways transport barely exists in our country. The most common solutions are the ones combining maritime transport with rail or road transport.
The essential element enabling the organization of intermodal transport is an efficient transport infrastructure, both linear as well as nodal.
Access to information exchanged internally and between entities participating in the organization of cargo transport constitutes an aspect as important as linear and nodal infrastructure. This follows from the simple fact that conducting business activity is virtually impossible without reliable data concerning the realized processes, such as among others information on the rolling stock and cargo, including its location, technical condition, anomalies as well as other elements crucial from the point of the view of a client and a carrier.
Not only is information involved in virtually every aspect of company's activity but it also has a material effect on the financial situation of the company. It is on the basis of the market data that the companies develop their strategies and run their day-to-day operations.

1.1. INFORMATION AS THE KEY FACTOR FOR TRANSPORT DEVELOPMENT AND OPTIMIZATION

Current trends in the world economy clearly show that further development depends on the knowledge-based economy and thus information. Companies that want to operate on the market, continue to grow and generate expected profits, have been forced to search for ways to increase the effectiveness of their day-to-day business activity.
Moreover, information has a major impact on the logistics costs. Particularly important are the costs of transport, which often constitute over half of all the logistics costs in the company. Such costs depend among others on whether and in what way the available transport resources are utilized.
Research conducted by the European Environment Agency shows that in majority of the European Union member states, the use of the available rolling stock for all modes of transport is on a very low level.

For the most commonly used means of transport, i.e. road transport, the average use of the available load capacity during the supply or distribution process is at 54%. Situation is much worse in the case of rail transport, in particular on the Polish market. In majority of cases the availability of rolling stock does not exceed 40-50%, and in some segments of the market it can be as low as 30%.

1.2. LOW LEVEL OF USE OF ROLLING STOCK = HIGH COSTS OF BUSINESS ACTIVITY

Maximum use of rail wagons and locomotives directly affects the price for the transport service paid by the ordering party.
For instance a monthly cost of lease of a wagon used for the transport of containers amounts to approximately 3 150 zlotys. Average monthly cost of lease of diesel locomotive amounts can be as high as 80 000 zlotys. These costs need to be included in the price of the transport service for the client. In the case of intermodal transport, the price comprises several factors with the most important being:

- Cost of maintenance/lease of a wagon,
- Cost of maintenance/lease of a locomotive,
- Cost of transport (fuel, traction, servicing),
- Cost of access to the rail infrastructure,
- Cost of reloading and terminal operations.

Therefore, as far as competitiveness of intermodal transport is considered it is desirable that both the wagons as well as locomotive are used to the maximum. In other words, the downtime, i.e. the time when the rolling stock do not realize transport services should be limited to minimum.
Table below depicts the analysis of the effect that the rolling stock's downtime has on its average monthly cost.

Table 1. Monthly cost of downtime of the rail vehicle [author's own compilation on the basis of the data of Rail Time Polska]

Analysis of use of rolling stock	**Cost/loss following from the downtime of a wagon [PLN]**	**Cost/loss following from the downtime of a locomotive [PLN]**
Downtime [0% - 0 days]	105	2666
Downtime [20% - 6 days]	630	16000
Downtime [50% - 15 days]	1575	40000

The above example clearly shows how bad management of the rolling stock may result in the increase of transport costs for a client or decrease the profitability of the provided service.

1.3. MANAGEMENT OF ROLLING STOCK – CURRENT PRACTICES

In theory, management of rolling stock seems to be fairly easy. All you need is reliable information on the current location of a given wagon, locomotive or means of transportation. Does it realize the transport service as per agreed timetable or was there an unplanned stoppage or a breakdown. However, it turns out that in reality obtaining the above information for rail transport proves to be a lot more complicated. To quote the French general Guyaux, business intelligence specialist: "information is valuable only if the right person gets it in the right time". And this is where there is a major problem from the point of view of monitoring the rolling stock. Currently the

are few solutions on the market, which enable a global, safe and cheap monitoring of rolling stock in real time. Moreover, companies in the rail industry still use inefficient methods of communication – telephone, e-mail. Businesses are also hampered by use of paper documents and complicated administrative procedures.

1.4. AVAILABILITY OF INFORMATION VS. REALITY

Information with respect to the organization as well as performance of transport services as such, due to the complex nature of the service, is essential both for companies providing the transport services as well as for companies using such services. Service recipients may contact service providers in several ways.

Until recently, direct contact was the most popular form. However, a dynamic development of electronic services resulted in changes in the way orders are placed, in form of contact between the ordering party and the contractor, and finally it enabled a fast and safe access to information in real time.

In Poland a poll was conducted among selected enterprises in order to establish which information concerning the events during the transport of goods, including rail transport, they would like to receive in the real time.

The poll was conducted among manufacturing companies, wholesalers and owners of cargo and among providers of transport and logistics services.

As a result of the poll, 90 different responses were obtained, which were then grouped and put in order in accordance with their importance for the companies. The results of the poll are presented in the table below.

Table 2. Ratios concerning monitoring of cargo parameters – expectations [author's own compilation based on data provided by the Institute of Logistics and Warehousing]

Status	% responses
Delivered	100.0%
Estimated date and time of delivery of the cargo	97.5%
Current location of the cargo	95%
Delivered, discrepancy in delivery	95.0%
Refusal to accept the delivery – goods inconsistent with the order	95.0%
Refusal to accept the delivery – same delivery performed twice	95.0%
Refusal to accept the delivery – damaged goods	92.5%
Not delivered – no recipient	92.5%
Unloading started	90.0%
Unloading completed	87.5%
Loading completed	87.5%
Not delivered – incorrect address	85.0%
Not delivered – other reason	85.0%
Breakdown of means of transport	82.5%
Loading started	82.5%
Accident	80.0%

A total of 56 entities participated in the poll, out of which 30 were transport services providers and 26 were entities which order the transport services and are the owners of the cargo. Most of the entities operate on global markets.

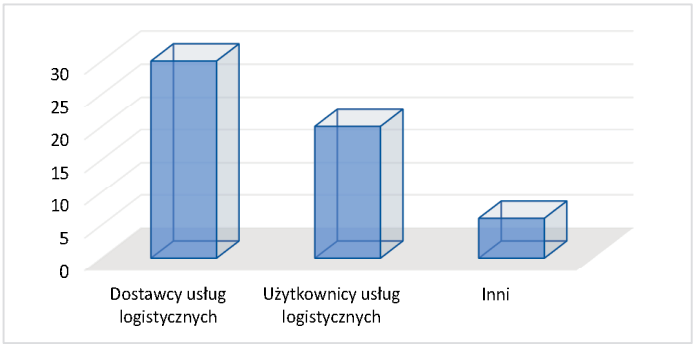


Fig. 1. Entities participating in the poll [author's own compilation]

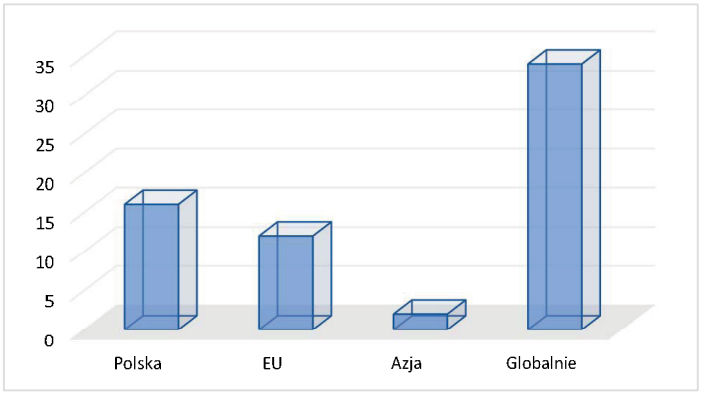


Fig. 2. Area of activity of the entities [author's own compilation]

In the next part of the poll, it was verified whether the companies monitor their transport resources and whether they measure the parameters of the load in real time. Over 50% of the companies currently monitor neither the means of transportation nor the load in real time (this applies to both service providers and service recipients). However, virtually 100% declare that there is such a need.

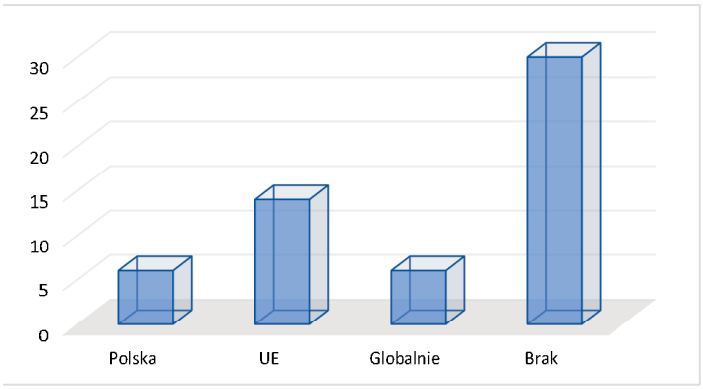


Fig. 3. Monitoring of transport resources [author's own compilation]

Similarly, as many as 42 of the polled companies do not monitor the load parameters in real time.

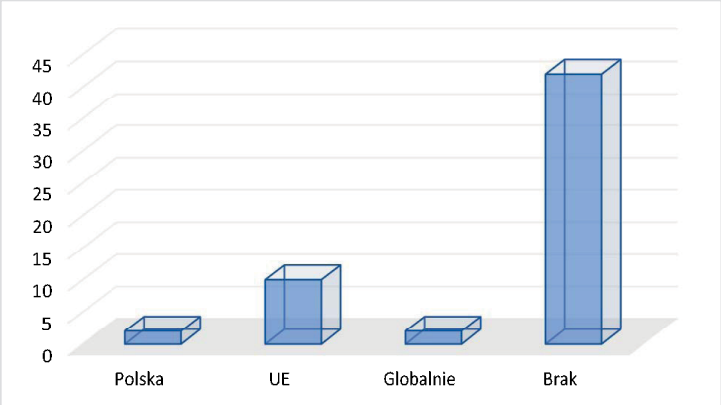


Fig. 4. Monitoring of cargo parameters [author's own compilation]

Majority of the companies also fail to monitor the location of their means of transport in real time.

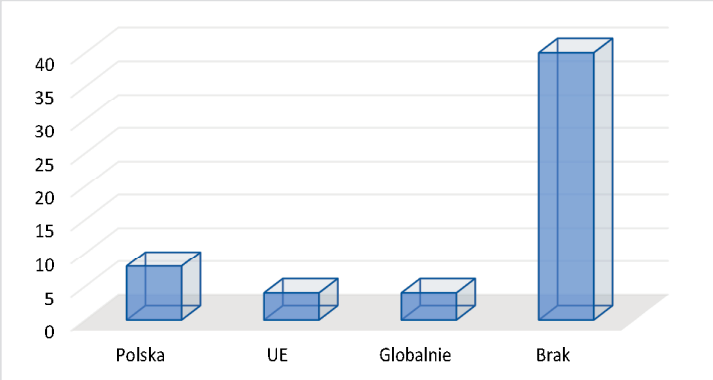


Fig. 5. Monitoring of vehicles/containers [author's own compilation]

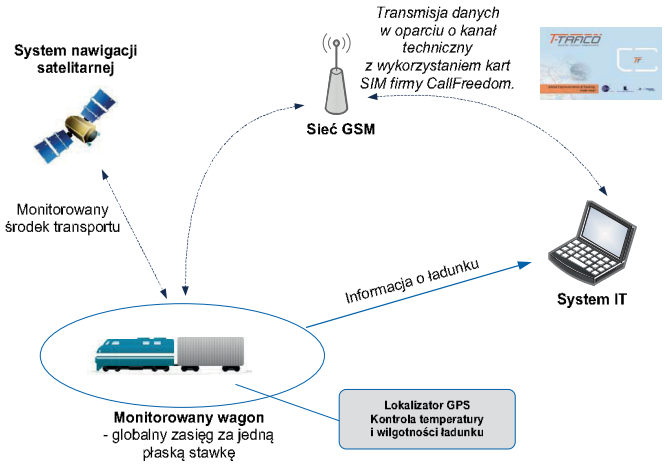
Results of the conducted polls clearly indicated that the majority of the transport companies will need to remedy their technological shortcomings in order to be able to meet the expectations of the service recipients as regards the access to information describing the transport events in real time.
It should be noted that the above poll concerned global transport activity in Poland. Road transport started to implement cargo tracking solutions much earlier and therefore the level of their application is much higher. It is estimated that at present only about 1% of wagons and cargo used and transported in Poland by rail is subject to monitoring in real time. This indicates how crucial it will be in the near future to implement this technology on railway market.

2. SUMMARY OF EXISTING SOLUTIONS ENABLING MONITORING OF THE ROLLING STOCK IN REAL TIME

Key element enabling the effective management of the rolling stock realizing intermodal transport services is the availability of reliable information in real time with respect to the current status of a wagon or a locomotive.

There are currently solutions, which utilize GPS system (Global Positioning System) and transmission of data that enable monitoring of means of transportation and sporadically cargo units (mainly containers). In order to be able to monitor rolling stock in real time, it is necessary to equip, for example wagons, with a monitoring device. The devices comprises three essential elements: GPS module – enabling the location of monitored means of transportation, GSM module with SIM card of the mobile phone operator – enabling sending via this channel to the server the information on the current location of the monitored means of transport and a battery responsible for the operation of the device for monitoring of the rolling stock.
GPS module enables the use of the GPS satellite navigation system. GPS is one of the global navigation satellite systems, launched by the U.S. Department of Defense, covering the whole globe. The system consists of three segments: the space segment – satellites in medium-earth orbit, control segment – control stations and dedicated monitor stations, and the user segment – signal receivers, i.e. monitored devices, e.g. on the rail carriage.
The purpose of the system is to provide the user with information on his location. Information is delivered in the text format containing information on the current geographical longitude and latitude. Data may be supplemented by data concerning a status of a given means of transport (data gathered by various types of sensors). This data is then transferred to the user's server, where it is then displayed on the map. The system operation chart is presented by the below figure.

Fig. 6. Rolling-stock management system operation chart [author's own compilation on the basis of t-traco.com]



At present there are several dozen solutions in the world enabling monitoring of the rolling stock and containers in real time. This analysis concerns selected products offered worldwide.
The following main characteristics of the currently existing solutions may be identified:
- access via Internet browser and visualization of the current location of the monitored means of transport on the map,
- locating the means of transport with the use of a mobile device with integrated GPS module, transfer of data module and a battery,
- access to the module enabling generation of reports.

Application of the module to transmit data and high roaming charges involved significantly restricted global use of the existing products. High cost of use of the solutions allowed the use of them only by medium and large local companies, exclusively in the territory of one country. In consequence, companies providing and using the logistics services were not able to take the full advantage of the available logistics resources. Currently, thanks to the significant decrease of the costs of the telecommunication services, in particular decrease of roaming charges, monitoring systems may be used globally. Therefore location of the vehicle and the directions in which it is headed do not constitute an obstacle in access to monitoring in real time.

3. DESCRIPTION OF THE SYSTEM OF LOCALIZATION AND MONITORING AT THE EXAMPLE OF INFRACERT TSI IMPLEMENTATIONS

Innovative approach to the issue of monitoring of means of railway transport, including the wagons, was presented by INFRACERT TSI, a notified body, which has already implemented in Poland several pilot monitoring programs dedicated in particular for wagons and railway transport.
The project is based in particular on the application of cutting-edge solutions, including for the most part, solutions connecting the issues of railway transport safety with modern telecommunication and IT solutions, among others, GPS localization, GSM/GPRS communication, detection sensors, Internet network as well as mobile applications and software.

3.1. GENERAL PRINCIPLES OF OPERATION OF INFRACERT TSI MONITORING SYSTEM

General principle of operation of the system is based on several straightforward pillars. Each element, device, system or railway vehicle is equipped with a dedicated, wireless communication and localization device, and in accordance with needs with any sensors monitoring its technical condition, parameters and other information on the object which is material from the safety point of view.
System collects all data on the status of a given railway component, including its current location, condition and any possible anomalies. System may also include sensors controlling and monitoring parameters of all components.
Next, data on the railway element is sent directly to the system platform and is processed to the form specified by the end user. At the same time, the end user receives information, reports, alerts, and visualization of all information on the monitored object. Archive data is gathered in the database and may be used at any time e.g. to analyze events, for statistical purposes, or supervise and control e.g. the technical condition.

3.2. VISUALIZATION OF INFORMATION ON THEMONITORED MEANS OF TRANSPORT

Visualization of information on a vehicle and threats may be configured at the discretion of the user of the System. The same information may be automatically transmitted via SMS, Smartphone, Tablet application by or e-mail to persons defined in the System.
What is particularly important from the railway transport safety point of view, based on visualization of a precise location of a device/vehicle, a person in charge may precisely determine a threat and in consequence is able to swiftly react to eliminate the threat, by e.g. notifying relevant authorities and providing the precise location of the threat. System is also able to identify the place and type of device or system breakdown located on the railway line.

3.3. BENEFITS FOR CARRIERS AND PERSONNEL

There are no restrictions in using the Monitoring System. It combines the functions of safety management, transport process management and use of the systems. That is why a pool of end users is very wide. The system may be connected in the scope of particular functions and as a result a comprehensive tool may be created for the management of the entire transport process in the railway organization. Monitoring system may also be included in the SMS, MMS and QMS system.
Functionality of the System may be used among others by the personnel of the entrepreneur:

- technical services, e.g. of infrastructure administrators, railway carrier, manufacturers, etc.,
- users, maintenance, operational, sale services of the above Entities,
- attorneys and safety personel,
- dispatchers,
- forwarders,
- managers of an organization and Management Board,
- supervisory and control bodies e.g. President of the Railway Transport Office,
- clients of transport services for goods, containers and other loading units.

3.4. POWER SOURCES FOR THE SYSTEM FOR WAGONS

Monitoring system does not require any external sources of power. Thanks to the application of traditional batteries with extended lifespan "LLTB", module and sensor devices are able to operate without the need of servicing, up to several years depending on the intensity of communication and information sent to the System. Thanks to the use of technology "Energy Harvesting" (independent energy generation), transmitters may be powered from their own sources of energy for many years, which provides even greater possibilities for the use of the System.
Remaining part of the Monitoring system acts as a virtual electronic tool, and that is why all activities take place at the level of user's server, software or application. Thanks to this configuration, the System does not require any significant maintenance outlays.

3.5. VISUALIZATION ON THE RAILWAY NETWORK MAP

For the purposes of the system, high quality railway maps were implemented.
Accuracy of the map enables the reading of very detailed information, both in Poland as well as in the whole of Europe. Thanks to the high level of detail of the maps, a given element of the railway system e.g. track, device, rail vehicle or other monitored object or element of rail infrastructure, may be precisely located.

3.6. OPTIMIZATION OF THE TRANSPORT PROCESS

User of the system, in particular a railway carrier, may use the System to optimize the process of maintenance of railway vehicles. He is able to easily manage the periodical tests of the vehicles, including particular levels of maintenance P1-P5. By using the system we know when and where a particular vehicle should be serviced in accordance with particular levels of activity. This contributes significantly to the level of safety and the same time enabling optimization of the costs of maintenance of railway vehicles.

3.7. BENEFITS OF IMPLEMENTATION OF THE MONITORING SYSTEM

Thanks to the application of the system, user may receive on an ongoing basis information and alerts regarding any vehicle or means of transportation. Based on this information it possible to undertake immediate action e.g. correctional or preventing.

The most important benefits and functionalities include:
- detailed localization of objects or vehicles,
- monitoring of technical condition,
- tracking of shipments and cargo,
- management of servicing cycle of the rolling stock and levels of maintenance P1-P5,
- monitoring of defects and breakdowns,
- analysis and statistics of rolling stock,
- detection of breakdowns,
- securing against theft and damage,
- monitoring transport safety,
- support for personnel,
- reduction of costs,
- increase of availability,
- optimization of the operations of the entire enterprise.

CONCLUSION

Railway carriers started to notice considerable benefits of the use of wagon monitoring and tracking systems. Having the systems not only enables an ongoing monitoring of the fleet of vehicles but it also enables optimization of the process of use, increase of availability of the rolling stock, higher level of security and reliability as well as in particular provides considerable financial benefits.
Current systems have independent sources of power enabling many years of use without the need of external interference and servicing activities. Thanks to this, the system has a versatile scope of application. Monitoring devices may be installed on any type of rail carriage as well as on every load or means of transportation e.g. container.
Interest of the carriers to install a monitoring system is not limited only to specialist vehicles or vehicles transporting processed or high risk goods. Increasingly, businesses decide to install monitoring on e.g. wagons transporting coal. It is no surprise. Analysis conducted by INFRACERT TSI, on the basis of its own implementations of monitoring systems for wagons of railway carriers, shows that the availability ratio for the rolling stock increases as much as by several dozen per cent and that results in a significant reduction of costs of transport activity.
Of course there are a lot more benefits. Easy localization of company's own rolling stock is one of them, the other include among others the possibility of easy management of the process of maintenance and monitoring of the technical condition, conducting statistics and analyzes, support for management systems, monitoring of defects and breakdowns, increase of the level of security and quality, etc.
Increasingly, monitoring systems combine the functions of safety management, transport process management and use of the systems. That is why a target group of recipients is very wide. System may also be connected with respect to particular functions, and as a result a comprehensive tool may be created for the management of the entire transport process in a rail organization. SMS, MMS and QMS systems may also be included in the monitoring system.
Functionality of such systems may be used among others by the personnel of technical, use, maintenance, operational and sales services. The systems also support the work of dispatchers, forwarders, attorneys and safety personnel, and with respect to the management systems, managers of the organization, management board of a given company as well as clients of the transport of goods services. Such wide scope

application of the monitoring systems, and thus considerable financial and technical advantages for the carriers, will likely result in the situation that the process of their implementation in Poland will take months rather than years.
In the near future effective management of railway activities will not be possible without the use of modern IT tools that are consistent with the European standards, including TSI TAP and TAF. Optimization of the carriers' business activity will not be possible without the application of modern systems enabling the management of rolling stock in real time.

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