Security on Railway Border Crossings – Development and Implementation of Modern Techniques

Zbigniew SZAFRAŃSKI[1], Dariusz LASKOWSKI[2]

Summary
The article presents the scope of the project proposed, and the description of activities aimed at precising this scope. The project is aimed at defining the technical and functional brief fore design, preparation of the documentation, and implementation of the monitoring system (demonstrator) at the selected railway border crossing in Poland. The basic function of the monitoring system, supporting protection of an extensive area of a RBC (called „MoRA System" or „MoRA Demonstrator"), is automatic, continuous and intelligent ***Mo***nitoring of ***R***ailway border crossing ***A***rea i.e. part of a railway line between a state border and a border railway station, an area of a railway station itself, and if necessary – adjoining areas. MoRA System will ensure implementation of current possibilities in automation of the system operation, and maximal inclusion of an infrastructure (telecom and IT networks) currently being operated, and data possible to be collected from systems in exploitation [2]. The scope of the MoRA System project will include also a technical infrastructure for data collection from monitoring devices, registration of it, and selected transfer to services and bodies interested. The future user will have a full disposal to the technical solutions with an option of adjustment, maintenance and training. The MoRA System will ensure security of RBC area, with a continuity, reliability and complexity of supervision at the level unavailable for traditional methods of monitoring.

Keywords: railway transport, border crossing, border security, security of state

1. Analysis of a Current Situation

The national railway network in Poland is managed by the company PKP Polskie Linie Kolejowe S.A. Its critical points, which need an extraordinary supervision, are 15 railway border crossings (RBC), out of which 11 are actually in operation. These RBCs transfers either passenger traffic, or intensive freight transport. Accordingly to forecasts prepared by the UIC, railway transport corridors East – West i.e. international railway lines E 20 and E 30, will carry in transit traffic at least 30% more freight by 2025. The increase may be higher, if efforts of railway undertakings and organizations to take over part of freight getting to Europe by sea prove to be successful.

The important factor for the need to improve security of RBCs is, that Eastern border of Poland functions as a political border (European Union – CIS countries), what means the necessity of custom control, and incentives for contraband and illegal immigration. This is also a technical border (change of the track gauge from European 1435 mm to Russian 1520mm system), what needs reloading of goods, or exchange bogies under wagons; this means long time for goods and wagons to be dwelled at border stations, and extensive track layouts necessary for these operations.

Polish Eastern border functions also as a legal border (change from the area of CIM law in the law of CIS countries – SMGS agreement), this means the necessity to perform complicated administrative procedures, related to transport and custom documents.

This specific way of operation means, that a railway border crossing differs from road ones or airports, taking a vast area, being composed of extensive groups of tracks, loading, unloading or reloading terminals, posts of bogies change etc. The security protection covers also the part of the railway line from a point of crossing with a state border to the place of execution of passenger and freight check-in procedures, which is normally at the railway station nearest to the state border. In a case of some border crossings this piece of the line is long, extends for several and more kilometres, and is located in conditions, which make monitoring difficult e.g. in forest.

On the other hand, due to its importance and functions performed, RBC area as well as a part of a railway line to the state border, present themselves a high risk territory. A great amount of passengers, railway per-

[1] Mgr inż.: Instytut Kolejnictwa, Ośrodek Koordynacji Projektów i Współpracy Międzynarodowej; e-mail: zszafranski@ikolej.pl.
[2] Dr hab. inż.: Wojskowa Akademia Techniczna, Wydział Elektroniki; e-mail: dlaskowski@wat.edu.pl.

sonnel, and other services, as well as rolling stock and equipment, and big volumes of goods are transferred through a state border and stay on an area of RBC for specific time. Devices for transport, reloading and storage of hazardous commodities (liquid fuels, compressed and condensed gases etc.) are frequently located on RBC area. Determinants mentioned above may impact favourably on attempts of illegal immigration or transport of forbidden commodities, as well as on initiating sabotage or terroristic actions.

Legal regulations, currently in force, concerning border control and check-in of trains concentrate themselves on issues related to people identification, verification of travel documents, and treatment of travellers trying to cross a state border illegally. Requirements concerning control and check-in of freight trains are formulated in more general manner. The most important ones in this area are: separation on the border station groups of tracks for execution of control of freight trains from groups of tracks dedicated for control of passenger trains, as well as separation, within groups for freight trains control, groups of tracks for trains arriving to EU country from groups of tracks for trains departing from EU.

Some requirements, simple in writing down to regulations, are difficult to practical and effective implementation. As an example: the requirement to fence a railway line between a state border and a border station, what seems technically simple to be realized, can be effective only when the technical condition of the fence on all entire length is monitored permanently.

The execution of supervision of the RBC area with mobile human patrols can't ensure the necessary, effective and continuous protection of the RBC area along all its borderlines. However, this may be done using technical devices. Similarly, it is difficult to execute effectively detailed check-in of arriving freight trains (including content of wagons), when the control is performed by a personnel of a Border Guard only.

The authors, thanks to good cooperation with the management of the Polish Border Guard, had the opportunity to pay some technical visits to chosen railway border crossings. These visits were realized between December 2013 – January 2014, and considered border crossings with differentiated local conditions with regard to land shape, neighbouring country, technical equipment, and features of railway traffic through the state border.

The exploration and multi-aspect analysis of possible incidents confirmed the necessity of supporting the Border Guard, and other services e.g. the Customs Office, the Railway Guard, with a technical system, which improves considerably the effectiveness of protection of a RBC area, together with a piece of a railway line to the state border, without increasing human forces involved in monitoring of this area.

2. Research Problem and Research Methodology

The technical system, applied to enhance effectiveness of RBC area[3] protection, should present itself three basic features:

1. An easy implementation of future techniques and technologies of video recording, analysis of images and other data processing etc. in existing infrastructure, enabling:
   - detection of illegal objects on a monitored area e.g. intruders on a protected space, or unidentified devices under a wagon body,
   - detection of improper or unauthorized movements of objects, or contrary – detection of objects being motionless for longer time at the same place e.g. suitcase or package in a hall of a railway station.
2. Automation of an intelligent data analysis, collected from monitoring devices, making system enable not only generate a proper alarm autonomously, but also set the necessary priority, and choose entitled addressees.
3. Integration and exchange of data, as well as distribution of defined reports, fulfilling needs of all services involved on an area of a RBC (Border Guard, Customs Office, Railway Guard, Police, phytosanitary check services etc.).

The authors are of the opinion, that there is a need, and justification to launch a research project, aimed at development of a demonstrator of such a monitoring system, supporting protection and security on an extensive area of a RBC, built on the selected RBC on Eastern border of Poland.

The basic function of the monitoring system (hereinafter called „MoRA System" or „MoRA Demonstrator") is automatic, continuous and intelligent ***Mo***nitoring of ***R***ailway border crossing ***A***rea i.e. part of a railway line between a state border and a border railway station, an area of a railway station itself, and if necessary – adjoining areas.

Intelligent monitoring of the RBC area means:

- collection, elaboration, transmission, registration, verification, and comparison of information sent

[3] To shorten the description the authors under the term „RBC area" will consider also a piece of the railway line from the state border to an area of execution of check-in procedures, as well as these areas, where track layouts and equipment for loading, unloading, reloading, and storage of goods, bogies exchange under wagons etc. are located, even if formally not included in a RBC area.

from monitoring devices (sensors, sondes, video recorders, movement detectors etc.) and creation of situation awareness;
- recognition of data (information), which may present anomalies (events or actions) inconsistent with rules, principles or regulations in force i.e. abnormal or improper;
- interpretation of data collected, referring to reference criteria written down to MoRA System, or data registered earlier;
- intuitive graphic interface of data presentation for MoRA System operator, and other decisive people, independently of their current location, via cable or radio media;
- generation of an alarm in case of thread or important irregularity;
- automation of processes inside MoRA System, supporting decision taking by people responsible for management of a railway infrastructure;
- interoperable interfaces offering integration of MoRA System with other systems used by e.g. Border Guard, Police, Customs Office, to enable access to data collected;
- MoRA System will elaborate automatically the rank of the alert or the information, as well as the range and the position of people from services (Border Guard, Railway Guard, Customs Office, others) to be informed.

Technical and functional equipment of MoRA System should enable performing automatically, continuously, and without necessity of operator interventions, the following tasks:
- monitoring of access, and intruder detection on an area of a RBC, other selected areas of a border station, and technical / commercial posts (e.g. tracks for dwelling wagons with hazardous goods), elements of a critical infrastructure e.g. border bridges;
- detection of abnormal or atypical elements or constructions mounted on roofs of wagons, or under their bodies;
- detection of escape of gases or vapours, efflux of liquids, radiation;
- detection of people travelling on rolling stock illegally.

The scope of the MoRA System project will include also a technical infrastructure for data collection from monitoring devices, registration of it, and selected transfer to services and bodies interested. The most important features of the newly worked out system, under the scope of the project, which need verification in on-site conditions, are:

1. *Detection of intrusion into the protected area*. „The protected area" means a land of a railway line between a state border and an area of border control (at a railway border station). This task will be fulfilled by elaboration of authors' method of intrusion detection, based on analysis of video frames transmitted from the area of detection. The optimal methods of image analysis will be tested and applied, based on extraction of characteristic features and modern tools and methods of exploration, and processing of image data e.g. PCA (Principal Component Analysis), LDA (Linear Discriminant Analysis), artificial neuron grids. The prototypes of algorithms will be prepared with scientific software as MATLAB and LabView. For practical development these algorithms will be implemented in one of programming environments type C#, available on the market. The hardware platform for telecom and IT networks, being the transmission media, will be analysed in details, with application of dedicated simulation software (e.g. Opnet, Comnet, Omnet, Net, Relex), and validated in Laboratory of Security and Reliability of Telecommunication Networks of the Military Technical Academy in Warsaw.
2. *Monitoring of illegal drops of commodities on a part of a railway line between a state border and an area of a border control*. This task will be completed by elaborating the algorithm of analysis of images transmitted from video recorders, aiming at detection of objects left. This solution will be optimised, concerning the aspect of maximal use of existing infrastructure, and rational extension of it. The main target will be the supporting system for the personnel, to enable quick localization of objects dropped.
3. *Detection of abnormal or atypical elements or constructions mounted on roofs of wagons, or under their bodies*, thanks newly elaborated system of active infrared video monitoring. The algorithms for image analysis from the trains passing by will be worked out. The base will be the collection of reference images, and the pictures captured on the run of the train will be compared with the reference base.
4. *Monitoring of presence of unauthorised people in protected areas*, based on identification: personnel vs. intruder. There are some possibilities to be tested. Firstly, the radio identification based on RFID. Secondly, recognition of characteristic features of dress of person entitled to enter the protected area, based on low level algorithms of characteristic features extraction. The method the most resistant to attempts of sabotage is biometric identification e.g. based on face image. It seems, that integration of different methods may be the most effective. In the future the functionality based on detection of unusual behaviour of people would be useful.

Figure 1 presents the general conception of the fragment of the monitoring system at the railway border crossing (with a bridge at the border). The system proposed contains video recorders for monitoring the running gear of rolling stock, installed in an embankment, with illuminators (Kam 4), and recorders for monitoring roofs of wagons (Kam 3).

This enables detection in advance of atypical elements mounted on bodies of wagons. Detection of objects dropped illegally along a railway line, or detection of passengers getting out of a train before arrival to a border station, is executed by recorders marked as Kam 1 and Kam 2 on Fig. 1.

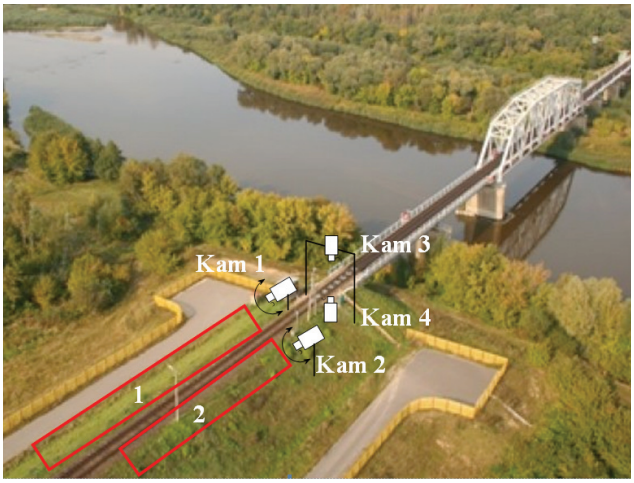

Fig. 1. The conception of the system infrastructure [fot. Authors]

Considering the specific of R&D issue, the Fig. 2 below presents a general architecture of the Security System for RBCs, which will constitute a backbone for a demonstrator model.

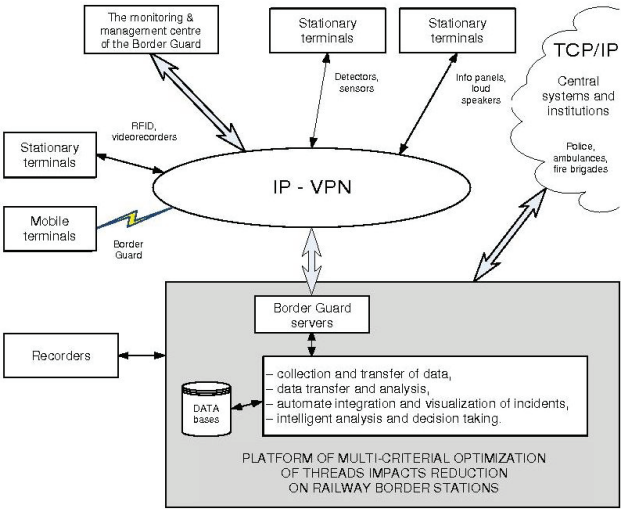

Fig. 2. The general architecture of the Security System for RBCs [Source: Authors]

The monitoring system covers:

- objects and an area of a RBC with implementation of different types of mobile and stationary terminals e.g. different surveillance CCTV systems (*Closed Circuit TeleVision*), detectors, sensors, information panels, loud speakers;
- passengers and other people on areas of RBCs with implementation of advanced algorithms of video analysis, working on a base of surveillance TV subsystems with possibility of monitoring of peoples' behaviour (passengers crossing a border).

The task for an intelligent platform will be collection, elaboration, intelligent analysis, and recommendation for responsible people or services decisions relevant to incidents and situations observed, and addressing of information elaborated to the management centre.

Execution of tasks by systems dedicated for information collection and distribution needs a separated from typical office networks, and appropriately secured, intranet network, with a high capacity, ensuring a high quality of telecommunication and IT services.

The system will enable exchange of data, via appropriately protected secret information channels, through generally accessible internet network, with the „outer world" e.g. with specified data bases of the Border Guard, Police, or Customs Office, to verify selected people when crossing a border state. Considering the distributed structure, and necessity of supervision of various security subsystems, the MoRA System will have a great scalability, and will be open for many different technologies applied in a technical protection equipment either by national manufacturers, or foreign ones. The other features of the MoRA System are: reliability, safety, and quality either in technical, or functional aspects.

Configuration and a scale of application of MoRA System elements should be relevant to a specific RBC. This is why the components architecture (either hardware, or software modules) is scalable, enabling connection to successive „sources" and "estuaries" of data via defined types of interfaces e.g. monitoring of new objects, or construction of a new service monitoring and management centre e.g. at a Police Command.

Basing on the theoretical knowledge collected, as well as on protection systems currently operated on the Polish railway network, the statement that the aim of the research project proposed – development of the MoRA System – constitutes the desirable component of a border protection system, seems to be justified.

The MoRA System will make use of perspective electronic and telecommunication techniques and technologies to ensure a secured transmission of credible data collected from monitored areas (objects). The existing technical infrastructure will be incorporated, and extended with the necessary element from re-

nowned suppliers of equipment and software. The future user will have at his disposal a full access to technical solutions implemented, with an option of development and maintenance, as well as training.

3. Summary and Conclusions

Currently there are not on the market of security systems the solutions dedicated for protection of an extensive area of railway lands, particularly railway border crossings. The construction of the system proposed from existing – incomplete and inconsistent products –would lead into highly complicated, ineffective (particularly at the level of subsystems integration), and with uncertain results process.

Considering above, from economical point of view the best solution is to develop the system from its foundations, basing on the potential available. Firstly, the subsystems critical for security and functionality will be developed, and then it will be completed with other solutions. The area of the RBC is particularly difficult to implement the solutions, currently available on the market e.g. detection of trespassers using active infrared barriers.

It seems to be reasonable to base the MoRA System on analysis of pictures recorded by monitoring video recorders. The use of video recorders in night might be problematic, nevertheless this problem may be solved by use of infrared lighting, in case of critical areas – also by use of thermovideo recorders. The area of control of arriving trains would be under strict supervision.

Full implementation of technical possibilities, created by the MoRA System, will require some changes in legal regulations, what on the other hand will enable the further development of the system e.g. completion with monitoring of potentially negative environmental impact of activities performed on a RBC area and an adjoining territory, for example private freight terminals.

The MoRA System components will have an extensive application in current telecommunication systems, performing a wide service palette at different level of protection via standard system interfaces. Irrespective of RBC areas there are many other elements of a critical infrastructure, where access of people, goods, and railway rolling stock should be strictly monitored. As an example may be presented the tunnel of the railway „diameter" line in Warsaw, located under densely populated city centre, and run by more than 800 railway services a day, including those coming from abroad, or the passenger station Warszawa Wileńska, located at the ground floor of a big „Carrefour Wileńska" supermarket.

Literature

1. Bajda A., Wrażeń M., Laskowski D.: *Diagnostyka jakości transferu danych w procesie zarządzania sytuacją kryzysową*, Przegląd Elektrotechniczny '87 (9A), s. 72–78, Sigma-Not, Polska, 2011.
2. Laskowski D., Łubkowski P., Pawlak E., Stańczyk P.: *Anthropo-technical systems reliability*, Safety and Reliability: Methodology and Applications – Proceedings of the European Safety and Reliability Conference, ESREL 2014, pp. 399–407, 2015.
3. Łubkowski P., Laskowski D., Pawlak E.: *Provision of the reliable video surveillance services in heterogeneous networks*, Safety and Reliability: Methodology and Applications – Proceedings of the European Safety and Reliability Conference, ESREL 2014 pp. 883–888, 2015.
4. Niczyporuk Z., Sienkiewicz-Małyjurek K.: *Systemy monitoringu wizyjnego w bezpieczeństwie publicznym*, Wydawnictwo Politechniki Śląskiej, Gliwice 2008.
5. Norman T.: *Integrated security systems design*, Butterworth Heinemann, 2007.
6. Siergiejczyk M., Gago S.: *Koncepcja systemu monitorowania i nadzoru w węźle kolejowym*, VI Międzynarodowa Konferencja Naukowo-Techniczna LOGITRANS 2009, Szczyrk, 2009.
7. Siergiejczyk M., Gago S.: *Public Safety Issues in Rail Transport*, Polish Journal of Environmental Studies, ISSN 1230–1485, Vol 17, No 3C (2008), HARD Publishing Company, Olsztyn 2008.
8. Siergiejczyk M., Rosiński A.: *Integracja elektronicznych systemów bezpieczeństwa w Warszawskim Węźle Kolejowym*, Monografia „Techniczne bezpieczeństwo w otoczeniu" pod redakcją naukową Tadeusza Zaborowskiego, Instytut Badań i Ekspertyz Naukowych w Gorzowie Wlkp., Gorzów Wlkp. 2013.
9. Siergiejczyk M., Rosiński A.: *Wykorzystanie wybranych elementów telematyki transportu w zapewnieniu bezpieczeństwa publicznego*, IV Międzynarodowa Konferencja Naukowa „Bezpieczeństwo Publiczne BP'11", Poznań 2011.
10. Siergiejczyk M., Rosiński A.: *Zagrożenia podczas podróży w transporcie kolejowym*, Monografia „SATORI w publicznym bezpieczeństwie" pod redakcją naukową Tadeusza Zaborowskiego, Instytut Badań i Ekspertyz Naukowych w Gorzowie Wlkp., Gorzów Wlkp. 2012.

Ochrona kolejowych przejść granicznych – rozwój i zastosowanie nowoczesnych technik

Streszczenie
W artykule przedstawiono zakres, proponowanego do realizacji, projektu badawczego i opisano działania zmierzające do sprecyzowania jego zakresu. Celem projektu ma być sformułowanie założeń techniczno-funkcjonalnych, opracowanie dokumentacji i wykonanie systemu monitoringu (demonstratora na poziomie co najmniej TRL6 według Narodowego Centrum Badań i Rozwoju w Warszawie) na wybranym kolejowym przejściu granicznym. Podstawową funkcją projektowanego systemu monitoringu wspierającego ochronę na rozległym obszarze kolejowego przejścia granicznego („Systemu MOP" lub „Demonstratora MOP") jest automatyczne, ciągłe w czasie i inteligentne ***M***onitorowanie ***O***bszaru ***P***rzejścia granicznego, tj. odcinka linii kolejowej od granicy państwowej do stacji granicznej oraz obszaru stacji granicznej i ewentualnie wybranych obszarów przyległych.
System MOP wykorzysta perspektywiczne techniki oraz technologie elektroniczne i telekomunikacyjne w celu zapewnienia poufnego przesyłu wiarygodnych danych pozyskanych z monitoringu terenu (obiektów) obserwacji [2]. Zamierza się wykorzystać obecną infrastrukturę techniczną i rozbudować ją o konieczne elementy renomowanych producentów sprzętu i oprogramowania. Przyszłościowy Gestor będzie dysponował pełnym dostępem do zastosowanych rozwiązań technologicznych z opcją skalowalności i utrzymania oraz szkoleń. System MOP zapewni ochronę obszaru kolejowego przejścia granicznego, gwarantując ciągłość, niezawodność i kompleksowość ochrony na poziomie nieosiągalnym dla rozwiązań tradycyjnych.

Słowa kluczowe: transport kolejowy, przejście graniczne, ochrona granicy, bezpieczeństwo państwa

Защита железнодорожных пунктов пропуска через границу – развитие и употребление современных техник

Резюме
В статье представлена сфера предложенного до реализации исследовательского проекта и описаны мероприятия имеющие в виду уточнение его сферы. Целью проекта является формулирование технических и формальных предложений, разработка документации и составление системы мониторинга (демонстратора на уровне по крайней мере TRL6 по указаниям Народного центра исследований и развития в Варшаве – Narodowego Centrum Badań i Rozwoju) на выбранном пограничном переходе. Основной функцией проектированной системы мониторинга поддерживаюшего защиту обширной территории железнодорожного пограничного перехода является автоматический, постоянный и интеллигентный мониторинг пограничного перехода, т.е. участка железнодорожной линии между границей государства и пограничной станцией, а также территории пограничной станции и выбранных прилегающих территорий (по-польски „System MOP").
Система MOP использует перспективные электронные и телекоммуникационные технологии для обеспечения конфиденциальной передачн достоверных данных полученных от мониторинга территории [2]. Предпологается использовать существующую техническую инфраструктуру и расширить ее на необходимые элементы от знаменитых производчиков оборудования и програмного обеспечения. Будущий администратор будет обладать полным доступом до используемых технологических решений с возможностью масштабируемости, обслуживания и обучения. Система MOP обеспечит защиту территории железнодорожного пункта пропуска через границу, гарантируя неперерывность, достоверность и комплектность защиты на уровне недоступном для традиционных решений.

Ключевые слова: железнодорожный транспорт, пункт пропуска через границу, защита границы, безопасность государства