Low market density lines for ERTMS regional system

A. BIAŁOŃa, P. GRADOWSKIB
aRailway Scientific and Technical Centre, Chłopickiego 50, 04-275 Warszawa, Poland;
Silesian University of Technology, ul. Krasińskiego 8, 40 019 Katowice, Poland,
bRailway Scientific and Technical Centre, Chłopickiego 50, 04-275 Warszawa, Poland,
EMAIL: abialon@cntk.pl, pgradowski@cntk.pl

ABSTRACT
The paper presents technical and formal aspects of the development and implementation of the ERTMS Regional. The main purpose of building the ERTMS Regional system is to create an ERTMS-based system which is maximally fitted to low-density lines. This paper presents differences between the specifications of ERTMS and ERTMS Regional systems. The article includes a technical description as well as the principles of ERTMS Regional, a description of the first stage of implementation, as well as an analysis of possible implementation of this system in Poland.

KEYWORDS: ERTMS, low density lines

1. Introduction
The amount of railroad infrastructure has been steadily decreasing since early 1990s. Total mileage of operated lines in 1990 was approx. 24,100 km, whereas in 2006 it was only approx. 18,960, which means that in 16 years over 22% of railroad transportation was cancelled.

The condition of railroad infrastructure is deteriorating, due to insufficient means for their repairs.

A comparison of changing scheduled speeds and distances operated with speed limitations prove that the infrastructure is depreciating.

Compared to 2000/2001 timetable:
• speed was increased on 4,476 km of tracks,
• speed was decreased on 13,151 km of tracks.

Quick progress in computer technologies, as well as their widespread use in industrial automation systems sets the direction of development for railroad control systems and devices (RCS). On-station RCS devices ensure effective and safe movement of trains within the station. On railroad routes managed by PKP PLK S.A., relay (43,11% of all devices) and mechanical (centralised 34,03%, key 11,45%) traffic control systems still dominate. Only 2,39% of all posts are equipped with the latest generation of computer RCS systems. Electric slide devices (7,07%) and computer relay devices (1,95%) are also in use.

The deteriorating condition of railroad infrastructure described above, as well as “dated” RCS devices force the infrastructure managers to make harder and harder decisions concerning modernization of their railroad lines.

2. Low-density lines as a market for ERTMS Regional in Poland
When discussing low-density lines, one should note that, there is no good and unambiguous definition of a low-density line. Simply speaking, it is a line, which is lightly loaded with traffic as compared to potential capacity of available tracks.
As of 31.12.2006, PKP Polskie Linie Kolejowe S.A. managed 18,964 of railroad lines, including:
- main 4,249 km,
- primary 10,103 km,
- secondary 3,408 km,
- local 1,204 km.

Railroad lines listed above are described in a database of railroad lines registry. This base is fundamental in determining the size of the railroad network, that can be described as low-density. This base includes the whole railroad network, divided into 1,512 sections. Every section is described by numerous parameters. To determine the size of low-density market, the main parameter to choose and group certain sections is the traffic load of given section in both directions.

The assumptions characterising low-density lines – a traffic density of 12-15 trains per day, 3-5 on line at the same time, no more than 2 trains per hour; mixed traffic; maximum speed of 100 km/h – allow for first filtering of data. However, due to the fact, that some sections, that comprise whole railroad lines, have higher traffic density, a limitation of traffic density was instituted between 0 and 20. After applying this limitation we ended up with 839 sections. As we can see, the limitation applies to almost a half of all lines.

In order to facilitate further analysis, the number of sections was grouped according to narrower brackets of traffic density. Three ranges were chosen, with the following results:
- 454 lines with traffic density of 0,00 to 6,00 – total length of 5,107 km;
- 270 lines with traffic density of 6,01 to 15,00 – total length of 3,797 km;
- 115 lines with traffic density of 15,01 to 20,00 – total length of 1,703 km;

Assumptions made when defining low-density lines concerning traffic density on individual sections (12-15 trains per day), would persuade us not to use the range of 0,00 to 6,00 in our further analyses. Such amount of haulage, combined with technical condition of the infrastructure, causes rationalisation of property and, in some cases, motions are made to cancel individual sections – in 2006 PKP Polskie Linie Kolejowe applied to cancel 34 sections of 554 km. The Ministry of Transportation, as part of their project “Strategy for railroad transportation until 2009”, whose aim it was to stop the tendency to limit the railroad network length, withheld the cancellation of these sections. To withhold the cancellation and fulfil the purpose of the above project, i.e. avoid the destruction of railroad infrastructure, PKP Polskie Linie Kolejowe S.A. can conclude lease agreements for obsolete section with territorial government units. Such revitalisation included 7 sections of 261 km in 2006.

When observing the growing interest of local governments in problems of transportation development, one should expect an increase in haulage over the next few years in analysed sections as well as in sections that will soon be revitalised.

Due to this, further analyses will include 724 sections in the range of 0,00 – 15,00, with total length of 8,904 km. These sections were grouped according to the length of individual sections, as shown below.

The above analyses show, that the market of low-density lines, with traffic density below 15 pairs of trains per day, includes 8,904 km. Such distance, which is 46.95% of all network managed by PKP Polskie Linie Kolejowe S.A, stemming above all from current decline in haulage, is the low-density network, on which low-cost devices, such as ERTMS Regional system’s devices, should be implemented.

### Table 1. Structure of scheduled speeds

<table>
<thead>
<tr>
<th>Speed Range</th>
<th>Rail length [km]</th>
<th>Percentage share</th>
</tr>
</thead>
<tbody>
<tr>
<td>V ≥ 160 km/h</td>
<td>1,303</td>
<td>4.7%</td>
</tr>
<tr>
<td>120 ≥ V ≥ 160 km/h</td>
<td>4,177</td>
<td>15.2%</td>
</tr>
<tr>
<td>80 ≥ V ≥ 120 km/h</td>
<td>10,513</td>
<td>38.2%</td>
</tr>
<tr>
<td>40 ≥ V ≥ 80 km/h</td>
<td>9,779</td>
<td>35.5%</td>
</tr>
<tr>
<td>80 ≥ V ≥ 40 km/h</td>
<td>1,776</td>
<td>6.4%</td>
</tr>
<tr>
<td>Total</td>
<td>27,548</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Fig.1. A percentage division of lines with given traffic density ranges.
Cars equipped with on-board ERTMS (ECTS and GSM-R) systems should be able to operate on both TEN networks (blue in illustration 1 above), and conventional lines (yellow).

That is why the ERTMS Regional system is an extension of rail-side equipment with centralised control and GSM-R system for transmitting data between the traffic control centre and on-site controllers along the line (steering and control: points, crossing devices, etc.). The Traffic Control Centre (TCC) has integrated RBC (Radio Block Centre), CTC (Centralised Traffic Control) and interlocking functions.

Analyses and calculations have shown, that ERTMS Regional can decrease the cost of traffic control on regional lines by 20 to 30%. The key elements contributing to such saving are:

- reduced station personnel;
- less on-rail equipment than in classic ERTMS system, e.g.: lack of need for total radio coverage, less base station, less balis;
- significant decrease in number of rail-side signalling devices, or total abandonment of their use;
- lack of traditional points, blocks and crossings, as well as cables needed for these systems. The control functions are taken over by the TCC, using radio communication GSM-R to control on-site controllers;
- lack of traditional track occupancy detection systems (track circuits and axle counters will only be used in specified places with high manoeuvrability needs);
- standard ETCS Eurocab equipment.

The basic structure of ERTMS Regional is presented in fig 4.

ERTMS Regional consists of the following subsystems:

- on-board equipment (ERTMS/ETCS+TIMS);
- radio communication system (GSM-R);
- Traffic Control Centre (TCC);
- Object Control (OC);

and is a level 3 expansion of ERTMS/ETCS. This means, among others, using an on-board odometer to determine trains’ location. Control of train’s continuity may be more easily executed in regional than in main lines. ERTMS Regional allows for significant cost reductions, as there is no need for traditional methods of rail occupancy and junction detection, and GSM-R communication used for controlling infrastructural objects (such as junctions, crossings, etc.) reduced the need for cable connections.

4. Functional requirements for ERTMS Regional

The basic principle behind FRS ERTMS Regional is a detailed specification of functionality of a Traffic Control Centre, including currently specified part concerning RBC, which includes a minimum set of requirements needed for interoperability in FRS ERTMS Regional.

During the specification process for ERTMS Regional, there were numerous important questions concerning the 3rd level of ETCS, so FRS ERTMS can also be used to prepare the main specification for ETCS level 3.

FRS for ERTMS Regional describes mainly the Traffic Control System for low-density lines. Requirements included in FRS for ERTMS Regional are mainly concentrated on this rail-side part of ERTMS/ETCS, that has not been described in detail in an FRS specification for classic ERTMS/ETCS system.
FRS for ERTMS /ETCS was constructed in such a way, as to ensure technical interoperability, while FRS for ERTMS Regional describes requirements concerning complete rail-side equipment without changing the requirements for on-board equipment included in ERTMS/ETCS specification.

5. Pilot implementation of ERTMS Regional

In 2004 UIC agreed with Swedish railroad company Banverket (BV) to implement a pilot ERTMS Regional system. When justifying their decision of choosing this railroad control system for Repbäcken-Malung line, BV listed the following reasons: interoperability, lower cost of operation compared to classic traffic control systems, increase in traffic capacity and safety, as well as the fact, that ERTMS Regional is designed specifically for regional (low-density) lines, that currently use outdated, worn-out systems, that generate high maintenance costs, frequently relying on ATP phone announcement systems without steering control.

The pilot line between Repbäcken and Malung is a non-electrified line with maximum speed of 90 km/h, 134 km long, without ATP/ATC systems, with 33 crossings, 5 stations and 9 train dispatchers and daily density of 16 trains. When creating a specification for ERTMS Regional, a risk analysis was also performed, according to EN 50126 standard and FRS, GRS (General Requirement Specification) and RAMS specifications. Based on this risk assessment and the specifications listed above, the following documents were drawn: SRS (System Requirement Specification), SVP (System Validation Plan), RAMS specification, DRS (Delta Requirement Specification).

Documents drawn by BV included: FRS, ARS (Architectural Requirement Specification), RAMS requirements.

ERTMS Regional implementation strategy adopted by BV is based on ERTMS Class 1 specifications, so ERTMS on-board equipment was used unchanged. Development in ERTMS Regional concentrates solely on changing rail-side equipment.

UIC and BV agreed, that all specifications, including technical and interface specifications will be made available by UIC, but owned by BV.

Procedures of developing new systems also require a new approach to safety assurance. But railroads are reluctant to change the current development methods.

ERTMS Regional is a brand new way of railroad traffic management. Traffic safety is ensured mainly by radio communication and train detection. The system should be as simple as possible, and as complex as the traffic conditions require. In future, the system can be developed at level 3 of ETCS where justified. ERTMS Regional is based on a brand new technical and operational approach, therefore it needs new technical and operational procedures to manage traffic based on this system.

When drawing up the specification for ERTMS Regional system, possible interrelations between the specifications of regional system and future level 3 ETCS system were considered. Some of them could be adopted by level 3 ETCS, while some had to be described in detail in the specifications for level 3 ETCS system. In such case, specifications for ERTMS-R system would serve as a preparation for partial requirements of ERTMS/ETCS level 3 systems.

The implemented ERTMS Regional solution has low investment costs. The reasons for such low installation costs are: lack of semaphore installations, minimised cable use, lack of classic systems of occupancy and junction detection systems, lack of classic trammels in stations. Projected return period in 10 years. According to the calculations and knowledge of Swedish railroads, approx. 20-30% of all European lines are regional lines qualifying for ERTMS Regional implementation.

6. Conclusion

Analyses have shown, that the low-density market in Poland includes 8,904 km of rails. This amounts to 46.95% of the network managed by PKP Polskie Linie Kolejowe S.A.

When making key investment decisions concerning modernisation, infrastructure manager for majority of lines in given region should seek new solutions with low investment costs. Such factors as cost reduction achieved by the lack of semaphore installations, minimised cable use, lack of classic occupancy and junction detection systems, lack of classic trammels in stations, combined with “quick” investment return, should point to ERTMS Regional as a dedicated system for low-density market.

Bibliography

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