Measurement innovations in railway infrastructure safety

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ABSTRACT

The paper proves that measurement innovations in railway infrastructure safety regard not only the railway transport but also railway surveying. It was found out that the measurement innovation in the railway infrastructure safety is both the manner of thinking and acting, including selection of measurement techniques and methods, as well as development and utilization of a measuring device that ensures good quality of acquired data. An innovative measurement device called the magnetic-measuring square (MMS) was presented along with adapters for installation of surveying prisms on a digital or manual track gauge with an adapter allowing for installation of a laser distance meter on a gauge meter. There were also some factors suggested that influence the changes in contemporary railway surveying, considering the emerging dilemmas. A component of the railway infrastructure are the road and railway crossings as well as the pedestrian crossings. It is the priority to ensure safety on the railway and road crossings. This is a highly dangerous type of level crossings, especially when it comes to D category - meaning the unguarded crossings. The paper focuses on application of the author's measurement innovations in the rail transport infrastructure, while referring to geometry of road and railway crossings. The article presents the author’s observations and conclusions. The article was prepared as part of the AGH statutory research no. 11.11.150.005.

Keywords: measurement innovations, railway surveying, Magnetic-Measuring Square, MMS, road and railway crossing, safety, railway infrastructure, visibility splay, measurements

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1. INTRODUCTION

The measurement innovations in the railway infrastructure safety are faced with numerous challenges, including the need for increased efficiency, greater reliability, optimization of measuring devices and their applications, acquisition of good-quality data and reduction of costs. At the same time, failure to meet those requirements decreases the railway surveying’s - and thus the railway transport’s - capability of reaching particular objectives, including the improvement in mobility and effectiveness of transport. There has been a measurement device called the magnetic-measuring square (MMS) developed to reach those objectives. There have been numerous innovative measures assumed, which are already implemented, and which can be expanded with additional measuring components. There were also adapters developed for installation of surveying prisms on a digital or manual track gauge with an adapter allowing for installation of a laser distance meter on a gauge meter. The measurement innovations in railway infrastructure safety regard not only the railway transport but also railway surveying (railway geodesy). Including its utilization for tram and underground transport. Application of the magnetic-measuring square and the manual or digital gauge meter equipped with surveying prisms and the distance laser meter in the field of railway surveying and diagnostics is broad. The paper focuses on utilization of those measurement innovations in the geometry of road and railway crossings, which are highly dangerous, especially when it comes to D category - the unguarded crossings. One of the components of the railway infrastructure are road and railway crossings as well as level crossings, including the devices and systems ensuring safety of road and pedestrian traffic. Furthermore, the paper demonstrates some factors that influence transformations in today’s railway surveying. The article presents the author’s observations and conclusions. The article was prepared as part of the AGH statutory research no. 11.11.150.005.

2. REVIEW AND ANALYSIS OF SELECTED LITERATURE OF RESEARCH SUBJECT

In their work [1] entitled “Modelling risk at low-exposure railway level crossings: supporting an argument for low-cost level crossing warning devices with lower levels of safety integrity” the authors presented a risk model for estimation of probability of collisions on road and railway crossings. They proved the influence of differences in safety integrity on the probability of collision. This model facilitates the comparison of advantages regarding safety between the railway crossings with passive control and the railway crossings, which where hypothetically modernized with conventional or low-cost warning devices. The scenario presented in the paper [1] shows how the road and railway crossings equipped with low-cost devices may ensure greater safety when compared to conventional warning devices. Authors of the paper [1] claim that the number of fatal accidents in Australia, resulting from collisions between road and railway vehicles, is about 30% (excluding suicides). In Poland, the percentage share of fatalities according to categories of crossings in 2015 reached 47.3% on D category road and railway crossings. At the same time, it is noticed in [1] that the accidents on road and railway crossings and their consequences generate high costs for the society and railway transport, which is why it is the priority to improve the level of safety.
Authors of the paper [4], entitled: “Lifecycle Based User Value Analysis of Rail - Road Level Crossings: Probabilistic Approach Using Monte Carlo Simulation” notice that railway operators (managers) keep pushing on minimization of the infrastructure maintenance costs, at the same time expecting that it will ensure operation thanks to optimum allocation of natural and economic resources. They also conclude that the road and railway crossings as well as the pedestrian crossings are long-standing types of assets that are in service for 30-100 years. In their article [4], the authors presented an approach that serves as support for the decision, thanks to which the expert’s knowledge can be integrated directly. The methodology suggested in the paper [4] illustrates some applications of road and railway crossings that are commonly employed in Austria by Wiener Lokalbahnen. Today, a great challenge in the railway sector is the increasing goods transport, a larger number of freight cars, greater loads to axles accompanied by an increase in speed what requires modernization of the network. Therefore, railway undertakings remain in their constant strive for modernization of railway routes to introduce some improvements for the users. The possible increase in speed improves the infrastructure availability and attractiveness of the railway transport, what in turn enhances the sustainable development. The routes modernized in terms of a greater number of trains, passengers and amount of freight need safe and optimum measures on the road and railway crossings. It is a challenge for the infrastructure owner or administrator to choose the road and railway crossings with longer service life and a minimum exploitation cost, at the same time fulfilling the social demand for a safe network of infrastructure.

The author of the paper [3], entitled: “New approach to determining visibility length on passive protected level railroad crossings” notices that majority of accidents in Slovenia took place on passive road and railway crossings. They conclude that traffic safety on passive crossings is highly dependent on the field of visibility. Apart from road signs, the field of visibility is the only and significant measure ensuring traffic safety on passive road and railway crossings. In turn, it is unambiguously stated in the paper [6] entitled: “An Automated System to Mitigate Loss of Life at Unmanned Level Crossings” that every life is precious and valuable. It includes a proposal for development and implementation of a safety system on road and railway crossings. The system is based on communication, the Internet and embedded systems, i.e. special-purpose computer system that pose an integral part of the object that they operate. Development of the real-time early-warning system is intended to serve the railroad crossings in India. The result shown in [6] is provision of visual communication and a warning against an approaching train.

The paper [1] also proves that the purpose of the efforts made by various researchers and practitioners in this sector is to ensure reliability, availability, maintainability and safety (RAMS) in the whole life-cycle. The authors of [1] conclude that interaction between roads and railways on the road and railway crossings is a critical point. The main function of a road and railway crossing is to ensure fluent and safe passage for motorized transport. The road and railway crossings combine the requirements of road and railway traffic. The “road” and “railway” subsystems influence each other. It is important that the subsystems and their components are maintained in good and safe conditions that correspond to safety requirements of the whole system. To achieve the maximum operability period with minimum direct and indirect maintenance costs. Service life of the road and railway crossings depends on technical and economic factors that exert direct or indirect impact on the whole system.

Authors of the paper [7], entitled: “Improving safety of level crossings by detecting hazard situations using video based processing” conclude that safety on road and railway
crossing is a priority issue for the discipline of smart transport systems. The presented video based approach, intended to detect and evaluate hazardous situations triggered by the users (i.e. drivers of the vehicles, pedestrians, unguarded objects) who use the railway crossings. The system detects and tracks the objects on the road and railway crossing via its video system sensors. Afterwards, there was the Hidden Markov Model developed, intended to recognize perfect trajectories of the objects that were detected during the tracing procedure. The hazard risk level is estimated immediately, by employing the Dempster-Shafer data synthesis technique. There are three hazard scenarios tested and evaluated against various real video sequences: the presence of barriers when passing the road and railway crossings, the presence of lines of the vehicles that stopped, staggering of vehicles between two closed semi-barriers).

In turn, the papers [2,5,8] discusses the notions regarding the visibility conditions on a road and railway crossings. In the author's work entitled ”Geometry of D category road and railway crossing” in the 6th Polish Scientific and Technical Conference, Rzeszow, 2017 - was claimed that railway crossings pose a specific element of the railway infrastructure. The load on road and railway level crossings increases the probability of an accident. Safety on road and railway crossings depends on the condition of its geometry, on behaviors of road users, proper execution of tasks by the railway and road infrastructure managers. The paper discusses the notions related to geometry measurements of the D category road and railway crossing, with consideration of the authors measurements on the railway line 143. The measurements were done with the magnetic-measuring square (MMS) with:

- a surveying measuring disc,
- an adapter with a laser distance meter,
- the GMP111 mini-prims,
- a rolled-up meter,

and Leica TC407 tachymeter no. 697413. The geometry measurements were also supported by diagnostic works related to the crossings.

In the next author's paper entitled ”Measurement of geometric visibility conditions level railroad crossing", discusses the notions regarding the visibility conditions on a road and railway crossings - with consideration of author’s measurements on the railway line 144. The presented results of works regarded the geometric conditions of visibility, which were obtained by employing the author's adapters that serve for installation of surveying prisms on a manual or digital gauge meter. The measurements also employed the magnetic measuring prism working with a measuring disk.

3. CHANGES IN RAILROAD SURVEYING

The railroad surveying means creation of safe and competitive conditions for provisions of railway transport services. The measurement innovations in the railway infrastructure safety are hi-tech as well as caring and ensuring high quality standards for rendering services on the railway transport market. The contemporary market requires an increasing level of comfort. Not only an immediate response to the emerging problems, but first of all this active delivery of solutions. And those solutions result in positive changes, development of railroad surveying and guaranteed acquisition of good-quality data.
What is specific for railway surveying is the enormous diversity of surveying tasks and cartographic works. Their results allow, among others, to determine the operation parameters of the railway infrastructure’s elements, resulting from their current technical condition. The ensure forecasts of changes in the technical condition of the infrastructure, regarding the operation conditions in various time horizons.

The measurement innovation in the railway infrastructure safety is both the manner of thinking and acting, including selection of measurement techniques and methods, as well as development and utilization of a measuring device that ensures good quality of acquired data. At the same time, it is a “flywheel” in railway surveying, as it means introducing “something” new. The technology is progressing constantly and at an increasing pace, regardless of the field of operations. Excellence is a feature of those elements that are adjusted to specific conditions and requirements. Launching a measurement tool on the market, and gaining the competitive advantage - these are the benefits from innovation. The consumers’ behavior is governed not only by prices, but also by quality that they have attached greater significance in recent years to, what results from their increased awareness. Changes in the railway surveying are modeled through:

1. Active development of research, covering among others: quality of data acquisition, optimization of measuring devices, automation of the data acquisition and processing procedures, computerization, development of computational methods and observations, normalization of technical solutions and procedures, emergences of new field of application.
2. Civilization progress and social circumstances.
3. Legal regulations.
4. Market requirements.
5. Economic factors.
6. Technological advancement: mobile technologies (e.g.: measurement vehicles), development of electronics and IT, railway diagnostics, miniaturization of measuring devices.

Facilitation of methods and techniques that ensure surveying and diagnostic data acquisition, is accompanied by development and improvement of the characteristics of the observed phenomena. Afterwards, these are the values and methodology for development of the collected data, by adopting adequate measurement devices. Dilemmas of the research in railway surveying cover among others: quality of surveying networks (quality of the Railway Surveying Grid – Kolejowa Osnowa Geodezyjna/KOG, including the Railway Special Grid (fixed point) – Kolejowa Osnowa Specjalna/KOS), optimization, quality and homogeneity of acquired data related to a status of the existing railway infrastructure, as well as newly constructed, modernized and expanded objects and devices on railway lines, errors in railway kilometers. These problems also refer to the notions of legal statuses of reals estates owned by the Polish State Railways - PKP S.A. (Polskie Koleje Państwowe S.A.).

4. SAFETY OF ROAD AND RAILWAY CROSSINGS

Safety on road and railway crossings depends on behavior of road users, and correct implementation of tasks by the railway and road infrastructure managers. The tasks under
Implementation by the railway and road infrastructure managers also cover the scope of surveying works. Legal regulations determined their duty to guarantee safe operation. The dilemma of accidents on road and railway crossings results among others from the fact that Poland is characterized with a great number of road and railway crossings in Europe, as confirmed by biennial Report "Railway Safety Performance in the European Union 2016" - European Union Agency For Railways (Fig. 1). The D category road and railway crossings - so-called unguarded - are characterized with the highest number of occurrences. The irregularities are, among others, improper location of the crossings, improper geometry of D category road and railway crossings (visibility splays), no cooperation and communication of information among infrastructure managers, police, road managers, regarding the performed audits. Afterwards, there is the issue of technical and operational documentation of a road and railway crossing or a pedestrian crossing that is kept improperly in a form of so-called crossing certificates, difficulties experienced by the infrastructure managers in obtaining the results of traffic intensity measurement from the road managers.

Safety of persons interested in using the road and railway crossings depends on adequate qualification of particular railway crossings to a proper category. This in turn depends on the current measurement of traffic intensity. There is a need for inspections and benchmarks of safety conditions, especially on those crossings that were provided with new categories resulting from a change in exposure factors. Safety on road and railway crossings relies on standard surveying works what was mentioned in the authors paper entitled: “Pomiar geometrycznych warunków widoczności przejazdu kolejowo-drogowego” (Measurement of geometric visibility conditions on a road and railway crossing) and in the article entitled: “Geometria przejazdu kolejowo-drogowego kategorii D” (Geometry of D category road and railway crossing) during the 6th Polish Scientific and Technical Conference.

![Figure 1](image.png)

**Figure 1.** Number of active and passive level crossings per 100 line-km in 2014: active road and railway crossings - protected with railway traffic operation devices, passive road and railway crossings - protected with road signs
Typical surveying works in case of D category railway crossings are, among others: measurement and identification of crossing angles between a road and railway line, development of site plans (with measurement and identification of visibility barriers from the road), cross-sections, visibility splays for D and E category crossings. Afterwards, measurements and identification of visibility conditions of the train front from the road, at a distance of 5, 10 and 20 m. Determination of:

- current longitudinal tilt on the approach fragments to the track, measurement of the length and width of the crossing, road, road prism, intertrack space (distance between track centers), etc.,
- geometric condition for location of the level crossing: on a straight track section, curved track section, straight and curved fragments of a road,
- height of the contact wires of the overhead line,
- distance of the B-20 “stop” sign from the G-3 “St. Andrew’s cross before a single-track railway crossing” or G-4 “St. Andrew’s cross before a multiple-track railway crossings” from the extreme rail of the track,
- status of the land utilities network,
- dewatering condition of the crossing,
- significance of the objects and devices that may limit the influence of visibility in a right-of-way on a 20-m fragment, from each side of the crossing, measured from the extreme rail,
- width and depth of track grooves (flangeway).

5. INNOVATIVE MEASUREMENT DEVICES

A measurement device’s task is to allow independent measurements or when combined with one or several additional devices. A basic component of a measurement device named magnetic-measuring square / MMS is (Patent application: P. 420214): measuring archet, an adapter of the measuring archet and right/left rail square as well as measurement accessories (Fig. 2). As it was proven, the measurement innovation in the railway infrastructure safety is both the manner of thinking and acting, including selection of measurement techniques and methods, as well as development and utilization of a measuring device that ensures good quality of acquired data. Therefore the magnetic-measuring square is composed of the left and right squares. They are a mirror reflection. Based on the mutual complementation principle of the “left and right hand”. Regarding the technology, measurement method and purpose, they are employed as a whole or separately. Its versatility and optimization leans on its compatibility with, among others: various surveying prisms, the author’s specialist measuring disk (with horizontal and vertical millimeter scale), reference signals for laser scanners, laser distance meters, specialist laser pointers, measuring line, e.g. with dia. of 0.2÷0.4 mm, a rolled-up meter.

The magnetic and measuring square, regarding the purpose of the measurement, ensures measurement in reference to the measurement point located 14 mm below the upper running surface of the rail or the lower edge of the rail head. The example of the above is posed by road and railway crossings where measurement of the flangeways width is carried out 14 mm below the upper running surface of the rail head.
Figure 2. A magnetic-measuring square: a) components of MMS, b) a measuring archet with an embedded adapter of the measuring archet
In turn, measurement of the distance between track centers (intertrack space) or of visibility splays is performed at the lower edge of the rail head. Application of the magnetic-measuring square is first of all the measurement of (Fig. 3):

- geometric parameters of tracks and turnouts (Fig. 3c),
- values of horizontal and vertical versines in tracks and turnouts,
- verification of perpendicularity of rails contacts to the track axis,
- cross-section of the rails,
- creeping of the rails (shifts of contactless tracks) on railway lines,
- tracks zeroing,
- subgrade floors,
- curvature of rails,
- track width in the intertrack space (Fig. 3a and 3b),
- structure gauge (Fig. 3b or 3d),
- measurement of second differences (gradients) of crossings height or of diamond crossings,
- leveling of tracks and turnouts,
- planeness,
- integration from adapter mode for installing reference signals for scanners.

Results of works carried out with the magnetic-measuring square are included among others in the 6th Polish Scientific and Technical Conference, Rzeszow, 2017.

![Figure 3. Work modes of a magnetic-measuring square: a) MMS with a surveying measuring disc, b) MMS with the Laser Distance Measuring Device (rangefinder laser), c) MMS with GMP111 mini-prism d) MMS with a rolled up meter](image-url)
Figure 4. A manual track gauge equipped with adapters for installation of: a) surveying prisms, b) laser distance meter
An innovative measurement solution in railway infrastructure safety is also posed by the adapters developed for installation of surveying prisms on a digital or manual track gauge with an adapter allowing for installation of a laser distance meter on a gauge meter. It significantly facilitates these simultaneous works on acquiring data that refer to the basic geometry of a railway track or turnout, i.e.: width and tilt (cant) of the track, as well as additional parameters required in technical inspections of the turnouts. Additionally, installation of surveying prisms ensures determination of an existing axis of the track and the turnout track in a form of X, Y, Z coordinates, integrated with an electronic tachymeter, and measurement of the structure gauge with an embedded laser distance meter.

6. CONCLUSIONS

The measurement innovation in railway infrastructure safety covers the areas of measurement works that are mutually dependent and complementary. Innovation in the sphere of safety poses a significant factor for improvement in data acquisition quality and proper operation of railway transport and railway surveying, and thus their development. The development innovative measurement devices support not only the workers from those surveying works industries and diagnostic works, but also experts and decision-makers. Studies in the field of measurements safety on the road and railway crossings proved that there is a need to expand the supervisory actions within the areas, where a safety level is required.

References


