TRACK GEOMETRY DEGRADATION AND MAINTENANCE OF THE RAILWAYS

Ivona Nedevska
MSc, Teaching Assistant
University “Ss. Cyril and Methodius”
Faculty of Civil Engineering – Skopje
nedevska@gf.ukim.edu.mk

Zlatko Zafirovski
PhD, Assistant Professor
University “Ss. Cyril and Methodius”
Faculty of Civil Engineering – Skopje
zafirovski@gf.ukim.edu.mk

Marijana Lazarevska
PhD, Assistant Professor
University “Ss. Cyril and Methodius”
Faculty of Civil Engineering – Skopje
marijana@gf.ukim.edu.mk

Riste Ristov
MSc, Teaching Assistant
University “Ss. Cyril and Methodius”
Faculty of Civil Engineering – Skopje
ristov@gf.ukim.edu.mk

Vasko Gacevski
MSc, Teaching Assistant
Ss. Cyril and Methodius University
Faculty of Civil Engineering – Skopje
gacevski@gf.ukim.edu.mk

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Today, rail networks across the world are getting busier with trains travelling at higher speeds and carrying more passengers and heavier axle loads than ever before. The combination of these factors has put considerable pressure on the existing infrastructure, leading to increased demands in inspection and maintenance of rail assets.

This paper studies track deterioration from geometric aspects and its influencing factors with a case study for railway line of pan – European Corridor 10 on the territory of North Macedonia.

The analysis made in the paper will obtain results that would reflect the actual state of the railway infrastructure on the territory of the Republic of North Macedonia..

Keywords: track geometry degradation, maintenance, measuring vehicle, railway quality, railway management, measurement visualization

1. INTRODUCTION

The maintenance of railway infrastructure is an economic issue with high costs. Predicting damage and degradation of railway geometry and planning and organizing maintenance work requires some experience and knowledge of various indicators of railway quality. The decision to maintain and intervene on the route requires a precise and qualitative definition of the goals to be achieved. These goals refer to the quality, quantity, and price of the performed maintenance. Therefore, it is necessary to define the maintenance process following the predefined goals and set good indicators to check the expected performance [1].

In maintaining the railway infrastructure, it is crucial to measure and maintain the geometry of the railway at an acceptable level and to minimize the risk of trains derailing. Therefore, the quality of the route geometry must be assessed to determine the levels of deviation. When the measured variation is above a predetermined limit, travel speeds must be reduced, affecting travel comfort and increasing transport costs. Thus, the correct geometry of the route can be considered a measure of both safe travel and travel quality [2].

Route degradation is a complex process. The quality of the route is assessed according to the condition of its components and its geometry. The poor state of one part usually contributes to the degradation of the other [3].

The complexity of studying railway degradation comes from the diversity of their components' characteristics and the system's traffic [4].

The trans-European networks and the pan-European corridors are designed to enable traffic connection in several directions to satisfy the needs for the transport of goods and people. Therefore, in the Republic of North Macedonia, it is necessary to develop the railway network to provide a regional connection with neighboring railway networks and contact with the nearest ports in neighboring countries and meet the principle of competition in the transport sector.

Macedonian railway infrastructure is included in the network of pan-European corridors and routes:

- Corridor 10: Thessaloniki - Skopje - Nis - - Belgrade - Zagreb - Ljubljana - Salzburg,
- Corridor 10d: Veles - Prilep - Bakarno Gumno - Bitola - Florina (Florina),
- Corridor 8: Durres - Tirana – Kafasan / / Lin - Kicevo - Skopje - Kriva Palanka - - Gjueshevo - Sofia - Plovdiv - Stara Zagora - - Varna / Burgas,
- Route 10 - Kosovo - Skopje border.

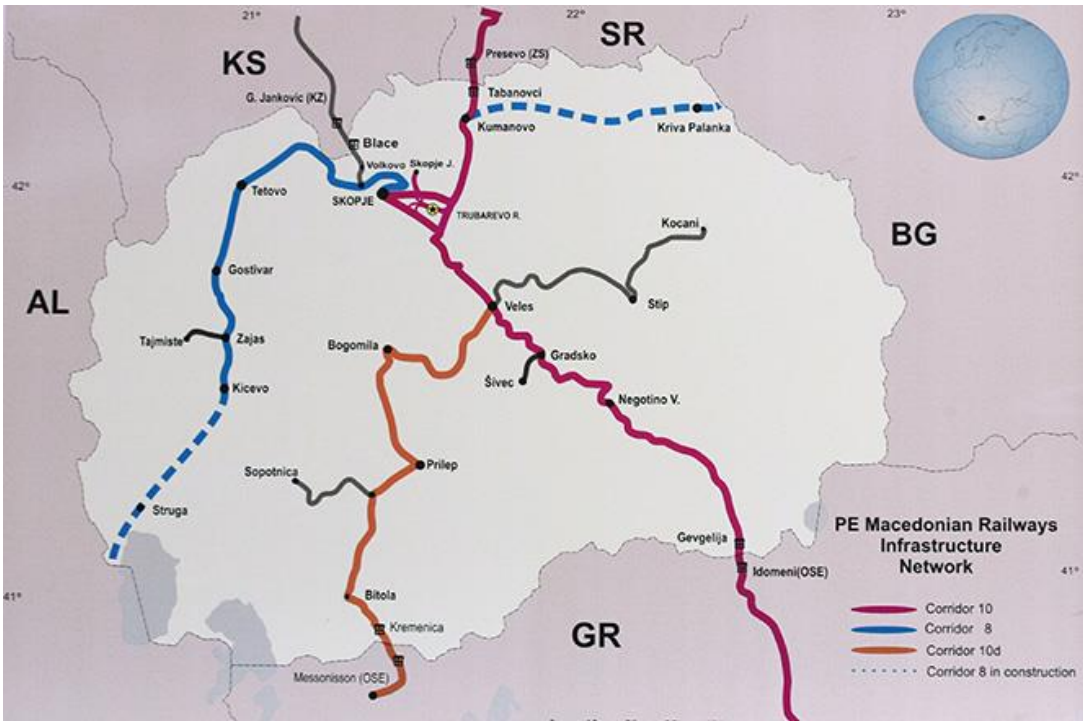

Figure 1. Pan-European Corridors on the territory of North Macedonia

The development of the railway infrastructure in the Republic of Northern Macedonia must be in function of sustainable and balanced development of the country and thus lead to the inclusion of the Republic of Northern Macedonia in the common market of the European Union.

Consequently, it is necessary, above all, on the railways that are important for the international traffic, to improve the railway infrastructure and harmonize in the technical-technological needs required for the trans-European railways to coordinate the development of the railway infrastructure with the others. Types of transport (road, sea, air, and combined) and most importantly, through modernization, overhaul, and maintenance of the existing railway infrastructure to supplement the necessary infrastructure capacity to increase the volume and functionality of rail transport.

2. RESEARCH SCOPE

The main problem that will be elaborated on in this paper refers to the research of the condition of the tracks of the railway infrastructure on the territory of North Macedonia with a particular reference to the geometric degradation of the track and the analysis of influential parameters that lead to the appearance of degradation of the track.

The research subject is the analysis and measurement of geometric degradation of the railway from Corridor 10 on the territory of North Macedonia.

The corridor is on route Tabanovce - Skopje - Veles - Gradsko - Demir Kapija - Gevgelija - Bogorodica. The railway is intended for mixed traffic (passenger and freight). The main railway line from Corridor 10 that runs along the Republic of Macedonia has a total length of 214.9 km and is electrified along its entire length, modernized, with an average speed of 90 km/h.

3. RAILWAY LINE ON CORRIDOR 10

The railway track on Corridor X is a single track and the present railway line allows a maximum speed of trains between 60 and 80 km/h. This situation is caused principally of geometry of railway line, which has built in XIX century, and in small part of bad condition of superstructure and substructure.

The total length of railway track is 214,9km and total length in the curve line is 114,1km; so the 53% of the railway track is in curve line and 47% in alignment.

The analysis of number and length of curve lines for three main sections on Corridor 10 shows that the section Tabanovci – Skopje has not any curve lines with radius less or equal than 300 m, and the section Skopje – Veles has about 12% of length in curve lines with radius between 250 m and 300 m.

There are 6 tunnels through Corridor 10 and total length of tunnel is 1029,4 m. All tunnels are located on the sections Skopje-Veles and Veles-Gevgelija. The speed of trains is limited to 60 km/h because in tunnel sections the radiuses are less than 350m.

The total number of bridges is 91 with total length of 2312 m. About 52% are steel bridges whose length is 1778 m, or 77% of total bridges length. All bridges on Corridor 10 can support

Figure 2. Corridor 10 on section Skopje – Veles
Source: Prospection in situ

axel load of 225 kN/80kN/m and they are classified in D4 – UIC group.

There are also 80 drainage culverts on the section Tabanovce-Skopje (1,6/km), 118 on the section Skopje-Veles (2,3/km), and 298 on the section Veles-Gevgelija (2,6/km).

The total railway track consists of continuous welded rails (CWR). The most used rail is S49 on 97,3% of track length and of 2,7% of rail length have rail type S54 (sections line between stations Tabanovci – Kumanovo and Romanovci – Miladinovci).

The timber is dominant with around 89% of total number of 329 727 sleepers on railway track of Corridor X. The normal sleeper spacing is between 600 - 650 mm.

The most wide - spread fastenings system on the track is rigid K-system for each section where the timber sleepers are set and elastic fastenings SKL-14 with greater elasticity in the case of prestressed concrete sleepers.

The ballast is constituted from crushed limestone with grading of 25/60 mm for sections between railway stations.

The thickness of the ballast bed is estimated 30 to 35 cm measured from the underside of the sleeper. The ballast is contaminated frequently by attrition of the ballast material or upwards penetration of fine particles in the form of a clay mixture or slurry.

Figure 3. Superstructure with railway track of CWR
Source: Prospection in situ

4. TRACK GEOMETRY MEASUREMENTS

Railway management institutions in all European countries are obliged to carry out measurements and technical and diagnostic tests of the elements of the railway infrastructure. These actions aim to determine the objects and devices' actual (real) condition. The information collected in this process is the basis for approving decisions to continue exploitation, take preventive measures, or start repairs. Such measurements require specialized construction tools adapted to the specific nature of the railway environment and to an accuracy that meets the requirements specified in the sector guidelines [5].

Infrastructure operators have recognized this and have changed their attitude towards measuring vehicles, especially in recent years. Gauges are no longer considered just a safety instrument but, in the broadest sense, enable "the right action at the right time." Changes in the meaning of measuring vehicles and new technological possibilities in measuring technology, primarily video surveillance, have led to significant technological advances in recent years [6].

The Track Geometry Measurement System provides accurate and reliable track data for immediate and long-term maintenance planning. The system can be installed on virtually any rail bound vehicle and provides all the data necessary for the optimum management of track assets [7].

For measuring, recording and analysis of the track geometry, the standard equipment of every track recording car is the track geometry

measuring system. This consists of an inertial navigational measuring system with integrated GPS positioning and a dual optical gauge measuring system. Track geometry faults with wavelengths up to 200 m can be recorded, regardless of the measuring speed [8].

Figure 4. Mermec measuring vehicle

The track geometry measurements of the railways on the territory of North Macedonia were carried out by measuring vehicles of the company Mermec (Figure 4) in 2010 and 2013.

The system offers highly accurate measurements with real time reports of exceedances of allowed geometry.

The vehicle measures:

- track gauge - the distance between the inner surfaces of the head rails measured 14 mm lower than the head tops,
- cross level/cant - difference in the height of rail heads in one cross section,
- twist - difference in cant on the base length of 5 m,
- alignment (D1 and D2) - horizontal deviation of the rail head from a base line (10 m long) measured independently for both rails,
- longitudinal level (D1 and D2) - vertical deviation of the rail from a base line made by points of tangency of 2 wheels with the rail (base distance equals to 10 m). It is measured independently for both rails.

According with the European Standard EN 13848-5, the thresholds used for defects detected by Track Geometry Measurement System are reported in the following tables:

Table 1. Thresholds for gauge measurement

Gauge [mm]			
IAL		IL	
Minimum	Maximum	Minimum	Maximum
-11	35	-9	30

Table 2. Thresholds for twist measurement

Twist [%]			
IAL		IL	
Minimum	Maximum	Minimum	Maximum
-7	7	-5	5

Table 3. Thresholds for alignment measurement

Alignment [mm]			
IAL		IL	
Minimum	Maximum	Minimum	Maximum
-17	17	-11	11

Table 4. Thresholds for longitudinal level measurement

Longitudinal level [mm]			
IAL		IL	
Minimum	Maximum	Minimum	Maximum
-26	26	-13	13

5. DATA COLLECTION AND ANALYSIS

One of the purposes of this quantitative analysis is to correlated track geometry data from the measurement campaigns with operating conditions, weather, superstructure elements and maintenance activity history.

Track geometry measurements were performed in 2010 and 2013 using a measuring vehicle from the Italian company Mermec.

The results presented are based on the data collected from two measurements during three years, from 2010 to 2013.

Most of this data must be visualized correctly for users to gain insight into the actual behaviour of the objects in question. Hence the utter need for high-quality visualization when it comes to infrastructure management. This is because, sometimes, even looking at the data, if displayed innovatively and adequately, can help infrastructure managers derive invaluable insights.

The Ramsys software system (Railway Asset Management System) developed by Mermec interprets the raw data from track geometry measurements on a user-friendly module.

Figure 5 shows some of the visualization capabilities of the Ramsys system. The important thing here is the complete freedom of the user in terms of defining Views and customizing them to his/her own needs and liking, as well as freedom in combining various data types in any user-defined way in order to gain better insight into mutual dependencies between the data, correlations in order to search for the root cause of the problems.

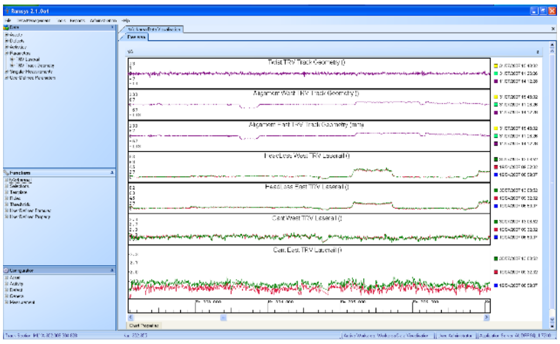

Figure 5. Measurement visualisation in Ramsys system

From the analyses data it is concluded that 22% of the railway network has been reported to be in very good and good condition, where approximately 70%-100% of designed speed can be achieved. The largest part of the railway network is in medium condition, with larger variations in the maximum allowed speed. On these sections, approximately 42%-88% of designed speed can be achieved. 31% of sections have been reported to be in a poor condition, where on average 55% of designed speed can be achieved (Figure 6).

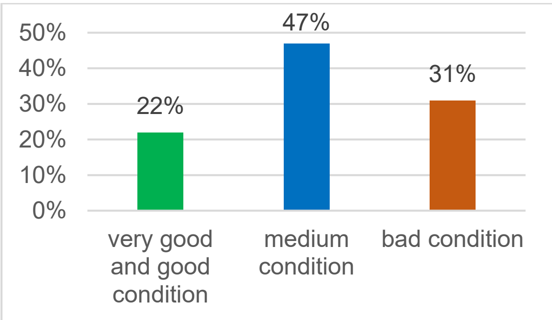

Figure 6. Condition of the railway Corridor 10 on the territory of North Macedonia

At this moment, the railway can respond to the current traffic volume. However, the fact that only 11% of the railway from corridor 10, which passes through the Balkan countries, is classified as a favourable condition, while the rest has medium or unfavourable conditions, indicates the need for reconstruction.

The primary interventions in the short term should ensure higher speed and technical standards of the network.

6. CONCLUSION

The available documents concluded that there is almost no record of the maintenance and renewal of railway infrastructure elements carried out over several decades. At best, an unsystematic approach to maintenance and renewal is present.

However, the actual and exact level of this poor condition, as well as the locations bearing the worst conditions endangering the safety of traffic, remain vastly unknown. This is due to the utter lack of:

- Consistent information about the exact location of all the Railway Infrastructure Assets,
- Consistent information about the systematic and regular Railway Infrastructure Assets condition measurements, especially over a more extended period,
- Methods, knowledge, and means for large-scale systematic Railway Infrastructure Assets condition-data collection,
- Methodology, standards, and tools for the processing and analysis of the collected condition-data to schedule the appropriate Maintenance and Renewal works.

Improving the condition of the superstructure of the busiest sections of Corridor 10 should be a priority task. The condition of the track on certain sections of the main line is terrible due to the total depreciation of the superstructure elements. This situation today leads to a reduction in train speeds and increased operating costs.

Considering that the price of road transport will largely depend on the oil prices in the world markets, the railways should pay particular attention to using these external factors for a more significant attraction of passengers. It will be of great importance to increase the travel speeds of passenger trains by reconstructing the track from Corridor 10.

For more efficient maintenance, it is necessary to acquire additional machinery that will be needed for more economical and higher-quality operations.

REFERENCES

[1] Antonio Ramos Andrade, Paulo Fonseca Teixeira, "Uncertainty in Rail – track geometry degradation: Lisbon – Oporto Line Case Study", Journal of Transportation Engineering, March 2011

[2] Genovefa Kefalidou, David Golightly, Sarah Sharples, "Identifying rail asset maintenance processes: a human – centric and sensemaking approach", Cognition, Technology & Work (2018) 20:73–92 https://doi.org/10.1007/s10111-017-0452-0

[3] Iman Soleimanmeigouni, Alireza Ahmadi, Arne Nissen, Xun Xiao (2020) "Prediction of railway track geometry defects", Structure and Infrastructure Engineering, 16:7, 987-1001, DOI: 10.1080/15732479.2019.1679193

[4] A.A. Iman Soleimanmeigouni, "Track geometry degradation and maintenance modelling: A review", Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, 2016

[5] Dr.-Ing. Dr. techn. Florian Auer, Multi-function track recording cars, 2013.

[6] Zdenka Popovic, Filip Trpcevski, Isidora Pancic, Luka Lazarevic (2014). Harmonizacija evropskog kvaliteta koloseka, GRADJEVINSKI MATERIJALI I KONSTRUKCIJE 57 (2014) 1 (29-44)

[7] Jovanović S, MER MEC S.p.A., Italy (2007): Modern railway Infrastructure Asset Management, Rail-Tech Russia 2007, Moscow, Russia, June 18-20, 200723

[8] Dr.-Ing. Dr. techn. Florian Auer, Multi-function track recording cars, 2013.