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Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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MAINTENANCE IN THE LIFE CYCLE OF RAILWAY INFRASTRUCTURE

Waldemar Alduk[1], Saša Marenjak[2]
1 HŽ Infrastruktura d.o.o. Zagreb, Croatia
2 Faculty of Civil Engineering Osijek, University of Osijek, Croatia

Abstract

This paper analysis a comparison of the current maintenance of railway tracks with the maintenance based on an analysis of the life cycle costs in order to define a new model for the maintenance of railway infrastructure. The model should generate a minimum total cost in the life cycle of railway tracks for the required level of track quality. The current model of corrective maintenance of track in use was analyzed, and an alternative model of preventive maintenance during the extended life cycle of the track is proposed.
The model was defined using a chosen track section, which was analyzed and reduced to two representative types of standard kilometer. Following these analyses, models for corrective maintenance and preventive maintenance for standard kilometers I and II were obtained, also considering corresponding subtypes depending on the anticipated traffic load up to 1, to 3 and to 5 million gross tons. Benefits for preventive maintenance are lower overall maintenance costs with great effects and longer periods of preserved high quality of the track, while deficiencies are increased maintenance costs at the beginning of the observed period of the life cycle, the need for good preparation of maintenance with strong logistics and unavailability of track for longer periods of time.
Benefits of corrective maintenance are lower initial costs of maintenance due to its use, since they are the only parts of the track where failures were found that are maintained, while the disadvantages are total higher maintenance costs, faster reduction in the overall quality of the track, small effects of maintenance and many short intervals of closed tracks due maintenance with high costs disorders in train traffic. The research results favored preventive maintenance with flexible quality maintenance limits during lifecycle of track.

Keywords: railway network, corrective maintenance, preventive maintenance, life cycle costs

1 Introduction

In the last few decades in Europe significant changes are occurring in the management of railway infrastructure. In all EU member states, but also outside the EU, continuous work on the restructuring of railways is taking place in order to separate the railway infrastructure management and transportation management. Infrastructure Managers (IM) today must ensure the system of railway infrastructure that provides reliable transport of passengers and cargo in a safe manner and that should be as simple to maintain. The decision on choosing the type of railway track is not only determined by the initial investment cost ("cost of acquisition"), but also by the costs that will be generated through the operation and maintenance ("cost of ownership") in the lifetime of the railway track. In order to make this possible, manufacturers and suppliers involved in the project of railway track construction are developing products that are reliable and cost-attractive in order to optimize the cost of acquisition and cost of ownership. This optimization should normally begin immediately at the beginning of the life cycle of the track, during concepts and definitions of the system, in order to anticipate all expenses that will occur during the life cycle of the track. All decisions of the infrastructure manager concerning the design, manufacture and construction of track components have an impact on the performance of the track safety, reliability, maintainability and total life-cycle costs. A key aspect of the railway track, as an essential part of the railway infrastructure, is its long lifespan (30 years or more), because once the track is built, later is extremely expensive and complicated to change its design. This means that decisions taken at the beginning of the life cycle and dynamic decision-making over a period of maintenance have a long-term impact on the lifetime of the track.

2 Maintenance of the railway infrastructure

The life cycle of the railway track system is a time period that encompasses the overall lifespan from the initial concept of the track until its disposal. European norm EN 60300-3-3:2004 Life Cycle Costing [1] defines the life cycle cost of the general system and its application to the track superstructure (Figure 1).

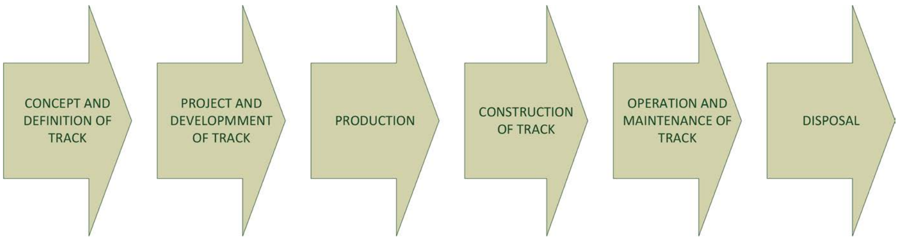

Figure 1 Life cycle of railway track [1]

Due to the long lifespan of the track, operation and maintenance phase is significant for the study of costs. During that phase periodic maintenance activities are performed that generate cost, and its more or less successful effects significantly contribute to the total cost in the lifetime of the railway track. Good maintenance can affect the life cycle of a railway track in such a way as to ensure the expected lifetime of the track, while flaws in maintenance activities can significantly shorten the track lifespan early and cause a irrecoverable decrease quality of the track, need for a subsequent increase in maintenance and therefore higher costs, as may ultimately result in earlier than expected renewal of the track. Rail infrastructure maintenance is a combination of technical and administrative activities, including inspection activities, which aim to preserve the railway track in operation or bring it to a state that can perform the intended function – the circulation of railway traffic in a reliable and secure manner, with a designed capacity and according to the defined requirements for speed limit and the permitted axle load. To design optimal maintenance it is important to ensure the necessary conditions [2] such as: Register of infrastructure as a first step maintenance management system to structure a complete record of railway track and its correlation with quality (determined by measurements), maintenance activities and generated traffic load. These data are mainly in possession of infrastructure manager, but in different databases and forms, which are relatively difficult and complicated for maintenance purposes. Maintenance models that determine methods to monitor the track degradation, frequency of maintenance activities and definition of required maintenance activities. Cost analysis in the life cycle enables the determination of the optimum between investment and maintenance, or comparison and selection maintenance type with the lowest total cost while ensuring the required quality of the track, using developed maintenance models, experiences in maintenance and expert assessment. Planning of maintenance and renewal of the track with the help of computer support facilitates the prioritization of maintenance activities, as well as identifying and planning the necessary resources such as time intervals for maintenance, necessary labor, materials, machinery and equipment for maintenance. Maintenance of the track is classified according to EN 50126-1999 [3] (Figure 2).

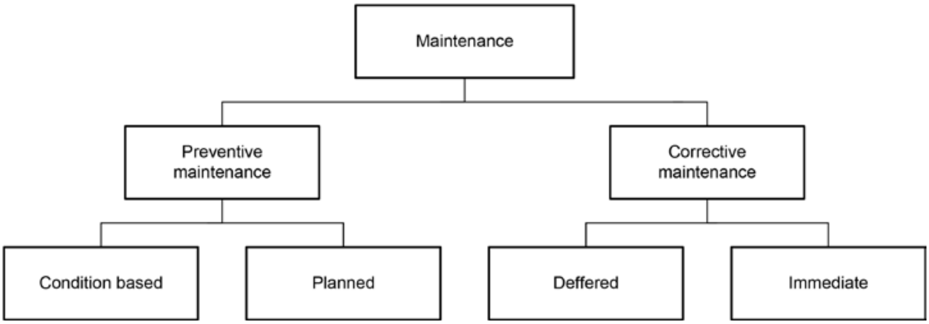

Figure 2 Types of maintenance of railway track [3]

The infrastructure manager during operation and maintenance of the track must make decisions that are aimed at preserving the balance between economic aspects (costs) and safety-technical aspects (safety) of railway track. The aim of the infrastructure manager in terms of maintenance is to find efficient and cost-effective models to optimize the operating hindrances and reduce train speed restrictions which finally contribute to the increased availability of the track in its lifetime.

3 Track maintenance models

On the track in use were considered the costs of present type of maintenance in prolonged life cycle of track and comparison with an alternative way of maintenance while maintaining the required quality of the track. Considered track in operation is single track R202 Dalj-Varazdin, section between Osijek and Nasice 48.159 km long. The section was built in 1974, category of load is D4 (22.5 t/axle, 8 t/m1), maximum speed of trains is 80 km/h. Designed lifespan of this section was 33 years which has been exceeded in 2007. This means the track section has been completely depreciated, so there are considered just projected maintenance costs in its estimated extended life cycle for a period of 12 years (2013.-2024). Superstructure of the considered track is based with wooden sleepers for a length 19.916 km (Table 1) and with concrete sleepers for a length of 28.243 km (Table 2). Based on the overall characteristics of the track section Osijek – Nasice, types of standard kilometers (SK) are defined that best describe the considered track section:

Table 1 Standard kilometer I

R > 600 m		**single track, 38 years old**		
MGT/year	rail/sleeper/track	rail grade	ballast bed	substructure
1 / 3 / 5	49E1, wooden (K), CWR	200-220	crushed stone	good

Table 2 Standard kilometer II

R > 600 m		**single track, 38 years old**		
MGT/year	rail/sleeper/track	rail grade	ballast bed	substructure
1 / 3 / 5	49E1, concrete (K), CWR	200-220	crushed stone	good

For standard kilometers subtypes were developed (a, b, c), depending on the expected traffic load on the track – to 1 (a), to 3 (b) and to 5 (c) millions gross tons per year (MBT). Standard kilometers define the main types of maintenance (work cycles) for track section one kilometer in length. In the following will be presented standard kilometer IIb for traffic load up to 3 MBT and maintenance of the track with concrete sleepers type HZ-70, fastening type K or ZEL, rail type 49E1 in the ballast bed of crushed stone. Track is continuously welded (CWR).

3.1 Corrective maintenance

The present method of track maintenance is mainly based on the principles of deferred corrective maintenance based on track condition and detection of failures that require corrective maintenance. Through review of the recorded data obtained by recording car for track geometry, visual inspection of the track and elements of superstructure, maintenance activities are executed only at places where failures are detected at the limit of intervention (category C) [4] and within the available budget for maintenance. If determined condition of the track is such that endangers traffic safety (exceeds intervention limit), it is necessary to immediately take actions to ensure the safety of railway traffic and take immediate corrective maintenance activities. The costs of such maintenance as compared to the effects achieved are relatively high because, for example, machine tamping performed on the track so far was with a relatively small number of machines and in short intervals between trains, resulting in repeated operating hindrances, long slow orders and trains delayed due to maintenance activities. Unavailability of track during maintenance often means expensive substitution of passenger trains with buses and thus increased maintenance costs, and need for passenger operators to provide additional sets of passenger trains.
A key working cycles with corrective and preventive maintenance are recognized through following maintenance activities: tamping of track (leveling-lining-tamping – LLT), adding crushed stone for ballast bed (necessary after LLT), exchange of sleepers, rail replacement, exchange of synthetic rail pads, small spot repairs and chemical weed control. Taking into account the data on the condition and quality of the track, available databases and available experience in track maintenance enables creation of standard kilometers for corrective maintenance and the traffic load up to 3 MBT/year (Table 3).

Table 3 Standard kilometer IIb – working cycles of corrective maintenance

Standard kilometer IIb														
R>600		single track												
Milions GT/year	rail/sleeper/track	grade	ballast bed			substructure								
up to 3	49E1, concr. (K/ZEL),CWR	220	crushed stone			good								
maintenance	life span	12	1	2	3	4	5	6	7	8	9	10	11	12
renewal	times in life span	0												
leveling-lining-tamping	times in life span	4,1	0,35	0,35	0,35	0,35	0,35	0,35	0,4	0,4	0,4	0,4	0,4	
additional ballast	times in life span	0,18		0,03		0,03		0,04		0,04		0,04		
rail exchange	times in life span	0,03			0,03									
sleeper exchange	times in life span	0												
rail pads exchange	times in life span	0,1		0,1										
small repairs	times in life span	3		1				1				1		
chemical weed control	times in life span	11	1	1	1	1	1	1	1	1	1	1	1	

3.2 Preventive maintenance

An alternate way of track maintenance in the life cycle of railway track is based on planned preventive maintenance for multi-year periods. In this way, maintenance costs of operating hindrances (costs of slow orders, substitutions of passenger trains with buses, delayed trains) are reduced to a minimum in a way to ensure long enough intervals of track possessions for maintenance (duration of min. 6 hours) with numerous and high quality machinery capable for large work effects and maximum utilization of the available time periods for maintenance. That allows execution of maintenance work with smaller total number periods of closed track and overall shorter duration of slow orders with less operating hindrances in railway traffic. Maintenance activities are planned through monitoring of the track quality index (TQIu) [4] in a way to maintain the overall quality of the track at the entire length of track section and up to the maintenance limit and prevention exceeding of intervention limit and need for corrective maintenance. Leveling-lining-tamping activities are executed in approved time intervals of track possessions for maintenance at the entire track section and the quality of the whole length of the track section is increased, as opposed to corrective maintenance where just a parts of the track section are maintained at sections with low quality (Table 4).

Table 4 Standard kilometer IIb– working cycles of preventive maintenance

Standard kilometer IIIb														
R›600		single track												
Milions GT/year	rail/sleeper/track	grade	ballast bed			substructure								
up to 3	49E1, concr. (K/ZEL),CWR	220	crushed stone			good								
maintenance	life span	12	1	2	3	4	5	6	7	8	9	10	11	12
renewal	times in life span	0												
leveling-lining-tamping	times in life span	4	1			1			1			1		
additional ballast	times in life span	0,16	0,04			0,04			0,04			0,04		
rail exchange	times in life span	0,03			0,03									
sleeper exchange	times in life span	0												
rail pads exchange	times in life span	0,1		0,1										
small repairs	times in life span	3		1				1				1		
chemical weed control	times in life span	11	1	1	1	1	1	1	1	1	1	1	1	

3.3 Comparison of maintenance costs

For each working cycle of standard kilometers and for all maintenance activities were calculated maintenance costs per kilometer of track, separately for corrective maintenance and preventive maintenance. Maintenance costs were calculated on the basis of available data of infrastructure manager (IM) HŽ Infrastruktura, Zagreb (period from 2012 and 2013) about costs of maintenance machinery, costs of superstructure materials, costs of labor and costs of operating hindrances. In order to determine the present value of the maintenance costs in expected life cycle of track, maintenance costs are discounted using a discount rate selected at the beginning of the observation period. With summing up the annual costs of the operation and maintenance phase discounted at the beginning of the observation period, present value of maintenance costs are determined in the observed life cycle of a railway track.

Table 5 Present values of corrective maintenance costs (CM) and preventive maintenance costs (PM) for standard kilometer IIb

Standard kilometer IIb													
MGT	concr.	year											
up to 3	total (kn)	1	2	3	4	5	6	7	8	9	10	11	12
Present value (CM)	259004	12123	63460	41849	21074	9974	33901	9881	21039	8962	28611	8129	0
Present value (PM)	228713	38405	41088	30868	33175	3534	12290	28658	3053	2907	32098	2637	0

To compare the costs of current model of corrective maintenance for railway tracks with the proposed model of preventive maintenance in the prolonged life cycle of 12 years, discount factor of 5 % was chosen to calculate the present value of maintenance costs, while the impact of inflation is not taken into account (Table 5). By comparing the value of the cost of corrective maintenance in relation to the expected costs of preventive maintenance for standard kilometer II and traffic load up to 3 MBT, noticeable are the potential savings up to 11.69 % for a given period of prolonged life cycle track in use for a period of 12 years [5]. Maintenance costs for corrective and preventive maintenance in a standard kilometer IIb can be shown in relation to the expected traffic load in the period of extended lifecycle, after which the costs of corrective and preventive maintenance are associated with the corresponding logarithmic regression curve (Figure 3).

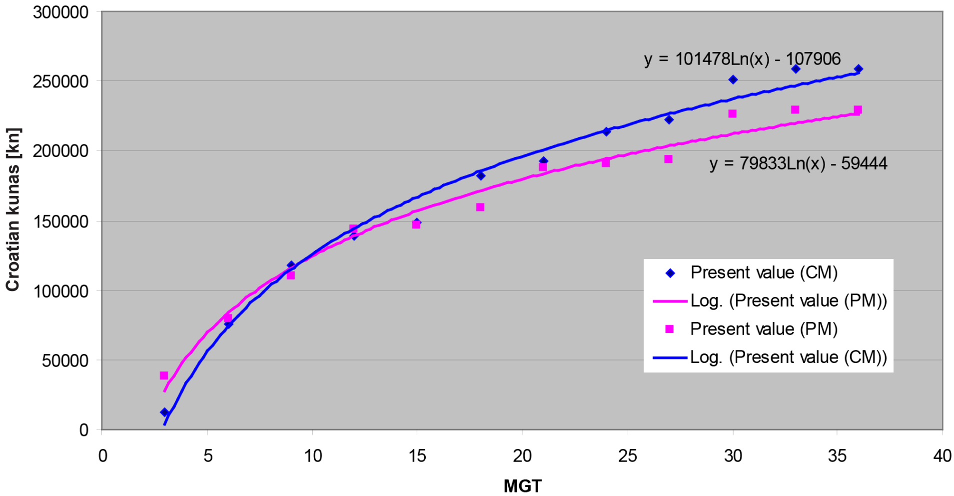

Figure 3 Comparison of corrective and preventive maintenance costs (present values) based on cumulative traffic load for standard kilometer IIb (7,5 kn = 1,0 EUR)

In the case under consideration, the comparison of corrective and preventive maintenance of the standard kilometer IIb shows that the cost of preventive maintenance at the beginning of the observed prolonged life cycle of 12 years are higher than the initial cost of corrective maintenance. Benefits of corrective maintenance are greater flexibility and faster execution of maintenance because it maintains only a portion of the track that requires maintenance, and in the beginning of the life cycle maintenance costs are smaller because of latter start with track maintenance and only on the sections where failures are detected. Disadvantages of corrective maintenance are cumulatively higher costs and higher quality loss than for preventive maintenance, harder prolongation of life cycle without reducing the speed on the track and more intervening corrective maintenance. Advantages of preventive maintenance are longer periods of high quality of the entire track in relation to corrective maintenance, total less maintenance costs, less intervening corrective maintenance because of the high quality of the track and a bigger potential for lifecycle extension of the track. Disadvantages of preventive maintenance are initially higher costs than for corrective maintenance, comprehensive and high-quality preparation to ensure necessary preconditions for the timely performance of maintenance (timely procurement of necessary quantities and types of materials, services, logistics and long enough time periods for maintenance works).

4 Conclusion

Track maintenance should be based on preventive maintenance based on track condition, overall quality of the track, resulting traffic load and past experiences of experts in maintenance. Through monitoring activities such as visual inspection of the track, inspection of track with special equipment for measuring and testing individual elements, inspection of track with locomotive of maintenance personal, analyzing the geometric diagram of the recording car and track quality index provide a basis for planning of preventive maintenance. Through inspections of track failures are observed regardless of their size, but according to their seriousness the necessary emergency corrective maintenance should be performed, and for the next period activities of delayed corrective or preventive maintenance should be planned. The fact is that through planned maintenance activities and working cycles it is not possible to achieve the level of quality that existed immediately after the track renewal [6], but it is also the fact that maintenance activities can slow down decline of track quality and ensure a certain lifecycle extension of the track. Preventive maintenance activities normally should be planned years in advance and for the total expected lifecycle of the track, while the potential number of failures for corrective maintenance activities is estimated based on past data on the frequency of errors and their impact on the traffic disturbances. For a successful preventive maintenance it is required to ensure quality computer support and development of software solutions which will be based on collected detailed data on the condition of track components, data on the changes of the quality of the track during operation in relation to traffic load, data on the quality of completed maintenance activities and data about previous maintenance costs. In that way it will be possible to successfully implement and realize the maintenance of the track based on the lowest whole life costs through planned life cycle of track.

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