



SAFETY ASPECTS OF RAILWAY VEHICLE MAINTENANCE PLANS WITHIN THE EUROPEAN REGULATORY FRAMEWORK

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Abstract – Maintenance of railway vehicles constitutes a fundamental control function within the Safety Management System (SMS), with direct implications for system reliability and risk mitigation. Deficiencies in maintenance planning may result in unmitigated risks and compromised operational safety. EN 17023 provides a structured framework for compliance with Directive (EU) 2016/798 and Regulation (EU) 2019/779 governing Entities in Charge of Maintenance (ECM), particularly regarding traceability, documentation, and continuous improvement based on operational feedback. This study evaluates the role of EN 17023 in enhancing safety through the integration of a systematic feedback loop between in-service failure data and maintenance planning. Although failure data is routinely collected through technical inspection reports, its integration into maintenance optimization remains limited. The analysis is based on empirical data obtained from official Technical Wagon Inspection (TWI) points of Užice between September 2022 and January 2024. The results demonstrate that implementing risk-informed, data-driven maintenance strategies (supported by targeted inspections of critical components) significantly improves safety performance and system reliability. The proposed approach facilitates alignment with EU regulatory frameworks, including ECM certification and the Common Safety Method (CSM), thereby enhancing safety levels in railway operations.

Keywords – maintenance planning, Safety Management System (SMS), Entity in Charge of Maintenance (ECM), Common Safety Method (CSM), risk-based maintenance.

1. INTRODUCTION

Across Europe, rolling stock maintenance is mandated by EU Directives, specifically Directive (EU) 2016/798 [1], and operationalized via the European standard EN 17023 [2], which governs the creation, modification, and validation of maintenance plans. Adopted widely across non-EU states to ensure interoperability, EN 17023 translates the legal provisions of Regulation (EU) 2019/779 [3] into standardized operational steps.

To satisfy the Regulation's requirement for comprehensive documentation, EN 17023 prescribes specific documentation criteria for each maintenance phase and provides a methodology for linking every installed component to a specific vehicle and the

technician who installed it. This simplifies the process of establishing accountability for executed work tasks. A key feature of EN 17023 in railway vehicle maintenance is its ability to outline a procedure for implementing changes in technology or regulations directly into the workshop technicians' workflows. The feedback loop within railway vehicle maintenance is a process that enables a connection between field operations (specifically within traffic and workshops) and the entities in charge of maintenance (ECMs) [4].

The objective of this paper is to examine the role of EN 17023 in improving railway vehicle maintenance planning through systematic integration of operational feedback into maintenance plans. The study further evaluates how this approach supports

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compliance with the European railway safety framework, particularly within the ECM certification process and the Common Safety Method for Risk Assessment (CSM-RA).

The scientific contribution of this paper is reflected in: (1) presenting a systematic framework for integrating operational failure data into the maintenance plan revision process in accordance with EN 17023; (2) linking the maintenance planning process with the CSM-RA; (3) proposing key performance indicators (KPIs) for continuous monitoring of maintenance effectiveness; and (4) validating the proposed approach using empirical data collected from freight wagon inspections in operational service.

2. REGULATORY FRAMEWORK

Railway safety in the European Union and the Republic of Serbia is governed by Directive (EU) 2016/798 and national legislation, which mandate a Safety Management System (SMS) to systematically control operational risks. Within this framework, a certified Entity in Charge of Maintenance (ECM) must ensure a vehicle's technical fitness across four dimensions: risk management, documentation control, fleet maintenance management, and maintenance execution.

The primary objective of a maintenance plan is to leverage preventive maintenance to ensure safety-relevant functions are continuously restored. To manage these safety-critical elements, the system must implement three actions:

- Identification: Map components against hazard lists and perform risk analyses.

- Evaluation & Definition: Assess wear patterns to define targeted maintenance intervals.
- Documentation: Trace and flag safety-critical tasks to facilitate future modifications.

The European standard EN 17023 defines processes for creating, modifying, and validating railway vehicle maintenance plans, translating the legal provisions of Regulation (EU) 2019/779 into operational steps. It harmonizes fleet maintenance across freight, passenger, and traction rolling stock. To govern the vehicle lifecycle, EN 17023 systematically covers data selection, plan development, execution procedures, review triggers, risk assessment, and monitoring regimes.

The EN 17023 standard serves as a domain-specific implementation of the CSM-RA within railway maintenance. When a change to a maintenance plan is proposed, EN 17023 operationalizes CSM-RA principles through three key mechanisms:

- Significant Change Assessment: A structured screening process evaluates whether a maintenance modification (e.g., extending intervals) introduces new hazards.
- Risk Evaluation and Hazard Identification: If a change is deemed significant, a formal risk evaluation is conducted using codes of practice, reference systems, or explicit risk estimation.
- Safety Feedback Loop (Fig. 1): Real-world operational data and workshop defect logs trigger a re-assessment of the maintenance plan, translating high-level legal requirements into traceable technician workflows.

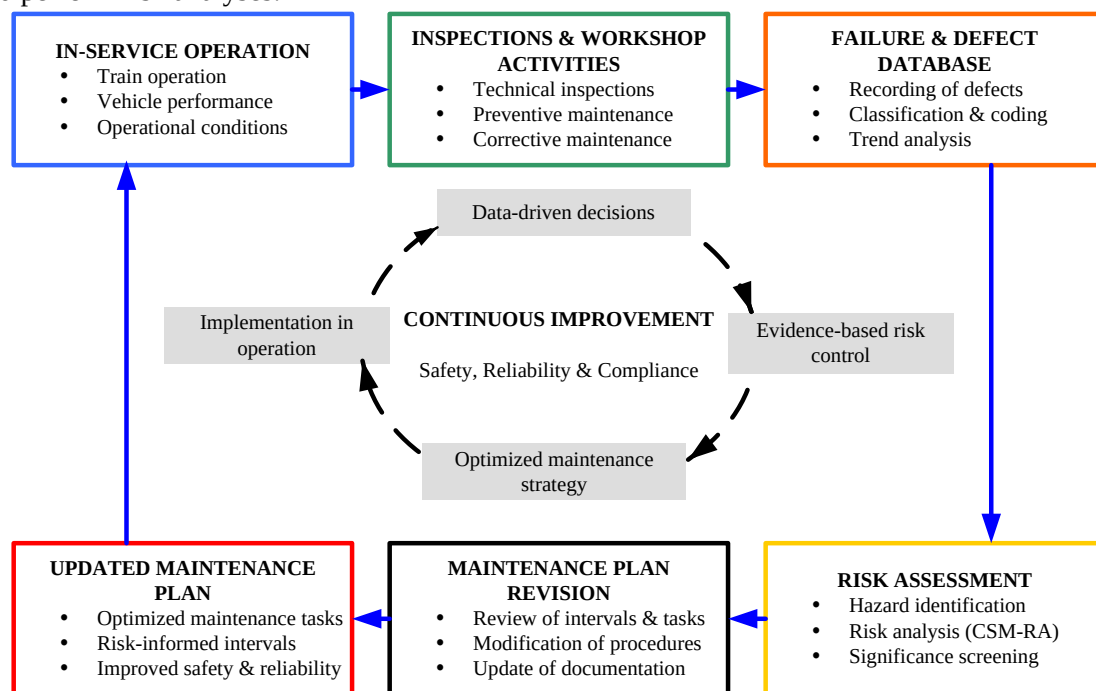


Fig 1. Feedback loop for maintenance plan development and revision in accordance with EN 17023

3. IMPACT OF THE MAINTENANCE PLAN

Risk assessment can be conducted using various methods. For any type of impact requiring a risk assessment, the baseline approach can be utilized by collecting and analyzing the necessary data, which includes operational experience gathered during service and operational experience from a maintenance perspective. Through predictive simulation and investigation of potential risks, combined with the definition of compliance criteria, the risk assessment of hazards arising from the introduction of a proposed change can be evaluated, taking existing safety measures into account [5,6].

3.1. Case Study

Data used in case study were obtained from regular monitoring of freight wagon operated by "Srbija Cargo" at technical wagon inspection (TWI) points at Užice Traction and TWI Section. The data from September 2022 to January 2024 revealed the following operational metrics [7]:

- Out of 5,443 recorded defects, rented wagons accounted for 34% of the total fleet issues.
- For company-owned wagons, the highest defect concentrations occurred within the wagon body (42%) and brake equipment (36%). Rented wagons exhibited a similar distribution, with the highest share of defects attributed to brake equipment

(56%) and the wagon body (23%).

- A defects of brake equipment on company wagons indicated that brake blocks constituted the vast majority of failures at 58%, while pneumatic and mechanical components accounted for 22% and 20%, respectively. Wear-related issues made up 91% of all brake block defects, meaning that brake block wear alone accounted for 48% of the total recorded fleet defects. Rented wagons exhibited the highest number of brake-related defects within the pneumatic system.

These data represent the operational feedback required to trigger a modification of the maintenance plan. Based on this case study, systemic brake block wear on "Srbija Cargo" freight wagons is isolated as the core technical problem, representing nearly half (48%) of all fleet defects. The proposed change to the maintenance plan involves shortening the time or mileage interval between technical brake inspections, to facilitate the replacement of worn brake blocks before they cause wheel damage or brake system failure during operation.

3.2. Risk assessment applying the CSM-RA

By applying the screening algorithm (Tab. 1) outlined in EN 17023, a preliminary analysis was conducted based on evaluation criteria reflecting the core principles of CSM-RA.

Tab. 1. Screening analysis of the proposed maintenance plan change

Criterion	Assessment	Justification
Consequence of failure	High (Safety)	Failure or inefficiency of the brake system due to maximum wear of brake blocks directly jeopardizes railway traffic safety.
Novelty	Low	Replacement of brake blocks modifications to inspection intervals are standard, long-standing operations within railway workshops using mature technologies.
Complexity	Medium	While component replacement is simple, the modification impacts complex fleet logistics, technical inspection scheduling, and operational line capacities.
Monitoring (Oversight)	Easy	The frequency and progression of wear on the newly implemented blocks can be easily monitored via regular TWI records and workshop.
Reversibility	Easy	If the new interval proves to be inefficient or economically unjustified, the system can revert to the baseline maintenance regime without permanent impact.

The consequence of failure receives a "High" assessment because it directly affects a safety-critical train function. According to the EN 17023 algorithm and CSM regulations, a high safety impact is an eliminating factor. Any change relating to safety-critical components (such as the brake system) cannot be introduced via an expedited procedure. Consequently, the proposed change to the maintenance plan is classified as a "significant change". It is mandatory to conduct a detailed risk assessment applying the CSM-RA methodology before the amended maintenance plan is officially validated and implemented.

The detailed risk assessment is structured through

hazard identification and application of risk acceptance principles.

3.3. Defined Safety Measures

To mitigate the identified risks to an acceptable level (As Low As Reasonably Practicable - ALARP), the following mandatory measures must be integrated into the amended maintenance plan:

- Technical Measure (Optimized Interval): Based on data showing block wear accounts for 48% of defects over 16 months, the preventive brake inspection interval for critical wagon series is shortened by half (or an equivalent mileage

threshold).

- Organizational measure (EN 17023 traceability): Each block replacement must be documented through a workshop order, where the serial number and type of block are linked to the wagon ID number and the mechanic who performed the installation.
- Operational measure (TWI control): A mandatory visual inspection of block thickness is introduced at TWI Užice for trains arriving from lines with steep gradients (where braking is more intensive).

In order to operationalize the system and close the loop between the workshop and safety management, Key Performance Indicators (KPIs) were proposed to introduce specific for the brake system maintenance. These indicators would serve as a direct, quantitative input for the CSM for monitoring, enabling early detection of deviations before critical failures occur.

Proposed KPIs for the Brake System:

- Brake reliability metric (KPI_b) - The number of in-service brake system defects per 10,000 train-km. This monitors failure trends to verify the efficacy of the shortened maintenance interval.
- Indicator of premature block wear (KPI_w) - Percentage of brake blocks replaced at TWI stations (unplanned) relative to the number of blocks replaced during regular maintenance in the workshop to detect accelerated material wear or quality issues with supplied components.
- Mean kilometers between failures (KPI_f) - Total fleet operational mileage divided by the number of registered brake defects.

The proposed indicators are directly implemented through defined model of the CSM for monitoring:

- Strategy and planning: Within the SMS, a target value ($KPI_b < 0.05$ defects per 10,000 km) and an alarm threshold (Trigger level) are established.
- Data collection and analysis: Data on replaced blocks from the Užice Section and the completed mileage of freight wagons are entered into the database. The system automatically calculates KPIs on a monthly basis.
- Development of action plans (Response): If KPI_b exceeds the alarm threshold, it serves as a signal to CSM monitoring that the risk control system is not functioning properly. Engineers immediately initiate a technical audit (e.g., verifying the material quality of the blocks or further shortening the interval).
- Reporting and improvement: Performance trends are formally documented and submitted to the national Directorate for Railways, proving that the ECM and railway undertaking actively supervise operational safety.

4. CONCLUSION

Based on the empirical data and risk screening conducted in this study, it can be concluded that the EN 17023 standard is not yet fully operationalized within the observed system. Although defect data is systematically tracked and recorded at TWI stations, the critical step prescribed by the standard to translating field asset data into official, dynamic updates of the maintenance plans, is absent in practice. The logs exist in isolation, breaking the data-driven "learning loop" and weakening the risk control mechanism.

The EN 17023 standard strictly mandates that a maintenance plan must behave as an evolving, safety-responsive document. The absence of an automated feedback loop between observed field failures and documentation updates directly elevates operational risks. A functional "learning loop" implies that real-world wear metrics (such as block wear causing 48% of fleet defects) must systematically trigger the re-evaluation and optimization of maintenance intervals. Without this coupling, the organization remains entirely reactive – remedying failures post-occurrence rather than dynamically adapting the maintenance plan to prevent them.

Future research should validate the proposed methodology on larger railway fleets and investigate the integration of predictive maintenance techniques and digital monitoring technologies into EN 17023 maintenance planning.

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