

# Comparative Analysis of Railway Rolling Stock Maintenance Standards Between United Kingdom and Indonesia

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## ABSTRACT

This study presents a comparative analysis of railway rolling stock maintenance standards between United Kingdom and Indonesia, addressing Indonesia's critical lack of specific legislation governing rolling stock maintenance systems and procedures. Employing systematic literature review, thematic analysis, and gap analysis methodologies, the research examines UK regulations (ROGS 2006, Railway Industry Guidance and Standards) and European standards (BS EN 17000-series) alongside Indonesian frameworks (UU 23/2007, PP 56/2009, ministerial regulations). Thematic analysis identified six key aspects of UK maintenance practice: Maintenance Organisational Structure, Maintenance Planning, Procedures and Standards, Documentation and Record-Keeping, Certification and Competency, and Safety and Quality Assurance. Comparative analysis reveals substantial gaps across four dimensions: technical gaps (limited SMS integration, rigid interval-based maintenance, no cross-border compatibility), regulatory gaps (absence of Entity in Charge of Maintenance mandate, insufficient maintenance plan specificity), institutional gaps (lack of systematic organisational certification and independent auditing), and documentation gaps (manual record-keeping, limited digital traceability). These findings demonstrate that while Indonesia ensures basic compliance, its maintenance framework lacks the performance-based, risk-driven structure characteristic of UK systems, highlighting the need for regulatory modernisation aligned with international best practices.

**Keywords:** rolling stock maintenance standards, thematic analysis, comparative analysis, gap analysis, regulatory framework.

## 1 INTRODUCTION

Maintenance encompasses all technical and administrative operations aimed at preserving a component in or restoring it to a condition that enables it to perform a necessary function. The maintenance policy is the comprehensive strategy implemented for the delivery of maintenance and maintenance support, along with the system's objectives and policies (Kumari et al., 2025). The main challenge to railway rolling stock maintenance in Indonesia is the lack of legislation that specifically govern the system and procedures for rolling stock maintenance. Although standard operating procedure documents have become mandatory requirements that operators must for the procurement of new or used rolling stock, there is a necessity for new regulations that specifically addressing rolling stock maintenance to encourage structured monitoring and documentation of rolling stock data for both operators and regulators.

Benchmarking United Kingdom (UK) rolling stock maintenance standards offers multiple benefits that directly address the challenges above. UK rail industries are known for their mature and comprehensive maintenance frameworks, which have evolved through decades of refinement and are embedded in legislation, standards, and industry culture. UK standards put a strong emphasis on safety in maintenance operations. Under the Railways and Other Guided Transport Systems (Safety) Regulations (ROGS) 2006, all mainline rolling stock must have an Entity in Charge of Maintenance (ECM) listed in the national vehicle register, and certain vehicles (notably freight wagons and passenger stock used internationally) require a certified maintenance system. This clear accountability ensures that maintenance is not ad-hoc but follows structured, audited processes.

The UK rolling stock maintenance standards provide a robust template for transforming Indonesia's maintenance practices. Improved safety through stricter maintenance accountability, interoperability through harmonised

procedures, and adherence to global best practices are compelling reasons for the adoption. Aligning with UK standards would effectively elevate Indonesia's maintenance regime to global best practice levels.

## 2 LITERATURE REVIEW

### 2.1 UK Rolling Stock Maintenance Standards

In the UK, the maintenance of rolling stock is governed by a framework of railway safety regulations that establish duties for railway operators and maintainers. The cornerstone ROGS 2006, which implemented EU rail safety directives into UK law. ROGS requires every railway undertaking to have a certified Safety Management System (SMS) and, importantly, mandates that no rail vehicle be operated on the mainline network unless it has an assigned ECM. Regulation 18A of ROGS (introduced via amendments) specifies that each vehicle's ECM must maintain it according to a defined system of maintenance, including compliance with applicable maintenance rules and standards. This means, before a train is put into service, the operating company must ensure a competent entity is responsible for its upkeep and that the vehicle has a maintenance file and plan in place. By law, the ECM's identity is recorded in the national vehicle register (NVR), tying each piece of rolling stock to a maintenance regime for accountability (Office of Rail and Road, 2022).

Table 1. UK rolling stock maintenance standards

No.	Regulation/Standard	Description
1.	The Railways and Other Guided Transport Systems (Safety) Regulations (ROGS) 2006 No. 599	The main regulation for railway safety
2.	The Railways (Interoperability) Regulations (RIR) 2011 No. 3066	Interoperability: common framework for new railways vehicle and infrastructure
3.	Rail Industry Guidance (RIG) Note - GMGN2697	Application of the Entity in Charge of Maintenance Regulations
4.	Railway Industry Standards (RIS)- 2004-RST	Rail vehicle maintenance standards
5.	Railway Industry Standards (RIS)- 2706-RST	Recording of rolling stock data standards
6.	Railway Industry Standards (RIS)- 2708-RST	Rail industry standard technical committee audit protocol

UK regulations embed technical standards within the safety framework, with the Railways (Interoperability) Regulations 2011 requiring new or upgraded rolling stock to meet specified technical requirements and maintain a compliant maintenance file for authorisation. Interoperability and safety are thus linked, as rolling stock must be maintained according to its technical file throughout its service life. Retained EU Common Safety Methods further mandate monitoring of maintenance effectiveness, creating a chain of responsibility in which operators implement maintenance through ECMs, comply with technical and safety standards, and remain under ORR oversight—reinforcing that proper maintenance is a legal necessity for safe railway operations.

### 2.2 UK Post-Brexit Equivalent (Technical Specifications and European Norm Standards)

The UK's post-Brexit maintenance standards regime rests on two pillars: (1) NTSNs, which legally enshrine the technical and maintenance requirements equivalent to EU standards, and (2) industry standards and guidance, which implement and enhance those requirements within railway companies. Together, they ensure that UK rolling stock maintenance remains rigorous and in line with European norms despite regulatory divergence.

Table 2. UK NTSN and EN standards

No.	Regulation/Standard	Description
1.	NTSN: Rolling Stock - Locomotive & Passenger	Technical Specification standards for locomotive & passenger rolling stock
2.	NTSN: Rolling Stock - Freight Wagons (WAG)	Technical Specification standards for freight wagon rolling stock
3.	BS EN 17018:2019	Railway applications – Rolling stock maintenance – Terms and definitions
4.	BS EN 17095:2019	Railway applications – Rolling stock maintenance – Maintenance records
5.	BS EN 17023:2018	Railway applications - Railway vehicle maintenance - Creation and modification of maintenance plan
6.	BS EN 50126:2017	Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

European Norm (EN) standards for railway rolling stock maintenance, developed by the European Committee for Standardization (CEN) with industry input and adopted by EU member states (and as BS EN standards in the UK), provide a harmonised technical framework and common terminology across Europe. The EN 17000-series standards, developed by CEN Technical Committee 256 on Railway Applications and adopted unchanged as national standards across the EU (and as British Standards in the UK), are generally voluntary unless mandated by regulation or contract, yet they strongly influence maintenance quality by providing a common framework.

### 2.3 Indonesia Rolling Stock Maintenance Regulations

Indonesia’s railway maintenance framework is established by Law No. 23 of 2007 (UU 23/2007) on Railways, which assigns the government, through the Ministry of Transportation, responsibility for regulating, guiding, and supervising safety, and obliges operators to keep rolling stock in safe operating condition. Government Regulation No. 56 of 2009 on the Implementation of Railways (as amended by PP 6/2017) specifies that trains undergo maintenance on daily, monthly, six-monthly, yearly, two-yearly, and four-yearly cycles, prohibits the operation of unsafe or uncertified rolling stock, and aligns maintenance practices from routine checks to major overhauls. Complementing this, Ministerial Regulation No. 24 of 2015 on Railway Safety Standards sets comprehensive safety criteria for infrastructure, rolling stock, operations, and personnel, mandating maintenance within technical lifespan limits and establishing government inspection and certification to ensure compliance.

Table 3. Indonesian government regulations for railway operation

No.	Regulation/Standard	Description
1.	National Law No. 23 of 2007 (UU 23/2007)	The main regulation for railway transportation in Indonesia
2.	Government Regulation No. 56 of 2009 (PP 56/2009)	Common regulation for railway operation in Indonesia
3.	Government Regulation No. 33 of 2021 (PP 33/2021)	The amendment of Government Regulation No. 56 of 2009

Under the 2007 Railway Law and its implementing regulations, the Ministry of Transportation (MoT) has issued a series of rules governing the testing, certification, technical specifications, design, modification, and maintenance of rolling stock. MoT Regulations No. 13–17 of 2011 set testing and certification procedures for different vehicle types: covering self-propelled stock, locomotives, passenger coaches, special vehicles, and freight wagons, requiring static and dynamic tests before operational certification, with oversight by the Directorate General of Railways (DGR) through inspections and audits. Technical specifications for each vehicle type, set out in regulations such as No. 175/2015 (self-propelled) and No. 153/2016 (locomotives), guide design, construction, testing, and maintenance, while Regulation No. 16/2022 mandates submission of maintenance plans or histories and staffing plans when procuring new or used vehicles. Regulation No. 24/2015 requires maintenance to use standard-compliant equipment and manufacturer-specified parts, with equipment calibrated regularly and work performed by certified personnel,

supported by Regulation No. 18/2019 on workshop and equipment standards and No. 16/2017 on maintenance personnel certification.

Table 4. Ministerial regulations for rolling stock operation in Indonesia

No.	Regulation/Standard	Description
1.	MOT Regulation No. 24 of 2015 (Permenhub No. 24 Tahun 2015)	Railway safety standards
2.	MOT No. 18 of 2019 (Permenhub No. 18 Tahun 2019)	Railway Rolling Stock Maintenance Workshop and Equipment Standards
3.	MOT No. 16 of 2017 (Permenhub No. 16 Tahun 2017)	Certification of railway maintenance personnel
4.	MOT Regulation No. 91 of 2011 (Permenhub No. 91 Tahun 2011)	Freight railway operation
5.	MOT Regulation No. 20 of 2021 (Permenhub No. 20 Tahun 2021)	Licensing for Public Railway Operation
6.	MOT Regulation No. 16 of 2022 (Permenhub No. 16 Tahun 2022)	Railway Rolling Stock Design and Modification
7.	MOT Regulation No. 175 of 2015 (Permenhub No. 175 Tahun 2015)	Technical specification standards for normal speed trains with self-propelled motors
8.	MOT Regulation No. 153 of 2016 (Permenhub No. 153 Tahun 2016)	Technical Specification Standards for Locomotive
9.	MOT Regulation No. 41 of 2010 (Permenhub No. 41 Tahun 2010)	Technical Specification Standards for Passenger Coach
10.	MOT Regulation No. 43 of 2010 (Permenhub No. 43 Tahun 2010)	Technical Specification standards for freight wagon
11.	MOT Regulation No. 44 of 2010 (Permenhub No. 44 Tahun 2010)	Technical Specification Standards for Special Vehicles
12.	MOT Regulation No. 13 of 2011 (Permenhub No. 13 Tahun 2011)	Standards, testing procedures and certification of self-propelled rolling stock feasibility
13.	MOT Regulation No. 14 of 2011 (Permenhub No. 13 Tahun 2011)	Standards, testing procedures and certification of locomotive feasibility
14.	MOT Regulation No. 15 of 2011 (Permenhub No. 13 Tahun 2011)	Standards, testing procedures and certification of passenger coach feasibility
15.	MOT Regulation No. 16 of 2011 (Permenhub No. 13 Tahun 2011)	Standards, testing procedures and certification of special vehicle feasibility
16.	MOT Regulation No. 17 of 2011 (Permenhub No. 13 Tahun 2011)	Standards, testing procedures and certification of freight wagon feasibility

While multiple regulations address aspects of rolling stock maintenance, MoT has not yet issued a dedicated regulation specifying maintenance standards and procedures, unlike for railway infrastructure, which is regulated under MoT Regulation No. 32 of 2011. Through the Directorate of Rolling Stock, the MoT enforces existing rules by requiring operators such as PT KAI to maintain records and submit rolling stock for periodic inspections, with non-compliant vehicles, such as those failing mandated braking efficiency tests, subject to certificate revocation and removal from service until repairs are completed.

### 3 METHODOLOGY

#### 3.1 Systematic Literature Review

In this study, the systematic literature review has been used to identify the key aspects and the critical themes of rolling stock maintenance in UK standards. The method used for conducting the systematic literature review is shown in Figure 1.

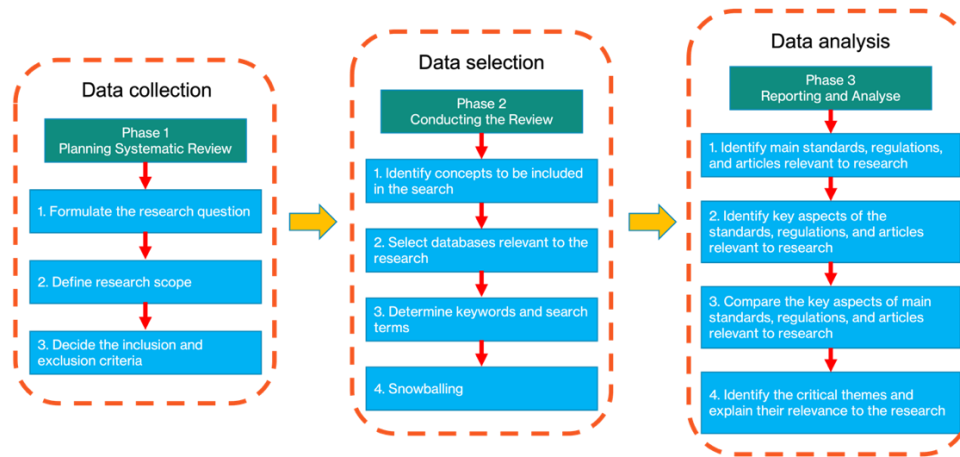


Figure 1. Literature review method.

Literature review is a secondary data collection method. Secondary sources used for this research include legal text, such as UK/EU regulations (ROGS 2006, EU directives/regulations like 2016/798, 2016/797, 2019/779), technical specification standards (TSIs, NTSNs, CEN standards), Indonesian laws and regulations (Railway Law 2007, MOT regulations), and relevant official reports or guidelines (ORR guidance for ECM, ERA reports, Indonesian Ministry reports). Each of these documents is treated as a data source to be systematically reviewed.

The inclusion and exclusion criteria of the sources are determined to ensure that the selected regulations and standards are legitimate and authentic. Also, to assure that the secondary data used focusses on the aspects of railway rolling stock maintenance in the UK and Europe. Key criteria for inclusion are the document’s focus on maintenance standards or regulatory policy and its authority (preference is given to primary legal instruments, official standards, and influential policy guidelines). The inclusion and exclusion criteria for data collection in this research are provide in Table 5.

Table 5. Inclusion and exclusion criteria

No.	Inclusion Criteria	Exclusion Criteria
1.	Official standard and legislation in UK	Superseded or withdrawn documents
2.	Industry guidelines and Technical Specifications related to rolling stock and maintenance aspects	Drafts or unfinalised documents
3.	English language	Non-English publications
4.	Relevance to key rolling stock maintenance objectives	The focus of the regulation is not related to railway rolling stock content

### 3.2 Thematic Analysis

Thematic analysis is a qualitative method for “identifying, analysing, and reporting patterns (themes) within data” (Braun and Clarke, 2006). Using this method, the text of regulations was carefully read and coded to extract recurring concepts, requirements, maintenance principles. The coding was accomplished manually annotating and employing tables in a spreadsheet to categorise analogous themes, instead of utilising automated technologies, to guarantee meticulous reading and contextual comprehension. Key documents analysed included British and European standards, such as TSIs, NTSNs, the EN maintenance series, ECM regulations, UK’s Railways and Other Guided Transport Systems Regulations 2006 (ROGS), and Rail Industry Standards such as RIS-2004. Themes and sub-themes identified from literature analysis will serve as the basis for a comparative analysis with the rolling stock maintenance regulations in Indonesia.

### 3.3 Comparative & Gap Analysis

A comparative analysis was conducted to assess Indonesian railway maintenance practices against UK standards through a structured literature review of national regulations, standards, and implementation reports, followed by thematic comparison with British frameworks. The analysis identified areas of alignment and divergence in maintenance requirements, organisational roles, and safety procedures, focusing on broad policy-level themes rather than technical specifications. Each theme was supported by documented evidence, citing corresponding provisions in Indonesia and UK regulations. This systematic approach ensured that subsequent gap analysis was grounded in a rigorous, theme-by-theme evaluation rather than ad hoc observations.

A gap analysis method was employed to comprehensively detect deficiencies in the Indonesian context compared to UK maintenance standards across several aspects. Gap analysis is a method or procedure used to uncover discrepancies between an organisation's existing state and the desired state. The organisation seeks to modify its current state to achieve a desired state through gap analysis (Kim and Ji, 2018). In this research, the “current state” is represented by Indonesia’s maintenance regulations and practices, and the “desired state” corresponds to the comprehensive standards exemplified by UK frameworks.

## 4 RESULTS

### 4.1 Thematic Analysis of UK Rolling Stock Maintenance Standards

Thematic analysis identified six main aspects in the practice of rolling stock maintenance in the UK and Europe: Maintenance Organisational Structure, Maintenance Planning, Procedures and Standards, Documentation and Record-Keeping, Certification and Competency, and Safety and Quality Assurance.

Table 6. Main aspect and sub-aspect of UK rolling stock maintenance framework

No.	Main Aspect	Sub-Aspect
1.	Maintenance Organisational Structure	Entity in Charge of Maintenance (ECM) Railway Undertaking (RU) Vehicle Keeper Manufacturer
2.	Maintenance Planning	Maintenance Plan Requirements Maintenance Plan Maintenance Activities Modification of Maintenance Plan
3.	Procedures and Standards	System of Maintenance Maintenance Procedures Maintenance Documentation Files Maintenance Standards Key Components for Maintenance
4.	Documentation and Record-Keeping	Maintenance Record Maintenance Record Requirements Maintenance Record Creation Process Recording Data
5.	Certification and Competency	Certification Body Certification Requirements Certification Process Competency Requirements
6.	Safety Quality Assurance	Safety Management Systems (SMS) Common Safety Methods (CSM) Safety Certificates Management of Safety Critical Components Management of Safety Critical Work Risk Assessment

#### 4.1.1 Maintenance organisational structure

UK legislation clearly define the organisational structure for rolling stock maintenance, outlining the responsibilities of key stakeholders. ECM is legally accountable for ensuring a vehicle remains in a safe state of running under the UK Railways and Other Guided Transport Systems (Safety) Regulations (ROGS). This involves managing a maintenance system compliant with an approved maintenance file, relevant rules, and technical standards, while maintaining oversight of outsourced tasks. The UK maintenance governance framework relies on clearly delineated but interdependent roles. The ECM is central to technical maintenance control, the RU ensures operational readiness and feedback into maintenance processes, the keeper enforces registration and compliance requirements, and the manufacturer provides the technical foundation for maintenance. Collaboration, accurate data exchange, and shared safety objectives between these actors form the backbone of the rolling stock maintenance regime.

#### 4.1.2 Maintenance planning

A formal maintenance plan is a legal requirement in UK frameworks, ensuring each rail vehicle is maintained according to a documented and regularly updated strategy. This plan, recorded in a maintenance file, outlines preventive maintenance tasks, inspection schedules, environmental considerations, and contingency procedures. Standards such as RIS-2004 and BS EN 17023:2018 require that it detail all activities, criteria, periodicities, resources, and working time estimates necessary to keep vehicles in compliance with original and updated design specifications. The maintenance file also incorporates general technical documentation, maintenance design justification, procedural instructions from the manufacturer, and configuration records for traceability.

The ECM is responsible for ensuring that such components are maintained to the highest standards, using certified parts and procedures, due to the potential catastrophic consequences of failure. The maintenance plan must integrate these requirements and enforce strict adherence to prescribed intervals, with non-compliance necessitating vehicle withdrawal from service or special authorisation. Maintenance plans are dynamic documents subject to review and modification in response to operational experience, technological developments, or updated regulations. EN 17023 set out a structured change process, requiring clear justification, impact and safety assessments, and formal approval by competent persons. Significant modifications may require the application of the Common Safety Method for Risk Evaluation and Assessment to ensure safety is not compromised. Regulators expect ECMs to treat this as part of a continuous improvement cycle, maintaining the plan's relevance and effectiveness so that vehicles remain safe and reliable throughout their operational life.

#### 4.1.3 Procedure and standard

Under UK ROGS framework, an ECM must operate a structured system of maintenance, comprising four interlinked functions. The maintenance management function (F1) retains top-level responsibility for safety policy, oversight, and integration of all other functions, which cannot be outsourced. The maintenance development function (F2) manages and updates maintenance documentation, ensuring compliance with interoperability requirements and incorporating operational feedback. The fleet maintenance management function (F3) plans and monitors vehicle maintenance schedules, while the maintenance delivery function (F4) executes the physical work, either in-house or contracted, under ECM oversight. This system is supported by documented maintenance procedures that translate the maintenance plan into step-by-step work instructions aligned with standards, manufacturer specifications, and industry best practices. Safety-critical tasks require enhanced procedural controls such as independent inspections and functional testing to ensure quality and consistency.

Maintenance documentation files consolidate the maintenance plan, procedures, and records into a coherent, traceable set of resources for each vehicle or fleet. These files include general technical drawings, system diagrams, design justifications, maintenance descriptions, and configuration data, structured in line with BS EN 17023 and BS EN 17095. The vehicle file contains the current maintenance plan and key technical information, while the maintenance order file records work instructions, reports, and release-to-service notices. Compliance is further supported by a hierarchy of regulations and standards, where legal frameworks define safety and interoperability objectives, and EN standards prescribe detailed processes, documentation requirements, and quality criteria.

#### 4.1.4 Documentation and record-keeping

Maintenance records, as defined in BS EN 17095:2019, are the formal evidence of all maintenance performed on rolling stock, documenting what was done, when, by whom, and with what result. They include vehicle files, maintenance orders, reports, and release-to-service notifications, and must be accurate, traceable, and readily retrievable. Regulations such as ROGS and the EU Safety Directive require ECMs and RUs to maintain these records

to demonstrate compliance. Records must clearly describe all tasks, confirm adherence to standards, and identify responsible personnel. Retention periods are determined by factors such as component life, task complexity, and legal obligations, and storage methods, paper or digital, must ensure legibility and security over time.

The creation of maintenance records is integrated into the maintenance workflow: plan, order, work, report, release, with each step documented in near real-time to ensure precision. Alongside formal records, broader rolling stock data must also be collected and managed, including component tracking, maintenance events, modifications, and defect reports. Frameworks such as RIS-2706-RST support the structured recording of this information, which can be stored in centralised systems like the GB R2 database, interfacing with the National Vehicle Register (NVR).

#### 4.1.5 Certification and competency

In the UK and EU, ECMs for certain vehicles must be certified by accredited Certification Bodies (CBs), which are independent organisations authorised to audit maintenance systems. CBs, accredited in the UK by UKAS and operating under frameworks such as EU Regulation 2019/779 and ROGS, conduct initial audits and annual surveillance to verify compliance, inspecting processes, records, and facilities. Certification ensures that an ECM has a complete and functional maintenance system, covering management, planning, procedures, documentation, competence, and safety assurance. Schedule 10 of ROGS mandate capabilities in four functional areas: maintenance management (policy, quality systems, risk management, and internal audits), maintenance development (updating maintenance files, managing safety-critical components, ensuring technical compliance), fleet maintenance management (scheduling, order control, incident response), and maintenance delivery (executing tasks with proper tools, parts, and documentation). Even exempt RUs or IMs must meet equivalent standards through their SMS.

Competence management is integral to both certification and ongoing safety. Regulations require ECMs and RUs to ensure that all staff and contractors performing or overseeing maintenance are trained, assessed, and re-evaluated at defined intervals, with systems in place for training delivery, skills assessment, and corrective retraining when necessary. Evidence for certification may include training matrices, course materials, and assessment records. Competence is not treated as a one-off achievement but as a continuous requirement, ensuring that maintenance plans and procedures are executed correctly, thereby converting regulatory and procedural frameworks into safe, reliable practice.

#### 4.1.6 Safety quality assurance

Safety and quality assurance in rolling stock maintenance are underpinned by integrated SMS for RUs and IMs, and maintenance management systems for ECMs, ensuring maintenance is embedded within operational safety governance. These systems are reinforced by Common Safety Method (CSM), which standardise approaches to risk evaluation (CSM RA), ongoing monitoring, and regulatory supervision. CSM RA mandates structured risk assessments for significant changes, while CSM Monitoring and Supervision ensure maintenance quality is continually verified and improved.

Risk assessment is central to maintenance strategy, informing inspection intervals, methods, and control measures based on hazard analysis and reliability data. Under ROGS, “suitable and sufficient” risk assessments, aligned with EN 50126 and EN 17023, are required for all operators, with CSM RA applied to significant technical, operational, or organisational changes. ROGS 2006 provides the guidance of five steps to carrying out risk assessment.

## 4.2 Comparative and Gap Analysis of UK and Indonesia Rolling Stock Maintenance Standards

This section examines regulatory gaps in rolling stock maintenance between Indonesia and UK/EU, categorised based on the main aspects resulting from thematic analyse above. The UK/EU framework, including Directives 2016/797 and 2016/798, ROGS, and relevant EN standards, establishes clear roles (such as, ECM), detailed maintenance planning (maintenance file and documentation), certification schemes, and rigorous safety management. Indonesian law, particularly UU 23/2007, PP 56/2009, and various ministerial regulation (*Permenhub*) provides a less specialised structure. Table 7 shows a comparative and gap matrix rolling stock maintenance standards between UK and Indonesia.

Table 7. Comparative and gap matrix of UK and Indonesia rolling stock maintenance standards

Aspect	UK	Indonesia	Gap	Dimension
Maintenance Organisational Structure	Clear separation of maintenance from operation functions through ECM	Maintenance functions typically centralised, limited independent auditing or accreditation	Indonesian system lacks clear separation of maintenance responsibilities and independent oversight	Regulatory gap
Maintenance Planning	Structured flexible intervals allowing adjustment based on risk assesment and performance data	Prescribed intervals generally rigid with minimal structured flexibility or adjustments	Indonesian practice lacks structured flexibility in adapting maintenance schedules based on operational performance and risk assessments	Technical gap
Procedures and Standards	Explicit detailed procedures, systematically documented, facilitating cross-border railway operation	General procedures, lack uniform standardisation, and primarily national technical requirements; limited traceability focus	Indonesian standards less systematic, lack detailed and not aligned for cross-border compatibility	Regulatory gap
Documentation and Record-Keeping	Structured digital documentation standard; Systematic traceability through centralised registers	Basic manual records; No standard digital format mandated; Limited traceability	Limited traceability due to absence of standardised digital formats	Documentation and digital traceability gap
Certification and Competency	Mandatory ECM organisational certification	No systematic organisational-level maintenance company certification	Lack of systematic organisational-level certification	Institutional gap
Safety and Quality Assurance	Explicit integration of SMS with maintenance processes	General SMS requirement but not specifically integrated with maintenance activities	Lack systematic integration of SMS with maintenance activities	Technical gap

A comparative analysis of rolling stock maintenance standards reveals a fundamental divergence between the UK’s advanced, risk-based approach and Indonesia’s centralised, prescriptive model. Whereas the UK ensures operational independence through ECM structure and utilises flexible, data-driven planning, the Indonesian system is characterised by rigid intervals, manual record-keeping, and limited independent auditing. These disparities manifest as critical regulatory, technical, and institutional gaps, particularly regarding Indonesia's lack of systematic organisational certification, insufficient integration of SMS with maintenance processes, and the lack of the standardised digital traceability that underpins the UK’s documented approach.

5 CONCLUSION

Thematic analysis identified six main aspects in the practice of rolling stock maintenance in the UK: Maintenance Organisational Structure, Maintenance Planning, Procedures and Standards, Documentation and Record-Keeping, Certification and Competency, and Safety and Quality Assurance. Comparative and gap analysis results show the railway rolling stock maintenance framework in Indonesia ensures basic compliance but lacks the detailed performance-based structure implemented in the UK. The four recurring gap dimensions identified are as follows:

- a) Technical gap  
 Rolling stock maintenance in Indonesia lacks systematic integration of SMS and comprehensive structural risk management. Also, maintenance is largely interval-based, with limited application of CSM and RAMS methods. Additionally, Indonesian standards are not aligned for cross-border compatibility or international interoperability.

- b) Regulatory gap  
Indonesian system lacks clear separation of maintenance responsibilities and independent oversight. There is no legal mandate for ECM. Indonesian regulations lack specificity and detailed tailoring of maintenance plans to individual vehicles. Additionally, Indonesia lacks comprehensive certification and oversight framework for third-party maintenance providers.
- c) Institutional gap  
Indonesian maintenance practice lacks systematic independent organisational auditing and accreditation. Role boundaries among the regulator, operator, certifier, and investigator are not formally defined. Consequently, this results in a lack of systematic organisational-level certification, which can reduce quality assurance.
- d) Documentation and digital gap  
Maintenance document traceability and accessibility are limited due to the lack of standard digital formats and fragmented records. In addition, enforcement and monitoring are less systematic and structured.

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