QuieterRail - A step change in prediction, mapping, acceptance testing and cost-effective mitigation for railway noise and vibration

Deliverable D4.1

List of use cases and optimisation criteria

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Name	**Beneficiary Short Name**	**Version**	**Details of contribution**
Jakob Oertli	SBB – Advisory Board SPOC	0.2	Report structure and initial content
Pinar Yilmazer	UIC	0.2	Report structure and initial content
Rosa Casquero	UIC	0.2	Report structure and initial content
Anup Chalisey	RSSB - Advisory Board members	0.2	Review
Mitsuru HOSODA	UIC	0.2	Review
David Thompson	ISVR	0.3	Review
Simon Blainey	ISVR/University of Birmingham	0.3	Review
Chang Wan	BaneNor - Advisory Board members	0.3	Review
Trygve Aasen	BaneNor - Advisory Board members	0.3	Review
László Véha	MAV - Advisory Board members	0.3	Review
Guenter Dinhobl	ÖBB-Infra - Advisory Board members	0.3	Review
Geert Degrande	KU Leuven	0.4	Review
Pinar Yilmazer	UIC	0.5	Revisions to include all comments
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Mariya Kayalova	RINA-C	1.0	Quality check
Jose Bertolin	UNIFE	1.0	Final check and submission to ERJU

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Executive Summary

Deliverable D4.1 presents the outcomes of Task 4.1 of the *QuieterRail* project, which focuses on defining representative **Use Cases** and associated **optimisation criteria** for the whole track system, considering noise, vibration, and life-cycle performance.

The task was led by UIC, in collaboration with ISVR, EMPA, and HES-SO, and represents the foundation for developing the project's web-based decision-support tool. The objective was to ensure that optimisation reflects not only engineering feasibility but also acoustic effectiveness, cost-efficiency, and broader socio-environmental impacts.

A multi-stage consultation process was carried out, including:

- Formation of an Advisory Board with infrastructure managers including noise, vibration and track experts to identify typical track configurations and relevant cost data;
- Workshops and bilateral discussions with broader railway stakeholders to refine the Use Cases and define asset and mitigation characteristics;
- Online consultations to identify key optimisation parameters and technical constraints.

The subsequent Use Cases demonstrate how the web-based tool will support evidence-based infrastructure planning by allowing users to evaluate noise and vibration mitigation strategies under varied operational scenarios. The optimisation criteria identified include:

- Changes in noise and vibration levels, including compliance with regulatory framework;
- Asset management parameters, such as life-cycle costs (LCC) and RAMS (Reliability, Availability, Maintainability, Safety);
- Externalities covering health impacts, environmental exposure, and societal effects.

These criteria will guide the whole-system optimisation approach to be developed in Task 4.5, ensuring alignment with both users' needs and regulatory objectives. The outcome is an international framework enabling multi-criteria decision-making for more sustainable and cost-effective asset management.

Abbreviations and acronyms

Abbreviation / Acronym	Description
AB	Advisory Board
DALY	Disability-Adjusted Life Years
EMPA	Swiss Federal Laboratories for Materials Science and Technology (Eidgenössische Materialprüfungs- und Forschungsanstalt)
GIS	Geographic Information System
HES-SO	University of Applied Sciences and Arts Western Switzerland (Haute école spécialisée de Suisse occidentale)
ISVR	Institute of Sound and Vibration Research (University of Southampton, UK)
LCC	Life Cycle Cost
MAV	Hungarian State Railways (Magyar Államvasutak)
ÖBB	Austrian Federal Railways (Österreichische Bundesbahnen)
RAMS	Reliability, Availability, Maintainability, and Safety
SBB	Swiss Federal Railways (Schweizerische Bundesbahnen)
SPOC	Single Point of Contact
TDR	Track Decay Rate
UIC	International Union of Railways (Union Internationale des Chemins de fer)
WP	Work Package
WP4	Work Package 4

1. Introduction

1.1 Background

The present document constitutes Deliverable D4.1 "List of use cases and optimisation criteria" in the framework of the Exploratory Project 101176865 – QuieterRail – HORIZON-JU-ER-2023-01 as described in the EU-RAIL MAWP. It is produced in the context of Work Package 4 (WP4) "Track optimisation for noise, vibration and life cycle costs". The overall aim of WP4 is to develop a web-based tool to support the whole system optimisation of railway tracks in terms of noise, vibration and life cycle costs (LCC).

Task 4.1 of QuieterRail, is led by UIC in collaboration with ISVR, EMPA, and HES-SO, and focuses on integrating noise and vibration considerations into railway asset management. The primary objective of Task 4.1 is to develop practical and stakeholder-informed "*Use Cases*", specific scenarios where the project's decision-support tools can be effectively applied.

The methodology for Task 4.1 follows a sequence of interconnected stages. It began with an online consultation, which helped establish a structured framework aligned with insights from the WP4 Advisory Board (AB). This board brought together experts from diverse disciplines, including track and acoustic engineers from railway infrastructure management. Their input helped to identify typical track component configurations, relevant cost parameters (such as installation and maintenance), and initial ideas for "*Use Cases*". This was followed by bilateral discussions to deepen the understanding of stakeholder needs and expectations. A dedicated workshop was then held, centred around the question: "*What would I ideally want this tool to do?*". This session played a key role in shaping the tool's possible capabilities including validating findings, refining concepts, and ensuring alignment with user requirements. In parallel, targeted consultations with noise and vibration specialists, as well as track engineers, were conducted to assess the technical feasibility and economic viability of both conventional and innovative mitigation strategies.

The data and insights collected in Task 4.1 will be directly integrated into the tool being developed in Task 4.4 and will feed into the optimisation methodology in Task 4.5. The aim is to develop "*Use Cases*" that reflect operational conditions and to define a comprehensive set of optimisation parameters. These parameters will cover acoustic performance, economic factors, and maintenance requirements. Furthermore, the defined criteria extend beyond technical measurements to include regulatory compliance, environmental impacts, public health considerations, and compatibility with existing asset management systems. These factors will be assessed using a combination of monetary valuation, qualitative scoring, and multi-criteria analysis techniques.

1.2 Objectives

Task 4.1 has two main objectives:

1. To develop evidence-based, representative "*Use Cases*" that illustrate how the QuieterRail web-based tool can be implemented in practice by various types of users.
2. To establish multi-dimensional optimisation criteria that address the diverse requirements of infrastructure planners, track engineers, acoustic specialists, and decision makers.

The project uses systems engineering principles to enable whole-system optimisation. This approach is supported through analysis across technical, economic, and environmental domains. The evaluation framework includes three key assessment criteria, see Figure 1:

- Life-Cycle Cost (LCC) analysis combined with RAMS (Reliability, Availability, Maintainability, Safety) parameters;
- Mitigation Effectiveness, listing the performance of noise and vibration control measures in different operational settings in different countries;
- Externalities – health impacts, environmental exposure, and societal costs linked to railway noise and vibration.

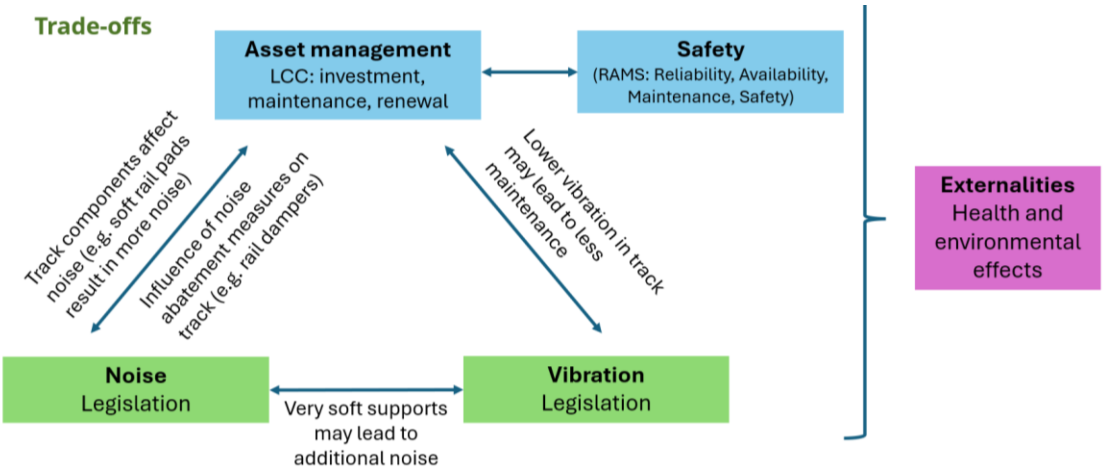

Figure 1: Conceptual Framework for Whole System Optimisation

The "*Use Cases*" selected in Task 4.1 ensure the web-based tool aligns with user needs while supporting an overarching strategy of whole-system optimisation including balancing cost, performance, and sustainability. The web-based tool will help Infrastructure Managers make smarter investment and design decisions that account for both long-term acoustic performance and asset durability.

Key motivations supporting the project include:

- Necessity for transparent, flexible data supporting evidence-based decisions on noise, vibration, and life-cycle costs.
- Balancing economic and environmental objectives using monetization and multi-criteria frameworks.
- Open-source design, enabling integration of new materials, mitigation methods and strategies.

The purpose and scope of the "*Use Cases*" and the methodology used to derive them are described in Section 2, following which the various "*Use Cases*" themselves are defined in Section 3. The approaches to optimisation are described in Section 4 and Section 5 explains the parameters required to define the "*Use Cases*". "*Case studies*" which are used to assess the tool after it has been developed are discussed briefly in Section 6.

2. Purpose and Scope

The "*Use Cases*" serve as scenario-based frameworks illustrating how QuieterRail's web-based decision-support tool can be effectively applied in practical railway contexts. This tool is designed to enhance infrastructure planning and asset management by enabling structured, data-driven decisions in the fields of noise and vibration mitigation.

2.1 Stakeholders

The "*Use Cases*" are aligned with the priorities of three core stakeholder groups:

- **Track Engineers and Asset Managers:** Focused on design, installation and maintenance and investment requests within technical constraints.
- **Noise and Vibration Experts:** Responsible of identifying and implementing effective mitigation strategies while minimising impact on environment and operations.
- **Decision Makers and Regulators:** Require evidence on how mitigation measures deliver societal and environmental benefits to inform policy and regulatory frameworks and provide investments.

The "*Use Cases*" and optimisation criteria defined in this deliverable have been developed in collaboration with user group representatives and guided by the technical expertise of the QuieterRail WP4 AB, as listed in Table 1. While the AB does not include direct representation from policy makers, user inputs reflect their needs by linking technical performance with decision-relevant outcomes. This ensures that system-level optimisation addresses both engineering feasibility and the evidence base required to support future decisions. The WP4 web-based tool is therefore expected to inform both decision processes and the evolution of broader regulatory frameworks.

Table 1: List of Advisory Board (AB) members

Name	Organisation	Role
Jakob Oertli	SBB, Switzerland AB Single Point of Contact (SPOC)	*Noise and Vibration Expert at the Track Engineering Department*
Anup Chalisey	RSSB, UK	*Head of Infrastructure, Track Engineer*
Chang Wan	BaneNor, Norway	*Track Engineer*
Trygve Aasen	BaneNor, Norway	*Noise and Vibration Expert*
László Véha	MAV, Hungary	*Track Engineer*
Guenter Dinhobl	ÖBB-Infra, Austria	*Noise and Vibration Expert*

2.2 Methodology

Use Case development followed a structured, multi-stage engagement process:

- Online discussions and bilateral expert consultations;
- Interactive workshops, including the UIC Railway Noise Days (60+ participants) [1];
- Technical exchanges and data collection throughout 2025.

This collaborative approach ensures the "*Use Cases*" reflect both current practices and emerging needs.

3. Use Cases

3.1 Definition and Needs

A Use Case is a scenario defined prior to tool development that describes how different stakeholders are expected to interact with the tool to achieve specific objectives. It outlines key functional requirements and desired outcomes based on user/stakeholder needs and serves as a conceptual foundation for guiding the design and development process. Unlike "Case studies", which evaluate a tool after implementation, "*Use Cases*" are forward-looking. They help identify the practical applications and key features the tool should offer in order to be effective and relevant in real-world contexts.

In the context of this project, "*Use Cases*" illustrate how various stakeholders—from infrastructure managers to noise and vibration specialists—might use the tool to address common challenges. For example, an infrastructure manager may use the tool to evaluate which track component combinations deliver the best cost-benefit ratio, including impacts related to noise and vibration, which are often overlooked in conventional analyses. Three core "*Use Cases*" have been defined to reflect these needs, as listed in Table 2.

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Table 2: Users and Corresponding Use Cases

Users/Stakeholders	Use Case	Objective
Track Engineers & Asset Managers	Evaluate combinations of track components	Identify cost-effective, compliant, and low-noise and -vibration configurations
Noise & Vibration Experts	Select mitigation strategies to meet legal limits	Ensure context-specific solutions meet legal limits
Decision and Policy Makers	Assess health, environmental, and economic trade-offs in setting limits	Balance societal, environmental, and cost considerations

3.2 Characteristics

The "*Use Cases*" are designed to capture the decision-making challenges faced by key stakeholders in the railway sector. The main objective is to ensure that the tool being developed can support informed, evidence-based investment decisions across a range of areas—including life-cycle costs, noise and vibration mitigation, and other environmental or societal impacts.

The objective of the work in Task 4.1 is not to prescribe exact functionalities but to encourage creative exploration of what the tool should do. Stakeholders are encouraged to ask: "What would I ideally want this tool to help me achieve in my role?". These early-stage concepts act as a strategic framework that:

- Clarifies the scope of the tool;
- Ensures relevance to stakeholder workflows;
- Guides technical development toward actionable outputs.

Each Use Case illustrates a specific scenario in which the tool could be applied, ensuring its design and functionality are grounded in operational reality. Insights from QuieterRail WP4 AB members have shaped these cases, helping to ensure the tool is not only theoretically sound but also practically useful—particularly for infrastructure managers, noise and vibration experts, and policy makers.

3.2.1 Track Component Combinations for Cost/Benefit Optimisation

Infrastructure managers are faced with the challenge of selecting track component combinations that not only meet safety and performance standards but also achieve cost efficiency, reduction in complaints and environmental protection control. This approach addresses the evaluation of track designs in terms of their long-term economic and acoustic performance. It considers how different combinations of rail, sleepers, fasteners, under-sleeper pads, and ballast influence investment costs, maintenance needs, and noise and vibration characteristics.

This Use Case supports the development of an optimisation tool that can simulate and compare multiple design options, helping track engineers and asset managers select the optimal configuration based on cost-benefit performance. The goal is to ensure compatibility with existing asset management systems and to integrate acoustic criteria into procurement and planning decisions.

Potential inputs that track engineers and asset managers can provide include technical specifications, material and installation costs, and reliability records. Outputs are design recommendations that balance cost-efficiency with compliance.

A critical challenge is integrating acoustic parameters into asset management tools that traditionally focus on cost, reliability, and safety. Compatibility with existing asset management software will be important to ensure adoption, however, the specific level of integration and exploitation strategy will require further discussion with the AB. This approach would support smarter and sustainable procurement and asset planning by quantifying the cost-effectiveness of various technical solutions.

3.2.2 Noise and Vibration Mitigation to Meet Limit Values

Noise and vibration experts need to select appropriate mitigation strategies that ensure compliance with increasingly stringent legal thresholds. This Use Case explores how to evaluate the effectiveness and cost of mitigation options—such as noise barriers, rail dampers, ballast mats, rail grinding and wheel treatments, - based on environmental context, traffic type, and infrastructure characteristics.

A primary objective is to identify which mitigation methods are most appropriate under different circumstances, and with different metrics for expressing regulatory targets such as average noise levels (Leq) or maximum levels. This Use Case supports the development of a decision-support tool that can recommend mitigation strategies by comparing effectiveness, cost, and operational feasibility. Inputs include site-specific characteristics and catalogues of mitigation measures including their costs. The output is a tailored mitigation plan that meets legal requirements with minimal financial and operational impact.

Special attention is paid to the ability of the tool to provide differentiated solutions for different rolling stock types and track characteristics, and to reflect both technical and regulatory constraint. For instance, a solution that is effective for high-speed passenger trains may not work for freight or urban rail. This "Use Case" enables evidence-based selection of mitigation packages and helps ensure legal compliance in the most efficient manner possible.

3.2.3 Societal Cost-Benefit Analysis of Noise and Vibration Mitigation

Decision and policy makers require evidence-based frameworks to prioritise investments. This Use Case aims to link the cost of implementing mitigation strategies with the broader benefits they generate, particularly in terms of societal benefits. These benefits may include reduced sleep disturbance, lower incidence of cardiovascular diseases, and improved general well-being in communities exposed to rail noise and vibration. The objective is to quantify these outcomes and compare them against the required investment to support evidence-based transport and health and environment policy.

Implementing this Use Case requires the integration of cost models, exposure-response functions from public health studies, and demographic data about affected populations. The tool shall include economic valuation models—such as those based on Disability-Adjusted Life Years (DALY) — as well as GIS systems to map exposure zones and model mitigation coverage.

Methods already exist for translating health and environmental effects into monetary terms (including long-term, cumulative impacts) and the calculations in the web-based tool will use these existing methods as codified in government transport appraisal guidance. However, there is some variation in both valuations and methods across countries to address the uncertainty in both cost and benefit estimates and to draw clear, traceable links between noise/vibration mitigation and health outcomes. The tool should provide comparison among various strategies and societies, supporting effective, health-oriented planning.

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4. Optimisation Approach

Based on the "*Use Cases*" defined above, a set of optimisation criteria aligned with stakeholder priorities has been identified in Table 3.

Table 3: Optimisation criteria in line with stakeholders' need

Stakeholder	Key Optimisation Criteria
Track Engineers & Asset Managers	Life-cycle costs, RAMS, acoustic compliance
Noise & Vibration Experts	Mitigation effectiveness, operational feasibility, adaptability
Policy Makers	Public health benefits, environmental impact, regulatory goals

These criteria form the basis of a decision-support framework designed to address diverse operational scenarios and users' needs. The variation in priorities highlights the necessity for a flexible, multi-dimensional optimisation tool. In addition, this deliverable outlines a set of cross-cutting optimisation criteria, derived from stakeholder feedback, to guide the ongoing development and refinement of the tool. This section outlines the technical rationale and decision-support architecture underlying the optimisation tool. Users can input characteristics such as:

- Traffic composition;
- Track component types;
- Site-specific data (e.g., rail roughness, decay rates);
- Available noise and vibration mitigation solutions with costs;
- Life-cycle costs;
- Maintenance and disposal unit/data.

Users can conduct scenario analyses and iterative simulations to explore trade-offs between acoustic performance, asset management strategies, and socio-environmental impacts. It will also interface with external models (e.g., noise reception tools) to assess mitigation needs based on population exposure and regulatory limits. Ultimately, this optimisation approach enables multi-criteria decision-making by identifying the solutions that provide the best balance between technical, economic, and environmental objectives.

5. Use Case Parameters

The optimisation tool will focus on a set of technical, operational, and environmental parameters that define each Use Case scenario. These parameters have been determined through collaboration with AB members and should enable realistic simulation and evaluation of diverse railway configurations. A key suggestion from AB members is to include customisable datasets, allowing users to adjust inputs for noise, vibration, and life-cycle costs to fit their specific operational situations. This flexibility will help make the tool more accurate and relevant for decision-making for railway infrastructure managers.

A main goal for these "Use Cases" is to figure out which combinations of track components and mitigation strategies offer the best balance between cost and benefit, considering noise and vibration impacts (see in Appendix A for an example of a 'what-if' scenario). The "Use Cases" primarily address rolling noise and ground-borne vibration generated by trains operating at constant speeds on straight, plain tracks-conditions representative of many railway environments. Key factors include:

- Rolling noise, mostly caused by the roughness of the wheel and rail surfaces, identified as the dominant noise source.
- Ground-borne noise and vibration, critical for environmental impact assessments.

5.1 Overview of Noise and Vibration Sources

Table 4 gives a classification schema used to determine whether various noise and vibration sources will be included in the tool. Table 5 and Table 6 list the principal noise and vibration sources associated with rail operations and infrastructure. Each source is evaluated against four criteria:

- **Data Availability:** Quality and extent of data accessible to characterise.
- **Model Availability and Maturity:** Readiness and reliability of predictive models for simulating.
- **Track influence on source:** Degree to which track components affect noise and vibration generation or transmission.
- **Uncertainty:** The degree of variability or confidence in predictions related to the source.

This assessment guides the prioritisation of parameters within the optimisation tool. Based on the classification schema in Table 4, each noise and vibration source in Table 5 and Table 6 is categorised as a core parameter, a passive inclusion, or excluded from the current tool scope.

Table 4: Parameter Inclusion Categories for the Tool

Classification	Categories
High	Core Parameters Included in the Optimisation Approach
Limited, Site-Specific, Passive, Large	Parameters Included Passively or for Future Integration
No, Unknown, N/A	Excluded from Current Scope

Table 5. Summary of noise sources

	Data Availability	Model Availability and Maturity	Track influence on source	Uncertainty	Include
Rolling	High	High	High	Moderate	Yes
Impact	Limited	Limited	High	Large	Passive
Curving (excl squeal)	Limited	None	High	Unknown	Passive
Tunnels	N/A	N/A	N/A	N/A	N/A
Roughness growth	Limited	Limited	High	Large	Passive
Curve squeal	Site-Specific	Limited	None	Large	No
Aerodynamic noise	Limited	Limited	None	Moderate	Passive
Traction noise	Some	Limited	None	Moderate	No
Bridges	Site-Specific	Limited	High	Large	No
Earthworks	Limited	Limited	None	Large	No
Transition zones	N/A	N/A	N/A	N/A	N/A

Table 6. Summary of vibration sources

	Data Availability	Model Availability and Maturity	Track influence on source	Uncertainty	Include
Rolling	High	High	High	Moderate	Yes
Impact	Limited	Limited	High	Large	Passive
Curving (excl squeal)	Limited	None	High	Unknown	Passive
Tunnels	Site-Specific	High	High	Large	Passive
Roughness growth	Limited	Limited	High	Large	Passive
Curve squeal	N/A	N/A	N/A	N/A	N/A
Aerodynamic noise	N/A	N/A	N/A	N/A	N/A
Traction noise	N/A	N/A	N/A	N/A	N/A
Bridges	Site-Specific	Limited	High	Large	No
Earthworks	Site-Specific	Limited	Limited	Large	No
Transition zones	Site-Specific	Limited	High	Large	No

5.2 Core Parameters Included in the Optimisation Approach

Rolling noise and rolling-induced vibration are identified as the primary sources due to their high availability of data, mature models, and strong influence from track design parameters. Despite moderate uncertainty, these sources critically affect acoustic and vibration outcomes and therefore form the core of the optimisation tool. Based on stakeholder input and AB collaboration, the key input parameters include:

- Train speed and wheel/rail roughness (including brake type);
- Sleeper type, rail pad and under-sleeper pad stiffness;
- Track form (slab or ballast) and track decay rate (TDR);
- Wheel design;
- Ground stiffness, and
- Applied mitigation measures.

These inputs will enable robust simulation of rolling noise and vibration, supporting effective cost-benefit analyses that balance technical performance, lifecycle cost, and environmental impact.

5.3 Parameters Included Passively or for Future Integration

Certain noise and vibration sources, while influenced by track design, have limited data or immature modelling, leading to their inclusion in the tool only through passive means or user-defined datasets. These include:

- Impact noise and vibration from rail joints, switches, and crossings—data and models are limited but can be incorporated via empirical correction factors.
- Curving effects (excluding curve squeal), which affect rolling noise and vibration but lack validated models.
- Roughness growth and corrugation, important for long-term maintenance considerations but currently modelled only through representative roughness spectra.
- Tunnel-related vibration, modelled site-specifically in tools like MOTIV, though general application is currently constrained by high variability in soil and structural properties.
- Aerodynamic noise, relevant mainly at very high speeds (>300 km/h), with limited track influence and modelling capability.

Inclusion of these parameters in passive or user-configurable form preserves tool flexibility and ensures it can evolve as more data and models become available.

5.4 Excluded from Current Scope

Several noise and vibration sources are currently excluded due to minimal influence from track design or high uncertainty in modelling:

- Curve squeal, an unpredictable and site-specific tonal noise with no reliable track design model.
- Traction noise, generated by locomotives motors and gearboxes, independent of track components and only significant at low speeds.
- Bridge-related noise and vibration effects, limited by site-specific factors and model applicability.
- Earthworks and transition zones, which require detailed, site-specific modelling beyond the scope.
- Operational factors like braking, acceleration, and gradients, which influence noise and vibration but are not tied directly to track design parameters.

While these are not addressed within the optimisation tool, its architecture supports the inclusion of user-supplied inputs or future module extensions to incorporate such factors where necessary.

By explicitly aligning parameter inclusion with the considerations of data availability, model maturity, track influence, and uncertainty (as summarised above), the optimisation tool will be planned to maintain a strong balance between robustness and adaptability. This ensures actionable outputs for critical noise and vibration sources while allowing ongoing expansion in response to future research and operational needs.

6. Case Studies

6.1 Definition and Purpose

A "*Case Study*" is a post-development evaluation method used to test and validate a tool's functionality in practical applications. In contrast to "Use Cases", which guide tool development by outlining potential user needs and applications, "Case studies" are applied after the tool is complete to determine whether it performs effectively in practice. They provide empirical insights into how the tool supports decision-making, and they help verify that the tool delivers relevant, actionable outcomes in specific contexts. The aim of conducting "*Case studies*" is to:

- Evaluate the tool's performance under practical conditions;
- Demonstrate the practical value of the tool to stakeholders;
- Identify any limitations or areas for improvement;
- Ensure the tool's results are aligned with sector needs and regulatory expectations.

At this stage of the QuieterRail project, "*Case studies*" are not required, and they will be developed later, once the tool has been built and initial "*Use Cases*" have guided its core design. Case study scenarios will be selected in collaboration with stakeholders to ensure relevance and impact.

6.2 Preliminary Examples (Subject to Refinement)

Although not yet finalised, the following case study scenarios can be proposed as potential validations:

- **Track Renewal Project:** Evaluate different track component configurations that include noise and vibration mitigation in total cost assessments. A didactic example provided as an imaginary scenario is given in the Appendices.
- **Line Expansion (e.g., from 2 to 3 tracks):** Identify optimal mitigation strategies for additional infrastructure.

- **Noise Complaint Site:** Compare multiple mitigation options to identify the most effective approach.
- **Vibration Complaint Site:** Assess technical solutions for areas affected by ground-borne vibration.

These examples are intended as starting points and may be revised or expanded based on feedback and project progress. The primary focus at this stage remains on refining **"*Use Cases*"** to inform tool development, with "Case studies" to follow in the validation phase.

6.3 Selection and Planning

These "Case studies" will be selected based on stakeholder relevance, data availability, and the maturity of tool development. A detailed selection plan will be defined in collaboration with project partners. The outcomes will be used to refine the tool and demonstrate its applicability.

7. Conclusion

WP4 of QuieterRail is developing a unified framework that adds noise and vibration into how tracks and assets are managed and planned. The main outcome is a free, web-based tool to help infrastructure managers compare technical and economic trade-offs across different scenarios.

In Task 4.1, stakeholder-driven "*Use Cases*" were developed through expert consultations to ensure that the tool meets practical operational requirements. With input from the AB, the task defined a clear set of optimisation parameters, considering assets and, infrastructure characteristics, maintenance planning, and investment planning.

The outputs of Task 4.1 will feed into subsequent tasks, including tool development (T4.4) and optimisation methodology (T4.5), ensuring continuity with project objectives. Continued engagement with the AB will help maintain alignment with operational priorities, users' needs and regulatory requirements, thereby enabling robust system-level optimisation across acoustic, economic, and infrastructure performance dimensions.

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8. References

[1] International Union of Railways (UIC) Sustainability Action Week, "ERJU QuieterRail Project - WP4 Whole System Optimisation event," March 2025. [Online]. Available: https://uic.org/events/IMG/pdf/uicrailwaynoiseday2_quieterrail_wp4-2.pdf.

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Appendix A: What-If Scenario: Noise Impact of Track Component Changes

An illustrative example of a 'what-if' scenario. A practical case study evaluated the life-cycle cost (LCC) and acoustic impact of different sleeper types used in track renewal on a 10 km, single-track freight line passing through a residential area. Two sleeper types were compared, as listed in Table 7.

Table 7: Properties of Sleeper Types

Steel sleepers (€80/unit):	Wooden sleepers (€30/unit):
• Lifespan: 70 years • Maintenance cost: €50 • Disposal cost: €5 • Noise increase: +2 dB	• Lifespan: 35 years (requiring one replacement) • Maintenance cost: €200 • Disposal cost: €40 (two cycles) • Lower noise emission

Over a 70-year period (as described in Table 8):

- **Steel sleepers** show a base LCC of €2.3 million. However, the associated 2 dB noise increase necessitates a 1 km noise barrier (€2.2 million), raising the total LCC to €4.7 million.
- **Wooden sleepers**, with higher maintenance and replacement needs, result in a comparable LCC of €4.5 million—without requiring additional noise mitigation.

Table 8: LCC Comparison – Sleeper Types (10 km line, 70 years)

Input	Output
• Freight traffic at night • Line passes through one town • Line length: 10 km • Steel sleepers: €80/unit, 70-year lifespan, low maintenance cost (€ 50 for 70 years), low disposal cost (€ 5) • Wooden sleeper: €30/unit, 35-year lifespan, higher maintenance cost (€ 200 for 70 years), higher disposal cost (€ 20 two replacements 2x) • Noise barrier: €2,000/m, maintenance cost (€200 for 70 years/m), disposal cost € 20/m • Insulated window: € 1000/unit	**Needs 16,667 sleepers, calculation for 70 years)** • LCC steel sleepers (70 years): € 2.3 Million • LCC wooden sleepers (70 years, incl one replacement): € 4.5 Million • Noise + 2 dB for steel sleepers, needs 1 km noise barrier for € 2.2 Million
Conclusion	
Despite the higher noise levels (+2 dB), steel sleepers with mitigation (barrier) match the cost of wooden sleepers when acoustic impacts are considered. Steel sleepers become economically equivalent to wooden sleepers only after factoring in noise mitigation. Therefore, acoustic performance must be integrated into long-term asset planning decisions.	

This analysis demonstrates the importance of incorporating noise impact into infrastructure cost evaluations. It can be expanded to investigate alternative mitigation measures such as rail dampers or façade insulation to identify more cost-effective solutions.

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Appendix B: Swiss Guidelines on Noise Effects of Track Component Changes.

Swiss noise legislation requires assessing noise effects if changes to a railway line result in a noise increase of 1 dB or more. For this purpose, a guideline was developed by the Swiss Federal Office of Transport, showing the effects of track component changes on noise. This guideline is revised regularly as new components or new combinations are introduced or if rolling stock is changed significantly. This table, shown in Figure 2, is only valid for Switzerland and may be different for other networks. It shows the importance of considering noise when making decisions about which track components to use. [2].

Track components have a noise effect:

Swiss table of noise impact of track changes

Current Track	New Track	Change in total noise
Rail 54E2	Rail 60E2	No change
Wood sleeper with tension clamp (Spannklemme)	Concrete sleeper with/without USP	No change
Wooden sleeper with clamp plate (Klemmplatte)	Concrete sleeper with 60E2 rail	+ 2 dB
Concrete sleeper without USP	Concrete sleeper with stiff USP	No change
Concrete sleeper	Steel sleeper with clamp plate	+ 2 dB
Wooden sleeper with clamp plate (	Steel sleeper with clamp plate	+ 4 dB
Stiff rail pad (Cstat > 800 kN/mm)	Soft rail pad (Cstat < 500 kN/mm)	+ 3 dB
Concrete sleepers and ballast	Slap track	+ 1 – 3 dB
Wooden sleeper with tension clamp	Steel sleeper with clamp plate	+ 2 dB
Steel sleeper with clamp plate	Concrete sleeper Ws14	- 2 dB
Wooden sleeper with clamp plate	Wooden sleeper Ke or concrete	+ 1 dB
Concrete sleeper with stiff rail pad	Concrete sleeper with high damping rail pad	-1 – 2 dB

For Swiss tack, other networks may be different
Rolling stock is important

→ Noise effects (costs for noise abatement) vs. asset management benefits should be weighed against each other

Figure 2: Example from Switzerland on noise impact of track changes

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