Deliverable D 5.2

Document proposal for coordinated Innovation Pillar and System Pillar Work programs

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1 Executive Summary

The MaDe4Rail Deliverable 5.2 explores the development of coordinated work programs within the Innovation Pillar and System Pillar of the Europe's Rail Joint Undertaking, focusing on Maglev-Derived Systems (MDS). These advanced rail solutions offer the potential to transform European mobility by achieving ultra-high-speed, energy-efficient, and sustainable transport systems. The document evaluates research and innovation activities aimed at advancing MDS technologies, with particular emphasis on integration with existing European railway infrastructure and standards.

The deliverable identifies the technical, regulatory, and operational challenges associated with MDS deployment. Key areas of focus include electromagnetic compatibility, track infrastructure adaptability, maintenance procedures, and interoperability with the European Train Control System (ETCS). Additionally, the project highlights the potential benefits of MDS, including reduced infrastructure costs, improved efficiency, and lower environmental impact, while providing a roadmap for addressing these challenges.

Building on insights from the Shift2Rail Digital Automatic Coupler Delivery Program (EDDP – European DAC Delivery Program), the deliverable identifies exportable elements such as standardization frameworks and digitalization strategies. However, it underscores the limitations of using the DAC program as a complete model for MDS deployment due to fundamental differences in scope, complexity, and infrastructure requirements.

The document also emphasizes the importance of stakeholder engagement and collaboration, above all the System Pillar for a smooth regulatory integration of technical requirements for MDS, through workshops, which fostered dialogue on technical challenges, standardization needs, and future activities. By aligning the development of MDS with the European Green Deal objectives and sustainable mobility goals, this deliverable provides a framework for phased deployment and integration of innovative maglev-based transport systems into the European rail network.

2 Abbreviations and Acronyms

Abbreviation / Acronym	Description
ATO	Automatic Train Operations
DAC	Digital Automatic Coupler
ETCS	European Train Control System
GoA4	Grade of Automation 4
GNSS	Global Navigation Satellite System
MDS	Maglev Derived System
RBC	Radio Block Center
S2R	Shift2Rail
TDS	Train Detection Systems
TMS	Transportation management system
TOP	Technical Open Points
TRL	Technology Readiness Level
TSI	Technical Specification of Interoperability
VB	Virtual Balise

3 Background

The present document constitutes the Deliverable D5.2 “Document proposal for Coordinated Innovation Pillar and System Pillar work programs”, which will outline a work program for future additional R&I activities in the Innovation Pillar and a coordinated work program for extensions to the CONOPS and system architecture in the System Pillar, both dedicated to development and eventual deployment of maglev-based transport systems in Europe. Leveraging the experience matured in developing the DAC program in Shift2Rail, the document will additionally study the possibility of establishing a European Maglev Deployment Program.

4 Objective/Aim

The aim of the Deliverable D5.2 is to is to develop a strategic and technical framework for the advancement and deployment of Maglev-Derived Systems (MDS) within the European rail network. The main focus is to align the research and innovation activities of the Innovation Pillar with the System Pillar in order to create a compatible work program to incorporate the technologies with real-world application. In this deliverable the knowledge gained from the Shift2Rail Digital Automatic Coupler (DAC) program allow to identify exportable elements such as interoperability frameworks, predictive maintenance techniques, and digitalization strategies that are applicable to MDS.

5 Further Research Developments Identified by Previous Deliverables

As a result of the comprehensive research undertaken in this project, several open points have been identified that warrant further investigation to advance the development and implementation of innovative railway systems within the European railway network. These open points highlight critical areas where additional research and development are essential to overcome existing challenges and leverage emerging opportunities. Addressing these points will not only enhance the effectiveness and efficiency of current systems but also pave the way for the successful integration of advanced technologies, such as maglev-derived systems, into the broader European rail network.

In this chapter, we will outline these open points, providing a clear roadmap for future research initiatives that are crucial for achieving the strategic goals of interoperability, sustainability, and competitiveness in the European railway sector. There are four key technical points that require further investigation: Electromagnetic and geometric compatibility, compatibility with existing track infrastructure, impact on maintenance, and speed on curves. Additionally, there is one open point related to regulation that must be addressed to ensure cohesive and standardized implementation across the network.

5.1 Electromagnetic and Geometric Compatibility

Eurobalises and CCS - Nevomo's Linear motor mover generates magnetic field with strength over 400 times higher than given in Eurobalise regulations while moving over it. Interaction between linear motor, Eurobalises, axle counters and other trackside equipment should be researched.

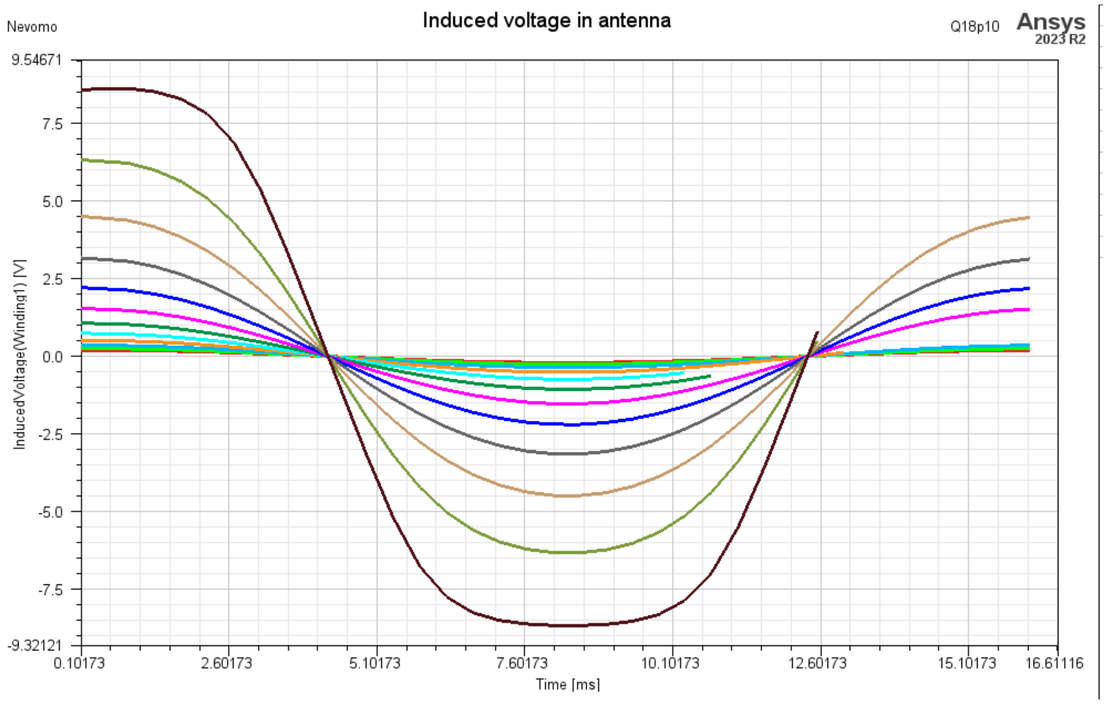

Figure 1: Induced voltage in antenna

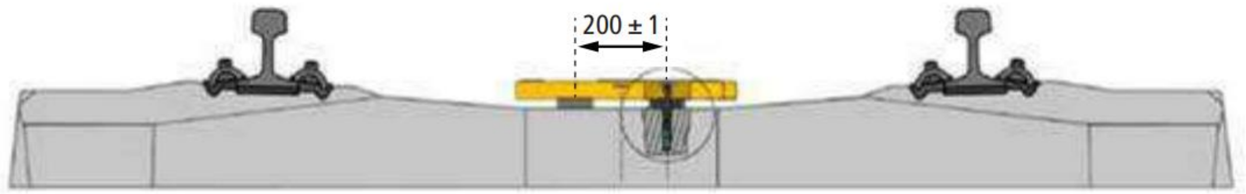

Figure 2: Eurobalise scheme

Compatibility with Eurobalise ERTMS L2 is a prerequisite for interoperability with the railway system. According to the EM simulations the electromagnetic field flux reaches allowable values at the 0.27 m from the stator (longitudinally). Therefore, given the exponential character of the field, it is assumed that 0.5m clearance would be sufficient to perform safe operations. This is a subject to further research and validation as well as axle counters.

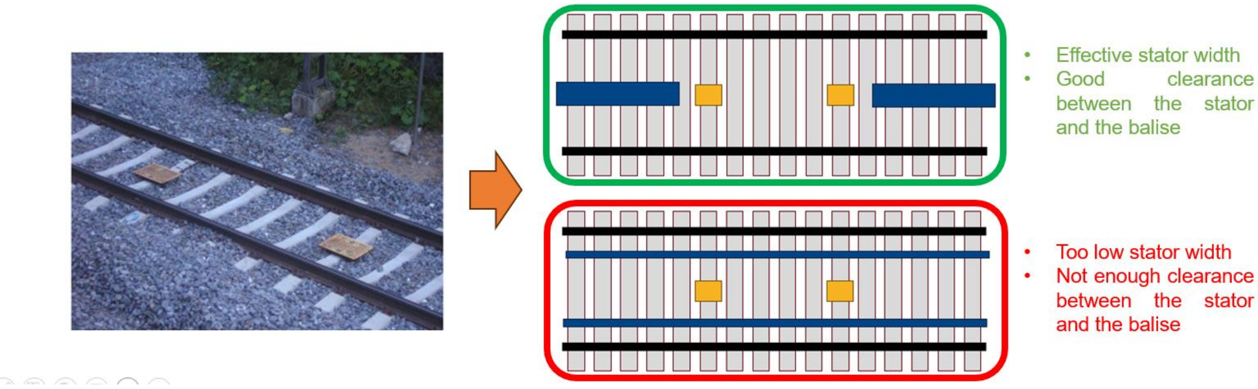

Figure 3: Fully Virtual Eurobalise

Fully Virtual Eurobalise - A Virtual Balise is a virtual point on the track that can be detected by a train equipped with a GNSS receiver and an antenna. The Virtual Balise Reader (VBR) processes GNSS signals to evaluate a condition of "matching" between the estimated train position and the known VB Location; if a VB detection event occurs, the related Balise Information is sent to ETCS Kernel as a Real BTM function would. The virtual balise functionality in ETCS can reduce the installation and maintenance costs (by replacing or complements the physical balise), increase the flexibility and scalability of the railway system, and improve the performance and safety of train control.

Figure 4: Scheme of GNSS experimenting on tracks

5.2 Compatibility with Existing Track Infrastructure

The maglev-derived system should meet the geometric clearance requirements, which are specific to the loading gauge of each line and country. Additionally, the MDS must not interfere geometrically with trackside equipment such as balises, axle counters, switches, and level crossings.

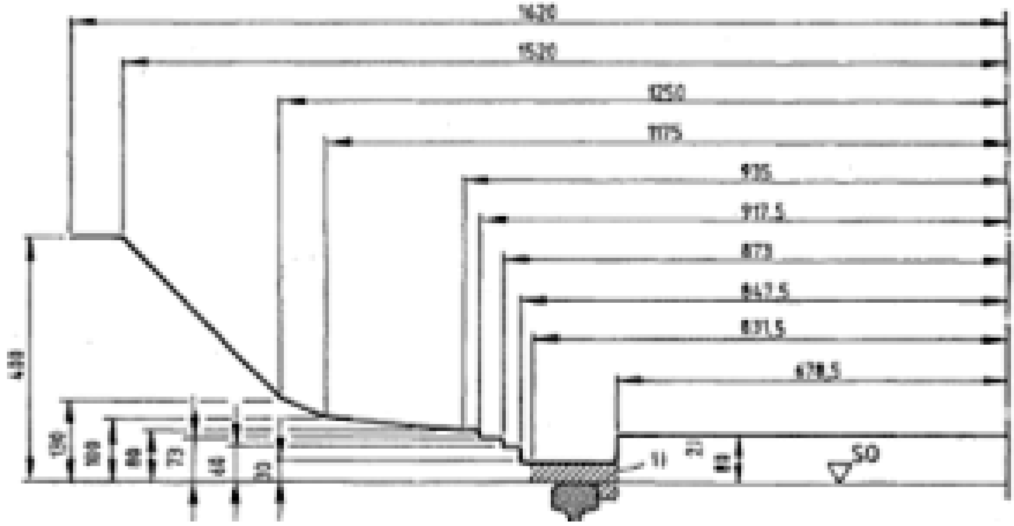

Figure 5: Geometry of trackside

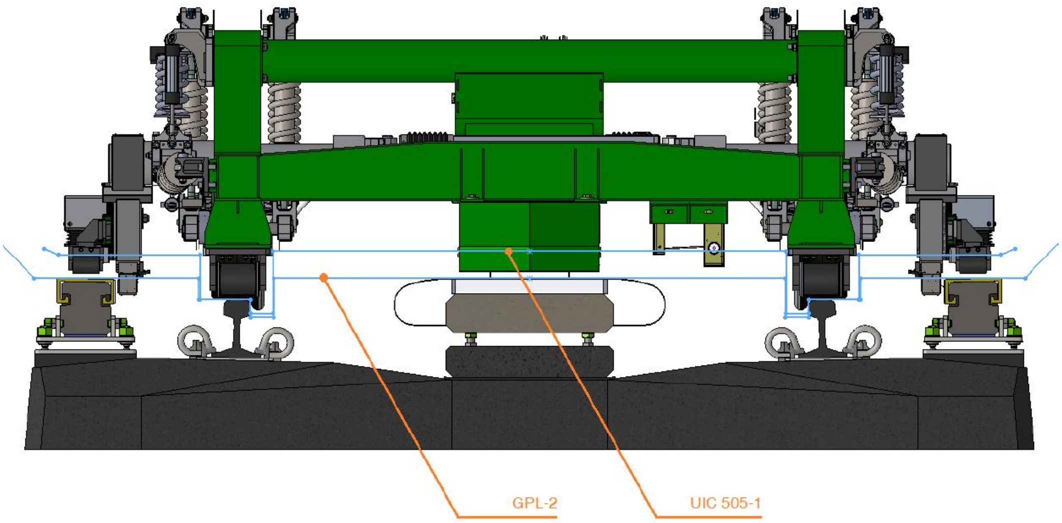

Figure 6: Scheme of sleepers and rail fastenings

Different propulsion systems can exert various forces on sleepers in both straight and curved track sections. Therefore, evaluating if current sleepers and rail fastenings can be adapted is essential. Possibly, designing and manufacturing new sleepers may be required to handle the forces from different propulsion systems.

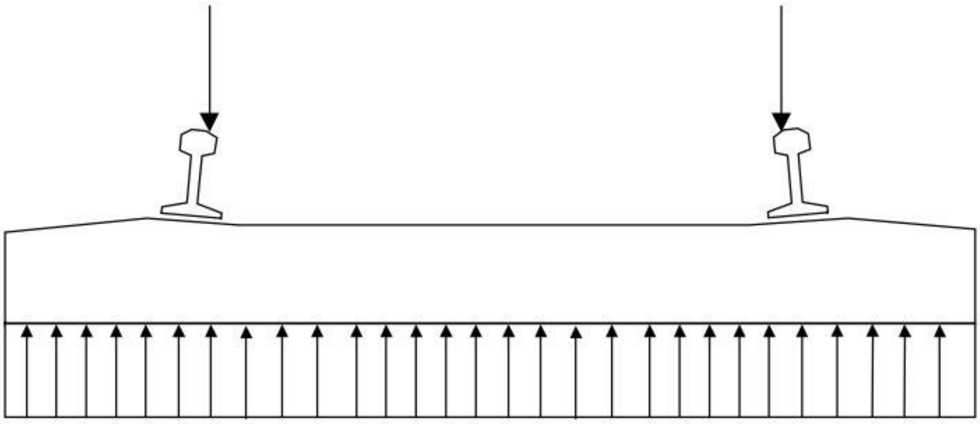

Figure 7: Design of sleepers

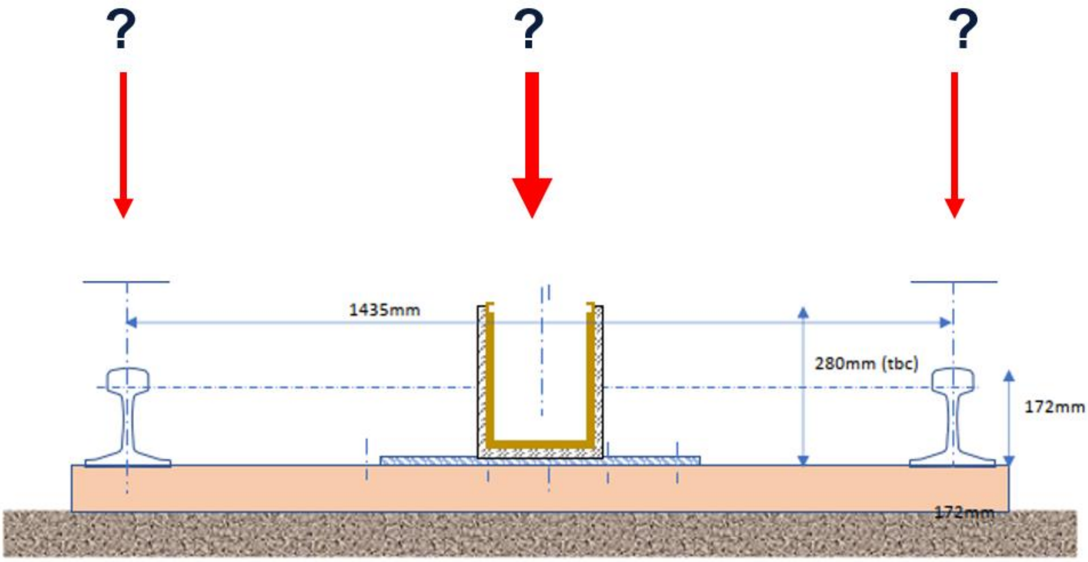

Figure 8: Profile of sleepers

5.3 Impact on Maintenance

The installation of the linear motor between the rails and the levitation system will necessitate adaptations to the track maintenance procedures. Activities such as tamping (required every 2-5 years), rail grinding (every 8 years), and the exchange of sleepers and rails (every 30 years or more) will need specific procedures once the linear motor is installed.

The entire process must be redesigned in collaboration with partners, taking into account the maintenance regimes, technical parameters of maintenance devices, and local maintenance regulations. This comprehensive approach will ensure that the integration of the linear motor is efficient and sustainable within the existing rail infrastructure.

Figure 9: Maintenance equipment

Similar considerations apply to the additional trackside devices, such as feeder and control cabling, and segment switches. Due to specific operating regimes, these devices must be positioned at a certain distance, approximately 3 meters, from the track axis and at a specific depth of around 0.5 meters. This is particularly important for power cables connected to the linear motor stator to ensure proper functionality and safety within the railway system.

Figure 10: The segment switch and cabling in Nevomo test facility in Nowa Sarzyna

5.4 Evaluation of the Maximum Tolerable Speed and Acceleration in Curves

Increasing the cant for levitating MDS vehicles is possible, without affecting conventional vehicles rolling on wheels. However, the current regulations regarding cants and cant deficiencies on the railway significantly limit the performance of MDS. To address this, static and dynamic studies and tests of the interoperable MDS infrastructure need to be conducted, considering factors such as ballast deterioration and sleeper twist. Additionally, the maximum allowed lateral accelerations and the ratio of cant increase in transition curves, referred to as "roll rates", should be carefully considered to ensure optimal performance and safety.

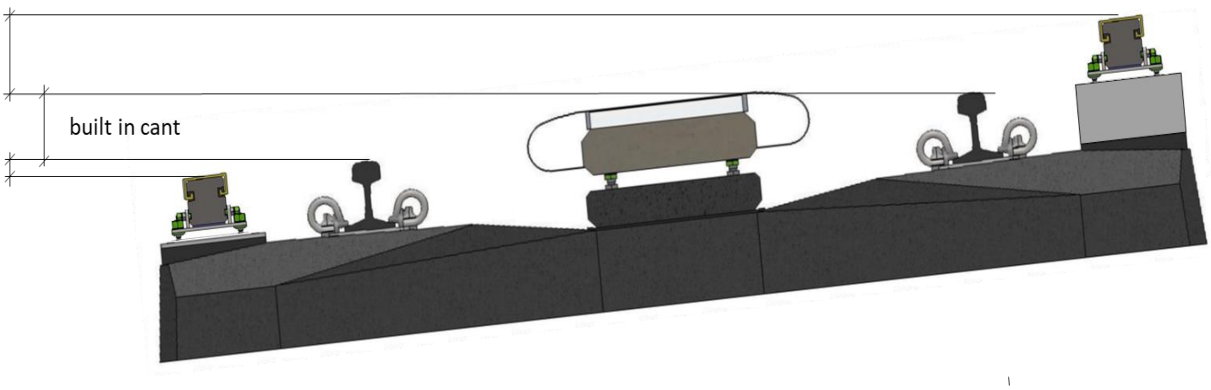

Figure 11: roll rates

6 Analysis of Shift2Rail DAC Deployment Program to Identify Elements Exportable to MDS Development and Deployment

Shift2Rail (S2R) was a European rail research and innovation program aimed at integrating innovative and cutting-edge technologies to enhance the competitiveness of the European rail system. One of its most significant achievements was the development and deployment of the Digital Automatic Coupler (DAC).

The DAC Delivery Program EDDP is currently in the process of defining a framework for deploying DAC technology and does not simply stand as an initiative for upgrading rolling stock. It represents a key element in the digital transformation of rail freight. The program's objectives include enhancing safety, reducing operational time, and increasing capacity and efficiency within existing infrastructure. Key achievements include:

- **Safety**: Safer shunting procedures and automated coupling processes.
- **Capacity and Efficiency**: Increased train weight, length, and throughput in marshalling yards.
- **Digitalization**: Integration with ETCS Level 3, enabling moving-block operations and digital supply chain integration.
- **Sustainability**: Reduced environmental impact by promoting rail over other transport modes.

The DAC program focuses on standardization, digitalization, efficiency, and sustainability, laying the groundwork for broader innovations in the rail sector. It offers some elements that can be useful, if adequately adapted, for the development and deployment of Maglev-Derived Systems (MDS). One of the most critical contributions stands in the emphasis on standardization. The DAC program's approach to ensuring interoperability across Europe through standardized components and protocols serves as a strong model for MDS. Establishing a global standardization program for MDS would be essential to facilitate compatibility between different systems and networks, both within and beyond Europe. Additionally, the regulatory frameworks developed under the DAC program can provide a foundational guide for the establishment of international standards that address the unique operational dynamics and infrastructure requirements of MDS.

These transferable elements highlight the importance of aligning MDS technologies with existing rail systems and regulatory frameworks to ensure a smooth integration process while maintaining operational safety, efficiency, and scalability.

6.1 EDDP as a Significant Framework for MDS Development and Deployment

Despite its valuable insights, the DAC Delivery Program cannot serve as a comprehensive model for MDS deployment due to some fundamental differences in scope, functionalities and design requirements:

1. **Different Functionalities**
    - The DAC program focuses on retrofitting the entire fleet of existing rail freight wagons, as an incremental innovation, automating the mechanical and digital connection for improved efficiency, safety and communication.
    - Maglev-Derived Systems (MDS) have been defined as innovative, fast track-bound transportation systems for rail application that use maglev-based technologies, such as linear motors with magnetic/pneumatic levitation, as their foundation. Based on the methodology and the MDS reported in the deliverable D2.1, three configurations have been distinguished in *Full MDS*, *Hybrid MDS* (based on air levitation and magnetic levitation), *Conventional railway systems upgraded with MDS technologies*.
2. **Infrastructure Requirements**
    - The DAC required minimal modifications to existing infrastructures as it assumes physical couplers between vehicles as part of its operating environment. It requires modification on the coupling system of freight wagons: new wagons or retrofitted old ones.
    - MDS has, as main advantages, the possibility to be applied on existing railway corridor by integrating the infrastructures to accommodate maglev technology in *Full MDS* and *Hybrid MDS* configurations and just to upgrade it in c) *Conventional railway systems upgraded with MDS technologies*. For this reason, the implementation of MDS requires minimal or no modifications to rail and vehicles. Tracks would be retrofitted locally, and existing trains or wagons would be retrofitted with linear motor components, where necessary, to improve propulsion and braking performances.

3. **Stakeholder Dynamics**
   - DAC involved a focused group of freight operators, infrastructure managers and coordination across a broader array of international stakeholders to ensure smooth operations at the borders.
   - MDS requires, at present level of development, the involvement of infrastructure managers and transport operators, with strong engagement from policymakers to ensure safety and security.
4. **Regulatory and Standardization Challenges**
   - DAC worked within existing standards as regarding the rail infrastructure, but it needs new TSI for the vehicles and the operations among them.
   - For MDS, it has been investigated the feasibility of their implementation in the conventional lines of the European interoperable network to determine whether subsystems and components are compatible with the TSI. Deliverable D4.1 includes a systematic cross-check analysis conducted with reference to the MDS system breakdown structure. The analysis provides a functional representation of the interfaces required to ensure the potential compatibility. Moreover, the need for robust standardization efforts developing frameworks that align MDS with EU Directives while addressing their unique requirements is essential.
5. **Environmental and Societal Implications**
   - The environmental and societal benefits of DAC have been largely demonstrated.
   - MDS can operate with dedicated infrastructure but can also integrate the existing railway infrastructure of the interoperable railway corridors with limited infrastructural intervention, enable hybrid operation of MDS and traditional railway services on the same corridor, reduce environmental impact by using existing infrastructure and brownfield spots by minimizing infrastructure footprint and avoid creating new barrier effects for ecosystems.

Therefore, though the DAC program approach cannot be directly applied as a model for MDS deployment, due to the significant differences in scope, complexity, and infrastructure requirements, it provides valuable insights that can inform the development of the MDS.

Key lessons come from the importance of a collaborative framework that brings together a diverse range of stakeholders, including infrastructure managers, rail undertakings but also national and local policymakers. By fostering such collaboration, the challenges of integrating MDS into existing systems can be effectively addressed. Additionally, the phased deployment approach used in the DAC program offers a blueprint for introducing MDS, starting with pilot corridors to demonstrate feasibility, collect data, and build public confidence before scaling up.

By incorporating these lessons, the deployment of MDS can be completely aligned with the European Green Deal objectives and will contribute to the broader vision of creating a sustainable, efficient, and innovative transportation network.

A **European MDS Deployment Programme** should involve:

- **Identifying pilot corridors** where MDS can be tested in real-world conditions to validate operational efficiency and safety.
- **Establishing a collaborative roadmap** that includes railway operators, infrastructure managers, industry leaders, and regulatory bodies to guide the integration process.
- **Securing funding mechanisms** through Horizon Europe and other EU financial instruments to support large-scale demonstration projects.
- **Aligning with EU mobility and sustainability goals**, particularly under the European Green Deal and TEN-T network strategies.

7 Exploring the Benefits, Challenges, and Stakeholder Engagement for MDS Integration in the European Railway System

The integration of Maglev-Derived Systems (MDS) into the existing European railway network presents unique challenges, particularly in the realm of signalling systems. A critical aspect of this integration is ensuring compatibility with the European Train Control System (ETCS), which serves as the foundation of current railway operations. This section explores the feasibility of MDS coexistence with conventional trains on shared tracks, highlighting both the technical challenges and the strategic solutions required to enable this transition. Additionally, it outlines the steps necessary to adapt ETCS Level 2 to accommodate MDS while preserving interoperability and operational efficiency.

7.1 Integrating Maglev-Derived Systems with Existing ETCS Signalling: Challenges and Solutions

The analysis of various use cases has shown that, though the ETCS signalling system currently used by railways is not perfectly suited for MDS, it does not preclude the coexistence of conventional trains and MDS on the same tracks. The project highlighted the need to evaluate the time and costs required to transition from ETCS Level 2 to a configuration that can accommodate MDS. Despite some challenges, such as compatibility issues with Train Detection Systems (TDS) and Eurobalises, the introduction of MDS technology promises significant benefits in terms of reliability and energy efficiency.

To integrate MDS into the existing railway system, the strategy involves maintaining the current signalling setup for conventional trains while introducing additional solutions to enable both systems to coexist. The ETCS Level 2 system, which relies on continuous radio communication, remains central, but alternatives are proposed to safely detect MDS vehicles on the line, such as using independent systems that detect MDS presence through levitation and traction activation. The concept of *virtual balises* is introduced to address Eurobalise compatibility issues, allowing MDS vehicles to use precise odometry and satellite localization for interaction with the signalling system. This approach complicates the Radio Block Center (RBC) management but ensures the overall ETCS structure and interoperability are preserved.

MDS systems are designed for seamless operation alongside traditional trains, with advanced infrastructure and vehicles. These systems use a linear motor embedded in the track for propulsion, levitation and guidance provided either by the track or integrated into the vehicle. MDS operates with Grade of Automation 4 (GOA4), enabling fully automated and driverless operations managed by a central control centre. High-precision vehicle positioning, achieved through a combination of linear motor technology, TMS communication, and GNSS, would allow MDS vehicles to reach speeds up to 250 km/h on regional lines while remaining compatible with standard gauge tracks.

The benefits of MDS include reduced infrastructure costs, improved operational efficiency, and environmental advantages, such as lower noise and emissions. Socio-economic benefits include increased service frequency and passenger comfort. To fully capitalize on these advantages, it is essential to identify the optimal configuration of subsystems across four areas: Vehicle, Infrastructure, Energy, and Command and Control. Each subsystem undergoes a comparative analysis to ensure effective integration into existing railway networks.

7.2 Stakeholder Workshops for Harmonizing Maglev-Derived Systems: Use Cases, Feedback, and Future Directions

To facilitate the harmonization of the concept of operation, use and employment of the maglev-derived technology, involving the Europe's Rail Joint Undertaking's System Pillars is recommendable. For this reason, a workshop, divided in two sessions, has been carried out within the MaDe4Rail project:

- The first part of the workshop presented the possible applications of the various maglev-derived configurations identified by the working group, to highlight technical topics that could emerge and identify standardization needs to implement MDS into existing European railway systems. The objective was to activate a proficiency dialogue with the System Pillar, the Railway and transportation community and participants from other Innovation Pillar's Flagship Areas/Projects.

- the second part of the workshop, held a month after the first part, provided the opportunity to collect feedback from the System Pillar, the railway and transportation community and participants from other Flagship Areas, and to raise awareness to the identified stakeholders of the state of the art of the MDS and the main results from the MaDe4Rail project.

Given the importance of sharing the initial feasibility analysis results for the introduction of MDS in Europe, as well as the need to raise awareness of the technical and regulatory challenges and propose innovative solutions for the European railway system — while always considering infrastructure constraints — the workshop provided a valuable opportunity for idea-sharing and productive discussions. It allowed participants to review progress made so far and, more importantly, to outline the next steps needed for the full integration of maglev-derived technology into the existing European railway network.

Presented below are some questions received from participants (particularly from EU-Rail) following the first part of the workshop, along with the corresponding answers provided by the technical experts during the second part of the workshop:

1. *Remote controlled, automatic & autonomous operations: are we talking about GoA 3 or 4? How would that interact with railway control systems?*

In some ways, the objectives of the two projects can be aligned: enhancing the capacity of existing rail networks through new technology. One of the objectives of the R2DATO project is to develop automation processes up to GoA4 for passenger and freight traffic. Furthermore, if ATO is to be aligned with railway standards, this aspect must also be considered for MDS systems. Only minor modifications are necessary to integrate ATO into new MDS systems. The idea is to replace the conventional train system with specific configurations tailored for managing MDS trains while keeping the TMS largely unchanged, requiring only minor adjustments. The management system remains the same, but some modifications are needed to ensure compatibility with ETCS Level 2.

2. *On tracks with catenary and when crossing borders, will the change of tension in the catenary affect the system?*

The Nevomo solution is not connected to the catenary, as propulsion is generated by the active stator in the infrastructure, which is powered separately by its own grid connection. Levitation functions passively, without external energy.

The TACV Lab U-LIM traction/braking system is optimized for DC 3kV catenary voltage and operates at reduced power on DC 1.5kV. For AC-25kV-50Hz and AC-15kV-16.7Hz systems, a conventional railway transformer with a PWM rectifier must be integrated, increasing the vehicle's mass by several tons. However, a new solution using high-frequency power converters and transformers could significantly reduce the total mass.

3. *Tracks without catenary usually have lower frequency of trains. Is it economically viable to upgrade those tracks with MDS?*

MDS technology provides cost-effective enhancements that improve speed, frequency, and sustainability, making secondary and regional railways more attractive and competitive. By maximizing benefits while minimizing implementation time and costs, MDS solutions offer a more efficient and appealing transport option, addressing the growing urbanization of small and medium-sized cities.

4. *Interaction with axle counters and the track circuits?*

The potential interaction with axle counters requires further investigation. Theoretically, some signal disturbance could occur. However, if the vehicle runs on wheels (in an upgraded vehicle configuration), track circuits should function correctly—except in cases of levitation. Therefore, it may be necessary for levitation-mode tracks to have a modern and compatible signalling system. Additionally, the potential for electromagnetic compatibility (EMC) side effects on parallel tracks must be studied.

5. *Cable theft and vandalism: How do you plan to handle it?*

Several measures can help discourage theft and vandalism. One approach is using highly durable materials, such as the EUROBALISE antenna's reinforced plastic, which is designed to withstand flying ballast but also offers protection against vandalism. Another strategy is exploring alternative materials to replace copper in stator windings or encasing key components in concrete or epoxy to make them significantly harder to remove. Additionally, security techniques used by Deutsche Bahn, such as synthetic DNA and UV tracers in copper cables and rails, have proven effective by making stolen metal more difficult to sell.

6. *After your study – what would be the level of compliance with the TSI's? The Vehicle authorization and the whole solution could follow rail ordinary procedures? If not, what would need to be different?*

The TRL achieved in MADE4RAIL is sufficient to identify which components and subsystems comply with TSIs and which require further analysis. Future studies with higher TRLs will focus on defining technical interfaces and conducting more detailed compliance assessments.

The level of compliance depends on the specific configuration—Air-Lev and Maglev systems will have different compliance requirements. Based on D3.2, Nevomo currently demonstrates the highest conceptual-level compatibility. However, further research is needed to provide definitive proof. The next steps involve addressing the TSI gaps identified in WP5 and WP3, securing the next grant to advance research, developing prototypes and test benches, and then initiating the authorization process.

8 System and Innovation Pillar Research and Innovation Activity Work Programs Requirements to Achieve Higher TRL outcomes

The integration of emerging technologies into Europe's railway network is essential for ensuring efficiency, sustainability, and competitiveness of the railway system. Based on the findings of the MaDe4Rail project, this proposal outlines the need of new activities in the Innovation Pillar to advance MDS research, address regulatory challenges, and establish a roadmap for European deployment of MDS.

8.1 Key Activities for MDS Deployment and Integration into Europe's Railway Network: Proposed Innovation Pillar Initiatives and Long-Term System Pillar Strategy

Building on the research and findings of the MaDe4Rail project, future activities under the Innovation Pillar should aim to further advance Maglev-Derived Systems by addressing the remaining technical open points, technical enablers, regulatory challenges, and the feasibility of a European MDS Deployment Programme.

The MaDe4Rail project has already provided substantial insights into the technical feasibility of MDS, particularly identifying Technical Open Points (TOPs), mainly related to electromagnetic compatibility, track infrastructure adaptability, maintenance strategies, and integration with ETCS and FRMCS. These TOPs represent the main challenges to ensuring feasibility of MDS and require further investigation and development. Deliverable D7.4 [2] further refines these aspects, highlighting the need for structured research and testing, particularly in refining vehicle-track interactions, electromagnetic interference mitigation, and ensuring compatibility with railway control and signalling systems.

The standardization and regulatory framework for MDS is a critical area that must be developed in parallel with technical advancements. The next activities should prioritize regulatory alignment and standardization efforts, ensuring that MDS can operate within the Technical Specifications for Interoperability (TSIs) and European safety frameworks. Deliverable D3.2 of the MaDe4Rail project [1] highlights the absence of European railway standards for EMC, gauging, and switches, as well as the need for standardized technical requirements for linear motor and levitation to enable interoperability testing of MDS. It also emphasizes the importance of defining the expected interoperability of MDS components within the railway system and the necessity of new requirements for compatibility checking between rolling stock and routes, including revisions to several TSI topics.

To address these challenges, technical enablers must be developed alongside regulatory advancements. Deliverable D7.4 [2] outlines key enablers such as Automatic Train Operations (ATO), enhanced Traffic Management Systems (TMS), virtual coupling, secure communication networks, and sustainable energy storage solutions. These technologies are fundamental to supporting MDS deployment by ensuring operational reliability, energy efficiency, and seamless integration with existing railway systems. Moreover, the roadmap emphasizes the need for regulatory adaptation to accommodate these innovations while maintaining compliance with European railway standards.

Given the complexity of integrating MDS into the existing railway ecosystem, a strong collaboration with the System Pillar is essential. The System Pillar's expertise in defining operational and technical standards will be crucial to ensuring that MDS technologies align with the European railway architecture and meet safety and interoperability requirements.

By strengthening the collaboration between the Innovation Pillar and System Pillar, future activities will ensure that MDS research leads to practical, deployable solutions that fit within the broader European railway modernization strategy. The Innovation Pillar can support the development of MDS by driving research in the specific technologies and their compatibility with existing railway system components. Meanwhile, the System Pillar can advise/be consulted the MDS activities to support the development of the necessary regulatory frameworks, standardization pathways, and infrastructure readiness assessments to facilitate the seamless deployment of MDS within the existing European railway network, ensuring interoperability, safety compliance, and compatibility with conventional rail infrastructure.

Potentisl new activities within the Innovation Pillar could address a structured approach for a European MDS Deployment Programme to support the phased implementation of MDS technologies across the European railway network. New projects should aim to:

- Advance the Technology Readiness Level (TRL) of key MDS components, ensuring they are ready for market deployment.
- Deliver prototypes and demonstration projects in selected pilot corridors.
- Provide regulatory and standardization recommendations for the seamless integration of MDS into the European rail network.
- Define a roadmap for a European MDS Deployment Programme, ensuring structured, scalable, and cost-effective implementation.

By building on MaDe4Rail's initial findings and focusing on the remaining technical, regulatory, and deployment challenges, these new activities will pave the way for the successful integration of MDS as a key component of Europe's future railway system. This structured approach will not only foster innovation and efficiency but also align with the EU's long-term sustainability and mobility goals, ensuring a modern, competitive, and decarbonized rail network.

Deliverable D7.4 [2] also proposes specific activities within the System Pillar, focusing on regulatory harmonization, the evolution of technical specifications, and the development of interoperable system architectures necessary for the coexistence of MDS with conventional railway infrastructure. This aligns with broader EU-Rail objectives and ensures that MDS technologies are integrated in a structured and sustainable manner.

Thus, following the studies conducted in the Made4rail project and the subsequent activities proposed for the Innovation Pillar, once the feasibility of Maglev-based systems, the necessary regulatory requirements, and the level of interoperability with the current railway system are clearer, it would be beneficial, in the long term, to establish a new task within the EU-Rail System Pillar.

The benefits of creating a new task dedicated to driving technological progress and ensuring the successful integration of new technologies into the existing railway infrastructure are:

- **To Accelerate the adoption of cutting-edge technologies** like maglev-derived systems (MDS), enabling a more efficient and sustainable rail network.
- **To promote innovation** while maintaining safety, interoperability, and compatibility with legacy systems.
- **To ensures Europe remains at the forefront of global railway advancements**, fostering economic growth and environmental sustainability.

This proactive approach would address the challenges and opportunities posed by disruptive technologies such as MDS, ensuring their successful integration into Europe's railway network.

9 Conclusions

Deliverable 5.2 concludes that the deployment of Maglev-Derived Systems (MDS) presents a transformative opportunity for the European railway network, offering advancements in speed, efficiency, and sustainability. However, the integration of MDS into existing railway systems requires significant efforts to address technical, regulatory, and operational challenges. Key areas include the development of new infrastructure, standardization frameworks, and solutions for interoperability with existing systems such as the European Train Control System (ETCS).

EDDP cannot be a complete model for Maglev-derived systems because it lacks the necessary capabilities to address magnetic levitation, propulsion, dynamic stability, high-speed operations, and energy optimization. On the other hand, insights from the DAC Delivery Program, particularly in standardization and digitalization, offer valuable guidance for aspects of MDS development. However, due to the unique scope and complexity of MDS, a tailored approach is necessary.

The deliverable emphasizes the importance of a phased deployment strategy, beginning with pilot corridors to validate technical feasibility and gather operational insights. Stakeholder workshops have been instrumental in fostering collaboration, identifying standardization needs, and addressing critical challenges for integrating MDS into the European rail network.

Leveraging the findings of MaDe4Rail, future activities under the Innovation Pillar should focus on addressing technical, regulatory, and feasibility challenges still open. New calls within the Innovation Pillar will prioritize advancing MDS technology, standardization, and deployment, with the System Pillar supporting integration efforts as needed.

10 References

[1] MaDe4Rail D3.2, 2024. Study of Railway standards potentially applicable to MDS and identification of new standardization needs.

[2] MaDe4Rail D7.4, 2024. Roadmap for maglev-derived systems