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Research Article

STATE OF THE ART OF THE FUTURE RAILWAY MOBILE COMMUNICATION SYSTEM (FRMCS) BASED ON 5G TECHNOLOGY

***Garazi Carranza Ruiz de Loizaga and Eneko Rada Martin**

Innovation Department, MAFEX, Leioa, 48940, Spain

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Abstract

This paper provides a comprehensive analysis of the current status, future plans, challenges, and opportunities associated with the deployment of the Future Railway Mobile Communication System (FRMCS) based on 5G technology in the railway sector. The study utilized a detailed survey distributed to key stakeholders, including engineering firms, consultancy companies, material manufacturers, infrastructure managers, traffic control system experts, and maintenance professionals. The findings reveal high awareness of FRMCS technologies, significant motivations for migration from GSM-R, and positive perceptions of the potential benefits. However, readiness for adoption varies, with notable challenges related to regulatory frameworks, interoperability, and deployment logistics. Expectations for the availability and maturity of FRMCS technologies are moderate, highlighting the need for continued development and standardization efforts. The study identifies critical gaps in 5G technology deployment and emphasizes the importance of strategic planning, cost-effective financial strategies, and robust risk management. The paper concludes with recommendations for future research, including detailed case studies, cost-benefit analyses, regulatory framework development, and strategies for engaging stakeholders. These insights aim to guide the railway sector in leveraging FRMCS for enhanced operational efficiency, safety, and innovation. The Future Railway Mobile Communication System (FRMCS) is a global initiative designed to replace the existing GSM-R system used in railway communications. Leveraging 5G technology, FRMCS offers significant improvements in capacity, reliability, and latency, facilitating the modernization and digital transformation of the railway sector.

Keywords: Future Railway Mobile Communication System (FRMCS), 5G Technologies, Railway sector, GSM-R, Deployment, Interoperability, Digital Transformation.

INTRODUCTION

The Future Railway Mobile Communication System (FRMCS) based on 5G technology represents a pivotal advancement in the railway sector, aimed at addressing the limitations of the current Global System for Mobile Communications-Railway (GSM-R) and leveraging the benefits of 5G to enhance operational efficiency, safety, and passenger services. The integration of 5G into railway systems offers significant opportunities for the industry, including improved communication capabilities, lower latency, higher data rates, and the support of massive machine-type communications (MTC) and Internet of Things (IoT) applications [1], [2]. The adoption of 5G technology in the railway sector is expected to bring about transformative changes, particularly in the context of the increasing demand for smart and sustainable transportation solutions. The deployment of FRMCS is seen as a critical step towards achieving these goals, providing a robust framework for enhancing railway operations and addressing the evolving needs of modern rail networks [1], [2] 5G technology offers numerous benefits that are particularly relevant to the railway industry. These include ultra-reliable, low-latency communications essential for mission-critical applications such as automated train control, predictive maintenance, and real-time video surveillance. The enhanced capabilities of 5G allow for greater flexibility and scalability in railway operations, enabling the deployment of advanced applications that can improve safety, efficiency, and passenger experience [1], [2]. The railway sector faces several priorities and challenges in adopting FRMCS and 5G technologies. Key priorities include ensuring the safety and reliability of railway operations, enhancing interoperability between different railway systems, and meeting regulatory and policy requirements. Additionally, the sector must address the technical challenges associated with integrating new technologies into existing infrastructure, managing the costs and resources required for deployment, and overcoming potential resistance to change from within the industry [1], [3]
One of the significant challenges is the allocation of sufficient spectrum to support the wide range of applications enabled by FRMCS. The limited availability of dedicated spectrum for railway communications necessitates the exploration of hybrid models that can leverage both dedicated and commercial networks. Furthermore, the need for robust cybersecurity measures to protect railway communications from potential threats and ensure the integrity and confidentiality of data is paramount [2], [3]. Ongoing research and development efforts are critical to the successful deployment of FRMCS. These efforts focus on developing and standardizing the technologies and protocols required to support 5G in the railway environment. Collaborative initiatives involving industry stakeholders, regulatory bodies, and research institutions are essential to address the technical, regulatory, and operational challenges associated with FRMCS deployment [2], [3]. For instance, studies have explored the potential of using artificial intelligence (AI) and big data analytics to enhance railway safety and operational efficiency. The integration of AI with 5G and IoT technologies can provide real-time insights and predictive capabilities, enabling more informed decision-making and proactive maintenance strategies. These advancements can significantly reduce the risk of accidents and improve the overall reliability of railway systems. The deployment of FRMCS based on 5G technology is a transformative development for the railway sector, offering

Corresponding Author:** ***Garazi Carranza Ruiz de Loizaga
Innovation Department, MAFEX, Leioa, 48940, Spain.

substantial benefits in terms of safety, efficiency, and passenger experience. However, achieving these benefits requires addressing several challenges, including spectrum allocation, regulatory compliance, and the integration of new technologies with existing infrastructure. Continued research and collaborative efforts are essential to overcoming these challenges and realizing the full potential of FRMCS in enhancing railway operations.

Background, state of art and objectives

FRMCS has been developed to address the technological obsolescence of GSM-R and capitalize on opportunities for digitization within the railway sector. Utilizing 5G technology, FRMCS provides ultra-reliable, low-latency communications essential for critical applications such as automated train control, predictive maintenance, and real-time video surveillance [1], [3] The implementation of FRMCS promises enhanced operational safety and efficiency, as well as innovative passenger services. The integration with 5G technology enables it to support massive machine-type communications (MTC) and Internet of Things (IoT) applications, creating a robust platform for future railway innovations [2], [4] One of the key challenges in implementing FRMCS is the allocation of sufficient spectrum and ensuring interoperability with existing systems. Currently, the dedicated spectrum for FRMCS is insufficient to meet the needs of modern railways. A viable solution is to create hybrid networks using 5G network slicing capabilities, allowing commercial service providers to supplement the required capacity for railway applications [2], [3] The success of FRMCS depends not only on technological advancements but also on the adoption of effective business models. Critical questions include who will build the network, the options for sharing with commercial networks, the involvement of rail infrastructure managers in defining use cases, and the financial and operational models to be adopted [3]. The transition to FRMCS will enable further digitization of the railway sector, including applications driven by 5G such as Automatic Train Operation (ATO) and the European Rail Traffic Management System (ERTMS). These advancements will significantly enhance the efficiency and safety of railway operations [2], [4]. The primary objective of this paper is to provide a comprehensive overview of the Future Railway Mobile Communication System (FRMCS) based on 5G technology, examining its current status, future plans, challenges, and opportunities within the railway sector. Specifically, the paper aims to assess the current level of adoption and readiness among railway operators for FRMCS, identify the expected timelines and key stages in the implementation process, and understand the technical, financial, regulatory, and operational challenges faced by railway operators. Additionally, it explores the potential improvements in operational efficiency, safety, and capacity that FRMCS can bring to the railway sector, and identifies new business models and revenue streams enabled by the transition to FRMCS. Furthermore, the paper seeks to gather detailed views from industry stakeholders on market developments and technology advancements related to FRMCS, and analyse the perceptions and expectations regarding the availability and maturity of FRMCS technologies and standards. It also aims to identify potential areas for collaboration and partnerships between different stakeholders in the railway sector to facilitate a more effective and coordinated approach to the implementation of FRMCS. Finally, the paper provides strategic recommendations based on the findings, aimed at overcoming identified challenges and maximizing the benefits of FRMCS, outlining best practices and strategies for railway operators and other stakeholders to follow. By achieving these objectives, the paper aims to contribute to a deeper understanding of the FRMCS framework, guide stakeholders through its implementation process, and highlight the transformative potential of 5G technology in the railway industry.

METHODOLOGY OF THE RESEARCH

The methodology for this study was structured to gather comprehensive insights into the current status, future plans, challenges, and opportunities associated with the deployment of the Future Railway Mobile Communication System (FRMCS) based on 5G technology in the railway sector. A detailed questionnaire was designed, covering a wide range of relevant topics divided into two main sections: Market Vision and Deployment Models. The topics addressed included familiarization with FRMCS technologies, motivations for migrating from GSM-R to FRMCS, perception of potential benefits, level of readiness for FRMCS adoption, and expectations regarding the availability and maturity of FRMCS technologies and standards. Additionally, the survey explored relevant issues in the deployment of FRMCS, gaps in the deployment of 5G technologies compared to the international market, identified business opportunities, and assessed expected revenue streams. A representative sample of key players in the railway sector was selected, including engineering and consultancy firms, material manufacturers, infrastructure managers, traffic control system experts, and maintenance professionals, ensuring a balanced and comprehensive view. The survey was distributed through various channels, including email and social media (LinkedIn), using Google Forms as the primary tool. A two-month deadline was set for response collection to allow detailed feedback, with regular follow-ups and reminders to maximize participation.

The data collected was securely stored and processed for analysis, involving rigorous data cleaning and validation to ensure quality and accuracy. Both quantitative and qualitative analysis techniques were employed: statistical methods were applied to numerical and categorical responses, while open-ended responses were reviewed and categorized to identify common themes and patterns. The results were then broken down by each of the participants' responses, providing insights into market familiarization, migration motivations, perception of benefits, readiness for adoption, regulatory and policy issues, impact on interoperability, deployment challenges, technology gaps, business opportunities, internal deployment plans, deployment timeline, infrastructure availability, interoperability expectations, and cost and resource perception. This structured approach ensured a thorough understanding of the current landscape and future outlook for FRMCS deployment in the railway sector.

Survey Design

The methodology for this study was structured to gather comprehensive insights into the current status, future plans, challenges, and opportunities associated with the deployment of the Future Railway Mobile Communication System (FRMCS) based on 5G technology in the railway sector.

Questionnaire Development

A detailed questionnaire was designed, covering a wide range of relevant topics divided into two main sections: Market Vision and Deployment Models. The topics addressed in each section included:

Market Overview

- Familiarization with FRMCS technologies
- Motivations for migrating from GSM-R to FRMCS
- Perception of potential benefits in terms of operational efficiency and network performance
- Level of readiness for FRMCS adoption
- Expectations regarding the availability and maturity of FRMCS technologies and standards
- The anticipated role in driving the adoption of FRMCS
- Criticalregulatory and policyissues
- Impact on interoperability and cooperation between different railway operators

Deployment Models

- Relevant issues in the deployment of FRMCS
- Gaps in the deployment of 5G technologies compared to the international market
- Business opportunities identified from the transition to FRMCS
- Expectedrevenuestreams
- Internaldeploymentplans
- Timeline for FRMCS deployment
- Availabilityof 5G infrastructure
- Expectations for interoperability with existing GSM-R systems
- Perceived costs and resources required for the transition
- Risk mitigation measures during the transition

Participant selection

A representative sample of key players in the railway sector was selected, including engineering and consultancy firms, material manufacturers, infrastructure managers, traffic control system experts, and maintenance professionals. The aim was to ensure that the survey captured a balanced and comprehensive view of the sector.

Data Collection

The survey was distributed through various channels, including email and social media (LinkedIn), using Google Forms as the primary tool. A two-month deadline was set for the collection of responses to ensure participants had ample time to provide detailed feedback. Regular follow-ups and reminders were sent to maximize the response rate.

Data Analysis

The data collected was securely stored and processed for analysis. A rigorous data cleaning and validation process was carried out to ensure the quality and accuracy of the responses. Both quantitative and qualitative analysis techniques were employed:

- **Quantitative Analysis:** Statistical methods were applied to analyse numerical and categorical responses.
- **Qualitative Analysis:** Open-ended responses were reviewed and categorized to identify common themes and patterns.

SURVEY RESULTS PRESENTATION

The results were broken down by each of the participants' responses, providing insights into the following areas:

- **Market Familiarization:** Degree of familiarity with FRMCS technologies among companies
- **Migration Motivations:** Main reasons for migrating from GSM-R to FRMCS
- **Perception of Benefits:** Expected benefits of transitioning to FRMCS
- **Readiness for Adoption:** Level of preparedness for adopting FRMCS
- **Expectations for Standards and Regulation:** Anticipations regarding the availability and maturity of FRMCS technologies and standards
- **Role in Adoption:** Expected role in driving the adoption of FRMCS
- **Regulatory and Policy Issues:** Key regulatory and policy challenges
- **Impact on Interoperability:** Expected impact on interoperability and cooperation between railway operators
- **Deployment Challenges:** Major issues in the deployment of FRMCS
- **Gaps in Technology Deployment:** Perceived gaps in the deployment of 5G technologies
- **Business Opportunities and Revenue Streams:** Identified opportunities and expected revenue sources
- **Internal Deployment Plans:** Availability and details of internal plans for FRMCS deployment
- **Deployment Timeline:** Expected timeline for the deployment of FRMCS
- **Infrastructure Availability:** Availability of 5G infrastructure in operational areas
- **Interoperability Expectations:** Expectations for interoperability with existing GSM-R systems
- **Cost and Resource Perception:** Perception of the costs and resources required for the transition
- **Risk Mitigation Measures:** Proposed measures to mitigate potential risks during the transition

This structured approach ensured a thorough understanding of the current landscape and future outlook for FRMCS deployment in the railway sector.

Results of the analysis

The study provides a comprehensive analysis of the current status, future plans, challenges, and opportunities associated with the deployment of the Future Railway Mobile Communication System (FRMCS) based on 5G technology in the railway sector. The key findings, illustrated by the accompanying graphs, highlight several critical insights:

Market Familiarization: The majority of respondents (41%) have high familiarity with FRMCS technologies, while a significant portion (23%) have moderate familiarity. This indicates strong awareness and understanding of FRMCS among industry stakeholders, though there remains a notable group with low or no familiarity (12% and 24%, respectively).

This suggests the need for continued education and information dissemination within the industry. The familiarity with 5G and its applications in the railway sector, as explored in recent studies, underscores the potential for FRMCS to revolutionize railway communications and operations[2], [3].

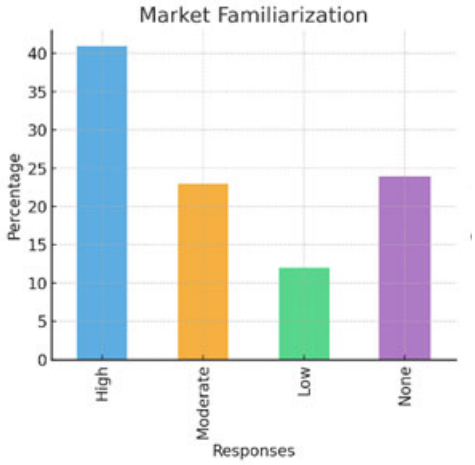

Figure 1. Market familiarization results with FRMCS technologies

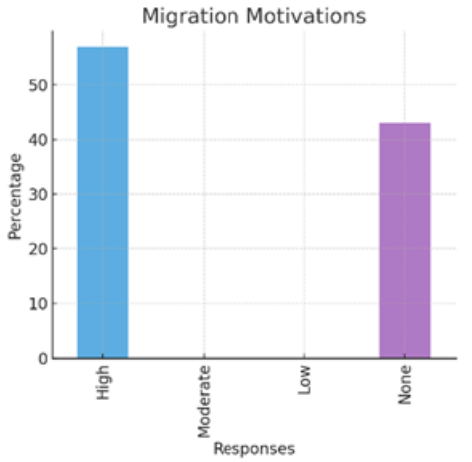

Figure 2. Driving motivations towards the migration from GSM-R to FRMCS

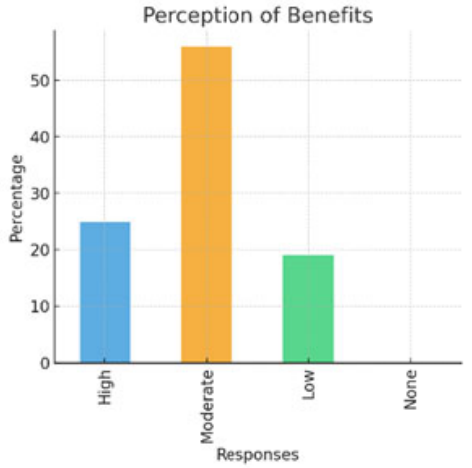

Figure 3. Benefits associated with FRMCS perceived by the respondents

Migration Motivations: A substantial majority (57%) cited strong motivations for migrating from GSM-R to FRMCS, driven primarily by the expected benefits in operational efficiency and network performance. However, 43% of the respondents showed no specific motivation, highlighting a divide in the perceived urgency or necessity for this transition. This reflects the broader industry trends where the adoption of 5G is seen as essential for maintaining competitive advantage and operational efficiency [1], [2].

Perception of Benefits: The perception of benefits associated with FRMCS is predominantly positive, with 56% expressing a favorable outlook on the expected improvements. Another 25% maintain a neutral stance, indicating some uncertainty or lack of information about the potential advantages. Only 19% showed low perception of benefits, which could stem from skepticism or insufficient data. These perceptions align with the recognized benefits of 5G in enhancing communication reliability and operational capabilities in the railway sector[1], [2], [3].

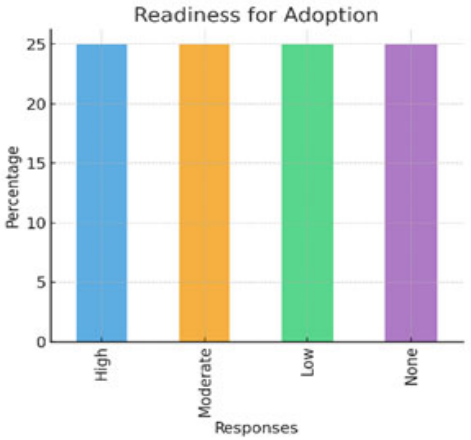

Figure 4. Preparedness for adoption of FRMCS

Readiness for Adoption: Readiness for FRMCS adoption is evenly distributed, with 25% of respondents at each level (high, moderate, low, and none). This balanced distribution reflects varied stages of preparedness across different organizations, underscoring the need for tailored support and resources to facilitate the transition. This highlights the importance of strategic planning and resource allocation to ensure successful deployment[2], [3].

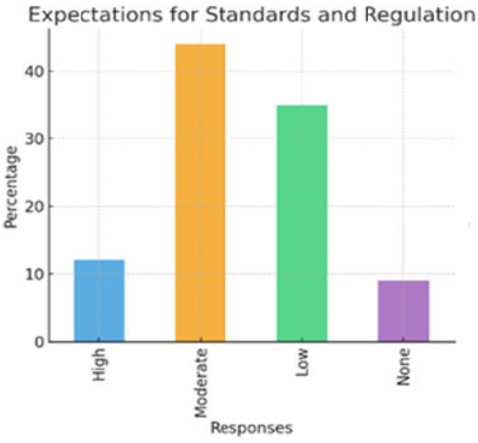

Figure 5. Results related to the expectation of respondents for standards and regulations of FRMCS technologies

Expectations for Standards and Regulation: Expectations regarding the availability and maturity of FRMCS technologies and standards are mostly moderate (44%) and low (35%), with

only 12% having high expectations. This highlights the importance of ongoing development and standardization efforts to meet industry needs. Aligning with global standards and regulatory frameworks is crucial for the seamless integration of 5G technologies in the railway sector [1], [2].

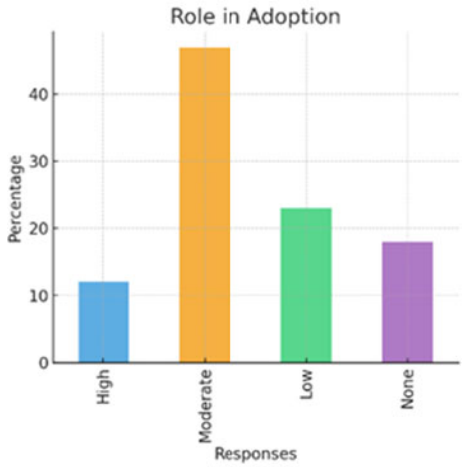

Figure 6. Expected roles in the adoption of FRMCS technologies by respondents

Role in Adoption: A significant portion of respondents (47%) anticipate playing a moderately active role in driving the adoption of FRMCS, while 23% see themselves as followers. This indicates a proactive stance among many stakeholders, though a portion remains less engaged (18%). Active participation and leadership in adoption efforts are vital for achieving widespread implementation and realizing the full benefits of FRMCS [3], [4].

Figure 7. Foreseen regulatory and policy challenges by respondents

Regulatory and Policy Issues: Regulatory and policy challenges are seen as significant by 28% of respondents, with 27% experiencing moderate issues. This points to the need for regulatory frameworks that support seamless integration and operation of FRMCS. Effective policy measures and regulatory support are critical for addressing the challenges and ensuring compliance with industry standards[2], [3].

Impact on Interoperability: The impact of FRMCS on interoperability is viewed positively, with 40% expecting significant improvements and 33% moderate improvements. This suggests that FRMCS is likely to enhance cooperation and operational efficiency between different railway operators. Improved interoperability is essential for the successful integration of new technologies and enhancing overall operational efficiency[2], [3].

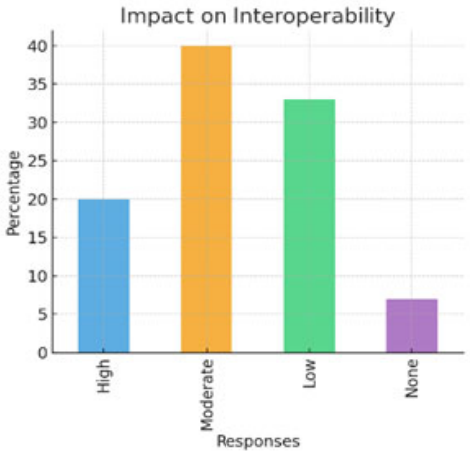

Figure 8. Expected impact on FRMCS interoperability with already existing technologies

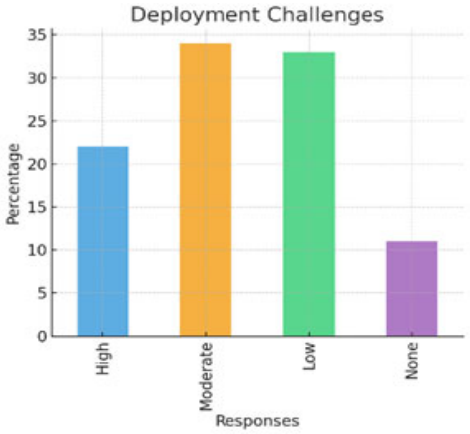

Figure 9. Expected FRMCS technologies deployment challenges

Deployment Challenges: Deployment challenges are seen as moderate (34%) and significant (33%), with 22% perceiving major issues. Addressing these challenges through strategic planning and resource allocation will be crucial for successful implementation. Overcoming these challenges is essential for ensuring the seamless deployment and operation of FRMCS [2], [3].

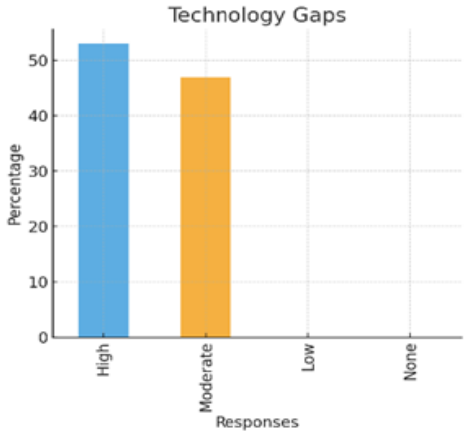

Figure 10. Gaps identification in the deployment of 5G technologies in Spain, compared to the international market

Technology Gaps: A majority (53%) identify significant gaps in the deployment of 5G technologies compared to the international market. This highlights the need for accelerated efforts to bridge these gaps and align with global advancements. Bridging these technology gaps is crucial for leveraging the full potential of 5G in the railway sector[2], [4].

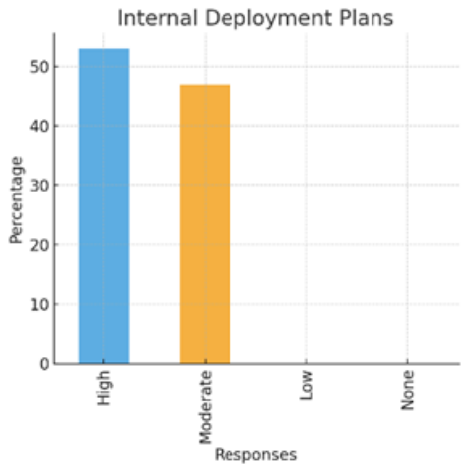

Figure 11. Participants internal defined plans for FRMCS deployment

Internal Deployment Plans: Similarly, 53% have clear internal plans for FRMCS deployment, while 47% do not, indicating a need for comprehensive internal strategies to ensure smooth implementation. Well-defined deployment plans are critical for achieving timely and effective implementation of FRMCS[2], [3]

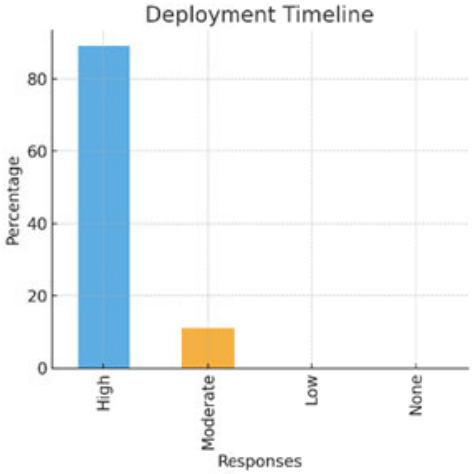

Figure 12. Expected deployment agility towards the next years

Deployment Timeline: Most respondents (89%) expect a highly agile deployment of FRMCS, expected to occur between 2025 and 2030, with a small percentage (11%) anticipating a later timeline. This consensus on the timeline provides a clear target for planning and coordination efforts. Establishing a realistic and achievable deployment timeline is essential for ensuring the successful rollout of FRMCS[3], [4]

Infrastructure Availability: Infrastructure availability is high (80%) among respondents, suggesting that the foundational elements for FRMCS deployment are largely in place. However, 13% still face challenges in this area. Ensuring the availability of robust infrastructure is crucial for supporting the deployment and operation of FRMCS[2], [3].

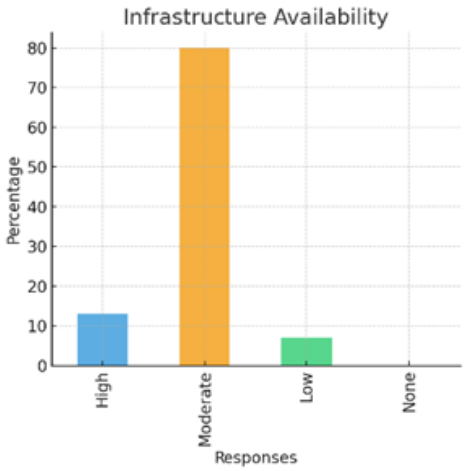

Figure 13. Advanced communications Infrastructure availability at present

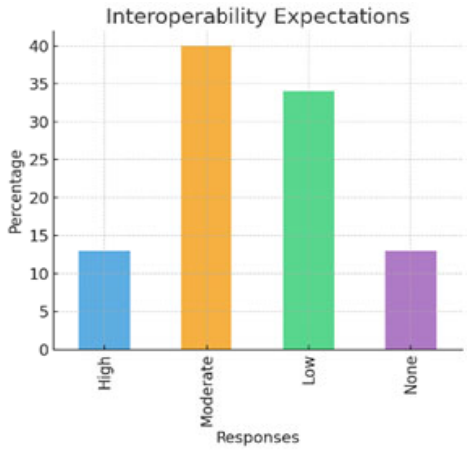

Figure 14. Expected interoperability challenges with already existing GSM-R communications systems

Interoperability Expectations: Expectations for interoperability with existing GSM-R systems are moderate (40%) and high (14%), indicating confidence in the ability to integrate new and existing technologies. Achieving seamless interoperability is vital for the successful transition to FRMCS and enhancing overall operational efficiency[1], [2].

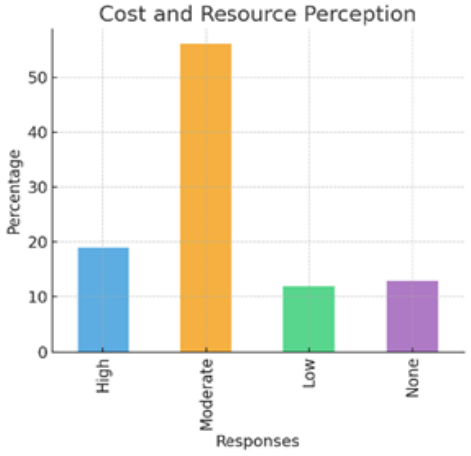

Figure 15. Perception of costs for the deployment of FRMCS

Cost and Resource Perception: The perception of costs and resources required for the transition is varied, with 56% considering it moderate (manageable), while 19% see it as very costly. This highlights the importance of cost-effective

strategies and financial planning. Effective cost management and resource allocation are essential for ensuring the economic viability of FRMCS deployment [2], [3].

DISCUSSION

The survey results highlight a significant level of familiarity with Future Railway Mobile Communication System (FRMCS) technologies among industry stakeholders, with 41% of respondents showing high familiarity. However, there remains a notable portion (12% with low familiarity and 24% with no familiarity) indicating the need for continued education and information dissemination. Most respondents (57%) are motivated to migrate from GSM-R to FRMCS due to anticipated benefits in operational efficiency and network performance, although 43% lack specific motivation, revealing a divide in perceived urgency. Perceptions of the benefits of FRMCS are predominantly positive, with 56% of respondents optimistic about improvements. Nevertheless, readiness for adoption is evenly distributed across different levels, underscoring the need for tailored support and strategic planning to facilitate the transition. The expectations for the maturity of FRMCS technologies are moderate to low, emphasizing the importance of ongoing development and standardization efforts. Deployment challenges are viewed as moderate to significant by most respondents, highlighting the need for strategic planning and resource allocation. While there are significant technology gaps compared to international standards, many organizations have clear internal plans for FRMCS deployment. The consensus on an agile deployment timeline between 2025 and 2030 provides a clear target for coordination efforts. High infrastructure availability among respondents suggests that foundational elements for deployment are largely in place, but ensuring robust infrastructure and addressing interoperability with existing systems remain critical for successful implementation. Overall, the findings underscore the need for comprehensive strategies, regulatory support, and collaborative efforts to achieve widespread adoption and realize the full benefits of FRMCS in the railway sector.

Conclusions and future research

The study provides a comprehensive analysis of the current status, future plans, challenges, and opportunities associated with the deployment of the Future Railway Mobile Communication System (FRMCS) based on 5G technology in the railway sector. The key findings highlight several critical insights. The majority of respondents exhibit a high level of familiarity with FRMCS technologies, indicating strong awareness within the industry, although a notable portion still lacks familiarity, underscoring the need for continued education. A substantial majority are motivated to migrate from GSM-R to FRMCS due to anticipated benefits in operational efficiency and network performance, yet a significant portion remains unmotivated, indicating a divide in perceived urgency. Perception of benefits is predominantly positive, though some stakeholders remain neutral or sceptical, suggesting the need for further evidence and demonstration of benefits. Readiness for adoption varies widely, with stakeholders evenly distributed across different levels of preparedness, indicating a need for tailored support to facilitate the transition. Expectations regarding the availability and maturity of FRMCS technologies and standards are generally moderate, highlighting the importance of ongoing development efforts. Many respondents anticipate playing an active role in driving the adoption of FRMCS, though some remain less engaged. Regulatory and policy challenges are significant, emphasizing the need for supportive regulatory frameworks. The impact of FRMCS on interoperability is viewed positively, with expectations for significant improvements in cooperation between railway operators. Deployment challenges are seen as moderate to significant, necessitating strategic planning and resource allocation. Significant gaps in the deployment of 5G technologies compared to the international market highlight the need for accelerated efforts to align with global advancements. While many respondents have clear internal plans for FRMCS deployment, a considerable portion does not, indicating a need for comprehensive internal strategies. Most respondents expect FRMCS deployment between 2025 and 2030, providing a clear target for planning efforts. High infrastructure availability suggests foundational elements for FRMCS deployment are largely in place, though some challenges remain. Expectations for interoperability with existing GSM-R systems are high, indicating confidence in integrating new and existing technologies. Perceptions of costs and resources required for the transition vary, with some viewing it as manageable and others as very costly, emphasizing the need for cost-effective strategies and financial planning.

Future research should focus on several areas to further support successful FRMCS deployment. Detailed case studies of early FRMCS adopters can provide empirical evidence of benefits, challenges, and best practices. Comprehensive cost-benefit analyses can quantify the economic impact of transitioning to FRMCS. Investigating the development of regulatory frameworks can facilitate international cooperation. Exploring technical solutions can enhance interoperability between FRMCS and existing GSM-R systems. Monitoring advancements in 5G and related technologies can ensure FRMCS remains at the forefront of development. Strategies to engage less familiar or motivated stakeholders can foster a more inclusive approach. Researching effective risk management strategies can ensure robust and resilient deployment processes. Addressing these areas in future research can help the railway sector navigate the complexities of FRMCS deployment, leveraging its transformative potential for enhanced efficiency, safety, and operational excellence.

Acknowledgements

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provide vertical services of a "mission-critical" level (specifically for Industry 5.0 and railways), meeting not only pure connectivity requirements but also resilience and end-to-end performance.

The MIMBRES project consists of two sub-projects:

Mimbres-fabric (TSI-063000-2021-27): Providing a technological fabric of connectivity and virtualized distributed computing based on current 5G SA components, offering segmentation and SBA, ZSM, NFV/SDN/MEC orchestration mechanisms over ETSI MANO/MEC.

Mimbres-locoforge (TSI-063000-2021-47): Operational validation of the defined and deployed platform within FABRIC through the deployment of mission-critical services in the industrial sector, specifically in the railway sector.

Statements of competing interests: The authors have no competing interests

List of abbreviations

AI - Artificial Intelligence
B5G - Beyond 5G
ETSI - European Telecommunications Standards Institute
FABRIC - Technological fabric of connectivity and virtualized distributed computing
FRMCS - Future Railway Mobile Communication System
GSM-R - Global System for Mobile Communications – Railway
IoT - Internet of Things
MEC - Multi-access Edge Computing
NQaS–Network Quality and Security Research Group
PRTR - Plan for the Recovery, Transformation, and Resilience of the Spanish Economy
SBA - Service-Based Architecture
SDN - Software-Defined Networking
UNICO-5G I+D - Universalisation of Digital Infrastructures for Cohesion Programme – 5G I+D
UPV/EHU - University of the Basque Country
ZSM - Zero-touch Service Management

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