

Immersive Technologies in 5G-Enabled Networks: A Systematic Review of Publication Trends and Adoption Recommendations

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Received:

December 4, 2025

Revised:

March 11, 2026

Accepted:

March 31, 2026

Published:

April 12, 2026

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DOI:

10.63158/journalisi.v8i2.1559

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Abstract. Fifth-generation (5G) infrastructure is unlocking the potential of immersive technologies across multiple sectors. This study examines the relationship between immersive technologies and 5G deployment by analyzing publication trends, adoption factors, and policy dimensions. Using a systematic review of peer-reviewed studies published between 2015 and 2025, the PRISMA method was applied to identify 43 articles for analysis. The review shows a marked rise in publications after 2018, with healthcare, education, and sector-specific training emerging as the main application areas. It also reveals that infrastructural barriers are the most frequently reported obstacle to adoption, followed by technical limitations and device-readiness challenges, with these constraints being especially severe in developing countries. The literature further identifies possible responses for the telecommunications industry and policymakers, including selective 5G deployment across organizations to support experimentation and gradual scaling. Despite ongoing advances in 5G, it remains unclear how organizations will adapt to these developments, limiting understanding of their broader sectoral impact. The review also finds limited research on 5G adoption barriers, highlighting the need for future studies using diverse methods to examine both opportunities and risks. This study provides practical insights for scaling immersive applications in resource-constrained settings.

Keywords: Immersive media, 5G adoption barriers, Virtual reality, systematic review

1. INTRODUCTION

Immersive technologies: including augmented reality, virtual reality, and mixed reality, are increasingly defining how digital environments are interacted with in numerous domains such as entertainment, education, healthcare, and industrial contexts. Global developments in both hardware and software, exemplified by the introduction of revolutionary XR-enabled headsets and high-powered Software Development Kits, are among the drivers that have spawned the rapid technology adoption trajectory across the globe throughout to date [1], [2]. Nevertheless, the successful incorporation of such immersive encounters necessitates reliable connectivity, sub-second latency, and immense data capacity. The three essentials are all strongly addressed by fifth-generation technology, (5G) networks [3], [4].

Fifth-generation vastly surpass all prior generations of mobile platforms and technologies. The ultra-reliable low-latency communication is a significant example, as is the power of mobile broadband with the potential attachment with the Tactile Internet of Things [5], [6]. Several such in-demand, real-time activities and interactions are provided as examples of anticipated endless possibilities [7], [8]. Furthermore, real-life immersive learning and industrial training simulations may benefit greatly from the high bandwidth and resilience that 5G provides, making consistent interactivity conceivable for remotely collaborating participants [9], [10]. The characteristics of free-viewpoint video streaming and distributed, interconnected AR architectures exhibit the demand for fundamental robustness inherent 5G network [11], [12].

There are multiple obstacles to address this vision. High bandwidth requirements, challenging infrastructure expenses, and the necessity for effective spectrum management remain a challenge for developing nations [13], [14], [15]. Immersive technologies simply cannot be available in these nations due to inadequate connectivity and affordability, injuring both ends of the economic equation. Yet the time has come. The 5G transformation is expected to create 5G networks available all over the globe, leading to wider, cost-effective use and controlled costs across distant frontiers [1], [3].

A scientific assessment of the publication exercises of immersive technologies in the framework of current research on 5G-enabled was carried out to better identify

elements of hype and influence. In considering such parameters concerning technical issues, alternatives and enablers that potentially offer beneficial outcomes for telecommunications and national policymakers, with a special emphasis on the developing world, may be drawn.

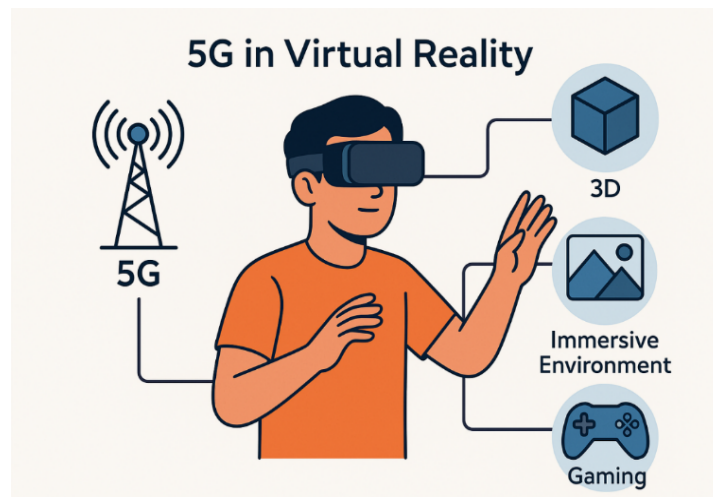


Figure 1. 5G in Virtual reality

The purpose of this study is to analyse the publication trends on immersive technologies within 5G-enabled networks and to propose guidelines and a conceptual framework to enhance the adoption of immersive technologies in 5G environments. The study will address the following research question to enhance the establishment of the purpose of the study:

- 1) What are the current publication trends on immersive technologies (AR, VR, MR) in 5G-enabled applications between 2015 and 2025?
- 2) Which technical, infrastructural, and socio-economic factors influence the adoption of immersive technologies in 5G environments, particularly in underdeveloped regions?
- 3) How can the telecommunication sector and policymakers take advantage of the 5G infrastructure to enhance the use of immersive applications in education, industry, and the entertainment sector?

By addressing the aforementioned research questions, this study contributes to the growing body of knowledge on immersive technologies by systematically examining publication trends and identifying key barriers influencing their adoption within 5G-

enabled environments. In particular, the study highlights factors that may limit the effective deployment of immersive applications in resource-constrained and developing regions. The study contributes guidelines and a conceptual framework to inform telecommunication stakeholders and policymakers on how 5G infrastructure can be leveraged to support the scalable adoption of immersive technologies across sectors such as education, industry, and entertainment.

2. LITERATURE REVIEW

5G plays a transformative role in enabling virtual reality (VR) by offering ultra-low latency, high bandwidth, and reliable connectivity essential for immersive experiences. It supports real-time rendering, multi-user interaction, and live free-viewpoint video streaming, thereby enhancing VR quality and responsiveness [7], [12]. Distributed architectures and edge computing further reduce delays, ensuring seamless immersive environments [11]. Moreover, network function virtualization (NFV) addresses the massive bandwidth demands of VR applications [13]. Spectrum sharing also ensures sustainable connectivity for immersive, data-intensive experiences [14].

The reviewed studies investigate how 5G and beyond can enable immersive technologies such as VR/AR by addressing latency, bandwidth, and computational challenges. They highlight the promise of ultra-low latency communication, edge computing, and intelligent resource management, while revealing persistent gaps in end-to-end performance, multi-user interactivity, and real-world deployment of integrated immersive systems [7].

[3] conducted a study to explore immersive services (e.g. VR/AR, holography, remote control) over 5G and beyond, with a focus on the strict latency, throughput, and positioning requirements of such services. They evaluated a remote-control immersive service streaming real-time 360° video from cameras to a VR HMD and found that achieving end-to-end (glass-to-glass) latency below ~20 ms is very challenging under present network/device/protocol constraints. They argue that new optimized techniques/devices/protocols are needed.

[7] surveyed and proposed the design strategies for achieving ultra-low latency (1-5 ms) communication in 5G and beyond networks to enable high-quality AR/VR experiences, looking at both hardware and software enablers. The results showed various technologies used, mmWave, massive MIMO, visible light communications (VLC), edge computing / MEC, learning-based scheduling, etc. The study propose a learning-based framework for combining some of these to meet stringent latency requirements. They identify trade-offs between latency, reliability, throughput, and cost, and highlight that while many components are promising, integrated solutions are still in early stages.

[8] also examined the architecture, technical challenges, and required building blocks to enable interconnected AR/VR over 5G + IoT, i.e., multiple users interacting across distances, with haptic feedback, etc. They estimate that rendering, sensing, motion capture etc., contribute certain latencies (e.g., 5-8 ms for computation/sensing/rendering/displays), leaving only about ~7 ms for transmission to stay under ~20 ms end-to-end latency. They outline many challenges: network slicing, ultra-reliable low latency communication (URLLC), haptic feedback, environmental heterogeneity, wireless access, etc. They conclude that current systems are far from achieving the full end-to-end target, especially when including multiple delays (device, network, display).

The study by [9] aimed to propose a framework for wireless VR in beyond-5G ("Internet of Intelligence") systems, jointly managing communication, computation, and caching (3C), to meet the heavy demands of throughput, latency, and computational burden. They introduce a novel framework including edge intelligence to coordinate computation, storage, and transmission. They propose a quantum-inspired reinforcement learning (QRL) method for multi-dimensional resource provisioning. Their simulations show that their scheme reduces latency, improves resource utilization, and allows trade-offs between energy, latency, and VR quality of experience. Table 1 below summarizes the gaps in the studies mentioned. The existing studies (Table 1) on immersive technologies in 5G-enabled applications mainly do not emphasize anything on the publication trends, influential authors, and technological enablers. While these studies provide valuable insights into the evolution of research, they focus on bibliometric patterns rather than addressing practical adoption, performance evaluation, or integration challenges.

Table 1. Summary of studies

Study	Focus	Gap Identified
[3]	Examined immersive services such as remote control, holography, VR/AR over 5G and beyond, with emphasis on strict latency and throughput requirements.	Lack of practical solutions and optimized protocols to meet latency requirements; no complete end-to-end system capable of consistently delivering <20 ms latency.
[7]	Surveyed design strategies for 1–5 ms ultra-low latency communication for Immersive AR/VR experiences in 5G and beyond.	Integration gap: While promising individually, technologies are not evaluated together in a real-world testbed; no end-to-end deployment evidence.
[8]	Investigated architectures for multi-user interconnected AR/VR with haptic feedback and motion capture over 5G + IoT.	Scalability gap: Existing systems cannot support multi-user, interactive, haptic experiences at ultra-low latency in real environments.
[9]	Proposed a 3C (communication-computation-caching) framework for wireless VR in beyond-5G systems using edge intelligence.	Real-world adoption gap: Findings are simulation-based only; no empirical validation or deployment on real immersive systems.

Critical gaps exist in examining how 5G-driven immersive technologies translate into real-world applications, particularly in multi-user, latency-sensitive, and resource-constrained environments. A notable gap in the existing literature concerns the limited representation of studies conducted in developing-country contexts. The vast majority of published research on immersive technologies in 5G-enabled networks originates from technologically advanced regions, where infrastructure deployment, device availability, and connectivity standards are significantly more established [16]. For instance, Korea, Germany, Finland, Switzerland, and Singapore are the top 5 nations that have invested early in 5G technology and are now enjoying the opportunities that come with faster networks [17]. In contrast, few studies emerge from developing nations, despite these regions presenting unique opportunities for immersive learning, digital healthcare, and mobile-based innovation. This creates a knowledge gap in understanding what factors

affect deployment and user experience in these regions. While innovation policies within the European Union (EU) have addressed some challenges and setbacks in 5G rollout, these approaches may not adequately consider the unique infrastructural, and regulatory conditions present in developing countries [18]. The current study seeks to bridge this gap by moving beyond bibliometric mapping toward investigating adoption factors, technical limitations, and practical strategies for immersive technology deployment in 5G ecosystems.

3. METHODS

In this study, a systematic literature review (SLR) approach has been adopted to identify the publication trends of immersive technologies in 5G-enabled applications. This approach is deemed appropriate because research on immersive technologies in 5G-enabled environments is rapidly evolving, multidisciplinary, and highly fragmented across disciplines such as computer science, engineering, education, healthcare, and telecommunications. Therefore, SLR provides a transparent research process to study patterns and evidence from prior research studies [19]. The approach follows the steps as outlined by [20]:

- 1) Formulate a Clear Research Question
- 2) Develop a Protocol / Review Plan
- 3) Define Eligibility Criteria
- 4) Search for Studies
- 5) Selection of Studies
- 6) Extract Data
- 7) Assess Study Quality / Risk of Bias
- 8) Analyze and Synthesize Evidence
- 9) Interpret Findings
- 10) Report the Review

This SLR attempts to explore the technical challenges, opportunities, and influential enablers in order to enhance 5G-enabled immersive technologies to boost 5G infrastructure and enable the transformative potential in immersive technologies. There is a narrow focus on least developed contexts where the enhancement of 5G

infrastructure will be vital in enabling transformative potential boost in immersive technologies.

3.1. Eligibility Criteria

Eligibility criteria were based on studies that had been published within the last ten years of the study period policy, between the years 2015 and 2025. The million-based publication language was inclined to English language. The study considered only open-access publications to ensure transparency, accessibility, and reproducibility of the analysed sources. A comprehensive criterion for inclusion and exclusion was used and is as presented in Table 2.

Table 2. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Articles Published between 2015 to 2025	Published before 2015
Written in the English language	Not written in the English language
Peer-reviewed journal articles and conference papers	Literature did not focus on 5G and immersive technology
Studies focusing on 5G and immersive technology	No full text available
Full text	
Open access	

3.2. Quality Criteria

To ensure the reliability and scholarly validity of this review, only publications from reputable sources were considered. Studies had to be published in accredited and peer-reviewed journals and established conference proceedings. This approach was adopted to avoid publications from predatory outlets and to maintain high research quality standards.

3.3. Search for Studies

Given the multidisciplinary nature of 5G and immersive technologies, the following electronic academic databases were searched to retrieve relevant peer-reviewed

publications: IEEE Xplore digital library, Scopus, Web of Science, and ACM Digital Library. Table 3 below has the search strings that were used across databases.

Table 3. Search strings used across databases

Database	Search String
Scopus, and Web of Science	TITLE-ABS-KEY ((("immersive technolog*" OR "virtual reality" OR "augmented reality" OR "mixed reality" OR "extended reality" OR "XR") AND ("5G" OR "fifth generation network" OR "5G-enabled"))) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")))
ACM Digital library	[[All: "immersive technology*"] OR [All: "virtual reality"] OR [All: "augmented reality"] OR [All: "mixed reality"] OR [All: "extended reality"] OR [All: "xr"]] AND [[All: "5g"] OR [All: "fifth generation network"] OR [All: "5g-enabled"]] AND [E-Publication Date: (01/01/2015 TO 12/31/2025)]
IEEE Xplore	(("immersive technology*" OR "virtual reality" OR "augmented reality" OR "mixed reality" OR "extended reality" OR "XR")) AND ("5G" OR "fifth generation network" OR "5G-enabled") Field restriction: "Abstract", "Document Title" Filters applied: year (2015-2025), Document types: Journal, Conferences

3.4. Study Selection

Figure 2 describes the process used to select the final set of studies. The review followed a thorough selection process, as illustrated in the PRISMA flow diagram [21]. Initially, 1154 records were identified from four databases: IEEE Digital Library (n = 248), ACM Library (n = 175), Scopus (n = 309), and Web of Science (n = 422). Before screening, 428 records were removed due to duplication. After this, 726 records proceeded to screening, and 214 full-text articles were assessed for eligibility. A further 171 studies were excluded based on specific criteria: 136 (out of scope of the review), and 35 (full text could not be retrieved). Eventually, only 43 studies met the eligibility criteria and were included in the final review.

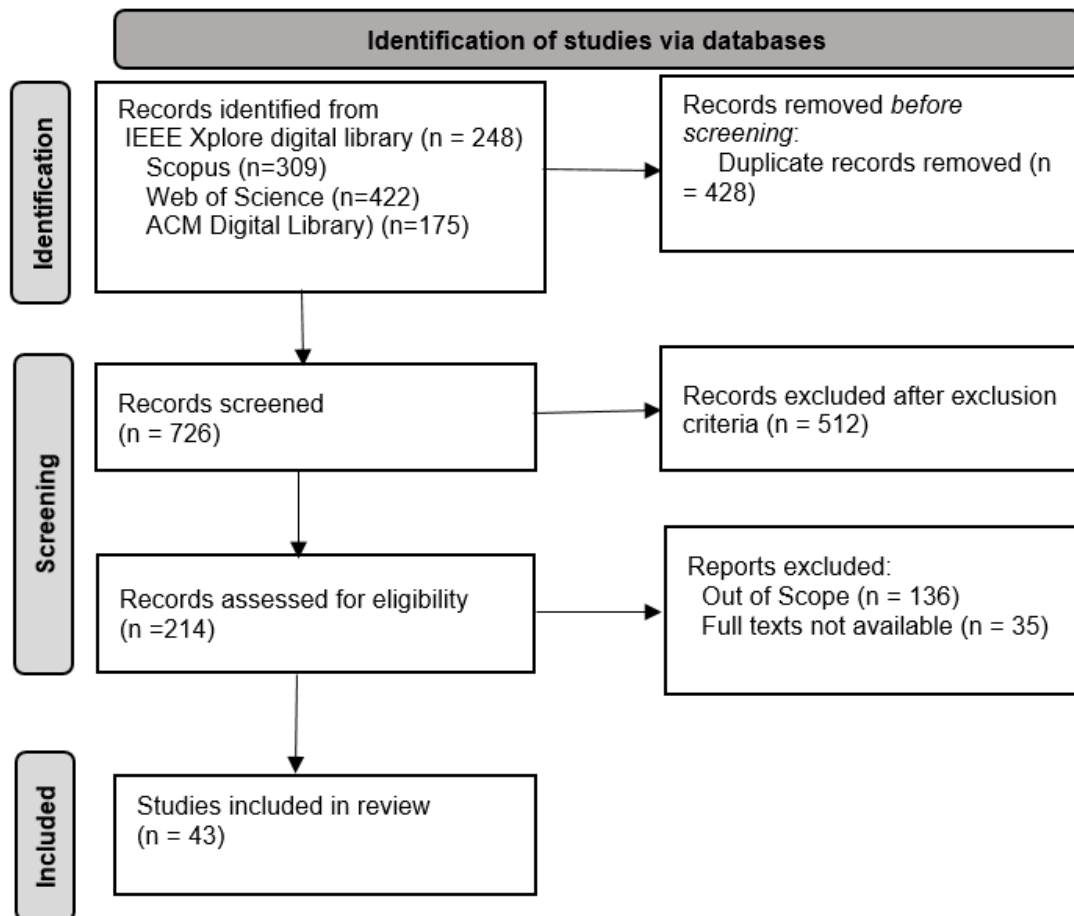


Figure 2. Selection Process (PRISMA)

The identification process was executed by a single researcher who employed predetermined search terms to discern potentially pertinent studies. Subsequently, a more stringent review procedure was implemented by two researchers operating autonomously. These researchers conducted the selection process, meticulously evaluating the identified studies against the predetermined eligibility criteria. The extracted data were then analyzed thematically, guided by predefined research questions. This thematic analysis involved identifying patterns, recurring ideas, and significant insights across the studies.

4. RESULTS AND DISCUSSION

The following set of results reflects the findings from the articles that were reviewed. They address the study research questions as they are stated in the introduction section.

4.1 Publication over the years

Publication volume growth began exponentially from 2019, coinciding with more extensive 5G trials and the COVID-19 pandemic, requiring more remote learning and telemedicine. Initial years' literature 2015–2018 predominated the mere presentation of technical demonstrations and proof-of-concept prototypes. However, the latest document types for 2019–2025 point to an apparent shift for application-focused study, both of which have been directly evaluated empirically, through quasi-experimental design, systematic review, and mixed-method approaches. Figure 3 shows that there was a shift between 2015 and 2025, on publication trends on immersive technologies in 5G-enabled applications, especially in focus and methodology.

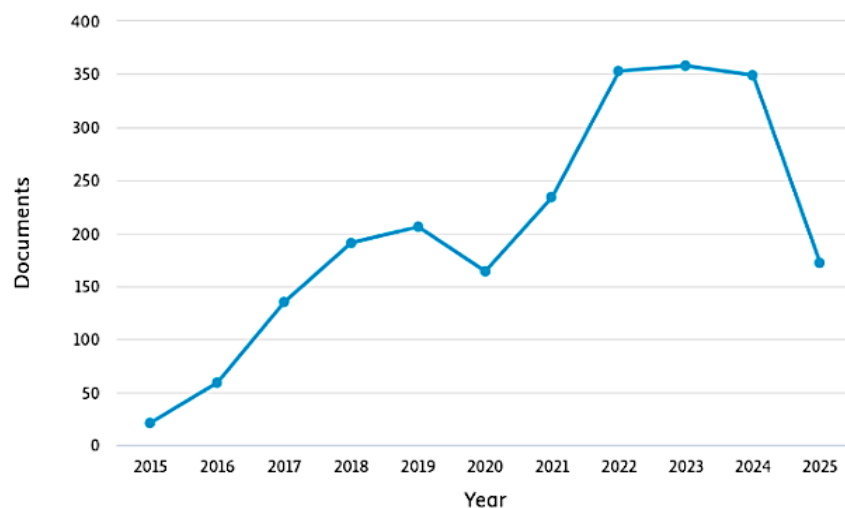


Figure 3. Publication over the years

4.2 Publication types

The distribution of document types listed in the yearly produced this article indicates that the discipline is more formed and perceived in journal literature than in conference ones and seems to have a strong base of peer-reviewed study. The conference paper seems to be less in number, showing the development of new experimental trends more than other research origins. This shift suggests a transition from experimental prototypes toward deployed and scalable solutions. Importantly, this trend supports a broader vision of Society 5.0, where high-speed connectivity and human-centred digital innovation are integrated to improve distribution of services [22]. Rigorous journal publications

accelerate knowledge transfer to policymakers, scholars, and industry stakeholders, supporting evidence-based strategies for immersive smart cities, intelligent systems, and digital services [23]. The reviewed publications comprised 72.1% journal articles and 27.9% conference papers, suggesting a predominance of journal-based publications, as shown in Figure 4.

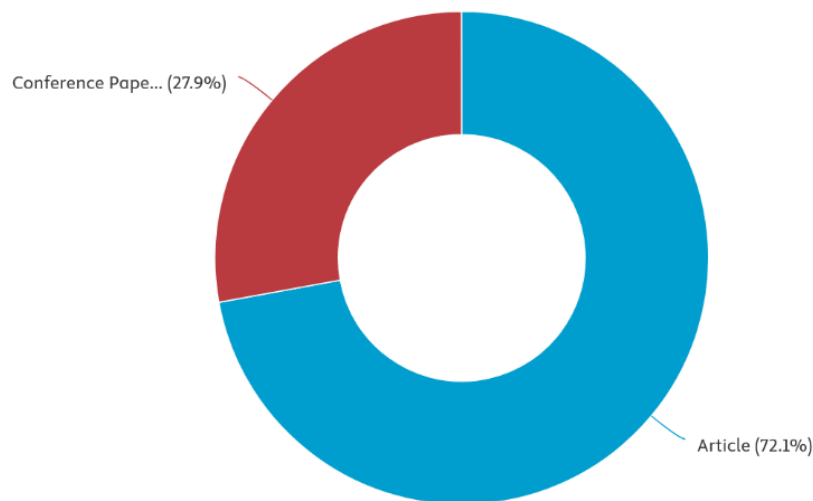


Figure 4. Document type

4.3 Publication by Country

Figure 5 presents the countries from where the reviewed articles came from. Analysis of reveals that the top five contributing countries are India, the United States, Italy, Norway, and Australia. Regional patterns show a concentration of research in Asia, the EU, and the US, with relatively few studies originating from Africa and other developing regions. The uneven distribution reflects differences in technological infrastructure, funding availability, policies, and the maturity of telecommunications and immersive technology ecosystems.

Most of the papers came from India, confirming the investment in technology and research to make the affected technology be widely accepted. For Instance, research has been conducted to identify the challenges related to 5G deployment [16]. Additionally, some of the countries in the figure below have been listed as early embracers of 5G technology [18]. Technology industry is growing, which presents new opportunities for exploration, including 5G, and their applications in various sectors.

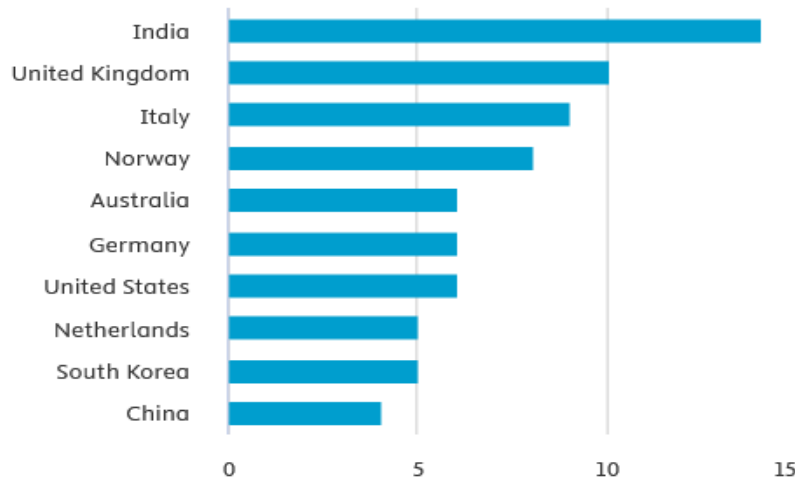


Figure 5. Publication by country

4.4 Benefits towards the adoption of immersive technologies in 5G environments and use cases

The need for the low latency, multi sensorial immersive service provisioning in industry, education, and entertainment in 5G enabled immersive does makes 5G wireless drive cloud offload, network slicing, and private networks [10], [24]. The benefits achievable in the various organization in 5G enabled in the immersive environments' deployment depending on their technology readiness, this is as shown in Figure 6. The area of concern is haptic systems.

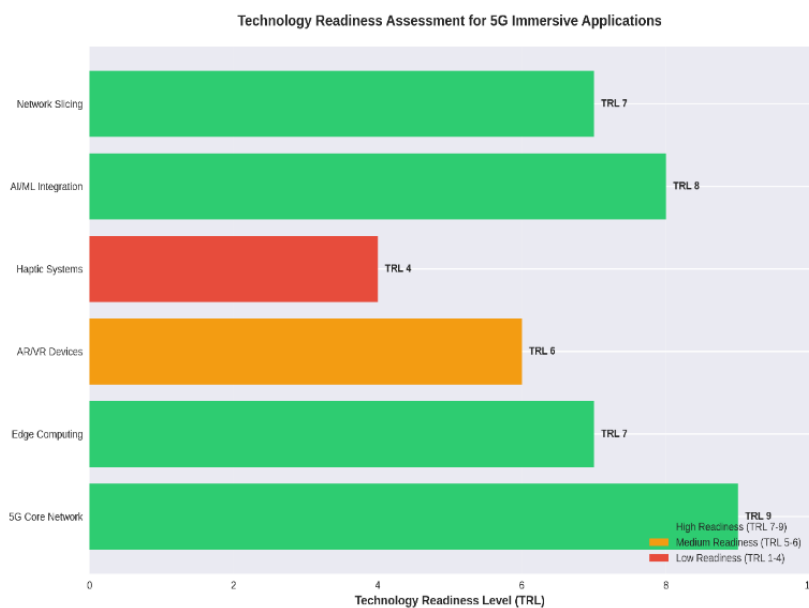


Figure 6. Technology readiness assessment

Industry research positions the Tactile Internet as well as the haptic systems to be the backbone for the remote teleoperation and tactile experiences in several organisations, such as training [5]. Therefore, there is a need for the organisations over investment in the initiatives that seek to accelerate the development and adoption of haptic technology. Table 4 compares the benefits and current immersive 5G use cases across education, industry, and entertainment. The benefit might differ from one organisation to another.

Table 4. Sector Benefits

Sector	Key benefits	Immersive use cases
Education	Lowered latency for real-time remote labs and tactile interaction; scalable shared XR classrooms enabling collaborative training [7], [25].	Remote laboratories and equipment control; immersive metaverse classrooms and field trips; surgical/technical training with haptics [7], [25].
Industry	Deterministic connections for tele-operation, real-time monitoring, and human-machine collaboration; private networks and slices for reliability and security [22], [26].	Tactile teleoperation of robots; predictive maintenance via AR overlays; remote commissioning and Operator 4.0 upskilling [22], [26].
Entertainment	High throughput and low latency for multi-user, high-fidelity VR/AR, cloud-rendered experiences and live multi-camera VR broadcasts	Cloud-rendered multiplayer VR, live immersive concerts/events, mobile AR with synchronized spatial audio, and low motion sickness risk [7].
Health	Remote diagnosis, better surgical or medical training, and more effective patient rehabilitation [27].	Rehabilitation programs using immersive simulations [28], and surgeons can visualise complex anatomical structures in three dimensions.
Public safety	Remote collaborations, augmented situational awareness, and improve accuracy in monitoring and early warning	transmission of high-resolution data from drones, body-worn cameras, and IoT sensors in disaster zones [29].

4.5 Challenges towards the adoption of 5G environment

The study reviewed the challenges of implementing 5G in immersive environments using the severity matrix (Figure 7), particularly in underdeveloped regions. Challenges are assessed using severity (1 = low impact, 5 = high impact) across various domains: Education, Industry, Entertainment, and Policy Implementation. Severity scores (1–5) were assigned using the author's judgement, informed by the literature, to provide a relative measure of impact [16], [18], [30]. Below is a matrix description of severity scales that were applied:

- 1) 1-2 (Light): Low impact (manageable with standard approaches)
- 2) 3 (Moderate): Medium impact (requires focused attention)
- 3) 4 (High): Significant impact (major barrier to adoption)
- 4) 5 (Critical): Severe impact (fundamental obstacle requiring urgent intervention)

Based on the findings, the drivers of the adoption of immersive technologies in 5G environments are a mix of factors with their level of severity. Specifically, technical challenges such as readiness of devices and systems are rated in severity at 4, reflecting already evident constraints for both users and institutions. This is common especially in the educational sector [4], [10]. Infrastructural aspects are also outlined with deployment costs described as the most severe obstacle in this area. Scholars have noted that, so far, the deployment of 5G is limited to urban areas only [23]. The need for more networks or lack of connectivity is an issue in rural and sparsely populated areas and is actively discussed as a requirement for implementation. Interoperability, which implies the possession of adequate software and hardware for supporting 5G technology, is another factor. Lastly, socio-economic problems, such as lack of proper skills, regulatory policy vagueness, and security and privacy issues, also have severity 4, reflecting the existing human capital and governance deficits. Scholars have emphasized that, when formulating 5G policies, it is crucial to account for socio-economic disparities across regions and sectors, including differences in infrastructure readiness, digital literacy, and institutional capacity [17], [30]. Addressing these variations is critical to ensuring inclusive, context-sensitive, and sustainable implementation of 5G-enabled technologies.

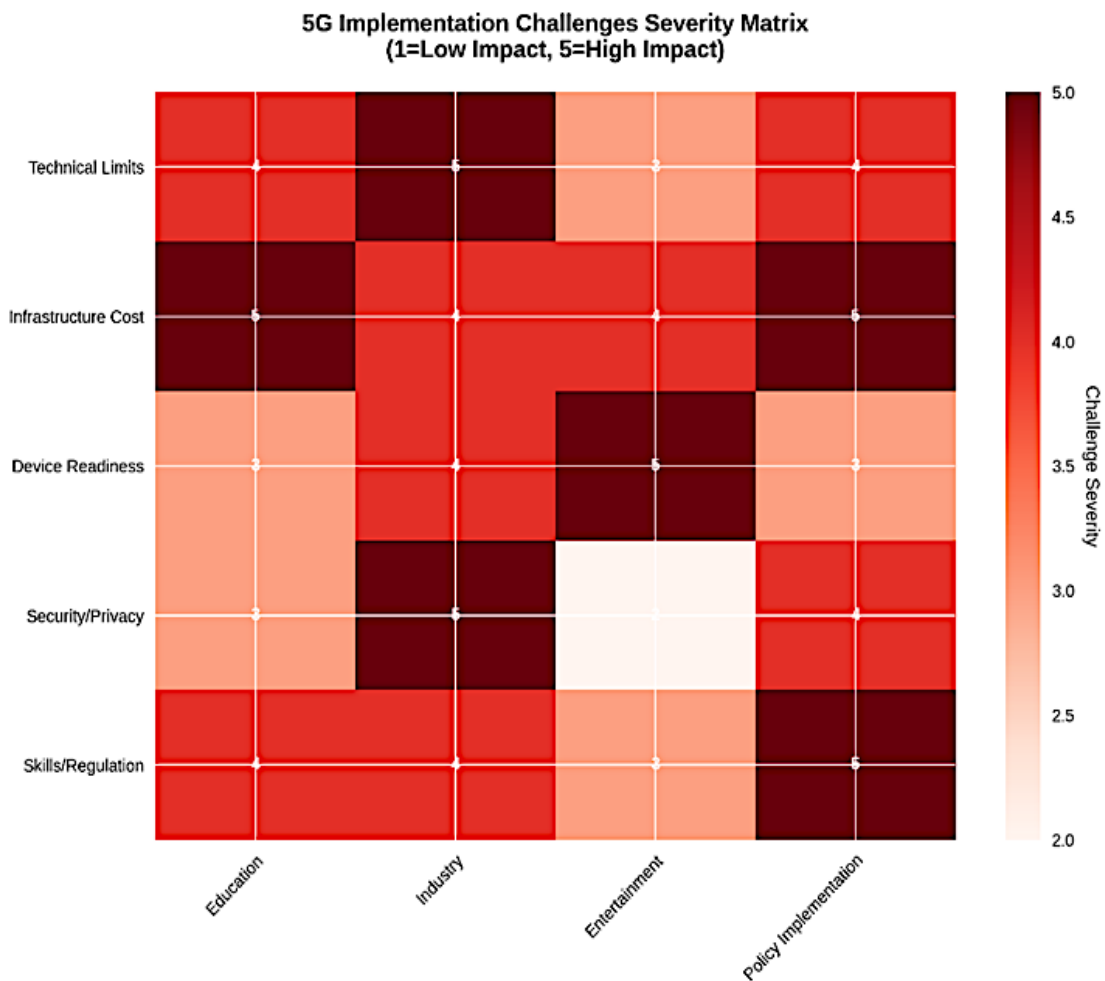


Figure 7. Severity Matrix

Although the scoring and analysis was guided by evidence from the literature, the interpretation of severity may vary across contexts and researchers; therefore, future studies are encouraged to validate these assessments using empirical approaches such as expert-based evaluations to improve generalisability of the findings. The table below explains why specific scores were allocated, focusing only on challenges with severe or significant impact.

Table 5. Challenge analysis

Challenge	Sector	Score	Justification
Technical limitation	Education	4	Remote laboratories require sub-20ms latency for haptic feedback; any lag makes tactile manipulation unsafe or ineffective [7].

Challenge	Sector	Score	Justification
	Industry	5	Industrial teleoperation and human-robot collaboration are safety-conscious applications. For instance, manufacturing case studies report that technical reliability below 90% makes industrial adoption impossible due to safety and liability concerns [22], [26].
	Policy implementation	4	Technical limitations undermine policy goals and create deployment uncertainties [18].
Infrastructural Cost	Education	5	Educational institutions have limited budgets and compete with other priorities. Studies identify cost as the #1 barrier preventing educational 5G adoption, particularly in developing countries[16]
	Industry	4	Industrial deployments are costly, but have clearer return on Investment justification
	Entertainment	4	Content delivery infrastructure and consumer device subsidies are costly
	Policy Implementation	5	Government deployment goals face fiscal constraints and political pressures
Device readiness	Industry	4	Reports identify device reliability and certification as top concerns, with many manufacturers citing device readiness as a deployment blocker [22].
	Entertainment	5	Consumer adoption depends entirely on device affordability and experience quality [3].
Security/Privacy	Industry	5	Studies on cybersecurity report industrial 5G as a high-value target, with documented proof-of-concept attacks on teleoperation and digital twin systems [7] [16].
	Policy implementation	4	Policy analyses report security/privacy regulation as a critical gap, with calls for immersive-specific frameworks [18].

Challenge	Sector	Score	Justification
Skills/Regulation	Education	4	Studies identify educator preparation as the key barrier to technology integration, ahead of cost and infrastructure [25].
	Industry	4	Specialized industrial 5G expertise is scarce and expensive [26].
	Policy Implementation	5	Analysis reveals regulatory fragmentation and skills gaps as key barriers, with recommendations for streamlined processes, international harmonization, and capacity building [23].

It is important to acknowledge that no one solution can address all the challenges identified. Instead, sector-specific strategies should be established based on industry needs. As technology evolves, it is also important to have continuous monitoring and evaluation initiatives to ensure alignment.

4.6 Leveraging 5G infrastructure to support adoption of immersive applications for education, industry, and entertainment

The reviewed publications are reporting prototype deployments, pilots, and policy checklists that policymakers and telecommunications organisations can use to accelerate safe, equitable roll-out. Simulations and pilots show concrete levers.

Education pilots and remote labs. Demonstrations of 5G-enabled remote laboratories show how edge-assisted VR can deliver tactile/remote instrumentation and synchronous collaborative learning [25], [31].

- 1) Industry trials and studios. Research describes 5G Industry 4.0 studios and smart-factory pilots using private slices and tactile internet concepts to support teleoperation, remote maintenance, and Operator 4.0 applications [22], [26].
- 2) Tactile Internet case studies. Case descriptions and conceptual frameworks highlight architecture components (master/network/slave layers) for integrating 5G and TI in manufacturing scenarios [22].
- 3) Policy and national strategies. Policymaker guidance recommends combining 5G with 4G/other tech, using spectrum and infrastructure sharing, and offering

- incentives (tax, infrastructure sharing) to attract investment and avoid widening the digital divide [17], [18].
- 4) Targeted innovation policies. Publications show that active innovation policy (support for trials, spectrum policy adjustments, public-private testbeds) can mitigate deployment failures [18].
 - 5) Simulation for policy design. System-dynamics modelling has been used to simulate national policies (e.g., incentives, sharing) and their impact on urban/rural rollout and economic outcomes [23].

4.7 Discussion

Implementing immersive technologies in 5G-Enabled Networks requires commitment and investment from organisations and the government. Especially where there are so many benefits to be explored, such as support for smart education, where students can conduct experiments in simulated environments without any network interruptions [10]. Other scholars share similar sentiments, emphasizing that the implementation of 5G will be a game changer for education 4.0 [25]. Technology-enabled education not only promises access to quality education but also improves knowledge retention and open access to hands-on experience. The benefits are also evident in the healthcare field, including improved remote diagnosis, training, and rehabilitation. While these technologies demonstrate strong potential to improve efficiency and interaction, security considerations remain critical. Depending on deployment procedures, it is essential to identify and address vulnerabilities that may compromise system integrity, confidentiality, and user privacy [32]. This includes ensuring robust cybersecurity measures, secure network architectures, and compliance with data protection regulations to mitigate risks and support trustworthy and sustainable implementation. These need to cut across all sectors using 5G network. Some regions have opted for partnerships to minimise the implementation costs, while adopting stronger security measures [17]. This is particularly important for low-income countries that might not be able to afford high-level infrastructure for a 5G network.

Countries like India are among the early embracers of 5G; however, they are still facing implementation challenges, like affordability and shortage of skilled workforce to implement and support security solutions [16]. These challenges further affect the implementation of emerging technologies in organisations, as many platforms or

applications used need to have security controls [8]. While corporate industry may justify these costs through clearer returns on investment, sectors such as entertainment and education often struggle to allocate the necessary resources [10]. It is necessary to identify sector-specific challenges in order to come up with appropriate strategies. Achieving sustainable and inclusive education will depend on the deployment of 5G technologies that can support low-latency, high-bandwidth immersive learning environments, particularly in remote and resource-constrained regions. Future studies should therefore investigate context-specific adoption models, cost-benefit dynamics, and scalable implementation strategies that account for varying resource constraints, as well as frameworks to support equitable and sustainable deployment across different domains.

Understanding that sectoral challenges exist, the adoption of immersive technologies in 5G environments requires a holistic approach that integrates technical, infrastructural, organizational, and regulatory considerations. The recommendations and the proposed conceptual framework provided here were developed through a thematic synthesis of the included studies. Key adoption barriers, enabling conditions, and application domains identified in the literature were grouped into broader categories, which informed the structure of the framework and the resulting guidelines for telecommunication stakeholders and policymakers.

First, technical enhancements are critical. Ultra-low latency, high bandwidth, and edge computing must be prioritized to ensure seamless immersive experiences in real-time applications such as AR/VR and holography [3], [7]. To achieve this, investment in advanced network slicing, spectrum sharing, and NFV solutions is recommended to handle the massive data and connectivity demands [13], [14]. Second, infrastructure and network deployment must emphasize scalability and integration with IoT systems to support multi-user, interactive, and distributed immersive applications [8], [11], [33]. Leveraging distributed architectures and mobile edge computing can reduce delays and improve system reliability. Third, user experience design should remain a central focus. Developers and providers should enhance Quality of Experience (QoE) by improving interactivity, haptic feedback, and rendering efficiency to encourage adoption [4], [9]. Fourth, organizational and economic strategies such as cost-sharing models, industry partnerships, and scalable business frameworks should be established to mitigate the

high investment burden [1]. Finally, policy and standardization are essential for ensuring interoperability, security, and trust across platforms [18], [23]. Policymakers and stakeholders must collaborate on unified standards to support global deployment. Collectively, these recommendations provide a roadmap for sustainable and impactful integration of immersive technologies in 5G ecosystems. Based on the recommendations, the following conceptual framework was depicted to demonstrate how multiple factors converge to influence the adoption of immersive technologies in 5G environments.

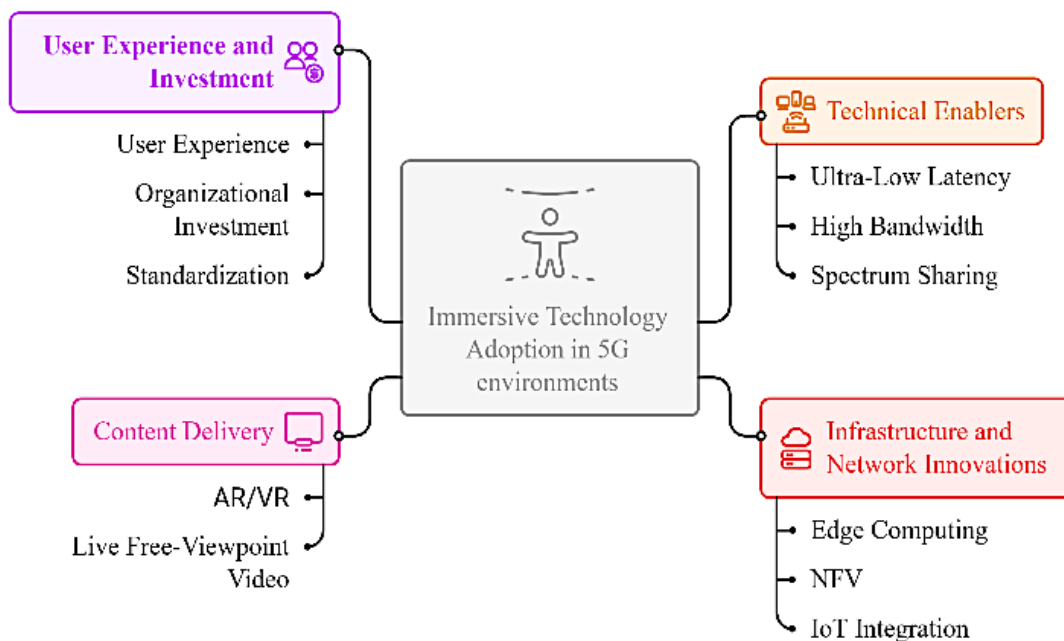


Figure 8. Recommended framework for the adoption immersive technologies in 5G environments

Technical enablers such as ultra-low latency, high bandwidth, and spectrum sharing ensure real-time responsiveness [7], [14]. Infrastructure and network innovations like edge computing, NFV, and IoT integration improve scalability and service quality [8], [13]. Content delivery, including AR/VR and live free-viewpoint video, relies on distributed architectures for immersive experiences [11], [12]. User experience, organizational investment, and standardization drive sustainable adoption [1], [3], [4], [9]. Collectively, these dimensions guide recommendations for effective immersive technology deployment.

5. CONCLUSION

This study presented a review of immersive technologies within the context of 5G-enabled networks. To extract studies for analysis, this study followed a PRISMA approach focusing on the search string, predefined selection protocol, and research questions. A total of 1154 articles published between 2015 and 2025 were identified based on the search string. After applying the inclusion and exclusion criteria, only 43 articles were deemed eligible for inclusion. As this study shows, convergence between immersive and 5G technologies is increasingly prominent, as evidenced by a surge in scholarly publications between 2015 and 2025 across different organisations. Nonetheless, underdeveloped countries face limited adoption, caged by a multitude of constraints. Infrastructural costs are the most prominent constraint at severity 5, followed by technical, device availability and socio-economic factors such as skill deficiencies, unclear regulations, and fear of perceived data privacy infringements all at severity 4. This means that there is a need for a concerted effort that extends beyond network deployment to device availability, skills development at the grass roots, and policy alignment. Telecommunication operators and regulatory bodies can drive the agenda through their planned initiatives such as focused deployment of 5G in high impact areas, investment in edge computing, device financing models and setting up regulatory sandboxes to allow for innovation. This review was limited to studies published in English and sourced from peer-reviewed academic databases (IEEE Xplore digital library, Scopus, Web of Science, and ACM Digital Library), excluding relevant findings from grey literature or non-English publications. This study also acknowledges that although a structured search strategy was employed, selection bias may still exist due to variations in indexing across databases and the exclusion of studies with inaccessible full texts. The study further limited the inclusion of studies to open-access publications, which may have excluded relevant studies published behind paywalls. While this criterion was adopted to ensure transparency and accessibility of the reviewed sources, it may introduce a degree of publication selection bias. While the jury is still out how organisations would react to 5G-empowered immersive applications, longitudinal, cross-sectoral and mixed-method approach should shape future research on the potential benefits and setbacks.

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