



MOTIVATEXR

Maintenance, Support & Operation Training using Immersive Virtual and Augmented Technology for Efficiency with XR

D3.2 SSH FRAMEWORK V2

31/12/2025



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Abstract	This deliverable presents a consolidated overview of social, ethical, and legal (SEL) issues relevant to the Motivate XR project. It integrates insights from consortium workshops, large-scale academic literature analysis, and automated extraction of negative impacts from scientific publications. The outcome is a harmonised and prioritised issue map covering domains such as health and well-being, policy and governance, infrastructure readiness, and social inclusion. Based on this analysis, a set of mitigation measures has been developed and prioritised, ranging from quick wins to more complex development- and use-related actions. The results are distilled into a set of recommendations. These recommendations will inform the revision of user requirements in Deliverable 3.4, ensuring that Motivate XR technologies are developed and deployed in a safe, inclusive, and responsible manner.
Keywords	Social, Ethical, Legal.

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EXECUTIVE SUMMARY

Understanding and addressing social, ethical, and legal (SEL) issues is essential for ensuring that XR technologies developed within Motivate XR are safe, inclusive, and aligned with societal expectations.

To build a robust evidence base, the project combined multiple independent datasets to provide a complete overview of issues for Motivate XR. A prioritisation survey then identified which issues are most likely to occur and most consequential. The final list of issues highlights pressing risks across health and well-being, economic, infrastructure, policy, legal and regulatory, and social, ethical, and cultural dimensions. Key issues include ill-fitting devices that reduce productivity, increased mental workload and safety risks such as cybersickness and fatigue, cybersecurity vulnerabilities, discomfort and reduced situational awareness leading to accidents, safety gaps due to outdated protocols, network limits and latency, infrastructure deficits as barriers to adoption, inadequate legal frameworks for disputes and virtual property, insufficient agility in updating safety standards, one-size-fits-all training approaches, and disparities in accessibility for differently abled users. These issues affect diverse stakeholder groups, from industrial trainees and technicians to educators, students, and general populations.

In response, a comprehensive set of mitigation measures was developed and assessed. These include ergonomic improvements and device adaptations, personalised interface calibration, monitoring of discomfort and safety, training and organisational preparedness, and the creation of ethical and regulatory standards. The resulting recommendations form an actionable roadmap presented in Section 7.3.

First, “quick wins” are high-impact safeguards that are straightforward to deploy across pilots, for example, preventive ergonomic testing, brief user training on safe device use, real-time posture or strain feedback, enforced session breaks and post-use cooldowns, pre-use safety briefings, formal inclusion of XR risks in organisational risk assessments, SSQ-based screening, staged acclimation through test sessions, and clear communication of data-handling responsibilities with transparency-by-design in XR interfaces.

Second, significant measures that require more effort include improving weight and heat balance in headsets, accommodating prescription lenses or adjustable dioptres, using eye-tracking-assisted fit checks, offering per-pilot UI calibration profiles, publishing official legal, ethical, and safety guidance for all user roles, establishing XR-specific safety and ethics standards with a clear update cycle, embedding XR modules in employee onboarding, running hands-on courses on XR interaction principles, and iterating training via pilot programs with controlled exposure times and feedback-driven updates. Each recommendation highlights its relevance to Motivate XR, offers practical implementation suggestions, and refers to applicable standards such as ISO 9241, ISO/TS 8102-1, ISO 45001, GDPR, and XRSI.

A key outcome of this deliverable is the translation of abstract issue areas into practical safeguards that directly inform Motivate XR’s design and deployment.

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ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
DDoS	Distributed Denial-of-Service
DNSH	Do No Significant Harm
DPO	Data Protection Officer
FPS	Frames Per Second
GDPR	General Data Protection Regulation
HMD	Head Mounted Display
IPD	Interpupillary Distance
IP	Intellectual Property
LLM	Large Language Model
MFA	Multi-factor authentication
MR	Mixed Reality
NLP	Natural Language Processing
PPE	Personal Protective Equipment
R&D	Research and Development
SEL	Social, Ethical and Legal
SSH	Social Science and Humanities
SSQ	Simulator Sickness Questionnaire
UI	User Interface
VR	Virtual Reality
WP	Work Package
XR	Extended Reality

1. INTRODUCTION

Background

The cutting-edge innovation work undertaken by researchers in Work Packages (WP) 4-7 takes place within the context of a SSH framework consisting of a comprehensive social, ethical and legal (SEL) framework (WP3), to promote the development of technical tools that respect moral and societal values, fundamental and human rights, and international legal norms.

In what follows, and as will be outlined, we focus our efforts on providing an updated set of social, ethical and legal (SEL) recommendations that end-users and contributing partners need to be aware of and take necessary action in order to support their compliance with the SEL framework.

Purpose and Scope

This deliverable sets out to define and keep updated the SSH framework ensuring that both the project's activities and outcomes are compliant and acceptable, and informing the project about societal, ethical and legal issues to consider, in particular those related to the use of AI and XR technologies.

As humans pare significantly involvement in the pilot activities by utilising new XR technologies and tools and being present in environments with significant data capturing capabilities and new physical features, it is of urgent and intrinsic importance to set about investigating how SEL principles can satisfactorily be upheld.

To this end, three specific outcomes will be provided within the scope of this report as outlined and numbered in the Grant Agreement, namely:

- 1) A comprehensive list of SEL issues raised by the use XR and AI in the industry context.
- 2) The identification of existing approaches developed to address these challenges, including ethical principles and guidelines for responsible research and innovation in AI and XR, and DNSH obligations.
- 4) the recommendations for the project to consider for its own implementation as for the tools it will create.

This is the second report on the SSH framework, which builds upon the outcomes documented in the first report on the topic, namely Deliverable 3.1. In Deliverable 3.1, initial work on SEL issues raised by the use XR and AI in the industry context was presented together with a comprehensive map of the stakeholders who may be affected by these issues. As it has not been found necessary to update the stakeholder map, it has not been included in this deliverable.

Fundamentally, the guidance provided in this document is intended to help technical partners design AI, XR and systems that safeguard human values and mitigate social, ethical and legal issues within the context of the use cases. Furthermore, it will help end-user partners and other contributing partners take further evaluating to ensure that pilot activities are carried out aligned with ethical and regulatory standards, and further mainstream mitigation and monitoring efforts into their research design and implementation.

Intended Readership

The primary intended readership of this deliverable is technical partners. They have a key role in ensuring tools that safeguard SEL outcomes as they are responsible for designing and developing the tools that will be deployed in the use case sites as well as processing different types of research data. To that end, it is firmly recommended that technical partners read and respond to, in their work, the insights provided here, which applies to them insofar as they supply equipment which should be safe and accessible, and that they are data controllers or are responsible for provision of tools utilised by data controllers that should in any case support General Data Protection Regulation (GDPR) compliance. Use-case partners are the secondary intended audience. They are recommended to read and reflect on the insights of this report as they operate the pilots and have the ultimate responsibility for ensuring the ethical and social conduct of research activities on their premises and ensuring that no harm or disadvantage comes to their employees, particularly as a result of their involvement in Motivate XR research and pilot activities.

A tertiary intended audience of this deliverable is members of other EU projects with similar goals, circumstances. The work presented here may represent a useful point of reference and guidance for future industrial demonstrations and pilot activities of a similar nature.

1.1. DOCUMENT OUTLINE

This document is structured as follows. Chapter 2 ‘Method’ presents the methodology applied, including the creation and integration of three independent datasets, the clustering of issues into thematic areas, and the process used to prioritise them. The section also explains the approach to identifying, comparing, prioritising, and recommending mitigation measures, and how these connect to pilot requirements and user needs.

Chapter 3 ‘Updated Map of Social, Ethical, and Legal Issues’ presents the consolidated issue map. It describes how issues were grouped into thematic clusters, highlights priority issue areas. Chapter 4 ‘Identification of Mitigation Approaches’ describes the process used to identify a broad set of technical, organisational, and regulatory measures, and provides an overview of the resulting catalogue. Chapter 5 ‘Comparison of Identified Measures with User and System requirements’ presents how the measures were analysed against user and system requirements from the five pilots as established in Deliverable D3.3.

Chapter 6 ‘Prioritisation of Mitigation Approaches’ explains how the measures were evaluated for their impact, ease of implementation, and coverage, leading to a prioritised set of interventions. Chapter 7 ‘Recommendations’ translates these findings into a practical roadmap for Motivate XR, including “quick wins” and more effort demanding mitigations. Finally, Chapter 8 ‘Conclusions’ reflects on the key outcomes and describes how the recommendations will inform the revision of user requirements in Deliverable D3.4.

2. METHOD

This section outlines the methodology used to identify, consolidate, and prioritise social, ethical, and legal (SEL) issues for Motivate XR, and to propose corresponding mitigation measures. The process was designed to combine partner knowledge, large-scale literature analysis, and structured evaluation in order to produce both context-specific and broadly validated recommendations.

The first step was the creation of a comprehensive map of SEL issues. To achieve this, three independent datasets were developed and later consolidated. The first dataset consisted of partner-elicited risks, collected through a structured SEL workshop and subsequent survey. The workshop ensured breadth by allowing individual brainstorming and then coherence through group consolidation. The follow-up survey rated each risk by likelihood and impact, producing an initial prioritised list of risks tailored to the consortium's use cases. Issues identified here were highly relevant to the Motivate XR context but reflected only the knowledge and viewpoints within the consortium. The second dataset was a literature-based issue map, developed through an AI-driven analysis of more than 180,000 XR-related scientific publications. This analysis identified and clustered issue topics, which were then refined during a second workshop where partners removed irrelevant items and added new concerns. The third dataset was a literature-based extraction of negative impacts, which used an LLM pipeline to collect fine-grained statements of harms discussed in the research literature, later organised into a taxonomy spanning:

- Social, ethical, and cultural dimensions
- Health and well-being dimensions
- Economic dimensions
- Scientific and technological dimensions
- Environmental dimensions
- Infrastructure dimensions
- Political, legal and regulatory dimensions

These three datasets were then consolidated manually. The research team reviewed overlaps, removed duplicates, and harmonised scope, ultimately producing a single-issue base that retained the specificity of partner risks, the breadth of academic debate, and the detail of literature-derived impacts. To make this consolidated set decision-ready, issues were clustered by thematic similarity and representative issue statements were written. Partners subsequently prioritised these statements in a survey by scoring likelihood and impact on a four-point scale. The results were analysed using scatter plots and quadrant interpretation, which helped identify the issues most critical to address within Motivate XR.

Building on this prioritised issue map, the next step was the identification of mitigation measures. Two complementary approaches were used. First, literature-derived measures were extracted from the dataset of negative impacts, filtered to ensure they were specific, actionable, and relevant to XR-induced risks. Second, partner-driven measures were proposed during targeted workshops, which generated both technical and non-technical interventions. These were merged and

categorised into a taxonomy of ten domains, ranging from ergonomics and interface design to training, governance, and regulatory strategy.

The identified measures were then compared to user and system requirements established in Deliverable D3.3. This step provided an overview of what measures were already foreseen within the project, to highlight both gaps and redundancies.

Following this, measures were prioritised using three criteria: expected impact (the degree to which a measure reduces the severity of prioritized issues), ease of implementation (as rated by relevant partners on a 1–4 scale), and issue coverage (calculated as a weighted function of the severity of the issues a measure addresses). Visualisations such as scatter plots were used to show trade-offs across these dimensions and to identify high-value candidates. Thresholds were applied to isolate “quick wins” and other strong candidates for adoption.

Finally, a set of recommendations were formulated based on the set of measures not yet addressed within the project. The recommendations focus on mitigation measures with high expected impact and issue coverage and distinguish between measures that can be implemented quickly with minimal effort, and those requiring more substantial technical or organisational work but offering significant benefits. For each recommended mitigation measure, Motivate XR specific examples of implementation actions are provided.

This multi-layered methodology ensures that the measures recommended for Motivate XR are simultaneously grounded in consortium needs, informed by the state of scientific knowledge, validated through structured prioritisation, and aligned with real-world pilot contexts.

3. UPDATED MAP OF SOCIAL, ETHICAL AND LEGAL ISSUES

In this section, we identify the focus issues for Motivate XR. In Section 3.1, we first build an extended list of issues for Motivate XR based on three different datasets. In Section 0, we cluster the list of issues by thematic similarities for a more manageable list of issues and formulated representative statements for every issue. The representative statements are then used in Section 3.3 for prioritization of issues for Motivate XR. The final list of issues can be found in Section 0.

3.1. CONSOLIDATION OF IDENTIFIED ISSUES

To build a complete and decision-ready map of social, ethical, and legal (SEL) issues for Motivate XR, we intentionally drew on three independent datasets and then consolidated them. Each dataset contributes a distinct vantage point—practical, thematic, and granular—that no single source could provide on its own. Using all three together allows us to triangulate findings, reduce blind spots, and translate a very broad evidence base into a focused set of project-relevant issues.

- Dataset 1 (partner-elicited risks) captures the practice ground truth: what consortium teams foresee as most likely and consequential in their real pilots and workflows. It anchors the issue space in Motivate XR's context, ensuring the final list reflects operational realities and constraints.
- Dataset 2 (literature-based issue map, refined with partners) provides a top-down view of what the academic community already recognizes as salient SEL concerns for XR. It broadens the horizon beyond our pilots, counterbalances local biases, and helps us detect important issues that partners might not yet have encountered but are well-documented in research.
- Dataset 3 (literature-based negative impacts) adds fine-grained detail: concrete impact statements extracted at scale from the scientific literature and organized into a taxonomy. It makes the space of issues operationally precise—pinpointing specific harms, mechanisms, and contexts that can later be mapped to mitigation measures.

Taken together, the three datasets form a complementary stack: Dataset 1 tells us what matters most on the ground; Dataset 2 validates and widens that view with established issue areas; Dataset 3 sharpens the resolution with detailed impact statements. The consolidation step (Section 3.1.4) then harmonizes scope and granularity—removing duplicates, reconciling overlapping formulations, and organizing all items under a shared categorical structure—so that the final list is both comprehensive and directly usable in prioritization and design. Without this three-way synthesis, we would risk either a context-bound set that misses known risks (if we used partner input alone) or an abstract catalogue that is hard to act on (if we relied only on literature).

3.1.1. DATASET 1 - PARTNER-ELICITED RISK IDENTIFICATION AND PRIORITISATION (D3.1)

The first dataset used was the prioritized list of Social, Ethical and Legal risks for Motivate XR from D3.1. This dataset was built the following way.

Through a workshop, participants were asked to capture risks for Motivate XR from their viewpoints. Participants first worked individually (to reduce anchoring and groupthink) and then moved into focused group dialogues to expand and refine the emerging list. This cadence ensured that both expert viewpoints (through solo ideation) and breadth (through group exercise) were achieved.

Immediately after the workshop, an online prioritisation survey was circulated to partners to transform the raw risk inventory into an actionable ranking. For each risk, respondents independently rated (i) the likelihood of occurrence and (ii) the severity of consequences should the risk materialise, using the categorical options “No,” “Low,” “Medium,” and “High.” To better reflect how such categories are typically perceived, responses were mapped to a non-linear numeric scale—No = 0, Low = 2, Medium = 3, High = 4—rather than assuming equal distances between categories. For each risk, we computed mean likelihood and mean consequence across available responses and then derived a composite severity score as the average of those two means. This yielded a first, survey-based prioritisation of risks tailored to Motivate XR.

3.1.2. DATASET 2 - LITERATURE-BASED ISSUE IDENTIFICATION AND WORKSHOP REFINEMENT

In parallel with the partner-elicited risks, we also used the analysis of the scientific literature of D3.1 that identified a broader set of social, ethical, and legal issues associated with XR. The goal was to ensure that Motivate XR’s risk framework was not limited to the consortium’s immediate perspectives but also reflected concerns already recognised and debated within academia.

That dataset was built by using an AI-driven big-data tool, which is specifically designed to detect values and issues in very large text corpora. A comprehensive dataset of over 180,000 peer-reviewed papers on XR and related immersive technologies was assembled from Scopus. As described in Deliverable D3.1, this resulted in the extraction of 112 topics and clustered into 18 issue areas. Of these, 52 topics were directly related to social, ethical, and legal issues.

This list of issues was then revised in a second SEL workshop with Motivate XR partners and performed as part of this deliverable. The purpose of this workshop was twofold: first, to assess which of the literature-based issues were relevant for the project context, and second, to allow partners to propose new issues that may not yet have been captured in the scientific debate, nor the initial SEL workshop.

Workshop setup

The second SEL workshop was held in person during the consortium meeting, bringing together 32 participants on site. An online interface with the tool was provided to support interactive exploration of the identified concern areas. Through this interface, participants could navigate visual maps displaying the most frequently discussed concerns in academic literature, either across

the full dataset or within user-defined subsets. The tool also illustrated how these concerns were connected to specific values and how the different issues were interrelated. Using this interface, participants discussed in groups the identified issues. The workshop was supported through a Miro board. Participants were provided with the following three objectives:

1. Identify additional risks and risk areas along dimensions not covered in the initial SEL workshop
2. Verify that some risk-areas from literature on XR are not relevant
3. Increase awareness of the potential issues – first step to mitigation is awareness

To introduce the workshop, main risks identified in D3.1 were first recalled. After an introduction of the tool’s interface, partners were asked to identify risks within each relevant topic and mark non-relevant topics. Finally, participants had to opportunity to add new risks and challenges. A print screen of the Miro board can be found in Figure 1.

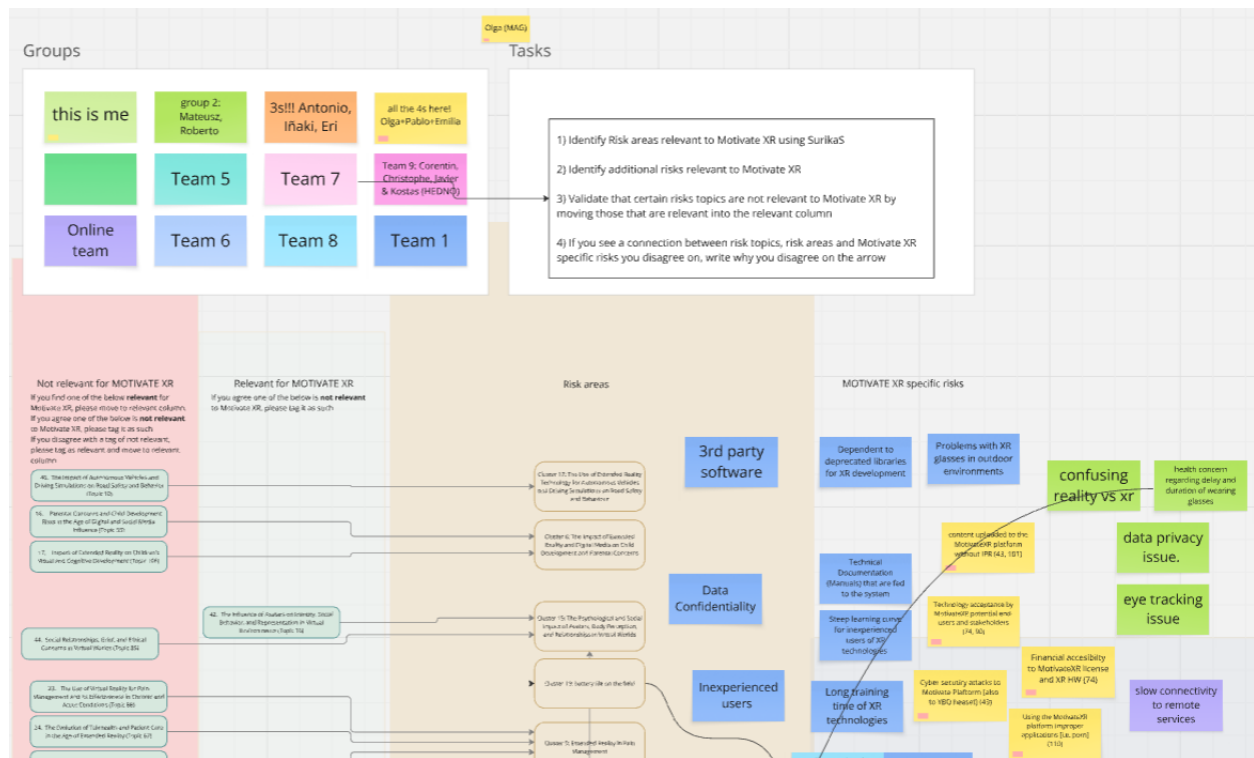


FIGURE 1: MIRO BOARD USED FOR THE SECOND SEL WORKSHOP

Workshop outcomes

The outcomes of the second SEL workshop are documented in Appendix A, B and C.

Appendix A contains the issues that were deemed irrelevant for the project. While these topics are widely discussed in the XR literature—such as child development impacts, medical applications, cultural heritage preservation, or immersive journalism—they were considered not applicable to Motivate XR’s pilots and objectives. Their exclusion ensures that the issue map remains focused on risks with direct relevance to the consortium’s industrial, training, and organizational use cases.

Appendix B captures the additional issues identified by workshop participants. These issues emerged directly from partners' expertise and practical perspectives and often reflect challenges that are underrepresented in academic discussions but critical in applied contexts. Examples include technical dependencies (e.g., deprecated libraries or scattered resources), risks related to data security and privacy, liability questions in case of accidents or system errors, worker well-being concerns tied to surveillance and performance tracking, and barriers to adoption such as accessibility, financial costs, or steep learning curves. Each issue was mapped to the taxonomy of risks used in this deliverable to ensure consistency and integration with the overall analysis.

Appendix C presents the updated list of relevant issues after this refinement process. It merges the literature-derived issues that remained relevant with the additional issues suggested in the workshop, while clearly noting where issues were excluded, reclassified, or mapped to related clusters in the taxonomy. This updated list forms the most complete and context-sensitive version of Dataset 2, striking a balance between academic coverage and partner-driven insights.

3.1.3. DATASET 3 - LITERATURE-BASED IDENTIFICATION OF NEGATIVE IMPACTS

As a third and independent input, we carried out a big-data analysis of the scientific literature focused specifically on identifying negative impacts of XR technologies. While the issue overview of dataset 2 captured broader themes and concerns discussed in academic discourse, this step aimed to extract concrete impact statements as they appear in research articles, thereby providing a fine-grained view of XR's potential downsides. In this section, we explain how the list of negative impact for Motivate XR was created.

Creation of the dataset

The dataset used to identify measures consists of 233,318 academic papers (including journal articles, conference proceedings, book chapters, and other peer-reviewed materials) retrieved from Scopus using the following search terms: "extended reality," "virtual reality," "augmented reality," "mixed reality," "virtual environments," and "immersive technologies." For each academic paper, we retrieve the title, publication year, abstract, and, when available, the full text of the article. The document types and top 20 sources in the dataset can be found in Figure 2.

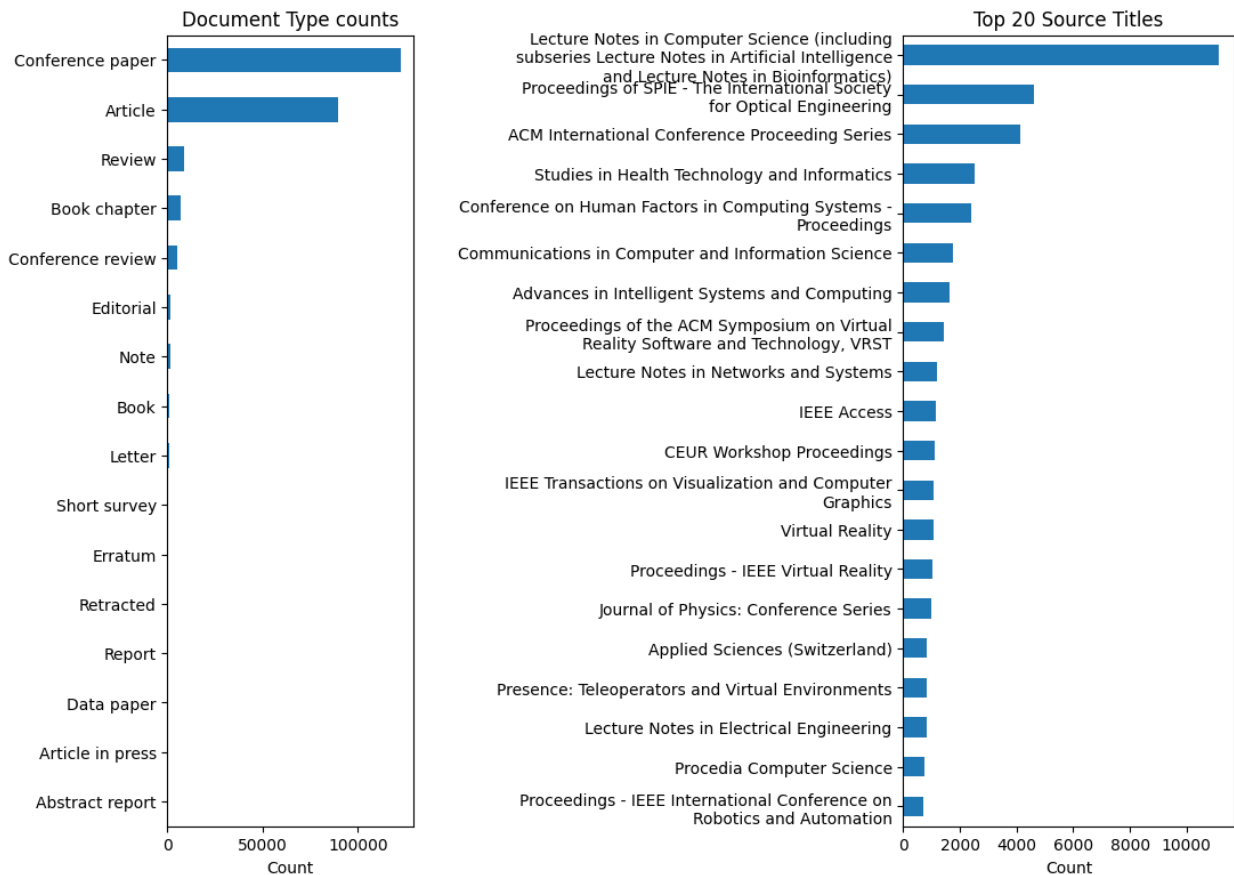


FIGURE 2: DOCUMENT TYPES AND TOP SOURCES IN DATASET 3

Taxonomy of negative impacts

The identification of negative impacts takes place in two steps: (1) Extraction of impacts statements in articles and (2) Taxonomy of impacts. First, impact statements are extracted from articles. This is done in an automated manner, using gemini-2.0-flash. The extraction includes AI-as-a-judge to validate the impact identified indeed is a negative impact caused by a technology and that the technology causing the impact fits the following descriptions of XR technology: “An Extended Reality (XR) is an umbrella term that encompasses Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) technologies. XR technologies blend digital and physical environments to create immersive or interactive experiences by overlaying, enhancing, or replacing real-world elements with virtual components”.

Second, we build a taxonomy of negative impacts. This is necessary because multiple articles may discuss the same impacts. The taxonomy uses a three-level approach to classify impacts. The first level (“categories”) captures impacts across a broad range of areas (see Table 1). The second level (“clusters”) provides an overview of high-level types of impacts within each category. The third level (“impacts”) refers to the specific, concrete negative impacts of the technologies.

TABLE 1: OVERVIEW OF CATEGORIES USED TO CLASSIFY NEGATIVE IMPACTS

Category	Definition
Social, ethical, and cultural category	Single or group of individuals and their patterns of relationships, way of living, culture, and institutions.
Health and well-being category	People's physical, mental and social well-being intended as quality of life.
Economic category	The economy of individuals, businesses, organisations, industries, and economic systems.
Scientific and technological category	Scientific research, technological innovation, and the advancement of knowledge across various domains.
Environmental category	The environment, natural ecosystems, the planet, and consequently environmental sustainability goals.
Infrastructure category	Basic systems and services that a country or organisation uses in order to work efficiently.
Political, legal and regulatory category	Legal and regulatory frameworks, governance structures, and political processes at local, national, and international levels.
Other category	Impacts that do not fit the previous categories.

The distribution of impacts identified across the different categories is presented in Figure 3. A single concern may be addressed in one or multiple publications, and each publication may in turn discuss several concerns. The *health and well-being* category represents the largest proportion, accounting for over 30% of all identified concerns. In contrast, *environmental* and *infrastructure* aspects appear only marginally represented in the literature.

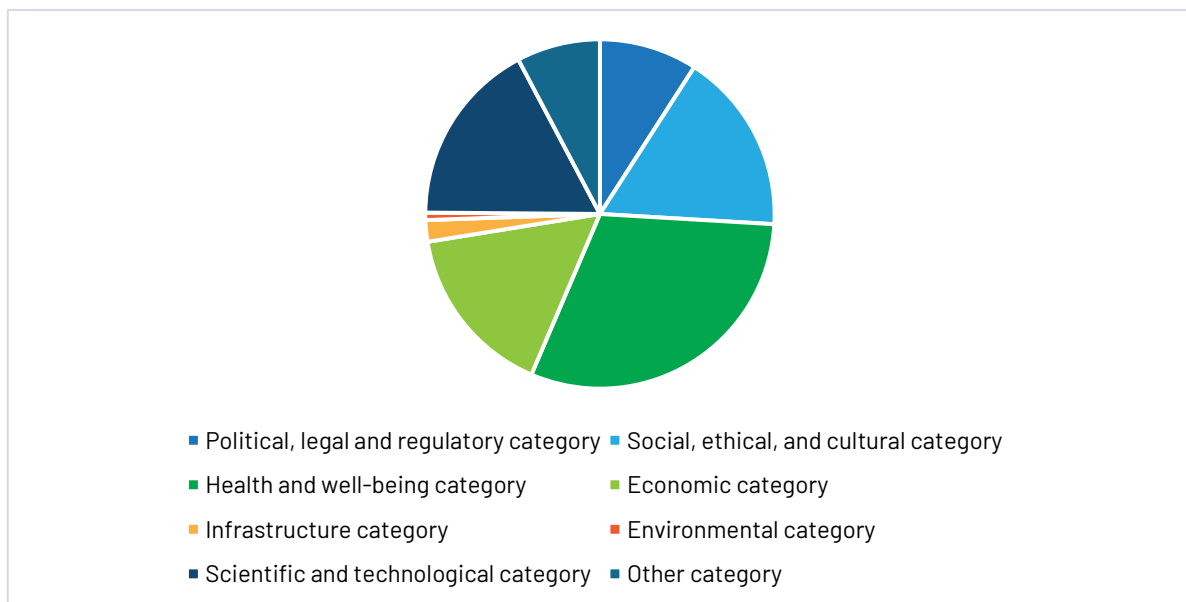


FIGURE 3: DISTRIBUTION OF ISSUES ACROSS CATEGORIES

3.1.4. CONSOLIDATION OF THE THREE DATASETS

The three datasets presented in Section 3.1.1, 3.1.2, and 3.1.3 were consolidated into one list of issues for Motivate XR: the partner-elicited risks from the first SEL workshop and survey (Dataset 1), the literature-based issue map derived from the big-data analysis and refined in the second SEL

workshop (Dataset 2), and the comprehensive set of negative impacts extracted from the scientific literature (Dataset 3).

The challenge at this stage was to merge these sources in a way that preserved their richness while avoiding duplication and fragmentation. The three datasets overlapped in scope but differed in granularity: workshop-derived risks were concrete and Motivate XR-specific, the issue map was broader and thematic, and the negative impacts were detailed and numerous. To achieve a coherent synthesis, we manually reviewed all entries across the datasets. Duplicates were removed, overlapping formulations were harmonized, and related items were grouped under common categories, following the structure presented in Table 1.

The consolidated list of negative impacts can be found in Appendix E. How Dataset 1 and 2 relate to the finally issue list can be found in Appendix C and D. In the rest of this section, we summarize the issues found in the different categories.

Social, ethical, and cultural category

The category social, ethical, and cultural issues highlight concerns ranging from privacy violations due to data collection, surveillance, and misuse of sensitive information, to challenges around identity, empathy, and social connection. XR is shown to blur boundaries between virtual and physical realities, which can distort perception, identity, and work-life balance. Ethical dilemmas also emerge in areas such as avatar representation, digital identity, inclusivity, and AI-driven assistance, raising questions about fairness, liability, and the adequacy of legal frameworks to keep pace with the rapid growth of XR. Additionally, there are worries about increased cybercrime, addiction, harmful illusions, and accessibility challenges for vulnerable groups.

Health and well-being category

The health and well-being category focuses on physical, psychological, and social health risks. XR use is linked to physical discomfort, cybersickness, eye strain, fatigue, and reduced spatial awareness that can increase accidents. On the psychological side, XR immersion can exacerbate anxiety, stress, addiction, and maladaptive behaviours while distorting perceptions of reality and reducing real-world social engagement. Vulnerable populations, including those with disabilities or limited resources, are at risk of exclusion, widening existing health inequalities. Ethical concerns around patient safety, data security, and the reduction of human connection in XR-mediated healthcare also feature prominently.

Economic category

In the economic category, the issues highlight significant financial and labour-related consequences. High costs of hardware, software, training, and maintenance create barriers to access and adoption, potentially reinforcing monopolies and digital divides. Workforce impacts include job displacement, deskilling, and the restructuring of business models as XR enables automation and remote operation. At the same time, XR may decrease productivity in some contexts due to usability issues, cybersecurity risks, and increased workload, all of which carry financial implications. Furthermore, XR technologies pose risks for consumer trust, intellectual

property, and regulatory uncertainties, leaving organizations vulnerable to inefficiency and economic hardship.

Scientific and technological category

The scientific and technological category addresses issues with XR's effectiveness, research reliability, and implementation challenges. XR-based training is often criticized for reduced realism, limited transfer of skills to real-world contexts, and decreased emphasis on hands-on experience. Methodological shortcomings—such as small sample sizes, lack of standardization, platform inconsistencies, and artificiality of virtual environments—undermine the validity and generalizability of research findings. On the technical side, challenges include limited realism, latency, poor usability, high costs, and difficulties with interoperability. Barriers to adoption are compounded by insufficient training for educators and users, lack of inclusivity for those with special needs, and potential violations of intellectual property or ethical norms. Broader societal concerns also emerge, such as reinforcing gender disparities in education and creating unequal access to opportunities.

Environmental category

In the environmental category, the issues underscore how XR technologies contribute to energy consumption and carbon emissions across hardware, cloud computing, and extended reality infrastructures. Device production and disposal create e-waste challenges, exacerbated by rapid obsolescence and material use with significant environmental impacts. There is also a social dimension, with immersive virtual environments potentially reducing appreciation for nature or shifting focus away from sustainability in design practices. Indirectly, XR may amplify consumerism and climate change.

Infrastructure category

The infrastructure category highlights the technical and logistical burdens of integrating XR at scale. XR applications demand high network bandwidth, low latency, and reliable data connections—conditions not consistently available, especially in underserved areas. The costs of hardware, setup, and maintenance pose barriers to adoption. Operational efficiency may suffer due to technical glitches, system complexity, and environmental limitations (like bright light or dirty conditions). Cybersecurity threats are particularly salient: XR systems are exposed to DDoS attacks, authentication vulnerabilities, insecure communications, and risks of data theft. Safety is another recurrent issue, with risks of reduced situational awareness, inaccurate spatial assessments, and confusion caused by poor interface design. These infrastructural challenges not only strain organizations financially but also raise questions of reliability, safety, and equitable access.

Political, legal and regulatory category

In the political, legal, and regulatory category, the issues emphasize how XR challenges existing laws and governance systems. Key concerns include unresolved questions around virtual property rights, liability for XR-related harms, and insufficient regulation of data privacy and security. XR systems collect vast amounts of sensitive information, leading to risks of surveillance, misuse, and violations

of user autonomy. This is a recurring issue across workplaces, education, and public spaces. Beyond privacy, XR technologies carry risks for democratic processes: manipulation of information, bias in algorithms, deepfakes, and corporate/military control of virtual spaces may undermine trust in political systems, weaken democratic governance, and exacerbate inequalities.

Other category

Finally, the “other” category captures a range of user-centred and societal concerns not covered by the above categories. Many revolve around usability, reliability, and training effectiveness: poor haptic feedback, realism limitations, technical glitches, and hardware constraints reduce user satisfaction, engagement, and trust in XR systems. Training outcomes are mixed, with XR sometimes falling short of traditional methods in skill transfer and trainer–trainee interaction. Collaboration is also problematic: technical and communication barriers, misaligned awareness among users, and conflicts in shared virtual environments reduce XR’s effectiveness compared to established platforms. More broadly, the table points to unforeseen consequences—new socio-technical system faults, loss of user experiences in ephemeral virtual worlds, cultural and economic disruptions, and unclear guidance for educators. These highlight the unpredictability of XR’s broader social impacts.

3.2. ISSUE MAP DEVELOPMENT

In this section, we create a map of issues relevant to Motivate XR. This is done by clustering the list of issues of Section 3.1 by thematic similarities and the formulation of representative statements for every issue.

3.2.1. APPROACH

In this section, the objective is to distil a focused and manageable subset of issues suitable for consortium evaluation and prioritisation. The methodological process involved two main steps: (1) clustering them based on thematic similarities, and (2) synthesising representative formulations that captured the core concerns of each cluster. These synthesised issue statements were then presented to consortium members in written, who assessed each one based on its perceived likelihood of occurrence and potential impact on the project. This prioritisation informed the selection of issues to be addressed during the design and development of the Motivate XR technology.

The extensive list of issues was first screened to exclude those falling outside the project’s technological scope. Each statement was automatically classified as *relevant* or *not relevant* by a Large Language Model (Google’s Gemini), after which a comprehensive human review was conducted to verify the accuracy and appropriateness of the model’s classifications.

Following the relevance screening, the remaining impact statements were subjected to thematic analysis to uncover underlying patterns and relationships. To identify recurring thematic structures

across the impact descriptions, a multi-step Natural Language Processing (NLP) and clustering approach was employed, structured as follows:

Sentence Embedding Generation: The issues were converted into numerical embeddings using a pre-trained transformer model. Within each broad category (e.g., Economic, Environmental, Health & Well-being), we applied unsupervised clustering to uncover recurring themes.

Clustering: To make sure the groupings were meaningful, we reviewed standard diagnostics (such as elbow and silhouette analyses) and visually inspected dendrograms. This helped confirm that the clusters represented coherent topics. After the clusters were created, they were subjected to extensive human review to ensure that the clustering was meaningful.

Consortium Prioritization: For each cluster, we distilled a single representative issue statement. These synthesized statements captured the essence of what the literature had described. Sometimes the clusters were too broad, in which case they were broken up into multiple clusters. One issue statement, that represent all underlying issues, was developed per cluster.

3.2.2. ISSUE MAP

The following is the final set of issue statements derived through the above-described process. Collectively, these issue statements are intended to capture the full scope of issues, identified in the literature, that are relevant to the Motivate XR project. For clarity, the issues are grouped into thematic sections, each introduced with a short explanation of its relevance.

Section 1: Environmental Issues

XR technologies rely on resource-intensive devices and infrastructures, raising concerns about sustainability. Environmental issues here focus on the lifecycle of XR hardware and the energy demands of supporting infrastructures, as well as potential indirect effects on user engagement with the natural environment. The overview of environmental issues can be found in Table 2.

TABLE 2: ENVIRONMENTAL ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
1	The manufacturing and disposal of XR devices—including head-worn displays and related equipment—and the specialized materials used in XR displays could generate significant electronic waste and environmental harm due to rapid obsolescence and problematic sourcing, processing, and disposal practices.
2	The infrastructure and operation of metaverse and XR technologies—including data centres, networks, blockchain systems, cloud computing services, hardware production, and AI computational demands—can consume substantial energy and could contribute significantly to carbon emissions.
3	Reliance on XR and immersive virtual environments in environmental settings could reduce users' engagement with and understanding of the real natural world, increase cognitive load and reaction-time risks, and potentially undermine environmental awareness and conservation efforts.

Section 2: Economic Issues

The adoption of XR can reshape business models, workflows, and labour markets. Economic issues cover potential job displacement, increased inequality in access, and new vulnerabilities arising from cybersecurity, legal uncertainties, and skill gaps. The overview of economic issues can be found in Table 3.

TABLE 3: ECONOMIC ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
4	The adoption of XR technologies could reduce the need for traditional roles through shifts toward virtual experiences and reduced foot traffic, and lead to job displacement.
5	The adoption of XR technologies could disrupt established business models through shifts toward virtual experiences and reduced foot traffic, and lead to decreased profitability and the need for workforce retraining.
6	In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity.
7	XR environments could alter task completion times and impede workflow, and managing virtual teams across geographies and time zones through XR could present unforeseen challenges that impact project timelines and outcomes.
8	The high costs of XR hardware, software, development, maintenance, and training could limit access for educational institutions, small businesses, and individuals—exacerbating existing inequalities.
9	Using XR technologies in certain tasks could increase mental workload and introduce health and safety risks (e.g., cybersickness, visual fatigue, physical discomfort), which could lower job satisfaction and indirectly lead to job displacement.
10	XR technologies could expose stakeholders to economic risks from cybersecurity threats (e.g., unauthorized access, in-app purchases without consent, CMR vulnerabilities).
11	XR technologies could expose stakeholders to economic risks from legal/regulatory uncertainties—such as unresolved virtual property issues and varied enforcement policies.
12	XR technologies could expose stakeholders to economic risks from the rising demand for 3D design files, which could weaken trade-secret protections and patent enforcement.
13	Over-reliance on XR can deskill the workforce and widen existing skills gaps, leaving workers unprepared for a changing job market, which could lead to increased unemployment, exacerbated economic hardship, and widen the digital divide.
14	Organizations unfamiliar with intellectual-property rights for XR-generated teaching content and instructors untrained in XR pedagogy, could risk unintentional infringement and deliver suboptimal guidance.

Section 3: Health and Well-Being Issues

Because XR technologies directly affect human perception and behaviour, their use can carry risks to physical safety, ergonomics, and psychological well-being. These issues include immediate concerns such as cybersickness and accidents, as well as longer-term effects like mental health challenges or inadequate safety protocols. The overview of health and well-being issues can be found in Table 4.

TABLE 4: HEALTH AND WELL-BEING ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
15	XR systems can cause physical discomfort (e.g., motion sickness, eye strain), distort spatial perception, and reduce real-world awareness—leading to accidents and potential medical incidents.

16	Excessive XR use can lead to addictive behaviours, social isolation, reduced physical activity, and blurred work-life boundaries, undermining real-world interactions and mental well-being.
17	XR system malfunctions—compounded by insufficient risk expertise and/or lack of maintenance—can compromise safety for both user and surrounding people and introduce hardware or software hazards.
18	The immersive nature of XR can trigger or worsen anxiety, distort reality, impair decision-making, and carry unforeseen long-term psychological risks.
19	XR can increase workload and cognitive load for professionals.
20	XR can expose users to harassment, cyberbullying, and inappropriate content, possibly heightening psychological distress—especially for children and vulnerable groups.
21	XR applications can introduce ergonomic and organizational challenges, increase scene complexity, disorient users, and be susceptible to environmental issues and unclear interfaces—all of which could compromise safety.
22	Traditional safety protocols—designed for non-immersive equipment—often fail to address XR’s unique hazards, leaving organizations unprepared to update policies, train staff, and enforce safeguards for immersive and interactive scenarios.

Section 4: Infrastructure Issues

Reliable infrastructure is essential for safe and effective XR use. These issues concern technical limitations (e.g., latency, bandwidth, device reliability), as well as gaps in IT support, system governance, and resilience to monopolistic practices. The overview of infrastructure issues can be found in Table 5.

TABLE 5: INFRASTRUCTURE ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
23	Integrating XR into existing workflows can disrupt established practices, may be less efficient than simpler methods for certain tasks, and could limit direct interaction with physical objects in remote collaboration.
24	XR can create new data security vulnerabilities—from authentication flaws to insecure communications and unauthorized access or tampering—which could lead to data breaches, reputational damage, and operational disruptions.
25	Environmental factors and limited sensory realism could hinder functionality and lead to inaccurate project outcomes.
26	Network bandwidth and latency can limit cloud-based XR performance; even small delays could degrade user experience.
27	Inaccurate XR information, over-reliance on XR, and neglect of traditional safety measures could compromise safety and reliability—leading to errors, accidents, and reduced decision-making effectiveness.
28	Poorly designed mixed reality systems can increase cognitive load and impair decision-making, reducing operational performance.
29	Lack of adequate IT infrastructure, affordable resources, skilled personnel, private spaces, and clear guidance can hinder XR adoption and accessibility.
30	Unreliable data connections, integration challenges, and unclear responsibilities can lead to governance issues, cybersecurity vulnerabilities, and conflicts over shared virtual objects can affect system stability.
31	Monopolistic practices in XR development and distribution can reduce speed of development and system stability.
32	Heavy multi-user XR use and dependence on stable wireless networks can strain existing networks, leading to degraded service quality and disrupted operations.
33	Device glitches, latency, and integration risks in XR systems could undermine reliability and performance in professional settings.

Section 5: Policy and Governance Issues

The legal and regulatory frameworks for XR remain underdeveloped. Issues in this section include gaps in liability, standards, and oversight, as well as concerns about surveillance, data protection, and broader impacts on governance and trust. The overview of policy and governance issues can be found in Table 6.

TABLE 6: POLICY AND GOVERNANCE ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
34	XR in workplaces and education enables surveillance and data collection that can breach privacy, erode trust, and blur work-life boundaries—especially in the absence of clear ethical guidelines and data protection measures.
35	Commercialization and militarization of virtual worlds could threaten democratic governance; lack of transparency and central control in the metaverse can erode public trust.
36	XR applications in industrial and education contexts can cause accidents or errors (e.g., due to system malfunctions or inaccurate AI assistance), leading to legal disputes and financial liabilities without proper safety standards, liability frameworks, and insurance.
37	Existing legal frameworks may be inadequate to address disputes, crimes, and virtual property issues in XR environments, necessitating new doctrines and enforcement mechanisms to govern virtual worlds effectively.
38	Implementing XR-based industrial certifications without updating assessment criteria could undermine the validity of technician qualifications and erode confidence in training outcomes.
39	Lack of clear liability mechanisms when human error occurs in XR-assisted tasks can leave impacted individuals without legal recourse and expose organizations to prolonged legal uncertainty.
40	Organizations may lack the capacity or agility to update safety standards and protocols as XR technologies evolve, resulting in regulatory gaps and increased risk of non-compliance with emerging legal requirements.

Section 6: Research and Development Issues

XR has enormous potential for innovation and training, but shortcomings in design, evaluation, and skill transfer may limit its effectiveness. These issues highlight potential barriers to realizing XR's promise in education, training, and industrial applications. The overview of research and development issues can be found in Table 7.

TABLE 7: RESEARCH AND DEVELOPMENT ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
41	Software and platform limitations, along with collaboration hurdles, could lead to decreased efficiency and increased costs when adopting XR.
42	Limited skill transfer, lack of standardized evaluation, and trainee isolation in XR training could compromise the training's overall effectiveness.
43	Technical and design shortcomings—such as rendering/latency issues, spatial mismatches, inadequate haptic feedback, and collaboration conflicts—could impede user experience and immersion.
44	Reduced realism, over-reliance on virtual experiences, technical constraints, and insufficient support in XR training could impair real-world preparedness.

Section 7: Social Issues

XR has implications for social interaction, equity, and inclusion. Social issues include reduced empathy or miscommunication in mediated interactions, privacy breaches, exclusion of certain user groups (such as visually impaired users), and the possibility that standardized XR training leaves some learners behind. The overview of social issues can be found in Table 8.

TABLE 8: SOCIAL ISSUES RELEVANT TO MOTIVATE XR

ID	Issue statement
45	Mediated XR interactions could lead to reduced empathy and social connection, blurred work-life boundaries, miscommunication, and coordination issues.
46	Extensive data collection and immersive environments could lead to increased privacy breaches, cyber-harassment, identity theft, and regulatory gaps.
47	One-size-fits-all XR training modules could lead to some participants failing to achieve proficiency.
48	Reliance on XR training could lead to diminished practical skills, inadequate real-world preparation, knowledge retention issues, workforce engagement problems, and administrative burdens.
49	Misinterpretation of XR functionality could lead to user confusion and unintended consequences.
50	Absence of built-in UI accessibility features could lead to exclusion of visually impaired users.

3.3. PRIORITISATION OF ISSUES

As discussed in the previous section, the MOTIVATE XR project has identified a broad range of potential Social, Ethical, and Legal issues. However, not all issues warrant the same level of attention. Some issues are more likely to occur or may have more severe consequences if realized. Prioritising these issues based on their likelihood and potential impact is therefore essential. This is particularly important in projects developing technologies intended for large-scale public use, where failures can have wide-reaching societal, ethical, or economic repercussions. Early identification and mitigation of high-priority issues not only improve the robustness and trustworthiness of the technology but also enables the integration of safeguards directly into the design process. This proactive approach can prevent costly redesigns or public backlash that might arise if such issues are discovered after deployment.

3.3.1. APPROACH FOR ISSUE PRIORITIZATION

Rationale for Survey

To ground the prioritisation within the Motivate XR context, a survey was conducted among consortium partners. The aim was to gather informed assessments of the likelihood and severity of each issue identified through the previous analysis and clustering activities. These assessments would provide an evidence-based ranking of issues, allowing the consortium to focus subsequent mitigation activities on those posing the greatest potential risks to responsible XR development and use.

The survey included all previously identified issue statements, structured according to the established thematic categories. Participants were asked to evaluate each issue individually based on their expertise and understanding of XR applications in industrial training and remote support. The full questionnaire is provided in Appendix F.

Choice of Scale

We use a risk approach to prioritize the severity of issues, where severity is the product of likelihood and impact. A four-point scale was employed to evaluate each issue statement. The scale was intentionally limited to four response options (e.g., from “Not likely” to “Very likely”) to eliminate the possibility of a neutral midpoint, thereby encouraging more deliberate engagement with the content. There was also an option for an issue being “Not Applicable”. The four-point format allowed for efficient completion while still capturing meaningful variance in participant perspectives. With approximately 50 items in the survey, an overly nuanced scale with 6 or 8 points might have led to cognitive fatigue or reduced response quality. Fewer than 50 questions would not provide us with enough data.

By grounding the survey in these methodological considerations, we aimed to generate structured, comparative insights into how experts assess the relative salience of XR-related issues across multiple domains.

The survey had a total of 13 respondents, and it was open from 5/6/2025 to 20/6/2025 (22 days).

Collection and visualization of responses

Following the consortium's completion of the survey, the collected responses were analysed and visualised to assess the relative importance of identified issues. Each issue was rated on a 1-to-4 scale, where 1 indicates the lowest likelihood or impact, and 4 the highest, along with an option to deem the issue as “Not Applicable” by giving it a 0. To represent the findings, a two-dimensional scatter plot was generated, with likelihood on the X-axis and impact on the Y-axis. A quadrant-based framework was applied, with the plot divided at the midpoints (2.5, 2.5), resulting in four quadrants for interpretation.

- **Quadrant I (top-right)** contains issues rated as both high likelihood and high impact. These are considered the most critical and should receive the highest priority in issue mitigation efforts.
- **Quadrant II (top-left)** includes issues rated as high impact but low likelihood, akin to ‘black swan’ events. These warrant contingencies planning due to their potential severity.
- **Quadrant III (bottom-left)** consists of issues rated as low likelihood and low impact, currently of minimal concern but potentially relevant in the longer term.
- **Quadrant IV (bottom-right)** captures issues rated having high likelihood but low impact – issues that may occur frequently but are generally manageable and less disruptive.

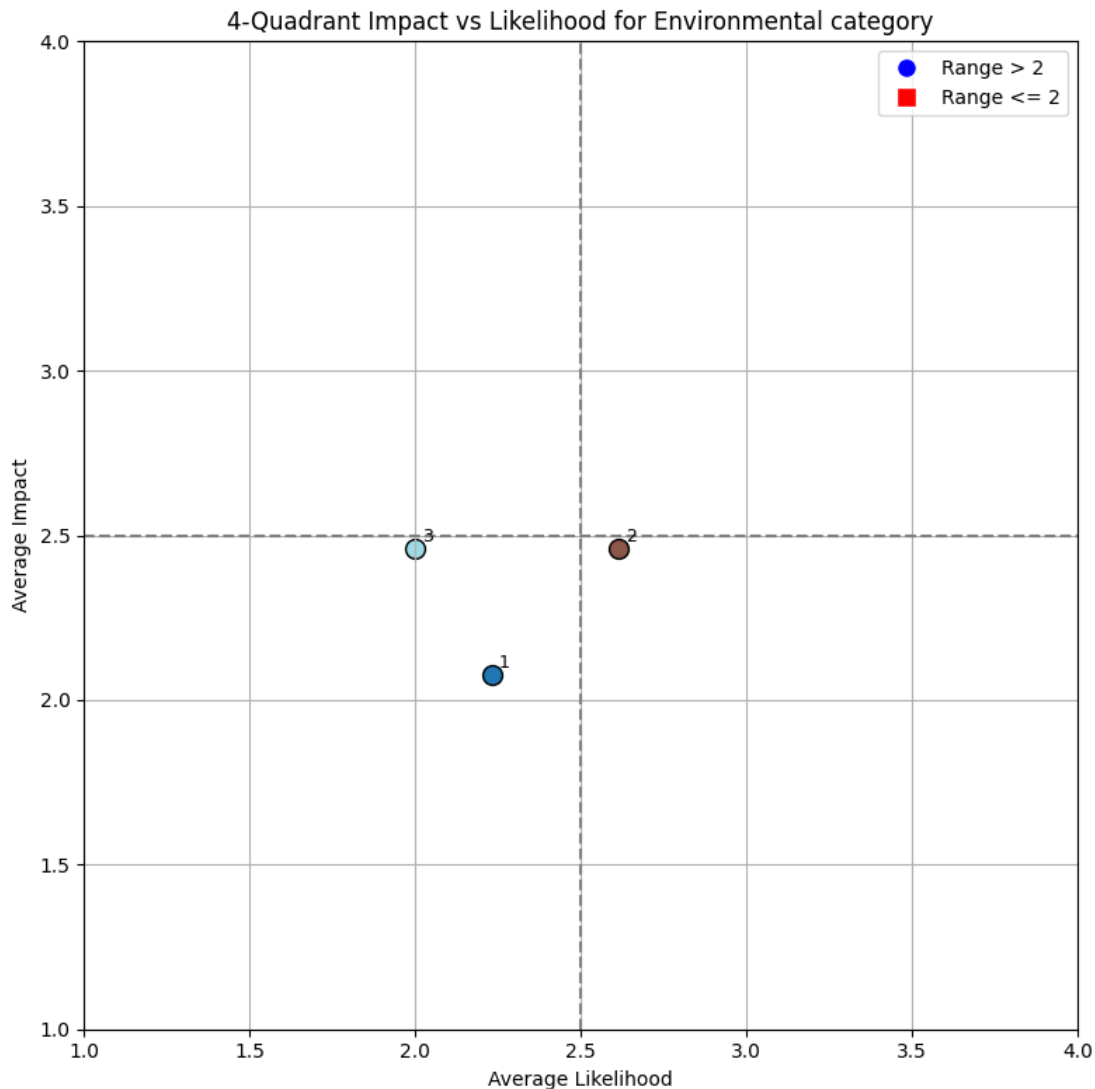
Each point on the graph represents a specific issue statement, identified by a reference number and corresponding legend. The location of the issue statement indicates the average likelihood and severity as rated by the Motivate XR partners. To indicate variability in the responses across consortium members, two marker types are used: squares and circles. A square marker denotes relatively consistent assessments, defined as having a range of two or less in both dimensions (i.e., the difference between the highest and lowest score for likelihood or impact does not exceed two). Circles represent greater variability in the responses, indicating lower consensus on the issue's severity or probability.

Some statements were indicated as not relevant by some respondents; they discussed at the end of the analysis section. For the scores, the “not applicable” responses were treated as any other response and given the score “0”. None of the statements were marked as “not applicable” by more than 1 respondent. It was therefore decided not to leave out those statements from the analysis.

3.3.2. PRIORITISATION RESULTS

The following section presents the results of the issue prioritisation survey. It summarises how consortium members evaluated the likelihood and severity of each identified concern, highlighting which issues are considered most critical for ensuring the responsible development and use of XR technologies within the MOTIVATE XR project.

3.3.2.1. PRIORITIZATION OF ENVIRONMENTAL ISSUES



Issue legend

1. The manufacturing and disposal of XR devices—including head-worn displays and related equipment—and the specialized materials used in XR displays could generate significant electronic waste and environmental harm due to rapid obsolescence and problematic sourcing, processing, and disposal practices.
2. The infrastructure and operation of metaverse and XR technologies—including data centres, networks, blockchain systems, cloud computing services, hardware production, and AI computational demands—can consume substantial energy and could contribute significantly to carbon emissions.
3. Reliance on XR and immersive virtual environments in environmental settings could reduce users’ engagement with and understanding of the real natural world, increase cognitive load and reaction-time risks, and potentially undermine environmental awareness and conservation efforts.

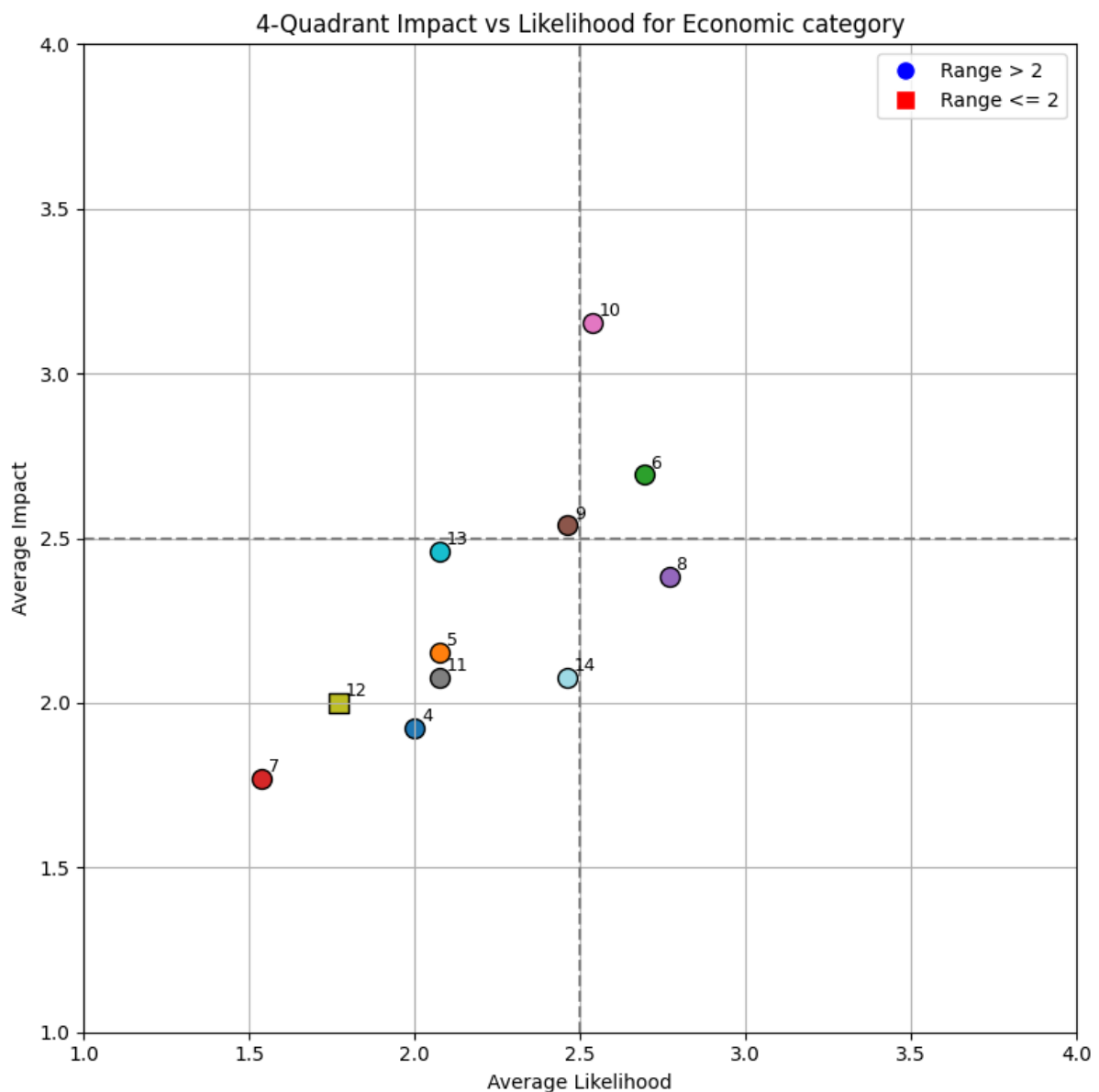
FIGURE 4: IMPACT AND LIKELIHOOD OF ENVIRONMENTAL ISSUES

Analysis

Figure 4 presents the distribution of environmental issues on a Cartesian plane defined by *likelihood* and *impact* scores. The results indicate that none of the assessed issues were perceived as highly

impactful. On the contrary, two issues—on manufacturing and disposal of e-waste (likelihood ≈ 2.23 ; impact ≈ 2.08) and on reduced engagement with real nature (likelihood = 2.00; impact ≈ 2.46)—fall within Quadrant 3 (*low likelihood, low impact*). These positions suggest that respondents regarded them as less probable and comparatively limited in severity relative to other concerns. An increased energy consumption with corresponding increased carbon emissions is perceived as somewhat likely.

3.3.2.2. PRIORITIZATION OF ECONOMIC ISSUES



Issue legend

- The manufacturing and disposal of XR devices—including head-worn displays and related equipment—and the specialized materials used in XR displays could generate significant electronic waste and environmental harm due to rapid obsolescence and problematic sourcing, processing, and disposal practices.

5. The adoption of XR technologies could reduce the need for traditional roles through shifts toward virtual experiences and reduced foot traffic, and lead to job displacement.
6. The adoption of XR technologies could disrupt established business models through shifts toward virtual experiences and reduced foot traffic, and lead to decreased profitability and the need for workforce retraining.
7. In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity.
8. XR environments could alter task completion times and impede workflow, and managing virtual teams across geographies and time zones through XR could present unforeseen challenges that impact project timelines and outcomes.
9. The high costs of XR hardware, software, development, maintenance, and training could limit access for educational institutions, small businesses, and individuals—exacerbating existing inequalities.
10. Using XR technologies in certain tasks could increase mental workload and introduce health and safety risks (e.g., cybersickness, visual fatigue, physical discomfort), which could lower job satisfaction and indirectly lead to job displacement.
11. XR technologies could expose stakeholders to economic risks from cybersecurity threats (e.g., unauthorized access, in-app purchases without consent, CMR vulnerabilities).
12. XR technologies could expose stakeholders to economic risks from legal/regulatory uncertainties—such as unresolved virtual property issues and varied enforcement policies.
13. XR technologies could expose stakeholders to economic risks from the rising demand for 3D design files, which could weaken trade-secret protections and patent enforcement.
14. Over-reliance on XR can deskill the workforce and widen existing skills gaps, leaving workers unprepared for a changing job market, which could lead to increased unemployment, exacerbated economic hardship, and widen the digital divide.

FIGURE 5: IMPACT AND LIKELIHOOD OF ECONOMIC ISSUES

Analysis

Figure 5 shows the distribution of economic issues on a likelihood vs impact cartesian plane.

Quadrant 1 (high likelihood ≥ 2.5 , high impact ≥ 2.5)

Two issues stand out. Issue #6—on XR glitches in industrial and collaborative settings—has a likelihood mean of about 2.69 and an impact mean of about 2.69, reflecting concerns that such technical failures could significantly disrupt efficiency and productivity. Likewise, Issue #10—on economic exposure to cybersecurity threats—registers a likelihood of approximately 2.54 and a notably higher impact of around 3.15, underscoring the serious financial consequences respondents associate with cyber-attacks on XR platforms.

Quadrant 2 (low likelihood < 2.5 , high impact ≥ 2.5)

Only one issue occupies Quadrant 2: Issue #9, which links XR use to increased mental workload and health/safety hazards that could undermine job satisfaction, has a likelihood mean of roughly 2.46 but an impact mean of about 2.54, indicating that while respondents see it as slightly less probable, they still regard the potential fallout as fairly severe.

Quadrant 4 (high likelihood ≥ 2.5 , low impact < 2.5)

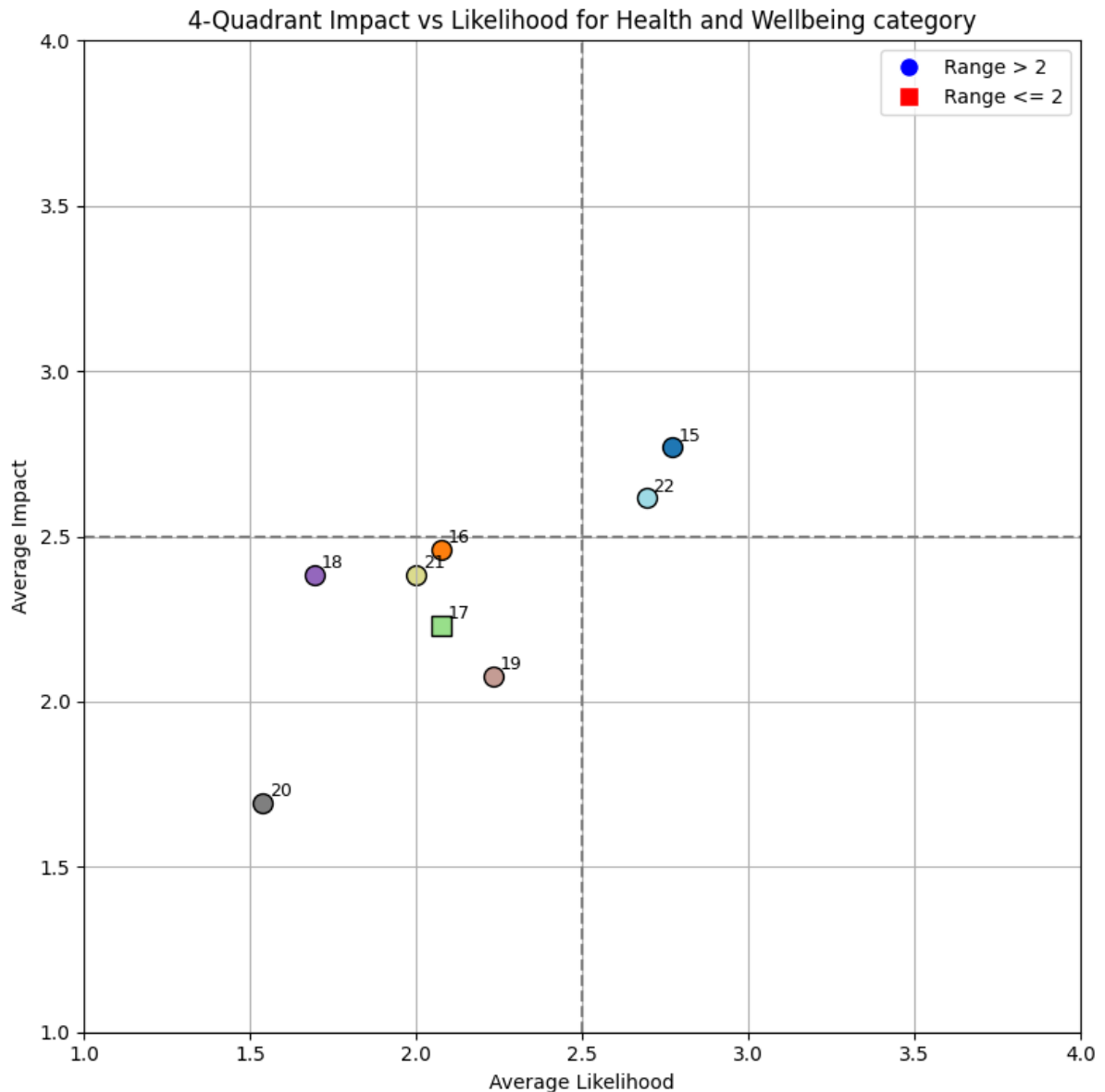
This contains just Issue #8 on the barrier posed by high XR hardware and service costs. With a mean likelihood of approximately 2.77 but an impact of about 2.38, this item is seen as quite likely to occur but of only moderate economic concern relative to other issues.

Quadrant 3 (low likelihood < 2.5, low impact < 2.5)

This groups seven issues that respondents view as both unlikely and of lower severity. These include #4 (on job displacement; likelihood ≈ 2.00 , impact ≈ 1.92), #5 (on business model disruption; ≈ 2.08 , ≈ 2.15), #7 (on workflow impediments across geographies; ≈ 1.54 , ≈ 1.77), #11 (on legal/regulatory economic risks; ≈ 2.08 , ≈ 2.08), #12 (on weakened trade-secret protections from 3D file demand; ≈ 1.77 , ≈ 2.00), #13 (on workforce deskilling; ≈ 2.08 , ≈ 2.46), and #14 (on IP-infringement risks in XR education; ≈ 2.46 , ≈ 2.08). Together, these items reflect concerns that are perceived as comparatively unlikely to materialize and less impactful if they do.

Between the Quadrant 3 issues, three items probe how XR adoption may reshape labour markets and skill requirements. Issue #4— on job displacement through reduced need for traditional roles— carries a likelihood of 2.00 and an impact of 1.92, while Issue #5— on business model disruption leading to decreased profitability and the need for workforce retraining—scores slightly higher at 2.08 for likelihood and 2.15 for impact. Issue #13— on deskilling of the workforce and widening skills gaps, with potential for increased unemployment—shares the 2.08 likelihood but rises to 2.46 on impact. Respondents view all three as moderately likely, suggesting a shared belief that XR will alter employment structures to some extent. However, they judge outright displacement as the least severe outcome, assign a greater burden to the costs of retraining, and reserve their highest concern for the long-term erosion of skills and its implications for workforce resilience.

3.3.2.3. PRIORITIZATION OF HEALTH AND WELLBEING ISSUES



Issue legend

- 15. XR systems can cause physical discomfort (e.g., motion sickness, eye strain), distort spatial perception, and reduce real-world awareness—leading to accidents and potential medical incidents.
- 16. Excessive XR use can lead to addictive behaviours, social isolation, reduced physical activity, and blurred work-life boundaries, undermining real-world interactions and mental well-being.
- 17. XR system malfunctions—compounded by insufficient risk expertise and/or lack of maintenance—can compromise safety for both user and surrounding people, and introduce hardware or software hazards.
- 18. The immersive nature of XR can trigger or worsen anxiety, distort reality, impair decision-making, and carry unforeseen long-term psychological risks.
- 19. XR can increase workload and cognitive load for professionals.
- 20. XR can expose users to harassment, cyberbullying, and inappropriate content, possibly heightening psychological distress—especially for children and vulnerable groups.

21. XR applications can introduce ergonomic and organizational challenges, increase scene complexity, disorient users, and be susceptible to environmental issues and unclear interfaces—all of which could compromise safety.
22. Traditional safety protocols—designed for non-immersive equipment—often fail to address XR’s unique hazards, leaving organizations unprepared to update policies, train staff, and enforce safeguards for immersive and interactive scenarios.

FIGURE 6: IMPACT AND LIKELIHOOD OF HEALTH & WELLBEING ISSUES

Analysis

Figure 6 shows the distribution of health & wellbeing issues on a likelihood vs impact cartesian plane. The issues under this category fall either under Quadrant 1 or Quadrant 3.

Quadrant 1 (High Likelihood ≥ 2.5 , High Impact ≥ 2.5)

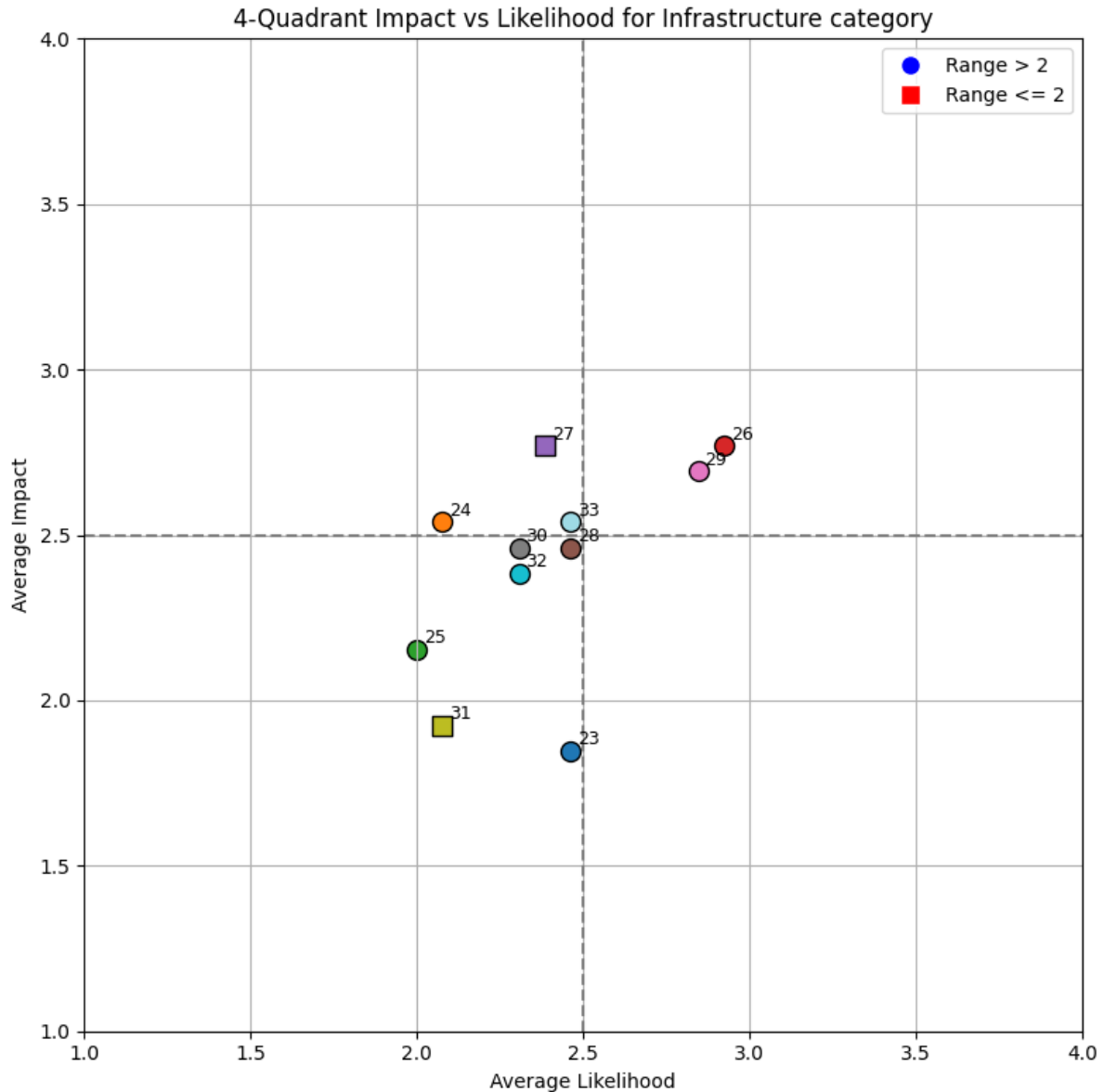
Issue #15 relates to the physical effects of XR—such as motion sickness, eye fatigue, and altered spatial awareness—which respondents’ rate at about 2.77 for both likelihood and impact, indicating concern that these issues could lead to accidents or health incidents. Issue #22 highlights the mismatch between standard safety procedures and the demands of immersive environments; it scores roughly 2.69 in likelihood and 2.62 in impact, underlining worries that organizations aren’t prepared to revise policies and training for XR’s unique hazards.

Quadrant 3 (Low Likelihood < 2.5 , Low Impact < 2.5)

Issue #16, concerning addictive use patterns, social isolation, reduced exercise, and blurred work-life boundaries in XR, has a likelihood of about 2.08 and impact of 2.46, making it a moderate but less frequent concern. Issue #17 addresses dangers from XR malfunctions amplified by inadequate maintenance or expertise; it carries means of approximately 2.08 for likelihood and 2.23 for impact. Issue #18 points to the potential for immersive experiences to provoke or worsen anxiety and distort judgment—rated 1.69 in likelihood and 2.38 in impact. Issue #19, which reflects extra cognitive demands on professionals using XR, scores around 2.23 for likelihood and 2.08 for impact. Issue #20 covers risks of harassment, cyberbullying, and exposure to inappropriate content in XR—especially for vulnerable users—with means of about 1.54 and 1.69. Finally, Issue #21, dealing with ergonomic challenges, complex interfaces, and environmental factors that could compromise safety, registers roughly 2.00 for likelihood and 2.38 for impact.

Within this quadrant, three items probe the emotional, cognitive, and social dimensions of XR use. Issue #16—addictive behaviours and social isolation—carries a mean likelihood of 2.08 and an impact of 2.46. Issue #18—anxiety, reality distortion, and long-term psychological effects—scores lower on likelihood at 1.69 but still rates 2.38 in impact. Finally, Issue #20—harassment, cyberbullying, and distress—sits at 1.54 for likelihood and 1.69 for impact. Respondents view addictive and isolating tendencies as both the most probable and the most severe psychological hazard, place anxiety-related concerns next, and regard harassment and content-based distress as the least pressing among these mental-health issues.

3.3.2.4. PRIORITIZATION OF INFRASTRUCTURE ISSUES



Issue legend:

23. Integrating XR into existing workflows can disrupt established practices, may be less efficient than simpler methods for certain tasks, and could limit direct interaction with physical objects in remote collaboration.

24. XR can create new data security vulnerabilities—from authentication flaws to insecure communications and unauthorized access or tampering—which could lead to data breaches, reputational damage, and operational disruptions.

25. Environmental factors and limited sensory realism could hinder functionality and lead to inaccurate project outcomes.

26. Network bandwidth and latency can limit cloud-based XR performance; even small delays could degrade user experience.

27. Inaccurate XR information, over-reliance on XR, and neglect of traditional safety measures could compromise safety and reliability—leading to errors, accidents, and reduced decision-making effectiveness.

28. Poorly designed mixed reality systems can increase cognitive load and impair decision-making, reducing operational performance.

- 29. Lack of adequate IT infrastructure, affordable resources, skilled personnel, private spaces, and clear guidance can hinder XR adoption and accessibility.
- 30. Unreliable data connections, integration challenges, and unclear responsibilities can lead to governance issues, cybersecurity vulnerabilities, and conflicts over shared virtual objects can affect system stability.
- 31. Monopolistic practices in XR development and distribution can reduce speed of development and system stability.
- 32. Heavy multi-user XR use and dependence on stable wireless networks can strain existing networks, leading to degraded service quality and disrupted operations.
- 33. Device glitches, latency, and integration risks in XR systems could undermine reliability and performance in professional settings.

FIGURE 7: IMPACT AND LIKELIHOOD OF INFRASTRUCTURE ISSUES

Analysis

Figure 7 shows the distribution of infrastructural issues on a likelihood vs impact cartesian plane

Quadrant 1 (High Likelihood ≥ 2.5 , High Impact ≥ 2.5)

Issue #26 points to the reality that network limitations—specifically bandwidth and latency—can noticeably degrade cloud-based XR experiences, earning a likelihood mean of about 2.92 and an impact mean of 2.77. Issue #29 highlights that shortages in IT infrastructure, funding, skilled staff, private facilities, and clear implementation guidance are viewed as both very likely (≈ 2.85) and significantly damaging to XR rollout (≈ 2.69).

Quadrant 2 (Low Likelihood < 2.5 , High Impact ≥ 2.5)

Issue #24 concerns new security gaps introduced by XR—ranging from weak authentication to insecure data channels and unauthorized access—with respondents rating its occurrence at roughly 2.08 but its potential harm at around 2.54. Issue #27 addresses the danger of relying on flawed XR outputs or forgoing standard safety measures, which while somewhat less probable (≈ 2.38), could have serious consequences (≈ 2.77). Issue #33 covers the issue that hardware glitches, lag, or poor integration in professional XR setups may undermine reliability; it sits at about 2.46 for likelihood and 2.54 for impact.

Quadrant 4 (High Likelihood ≥ 2.5 , Low Impact < 2.5)

No issues fall into this quadrant.

Quadrant 3 (Low Likelihood < 2.5 , Low Impact < 2.5)

Issue #23 reflects concerns that adding XR to existing workflows may disrupt established methods and prove less efficient than simpler approaches (likelihood ≈ 2.46 ; impact ≈ 1.85). Issue #25 notes that environmental conditions and limited sensory fidelity in XR can lead to errors or misaligned outcomes (≈ 2.00 likelihood; ≈ 2.15 impact). Issue #28 describes how poorly crafted mixed-reality systems can overload users cognitively and impair decision-making, with both likelihood and impact around 2.46. Issue #30 covers governance and security gaps arising from unstable connections, integration hurdles, and unclear responsibilities (≈ 2.31 likelihood; ≈ 2.46 impact). Issue #31 flags that market concentration in XR development could slow innovation and reduce stability, though it's seen as less pressing (≈ 2.08 likelihood; ≈ 1.92 impact). Finally, Issue #32 suggests that heavy, multi-

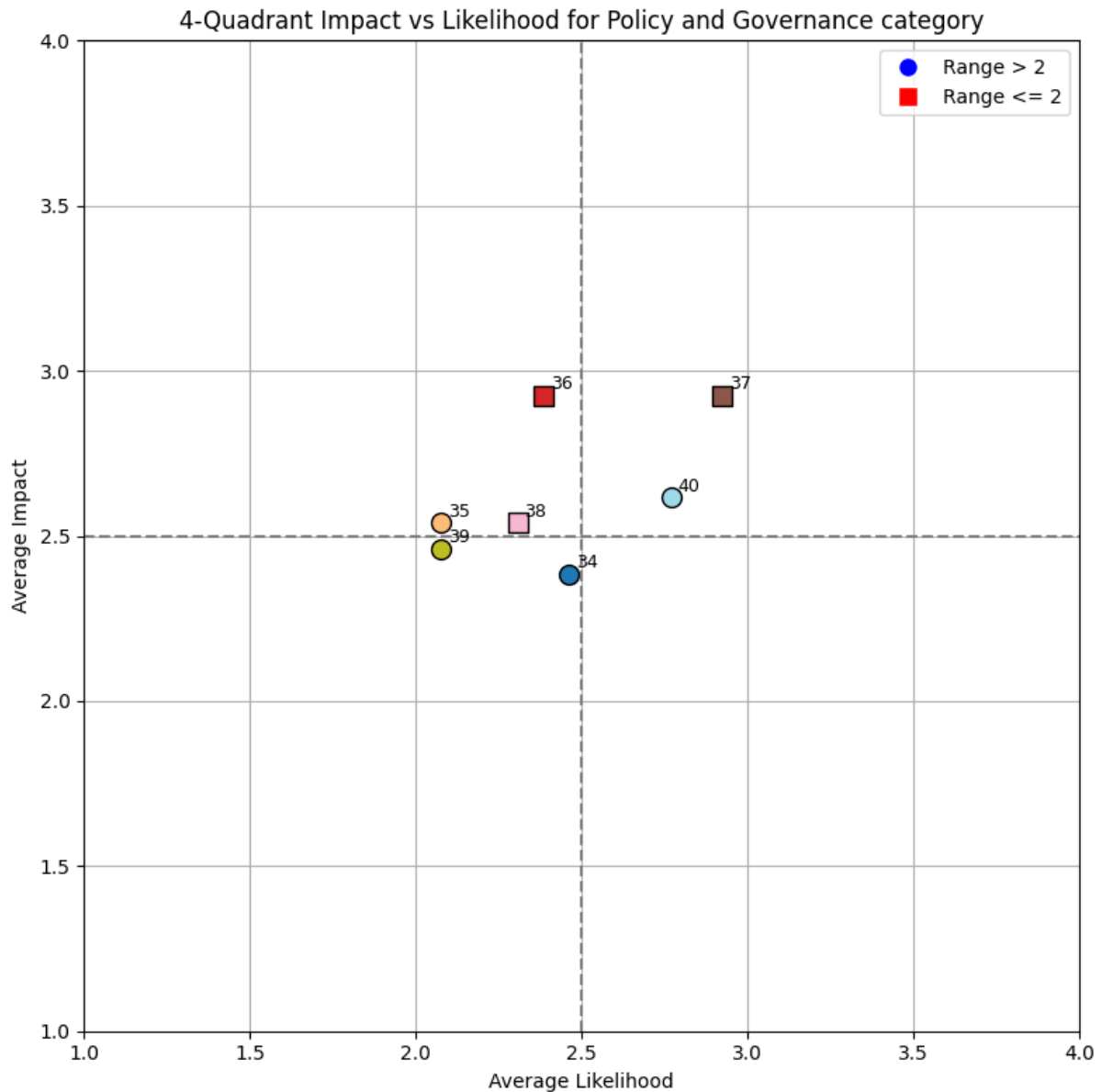
user XR demand on wireless networks may strain existing infrastructure—rated about 2.31 for likelihood and 2.38 for impact.

We also examined only those infrastructure issues that share thematic relationships, comparing their mean likelihood and impact ratings to reveal differences in respondent perceptions.

Network Performance

Two items capture the core challenges XR places on connectivity. Issue #26—network bandwidth and latency limitations—earns a likelihood of 2.92 and an impact of 2.77, while Issue #32—strain on existing wireless networks under heavy multi-user loads—scores 2.31 for likelihood and 2.38 for impact. Although both issues are viewed as relatively probable, respondents assign greater severity to basic bandwidth and latency constraints than to network-strain issues. This suggests that ensuring sufficient capacity and low latency is perceived as the more critical prerequisite for delivering reliable XR experiences.

3.3.2.5. PRIORITIZATION OF POLICY AND GOVERNANCE ISSUES



Issue legend:

- 34. XR in workplaces and education enables surveillance and data collection that can breach privacy, erode trust, and blur work-life boundaries—especially in the absence of clear ethical guidelines and data protection measures.
- 35. Commercialization and militarization of virtual worlds could threaten democratic governance; lack of transparency and central control in the metaverse can erode public trust.
- 36. XR applications in industrial and education contexts can cause accidents or errors (e.g., due to system malfunctions or inaccurate AI assistance), leading to legal disputes and financial liabilities without proper safety standards, liability frameworks, and insurance.
- 37. Existing legal frameworks may be inadequate to address disputes, crimes, and virtual property issues in XR environments, necessitating new doctrines and enforcement mechanisms to govern virtual worlds effectively.
- 38. Implementing XR-based industrial certifications without updating assessment criteria could undermine the validity of technician qualifications and erode confidence in training outcomes.
- 39. Lack of clear liability mechanisms when human error occurs in XR-assisted tasks can leave impacted individuals without legal recourse and expose organizations to prolonged legal uncertainty.

40. Organizations may lack the capacity or agility to update safety standards and protocols as XR technologies evolve, resulting in regulatory gaps and increased risk of non-compliance with emerging legal requirements.

FIGURE 8: IMPACT AND LIKELIHOOD OF POLICY & GOVERNANCE ISSUES

Analysis

Figure 8 shows the distribution of policy and governance issues on a likelihood vs impact cartesian plane.

Quadrant 1 (High Likelihood ≥ 2.5 , High Impact ≥ 2.5)

Issue #37 concerns the gap between current laws and the demands of virtual environments, scoring 2.92 on both likelihood and impact—making it the top-rated issue. Issue #40 highlights that many organizations struggle to revise their safety policies quickly enough as XR technology evolves, with a likelihood of 2.77 and an impact of 2.62.

Quadrant 2 (Low Likelihood < 2.5 , High Impact ≥ 2.5)

Issue #35 addresses how commercial or military uses of virtual spaces could pose a challenge to democratic processes, scoring 2.08 for likelihood and 2.54 for impact. Issue #36 points to the potential for XR-related accidents and errors to trigger significant legal and financial consequences, with a likelihood of 2.38 and an impact of 2.92. Issue #38 reflects concerns that introducing XR-based certifications without adjusting assessment standards may invalidate qualifications, registering 2.31 on likelihood and 2.54 on impact.

Quadrant 4 (High Likelihood ≥ 2.5 , Low Impact < 2.5)

No issues fall into this category.

Quadrant 3 (Low Likelihood < 2.5 , Low Impact < 2.5)

Issue #34 relates to the use of XR for monitoring and data collection in work and educational settings, which may infringe on privacy and blur boundaries, scoring 2.46 in likelihood and 2.38 in impact. Issue #39 concerns the absence of clear liability rules when XR-assisted errors occur, leaving affected parties without straightforward legal remedies; it rates 2.08 for likelihood and 2.46 for impact.

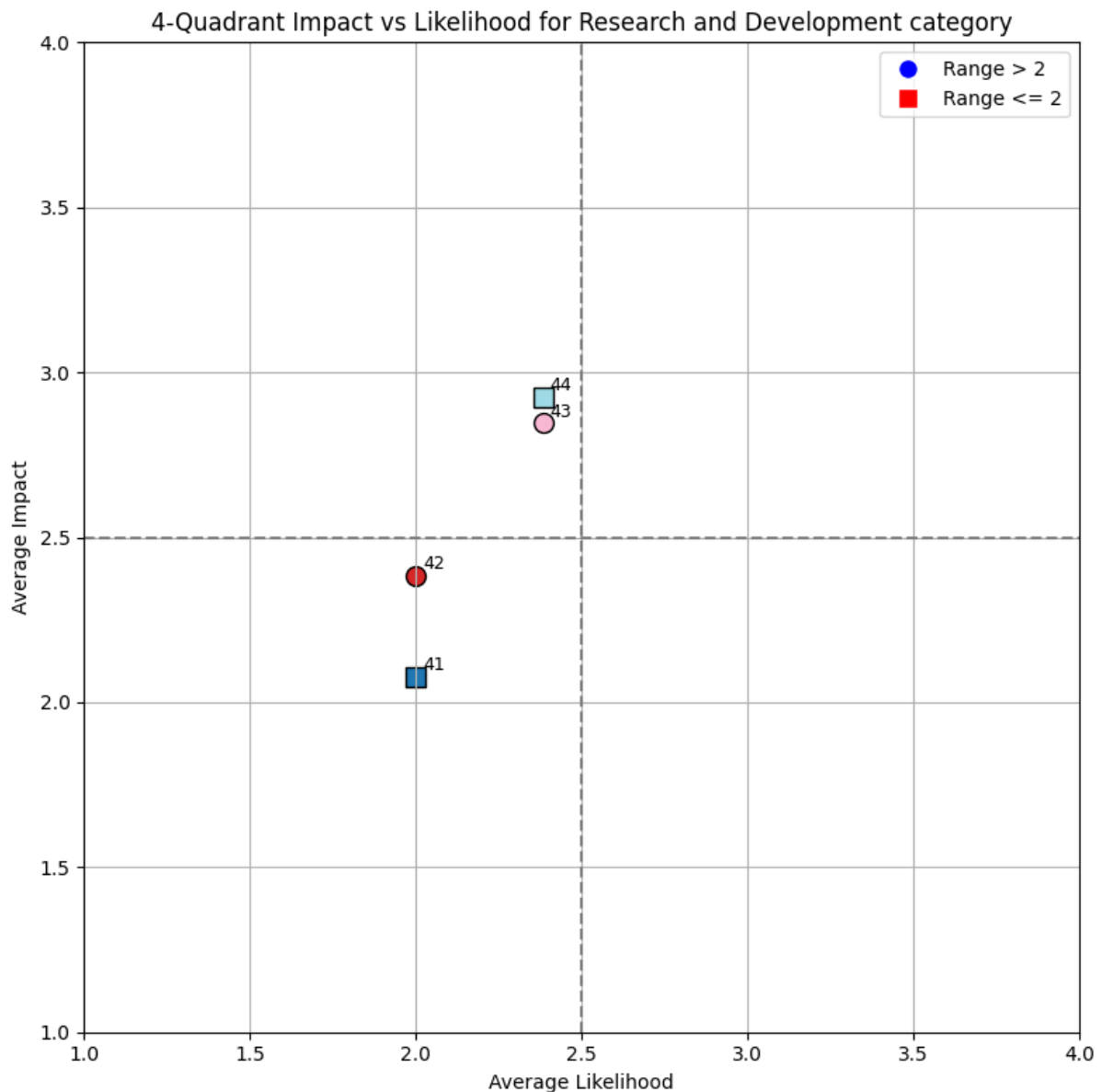
We also examined only those policy & governance issues that share thematic relationships, comparing their mean likelihood and impact ratings to reveal differences in respondent perceptions.

Liability & Legal Recourse

Within the theme of liability & legal recourse, two items stand out. Issue #36—on legal disputes and financial liabilities arising from system malfunctions or AI errors—carries a likelihood of 2.38 and an impact of 2.92, while Issue #39—on the absence of clear liability mechanisms for XR-assisted human error—scores 2.08 for likelihood and 2.46 for impact. Respondents assign significantly greater severity to accident-induced liabilities than to ambiguities in legal recourse, reflecting acute

concern over costly litigation and insurance gaps, even though both issues are judged only moderately likely. Issue #36 also shows strong consensus among participants, with the range between highest and lowest scores falling within two points.

3.3.2.6. PRIORITIZATION OF RESEARCH AND DEVELOPMENT ISSUES



Issue legend:

- 41. Software and platform limitations, along with collaboration hurdles, could lead to decreased efficiency and increased costs when adopting XR.
- 42. Limited skill transfer, lack of standardized evaluation, and trainee isolation in XR training could compromise the training's overall effectiveness.
- 43. Technical and design shortcomings—such as rendering/latency issues, spatial mismatches, inadequate haptic feedback, and collaboration conflicts—could impede user experience and immersion.
- 44. Reduced realism, over-reliance on virtual experiences, technical constraints, and insufficient support in XR training could impair real-world preparedness.

FIGURE 9: IMPACT AND LIKELIHOOD OF RESEARCH & DEVELOPMENT ISSUES

Analysis

Figure 9 shows the distribution of research and development issues on a likelihood vs impact cartesian plane. All impacts in this category were perceived to have modest likelihood.

Quadrant 2 (Low Likelihood < 2.5, High Impact ≥ 2.5)

Issue #43 identifies that flaws in XR systems—such as slow rendering, latency hiccups, mismatched spatial alignment, weak haptic responses, and collaboration breakdowns—are considered moderately likely (≈ 2.38) but capable of substantially undermining user engagement (≈ 2.85). Issue #44 highlights that when XR scenarios lack sufficient realism, rely too heavily on virtual practice, suffer technical constraints, or fail to provide adequate instructional support, they pose a significant threat to preparing users for real-world tasks (likelihood ≈ 2.38 ; impact ≈ 2.92).

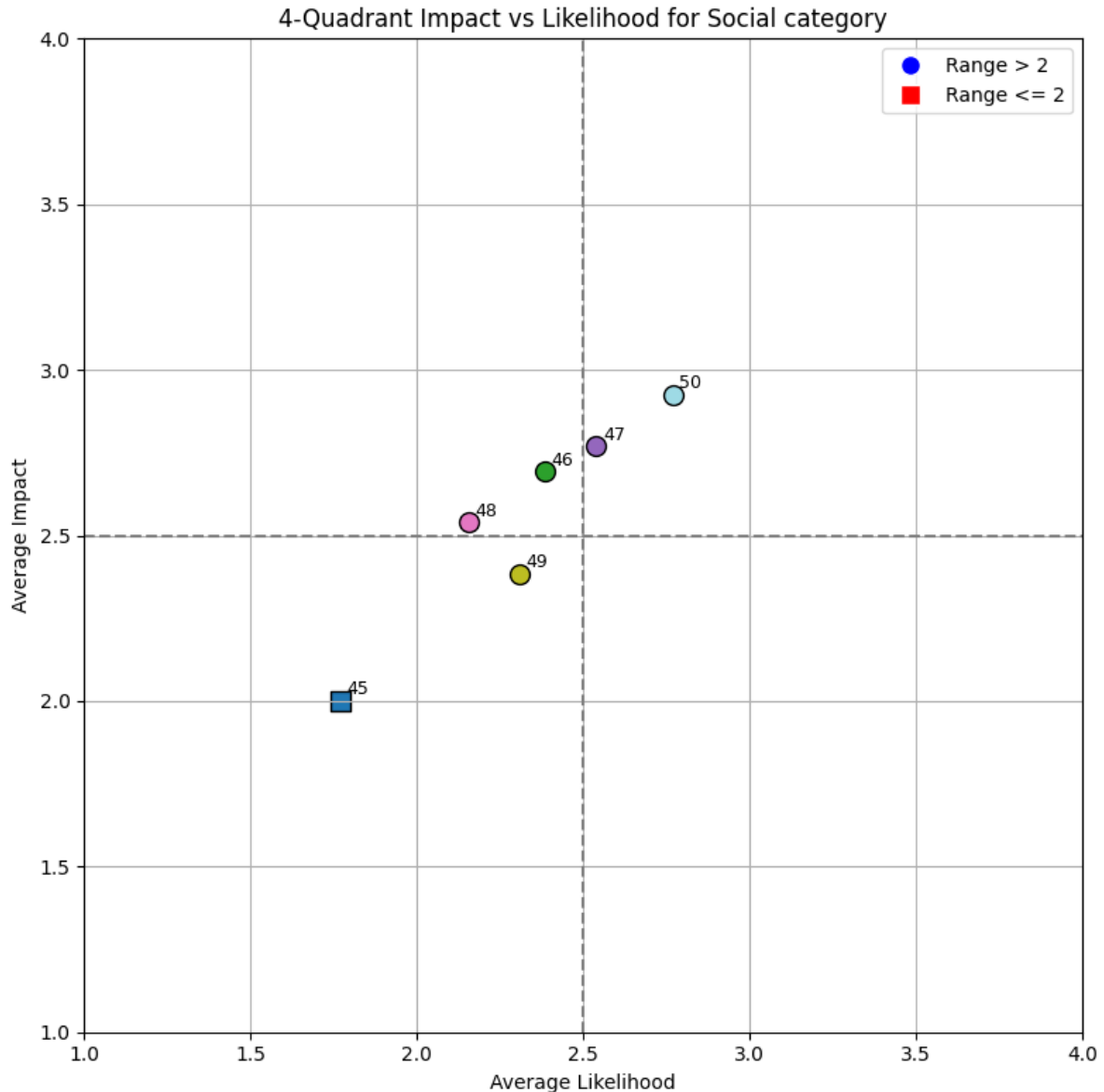
Quadrant 3 (Low Likelihood < 2.5, Low Impact < 2.5)

Issue #41 points out that limitations in XR software and platforms, combined with difficulties in coordinating multiple users, could slow down processes and drive-up costs during implementation (likelihood ≈ 2.00 ; impact ≈ 2.08). Issue #42 notes that if XR training lacks standardized assessments, fails to ensure effective skill transfer, and leaves learners isolated, it may reduce overall training effectiveness (likelihood ≈ 2.00 ; impact ≈ 2.38).

Training Effectiveness & Real-World Transfer

Two issues focus on how training using XR impacts skill transfer and preparedness. Issue #42 on Limited skill transfer and trainee isolation due to lack of standardized evaluation (Likelihood = 2.00; Impact = 2.38) and Issues #44 on Reduced realism, over-reliance on virtual scenarios, and insufficient support undermining preparedness (Likelihood = 2.38; Impact = 2.92). Respondents rate real-world preparedness notably higher on likelihood and impact than standard evaluation and isolation issues. This indicates that shortcomings in immersive support and realism are perceived as the most critical threats to effective XR-based training. Apart from this, #44 and #43 have a strong consensus within the respondents on their scores.

3.3.2.7. PRIORITIZATION OF SOCIAL ISSUES



Issue legend:

- 45. Mediated XR interactions could lead to reduced empathy and social connection, blurred work-life boundaries, miscommunication, and coordination issues.
- 46. Extensive data collection and immersive environments could lead to increased privacy breaches, cyber-harassment, identity theft, and regulatory gaps.
- 47. One-size-fits-all XR training modules could lead to some participants failing to achieve proficiency.
- 48. Reliance on XR training could lead to diminished practical skills, inadequate real-world preparation, knowledge retention issues, workforce engagement problems, and administrative burdens.
- 49. Misinterpretation of XR functionality could lead to user confusion and unintended consequences.
- 50. Absence of built-in UI accessibility features could lead to exclusion of visually impaired users.

FIGURE 10: IMPACT AND LIKELIHOOD OF SOCIAL ISSUES

Analysis

Figure 10 shows the distribution of social issues on a likelihood vs impact cartesian plane.

Quadrant 1 (High Likelihood ≥ 2.5 , High Impact ≥ 2.5)

In this quadrant, two concerns emerge. First, Issue #47 on standardized XR training programs that don't adapt to individual needs are seen as fairly likely (≈ 2.54) and notably impactful (≈ 2.77), since one-size-fits-all modules issue leaving some learners without the skills they require. Second, Issue #50 on the absence of integrated accessibility options in XR interfaces is rated even higher—about 2.77 for likelihood and 2.92 for impact—reflecting the real possibility that visually impaired users could be excluded if tools aren't designed inclusively.

Quadrant 2 (Low Likelihood < 2.5 , High Impact ≥ 2.5)

Two issues fall here. Issue #46 involves the extensive data capture and immersive nature of XR, which could lead to privacy violations, cyber-harassment, identity theft, and gaps in regulation; it scores roughly 2.38 for likelihood and 2.69 for impact. Issue #48 concerns over-reliance on XR for training, which may undermine hands-on skills, leave participants underprepared for real-world tasks, and impose extra administrative overhead—an outcome seen as somewhat less probable (≈ 2.15) but still serious if it occurs (≈ 2.54).

Quadrant 4 (High Likelihood ≥ 2.5 , Low Impact < 2.5)

No issues are mapped to this quadrant.

Quadrant 3 (Low Likelihood < 2.5 , Low Impact < 2.5)

Two issues are assessed as both relatively unlikely and of lower severity. Issue #45 on diminished empathy, blurred boundaries between work and personal life, and introduction of communication challenges—rated about 1.77 for likelihood and 2.00 for impact. Issue #49 is on the potential for misunderstandings around XR features to cause user confusion and unintended outcomes, with scores near 2.31 for likelihood and 2.38 for impact.

Training Effectiveness & Accessibility

Within the theme of training effectiveness and accessibility, two concerns emerge. Issue #47, which captures the pitfalls of “one-size-fits-all” training modules, carries a mean likelihood of 2.54 and an impact of 2.77. Issue #48, describing the danger that excessive reliance on XR may erode real-world skills, scores lower on both dimensions—2.15 for likelihood and 2.54 for impact. Respondents judge the rigidity of standardized modules to be both more probable and more severe than potential losses in practical skills. This pattern suggests that, in development of XR-based instruction, ensuring modular adaptability to individual learner needs is paramount to foster true competence without sacrificing real-world proficiency.

3.3.3. SELECTION OF FOCUS ISSUES FOR MOTIVATE XR

In order to select most important issues for Motivate XR, we compare the impact and likelihood of each issue across categories. Figure 11 shows the distribution of all issues on a likelihood vs impact cartesian plane, where each issue is indicated with a circle or a square, as introduced above. Each issue is marked with a number, that corresponds to their position in the survey and the above discussions and legends.

In Section 3.3.3.1, we discuss the most likely and impactful statements. In Section 3.3.3.2, we pay attention to the fact that some issues were marked as irrelevant by some participants while rated as highly impactful, and likely by others and discuss implications for considering these issues in the rest of the analysis.

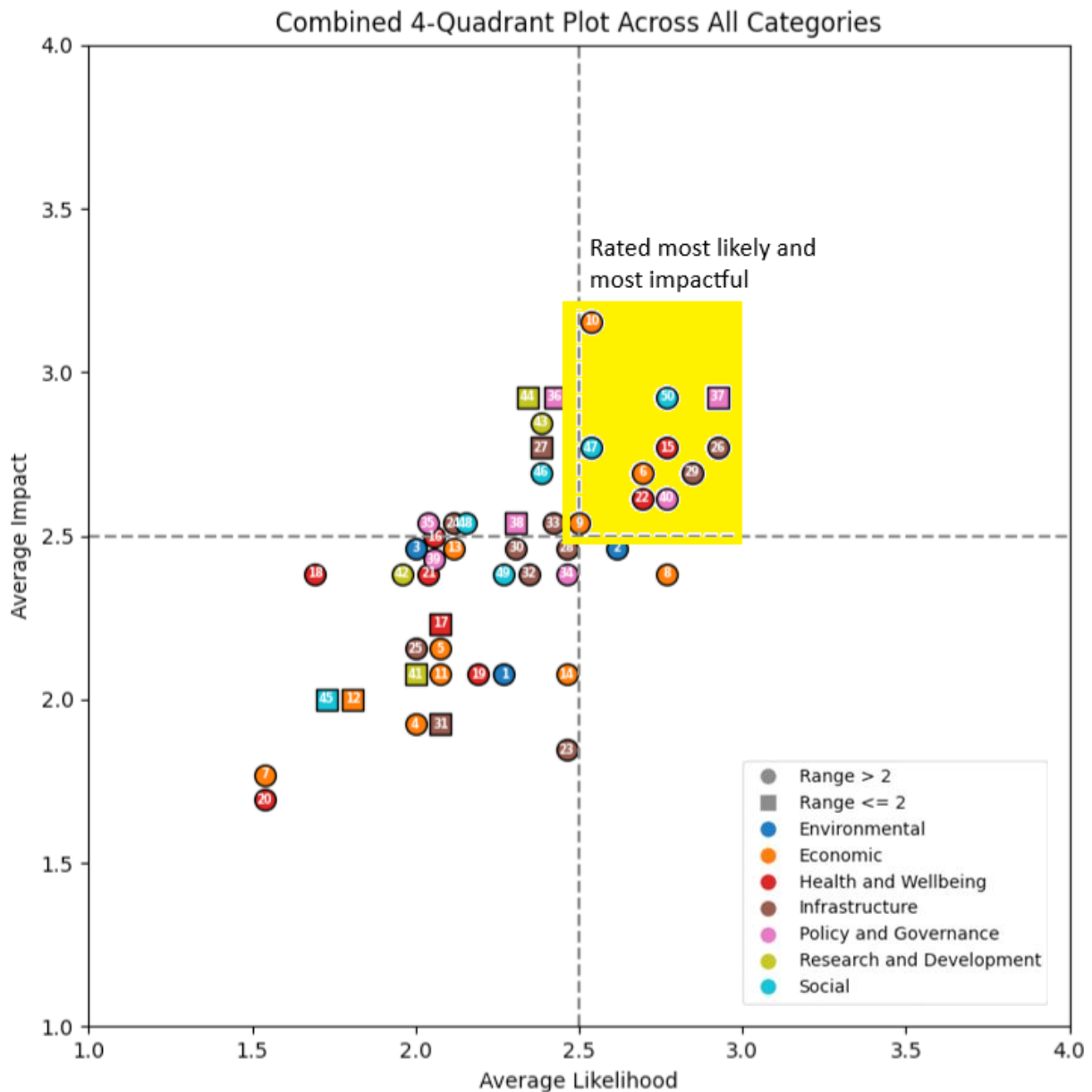


FIGURE 11: IMPACT AND LIKELIHOOD OF ALL ISSUES

3.3.3.1. MOST LIKELY AND IMPACTFUL ISSUE STATEMENTS

A total of eleven issues were identified with mean *likelihood* and *impact* scores above the overall average (2.5). These were considered by respondents to represent both the most probable and the most consequential risks. It is therefore recommended that MOTIVATE XR prioritise these issues in their mitigation planning, ensuring that appropriate safeguards and control measures are integrated throughout the project. Issues from all categories except Environmental and Research and development are present. The identified high-priority issues are presented below for clarity:

Economic issues

#6 Ill-fitting XR Devices and Productivity Likelihood=2.69; Impact =2.69

Statement: In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity.

#9 Health & safety and mental-workload issues Likelihood=2.5; Impact=2.53

Statement: Using XR technologies in certain tasks could increase mental workload and introduce health and safety issues (e.g., cybersickness, visual fatigue, physical discomfort), which could lower job satisfaction and indirectly lead to job displacement.

#10 Cybersecurity issues Likelihood=2.54; Impact=3.15

Statement: XR technologies could expose stakeholders to economic issues from cybersecurity threats (e.g., unauthorized access, in-app purchases without consent, CMR vulnerabilities).

Health and Wellbeing issues

#15 Discomfort and Reduced Awareness Likelihood=2.77; Impact=2.77

Statement: XR systems can cause physical discomfort (e.g., motion sickness, eye strain), distort spatial perception, and reduce real-world awareness—leading to accidents and potential medical incidents.

#22 Safety Gaps Likelihood=2.69; Impact=2.62

Statement: Traditional safety protocols—designed for non-immersive equipment—often fail to address XR’s unique hazards, leaving organizations unprepared to update policies, train staff, and enforce safeguards for immersive and interactive scenarios.

Infrastructure issues

#26 Network limits & latency Likelihood=2.92; Impact=2.77

Statement: Network bandwidth and latency can limit cloud-based XR performance; even small delays could degrade user experience.

#29 Infrastructure as a barrier in adoption Likelihood=2.85; Impact=2.69

Statement: Lack of adequate IT infrastructure, affordable resources, skilled personnel, private spaces, and clear guidance can hinder XR adoption and accessibility.

Policy and Governance issues

#37 Inadequate legal frameworks for disputes & virtual property Likelihood=2.92; Impact=2.92

Statement: Existing legal frameworks may be inadequate to address disputes, crimes, and virtual property issues in XR environments, necessitating new doctrines and enforcement mechanisms to govern virtual worlds effectively.

#40 Inadequate agility in updating safety standards Likelihood=2.77; Impact=2.62

Statement: Organizations may lack the capacity or agility to update safety standards and protocols as XR technologies evolve, resulting in regulatory gaps and increased risk of non-compliance with emerging legal requirements.

Social issues

#47 Lack of different modes in XR Training Likelihood=2.54; Impact=2.77)

Statement: One-size-fits-all XR training modules could lead to some participants failing to achieve proficiency.

#50 Disparities in Accessibility for Differently Abled People Likelihood=2.77; Impact=2.92)

Statement: Absence of built-in UI accessibility features could lead to exclusion of visually impaired users.

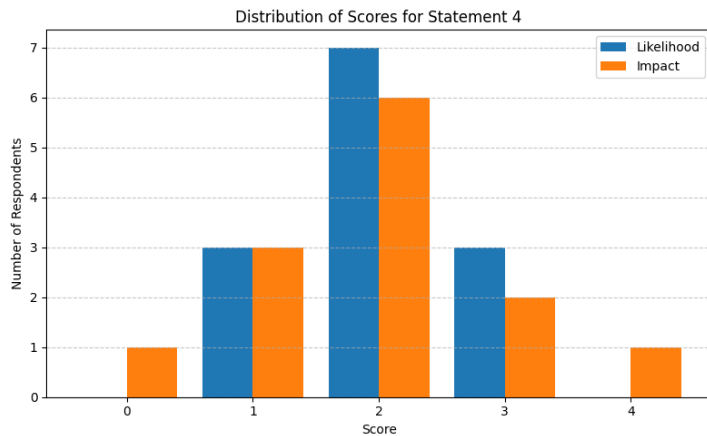
3.3.3.2. NON-APPLICABLE ISSUES

While the prioritisation survey performed in Section 3.3.3.1 provided clear signals about which issues scored highest on likelihood and impact, it also revealed a smaller set of issues where responses diverged. In a few cases, some participants selected “0” (not applicable) for either the likelihood or the impact of an issue, while others rated the same issue as impactful/likely or even highly impactful/likely. Analysing these discrepancies is important, since they highlight areas where risk perception may depend on sectoral context, organisational priorities, or specific pilot requirements. Rather than discarding such issues outright, it is necessary to examine whether their broader significance justifies their inclusion in the final list of priorities.

A particularly notable case is Issue #50 – Absence of built-in UI accessibility features could lead to exclusion of visually impaired users. Although one respondent considered this issue irrelevant, the majority rated it as both highly likely and highly impactful. We have chosen to retain this issue in the analysis to ensure that accessibility remains a core design and deployment requirement.

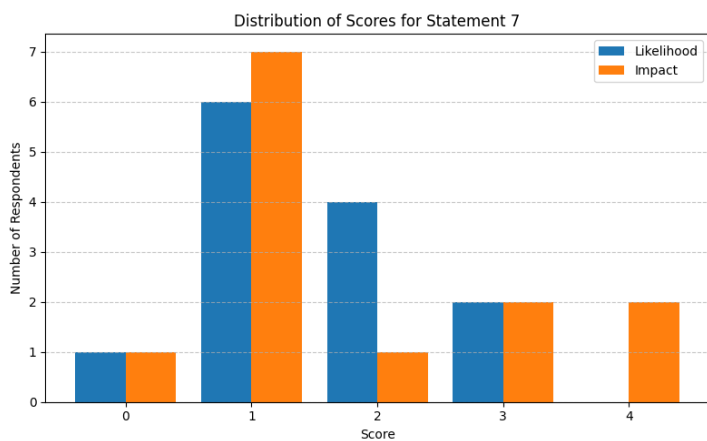
#4 The manufacturing and disposal of XR devices—including head-worn displays and related equipment—and the specialized materials used in XR displays could generate significant electronic waste and environmental harm due to rapid obsolescence and problematic sourcing, processing, and disposal practices.

Other participants rated this dimension with the following scores – an average of 2.08 without the 0 and 1.92 with. Although not the top-ranked concern, the rest of the respondents indicate this issue remains non-negligible and warrants monitoring.



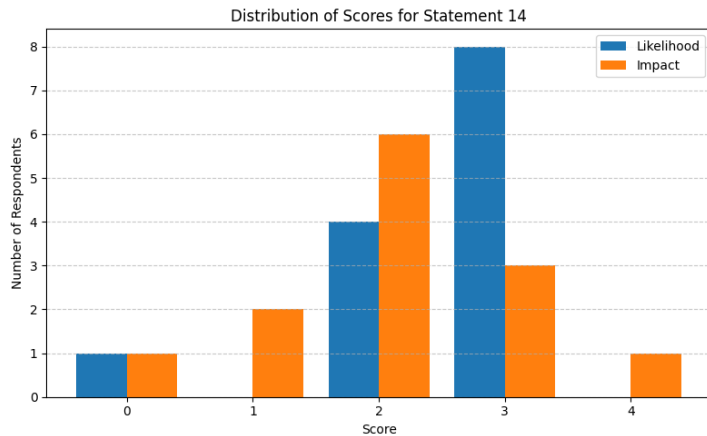
#7 In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity.

Other respondents rated this issue on the lower side, with averages for likelihood and impact being 1.54 and 1.77 respectively. These relatively low scores indicate limited perceived urgency, yet the risk remains pertinent to project planning.



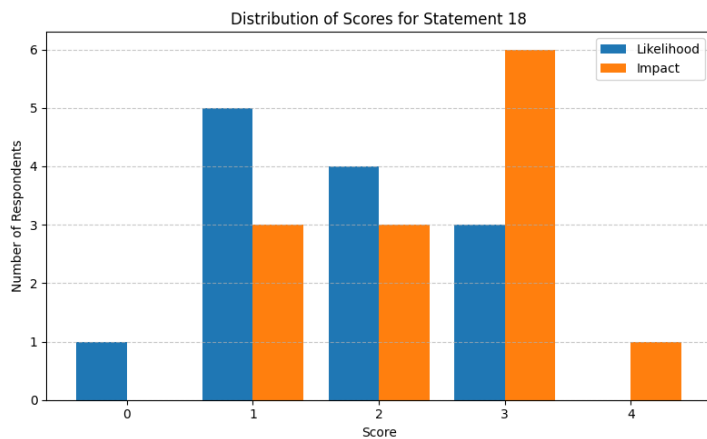
14 Over-reliance on XR can deskill the workforce and widen existing skills gaps, leaving workers unprepared for a changing job market, which could lead to increased unemployment, exacerbated economic hardship, and widen the digital divide.

The averages for #14 are 2.46 and 2.08 for likelihood and impact respectively position it as an issue to monitor but not yet prioritise. However, eight respondents perceived this impact as likely to happen, making it relevant to keep in the results.



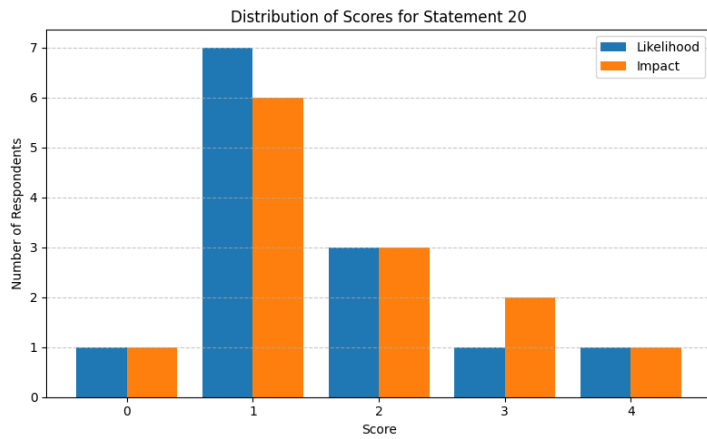
18 The immersive nature of XR can trigger or worsen anxiety, distort reality, impair decision-making, and carry unforeseen long-term psychological risks.

Although this issue's likelihood is perceived as relatively low, with an average of 1.69, the perceived potential impact of on average 2.38 justifies its inclusion.



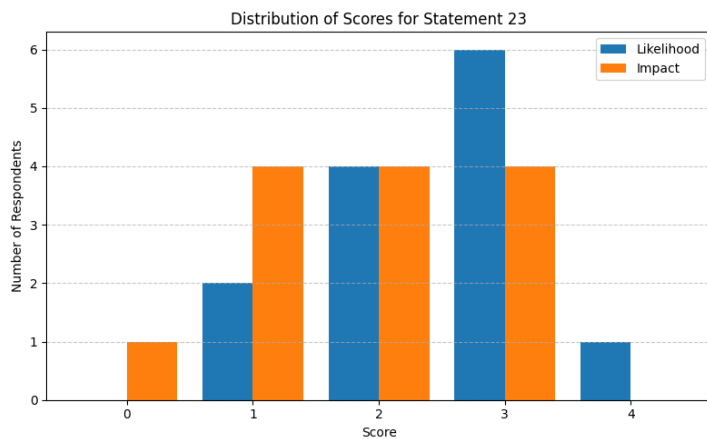
20 XR can expose users to harassment, cyberbullying, and inappropriate content, possibly heightening psychological distress—especially for children and vulnerable groups.

This issue has low scores across likelihood and impact, with averages of 1.54 and 1.69 respectively. Despite lower scores, the high concern expressed by few consortium members and the real-world implications of this risk merit ongoing attention.



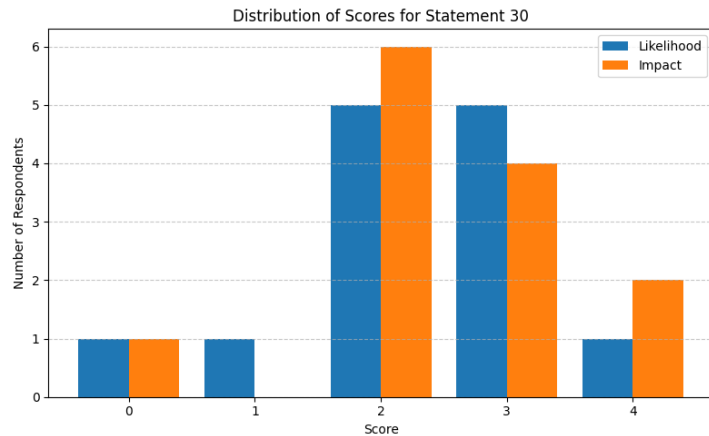
23 Integrating XR into existing workflows can disrupt established practices, may be less efficient than simpler methods for certain tasks, and could limit direct interaction with physical objects in remote collaboration.

This issue has been rated with an average of 2.46 for likelihood and 1.85 for impact. High likelihood but relatively low impact makes this a persistent operational annoyance deserving mitigation.



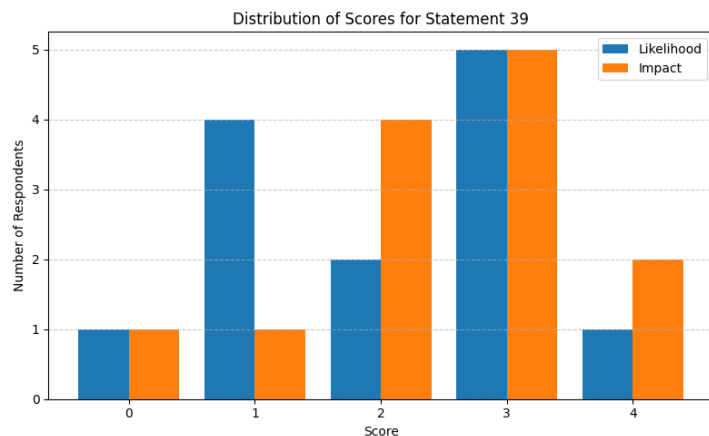
30 Unreliable data connections, integration challenges, and unclear responsibilities can lead to governance issues, cybersecurity vulnerabilities, and conflicts over shared virtual objects can affect system stability.

This issue has been favourably rated by the other respondents, with average scores of 2.31 and 2.46 for likelihood and impact respectively and hence being kept in the analysis. Consistently moderate scores reinforce its relevance to system planning and security.



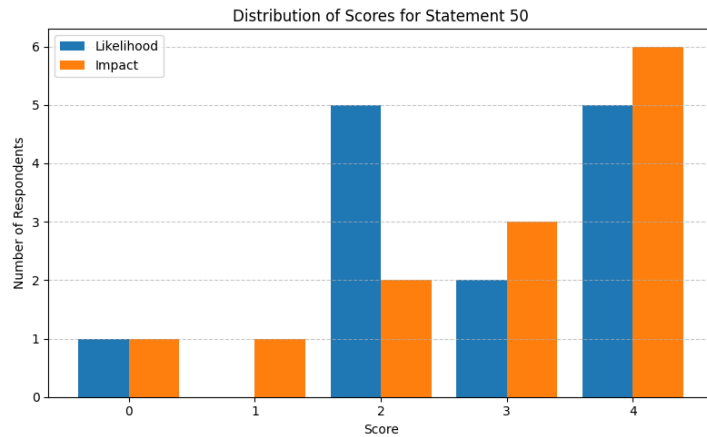
39 Lack of clear liability mechanisms when human error occurs in XR-assisted tasks can leave impacted individuals without legal recourse and expose organizations to prolonged legal uncertainty.

This issue has been rated 2.08 and 2.46 for impact and likelihood respectively. Legal and compliance considerations underpin the decision to retain this risk.



#50 – Absence of built-in UI accessibility features could lead to exclusion of visually impaired users.

This issue is a first quadrant risk, with average scores of 2.77 and 2.92 respectively. It may have been unimportant from the point of view of one respondent based on their use-case or technology, but it is perceived as very important from the broader context of the project and thus kept among the focus issues.



3.4. FINAL OVERVIEW OF PRIORITIZED ISSUES FOR MOTIVATE XR

The final overview of focus issues for Motivate XR can be found in **Error! Not a valid bookmark self-reference..** These issues represent the issues judged to be most critical for the socially, ethically and legally responsible deployment of XR technologies within the project. They span multiple dimensions—Social, ethical, and cultural, Health and well-being, Economic, Infrastructure, and Political, legal and regulatory—demonstrating that XR-related issues are not confined to technical performance alone but cut across organizational, regulatory, and societal contexts.

The table shows that economic concerns such as ill-fitting devices, increased workload, and cybersecurity threats stand alongside health-related issues like physical discomfort and inadequate safety protocols as top priorities. Infrastructure limitations, particularly network latency and uneven access to IT resources, are also highlighted as major barriers to effective XR adoption. On the governance side, gaps in legal frameworks and the agility of organizations to update standards reflect the need for proactive policy development. Finally, social issues—including the lack of diverse training modes and insufficient accessibility for differently abled users—underscore the importance of inclusivity in XR design.

Together, these prioritized issues provide a roadmap for where Motivate XR must concentrate its mitigation efforts. We recommend these are treated like core requirements, embedding safeguards and controls into system architecture, organizational processes, and deployment practices from the earliest stages of the project.

TABLE 9: FINAL OVERVIEW OF KEY ISSUES FOR MOTIVATE XR

Issue	Statement	Category
#6 Ill-fitting XR Devices and Productivity	In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity.	Economic
#9 Health & safety and mental-workload issues	Using XR technologies in certain tasks could increase mental workload and introduce health and safety risks (e.g., cybersickness, visual fatigue, physical discomfort), which could lower job satisfaction and indirectly lead to job displacement.	Economic
#10 Cybersecurity issues	XR technologies could expose stakeholders to economic risks from cybersecurity threats (e.g., unauthorized access, in-app purchases without consent, CMR vulnerabilities).	Economic
#15 Discomfort and Reduced Awareness	XR systems can cause physical discomfort (e.g., motion sickness, eye strain), distort spatial perception, and reduce real-world awareness—leading to accidents and potential medical incidents.	Health and Wellbeing
#22 Safety Gaps	Traditional safety protocols—designed for non-immersive equipment—often fail to address XR’s unique hazards, leaving organizations unprepared to update policies, train staff, and enforce safeguards for immersive and interactive scenarios.	Health and Wellbeing
#26 Network limits & latency	Network bandwidth and latency can limit cloud-based XR performance; even small delays could degrade user experience.	Infrastructure
#29 Infrastructure as a barrier in adoption	Lack of adequate IT infrastructure, affordable resources, skilled personnel, private spaces, and clear guidance can hinder XR adoption and accessibility.	Infrastructure
#37 Inadequate legal frameworks for disputes & virtual property	Existing legal frameworks may be inadequate to address disputes, crimes, and virtual property issues in XR environments, necessitating new doctrines and enforcement mechanisms to govern virtual worlds effectively.	Policy and Governance
#40 Inadequate agility in updating safety standards	Organizations may lack the capacity or agility to update safety standards and protocols as XR technologies evolve, resulting in regulatory gaps and increased risk of non-compliance with emerging legal requirements.	Policy and Governance
#47 Lack of different modes in XR Training	One-size-fits-all XR training modules could lead to some participants failing to achieve proficiency.	Social
#50 Disparities in Accessibility for Differently Abled People	Absence of built-in UI accessibility features could lead to exclusion of visually impaired users.	Social

4. IDENTIFICATION OF MITIGATION APPROACHES

In this section, we seek to find measures to the issues identified in Chapter 3. In Section 4.1, we discuss the approach used to identify measures. Section **Error! Reference source not found.** presents the identification of an initial list of measures based on a review of the scientific literature. Section 4.3 discusses the workshop carried out to identify measures with Motivate XR partners. Section 4.4 produces a consolidated list of measures based on the input of the scientific literature and the workshop.

4.1. APPROACH FOR IDENTIFYING MEASURES

The identification of measures for Motivate XR followed a structured process that combined insights from academic research with the expertise of project partners. This ensured that the final set of measures was both evidence-based and tailored to the specific needs of the project.

The process began with an analysis of scientific literature (see Section **Error! Reference source not found.**), where potential measures were extracted and validated with the support of a large language model. This step provided a broad and systematic overview of possible interventions, ensuring that no major approaches were overlooked. To make the results usable for later stages, the measures were organized into thematic categories. This categorization helped create a clear structure and served as inspiration for the partner workshops.

Two workshops with Motivate XR partners followed, bringing in practical expertise from both technical developers and use case partners (see Section 4.3). While the literature review guaranteed breadth, the workshops added contextual depth and realism. Participants focused on the most pressing issues identified in the project and suggested measures based on their experience, refining and complementing the categories presented to them.

Finally, the measures from the literature and workshops were consolidated into a single list (see Section 4.4). This step was essential to remove duplicates, merge similar suggestions, and group measures consistently across issues. The result was a comprehensive, well-structured set of measures that reflects both the state of the art in XR research and the operational realities of Motivate XR.

4.2. ACADEMIC MITIGATION MEASURES

The identification of mitigation measures from academic literature was conducted through a structured, multi-stage analysis combining automated language model reasoning with targeted human oversight. The process was based on a custom large language model (LLM) workflow specifically configured for the MOTIVATE XR project. This workflow enabled the systematic extraction of mitigation measures from academic literature while maintaining traceability and quality control at each stage. The model used was Gemini 2.0 Flash, integrated into a controlled

environment and guided by a predefined analytical protocol. A distinction is made between technical and non-technical measures, as the results shaped the frameworks for the following workshops. Workshop participants are expected to have more expertise in one area or the other.

4.2.1. DATASET

The dataset used to determine the measures is the same as the one applied to identify issues in Section 3.1.3. It comprises 233,318 scholarly works (including journal articles, conference papers, book chapters, and other peer-reviewed publications) collected from Scopus through the following search terms: “extended reality,” “virtual reality,” “augmented reality,” “mixed reality,” “virtual environments,” and “immersive technologies.”

4.2.2. EXTRACTION

The first stage involved mapping academic publications to the relevant issues identified in Section 3.1. Only publications meeting the predefined threshold were retained for further analysis. This step produced an evidence base linking each issue to the subset of academic sources most pertinent to it. The number of publications identified for each issue is shown in Table 10.

TABLE 10: NUMBER OF PUBLICATIONS ADDRESSING EACH ISSUE

Issues	Issue 6	Issue 9	Issue 10	Issue 15	Issue 22	Issue 26	Issue 29	Issue 37	Issue 40	Issue 47	Issue 50
Count	6612	6338	810	10918	220	6573	6463	532	161	4967	2276

In the second stage, the model extracted candidate mitigation measures from the filtered literature. To ensure conceptual precision, the model was guided by an internal reasoning framework specifying what constitutes a *measure* within the MOTIVATE XR context. This included identifying explicit causal links between XR use, the resulting issue, and the proposed mitigation action. Measures had to be actionable and described in sufficient detail to explain how they reduced the identified harm. Each extracted measure was further classified as *technical* or *non-technical*, distinguishing between interventions that modify the XR system itself and those addressing behavioural, organisational, or regulatory dimensions. The total and classified counts of extracted measures per issue are shown in Table 11. Some measures were not classified as either technical or non-technical.

TABLE 11: NUMBER OF MEASURES ADDRESSING EVERY ISSUE

Issues	Issue 6	Issue 9	Issue 10	Issue 15	Issue 22	Issue 26	Issue 29	Issue 37	Issue 40	Issue 47	Issue 50
Total	1264	1003	182	1642	26	1863	278	142	24	106	369
Technical	952	662	132	1151	9	1849	94	14	8	48	286
Non-technical	312	341	50	491	17	14	184	128	16	58	83

The final stage involved an iterative verification process combining structured human review with targeted LLM-based re-evaluation. This phase was designed to ensure conceptual accuracy,

eliminate false positives, and refine the quality of the extracted measures. Human experts systematically examined a subset of the model outputs, identifying patterns of misclassification or conceptual drift—such as instances where XR was presented as a solution rather than the source of the issue.

Based on these findings, the LLM was re-engaged in controlled review cycles to reassess and filter the measures according to revised exclusion criteria. These criteria focused on ensuring that each measure explicitly linked the mitigation to an XR-induced hazard and represented a genuine modification, safeguard, or constraint on the technology, rather than the introduction of new XR functionalities. The process continued iteratively until consistency and conceptual alignment were achieved across the dataset.

This combination of automated reasoning and human judgment ensured methodological robustness and transparency while maintaining oversight at all critical stages of the analysis. The number of validated measures for every issue can be found in Table 12. Some measures were not classified as either technical or non-technical.

TABLE 12: NUMBER OF VALIDATED MEASURES ADDRESSING EVERY ISSUE

Issues	Issue 6	Issue 9	Issue 10	Issue 15	Issue 22	Issue 26	Issue 29	Issue 37	Issue 40	Issue 47	Issue 50
Total	1060	982	119	1638	14	1774	221	226	16	83	287
Technical	794	655	63	1149	4	1765	75	14	2	38	222
Non-technical	266	327	56	489	10	9	146	112	14	45	65

4.2.3. CATEGORIZATION OF MEASURES

This section describes the process used to develop the categories of mitigation measures that later formed part of the MOTIVATE XR workshop framework. The categorisation was conducted through a custom, two-stage analytical workflow combining large language model (LLM) reasoning with structured human oversight. The workflow was designed to identify conceptual groupings of mitigation measures while ensuring methodological consistency and robustness.

The process employed two distinct LLMs in sequential stages: Gemini 2.0 Flash was used for the initial categorisation, and GPT-4o was subsequently applied for verification and refinement. Both models operated under controlled analytical protocols, and all outputs underwent iterative human review to ensure the conceptual validity and relevance of the resulting categories.

Initial categorization of measures

In the first stage, the measures associated with each issue identified in Section 3.1 were analysed and grouped according to shared mechanisms, design principles, or strategic approaches for mitigation. This stage aimed to identify underlying patterns across the diverse set of measures rather than to cluster them based solely on linguistic similarity.

The categorisation process produced preliminary clusters that represented common tactics or conceptual logics for addressing the issues. Each cluster was assigned a concise label and description summarising its core rationale and distinguishing features.

Verification of the categorization of measures

The preliminary categorisation was subjected to a structured verification and refinement process to ensure both the coherence of the groupings and the accuracy of their accompanying labels and descriptions. This phase combined automated analysis with human oversight in an iterative cycle.

An independent review was conducted using a secondary analytical model (GPT-4o) to assess whether the measures within each cluster were conceptually aligned and whether the assigned labels and summaries accurately reflected their shared rationale. Human experts systematically examined these outputs, reconciling discrepancies, refining category boundaries, and adjusting descriptions where necessary.

The process was repeated until the categorisation achieved internal consistency and conceptual clarity, resulting in a set of stable, well-defined categories that accurately represent the diversity of mitigation strategies identified in the literature.

Final categorization of measures

Table 13 through Table 23 present the categories of measures identified for each issue. The description of categories can be found in Appendix G.

TABLE 13: CATEGORIES OF MEASURES FOR ISSUE 6

Technical categories	Non-technical categories
Headset Ergonomics & Physical Comfort	User Involvement & Participatory Design
Calibration & Alignment Accuracy	Usability Evaluation & Feedback
Robust Tracking & Sensor Fusion	Contextual & Real-World Validation
Interaction Methods & Input Modalities	User Training & Support
Visual & Sensory Feedback	Operational Support & Deployment Practices
Adaptive UI & Content Personalization	Ergonomics & Safety Considerations
Rendering Performance & System Stability	
Text & Symbol Legibility	
Multimodal Integration & Context Awareness	
Industrial-grade Hardware Reliability	

TABLE 14: CATEGORIES OF MEASURES FOR ISSUE 9

Technical categories	Non-technical categories
User State Monitoring and Detection	Limiting Exposure Time and Providing Breaks
Adaptive XR Systems and Content to user state or context	Managing Visual Discomfort and Physical Fatigue
Visual Ergonomics and Fatigue Mitigation	Monitoring and Supporting Psychological & Cognitive Health
Cybersickness Prediction and Prevention	Providing Safe Use Guidelines and Training
Latency, Tracking, and Rendering Optimization	Assessing User Well-being Through Questionnaires
Motion and Locomotion Management	Understanding and Addressing Individual Differences
Multimodal Feedback and Interaction Support	Implementing Feedback Loops and Usability Evaluation

Hardware Ergonomics and Physical Comfort	Supporting Content Creators with Human-Centred Design Guidance
User Interface and Information Design	Workplace and Environmental Ergonomics
Environmental and Contextual Design for Mental Load Relief	

TABLE 15: CATEGORIES OF MEASURES FOR ISSUE 10

Technical categories	Non-technical categories
Advanced user verification (e.g., biometric, multi-factor, continuous)	Implement Tailored Risk Management and Security Strategies
Secure Data Transmission and Communication	Prioritize Security and Consent in XR Development and Business Logic
Data Privacy and Anonymization	Implement Comprehensive Security and Privacy Controls
Intrusion Detection and Anomaly Response Systems	Conduct Systematic Security and Privacy Analysis
Secure System and Interface Design	Ensure Legal and Regulatory Compliance
Platform, Device, and Hardware Security	Educate Users on Cybersecurity Risks and Best Practices
AI-Driven Cybersecurity and Risk Mitigation	Address Social Engineering and Privacy Concerns
Collaborative and Multi-User XR Security	Establish Trust Frameworks and Ethical Guidelines to Guide XR Use
	Promote Stakeholder Collaboration and Governance

TABLE 16: CATEGORIES OF MEASURES FOR ISSUE 15

Technical categories	Non-technical categories
Display and Optics Optimization	Usage Scheduling and Rest Protocols
Latency Reduction and Rendering Performance	User Assessment and Screening
Real-Time User State Monitoring and Adaptation	Training, Education, and User Guidance
Sensory Conflict Compensation	Personalized User Adaptation
Locomotion and Navigation Design	Ergonomic Environment and Equipment Practices
Real-World Awareness and Safety Systems	Shared Physical Space Safety Protocols
Ergonomic and Thermal Hardware Design	Safe Locomotion and Interaction Design Policy
Adaptive User Interface and Interaction Design	Monitoring, Feedback, and Incident Response
Predictive Analytics and Risk Mitigation	Standards, Compliance, and Health & Safety Governance

TABLE 17: CATEGORIES OF MEASURES FOR ISSUE 22

Technical categories	Non-technical categories
Secure Activity Provenance and Auditability	Integrating Risk Assessment into XR Design and Use
Consent, Privacy, and Boundary Management	Scenario-Based and Context-Specific Safety Training
Behavioural Moderation and Safety Enforcement	Addressing User Experience Levels and Hazard Perception
	Ensuring Ongoing Competency and Safety Training Refreshers
	Establishing XR Safety Governance and Compliance Frameworks

	XR Equipment Management and Operational Readiness
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TABLE 18: CATEGORIES OF MEASURES FOR ISSUE 26

Technical categories	Non-technical categories
Edge and Cloud Offloading	Defining Network Performance Indicators
Adaptive XR Content and Application Layer Optimization	Research & Evaluation Methodology
Network Prioritization and Protocol Optimization	Human Factors in Latency Perception
Wireless and Network Technology Optimization	Planning XR Content Delivery Strategies
Predictive and ML-Driven Resource Management	User Training and Familiarization Programs
Advanced Media Encoding and Compression	Infrastructure & Policy Advocacy
Multiconnectivity and Load Balancing	Standards & Interoperability Initiatives

TABLE 19: CATEGORIES OF MEASURES FOR ISSUE 29

Technical categories	Non-technical categories
Platform Interoperability and Cross-Device Accessibility	Early Stakeholder Involvement in XR Planning
Cost-Effective XR Hardware and Deployment Strategies	Proactive Assessment and Strategic Implementation Planning
Optimized 3D Content and Performance Engineering	Financial Models and Cost Management
Network Infrastructure and Cloud Delivery	Establishing Robust Technological and Physical Infrastructure
AI-Powered Assistance, Guidance, and Automation	Standardizing XR Deployment and Support Processes
System Integration and Interoperability	Long-Term Expertise Development and Training
Security, Privacy, and Data Protection	Providing Comprehensive Technology Support
	Adapting XR Learner and Worker Experience Design
	Promoting Accessibility and Inclusivity in XR
	Policy, Governance, and Compliance

TABLE 20: CATEGORIES OF MEASURES FOR ISSUE 37

Technical categories	Non-technical categories
Tokenization of Rights and Virtual Property	Enhancing Data Protection and Privacy in XR
Governance Mechanisms and Smart Legal Frameworks	Enhancing User Safety and Protection
Privacy-Aware UI and User Empowerment Tools	Safeguarding Perceptual Autonomy and Cognitive Rights
Platform-Embedded Arbitration and Legal Support Tools	Addressing Cybercrime and Security in XR
	Promoting Ethical Considerations and Responsible Innovation
	Establishing Governance and Accountability Mechanisms
	Establishing Legal and Dispute Resolution Frameworks for Virtual Worlds
	Fostering International and Multistakeholder Coordination

TABLE 21: CATEGORIES OF MEASURES FOR ISSUE 40

Technical categories	Non-technical categories
Standardized XR Motion Dataset Accessibility	Updating XR Safety Standards and Protocols
AI-Powered Hazard Detection and Monitoring Systems	Establishing Safe Operational Parameters for XR Technologies
Synthetic Data Generation and Safety Simulation	Implementing Monitoring and Compliance Mechanisms
Standards-Aligned Safety Ontologies and Rule Engines	Embedding Ethical and Legal Safeguards in XR Deployment
Automated Compliance Monitoring and Reporting Tools	Promoting Responsible XR Use Through Organizational Practice
Adaptive Safety Protocol Update Framework	Developing Adaptive XR Policy and Governance Frameworks
	Facilitating Multi-Stakeholder Coordination in XR Regulation

TABLE 22: CATEGORIES OF MEASURES FOR ISSUE 47

Technical categories	Non-technical categories
Adaptive Learning Systems	Personalizing Instruction to Learner Profiles
AI-Powered Content Personalization	Personalizing Educational Technologies and Interfaces
Personalized XR Environment & Interface Customization	Adapting to Learner Progress and Performance
High-Fidelity XR Simulation Modelling	Enhancing Instructional and Content Quality
Learning Support, Repetition & Self-Regulation Tools	Using Pedagogical Frameworks for Instructional Design
Multi-modal XR Data Analytics	Aligning Learning with Real-World Contexts and Job Tasks
Collaborative Personalization & Co-Authoring Tools	Engaging Experts in Design and Feedback Loops
	Supporting Collaborative and Social Learning
	Establishing Assessment and Feedback Mechanisms

TABLE 23: CATEGORIES OF MEASURES FOR ISSUE 50

Technical categories	Non-technical categories
Voice Command and Speech Synthesis Integration	Universal Design and Inclusion Principles
Spatial Audio and Auditory Cue Systems	Developing and Applying Accessibility Guidelines
Haptic Feedback and Tactile Interfaces	Legal and Regulatory Compliance
Customizable and Adaptive Interface Design	User-centered Co-Design and Feedback Integration
Accessibility-Aware XR Authoring Tools	Simulation and Empathy Tools for Visual Impairment
Scene Understanding and AI-Powered Assistance	Tailored Design for Vision-Specific Needs
Simulation and Evaluation of Visual Impairments	Inclusive Education and Learning Design
Interface Navigation Alternatives	Accessibility Evaluation and Testing
	Training and Capacity Building for Accessibility

4.3. WORKSHOPS

The objective of the workshops is to identify measures intuitive to the consortium, that address each of the focus issue statements outlined in Chapter 3, this time based on the input of Motivate XR partners. While the analysis of scientific literature helps build a comprehensive list of potential measures, Motivate XR partners bring valuable expertise specific to the design and application of the Motivate XR tools.

Two workshops were held: one focused on technical measures and the other on non-technical measures. Technical measures are those that modify, add, or remove hardware, firmware, software code, data pipelines, network settings, or algorithmic logic to mitigate the identified XR impact. Non-technical measures reduce the XR impact through human-centred, organizational, educational, or policy actions, rather than by altering the underlying technology stack.

Partners involved in the design of the Motivate XR system contributed primarily to identifying technical measures, while those involved in applying Motivate XR to use cases supported the identification of non-technical measures.

4.3.1. WORKSHOP SETUP

The workshops were conducted online using Miro and lasted two hours each. In both sessions, participants were provided with the objective of the workshop: *“Identify mitigation measures relevant to Motivate XR.”* Partners were informed that the workshop would focus on the 11 issues with the highest impact and frequency for Motivate XR, issues they had helped to prioritize in an earlier stage (see Section 3.3). Measures were found for each issue separately. For each issue, participants were presented with a list of suggested categories of measures, along with an explanation of the distinction between technical and non-technical measures.

The workflow for each issue followed this structure:

1. Introduction of the issue by the workshop facilitator (1 minute)
2. Independent identification of measures by participants (5 minutes)
3. Group discussion of the suggested measures (3 minutes)

An example of a completed template by workshop participants for one issue is shown in Figure 12.

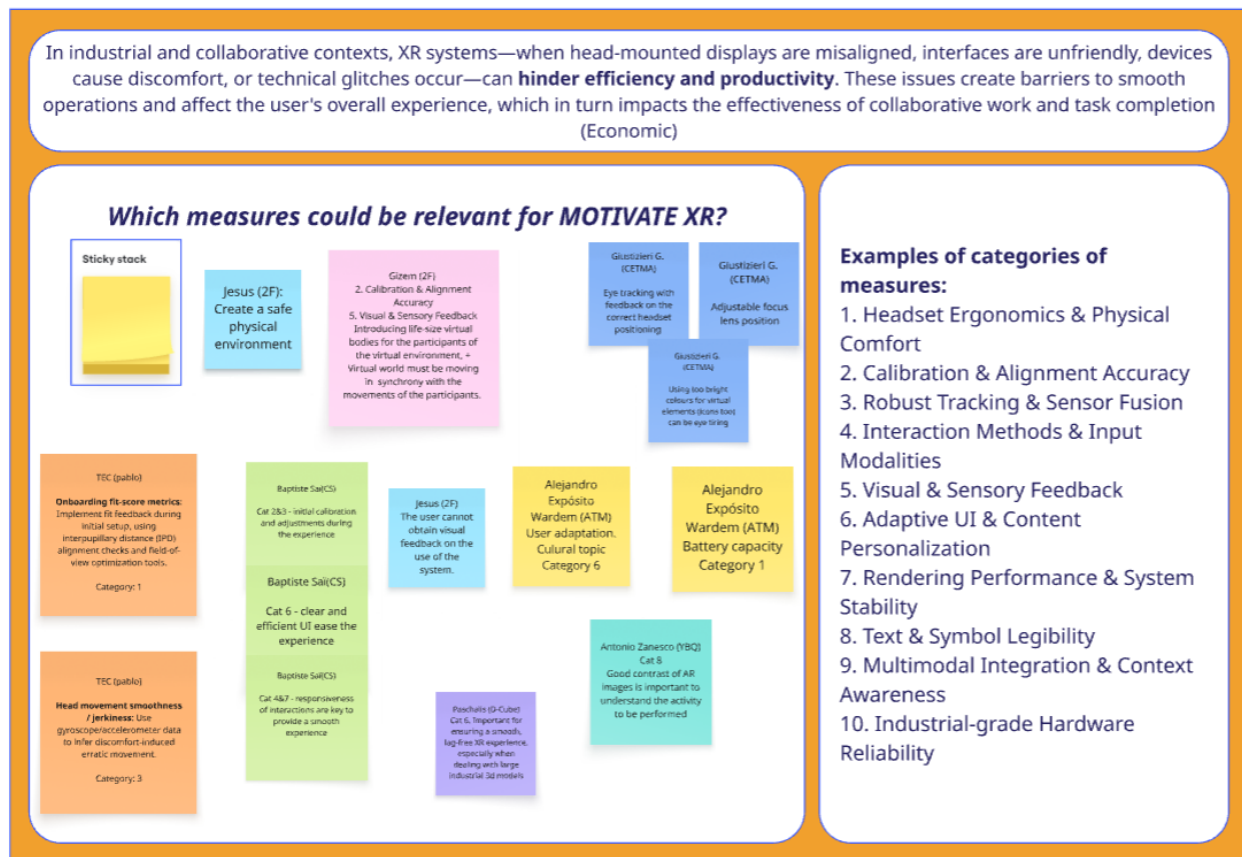


FIGURE 12: EXAMPLE OF MEASURES IDENTIFIED BY WORKSHOP PARTICIPANTS

4.3.2. WORKSHOP OUTCOMES

The lists of measures identified by workshop participants are presented in Table 24 through Table 34.

TABLE 24: MEASURES IDENTIFIED FOR ISSUE 6

Technical measures	Non-technical measures
Eye tracking with feedback on the correct headset positioning	Usability evaluation (pre-post questionnaires like SSQ and/or SUS) 6. Ergonomics (Improving hardware solutions, as well as software solutions like decreasing the lagging, increasing the FPS etc)
Adjustable focus lens position	Create spaces dedicated to the use of XR technologies / Prepare the users themselves before the actual application
Calibration & Alignment Accuracy 5. Visual & Sensory Feedback Introducing life-size virtual bodies for the participants of the virtual environment, + Virtual world must be moving in synchrony with the movements of the participants.	Provide continuous support and tech & operational helpdesks Categories 4,5

Train employees in cybersecurity practices	Cat 2&6- Prior evaluation of needs, to ensure adaptative hardware/software
Create a safe physical environment	Safety evaluation and training prior to XR experience Categories 6
Using too bright colours for virtual elements (icons too) can be eye tiring	Cat. 1: Pre-usage experience with safety evaluation and adaptation of experience for each user.
Onboarding fit-score metrics: Implement fit feedback during initial setup, using interpupillary distance (IPD) alignment checks and field-of-view optimization tools. Category: 1	Cat 4- trainings to help users' adaption for these technologies
Cat 2&3 - initial calibration and adjustments during the experience	Cat 4- trainings to help users' adaption for these technologies
User adaptation. Cultural topic Category 6	Testing in the real environment with background noise for instance
Battery capacity Category 1	interviews with participants and recording the training sessions. Spotting places where issues have been detected
The user cannot obtain visual feedback on the use of the system.	Inform users about all the risks is possible to face during every process is planned into their company (both training and assistance) Category 3
Baptiste Sai(CS) Cat 6 - clear and efficient UI ease the experience	1. User involvement: pilot testing with a diversified pool of users 2. Early identification of technical malfunctioning
Cat 8 Good contrast of AR images is important to understand the activity to be performed	1. preventive fitting and ergonomic testing activities 2. user experience feedback mechanisms
Head movement smoothness / jerkiness: Use gyroscope/accelerometer data to infer discomfort-induced erratic movement. Category: 3	1. User involvement - involve, from the beginning, different users age 2. Usability - hardware compatibility for usable XR contents in both indoor and outdoor environments
Cat 4&7 - responsiveness of interactions are key to provide a smooth experience	Supporting user during operations by remote call
Cat 6. Important for ensuring a smooth, lag-free XR experience, especially when dealing with large industrial 3d models	

TABLE 25: MEASURES IDENTIFIED FOR ISSUE 9

Technical measures	Non-technical measures
'+ Preventive: Participants of the virtual environment can complete a motion sickness questionnaire before the experience to determine whether they previously suffer from similar feelings while travelling in car, boat or airplane.'	Setting up clear guidelines, instructions for user of max time of use + adding some alert to software regarding when the time is up
Preventive measure: Exclusion Criteria. Some participants can be more susceptible to simulator sickness. Not including people who suffer form epilepsy or regularly use psychoactive medication .	testing period on users and their adaptability to those issues. First training sessions should be set up to measure individual abilities and user will be guided to stop the process when eg. dizziness will occur. Based on this data the system should be able to analyse individual abilities of each user.

make the app as easy and quick to use as possible by minimizing information that would not add value in augmented (or virtual) reality compared to traditional 2D manuals	Personal training for the users can be provided before the XR experience, later, well-being of the users can be regularly monitored and psychological support can be provided if necessary.
take regular breaks	Give users a questionnaire, after testing the XR experience, about their feelings. Repeat the questionnaire after different XR using time (es. 10 min, 20 min, 40 min, etc.) Category 7
Train employees in cybersecurity practices	Prepare pilots to limit time on XR experiences and/or include breaks Category 1
Create a safe physical environment	Limiting exposure time (having a specific time schedule for the use of the XR tools)
<- Agree-exclusion if not suited	Cat 1- Put a frame to the use of XR technologies to reduce risks
Usage of soft pads where possible	Small personalisations of the experiences to different users Category 6
Cat 4 - sessions to get used to those types of technologies	Cat3 - continuously evaluate and assess impacts
optimize lighting conditions	Provide feedback opportunities for users during pilots Category 7
Post-measure: Not be driving motorised vehicle or type of complex machinery at least 3 hours after the virtual experience.	Creation of a set of measures, with time and other kind of limitations, to limit the exposure to unsafe and health risks. C1
Use a dedicated network for the running of XR experience to reduce latency and associated issues Category: 5	Inform users about all the risks is possible to face during every process is planned into their company (both training and assistance) Category 3
cat 1 - monitoring to allow end of session in case of "bad" signals	1. Make sure users are allowed personalised break times during work shifts 3/5. Recurring monitoring of user's well-being and health
Difficult to interact with other colleagues' category 6	monitoring of usage time with alerts on recommended breaks and detection of movements that are too fast with alerts on possible risks of motion sickness
Head/neck motion tracking (jerkiness, stiffness patterns) Category: 1	1.Limit maximum usage time. Set mandatory breaks. 4. inform about rules for correct use in terms of time 9. the tool must include adjustment mechanisms (colors/transparencies) depending on the workplace
Register session duration until voluntary dropout Category: 1	1.Set strict time periods using the devices. 9. Recommend frequent brakes.
Cat 4. Motion discomfort or disorientation. Stable anchoring, low-latency rendering can help.	
Cat 9. Clear, consistent, non-cluttered UI design reduces cognitive load.	
Vision problems (Myopia, farsightedness Category 3	

TABLE 26: MEASURES IDENTIFIED FOR ISSUE 10

Technical measures	Non-technical measures
Perhaps iris recognition like on Microsoft's Hololens?	1. Risk management can also involve educating users 6. about the potential threats. 2. Security must be

	prioritised with implementations of secure authentication (two-factor, end-to-end encryption, etc) 4. Regular penetration testing.
Implementation of "human's controls"	Prepare a team on each pilot site to monitor legal compliance Category 5
3. Anonymisation/Data protection. Encryption. + Expanded ethics training for data managers to raise awareness of data sensitivity.	Include hints in XR experiences for potential risk actions Category 6
Train employees in cybersecurity practices	Cat 4 - continuous monitoring and security checks
Train employees in cybersecurity practices	6. Each pilot can have a specific guide about cybersecurity. Based on this guide, users of the XR tools can be educated and informed.
Create a safe physical environment	Create clear ethical guidelines prior to pilot starting and present them to users Category 6
1. User verification: two factor authentication and passkeys	Cat 6 - share and train on best practices and risks
Do not allow users to choose passwords that are too simple.	train users on the correct procedures to follow and give advice on how to minimize the risks arising from security breaches (for example, avoid automatic switching between networks if they are not trusted)
CAT 1 - Closed & secure system - IT measures to restrict access	Inform users about all the risks is possible to face during every process is planned into their company (both training and assistance) Category 3
CAT 2 - Data transmission protocol securizing	Adapt the experience to have less risk to intrusions, exposing he least information possible to unauthorized access. C1
Install apps ain kiosk mode Category: 6?	2. Prepare the Business itself against threats 6. Prepare the users on the dangers of cyberspace / Help them avoid said threats
Cat 7 Perform penetration tests on a regular basis	1. Two factors authentication mechanisms 6. User trainings and best practices
Implement multi-factor authentication (MFA) support in our XR login flows Category: 1	
Implement multi-factor authentication (MFA) support in our XR login flows Category: 6?	
MFA use to use mobile devices, in some areas are not allowed to use it and is possible that the user does not want to use his personal device for that	
Cat 6. Using Trusted Certificates, keeping firmware/software updated on devices.	
Use of biometric is forbidden in some industries	

TABLE 27: MEASURES IDENTIFIED FOR ISSUE 15

Technical measures	Non-technical measures
'+ Understanding the type of motion sickness that participants experienced/or prone to experiencing by using some questionnaires such as "Simulator Sickness	3. Users can have some information sessions before the XR usage and give a voluntary consent. As a preventive measure: Maybe not involving certain users who are susceptible to motion sickness. 2. Getting constant user

Questionnaire (Kennedy et al., 1993) Nausea? Oculomotor? Disorientation='	feedback by using usability questionnaires, other open-ended questionnaires that can be analysed with sentiment analysis etc.
The same "preventive" and "post" measures described in Issue 52 can be applied.	Prepare pilots to limit time on XR experiences and/or include breaks Category 1
request the signed consent of employees to use the devices and have them approved by the occupational health and safety department, and if necessary, by the trade unions to prevent possible occupational health and safety complaints	Monitor users regarding physical status Category 2
Limit repetitive motions	Cat 1 - Put a frame to the use, and have protocols
Create a safe physical environment	Train users for a correct ergonomical and physical use of XR devices and experiences Category 3
Optimize field of view of device, and combine it with availability to re-position objects... Category: 1	Cat 8 - Follow up, and monitor signs of discomfort
Limit time of use per person	provide guidelines on clinical cases in which it is not advisable to use the devices (e.g., if the user is wearing a neck brace due to an accident) and give advice on how to limit the health risks associated with them
Use a dedicated network for the running of XR experience to reduce latency and associated issues Category: 2	Inform users about all the risks is possible to face during every process is planned into their company (both training and assistance) Category 3
Optimize interactions & User Interfaces	Inform users about all the risks is possible to face during every process is planned into their company (both training and assistance) Category 3
Optimize interactions & User Interfaces	3. Provide proper training concerning the risks of using XR technologies so users are well informed and aware
distribute the hardware in such a way as to balance the weight and prevent the cooling system (fan) and therefore the hardware that heats up from being located at the front	Creation of a set of measures, with time and other kind of limitations, to limit the exposure to unsafe and health risks. C1
Head movement smoothness & tremor analysis: Inconsistencies in head motion may indicate nausea or proprioceptive mismatch. Category: 3	No. 6 along with guidelines for specific usage time (no. 3)
Hardware improvements	
Giving the opportunity to quickly hide virtual elements if a clear view of the surrounding area is suddenly needed (in case of danger for example)	
Cat 6. Spatial boundary warnings, pass-through awareness features to prevent collisions or accidents.	

TABLE 28: MEASURES IDENTIFIED FOR ISSUE 22

Technical measures	Non-technical measures
organize training and information courses on the use of XR devices	Train users for a correct ergonomical and physical use of XR devices and experiences Category 2
Create a safe physical environment	Adapt training to different experience levels and safety awareness perception Category 3
Create a safe physical environment	integrate the health risks to workers arising from the use of devices into risk assessment documents

report the advice on the use of devices that the manufacturers themselves often implement	Cat 2 - safety trainings
Presenting information sheet (or similar) beforehand + Participant/User Consent Form prior to XR usage	2. Safety Training for stuff and users
set up adapted safety protocols Train people	Dedicated internal implementation team that together with service provider will work on group of dedicated users
trainings + set up of safety protocols	Manuals dedicated to each specific pilot/case
trainings + set up of safety protocols	Preparing always ready to use graphic manuals with highlighting hazardous elements in training
decide if the device is for shared use or personal use in base of this you can create or update the policies	4. Prior XR specific training, information sheet, volunteer user consent) 5. Organizations can develop XR specific internal or shared policies. + Maybe using AI-based tools for constant safety monitoring.
User safety zone calibration & enforcement (e.g., guardian systems) Category:2	Verify if different PPE are needed during XR experiences Category 2
User safety zone calibration & enforcement (e.g., guardian systems) Category:9	

TABLE 29: MEASURES IDENTIFIED FOR ISSUE 26

Technical measures	Non-technical measures
Optimize content delivery	Reduce experiences duration and complexity if network conditions are not good Category 1?
-Offline XR training modules, such as standalone, on-device training and self-contained applications -Using wired connection for certain use cases.	Train users on hand-tracking gestures and latency considerations Category 3
Cat 2&6 - adaptative content depending on bandwidth	Increase offline training modules
Work close with legal and compliance department	Maybe reduce the dependency on online activities?
Cat 7 - Dedicated high quality networks + load balancing	Cat1- follow up network performance and have measures to have a mitigation strategy
Try to capture real-time network quality metrics affecting XR streaming stability (bandwidth, jitter, packet loss, round-trip time) Category:3	improve connectivity within the local network in use and perhaps consider the use of dedicated subnets with higher priority on the use of available bandwidth in cases where it is strictly necessary.
Having access to high-level hardware services in the cloud (such as Shadow) could help in cases of shared use of multiple devices.	
Install dedicated 5G network	

TABLE 30: MEASURES IDENTIFIED FOR ISSUE 29

Technical measures	Non-technical measures
Cross-device accessibility & adaptative content quality (adapted hardware depending on possible use for the structure)	Adapt experiences complexity to IT infrastructure and resources of each organisation Category 1

Cat 1 XR technologies need to be integrated in the technological industry flow	Implement a program for the common purchase or leasing of devices among MotivateXR organisations/users Category 1
For complex cases, human assistance (skilled personal), for basic cases, AI assistance (LLM) can be used to improve adoption and accessibility.	9. Promote accessibility by providing the necessary tools for users (hardware or software)
For the personnel trainings in order to upskill them and Cat5 AI-Powered Assistance to further support them	searching sources of financial contribution - local/regional
Optimized infrastructures for XR use, along with training for employees as they begin accessing the system, to ensure proper use of all components.	Organize meetings to demonstrate the XR benefits for the real process planned in the specific company Category 8
Regarding the IT infrastructure issues Cat4 could help	Training centres
Latency and network health benchmarking across different deployment sites/spaces Category: 4	Trial periods
Train IT people in support XR devices, and encourage them to use it	Cat 1&4 - Define a suited policy including specifying the needs in terms of infrastructure & trainings
Include easily accessible, short tutorials on how to use the specific device, perhaps guided by AI with support for calibrating the device for each user.	Increasing AI-assisted help and combining it with human-assisted help strategies
It could always be useful to have screens that display (for example, in mirroring mode) the scene seen by each user so that an experienced user can guide them.	Provide dedicated spaces for using the devices and fill them with digital tips and help guides that are easily accessible to users.

TABLE 31: MEASURES IDENTIFIED FOR ISSUE 37

Technical measures	Non-technical measures
Submitting access requests for the use of XR facilities or systems and reviewing permission logs in case of any issues.	Maybe for a rapid solution, combination of non-technical with technical approaches. Defining potential rules 6. 7. for the XR specific training and using this information combined with AI-assistance (Using RAG and/or custom training, fine-tuning an LLM model for building a policy bot for assistance etc).
Train employees in cybersecurity practices	Identify a DPO for each organisation and "force" XR authoring to be checked by him Categories 1, 7
AI-driven tools (legal/ethics bots) to identify inadequate behaviour and help users within the XR framework. Category 2+4 both at a higher-level Governance Frameworks (2) but also at XR platform level (4)	Implement periodical trainings to remind ethical and legal considerations of XR experiences Categories 3 creating policy recommendations and ready to implement laws prepared by experienced projects
Action/event audit logs (who did what, when, where) Category: 4	3. Establishing personal data ownership rights in the virtual space / strict limits on the usage rights (in combination with no. 6)
always have data on where and when the device was used, perhaps with a GPS system, or make it unusable outside the specific internal network	Cat1 & 7 - ensure data protection & define legal aspects in case the risk materializes
	inform users about issues relating to the sharing of personal data and any responsibilities they may incur in the event of illegal use being detected
	2. Provide comprehensive safety guidelines for user 7. Internal self-regulatory bodies to ensure legal alignment

TABLE 32: MEASURES IDENTIFIED FOR ISSUE 40

Technical measures	Non-technical measures
Create a mandatory training program to ensure all employees understand the protocols and standards applied to XR systems	Provide support on safety standards and protocols from MotivateXR to users and organisations Category 1
Creating "shared" safety guidelines between organisations and getting feedback from the "experts" during this process to standardize the protocols.	Nominate a legal/ethical committee in MotivateXR to monitor compliance of users of the system Category 3
CAT 4 & 6 - set up adapted safety protocols in advance - update with time	Generate official MotivateXR trainings on ethical and legal issues and release them to all the users of the system Category 1, 5
need to include health risks associated with the use of XR devices in each company's risk assessment documents	Cat 1 - Define standards, and train users to be aware of it
Create a consortium at EU level which regulate the use of XR similar than the one who regulate the use of IA	Establish point of contact/reference within Motivate XR project to consult those kinds of documents
Use policy-aware content deployment pipeline (with compliance checks) Category: 5	Defining XR specific safety standards and constantly updating them with the user and expert feedback
Work close with legal and compliance department	organize regular meetings with security experts to stay up to date on the latest regulations issued by the relevant authorities
Work close with legal and compliance department	Establish shared Project protocols, along with regular monitoring and compliance mechanisms
	7. Connect with relevant stakeholders that can help ensure alignment and compliance with novel legal requirements
	Create a "specialist" team, specialized in such tasks, to avoid irregularities and/or gaps in their standards and protocols.

TABLE 33: MEASURES IDENTIFIED FOR ISSUE 47

Technical measures	Non-technical measures
Definitely 1, 2, and 3. + Getting feedback from the users by using questionnaires like System Usability Scale (Brooke, 1995) + combining with open-ended non-biased qualitative questionnaires, analysing the sentiment of their responses to understand the reasons behind the potential usability and proficiency issues.	Adapt training and XR experiences to users experience and proficiency levels Category 3
Offer flexible scheduling	Train XR authors from organisations on pedagogical approaches to create the experiences Category 5
Train employees in cybersecurity practices	1,2,3. -> Assessment of the user beforehand for correct assignment,
Include XR training as a standard part of the onboarding process for new employees	Cat 1 - adapt to learners' profiles

Include easily accessible, short tutorials on how to use the specific device, perhaps guided by AI with support for calibrating the device for each user.	create those open modules of training for general public to create interest and critical mass for XR experience and present its potential
CAT 7 - Content personalization - adaptive learnings (complexity)	Cat 7 - get feedback and ensure continuous improvements & adaptations
benchmarking of device usage for completing simple tasks and AI-guided assessment of the most difficult instructions to understand, the most difficult movements to perform, or the most complex interactions, etc...	Identify the types of users who will benefit from the XR experience, categorize them based on their experience in using digital tools, and provide specific training for each category.
Promote the use of XR not only for business use,	
Real-time performance metrics (task completion time, error rate, retries) - Tracks individual learner performance to detect struggles or gaps in understanding. Category:1	
Category 1 assessments/tools to evaluate the users' level of experience with XR and adapt learning paths based on this	

TABLE 34: MEASURES IDENTIFIED FOR ISSUE 50

Technical measures	Non-technical measures
Create a testing program that includes all user scenarios to adapt the systems for everyone."	Train XR authors from organisations on inclusion principles to create the experiences Category 1
Train employees in cybersecurity practices	Include end-users with visual impairment in the co-design process of XR experiences Category 4i'm back
AI-guided voice that, for example, helps the user to frame the scene from a better position in case of incomprehensible or distant interactions	6. Audio-Haptic design integration 7. Inclusive education for all, both for developers and users
implementation of intelligent voice commands (such as on Hololens, for example)	Cat 4 & 6 - Initial design to take into account specific needs + feedback integration
Multi-sensory integration (audio-TTS-STT, haptic) Using combined computer vision + LLM model architectures for visual descriptions and help for navigation	Prep profile of 'standard' user
possibility to change the colors of elements (icons palettes for example) or scale them for visually impaired or color blind users, and so on...	Cat 8 - continuous evaluation for improvements
CAT 1-3-8 : Multimodal interactions (voice, haptic etc)	benchmarking of the XR experience for visually impaired users and subsequent correction of aspects that limit their ability to use it
Audit UI for example contrast or font size. Perform something like WCAG tests. Category: 4	5. View the experience from that side to find the specific solution + 7. In combination with no.5.
Categories 1+3+4 using adaptive UI for users (higher contrast visuals larger fonts more dynamic colors) and including voice interactions (audio descriptions) and haptic feedback to assist them	
Orden confirmation by voice (device reply with the confirmation of the order or movement)	
Automated orders based on environment and process automation	

4.4. CONSOLIDATED LIST OF MEASURES

This section outlines the approach used to consolidate the measures identified in the workshops with those derived from the analysis of academic papers.

4.4.1. APPROACH TO CONSOLIDATE THE LIST OF MEASURES

The consolidation of mitigation measures from the workshops and the academic literature involved addressing two main challenges. First, several workshop-derived measures were duplicates or subsets of one another and therefore required cleaning and refinement. Second, many measures were relevant to multiple issues, necessitating a classification system to avoid redundancy and ensure conceptual consistency.

To resolve these challenges, all measures were organised according to the type of action they proposed, allowing similar interventions to be grouped under shared conceptual categories (e.g., Physical Ergonomics & Device Setup, Interaction Design & User Interfaces). This typology was first developed based on the set of measures generated during the workshops. This process combined automated analysis using GPT-4o with structured human oversight in an iterative workflow. Initially, the workshop measures linked to a single issue (Issue 6) were classified into distinct categories, which served as the foundation for the typology. In subsequent iterations, measures from additional issues were integrated and either assigned to existing categories or used to refine or expand the typology where new concepts emerged.

After each iteration, the categorisation and associated labels were reviewed to ensure that each measure was grouped appropriately and that category descriptions accurately represented their content and intent. This iterative process continued until a stable and coherent typology was established. The final list of categories is presented in Table 35.

TABLE 35: CATEGORIES OF MEASURES FOUND THROUGH THE WORKSHOP

Category	Description
Physical Ergonomics & Device Setup	Ensures that XR hardware is comfortable, safe, and adjustable for prolonged use across diverse user profiles by addressing physical strain, fit, and usage conditions.
Interaction Design & User Interfaces	Focuses on creating intuitive, adaptive, and multi-sensory XR interfaces that enhance usability, reduce cognitive load, and support inclusive and immersive interaction.
System Performance & Stability	Addresses the need for reliable, low-latency, and scalable XR system performance across networks, devices, and deployment environments to ensure smooth user experiences.
Safety & Environmental Conditions	Ensures the physical safety of XR users by managing environmental risks, defining safety protocols, and enabling real-time monitoring and emergency responsiveness.
Health Risk Management & User Well-being	Protects user health by managing simulator sickness, physical discomfort, and cognitive overload through screening, monitoring, and well-being support before, during, and after XR use.
Data Security & Access Control	Implements strong cybersecurity practices, data protection measures, and access restrictions to secure sensitive user information and prevent unauthorized system access.

XR Training & Organizational Preparedness	Supports effective and safe XR deployment through structured training, role-based education, onboarding, and internal coordination tailored to user capabilities and tasks.
XR Accessibility, Inclusion & Deployment Infrastructure	Ensures XR systems are inclusive, accessible, and equitable by adapting interfaces, infrastructure, and training to diverse user needs, abilities, and operational contexts.
Legal Governance & Accountability in XR	Establishes organizational structures, policies, and oversight mechanisms to ensure legal compliance, ethical use, and transparent accountability in XR environments.
XR Regulatory Strategy & Standards Alignment	Aligns XR deployments with evolving regulations and industry standards by creating shared protocols, compliance frameworks, and engagement with legal and regulatory bodies.

Following the establishment of the workshop-based typology, the measures identified through the analysis of academic papers were integrated. Using GPT-4o, each measure from the literature was compared against the typology to determine which existing categories it addressed. When relevant measures were identified in the academic sources that did not correspond to any existing category, these were added to extend the typology.

This comparison also allowed for cross-validation between the two datasets, identifying overlaps and complementarities between issues discussed in the literature and those raised during the workshops. Section 4.4.2 presents the consolidated set of measures.

4.4.2. RESULTS

The consolidated list of measures can be found in Table 36 through Table 45 below provides a comprehensive overview of possible interventions to address the issues identified through both the stakeholder workshops and the review of academic literature. In total, 268 distinct measures were identified and grouped into ten thematic categories covering the full spectrum of XR deployment: physical ergonomics and device setup, interaction design and user interfaces, system performance and stability, safety and environmental conditions, health risk management and user well-being, data security and access control, XR training and organizational preparedness, accessibility and deployment infrastructure, legal governance and accountability, and regulatory strategy and standards alignment.

Looking across the categories, the distribution of measures is uneven, with some areas considerably more populated than others. The single largest cluster is in XR accessibility, inclusion, and deployment infrastructure, which contains 51 measures. This reflects strong recognition in both the workshops and the literature that XR systems must be designed for diverse users and contexts, and that deployment depends on accessible infrastructure and support. Measures here include multimodal sensory feedback (haptics, audio descriptions, adaptive visuals), screen reader compatibility, co-design with visually impaired users, as well as organizational supports such as dedicated helpdesks, training policies, and low-cost XR deployment options. This category directly addresses Issue 50 (exclusion of visually impaired users) and Issue 29 (infrastructure and accessibility gaps) but also links to more general concerns about equitable and sustainable adoption.

The second most numerous category is XR training and organizational preparedness, with 30 measures. These address Issues 22, 29, and 47 by proposing structured onboarding, adaptive training paths tailored to learner profiles, pilot programs with diverse users, XR “champions” to support adoption within departments, and continuous feedback mechanisms such as usability surveys and post-session assessments. Taken together, these measures highlight that training and preparedness are perceived as central to safe and effective XR adoption, with a breadth that ranges from individual skills to organizational readiness.

Other categories with substantial coverage include health risk management and user well-being (28 measures) and safety and environmental conditions (27 measures). These directly respond to Issues 9 and 15, which concern physical discomfort, cybersickness, and accident risks, as well as Issue 22 on updating safety protocols. Interventions here include pre-use screening, post-use recovery periods, real-time monitoring of discomfort, guardian systems and pass-through features, and structured cooldown protocols. These categories combine preventive measures (screening, ergonomic training, exclusion criteria) with responsive ones (real-time monitoring, adaptive adjustments), offering a broad toolkit for protecting users’ physical and cognitive well-being.

The mid-range categories, physical ergonomics and device setup (25 measures), interaction design and user interfaces (25 measures), data security and access control (24 measures), and system performance and stability (22 measures), are equally important, but slightly more focused. Ergonomics and UI measures primarily address Issues 6, 9, 15, 47, and 50, with interventions such as adjustable optics and fit checks, dynamic contrast and brightness settings, adaptive UIs, multimodal input, and clear visual metaphors to reduce cognitive load. Security measures concentrate on Issue 10 (cybersecurity and economic risks) through layered approaches including zero-trust architectures, multi-factor authentication, anomaly detection, and secure device pairing. Performance measures respond chiefly to Issue 26 (latency and bandwidth) with highly technical proposals such as maintaining motion-to-photon latency below 10 ms, foveated rendering, edge/fog offloading, and adaptive frame rates.

By contrast, the categories of legal governance and accountability in XR (21 measures) and XR regulatory strategy and standards alignment (17 measures) are the least populated. These categories nonetheless play a strategic role in addressing Issues 37 and 40 on the adequacy of legal frameworks and the need for updated standards. Measures here include appointing Data Protection Officers, establishing compliance teams, embedding privacy-by-design into authoring tools, developing shared safety protocols across organizations, and participating in regulatory consortia. Though fewer in number, these interventions provide the essential governance backbone without which the more technical and ergonomic measures cannot be sustained over time.

In terms of impacts, the consolidated list shows that some issues are addressed more extensively than others. Physical discomfort and accident risks (Issue 15) dominate with 109 measures, followed by health and cognitive risks (Issue 9, 83 measures) and efficiency and usability challenges (Issue 6, 76 measures). Together, these three issues account for the majority of measures, underlining the central concern with user safety, health, and usability. A second cluster, Issues 22, 29, 40, 47, and 50, is moderately covered, with between 38 and 43 measures each, focusing on preparedness,

inclusivity, and organizational adaptation. Cybersecurity (Issue 10, 39 measures) is well covered but confined to a narrower set of security-focused interventions. Legal frameworks (Issue 37, 26 measures) and performance/latency (Issue 26, 20 measures) are least frequently addressed, suggesting that while they are recognized, they have received comparatively less attention in both workshop discussions and the academic literature.

Below are overviews of the consolidated mitigation measures grouped by category.

TABLE 36: MEASURES IDENTIFIED FOR THE CATEGORY 'PHYSICAL ERGONOMICS & DEVICE SETUP'

Measures	Issues addressed	Source
Optimize battery-to-weight ratio to balance comfort with usage time.	[6,9,15]	Workshop, Papers
Design hardware for balanced weight distribution, avoiding heat concentration near the face.	[6,9,15]	Workshop, Papers
Use soft padding and adjustable straps to enhance long-term wear comfort.	[6,9,15]	Workshop, Papers
Reduce device weight and bulk to support prolonged use without causing fatigue.	[6,9,15]	Papers
Design headset form factors and IPD ranges to fit a wider diversity of head shapes, sizes, and gender-related anatomical differences.	[6,9,15,50]	Papers
Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision correction needs.	[6,9,15,50]	Papers
Implement fit-score metrics during onboarding, including interpupillary distance (IPD) checks and field-of-view alignment.	[6,9,15]	Workshop, Papers
Include adjustable focus lenses to accommodate vision differences (e.g., myopia, hyperopia).	[6,9,15,50]	Workshop, Papers
Use eye-tracking feedback to assist users in correctly positioning the headset.	[6,9,15]	Workshop, Papers
Integrate dynamic vergence and accommodation adjustment to reduce eye strain and visual discomfort during immersive use.	[9,15]	Papers
Use adjustable optics and personalized visual calibration to improve clarity and reduce fatigue from mismatched focal alignment.	[9,15]	Papers
Implement pre-use visual calibration routines based on stereo acuity, eye dominance, and interpupillary distance for optimal fit.	[9,15]	Papers
Adjust display brightness and contrast automatically or manually to reduce visual fatigue under different lighting conditions.	[9,15]	Papers
Limit continuous XR session duration to avoid physical fatigue and strain.	[9,15]	Workshop, Papers
Provide acclimation sessions to help users gradually adapt to XR hardware.	[9,15]	Workshop, Papers
Add cooling mechanisms or materials to XR headsets to prevent heat build-up around the face during extended sessions.	[9,15]	Papers
Design the XR system to support thermal comfort across varying durations, activities, and individual physiological differences.	[9,15]	Papers
Perform initial device calibration and enable real-time adjustments during use.	[6,9,15]	Workshop, Papers
Conduct preventive ergonomic testing for different user profiles before deployment.	[6,15,47]	Workshop, Papers

Track head/neck motion patterns to detect signs of discomfort or strain.	[6,15]	Workshop, Papers
Monitor head movement smoothness and tremor as indicators of user disorientation or fatigue.	[6,15]	Workshop, Papers
Log session duration and voluntary dropouts to identify potential ergonomic issues.	[6,15]	Workshop, Papers
Provide real-time ergonomic feedback through posture tracking and alerts to help users avoid strain during XR interactions.	[6,15]	Papers
Train users in proper ergonomic use of XR devices to avoid strain and injury.	[6,15,22]	Workshop, Papers
Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.	[6,15,22,47]	Workshop, Papers

TABLE 37: MEASURES IDENTIFIED FOR THE CATEGORY 'INTERACTION DESIGN & USER INTERFACES'

Measures	Issues addressed	Source
Design clear, consistent, and non-cluttered UIs to reduce cognitive load and improve usability.	[6, 9, 47, 50]	Workshop, Papers
Design interfaces that reduce visual clutter by automatically adjusting displayed information based on task complexity and cognitive load.	[6, 9, 47]	Papers
Optimize interactions for XR by reducing non-essential information compared to traditional 2D interfaces.	[6, 9]	Workshop, Papers
Optimize text and icon legibility using clutter-reduction techniques and enhanced contrast on complex backgrounds.	[9, 50]	Papers
Use appropriate visual contrast and avoid overly bright elements to reduce eye fatigue.	[9, 15, 50]	Workshop, Papers
Provide immediate visual or auditory feedback for all user actions to reinforce interaction.	[6, 47]	Workshop, Papers
Implement visual feedback mechanisms like highlighting or snapping to assist accurate target selection.	[6, 47]	Papers
Provide spatial visual cues such as drop shadows or contact webs to improve depth perception and interaction accuracy.	[15]	Papers
Enable adaptive user interfaces, adjusting complexity and layout to user experience level and context.	[47, 50]	Workshop, Papers
Support real-time adjustment of interface layout and interaction modes based on user skill level and task progression.	[47]	Papers
Adapt interface elements dynamically based on user attention, workload, or environmental lighting conditions.	[6, 9]	Papers
Allow individual calibration of the XR interface to accommodate user preferences and reduce discomfort during prolonged use.	[6, 9, 15]	Papers
Incorporate multimodal interaction options such as voice commands, haptics, and gestures.	[50]	Workshop, Papers
Support multi-sensory integration, including text-to-speech (TTS), speech-to-text (STT), and haptic feedback.	[50]	Workshop, Papers
Enable intuitive object selection and manipulation through gaze-assisted or multimodal input (e.g., eye + hand coordination).	[6, 9]	Papers
Integrate micro gestures and fine motor control to support precise and low-effort interaction with virtual objects.	[6, 15]	Papers

Offer intuitive head-controlled or radial menu options to reduce arm fatigue and physical strain in hands-free scenarios.	[9, 15, 50]	Papers
Facilitate real-time collaboration by improving interaction methods with virtual representations of colleagues (e.g., life-size avatars, voice sync).	[6, 26]	Workshop, Papers
Ensure motion synchrony between user actions and the virtual environment to maintain immersion and reduce disorientation.	[9, 15]	Workshop, Papers
Include context-aware automation, like automated task prompts based on user environment or behaviour.	[47]	Workshop, Papers
Implement real-time UI adjustments (e.g., colour modes, transparency) to suit different work environments.	[6, 9, 29]	Workshop, Papers
Use user-friendly visual metaphors and consistent layout logic to support recognition over recall in interface navigation.	[47]	Papers
Include safety hints and risk prompts within the interface to alert users during potentially unsafe actions.	[15, 22, 40]	Workshop
Personalize content and UI layouts based on pre-assessed user profiles and learning paths.	[47]	Workshop, Papers
Incorporate guided tutorials and walk-up-and-use interfaces to lower the learning curve for new XR users.	[29, 47]	Papers

TABLE 38: MEASURES IDENTIFIED FOR THE CATEGORY ‘SYSTEM PERFORMANCE & STABILITY’

Measures	Issues addressed	Source
Ensure responsiveness and low-latency rendering to maintain smooth, lag-free user interactions—especially critical in complex 3D environments.	[6, 9, 15, 26]	Workshop, Papers
Minimize motion-to-photon latency to below 10 milliseconds to reduce sensory mismatch and ensure real-time system responsiveness in XR environments.	[6, 9, 15, 26]	Papers
Benchmark motion-to-display latency and rendering performance under realistic usage scenarios to detect bottlenecks and guide optimization.	[6, 15, 26]	Papers
Maintain consistently high framerates across devices to prevent visual discomfort and motion sickness, especially during prolonged XR sessions.	[9, 15]	Papers
Improve both hardware and software performance, including optimizing FPS and minimizing lag, especially during graphics-intensive tasks.	[6, 15, 26]	Workshop, Papers
Reduce display lag in XR headsets to improve interaction precision and lower the likelihood of simulator sickness.	[9, 15]	Papers
Optimize 3D assets and reduce polygon counts to lower GPU load and improve rendering speed without compromising visual fidelity.	[6, 26]	Papers
Adapt rendering resolution dynamically to hardware capabilities and runtime performance to maintain stable frame rates and reduce cybersickness.	[9, 15, 26]	Papers
Adapt XR content dynamically based on available bandwidth to ensure stability during fluctuating network conditions.	[26]	Workshop, Papers
Apply adaptive frame rendering techniques to prioritize motion or spatial detail based on scene dynamics and user activity, improving latency handling.	[6, 26]	Papers
Use foveated rendering techniques to reduce processing in peripheral vision and improve overall rendering performance with minimal perceived quality loss.	[26]	Papers
Use dedicated high-quality networks or wired connections to reduce latency and jitter, particularly for real-time or multi-user XR experiences.	[26]	Workshop, Papers
Install and prioritize dedicated 5G or private subnets to guarantee bandwidth availability during XR sessions.	[26]	Workshop, Papers

Use predictive prefetching and caching techniques at the network edge to ensure timely content delivery during XR sessions, even in fluctuating conditions.	[26]	Papers
Deploy load-balancing mechanisms to distribute XR traffic and prevent bottlenecks across devices or locations.	[26]	Workshop, Papers
Use cloud-based high-performance computing resources (e.g., Shadow or similar) to offload rendering when using multiple or low-power devices.	[26]	Workshop, Papers
Offload rendering tasks to fog or edge computing nodes to bring processing closer to the user and reduce latency in real-time XR applications.	[26]	Papers
Monitor real-time network metrics (e.g., bandwidth, jitter, packet loss, round-trip time) to detect and respond to performance issues.	[26]	Workshop, Papers
Conduct latency and performance benchmarking across deployment sites to identify performance gaps or optimization needs.	[26]	Workshop, Papers
Continuously monitor network and system performance, and implement mitigation strategies proactively.	[6, 15]	Workshop
Enable early detection of technical malfunctions, with alerts and system diagnostics to prevent user disruption.	[6, 15]	Workshop
Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.	[9, 15, 26]	Workshop

TABLE 39: MEASURES IDENTIFIED FOR THE CATEGORY 'SAFETY & ENVIRONMENTAL CONDITIONS'

Measures	Issues addressed	Source
Ensure a safe physical environment for XR use, including dedicated spaces optimized for movement and spatial awareness.	[6, 15, 22]	Workshop, Papers
Calibrate and enforce safety zones using tools like guardian systems and spatial boundary warnings.	[15, 22]	Workshop, Papers
Use visual, auditory, or haptic boundary warnings to alert users when approaching physical hazards during immersive XR sessions.	[15, 22]	Papers
Incorporate real-time collision detection systems or obstacle alerts to prevent accidents due to reduced real-world awareness.	[15, 22]	Papers
Enable pass-through and quick-hide features to allow immediate visibility of the real environment in case of emergency or disorientation.	[15]	Workshop, Papers
Optimize environmental conditions, including appropriate lighting and ventilation to support XR use.	[6, 15]	Workshop, Papers
Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.	[6, 9, 15]	Papers
Ensure headset ergonomics, including balanced weight and adjustable fit, to reduce neck strain and physical discomfort during extended use.	[6, 9, 15]	Papers
Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.	[9, 15, 22]	Workshop, Papers
Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.	[9, 15, 22]	Papers
Limit continuous use of XR headsets in high-intensity applications and enforce stricter break schedules based on observed discomfort indicators.	[15, 22]	Papers
Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emergency procedures.	[15, 22]	Workshop, LLM
Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.	[6, 15, 22]	Workshop

Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.	[15, 22, 40]	Workshop
Develop shared safety guidelines collaboratively with experts and partner organizations for standardization and consistency.	[22, 40]	Workshop
Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment site.	[15, 22]	Workshop
Incorporate manufacturer safety guidance into internal training and documentation.	[22]	Workshop
Use AI-based or automated tools to monitor real-time usage signals (e.g., discomfort, confusion) and trigger session end if needed.	[9, 15]	Workshop, Papers
Monitor user head and eye movement data to detect early signs of cybersickness and automatically adapt the XR experience accordingly.	[9, 15]	Papers
Implement standardized assessment tools like the Simulator Sickness Questionnaire (SSQ) to monitor and document cybersickness symptoms.	[9, 15]	Papers
Evaluate and minimize the risk of cybersickness for vulnerable users by accounting for gender, previous VR exposure, and motion sickness history.	[9, 15]	Papers
Design virtual environments to minimize sudden movements, motion mismatches, or acceleration patterns that contribute to motion sickness.	[9, 15]	Papers
Integrate dynamic field-of-view (FOV) reduction or rest frame techniques to minimize disorientation and cybersickness during XR use.	[9, 15]	Papers
Adjust interpupillary distance (IPD), screen brightness, and refresh rate settings to reduce eye strain and visual discomfort.	[15, 22]	Papers
Verify whether different PPE (personal protective equipment) is required based on the context and use case.	[6, 15, 22]	Workshop
Inform users of all potential risks, including physical, operational, and situational hazards, before and during XR usage.	[15, 22]	Workshop
Establish policies distinguishing between shared vs. personal use of XR devices, and adapt hygiene and safety protocols accordingly.	[15, 22]	Workshop, Papers

TABLE 40: MEASURES IDENTIFIED FOR THE CATEGORY ‘HEALTH RISK MANAGEMENT & USER WELL-BEING’

Measures	Issues addressed	Source
Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.	[9,15,22]	Workshop, Papers
Evaluate users’ well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.	[9,15,22]	Workshop, Papers
Integrate multimodal discomfort monitoring (e.g., combining SSQ, heart rate, and behavioral cues) to trigger session termination if thresholds are exceeded.	[9,15,22]	Papers
Administer structured post-use recovery times (e.g., at least 10-15 minutes) before users return to high-focus tasks such as driving or machinery operation.	[9,15]	Papers
Educate users on safe post-use behavior, such as avoiding driving or operating machinery immediately after XR sessions.	[15]	Workshop, Papers
Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid exposing vulnerable users to XR-related health risks.	[9,15]	Workshop
Provide users with clear information sheets and obtain informed consent before XR use, including any known risks or side effects.	[37]	Workshop

Integrate XR-related health risks into organizational risk assessment documents and update them regularly.	[22]	Workshop
Provide follow-up support, including psychological or medical guidance if discomfort persists after XR use.	[15]	Workshop, Papers
Use test sessions to gauge users' initial adaptation and guide recommendations for further participation.	[9,15,47]	Workshop
Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort.	[9,15,47]	Workshop
Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements) and allow or trigger session termination if needed.	[9,15,22]	Workshop, Papers
Detect early signs of cybersickness using physiological signals (e.g., heart rate, head movement) and automatically apply mitigation strategies like FOV reduction or scene blur.	[9,15]	Papers
Use real-time eye-tracking data (e.g., pupil dilation) to monitor cognitive load and trigger adaptive task adjustments or rest breaks when mental strain is detected.	[9,15]	Papers
Train systems to predict cybersickness onset using motion data and user behavior to proactively intervene before discomfort escalates.	[9,15]	Papers
Set and enforce session duration limits, with alerts and mandatory breaks to prevent overexposure and fatigue.	[9,15]	Workshop, Papers
Limit exposure to immersive XR sessions based on evidence-based thresholds (e.g., max 30-60 minutes) to prevent visual fatigue and simulator sickness.	[9,15]	Papers
Allow personalized break schedules based on user comfort and adaptability.	[9,15]	Workshop
Offer passive viewing modes (e.g., guided or pre-recorded tours) as an alternative for users sensitive to active interaction in XR environments.	[9,15]	Papers
Use hybrid locomotion methods (e.g., HeadJoystick or body-lean navigation) to minimize motion sickness compared to controller-based movement.	[9,15]	Papers
Ensure hardware and software support ergonomic use (e.g., hand posture techniques like ProxyHand) to prevent fatigue during extended XR sessions.	[15]	Papers
Include ergonomics-based posture monitoring (e.g., via visual/auditory cues) to help users maintain safe physical positioning during XR use.	[15]	Papers
Adjust interpupillary distance (IPD) settings on headsets for each user to reduce eyestrain and depth perception errors.	[15]	Papers
Apply adaptive brightness and contrast settings to accommodate user comfort and reduce the likelihood of visual fatigue or disorientation.	[15]	Papers
Incorporate haptic or vibrotactile feedback to balance sensory input and reduce overreliance on visual cues, lowering the risk of simulator sickness.	[15]	Papers
Design virtual environments with simplified visuals or reduced scene complexity to lessen cognitive load and spatial disorientation, especially for vulnerable users.	[9,15]	Papers
Provide real-time session feedback through virtual agents or avatars that can recognize discomfort and offer personalized guidance or suggest a break.	[9,15]	Papers
Include special usage guidelines for clinical or physical conditions (e.g., neck braces, recovering from injuries).	[9,15]	Workshop

TABLE 41: MEASURES IDENTIFIED FOR THE CATEGORY 'DATA SECURITY & ACCESS CONTROL'

Measures	Issues addressed	Source
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Ensure a closed and secure system architecture with access restrictions tailored to user roles.	[10]	Workshop, Papers
Use zero-trust architecture principles to authenticate every access request within the XR infrastructure, regardless of network origin.	[10]	Papers
Use secure data transmission protocols (e.g., HTTPS, VPNs, encrypted APIs) to protect data in transit.	[10]	Workshop, Papers
Apply data anonymization and encryption techniques to protect sensitive user data both in transit and at rest.	[10]	Workshop, Papers
Restrict and monitor access to XR sensor data (e.g., motion, location) to prevent unauthorized use or inference of sensitive personal information.	[10]	Papers
Mitigate side-channel attacks by securing XR input devices (e.g., controllers, eye tracking, motion sensors) against inference-based intrusions.	[10]	Papers
Implement strong multi-factor authentication (MFA), including options like passkeys or hardware tokens where mobile use is restricted.	[10]	Workshop, Papers
Use biometric authentication (e.g., iris recognition) only where compliant with privacy laws and supported by the hardware and user context.	[10]	Workshop, Papers
Implement continuous, passive biometric authentication methods (e.g., gait or head motion) to secure access during extended XR sessions.	[10]	Papers
Enable secure device pairing mechanisms for XR peripherals (e.g., finger-tracking-based pairing) to prevent unauthorized connections.	[10]	Papers
Enforce strong password policies, preventing the use of weak or easily guessed passwords.	[10]	Workshop
Deploy machine learning-based anomaly detection systems to identify suspicious access patterns or user behaviours in real time.	[10]	Papers
Integrate intrusion detection systems (IDS) at both network and application levels to monitor and respond to threats targeting XR components.	[10]	Papers
Enable continuous security monitoring and real-time threat detection across XR infrastructure.	[10]	Workshop, Papers
Perform regular penetration testing and vulnerability assessments to identify and fix security gaps.	[10]	Workshop, Papers
Use blockchain-based provenance tracking to ensure tamper-proof logging of access and actions within collaborative XR environments.	[10]	Papers
Embed secure-by-design principles in XR hardware and software development to reduce exploitable vulnerabilities at the system level.	[10]	Papers
Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.	[10]	Workshop, Papers
Enable kiosk mode for XR apps to restrict access and prevent unauthorized modifications.	[10]	Workshop
Design experiences to minimize data exposure, only collecting and storing what is strictly necessary.	[10]	Workshop, Papers
Establish human oversight mechanisms to review system decisions or anomalies related to user access or security behavior.	[10]	Workshop
Train data managers and IT staff on data ethics, privacy responsibilities, and regulatory compliance.	[40]	Workshop
Coordinate closely with legal and compliance departments to ensure security strategies align with organizational and legal requirements.	[40]	Workshop
Apply differential privacy techniques to XR data collection workflows to minimize the risk of re-identifying users while preserving utility.	[10]	Papers

TABLE 42: MEASURES IDENTIFIED FOR THE CATEGORY 'XR TRAINING & ORGANIZATIONAL PREPAREDNESS'

Measures	Issues addressed	Source
Develop structured XR training programs for employees, including mandatory sessions on safety, proper use, and organizational protocols.	[6, 9, 15, 22]	Workshop, Papers
Include XR training in onboarding for all new employees to ensure consistent baseline knowledge.	[9, 15, 22, 29, 47]	Workshop, Papers
Provide structured onboarding tutorials for XR environments to help novice users build confidence and reduce cognitive overload.	[6, 9, 47]	Papers
Organize hands-on training sessions and courses on XR device usage and interaction principles.	[9, 15, 22, 47]	Workshop, Papers
Train users on specific XR interaction techniques, such as hand tracking and latency-aware gestures.	[6, 47]	Workshop, Papers
Adapt training to learner profiles, accounting for experience level, digital proficiency, and safety awareness.	[47]	Workshop, Papers
Use pre-assessments to assign training levels and customize content based on user proficiency.	[47]	Workshop, Papers
Adapt training materials and interaction techniques to accommodate users with varying levels of spatial ability and digital fluency.	[47]	Papers
Use learning style assessments to tailor XR training content to users' preferred modalities, such as visual, auditory, or kinesthetic learning.	[47]	Papers
Identify different user groups (based on tool familiarity) and deliver customized training paths accordingly.	[29, 47]	Workshop, Papers
Implement adaptive XR training systems that adjust difficulty and content in real-time based on individual performance and cognitive load.	[47]	Papers
Integrate personalized feedback mechanisms that guide users toward safer and more effective interaction patterns in XR environments.	[47]	Papers
Develop performance dashboards and self-assessment tools to help users track progress and identify skill gaps during XR training.	[47]	Papers
Incorporate continuous feedback mechanisms, including: System Usability Scale (SUS), Simulator Sickness Questionnaire (SSQ), open-ended sentiment surveys and interviews, and post-training assessments.	[15, 47]	Workshop, Papers
Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates.	[6, 15, 22, 47]	Workshop, Papers
Involve diverse users in pilot testing (age, background, familiarity) to validate and improve training design.	[6, 47]	Workshop, Papers
Create dedicated training centers or designated XR zones for practice and onboarding.	[29]	Workshop
Assign XR champions within departments to support local adoption, mentor peers, and assist with technical or onboarding challenges.	[29, 40]	Papers
Establish a dedicated XR implementation team within the organization to coordinate training, feedback, and technical support.	[29, 40]	Workshop, Papers
Train XR content authors on pedagogical approaches and user-centered design.	[6, 47]	Workshop, Papers
Provide visual and written guides, including manuals and quick-reference materials highlighting key tasks and hazards.	[6, 47]	Workshop
Encourage safe use of XR through targeted safety training, including potential health and security risks.	[15, 22]	Workshop, Papers
Provide cyber-awareness training to mitigate risks such as unsafe network usage and data exposure.	[10, 29]	Workshop, Papers

Ensure risk and safety procedures are embedded in training, including consent forms and approval from workplace safety authorities.	[15, 22]	Workshop, Papers
Incorporate motion sickness mitigation strategies, such as exposure time limits, rest breaks, and gradual acclimatization protocols.	[15]	Papers
Offer real-time ergonomic feedback during XR training sessions to improve posture and reduce risk of physical strain or injury.	[15]	Papers
Design XR simulations with realistic environments and task fidelity to enhance transfer of training to real-world job performance.	[6, 47]	Papers
Promote XR benefits through in-person demonstrations linked to real processes within the organization.	[29]	Workshop
Develop training content for the general public to raise awareness and build a critical mass of XR users.	[29]	Workshop
Provide specific training materials per pilot or use case, tailored to tasks and roles.	[47]	Workshop

TABLE 43: MEASURES IDENTIFIED FOR THE CATEGORY 'XR ACCESSIBILITY, INCLUSION & DEPLOYMENT INFRASTRUCTURE'

Measures	Issues addressed	Source
Ensure compliance with accessibility regulations and standards (e.g., WCAG, ADA, CVAA, EN17161) to provide equitable digital access across XR platforms.	[37,50]	Papers
Design XR content with adaptive UI elements, including high contrast visuals, larger fonts, dynamic colours, voice interactions, audio descriptions, and haptic feedback (e.g., WCAG-inspired accessibility tests).	[6,9,50]	Workshop, Papers
Provide customizable visual settings such as brightness, contrast, and text size to accommodate users with varying visual needs.	[6,15,50]	Papers
Design adaptive XR interfaces that automatically adjust based on users' needs, device capabilities, and environmental conditions.	[6,9,50]	Papers
Integrate accessible audio-based interfaces and screen reader compatibility for users with low or no vision.	[50]	Papers
Apply spatial audio techniques to convey gaze direction, object location, and environmental context.	[50]	Papers
Offer multimodal sensory cues, including spatialized audio and audio feedback, to support navigation and information delivery for visually impaired users.	[50]	Papers
Integrate audio-haptic design to support multimodal interaction.	[6,9,50]	Workshop, Papers
Use haptic feedback to support spatial orientation, object interaction, and task execution in immersive environments.	[6,9,50]	Papers
Include order/action confirmation by voice, enhancing clarity and accessibility during interactions.	[6,9,50]	Workshop
Implement intelligent voice commands and AI-guided voice feedback to assist with scene framing, navigation, and task execution.	[6,9,50]	Workshop, Papers
Support voice-based navigation and content interaction for users with limited manual dexterity or low vision.	[6,9,50]	Papers
Use computer vision + LLM architectures to provide real-time visual descriptions and accessibility support for users with visual impairments.	[6,50]	Workshop, Papers
Provide real-time object labelling and descriptive audio overlays via AI to support task comprehension in training scenarios.	[6,50]	Papers

Simulate visual impairments during development (e.g., using tools like VisionPainter) to test and refine accessibility features from the user's perspective.	[50]	Papers
Implement a feedback loop with visually impaired users to continuously adapt interface design and content delivery.	[50]	Papers
Benchmark XR experiences with visually impaired users and apply feedback to address usability barriers.	[50]	Workshop, Papers
Include end-users with visual impairments in co-design processes to tailor experiences to diverse needs.	[50]	Workshop, Papers
Create 'standard user' profiles to guide inclusive design and test from multiple perspectives.	[47,50]	Workshop
Use tactile maps, glyphs, or embossed layouts to support spatial awareness and orientation in XR environments.	[50]	Papers
Enable accessible XR content creation through no-code authoring tools compatible with assistive technologies.	[29,50]	Papers
Train XR authors on inclusive design principles, emphasizing accessibility and user diversity.	[6,29,50]	Workshop, Papers
Promote inclusive XR education targeting both developers and users.	[29,50,47]	Workshop, Papers
Incorporate inclusive design guidelines and checklists into all phases of XR system and content development.	[50]	Papers
Provide personalized user profiles that store accessibility preferences across sessions and devices.	[47,50]	Papers
Enable prior needs assessments to match users with suitable hardware and software configurations.	[6,29]	Workshop
Ensure cross-device compatibility and adaptive content quality depending on user hardware capabilities.	[6,29]	Workshop, Papers
Offer low-cost XR deployment options (e.g., cardboard VR, desktop-mode alternatives) to ensure equitable access in resource-limited contexts.	[29]	Papers
Provide dedicated XR usage spaces equipped with accessible help guides and digital prompts.	[6,29]	Workshop
Provide dedicated helpdesks and continuous tech support (AI + human assistance), especially during onboarding and troubleshooting.	[6,29]	Workshop, Papers
Create easily accessible tutorials, both on-device and offline, to support quick onboarding and recalibration.	[29,47]	Workshop
Provide offline training modules and reduce reliance on online connectivity where appropriate.	[26,29]	Workshop
Support remote guidance, including mirrored views and remote assistance calls for real-time problem solving.	[6,29]	Workshop, Papers
Ensure remote XR support tools provide descriptive narration and shared visual/audio channels for inclusive troubleshooting.	[29,50]	Papers
Implement hands-free interaction methods such as eye-tracking, head tracking, or gesture-based controls to accommodate motor impairments.	[6,50]	Papers
Evaluate hardware usability in both indoor and outdoor environments, considering lighting, noise, and user movement.	[6,29]	Workshop
Conduct real-environment testing (e.g., with background noise or limited lighting) to validate usability in operational settings.	[6,29]	Workshop
Design and test XR infrastructure to be resilient under varying conditions (e.g., low light, noisy environments, or poor connectivity).	[6,29]	Papers
Optimize XR infrastructure (networks, devices) for stable deployment; align content complexity with organizational IT capabilities.	[6,29]	Workshop, Papers

Train IT staff on XR-specific maintenance and support tasks to build internal capacity.	[6,29]	Workshop
Define XR infrastructure & training policies, tailored to organizational needs and resource levels.	[6,29]	Workshop
Implement shared purchase/leasing programs for XR hardware among partner organizations.	[22,29]	Workshop
Seek local or regional funding sources to support inclusive XR adoption.	[29]	Workshop
Encourage trial periods and phased rollouts, allowing adaptation time and user familiarization.	[22,29]	Workshop
Foster awareness of XR integration in wider digital industry flows, supporting long-term strategic deployment.	[29]	Workshop
Include accessibility in organizational digital transformation plans to ensure long-term alignment.	[29]	Workshop
Create a comprehensive testing program to simulate diverse user scenarios and adapt systems accordingly.	[47]	Workshop
Use real-time performance metrics (completion time, error rates, retries) to detect learning gaps and adapt experiences.	[29]	Workshop, Papers
Benchmark device usage during task execution, using AI to identify difficult instructions or interactions.	[29]	Workshop, Papers
Implement continuous evaluation cycles, integrating user feedback for ongoing improvements.	[29]	Workshop, Papers
Integrate accessibility-focused KPIs and compliance checks into XR system monitoring and analytics pipelines.	[6,15,22]	Papers

TABLE 44: MEASURES IDENTIFIED FOR THE CATEGORY 'LEGAL GOVERNANCE & ACCOUNTABILITY IN XR'

Measures	Issues addressed	Source
Define and enforce access control policies, including formal access requests and logging of user permissions for XR systems.	[10, 37, 40]	Workshop, Papers
Implement action and event audit logs to track user activity (who did what, when, and where) for accountability and traceability.	[10, 37, 40]	Workshop, Papers
Ensure the auditability of XR systems by capturing and logging system operations to enable oversight, investigation, and user accountability.	[10, 37, 40]	Papers
Establish XR usage tracking, such as location-based usage restrictions (e.g., internal network only) or device telemetry for security monitoring.	[10, 40]	Workshop
Prepare legal and risk mitigation plans, outlining how to handle data breaches, misuse of XR tools, or other legal disputes.	[10, 37, 40]	Workshop, Papers
Appoint a Data Protection Officer (DPO) for each organization to oversee compliance with data privacy laws and review XR content before deployment.	[37, 40]	Workshop
Establish internal self-regulatory bodies or compliance teams responsible for ensuring alignment with current legal standards and organizational policies.	[37, 40]	Workshop, Papers
Provide periodic training on legal and ethical aspects of XR to all relevant stakeholders, including content creators and end-users.	[40]	Workshop, Papers
Create and present clear ethical guidelines to all users before the start of any XR pilot or deployment.	[40]	Workshop, Papers
Embed ethical and privacy-by-design principles into the development of XR authoring and experiencing tools, ensuring legal compliance from the outset.	[40]	Papers

Deploy AI-based legal/ethics assistants to identify inappropriate user behavior, support compliance, and provide real-time guidance.	[40]	Workshop
Define personal data ownership rights in XR environments and set strict limits on usage and processing of user-generated data.	[10, 37, 40]	Workshop, Papers
Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.	[10, 37, 40]	Workshop
Apply stricter and more meaningful standards for obtaining informed consent from XR users, ensuring transparency and user agency in data collection and processing.	[10, 37, 40]	Papers
Design consent mechanics directly into XR systems to support user decision-making and prevent boundary violations in immersive environments.	[6, 9, 15, 40]	Papers
Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access.	[10, 37, 40]	Papers
Establish legal instruments to govern the collection, processing, and storage of data generated in XR environments, aligning with applicable data protection laws.	[10, 37, 40]	Papers
Safeguard biometric and eye-tracking data collected by XR devices through explicit privacy protections and restrictions on secondary use.	[10, 37, 40]	Papers
Define policies for avatar identity protection to prevent impersonation, identity theft, and misuse of digital representations in collaborative XR experiences.	[10, 37, 40]	Papers
Extend existing legal frameworks and doctrines to address disputes, virtual property, and user rights specific to immersive industrial XR contexts.	[37, 40]	Papers
Apply relevant European legal and ethical frameworks to XR-based training and assistance activities, particularly those involving AI-generated or AI-supported content.	[6, 9, 15, 22, 37, 40, 47]	Papers

TABLE 45: MEASURES IDENTIFIED FOR THE CATEGORY 'XR REGULATORY STRATEGY & STANDARDS ALIGNMENT'

Measures	Issues addressed	Source
Collaborate with stakeholders and regulatory bodies, including participation in EU-level or industry-wide consortia to shape harmonized legal frameworks for XR (similar to AI regulations).	[37, 40]	Workshop, Papers
Support the development of legal doctrines and enforcement mechanisms tailored to immersive environments, including virtual property, dispute resolution, and user protection.	[37, 40]	Papers
Form a legal/ethical oversight committee (e.g. within MotivateXR) to ensure consistent application and review of policies across deployments.	[37, 40]	Workshop
Establish shared protocols across projects and partners, with built-in mechanisms for regular monitoring and compliance review.	[22, 37, 40]	Workshop
Develop forward-looking legal and ethical principles to guide responsible XR innovation and anticipate emerging regulatory challenges.	[37, 40]	Papers
Encourage the creation and adoption of voluntary developer codes of ethics to promote safe and responsible XR design practices.	[9, 22, 40]	Papers
Develop official guidelines and training materials (e.g. from MotivateXR) on legal, ethical, and safety requirements for all system users.	[9, 22, 40, 47]	Workshop
Define and disseminate XR-specific rules and best practices for training, ideally supported by AI-powered assistance tools (e.g. policy bots, RAG/LLM guidance).	[9, 22, 47]	Workshop

Provide regulatory support and training to organizations, helping them implement and align with safety protocols and emerging standards.	[22, 29, 40]	Workshop
Designate clear points of contact or helpdesks for legal and regulatory consultation within XR initiatives.	[37, 40]	Workshop
Use policy-aware content deployment pipelines that integrate automated compliance checks during XR content publication.	[10, 22, 40]	Workshop
Implement auditability mechanisms in XR systems to enable oversight, transparency, and accountability in case of failure or harm.	[10, 37, 40]	Papers
Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback.	[9, 15, 22, 40]	Workshop
Adopt and monitor compliance with health and safety standards for XR use, including IEEE 3079 for cybersickness, IEC 60825 for laser safety, and EMF exposure guidelines.	[9, 15, 22]	Papers
Stay up to date on new legal developments, for example by organizing regular meetings or consultations with data protection and security experts.	[10, 37, 40]	Workshop
Define and enforce XR-specific data privacy and informed consent policies, including safeguards for biometric data, avatar identity, and behavioral tracking.	[10, 37]	Papers
Ensure accessibility compliance of XR tools and content by aligning with established standards such as WCAG, ISO 9241, ADA, and CVAA.	[29, 50]	Papers

5. COMPARISON OF IDENTIFIED MEASURES WITH U/S REQUIREMENTS

5.1. APPROACH TO COMPARE IDENTIFIED MEASURES

After identifying and consolidating measures in Chapter 3, the next step is to evaluate which of these measures are already considered in the design of Motivate XR. This will be instrumental for the final list of proposed measures to address social, ethical and legal issues for Motivate XR.

We compare the measures identified in Chapter 3 with the user requirements and system requirements defined for the five Motivate XR pilot projects (Pilot 1: Aerospace industry, Pilot 2: Home Appliance industry, Pilot 3: Aluminium Industry, Pilot 4: Energy Distribution Industry, Pilot 5: Human-robot hybrid Manufacturing) in Deliverable D3.3 (produced in 2024).

The comparison of measures was carried out in three steps to ensure a consistent and accurate alignment with the MOTIVATE XR user and system requirements. First, the list of measures was analysed using GPT-4o, together with the corresponding requirements, for each pilot project and measure category. This enabled the identification of initial links between mitigation actions and design needs. Next, humans verified the appropriateness of each of these assignments individually and ensure consistency across pilots. Finally, the resulting assignments were independently validated by CETMA, which coordinated the definition of user requirements and system requirements, providing an additional quality control layer and ensuring coherence across all classifications.

5.2. RESULTS

An overview of the measures that are already considered in the user and system requirements for each pilot project can be found in Table 46 through Table 55.

The pilot requirements already cover a substantial core of authoring/experiencing and usability measures, particularly within the categories of Interaction Design & User Interfaces and Physical Ergonomics & Device Setup. Across all five pilots, recurring specifications include guided process flows, clear layouts, 3D/2D assets, multilingual support, progress saving, and display controls for brightness and contrast. Gesture and voice input appear in several pilots, and ergonomics is consistently addressed as a non-functional requirement through fit, comfort, and visual calibration provisions. Personalisation hooks (e.g., layout positioning) and modular scene structuring indicate that the day-to-day interaction layer is comparatively well specified and close to implementation readiness.

By contrast, Health Risk Management & User Well-being and Safety & Environmental Conditions are represented mainly through foundational elements. Present provisions include PPE guidance, working-area boundary visualisation in the more hazardous contexts, user guidance and consent information, and session pausing via progress controls. However, more proactive measures, such

as pre-use screening (e.g., SSQ), real-time discomfort monitoring and adaptive mitigation (e.g., dynamic field-of-view/rest frames), and structured post-session recovery protocols, are largely absent. If these remain out of scope for the minimum viable phase, this should be stated explicitly; otherwise, a lightweight, reusable health and safety module (screeners, per-session check-ins, and configurable mitigations) is recommended across pilots.

Two areas appear clearly under-specified: System Performance & Stability and Data Security & Access Control. On performance, the requirements address networks and asset formats but do not set quantitative targets or test hooks for motion-to-photon latency, minimum frame rates, adaptive resolution/foveation, site-level benchmarking, or pass/fail gates, key mechanisms for mitigating latency-related risks. On security, apart from authentication in selected pilots and a small number of access-control references, there is minimal coverage of multi-factor authentication, zero-trust postures, sensor-data permissions, anomaly detection/IDS, or secure device pairing. Given the salience of these risks, the addition of a cross-pilot security baseline (including MFA, attestation, encrypted transport and storage, role-based access, kiosk mode, and secure pairing) and a performance test plan (targets, instrumentation, and acceptance criteria) is recommended as horizontal work.

Legal Governance & Accountability and XR Regulatory Strategy & Standards Alignment are only weakly represented in the pilot-level requirements. This reflects a common situation in technology-driven initiatives, where the emphasis is placed on technical feasibility and user experience, while legal and regulatory considerations are left less developed. Still, the requirements analysis confirms that compliance is a decisive factor: XR systems will only achieve sustainable adoption if they operate within authorised legal boundaries and align with emerging regulatory frameworks. To address this gap, measures could be introduced that embed lightweight compliance mechanisms directly into system design and deployment. Examples include audit and logging functions for accountability, consent and transparency prompts integrated in user interfaces, and policy-aware deployment pipelines that check alignment with data protection and safety standards. In addition, closer collaboration with external legal experts, policymakers, or industry consortia could ensure that future iterations of the pilots not only demonstrate technical excellence but also anticipate and conform to the regulatory environment in which they will ultimately operate.

Table 46 through Table 55 summarises the mapping between the mitigation measures and the existing user and system requirements as presented in Deliverable D3.3.

TABLE 46: FORESEEN MEASURES FOR THE CATEGORY 'PHYSICAL ERGONOMICS & DEVICE SETUP'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Optimize battery-to-weight ratio to balance comfort with usage time.					
Design hardware for balanced weight distribution, avoiding heat concentration near the face.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Use soft padding and adjustable straps to enhance long-term wear comfort.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5

Reduce device weight and bulk to support prolonged use without causing fatigue.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Design headset form factors and IPD ranges to fit a wider diversity of head shapes, sizes, and gender-related anatomical differences.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision correction needs.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Implement fit-score metrics during onboarding, including interpupillary distance (IPD) checks and field-of-view alignment.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Include adjustable focus lenses to accommodate vision differences (e.g., myopia, hyperopia).	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Use eye-tracking feedback to assist users in correctly positioning the headset.	UR-NFUN-0500-P1	UR-NFUN-0500-P2	UR-NFUN-0500-P3	UR-NFUN-0500-P4	UR-NFUN-0500-P5
Integrate dynamic vergence and accommodation adjustment to reduce eye strain and visual discomfort during immersive use.					
Implement pre-use visual calibration routines based on stereo acuity, eye dominance, and interpupillary distance for optimal fit.	UR-NFUN-0500-P1	UR-NFUN-0500-P2	UR-NFUN-0500-P3	UR-NFUN-0500-P4	UR-NFUN-0500-P5
Adjust display brightness and contrast automatically or manually to reduce visual fatigue under different lighting conditions.	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP, SR-0600-P2	SR-1400-AP, SR-1500-AP, SR-0700-P3	SR-1400-AP, SR-1500-AP, SR-0300-P4	SR-1400-AP, SR-1500-AP, SR-0400-P5
Limit continuous XR session duration to avoid physical fatigue and strain.	SR-1900-AP	SR-1900-AP	SR-1900-AP	SR-1900-AP	SR-1900-AP
Provide acclimation sessions to help users gradually adapt to XR hardware.					
Add cooling mechanisms or materials to XR headsets to prevent heat build-up around the face during extended sessions.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Design the XR system to support thermal comfort across varying durations, activities, and individual physiological differences.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Perform initial device calibration and enable real-time adjustments during use.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Conduct preventive ergonomic testing for different user profiles before deployment.					
Track head/neck motion patterns to detect signs of discomfort or strain.					
Monitor head movement smoothness and tremor as indicators of user disorientation or fatigue.					
Log session duration and voluntary dropouts to identify potential ergonomic issues.					

Provide real-time ergonomic feedback through posture tracking and alerts to help users avoid strain during XR interactions.					
Train users in proper ergonomic use of XR devices to avoid strain and injury.					
Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.	SR-1600-AP	SR-1600-AP	SR-1600-AP	SR-1600-AP	SR-1600-AP

TABLE 47: FORESEEN MEASURES FOR THE CATEGORY 'INTERACTION DESIGN & USER INTERFACES'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Design clear, consistent, and non-cluttered UIs to reduce cognitive load and improve usability.	SR-0100-AP UR-NFUN-0500-P1	SR-0100-AP, UR-NFUN-0500-P2	SR-0100-AP, UR-NFUN-0500-P3	SR-0100-AP, UR-NFUN-0500-P4	SR-0100-AP, UR-NFUN-0500-P5
Design interfaces that reduce visual clutter by automatically adjusting displayed information based on task complexity and cognitive load.	SR-0100-AP, SR-1600-AP, SR-1700-AP	SR-0100-AP, SR-1600-AP, SR-1700-AP, SR-0200-P2	SR-0100-AP, SR-1600-AP, SR-1700-AP, SR-0200-P3, SR-0300-P3	SR-0100-AP, SR-1600-AP, SR-1700-AP	SR-0100-AP, SR-1600-AP, SR-1700-AP
Optimize interactions for XR by reducing non-essential information compared to traditional 2D interfaces.	SR-0100-AP, UR-NFUN-0500-P1	SR-0100-AP, UR-NFUN-0500-P2	SR-0100-AP, UR-NFUN-0500-P3	SR-0100-AP, UR-NFUN-0500-P4	SR-0100-AP, UR-NFUN-0500-P5
Optimize text and icon legibility using clutter-reduction techniques and enhanced contrast on complex backgrounds.	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP
Use appropriate visual contrast and avoid overly bright elements to reduce eye fatigue.	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP, SR-1500-AP
Provide immediate visual or auditory feedback for all user actions to reinforce interaction.					
Implement visual feedback mechanisms like highlighting or snapping to assist accurate target selection.					
Provide spatial visual cues such as drop shadows or contact webs to improve depth perception and interaction accuracy.					
Enable adaptive user interfaces, adjusting complexity and layout to user experience level and context.	SR-1600-AP	SR-1600-AP	SR-1600-AP	SR-1600-AP SR-0600-P4	SR-1600-AP

				SR-0900-P4	
Support real-time adjustment of interface layout and interaction modes based on user skill level and task progression.					
Adapt interface elements dynamically based on user attention, workload, or environmental lighting conditions.					
Allow individual calibration of the XR interface to accommodate user preferences and reduce discomfort during prolonged use.					
Incorporate multimodal interaction options such as voice commands, haptics, and gestures.	SR-0200-P1	SR-0800-P2	SR-1000-P3	SR-0400-P4	SR-0700-P5
Support multi-sensory integration, including text-to-speech (TTS), speech-to-text (STT), and haptic feedback.		SR-0300-P2	SR-0400-P3		SR-0800-P5
Enable intuitive object selection and manipulation through gaze-assisted or multimodal input (e.g., eye + hand coordination).					
Integrate micro gestures and fine motor control to support precise and low-effort interaction with virtual objects.					
Offer intuitive head-controlled or radial menu options to reduce arm fatigue and physical strain in hands-free scenarios.					
Facilitate real-time collaboration by improving interaction methods with virtual representations of colleagues (e.g., life-size avatars, voice sync).	SR-0500-P1	SR-0100-P2	SR-0100-P3		SR-0100-P5
Ensure motion synchrony between user actions and the virtual environment to maintain immersion and reduce disorientation.		SR-0600-P2	SR-0700-P3	SR-0300-P4	SR-0400-P5
Include context-aware automation, like automated task prompts based on user environment or behaviour.					
Implement real-time UI adjustments (e.g., colour modes, transparency) to suit different work environments.	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP SR-0600-P2	SR-1400-AP SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP, SR-1500-AP
Use user-friendly visual metaphors and consistent layout logic to support recognition over recall in interface navigation.	SR-0100-AP SR-1600-AP	SR-0100-AP SR-1600-AP	SR-0100-AP SR-1600-AP	SR-0100-AP SR-1600-AP	SR-0100-AP SR-1600-AP
Include safety hints and risk prompts within the interface to alert users during potentially unsafe actions.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Personalize content and UI layouts based on pre-assessed user profiles and learning paths.	SR-1600-AP	SR-1600-AP	SR-1600-AP	SR-1600-AP	SR-1600-AP

Incorporate guided tutorials and walk-up-and-use interfaces to lower the learning curve for new XR users.					
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TABLE 48: FORESEEN MEASURES FOR THE CATEGORY 'SYSTEM PERFORMANCE & STABILITY'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Ensure responsiveness and low-latency rendering to maintain smooth, lag-free user interactions—especially critical in complex 3D environments.					
Minimize motion-to-photon latency to below 10 milliseconds to reduce sensory mismatch and ensure real-time system responsiveness in XR environments.					
Benchmark motion-to-display latency and rendering performance under realistic usage scenarios to detect bottlenecks and guide optimization.					
Maintain consistently high framerates across devices to prevent visual discomfort and motion sickness, especially during prolonged XR sessions.					
Reduce display lag in XR headsets to improve interaction precision and lower the likelihood of simulator sickness.					
Optimize 3D assets and reduce polygon counts to lower GPU load and improve rendering speed without compromising visual fidelity.	SR-0500-AP	SR-0500-AP	SR-0500-AP	SR-0500-AP	SR-0500-AP
Adapt rendering resolution dynamically to hardware capabilities and runtime performance to maintain stable frame rates and reduce cybersickness.					
Adapt XR content dynamically based on available bandwidth to ensure stability during fluctuating network conditions.					
Apply adaptive frame rendering techniques to prioritize motion or spatial detail based on scene dynamics and user activity, improving latency handling.					
Use foveated rendering techniques to reduce processing in peripheral vision and improve overall rendering performance with minimal perceived quality loss.					
Use dedicated high-quality networks or wired connections to reduce latency and jitter, particularly for real-time or multi-user XR experiences.	SR-0100-P1	SR-0400-P2	SR-0500-P3	SR-0100-P4	SR-0200-P5

Install and prioritize dedicated 5G or private subnets to guarantee bandwidth availability during XR sessions.	SR-0100-P1	SR-0400-P2	SR-0500-P3	SR-0100-P4	SR-0200-P5
Use predictive prefetching and caching techniques at the network edge to ensure timely content delivery during XR sessions, even in fluctuating conditions.					
Deploy load-balancing mechanisms to distribute XR traffic and prevent bottlenecks across devices or locations.					
Use cloud-based high-performance computing resources (e.g., Shadow or similar) to offload rendering when using multiple or low-power devices.					
Offload rendering tasks to fog or edge computing nodes to bring processing closer to the user and reduce latency in real-time XR applications.					
Monitor real-time network metrics (e.g., bandwidth, jitter, packet loss, round-trip time) to detect and respond to performance issues.	SR-0100-P1	SR-0400-P2	SR-0500-P3	SR-0100-P4	SR-0200-P5
Conduct latency and performance benchmarking across deployment sites to identify performance gaps or optimization needs.					
Continuously monitor network and system performance, and implement mitigation strategies proactively.					
Enable early detection of technical malfunctions, with alerts and system diagnostics to prevent user disruption.					
Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.	SR-1900-AP	SR-1900-AP	SR-1900-AP	SR-1900-AP	SR-1900-AP

TABLE 49: FORESEEN MEASURES FOR THE CATEGORY ‘SAFETY & ENVIRONMENTAL CONDITIONS’

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Ensure a safe physical environment for XR use, including dedicated spaces optimized for movement and spatial awareness.	SR-0600-P1		SR-0900-P3		SR-0600-P5
Calibrate and enforce safety zones using tools like guardian systems and spatial boundary warnings.	SR-0600-P1		SR-0900-P3		SR-0600-P5
Use visual, auditory, or haptic boundary warnings to alert users when approaching physical hazards during immersive XR sessions.	SR-0600-P1		SR-0900-P3		SR-0600-P5
Incorporate real-time collision detection systems or obstacle alerts to prevent accidents due to reduced real-world awareness.					

Enable pass-through and quick-hide features to allow immediate visibility of the real environment in case of emergency or disorientation.					
Optimize environmental conditions, including appropriate lighting and ventilation to support XR use.					
Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.					
Ensure headset ergonomics, including balanced weight and adjustable fit, to reduce neck strain and physical discomfort during extended use.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.					
Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.					
Limit continuous use of XR headsets in high-intensity applications and enforce stricter break schedules based on observed discomfort indicators.					
Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emergency procedures.					
Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.					
Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.					
Develop shared safety guidelines collaboratively with experts and partner organizations for standardization and consistency.					
Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment site.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Incorporate manufacturer safety guidance into internal training and documentation.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Use AI-based or automated tools to monitor real-time usage signals (e.g., discomfort, confusion) and trigger session end if needed.					
Monitor user head and eye movement data to detect early signs of cybersickness and automatically adapt the XR experience accordingly.					

Implement standardized assessment tools like the Simulator Sickness Questionnaire (SSQ) to monitor and document cybersickness symptoms.					
Evaluate and minimize the risk of cybersickness for vulnerable users by accounting for gender, previous VR exposure, and motion sickness history.					
Design virtual environments to minimize sudden movements, motion mismatches, or acceleration patterns that contribute to motion sickness.					
Integrate dynamic field-of-view (FOV) reduction or rest frame techniques to minimize disorientation and cybersickness during XR use.					
Adjust interpupillary distance (IPD), screen brightness, and refresh rate settings to reduce eye strain and visual discomfort.	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP
Verify whether different PPE (personal protective equipment) is required based on the context and use case.		SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Inform users of all potential risks, including physical, operational, and situational hazards, before and during XR usage.	SR-0600-P1				
Establish policies distinguishing between shared vs. personal use of XR devices, and adapt hygiene and safety protocols accordingly.					

TABLE 50: FORESEEN MEASURES FOR THE CATEGORY 'HEALTH RISK MANAGEMENT & USER WELL-BEING'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.					
Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.					
Integrate multimodal discomfort monitoring (e.g., combining SSQ, heart rate, and behavioral cues) to trigger session termination if thresholds are exceeded.					
Administer structured post-use recovery times (e.g., at least 10–15 minutes) before users return to high-focus tasks such as driving or machinery operation.					
Educate users on safe post-use behavior, such as avoiding driving or operating machinery immediately after XR sessions.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5

Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid exposing vulnerable users to XR-related health risks.					
Provide users with clear information sheets and obtain informed consent before XR use, including any known risks or side effects.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Integrate XR-related health risks into organizational risk assessment documents and update them regularly.					
Provide follow-up support, including psychological or medical guidance if discomfort persists after XR use.					
Use test sessions to gauge users' initial adaptation and guide recommendations for further participation.					
Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort.					
Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow or trigger session termination if needed.					
Detect early signs of cybersickness using physiological signals (e.g., heart rate, head movement) and automatically apply mitigation strategies like FOV reduction or scene blur.					
Use real-time eye-tracking data (e.g., pupil dilation) to monitor cognitive load and trigger adaptive task adjustments or rest breaks when mental strain is detected.					
Train systems to predict cybersickness onset using motion data and user behavior to proactively intervene before discomfort escalates.					
Set and enforce session duration limits, with alerts and mandatory breaks to prevent overexposure and fatigue.					
Limit exposure to immersive XR sessions based on evidence-based thresholds (e.g., max 30-60 minutes) to prevent visual fatigue and simulator sickness.					
Allow personalized break schedules based on user comfort and adaptability.	SR-1900-AP	SR-1900-AP	SR-1900-AP	SR-1900-AP	SR-1900-AP
Offer passive viewing modes (e.g., guided or pre-recorded tours) as an alternative for users sensitive to active interaction in XR environments.					
Use hybrid locomotion methods (e.g., HeadJoystick or body-lean navigation) to					

minimize motion sickness compared to controller-based movement.					
Ensure hardware and software support ergonomic use (e.g., hand posture techniques like ProxyHand) to prevent fatigue during extended XR sessions.	UR-NFUN-1100-P1, SR-0200-P1	UR-NFUN-1100-P2, SR-0800-P2	UR-NFUN-1100-P3, SR-1000-P3	UR-NFUN-1100-P4, SR-0400-P4	UR-NFUN-1100-P5, SR-0700-P5
Include ergonomics-based posture monitoring (e.g., via visual/auditory cues) to help users maintain safe physical positioning during XR use.					
Adjust interpupillary distance (IPD) settings on headsets for each user to reduce eyestrain and depth perception errors.	UR-NFUN-1100-P1	UR-NFUN-1100-P2	UR-NFUN-1100-P3	UR-NFUN-1100-P4	UR-NFUN-1100-P5
Apply adaptive brightness and contrast settings to accommodate user comfort and reduce the likelihood of visual fatigue or disorientation.	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP, SR-0600-P2	SR-1400-AP, SR-1500-AP, SR-0700-P3	SR-1400-AP, SR-1500-AP, SR-0300-P4	SR-1400-AP, SR-1500-AP, SR-0400-P5
Incorporate haptic or vibrotactile feedback to balance sensory input and reduce overreliance on visual cues, lowering the risk of simulator sickness.					
Design virtual environments with simplified visuals or reduced scene complexity to lessen cognitive load and spatial disorientation, especially for vulnerable users.	SR-0100-AP, SR-1600-AP, SR-1700-AP	SR-0100-AP, SR-1600-AP, SR-1700-AP	SR-0100-AP, SR-1600-AP, SR-1700-AP	SR-0100-AP, SR-1600-AP, SR-1700-AP	SR-0100-AP, SR-1600-AP, SR-1700-AP
Provide real-time session feedback through virtual agents or avatars that can recognize discomfort and offer personalized guidance or suggest a break.					
Include special usage guidelines for clinical or physical conditions (e.g., neck braces, recovering from injuries).					

TABLE 51: FORESEEN MEASURES FOR THE CATEGORY 'DATA SECURITY & ACCESS CONTROL'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Ensure a closed and secure system architecture with access restrictions tailored to user roles.	SR-0100-P1			SR-0900-P4	
Use zero-trust architecture principles to authenticate every access request within the XR infrastructure, regardless of network origin.					
Use secure data transmission protocols (e.g., HTTPS, VPNs, encrypted APIs) to protect data in transit.					
Apply data anonymization and encryption techniques to protect sensitive user data both in transit and at rest.					

Restrict and monitor access to XR sensor data (e.g., motion, location) to prevent unauthorized use or inference of sensitive personal information.					
Mitigate side-channel attacks by securing XR input devices (e.g., controllers, eye tracking, motion sensors) against inference-based intrusions.					
Implement strong multi-factor authentication (MFA), including options like passkeys or hardware tokens where mobile use is restricted.					
Use biometric authentication (e.g., iris recognition) only where compliant with privacy laws and supported by the hardware and user context.					
Implement continuous, passive biometric authentication methods (e.g., gait or head motion) to secure access during extended XR sessions.					
Enable secure device pairing mechanisms for XR peripherals (e.g., finger-tracking-based pairing) to prevent unauthorized connections.					
Enforce strong password policies, preventing the use of weak or easily guessed passwords.					
Deploy machine learning-based anomaly detection systems to identify suspicious access patterns or user behaviors in real time.					
Integrate intrusion detection systems (IDS) at both network and application levels to monitor and respond to threats targeting XR components.					
Enable continuous security monitoring and real-time threat detection across XR infrastructure.					
Perform regular penetration testing and vulnerability assessments to identify and fix security gaps.					
Use blockchain-based provenance tracking to ensure tamper-proof logging of access and actions within collaborative XR environments.					
Embed secure-by-design principles in XR hardware and software development to reduce exploitable vulnerabilities at the system level.					
Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.					
Enable kiosk mode for XR apps to restrict access and prevent unauthorized modifications.					

Design experiences to minimize data exposure, only collecting and storing what is strictly necessary.					
Establish human oversight mechanisms to review system decisions or anomalies related to user access or security behavior.					
Train data managers and IT staff on data ethics, privacy responsibilities, and regulatory compliance.					
Coordinate closely with legal and compliance departments to ensure security strategies align with organizational and legal requirements.					
Apply differential privacy techniques to XR data collection workflows to minimize the risk of re-identifying users while preserving utility.					

TABLE 52: FORESEEN MEASURES FOR THE CATEGORY 'XR TRAINING & ORGANIZATIONAL PREPAREDNESS'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Develop structured XR training programs for employees, including mandatory sessions on safety, proper use, and organizational protocols.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Include XR training in onboarding for all new employees to ensure consistent baseline knowledge.					
Provide structured onboarding tutorials for XR environments to help novice users build confidence and reduce cognitive overload.					
Organize hands-on training sessions and courses on XR device usage and interaction principles.					
Train users on specific XR interaction techniques, such as hand tracking and latency-aware gestures.					
Adapt training to learner profiles, accounting for experience level, digital proficiency, and safety awareness.					
Use pre-assessments to assign training levels and customize content based on user proficiency.					
Adapt training materials and interaction techniques to accommodate users with varying levels of spatial ability and digital fluency.	UR-NFUNC-0500-P1	UR-NFUNC-0500-P1	UR-NFUNC-0500-P1	UR-NFUNC-0500-P1	UR-NFUNC-0500-P1
Use learning style assessments to tailor XR training content to users' preferred modalities, such as visual, auditory, or kinesthetic learning.					
Identify different user groups (based on tool familiarity) and deliver customized training paths accordingly.					

Implement adaptive XR training systems that adjust difficulty and content in real-time based on individual performance and cognitive load.					
Integrate personalized feedback mechanisms that guide users toward safer and more effective interaction patterns in XR environments.					
Develop performance dashboards and self-assessment tools to help users track progress and identify skill gaps during XR training.	SR-0400-P1			SR-0800-P4	
Incorporate continuous feedback mechanisms, including: System Usability Scale (SUS), Simulator Sickness Questionnaire (SSQ), open-ended sentiment surveys and interviews, and post-training assessments.					
Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates.					
Involve diverse users in pilot testing (age, background, familiarity) to validate and improve training design.					
Create dedicated training centers or designated XR zones for practice and onboarding.					
Assign XR champions within departments to support local adoption, mentor peers, and assist with technical or onboarding challenges.					
Establish a dedicated XR implementation team within the organization to coordinate training, feedback, and technical support.					
Train XR content authors on pedagogical approaches and user-centered design.					
Provide visual and written guides, including manuals and quick-reference materials highlighting key tasks and hazards.	SR-0100-AP, SR-0200-AP, SR-0300-AP, SR-0400-AP, SR-0700-AP, AR-1000-AP. SR-1100-AP, SR-1200-AP, SR-1300-AP, SR-2000-AP, SR-0600-P1, SR-0700-P1, SR-0800-	SR-0100-AP, SR-0200-AP, SR-0300-AP, SR-0400-AP, SR-0700-AP, AR-1000-AP. SR-1100-AP, SR-1200-AP, SR-1300-AP, SR-2000-AP, SR-0100-P2, SR-0700-P2,	SR-0100-AP, SR-0200-AP, SR-0300-AP, SR-0400-AP, SR-0700-AP, AR-1000-AP. SR-1100-AP, SR-1200-AP, SR-1300-AP, SR-2000-AP, SR-02-00-P3, SR-0300-P3, SR-0800-	SR-0100-AP, SR-0200-AP, SR-0300-AP, SR-0400-AP, SR-0700-AP, AR-1000-AP. SR-1100-AP, SR-1200-AP, SR-1300-AP, SR-2000-AP, SR-0500-P4, SR-0600-P4	SR-0100-AP, SR-0200-AP, SR-0300-AP, SR-0400-AP, SR-0700-AP, AR-1000-AP. SR-1100-AP, SR-1200-AP, SR-1300-AP, SR-2000-AP, SR-0500-P5, SR-0600-P5

	P1, SR-09-P1	SR-0900-P2	P3, SR-0900-P3		
Encourage safe use of XR through targeted safety training, including potential health and security risks.	SR-0600-P1	SR-0700-P2	SR-0800-P3	SR-0500-P4	SR-0500-P5
Provide cyber-awareness training to mitigate risks such as unsafe network usage and data exposure.					
Ensure risk and safety procedures are embedded in training, including consent forms and approval from workplace safety authorities.	SR-0600-P1, SR-0900-P1	SR-0700-P2	SR-0800-P3, SR-0900-P3	SR-0500-P4	SR-0500-P5, SR-0600-P5
Incorporate motion sickness mitigation strategies, such as exposure time limits, rest breaks, and gradual acclimatization protocols.					
Offer real-time ergonomic feedback during XR training sessions to improve posture and reduce risk of physical strain or injury.					
Design XR simulations with realistic environments and task fidelity to enhance transfer of training to real-world job performance.	SR-0100-AP, SR-0300-P1	SR-0100-AP, SR-0600-P2	SR-0100-AP, SR-0700-P3	SR-0100-AP, SR-0300-P4	SR-0100-AP, SR-0400-P5
Promote XR benefits through in-person demonstrations linked to real processes within the organization.					
Develop training content for the general public to raise awareness and build a critical mass of XR users.					
Provide specific training materials per pilot or use case, tailored to tasks and roles.					

TABLE 53: FORESEEN MEASURES FOR THE CATEGORY 'XR ACCESSIBILITY, INCLUSION & DEPLOYMENT INFRASTRUCTURE'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Ensure compliance with accessibility regulations and standards (e.g., WCAG, ADA, CVAA, EN17161) to provide equitable digital access across XR platforms.					
Design XR content with adaptive UI elements, including high contrast visuals, larger fonts, dynamic colors, voice interactions, audio descriptions, and haptic feedback (e.g., WCAG-inspired accessibility tests).					
Provide customizable visual settings such as brightness, contrast, and text size to accommodate users with varying visual needs.	SR-1400-AP SR-1500-AP	SR-1400-AP, SR-1500-AP	SR-1400-AP, SR-1500-AP	SR-1400-AP SR-1500-AP	SR-1400-AP, SR-1500-AP
Design adaptive XR interfaces that automatically adjust based on users' needs,					

device capabilities, and environmental conditions.					
Integrate accessible audio-based interfaces and screen reader compatibility for users with low or no vision.					
Apply spatial audio techniques to convey gaze direction, object location, and environmental context.					
Offer multimodal sensory cues, including spatialized audio and sonified feedback, to support navigation and information delivery for visually impaired users.					
Integrate audio-haptic design to support multimodal interaction.					
Use haptic feedback to support spatial orientation, object interaction, and task execution in immersive environments.					
Include order/action confirmation by voice, enhancing clarity and accessibility during interactions.					
Implement intelligent voice commands and AI-guided voice feedback to assist with scene framing, navigation, and task execution.		UR-FUNC-2600-P2	SR-2900-P3, UR-FUNC-2600-P3		UR-FUNC-2500-P5, SR-0800-P5
Support voice-based navigation and content interaction for users with limited manual dexterity or low vision.					
Use computer vision + LLM architectures to provide real-time visual descriptions and accessibility support for users with visual impairments.					
Provide real-time object labeling and descriptive audio overlays via AI to support task comprehension in training scenarios.					
Simulate visual impairments during development (e.g., using tools like VisionPainter) to test and refine accessibility features from the user's perspective.					
Implement a feedback loop with visually impaired users to continuously adapt interface design and content delivery.					
Benchmark XR experiences with visually impaired users, and apply feedback to address usability barriers.					
Include end-users with visual impairments in co-design processes to tailor experiences to diverse needs.					
Create 'standard user' profiles to guide inclusive design and test from multiple perspectives.				SR-0900-P4	

Use tactile maps, glyphs, or embossed layouts to support spatial awareness and orientation in XR environments.					
Enable accessible XR content creation through no-code authoring tools compatible with assistive technologies.					
Train XR authors on inclusive design principles, emphasizing accessibility and user diversity.					
Promote inclusive XR education targeting both developers and users.					
Incorporate inclusive design guidelines and checklists into all phases of XR system and content development.	SR-0100-AP	SR-0100-AP	SR-0100-AP	SR-0100-AP	SR-0100-AP
Provide personalized user profiles that store accessibility preferences across sessions and devices.				SR-0900-P4 SR-0600-P4	
Enable prior needs assessments to match users with suitable hardware and software configurations.					
Ensure cross-device compatibility and adaptive content quality depending on user hardware capabilities.					
Offer low-cost XR deployment options (e.g., cardboard VR, desktop-mode alternatives) to ensure equitable access in resource-limited contexts.	UR-NFUN-1400-P1	UR-NFUN-1400-P2	UR-NFUN-1400-P3	UR-NFUN-1400-P4	UR-NFUN-1400-P5
Provide dedicated XR usage spaces equipped with accessible help guides and digital prompts.					
Provide dedicated helpdesks and continuous tech support (AI + human assistance), especially during onboarding and troubleshooting.					
Create easily accessible tutorials, both on-device and offline, to support quick onboarding and recalibration.	UR-NFUN-0500-P1	UR-NFUN-0500-P2	UR-NFUN-0500-P3	UR-NFUN-0500-P4	UR-NFUN-0500-P4
Provide offline training modules and reduce reliance on online connectivity where appropriate.	SR-0100-P1	SR-0400-P2	SR-0500-P3	SR-0100-P4	SR-0200-P5
Support remote guidance, including mirrored views and remote assistance calls for real-time problem solving.	SR-0500-P1	SR-0100-P2	SR-0100-P3		SR-0100-P5
Ensure remote XR support tools provide descriptive narration and shared visual/audio channels for inclusive troubleshooting.	SR-0900-AP	SR-0900-AP	SR-0900-AP	SR-0900-AP	SR-0900-AP
Implement hands-free interaction methods such as eye-tracking, head tracking, or gesture-based controls to accommodate motor impairments.	SR-0200-P1	SR-0800-P2	SR-1000-P3	SR-0400-P4	SR-0700-P5

Evaluate hardware usability in both indoor and outdoor environments, considering lighting, noise, and user movement.					
Conduct real-environment testing (e.g., with background noise or limited lighting) to validate usability in operational settings.					
Design and test XR infrastructure to be resilient under varying conditions (e.g., low light, noisy environments, or poor connectivity).					
Optimize XR infrastructure (networks, devices) for stable deployment; align content complexity with organizational IT capabilities.					
Train IT staff on XR-specific maintenance and support tasks to build internal capacity.					
Define XR infrastructure & training policies, tailored to organizational needs and resource levels.					
Implement shared purchase/leasing programs for XR hardware among partner organizations.					
Seek local or regional funding sources to support inclusive XR adoption.					
Encourage trial periods and phased rollouts, allowing adaptation time and user familiarization.					
Foster awareness of XR integration in wider digital industry flows, supporting long-term strategic deployment.					
Include accessibility in organizational digital transformation plans to ensure long-term alignment.					
Create a comprehensive testing program to simulate diverse user scenarios and adapt systems accordingly.	UR-NFUN-0500-P1	UR-NFUN-0500-P2	UR-NFUN-0500-P3	UR-NFUN-0500-P4	UR-NFUN-0500-P5
Use real-time performance metrics (completion time, error rates, retries) to detect learning gaps and adapt experiences.					
Benchmark device usage during task execution, using AI to identify difficult instructions or interactions.					
Implement continuous evaluation cycles, integrating user feedback for ongoing improvements.					
Integrate accessibility-focused KPIs and compliance checks into XR system monitoring and analytics pipelines.					

TABLE 54: FORESEEN MEASURES FOR THE CATEGORY 'LEGAL GOVERNANCE & ACCOUNTABILITY IN XR'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
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Define and enforce access control policies, including formal access requests and logging of user permissions for XR systems.	SR-0100-P1	SR-0500-P2		SR-0900-P4	
Implement action and event audit logs to track user activity (who did what, when, and where) for accountability and traceability.					
Ensure the auditability of XR systems by capturing and logging system operations to enable oversight, investigation, and user accountability.					
Establish XR usage tracking, such as location-based usage restrictions (e.g., internal network only) or device telemetry for security monitoring.	SR-0100-P1			SR-0700-P4	
Prepare legal and risk mitigation plans, outlining how to handle data breaches, misuse of XR tools, or other legal disputes.					
Appoint a Data Protection Officer (DPO) for each organization to oversee compliance with data privacy laws and review XR content before deployment.					
Establish internal self-regulatory bodies or compliance teams responsible for ensuring alignment with current legal standards and organizational policies.					
Provide periodic training on legal and ethical aspects of XR to all relevant stakeholders, including content creators and end-users.					
Create and present clear ethical guidelines to all users before the start of any XR pilot or deployment.					
Embed ethical and privacy-by-design principles into the development of XR authoring and experiencing tools, ensuring legal compliance from the outset.					
Deploy AI-based legal/ethics assistants to identify inappropriate user behavior, support compliance, and provide real-time guidance.					
Define personal data ownership rights in XR environments and set strict limits on usage and processing of user-generated data.					
Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.					
Apply stricter and more meaningful standards for obtaining informed consent from XR users, ensuring transparency and user agency in data collection and processing.					
Design consent mechanics directly into XR systems to support user decision-making and					

prevent boundary violations in immersive environments.					
Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access.					
Establish legal instruments to govern the collection, processing, and storage of data generated in XR environments, aligning with applicable data protection laws.					
Safeguard biometric and eye-tracking data collected by XR devices through explicit privacy protections and restrictions on secondary use.					
Define policies for avatar identity protection to prevent impersonation, identity theft, and misuse of digital representations in collaborative XR experiences.					
Extend existing legal frameworks and doctrines to address disputes, virtual property, and user rights specific to immersive industrial XR contexts.					
Apply relevant European legal and ethical frameworks to XR-based training and assistance activities, particularly those involving AI-generated or AI-supported content.					

TABLE 55: FORESEEN MEASURES FOR THE CATEGORY 'XR REGULATORY STRATEGY & STANDARDS ALIGNMENT'

Measures	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Collaborate with stakeholders and regulatory bodies, including participation in EU-level or industry-wide consortia to shape harmonized legal frameworks for XR (similar to AI regulations).					
Support the development of legal doctrines and enforcement mechanisms tailored to immersive environments, including virtual property, dispute resolution, and user protection.					
Form a legal/ethical oversight committee (e.g. within MotivateXR) to ensure consistent application and review of policies across deployments.					
Establish shared protocols across projects and partners, with built-in mechanisms for regular monitoring and compliance review.					
Develop forward-looking legal and ethical principles to guide responsible XR innovation and anticipate emerging regulatory challenges.					

Encourage the creation and adoption of voluntary developer codes of ethics to promote safe and responsible XR design practices.					
Develop official guidelines and training materials (e.g. from MotivateXR) on legal, ethical, and safety requirements for all system users.					
Define and disseminate XR-specific rules and best practices for training, ideally supported by AI-powered assistance tools (e.g. policy bots, RAG/LLM guidance).					
Provide regulatory support and training to organizations, helping them implement and align with safety protocols and emerging standards.					
Designate clear points of contact or helpdesks for legal and regulatory consultation within XR initiatives.					
Use policy-aware content deployment pipelines that integrate automated compliance checks during XR content publication.					
Implement auditability mechanisms in XR systems to enable oversight, transparency, and accountability in case of failure or harm.					
Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback.					
Adopt and monitor compliance with health and safety standards for XR use, including IEEE 3079 for cybersickness, IEC 60825 for laser safety, and EMF exposure guidelines.					
Stay up to date on new legal developments, for example by organizing regular meetings or consultations with data protection and security experts.					
Define and enforce XR-specific data privacy and informed consent policies, including safeguards for biometric data, avatar identity, and behavioral tracking.					
Ensure accessibility compliance of XR tools and content by aligning with established standards such as WCAG, ISO 9241, ADA, and CVAA.					

6. PRIORITISATION OF MITIGATION APPROACHES

Given the large number of mitigation measures identified through both the literature analysis and the workshops, it was essential to determine which actions should be addressed first. Prioritisation enables the MOTIVATE XR consortium to focus its efforts on the most suitable measures that are most capable of reducing risks, feasible to implement within project constraints, and relevant across significant issues. By systematically ranking the measures, the project ensures that development and design activities concentrate on interventions that are both effective and actionable, supporting a responsible and efficient integration of XR technologies.

6.1. APPROACH

The prioritization of mitigation measures in this deliverable was based on a structured, multi-dimensional assessment of their impact, ease of implementation, and issue coverage. These three dimensions were selected because they jointly capture the essential trade-offs in selecting measures that are both effective and realistic for the Motivate XR context.

- Impact reflects the extent to which a measure can mitigate the social, ethical, and legal issues associated with XR. This ensures that the prioritization does not only consider the existence of measures but also their actual potential to reduce risks in meaningful ways.
- Ease of implementation captures the feasibility of adopting a measure within organizations, taking into account practical constraints such as resources, technical expertise, and organizational readiness. Including this dimension ensures that the proposed measures are not only ambitious but also achievable.
- Issue coverage assesses the breadth and severity of the issues that each measure addresses. By accounting for both the average and maximum severity of the issues addressed, this dimension ensures that measures addressing relevant issues are not overlooked.

Together, these three dimensions provide a balanced framework: impact highlights effectiveness, ease accounts for feasibility, and coverage captures urgency. Evaluating measures across all three provides a robust basis for prioritization, as it avoids overemphasizing any single criterion in isolation. Each dimension was first calculated separately, and the results were then combined through cross-comparison analyses. This systematic approach ensures that prioritization reflects both the potential benefits of each measure and the practical realities of adopting them in the context of XR development and deployment.

For the impact and ease of implementation measurement, we have used a survey which was filled in by Motivate XR partners (see Section 6.2). For the issue coverage, we have used the outcomes of Section 3.3 where social, ethical and legal issues for Motivate XR have been prioritized based on likelihood and impact.

6.2. PRIORITIZATION OF MEASURES BY IMPACT AND EASE OF IMPLEMENTATION

The survey was designed to translate the conceptual prioritisation framework into practical assessments informed by expert judgment. It enabled the consortium to quantify how each mitigation measure performs in terms of its expected effectiveness and feasibility within real organisational contexts, ensuring that the final prioritisation reflects both strategic relevance and practical applicability.

The full survey outcomes can be found in Appendix H. In this survey, Motivate XR partners were asked to rate the impact and ease of implementation of mitigation measures. This was done in two steps.

In a first step, Motivate XR partners were asked to assess the relative importance of ten overarching categories of measures, each corresponding to a distinct dimension of social, ethical, or legal challenges in XR. Each partner was given 100 points to distribute across measure categories (see Table 26), indicating which areas they considered most important to address in order to mitigate the social, ethical, and legal issues raised by the Motivate XR technologies. This step provided an initial weighting of categories, reflecting the collective judgment of the consortium on priority domains. The distribution of points across categories can be found in Figure 13. The green lines indicate the average ratings and the orange the median.

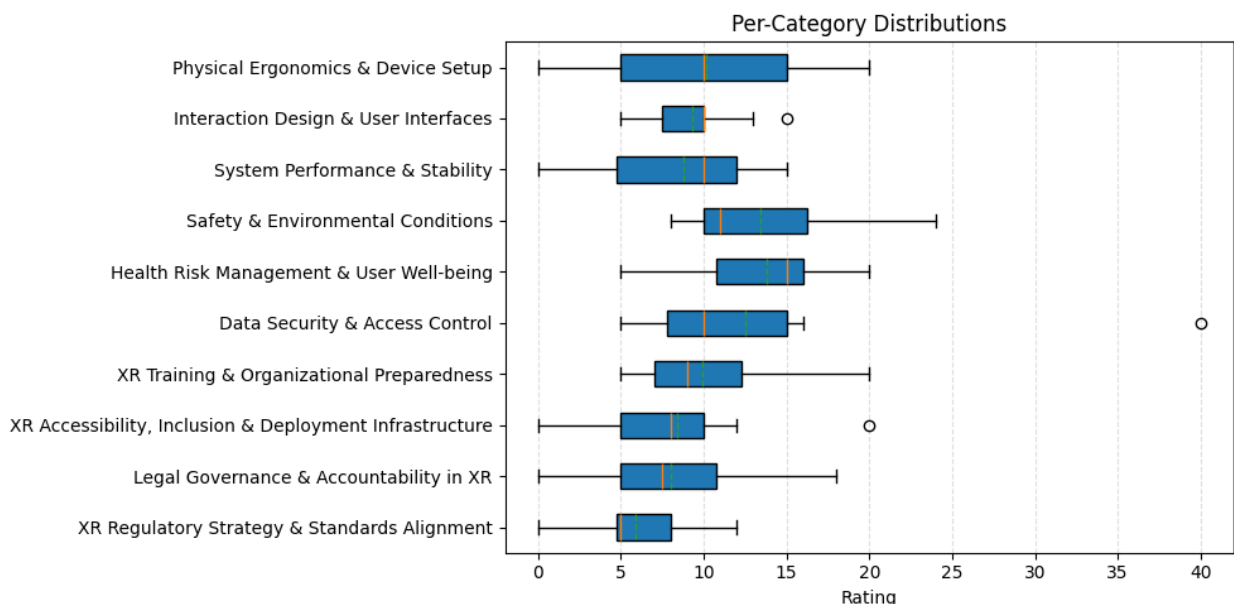


FIGURE 13: DISTRIBUTION OF POINTS ACROSS MEASURE CATEGORIES

In a second step, partners were asked to focus on the two categories to which they had allocated the most points. For all measures within those two categories, partners provided two types of ratings:

- Impact rating: Partners scored each measure on a scale from 1 to 4, where 1 represented a measure with low potential to mitigate social, ethical, or legal issues, and 4 represented a measure with high potential impact.
- Ease of implementation rating: For the subset of measures that could realistically be implemented by their organization, partners rated feasibility on a scale from 1 to 4, where 1 represented a very difficult measure to implement and 4 represented a very easy measure.

Participants were asked to only rate the feasibility for measures that could realistically be implemented by their organization to ensure the quality of the provided ratings. Such restrictions were not put on impact ratings as diverse viewpoints covers the impact from different angles.

Calculation of measures with highest impacts

Using the outcomes of the survey, we have calculated the impact scores the following way:

1. The importance weight of each category was derived from the distribution of 100 points across all ten categories, ensuring that categories deemed more important by the consortium carried higher weight.
2. Within the two categories that each partner had prioritized, partners rated the impact of individual measures on a scale from 1 to 4. These ratings were averaged across respondents, producing a mean impact value per measure.
3. To calculate the final impact score of each measure, the category weight and the average impact rating were multiplied. This integration ensured that both category-level importance and measure-level effectiveness were reflected in the final score.

Finally, the raw scores were normalized using min-max scaling (0-1). This allowed for direct comparison across all measures and facilitated visualization in scatter plots. Measures closer to 1 represent those with the strongest overall effectiveness.

The mathematical formulation of the calculation of highest impacts can be found hereunder.

Sets and inputs

- Partners $p \in \mathcal{P}$, categories $c \in \mathcal{C}$, measures $m \in \mathcal{M}$ with category $c(m)$.
- Points distribution: $w_{p,c} \in [0, 100]$ (per-partner, sums to 100 across c).
- Impact ratings (only for the two categories each partner prioritized): $r_{p,m} \in \{1, 2, 3, 4\}$ when provided; otherwise missing.
- Indicator of whether a partner rated a measure: $I_{p,m} = \mathbf{1}[r_{p,m} \text{ exists}]$.

Category weights

$$W_c = \frac{1}{|\mathcal{P}|} \sum_{p \in \mathcal{P}} \frac{w_{p,c}}{100}$$

Raw impact score (category-weighted mean rating)

$$S_m^{\text{raw}} = W_{c(m)} \cdot \left(\frac{\sum_{p \in \mathcal{P}} I_{p,m} r_{p,m}}{\sum_{p \in \mathcal{P}} I_{p,m}} \right)$$

Min-max normalization across all measures

$$S_m^{\text{norm}} = \frac{S_m^{\text{raw}} - \min_{k \in \mathcal{M}} S_k^{\text{raw}}}{\max_{k \in \mathcal{M}} S_k^{\text{raw}} - \min_{k \in \mathcal{M}} S_k^{\text{raw}}}$$

Calculation of measures with highest ease of implementation

The calculation of the ease of implementation was done the following way:

1. Partners rated the feasibility of each measure on a scale from 1 (very difficult) to 4 (very easy), but only within the two categories they had prioritized as most important. For each measure, the ratings were averaged across all partners who provided an evaluation, yielding a mean ease score that reflects the perceived feasibility of implementation at the organizational level.
2. Next, the raw ease scores were normalized to a 0–1 range to enable comparability across all measures and inclusion in the cross-comparison analyses.

The mathematical formulation of the calculation of ease of implementation is as follows:

Sets and inputs

- \mathcal{P} : set of partners
- $J_{p,m}$: indicator variable (1 if partner p rated measure m , 0 otherwise)
- $e_{p,m}$: ease rating given by partner p to measure m , where $e_{p,m} \in \{1, 2, 3, 4\}$

Raw ease of implementation score (mean rating)

$$E_m^{raw} = \frac{\sum_{p \in P} J_{p,m} e_{p,m}}{\sum_{p \in P} J_{p,m}}$$

Min-max normalization across all measures

$$E_m = \frac{E_m^{raw} - \min(E^{raw})}{\max(E^{raw}) - \min(E^{raw})}$$

6.3. PRIORITIZATION OF MEASURES BY ISSUE COVERAGE

The issue coverage dimension captures urgency, i.e., the breadth and severity of the issues addressed by each measure. Its calculation required a slightly different approach:

1. For each issue identified in the Motivate XR project, a severity score was calculated as the average of its likelihood and its impact (see scores in Section 3.3.2).
2. Using the mapping of measures to issues (see Section 4.4.2), each measure was linked to the set of issues it addressed.
3. For each measure, an issue coverage score was calculated by multiplying the maximum severity of the issues it addressed with the average severity of those same issues.

This method provides a balanced indicator: by including the average severity, the score captures how broadly a measure contributes across issues, while by including the maximum severity, it ensures that measures addressing at least one highly critical issue are not undervalued. Multiplying the two values strengthens this balance, as the score only becomes high when a measure performs well on both dimensions. If only the average were used, measures addressing many moderate issues could outrank those targeting a very severe issue. The multiplicative approach therefore avoids overemphasizing either breadth or depth in isolation and instead highlights measures that both mitigate the most severe risks and address a wide range of relevant issues. Finally, the raw scores were normalized (0-1), enabling comparison with the impact and ease scores.

The mathematical formulation of the calculation of issue coverage can be found hereunder.

Sets, data, and notation

- Issues $i \in \mathcal{I}$.
- Measures $m \in \mathcal{M}$.
- Mapping of measures to issues via an indicator:

$$A_{m,i} = \begin{cases} 1 & \text{if measure } m \text{ addresses issue } i \\ 0 & \text{otherwise} \end{cases}$$

- For each issue i , a **severity** score S_i (precomputed as the average of its likelihood and impact; cf. Sec. 3.2.3).

Per-measure issue set and counts

$$\mathcal{I}(m) = \{i \in \mathcal{I} \mid A_{m,i} = 1\}, \quad n_m = |\mathcal{I}(m)|.$$

Average and maximum severities covered by a measure

$$\bar{S}_m = \begin{cases} \frac{1}{n_m} \sum_{i \in \mathcal{I}(m)} S_i, & n_m > 0, \\ 0, & n_m = 0, \end{cases} \quad S_m^{\max} = \begin{cases} \max_{i \in \mathcal{I}(m)} S_i, & n_m > 0, \\ 0, & n_m = 0. \end{cases}$$

Raw issue-coverage score (breadth \times depth)

$$C_m^{\text{raw}} = \bar{S}_m \cdot S_m^{\max}.$$

Min-max normalization across measures

$$C_m^{\text{norm}} = \begin{cases} \frac{C_m^{\text{raw}} - \min_{k \in \mathcal{M}} C_k^{\text{raw}}}{\max_{k \in \mathcal{M}} C_k^{\text{raw}} - \min_{k \in \mathcal{M}} C_k^{\text{raw}}}, & \text{if } \max C^{\text{raw}} \neq \min C^{\text{raw}}, \\ 0, & \text{otherwise.} \end{cases}$$

6.4. RESULTS

The section hereunder shows the measures with highest impacts, ease of implementation and issue coverage. The section ends with a cross-comparison of the three dimensions, which we will use to select measures that will be recommended to Motivate XR.

6.4.1. MEASURES WITH HIGHEST IMPACTS

The analysis of the 50 highest-impact measures in Table 56 highlights several clear trends. First, measures from the category Safety & Environmental Conditions are strongly represented at the top of the list. The highest-scoring measure, conducting safety evaluations and user briefings before XR use, emphasizes the central importance of ensuring physical and procedural safety in immersive environments. Other measures in this category, such as setting up boundary warnings, limiting session durations, and establishing clear safety protocols, are also clustered among the top-ranking items. This shows a shared recognition that foundational safety procedures are critical prerequisites for trustworthy and sustainable XR deployments.

Another category that emerges prominently is Data Security & Access Control. Several measures in this area appear consistently in the upper half of the ranking, including ensuring firmware updates, coordinating with compliance departments, restricting access to sensitive sensor data, and embedding secure-by-design principles. This reflects growing awareness that XR systems are not only immersive environments but also complex data ecosystems, carrying significant risks of misuse, intrusion, or breaches. Ensuring resilience against these risks is thus considered highly impactful for the responsible adoption of XR technologies.

Health Risk Management & User Well-being also features strongly, although its measures tend to rank slightly lower than those related to physical safety and cybersecurity. Measures such as defining exclusion criteria for vulnerable users, limiting exposure times, or providing adaptive display settings are nevertheless considered important. Their relatively high representation indicates concern about protecting users from direct physiological and cognitive risks, particularly cybersickness, visual fatigue, and ergonomic discomfort. This aligns well with earlier analyses showing that many societal and ethical issues in XR adoption are linked to health and well-being.

Finally, XR Training & Organizational Preparedness appears in the middle tier of the rankings. Measures like organizing hands-on training, pre-assessing user levels, and providing cyber-awareness training are all included in the top 50, but their overall impact scores are slightly lower than those of safety or security. This suggests that while training is considered essential, its impact is seen as more supportive, enabling the safe and effective application of XR, rather than as directly addressing risks. Nonetheless, it highlights the importance of capacity building and user readiness in reducing barriers to adoption.

Taken together, the analysis shows a clear prioritization of measures related to safety, security, and health as the most impactful areas for Motivate XR. Training and preparedness complement these, but play a secondary role. Categories such as interaction design, performance optimization, and

accessibility are less prominent in this ranking, which suggests they are perceived as important but less directly tied to the highest-impact societal, ethical, and legal issues at stake.

TABLE 56: TOP 50 MEASURES WITH HIGHEST IMPACTS TO ADDRESS SOCIAL, ETHICAL AND LEGAL ISSUES IN MOTIVATE XR

Measure Category	ID	Measure	Impact score
4. Safety & Environmental Conditions	83	Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.	1
6. Data Security & Access Control	143	Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.	0,93
6. Data Security & Access Control	148	Coordinate closely with legal and compliance departments to ensure security strategies align with organizational and legal requirements.	0,93
4. Safety & Environmental Conditions	73	Use visual, auditory, or haptic boundary warnings to alert users when approaching physical hazards during immersive XR sessions.	0,92
4. Safety & Environmental Conditions	79	Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.	0,92
4. Safety & Environmental Conditions	82	Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emergency procedures.	0,92
4. Safety & Environmental Conditions	95	Verify whether different PPE (personal protective equipment) is required based on the context and use case.	0,92
5. Health Risk Management & User Well-being	103	Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid exposing vulnerable users to XR-related health risks.	0,86
6. Data Security & Access Control	126	Ensure a closed and secure system architecture with access restrictions tailored to user roles.	0,85
4. Safety & Environmental Conditions	71	Ensure a safe physical environment for XR use, including dedicated spaces optimized for movement and spatial awareness.	0,83
4. Safety & Environmental Conditions	74	Incorporate real-time collision detection systems or obstacle alerts to prevent accidents due to reduced real-world awareness.	0,83
4. Safety & Environmental Conditions	84	Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.	0,83
4. Safety & Environmental Conditions	85	Develop shared safety guidelines collaboratively with experts and partner organizations for standardization and consistency.	0,83
4. Safety & Environmental Conditions	86	Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment site.	0,83
4. Safety & Environmental Conditions	96	Inform users of all potential risks, including physical, operational, and situational hazards, before and during XR usage.	0,83
5. Health Risk Management & User Well-being	114	Limit exposure to immersive XR sessions based on evidence-based thresholds (e.g., max 30-60 minutes) to prevent visual fatigue and simulator sickness.	0,82
5. Health Risk Management & User Well-being	120	Adjust interpupillary distance (IPD) settings on headsets for each user to reduce eyestrain and depth perception errors.	0,82
6. Data Security & Access Control	130	Restrict and monitor access to XR sensor data (e.g., motion, location) to prevent unauthorized use or inference of sensitive personal information.	0,82
6. Data Security & Access Control	136	Enforce strong password policies, preventing the use of weak or easily guessed passwords.	0,82
5. Health Risk Management & User Well-being	113	Set and enforce session duration limits, with alerts and mandatory breaks to prevent overexposure and fatigue.	0,77
5. Health Risk Management & User Well-being	115	Allow personalized break schedules based on user comfort and adaptability.	0,77
4. Safety & Environmental Conditions	72	Calibrate and enforce safety zones using tools like guardian systems and spatial boundary warnings.	0,75
4. Safety & Environmental Conditions	75	Enable pass-through and quick-hide features to allow immediate visibility of the real environment in case of emergency or disorientation.	0,75
4. Safety & Environmental Conditions	77	Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.	0,75

4. Safety & Environmental Conditions	80	Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.	0,75
4. Safety & Environmental Conditions	81	Limit continuous use of XR headsets in high-intensity applications and enforce stricter break schedules based on observed discomfort indicators.	0,75
4. Safety & Environmental Conditions	94	Adjust interpupillary distance (IPD), screen brightness, and refresh rate settings to reduce eye strain and visual discomfort.	0,75
7. XR Training & Organizational Preparedness	153	Organize hands-on training sessions and courses on XR device usage and interaction principles.	0,74
7. XR Training & Organizational Preparedness	154	Train users on specific XR interaction techniques, such as hand tracking and latency-aware gestures.	0,74
7. XR Training & Organizational Preparedness	156	Use pre-assessments to assign training levels and customize content based on user proficiency.	0,74
7. XR Training & Organizational Preparedness	165	Involve diverse users in pilot testing (age, background, familiarity) to validate and improve training design.	0,74
7. XR Training & Organizational Preparedness	172	Provide cyber-awareness training to mitigate risks such as unsafe network usage and data exposure.	0,74
7. XR Training & Organizational Preparedness	175	Offer real-time ergonomic feedback during XR training sessions to improve posture and reduce risk of physical strain or injury.	0,74
5. Health Risk Management & User Well-being	99	Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.	0,73
5. Health Risk Management & User Well-being	102	Educate users on safe post-use behavior, such as avoiding driving or operating machinery immediately after XR sessions.	0,73
5. Health Risk Management & User Well-being	104	Provide users with clear information sheets and obtain informed consent before XR use, including any known risks or side effects.	0,73
5. Health Risk Management & User Well-being	109	Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow or trigger session termination if needed. Use hybrid locomotion methods (e.g., HeadJoystick or body-lean navigation) to minimize motion sickness compared to controller-based movement.	0,73
5. Health Risk Management & User Well-being	117	Ensure hardware and software support ergonomic use (e.g., hand posture techniques like ProxyHand) to prevent fatigue during extended XR sessions.	0,73
5. Health Risk Management & User Well-being	118	Include ergonomics-based posture monitoring (e.g., via visual/auditory cues) to help users maintain safe physical positioning during XR use.	0,73
5. Health Risk Management & User Well-being	119	Apply adaptive brightness and contrast settings to accommodate user comfort and reduce the likelihood of visual fatigue or disorientation.	0,73
5. Health Risk Management & User Well-being	121	Apply adaptive brightness and contrast settings to accommodate user comfort and reduce the likelihood of visual fatigue or disorientation.	0,73
6. Data Security & Access Control	128	Use secure data transmission protocols (e.g., HTTPS, VPNs, encrypted APIs) to protect data in transit.	0,7
6. Data Security & Access Control	129	Apply data anonymization and encryption techniques to protect sensitive user data both in transit and at rest.	0,7
6. Data Security & Access Control	135	Enable secure device pairing mechanisms for XR peripherals (e.g., finger-tracking-based pairing) to prevent unauthorized connections.	0,7
6. Data Security & Access Control	138	Integrate intrusion detection systems (IDS) at both network and application levels to monitor and respond to threats targeting XR components.	0,7
6. Data Security & Access Control	139	Enable continuous security monitoring and real-time threat detection across XR infrastructure.	0,7
6. Data Security & Access Control	140	Perform regular penetration testing and vulnerability assessments to identify and fix security gaps.	0,7
6. Data Security & Access Control	142	Embed secure-by-design principles in XR hardware and software development to reduce exploitable vulnerabilities at the system level.	0,7
6. Data Security & Access Control	144	Enable kiosk mode for XR apps to restrict access and prevent unauthorized modifications.	0,7

6. Data Security & Access Control	145 Design experiences to minimize data exposure, only collecting and storing what is strictly necessary.	0,7
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6.4.2. MEASURES WITH HIGHEST EASE OF IMPLEMENTATION

The analysis of the 50 measures with highest ease of implementation shows in Table 57 that a broad set of interventions are considered relatively easy to implement across different domains. A large cluster of measures in Safety & Environmental Conditions appears prominently, including limiting session durations, enforcing breaks, providing safety manuals, incorporating manufacturer guidance, verifying the need for personal protective equipment, and informing users about risks. These measures primarily rely on organizational protocols, user briefings, and straightforward procedural adjustments, making them accessible to most organizations without the need for significant technical development.

Data Security & Access Control is another strong cluster in the ranking. Practices such as using secure data transmission protocols, enforcing strong passwords, keeping firmware updated, and enabling kiosk mode are well-established in general IT and cybersecurity contexts. Their transfer to XR environments is expected to be straightforward, as they build on existing expertise and widely available tools.

The table also highlights a large number of XR Accessibility, Inclusion & Deployment Infrastructure measures, such as ensuring compliance with accessibility standards, designing adaptive user interfaces, including visually impaired users in co-design processes, offering offline training modules, and integrating accessibility metrics into monitoring systems. These measures reflect growing attention to inclusivity in XR. Importantly, they often draw on established accessibility frameworks (e.g., WCAG, ADA, EN17161), which lowers the barrier to implementation by providing clear guidelines.

Finally, measures related to Health Risk Management & User Well-being and Physical Ergonomics & Device Setup are also present. These include pre-use screening, continuous well-being evaluation, post-use recovery protocols, and structured session duration limits. While some of these can be integrated procedurally (e.g., distributing surveys or providing consent forms), others that rely on systematic monitoring of users or integration of recovery schedules may be somewhat more resource-intensive. This is reflected in their lower ease scores (between 0.75 and 0.85), suggesting that while feasible, they may require more planning, coordination, or technical support compared to purely procedural safety measures.

Overall, the table suggests that measures spanning organizational safety practices, standard IT security protocols, and inclusivity principles are generally perceived as highly feasible. By contrast, measures involving systematic user monitoring or ergonomics testing, while still practical, may demand a greater level of investment and coordination.

TABLE 57: TOP 50 MEASURES WITH HIGHEST EASE OF IMPLEMENTATION IN MOTIVATE XR

Measure Category	ID	Measure	Ease score
3. System Performance & Stability	70	Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.	1
4. Safety & Environmental Conditions	79	Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.	1
4. Safety & Environmental Conditions	86	Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment site.	1
4. Safety & Environmental Conditions	87	Incorporate manufacturer safety guidance into internal training and documentation.	1
4. Safety & Environmental Conditions	95	Verify whether different PPE (personal protective equipment) is required based on the context and use case.	1
4. Safety & Environmental Conditions	96	Inform users of all potential risks, including physical, operational, and situational hazards, before and during XR usage.	1
6. Data Security & Access Control	128	Use secure data transmission protocols (e.g., HTTPS, VPNs, encrypted APIs) to protect data in transit.	1
6. Data Security & Access Control	136	Enforce strong password policies, preventing the use of weak or easily guessed passwords.	1
6. Data Security & Access Control	143	Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.	1
6. Data Security & Access Control	144	Enable kiosk mode for XR apps to restrict access and prevent unauthorized modifications.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	180	Ensure compliance with accessibility regulations and standards (e.g., WCAG, ADA, CVAA, EN17161) to provide equitable digital access across XR platforms.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	181	Design XR content with adaptive UI elements, including high contrast visuals, larger fonts, dynamic colors, voice interactions, audio descriptions, and haptic feedback (e.g., WCAG-inspired accessibility tests).	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	196	Benchmark XR experiences with visually impaired users, and apply feedback to address usability barriers.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	197	Include end-users with visual impairments in co-design processes to tailor experiences to diverse needs.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	198	Create 'standard user' profiles to guide inclusive design and test from multiple perspectives.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	200	Enable accessible XR content creation through no-code authoring tools compatible with assistive technologies.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	201	Train XR authors on inclusive design principles, emphasizing accessibility and user diversity.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	202	Promote inclusive XR education targeting both developers and users.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	210	Create easily accessible tutorials, both on-device and offline, to support quick onboarding and recalibration.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	211	Provide offline training modules and reduce reliance on online connectivity where appropriate.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	215	Evaluate hardware usability in both indoor and outdoor environments, considering lighting, noise, and user movement.	1

8. XR Accessibility, Inclusion & Deployment Infrastructure	219	Train IT staff on XR-specific maintenance and support tasks to build internal capacity.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	220	Define XR infrastructure & training policies, tailored to organizational needs and resource levels.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	225	Include accessibility in organizational digital transformation plans to ensure long-term alignment.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	227	Use real-time performance metrics (completion time, error rates, retries) to detect learning gaps and adapt experiences.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	228	Benchmark device usage during task execution, using AI to identify difficult instructions or interactions.	1
8. XR Accessibility, Inclusion & Deployment Infrastructure	230	Integrate accessibility-focused KPIs and compliance checks into XR system monitoring and analytics pipelines.	1
9. Legal Governance & Accountability in XR	243	Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.	1
9. Legal Governance & Accountability in XR	245	Design consent mechanics directly into XR systems to support user decision-making and prevent boundary violations in immersive environments.	1
5. Health Risk Management & User Well-being	116	Offer passive viewing modes (e.g., guided or pre-recorded tours) as an alternative for users sensitive to active interaction in XR environments.	0,95
5. Health Risk Management & User Well-being	102	Educate users on safe post-use behavior, such as avoiding driving or operating machinery immediately after XR sessions.	0,94
5. Health Risk Management & User Well-being	104	Provide users with clear information sheets and obtain informed consent before XR use, including any known risks or side effects.	0,9
1. Physical Ergonomics & Device Setup	13	Limit continuous XR session duration to avoid physical fatigue and strain.	0,88
1. Physical Ergonomics & Device Setup	23	Train users in proper ergonomic use of XR devices to avoid strain and injury.	0,88
2. Interaction Design & User Interfaces	27	Optimize interactions for XR by reducing non-essential information compared to traditional 2D interfaces.	0,88
2. Interaction Design & User Interfaces	44	Include context-aware automation, like automated task prompts based on user environment or behaviour.	0,88
4. Safety & Environmental Conditions	80	Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.	0,88
4. Safety & Environmental Conditions	81	Limit continuous use of XR headsets in high-intensity applications and enforce stricter break schedules based on observed discomfort indicators.	0,88
4. Safety & Environmental Conditions	82	Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emergency procedures.	0,88
4. Safety & Environmental Conditions	97	Establish policies distinguishing between shared vs. personal use of XR devices, and adapt hygiene and safety protocols accordingly.	0,88
5. Health Risk Management & User Well-being	103	Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid exposing vulnerable users to XR-related health risks.	0,88
5. Health Risk Management & User Well-being	98	Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.	0,85
5. Health Risk Management & User Well-being	99	Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.	0,85
5. Health Risk Management & User Well-being	101	Administer structured post-use recovery times (e.g., at least 10-15 minutes) before users return to high-focus tasks such as driving or machinery operation.	0,85

5. Health Risk Management & User Well-being	114	Limit exposure to immersive XR sessions based on evidence-based thresholds (e.g., max 30–60 minutes) to prevent visual fatigue and simulator sickness.	0,85
1. Physical Ergonomics & Device Setup	21	Log session duration and voluntary dropouts to identify potential ergonomic issues.	0,81
5. Health Risk Management & User Well-being	113	Set and enforce session duration limits, with alerts and mandatory breaks to prevent overexposure and fatigue.	0,8
1. Physical Ergonomics & Device Setup	14	Provide acclimation sessions to help users gradually adapt to XR hardware.	0,75
1. Physical Ergonomics & Device Setup	17	Perform initial device calibration and enable real-time adjustments during use.	0,75
2. Interaction Design & User Interfaces	26	Design interfaces that reduce visual clutter by automatically adjusting displayed information based on task complexity and cognitive load.	0,75

6.4.3. COVERAGE OF ISSUES ADDRESSED

The analysis in this section shows the extent to which different measures cover the issues identified in Chapter 3. The top-50 measures with the highest issue coverage span a broad mix of categories, but some stand out as particularly prominent. Legal Governance & Accountability in XR and XR Regulatory Strategy & Standards Alignment are strongly represented, with several measures clustered in the upper range of the table. This reflects the fact that governance and compliance measures often address multiple high-severity risks simultaneously, such as legal liability, data protection, accountability, and systemic regulatory gaps. Even when individual measures are narrowly scoped, their connection to high-severity legal and governance issues ensures consistently strong coverage scores.

XR Training & Organizational Preparedness also features prominently in the top 50. Training-oriented measures, such as onboarding, structured programs, and pilot initiatives, achieve relatively high coverage because they cut across both technical and organizational dimensions of XR deployment. By preparing users to recognize and manage risks, these measures provide indirect mitigation of multiple issues, from safety and health to usability and adoption challenges.

In addition, Physical Ergonomics & Device Setup and System Performance & Stability appear repeatedly among the higher-ranked measures. Ergonomic design choices (e.g., accommodating diverse users or reducing visual strain) and performance safeguards (e.g., minimizing latency) are fundamental for preventing common XR-related health and usability issues. Their coverage scores reflect how strongly these technical aspects connect to the high-severity risks of motion sickness, discomfort, and reduced awareness in XR.

Safety & Environmental Conditions is less numerous in the very top positions but still contributes key measures with strong coverage, particularly those ensuring safe physical environments and user briefings. These emphasize the importance of organizational safety practices as a complement to technical or governance-focused approaches.

Finally, XR Accessibility, Inclusion & Deployment Infrastructure and Interaction Design & User Interfaces appear in the mid-to-lower range of the top 50. Although their coverage scores are somewhat lower than those of governance or training measures, they remain important because

they tie accessibility and usability to broader safety and inclusion concerns. This demonstrates that accessible and user-friendly design does not only promote equity but also contributes to mitigating high-severity operational risks.

TABLE 58: TOP 50 MEASURES WITH HIGHEST ISSUE COVERAGE

Category	ID	Measure	Issue coverage
9. Legal Governance & Accountability in XR	251	Apply relevant European legal and ethical frameworks to XR-based training and assistance activities, particularly those involving AI-generated or AI-supported content.	1
7. XR Training & Organizational Preparedness	151	Include XR training in onboarding for all new employees to ensure consistent baseline knowledge.	0,64
1. Physical Ergonomics & Device Setup	5	Design headset form factors and IPD ranges to fit a wider diversity of head shapes, sizes, and gender-related anatomical differences.	0,53
1. Physical Ergonomics & Device Setup	6	Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision correction needs.	0,53
1. Physical Ergonomics & Device Setup	8	Include adjustable focus lenses to accommodate vision differences (e.g., myopia, hyperopia).	0,53
3. System Performance & Stability	50	Ensure responsiveness and low-latency rendering to maintain smooth, lag-free user interactions—especially critical in complex 3D environments.	0,53
3. System Performance & Stability	51	Minimize motion-to-photon latency to below 10 milliseconds to reduce sensory mismatch and ensure real-time system responsiveness in XR environments.	0,53
2. Interaction Design & User Interfaces	25	Design clear, consistent, and non-cluttered UIs to reduce cognitive load and improve usability.	0,52
1. Physical Ergonomics & Device Setup	24	Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.	0,49
7. XR Training & Organizational Preparedness	164	Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates.	0,49
7. XR Training & Organizational Preparedness	150	Develop structured XR training programs for employees, including mandatory sessions on safety, proper use, and organizational protocols.	0,49
9. Legal Governance & Accountability in XR	245	Design consent mechanics directly into XR systems to support user decision-making and prevent boundary violations in immersive environments.	0,49
10. XR Regulatory Strategy & Standards Alignment	264	Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback.	0,49
7. XR Training & Organizational Preparedness	153	Organize hands-on training sessions and courses on XR device usage and interaction principles.	0,48
10. XR Regulatory Strategy & Standards Alignment	258	Develop official guidelines and training materials on legal, ethical, and safety requirements for all system users.	0,45
9. Legal Governance & Accountability in XR	231	Define and enforce access control policies, including formal access requests and logging of user permissions for XR systems.	0,42
9. Legal Governance & Accountability in XR	232	Implement action and event audit logs to track user activity (who did what, when, and where) for accountability and traceability.	0,42
9. Legal Governance & Accountability in XR	233	Ensure the auditability of XR systems by capturing and logging system operations to enable oversight, investigation, and user accountability.	0,42
9. Legal Governance & Accountability in XR	235	Prepare legal and risk mitigation plans, outlining how to handle data breaches, misuse of XR tools, or other legal disputes.	0,42

9. Legal Governance & Accountability in XR	242	Define personal data ownership rights in XR environments and set strict limits on usage and processing of user-generated data.	0,42
9. Legal Governance & Accountability in XR	243	Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.	0,42
9. Legal Governance & Accountability in XR	244	Apply stricter and more meaningful standards for obtaining informed consent from XR users, ensuring transparency and user agency in data collection and processing.	0,42
9. Legal Governance & Accountability in XR	246	Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access.	0,42
9. Legal Governance & Accountability in XR	247	Establish legal instruments to govern the collection, processing, and storage of data generated in XR environments, aligning with applicable data protection laws.	0,42
9. Legal Governance & Accountability in XR	248	Safeguard biometric and eye-tracking data collected by XR devices through explicit privacy protections and restrictions on secondary use.	0,42
9. Legal Governance & Accountability in XR	249	Define policies for avatar identity protection to prevent impersonation, identity theft, and misuse of digital representations in collaborative XR experiences.	0,42
10. XR Regulatory Strategy & Standards Alignment	263	Implement auditability mechanisms in XR systems to enable oversight, transparency, and accountability in case of failure or harm.	0,42
10. XR Regulatory Strategy & Standards Alignment	266	Stay up to date on new legal developments, for example by organizing regular meetings or consultations with data protection and security experts.	0,42
10. XR Regulatory Strategy & Standards Alignment	255	Establish shared protocols across projects and partners, with built-in mechanisms for regular monitoring and compliance review.	0,41
3. System Performance & Stability	52	Benchmark motion-to-display latency and rendering performance under realistic usage scenarios to detect bottlenecks and guide optimization.	0,39
8. XR Accessibility, Inclusion & Deployment Infrastructure	182	Provide customizable visual settings such as brightness, contrast, and text size to accommodate users with varying visual needs.	0,39
8. XR Accessibility, Inclusion & Deployment Infrastructure	201	Train XR authors on inclusive design principles, emphasizing accessibility and user diversity.	0,39
8. XR Accessibility, Inclusion & Deployment Infrastructure	202	Promote inclusive XR education targeting both developers and users.	0,39
10. XR Regulatory Strategy & Standards Alignment	262	Use policy-aware content deployment pipelines that integrate automated compliance checks during XR content publication.	0,38
2. Interaction Design & User Interfaces	29	Use appropriate visual contrast and avoid overly bright elements to reduce eye fatigue.	0,38
2. Interaction Design & User Interfaces	41	Offer intuitive head-controlled or radial menu options to reduce arm fatigue and physical strain in hands-free scenarios.	0,38
3. System Performance & Stability	56	Adapt rendering resolution dynamically to hardware capabilities and runtime performance to maintain stable frame rates and reduce cybersickness.	0,38
3. System Performance & Stability	70	Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.	0,38
8. XR Accessibility, Inclusion & Deployment Infrastructure	181	Design XR content with adaptive UI elements, including high contrast visuals, larger fonts, dynamic colors, voice interactions, audio descriptions, and haptic feedback (e.g., WCAG-inspired accessibility tests).	0,37
8. XR Accessibility, Inclusion & Deployment Infrastructure	183	Design adaptive XR interfaces that automatically adjust based on users' needs, device capabilities, and environmental conditions.	0,37

8. XR Accessibility, Inclusion & Deployment Infrastructure	187	Integrate audio-haptic design to support multimodal interaction.	0,37
8. XR Accessibility, Inclusion & Deployment Infrastructure	188	Use haptic feedback to support spatial orientation, object interaction, and task execution in immersive environments.	0,37
8. XR Accessibility, Inclusion & Deployment Infrastructure	189	Include order/action confirmation by voice, enhancing clarity and accessibility during interactions.	0,37
8. XR Accessibility, Inclusion & Deployment Infrastructure	190	Implement intelligent voice commands and AI-guided voice feedback to assist with scene framing, navigation, and task execution.	0,37
8. XR Accessibility, Inclusion & Deployment Infrastructure	191	Support voice-based navigation and content interaction for users with limited manual dexterity or low vision.	0,37
1. Physical Ergonomics & Device Setup	18	Conduct preventive ergonomic testing for different user profiles before deployment.	0,35
1. Physical Ergonomics & Device Setup	23	Train users in proper ergonomic use of XR devices to avoid strain and injury.	0,35
2. Interaction Design & User Interfaces	47	Include safety hints and risk prompts within the interface to alert users during potentially unsafe actions.	0,35
4. Safety & Environmental Conditions	71	Ensure a safe physical environment for XR use, including dedicated spaces optimized for movement and spatial awareness.	0,35
4. Safety & Environmental Conditions	83	Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.	0,35

6.5. CROSS-COMPARISON ANALYSIS

In this section, we perform a cross-comparison analysis of measures based on their score on impact, ease of implementation and issue coverage. This step is particularly relevant to define thresholds for selecting the measures that will be recommended to the Motivate XR consortium. By plotting measures across the pairs of dimensions, it becomes possible to identify clusters of promising candidates as well as trade-offs that must be considered.

Impact vs. Ease of Implementation

Looking at the cross-comparison of all measures (Figure 14), the distribution shows that while impact scores vary widely across the spectrum, a large share of measures achieve relatively high ease-of-implementation scores. This clustering toward the top of the ease axis suggests that many measures are not perceived as particularly difficult to put in place, with feasibility posing less of a barrier than impact in determining priorities. The lower-left quadrant (low impact, low ease) is sparsely populated, indicating that few measures are regarded as both ineffective and hard to implement. Instead, the bulk of the measures fall into the middle-to-high range for ease, with impact acting as the main differentiating factor.

When focusing on the top 30 measures (Figure 15), calculated based on the average of impact and ease scores, a clearer picture emerges. The shortlist is dominated by measures from Safety & Environmental Conditions, Health Risk Management & User Well-being, and Data Security & Access Control, alongside a smaller but notable presence from System Performance & Stability and Physical

Ergonomics & Device Setup. This indicates that measures relating to user safety, health, and secure digital practices are perceived not only as highly beneficial but also as achievable in practice.

Among the highest-ranked, Safety & Environmental Conditions measures include limiting session duration (IDs 13, 79, 81, 82), providing risk information and manuals (IDs 86, 96), and conducting safety evaluations (ID 83). These reflect straightforward procedural safeguards that directly reduce risks of overexposure, physical accidents, or inadequate user preparation. Similarly, Health Risk Management measures such as informed consent (ID 104), pre-use screening (ID 98), and continuous well-being evaluation (ID 99) highlight the central role of health monitoring and user guidance.

From the Data Security & Access Control category, measures such as enforcing secure transmission protocols (ID 128), keeping software updated (ID 143), and applying strong password policies (ID 136) appear prominently. These measures draw on established digital security practices and can be readily transferred to XR contexts, making them low-effort, high-value actions. Finally, selected System Performance & Stability (ID 70) and Physical Ergonomics (ID 13) measures underline the importance of maintaining usability and comfort as core enablers of safe and effective XR experiences.

A point of caution remains for measures with an ease score of zero in the overall plot. These correspond mainly to XR Training & Organizational Preparedness and XR Regulatory Strategy & Standards Alignment, which were not rated on ease (and, in some cases, on impact). Several of these still show strong potential based on their impact scores, meaning they could warrant further consideration if feasibility turns out to be high in practice.

Taken together, the updated analysis shows that Motivate XR's strongest opportunities lie in measures that directly safeguard user health and safety and data security, areas that combine high benefit with straightforward adoption. At the same time, training and regulatory measures may emerge as priorities once their ease of implementation is better understood if they fall within the project scope.

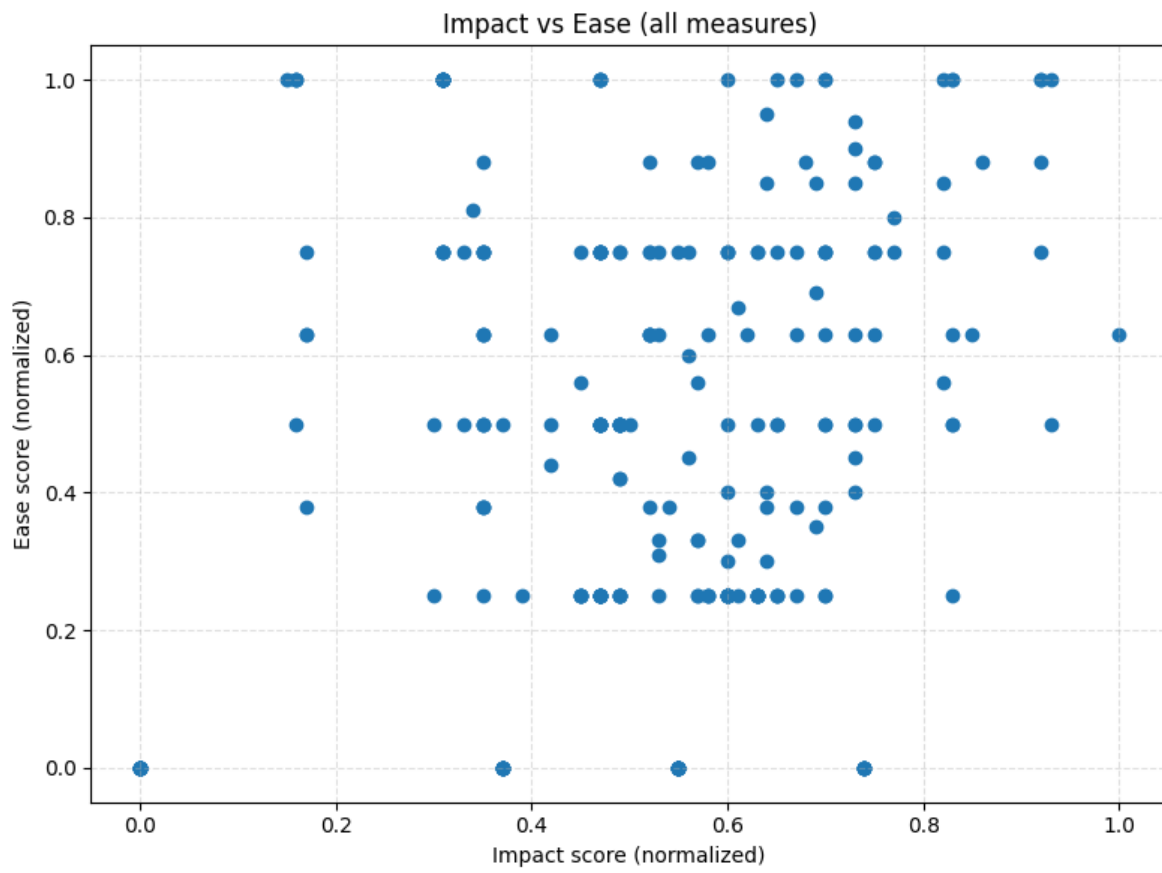
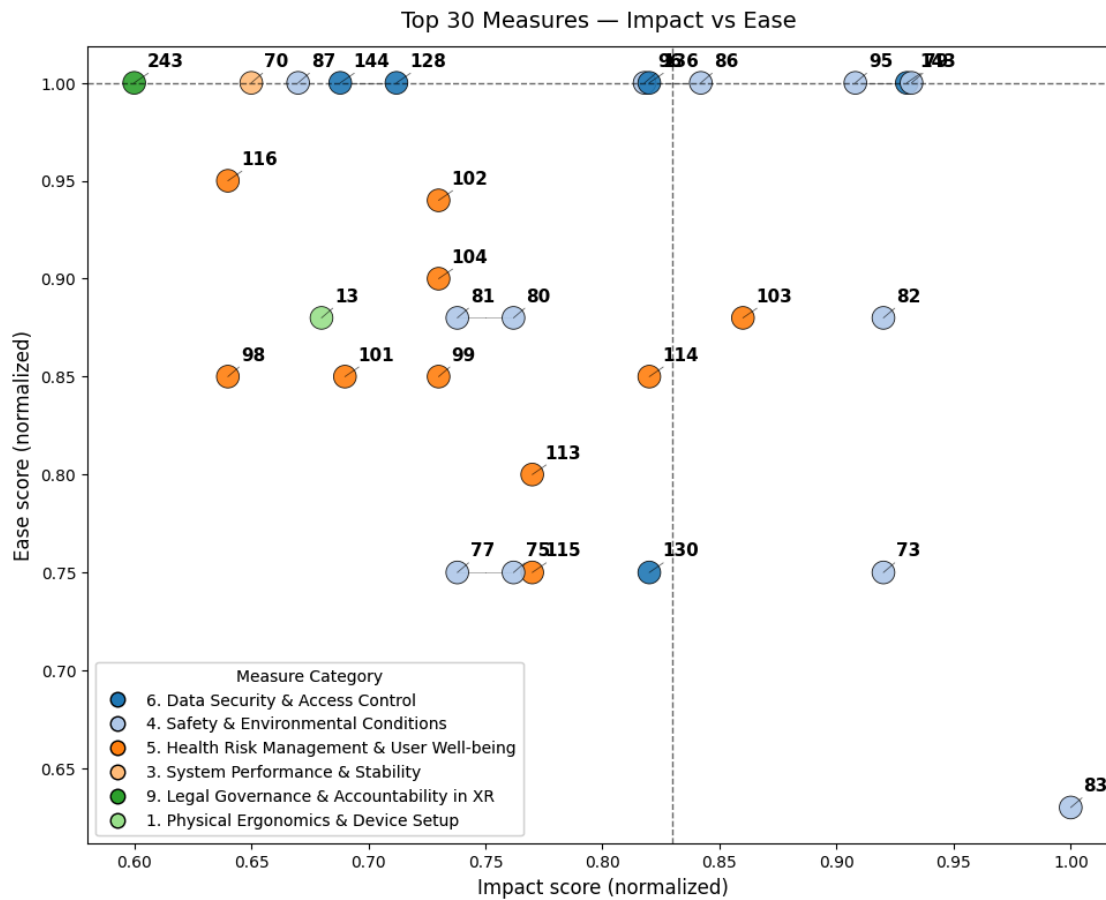


FIGURE 14: SCATTER PLOT OF MEASURES BASED ON IMPACT AND EASE OF IMPLEMENTATION



- Measures (Top by Impact score (normalized) × Ease score (normalized))
- 13 — Limit continuous XR session duration to avoid physical fatigue and strain.
 - 70 — Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.
 - 73 — Use visual, auditory, or haptic boundary warnings to alert users when approaching physical hazards during imme...
 - 75 — Enable pass-through and quick-hide features to allow immediate visibility of the real environment in case of e...
 - 77 — Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical str...
 - 79 — Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.
 - 80 — Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issue...
 - 81 — Limit continuous use of XR headsets in high-intensity applications and enforce stricter break schedules based ...
 - 82 — Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emerg...
 - 83 — Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awarenes...
 - 86 — Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment si...
 - 87 — Incorporate manufacturer safety guidance into internal training and documentation.
 - 95 — Verify whether different PPE (personal protective equipment) is required based on the context and use case.
 - 96 — Inform users of all potential risks, including physical, operational, and situational hazards, before and duri...
 - 98 — Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibi...
 - 99 — Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to id...
 - 101 — Administer structured post-use recovery times (e.g., at least 10-15 minutes) before users return to high-focus...
 - 102 — Educate users on safe post-use behavior, such as avoiding driving or operating machinery immediately after XR ...
 - 103 — Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid e...
 - 104 — Provide users with clear information sheets and obtain informed consent before XR use, including any known ris...
 - 113 — Set and enforce session duration limits, with alerts and mandatory breaks to prevent overexposure and fatigue.
 - 114 — Limit exposure to immersive XR sessions based on evidence-based thresholds (e.g., max 30-60 minutes) to preven...
 - 115 — Allow personalized break schedules based on user comfort and adaptability.
 - 116 — Offer passive viewing modes (e.g., guided or pre-recorded tours) as an alternative for users sensitive to acti...
 - 128 — Use secure data transmission protocols (e.g., HTTPS, VPNs, encrypted APIs) to protect data in transit.
 - 130 — Restrict and monitor access to XR sensor data (e.g., motion, location) to prevent unauthorized use or inferenc...
 - 136 — Enforce strong password policies, preventing the use of weak or easily guessed passwords.
 - 143 — Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.
 - 144 — Enable kiosk mode for XR apps to restrict access and prevent unauthorized modifications.
 - 243 — Inform users about personal data handling responsibilities, including potential liabilities for misuse or unau...

FIGURE 15: TOP-30 MEASURES WITH HIGHEST IMPACT AND EASE OF IMPLEMENTATION

Impact vs. Issue coverage

Looking at the cross-comparison plot of all measures (Figure 16), the distribution shows that most measures cluster in the mid-to-low coverage range, regardless of their ease of implementation. This indicates that while many measures may be relatively straightforward to implement, their contribution to addressing a broad set of issues is limited. A notable aspect is the vertical line of points at a normalized ease score of zero, which, as discussed earlier, reflects unrated measures rather than genuine difficulty. These unrated measures complicate interpretation, since some may in reality be both impactful and wide in coverage. Aside from this, the overall spread suggests that only a small number of measures achieve both high ease and high coverage simultaneously.

When narrowing down to the top 30 measures (Figure 17), a clearer picture emerges. At the upper-right end of the scale, measure 251 (“Apply relevant European legal and ethical frameworks...”) in the Legal Governance & Accountability category stands out with the highest coverage and relatively strong ease. This reflects the broad, cross-cutting importance of governance measures, which may be administratively easier to put into place than technical ones, while addressing multiple systemic issues at once. Other governance-related measures (e.g., 245, 231, 249) also appear prominently, confirming the central role of accountability and regulatory alignment for broad issue coverage.

Measures in Safety & Environmental Conditions also feature strongly among the top 30, though they are spread more across the ease spectrum. For instance, measures such as 71, 73, 82, and 83 score high on both ease and coverage, highlighting their practical value in ensuring safe XR deployment environments. These include basic provisions like collision detection, safe spaces, and risk assessments, which are relatively straightforward to implement but contribute to reducing a broad range of safety issues. By contrast, measures like 84 or 86 are somewhat lower in coverage, but still land among the top 30 due to their ease and specific contributions to organizational safety protocols.

Interestingly, several Health Risk Management & User Well-being measures (e.g., 99, 100, 109, 103) appear in the middle-to-upper coverage range but with only moderate ease scores. This suggests that while health-related safeguards are central for mitigating XR-related risks, they may require more resources, specialized monitoring, or organizational changes, reducing their ease of adoption. Similarly, Physical Ergonomics & Device Setup measures like 5, 6, 8, and 24 combine moderate coverage with medium ease, pointing to their relevance in addressing specific user discomfort issues but not covering the same breadth as governance or safety-oriented measures.

Measures in the XR Regulatory Strategy & Standards Alignment category were not rated for impact and therefore have a non-normalized score of 0. This absence of data makes it difficult to judge their true position in the comparison, as it cannot be ruled out that they might also deliver high impact. However, their normalized coverage scores remain relatively modest, with the highest around 0.48 and most clustered between 0.2 and 0.3. This indicates that, even if their impact were rated more highly, these measures would likely not reach the top tier of priority candidates when compared with others that combine both broader coverage and demonstrated impact. Instead, they should be seen

as complementary measures that add value by addressing regulatory and governance aspects not captured by more technical or safety-focused actions.

Overall, the cross-comparison of ease versus coverage shows that the most promising candidates for broad uptake lie in Legal Governance & Accountability and Safety & Environmental Conditions. These categories provide measures that are both relatively easy to implement and cover a wide range of issues, making them strategic starting points for Motivate XR. Meanwhile, ergonomic and health-related measures, though narrower in coverage, remain important complements where specific user risks must be addressed.

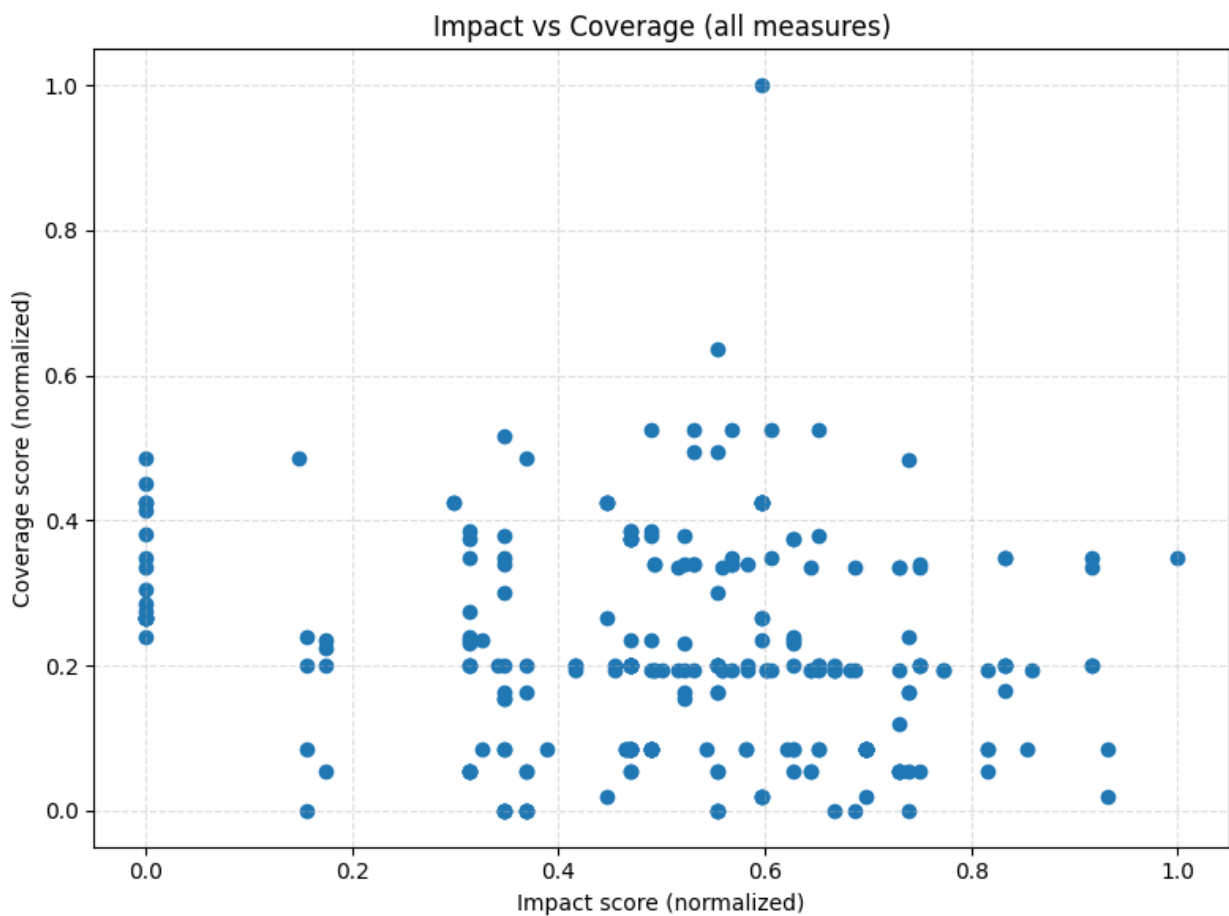
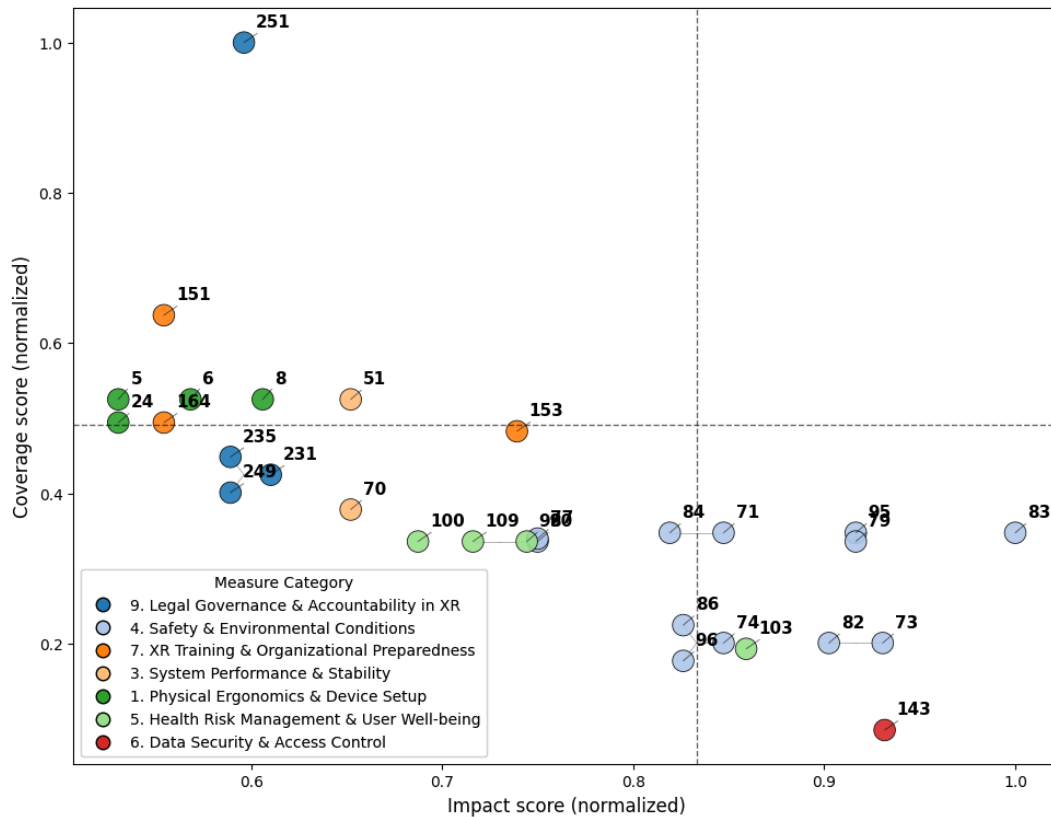


FIGURE 16: SCATTER PLOT OF MEASURES BASED ON IMPACT AND ISSUE COVERAGE

Top 30 Measures — Impact vs Coverage



- Measures (Top by Impact score (normalized) × Coverage score (normalized))
- 5 — Design headset form factors and IPD ranges to fit a wider diversity of head shapes, sizes, and gender-related ...
 - 6 — Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision...
 - 8 — Include adjustable focus lenses to accommodate vision differences (e.g., myopia, hyperopia).
 - 24 — Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.
 - 51 — Minimize motion-to-photon latency to below 10 milliseconds to reduce sensory mismatch and ensure real-time sys...
 - 70 — Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.
 - 71 — Ensure a safe physical environment for XR use, including dedicated spaces optimized for movement and spatial a...
 - 73 — Use visual, auditory, or haptic boundary warnings to alert users when approaching physical hazards during imme...
 - 74 — Incorporate real-time collision detection systems or obstacle alerts to prevent accidents due to reduced real...
 - 77 — Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical str...
 - 79 — Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.
 - 80 — Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issue...
 - 82 — Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emerg...
 - 83 — Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awarenes...
 - 84 — Include XR-related health and safety risks in organizational risk assessments, with supporting documentation a...
 - 86 — Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment si...
 - 95 — Verify whether different PPE (personal protective equipment) is required based on the context and use case.
 - 96 — Inform users of all potential risks, including physical, operational, and situational hazards, before and duri...
 - 99 — Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to id...
 - 100 — Integrate multimodal discomfort monitoring (e.g., combining SSQ, heart rate, and behavioral cues) to trigger s...
 - 103 — Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid e...
 - 109 — Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow o...
 - 143 — Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.
 - 151 — Include XR training in onboarding for all new employees to ensure consistent baseline knowledge.
 - 153 — Organize hands-on training sessions and courses on XR device usage and interaction principles.
 - 164 — Use pilot programs to test and refine training, including options for breaks, limited time exposure, and itera...
 - 231 — Define and enforce access control policies, including formal access requests and logging of user permissions f...
 - 235 — Prepare legal and risk mitigation plans, outlining how to handle data breaches, misuse of XR tools, or other l...
 - 249 — Define policies for avatar identity protection to prevent impersonation, identity theft, and misuse of digital...
 - 251 — Apply relevant European legal and ethical frameworks to XR-based training and assistance activities, particula...

FIGURE 17: TOP-30 MEASURES WITH HIGHEST IMPACT AND ISSUE COVERAGE

Ease of Implementation vs. Issue coverage

The cross-comparison of all measures (Figure 17) shows that most measures cluster in the lower to mid-range of issue coverage, with only a handful reaching higher values. This confirms that many measures are relatively targeted, addressing specific risks rather than covering a broad relevant spectrum of issues. On the ease axis, however, a large share of measures scores at or near the maximum, reflecting the prevalence of organizational and procedural actions that partners considered straightforward to implement. Still, a number of measures appear with zero ease values, not because they are necessarily difficult, but because they were not rated by partners. This underlines the need for caution in interpreting the lower end of the ease distribution.

When focusing on the top 30 measures (Figure 19), clearer insights emerge. Several Legal Governance & Accountability measures stand out for achieving the highest coverage, including applying European legal and ethical frameworks (ID 251), defining data ownership rights (ID 242), and integrating transparency guidelines into XR design (ID 246). These measures are powerful in scope, addressing a wide range of systemic risks, but they appear at varying levels of ease, often reflecting structural or organizational complexity rather than technical barriers.

At the same time, Safety & Environmental Conditions measures occupy an important position in the top 30, particularly those that balance relatively high ease with moderate coverage. Examples include safety briefings before XR use (ID 83), incorporating collision detection (ID 74), and establishing cooldown protocols after XR sessions (ID 80). These measures may not be as broad in coverage as governance-related ones, but their straightforward procedural nature makes them attractive for rapid adoption.

Health Risk Management & User Well-being measures, such as discomfort monitoring (ID 100) and continuous well-being evaluation (ID 99), appear in the middle range of coverage but with relatively strong ease scores. These measures primarily target individual health outcomes, making them narrower in scope but essential for safe and responsible XR use. Similarly, some Physical Ergonomics & Device Setup measures, such as accommodating prescription glasses (ID 6) or adjustable focus lenses (ID 8), combine moderate coverage with high ease, showing their relevance for inclusivity and user comfort.

Finally, several XR Training & Organizational Preparedness measures (e.g., onboarding training ID 151 and pilot testing programs ID 164) appear among the top 30 despite not being rated for ease of implementation by partners. These measures show relatively strong coverage, and while their exact feasibility remains uncertain, they could represent low-barrier opportunities once piloting or organizational integration is underway.

Taken together, the analysis suggests that broad-coverage governance measures and highly practical safety protocols form the strongest candidates for prioritization, while training-oriented measures may warrant further exploration despite gaps in ease assessments.

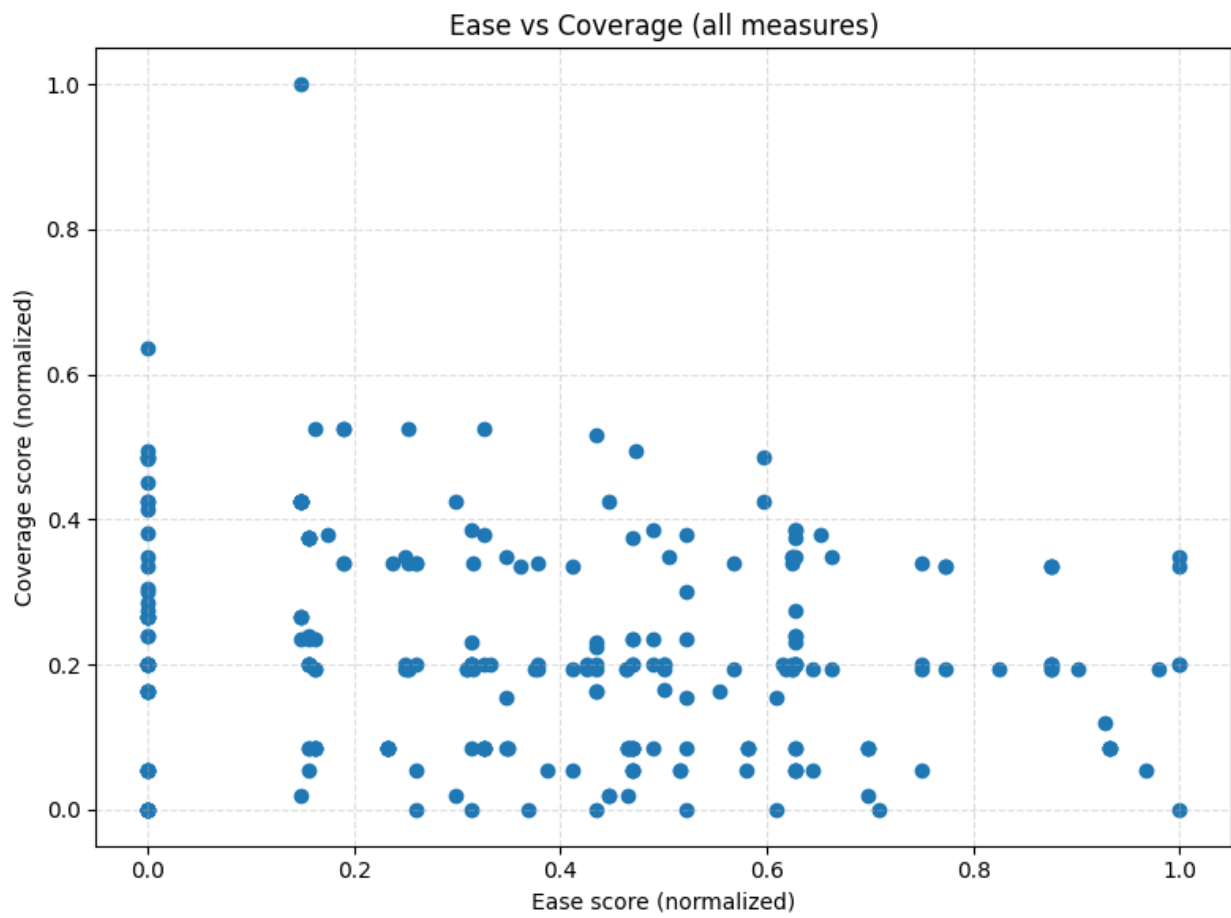
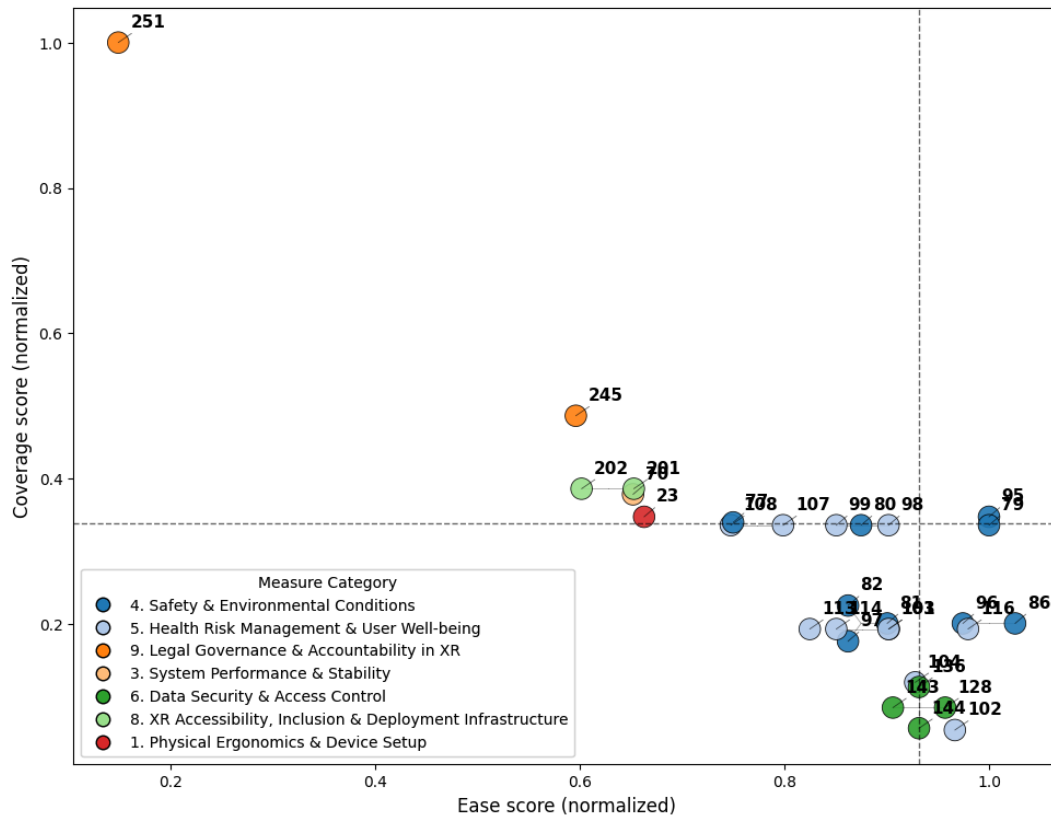


FIGURE 18: SCATTER PLOT OF MEASURES BASED ON EASE OF IMPLEMENTATION AND ISSUE COVERAGE

Top 30 Measures — Ease vs Coverage



- Measures (Top by Ease score (normalized) × Coverage score (normalized))
- 23 — Train users in proper ergonomic use of XR devices to avoid strain and injury.
 - 70 — Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.
 - 77 — Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical str...
 - 79 — Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.
 - 80 — Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issue...
 - 81 — Limit continuous use of XR headsets in high-intensity applications and enforce stricter break schedules based ...
 - 82 — Set up and regularly update XR-specific safety protocols, including session limits, device handling, and emerg...
 - 86 — Provide users with comprehensive and accessible safety manuals tailored to each XR experience or deployment si...
 - 95 — Verify whether different PPE (personal protective equipment) is required based on the context and use case.
 - 96 — Inform users of all potential risks, including physical, operational, and situational hazards, before and duri...
 - 97 — Establish policies distinguishing between shared vs. personal use of XR devices, and adapt hygiene and safety ...
 - 98 — Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibi...
 - 99 — Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to id...
 - 101 — Administer structured post-use recovery times (e.g., at least 10-15 minutes) before users return to high-focus...
 - 102 — Educate users on safe post-use behavior, such as avoiding driving or operating machinery immediately after XR ...
 - 103 — Define and apply exclusion criteria (e.g., epilepsy, use of psychoactive medication, neck injuries) to avoid e...
 - 104 — Provide users with clear information sheets and obtain informed consent before XR use, including any known ris...
 - 107 — Use test sessions to gauge users' initial adaptation and guide recommendations for further participation.
 - 108 — Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort...
 - 113 — Set and enforce session duration limits, with alerts and mandatory breaks to prevent overexposure and fatigue.
 - 114 — Limit exposure to immersive XR sessions based on evidence-based thresholds (e.g., max 30-60 minutes) to preven...
 - 116 — Offer passive viewing modes (e.g., guided or pre-recorded tours) as an alternative for users sensitive to acti...
 - 128 — Use secure data transmission protocols (e.g., HTTPS, VPNs, encrypted APIs) to protect data in transit.
 - 136 — Enforce strong password policies, preventing the use of weak or easily guessed passwords.
 - 143 — Keep all XR firmware and software updated, using trusted certificates to ensure authenticity.
 - 144 — Enable kiosk mode for XR apps to restrict access and prevent unauthorized modifications.
 - 201 — Train XR authors on inclusive design principles, emphasizing accessibility and user diversity.
 - 202 — Promote inclusive XR education targeting both developers and users.
 - 245 — Design consent mechanics directly into XR systems to support user decision-making and prevent boundary violati...
 - 251 — Apply relevant European legal and ethical frameworks to XR-based training and assistance activities, particula...

FIGURE 19: TOP-30 MEASURES WITH HIGHEST EASE OF IMPLEMENTATION AND ISSUE COVERAGE

Conclusion of the cross-comparison analysis

Taken together, the three cross-comparison analyses provide a comprehensive view of how measures perform across impact, ease of implementation, and issue coverage.

The analysis of impact versus ease of implementation showed a large cluster of measures achieving maximum ease scores, particularly in Safety & Environmental Conditions, Data Security & Access Control, and Accessibility & Inclusion. This reflects the fact that many procedural and governance-oriented measures are seen as straightforward to apply in practice. Within this cluster, a number also achieved high impact, making them strong candidates for early adoption. In contrast, categories such as Interaction Design and System Performance appear less prominently, suggesting their measures are either more technically demanding or perceived as less impactful in the current context.

The comparison of impact versus issue coverage confirmed the broad systemic relevance of Legal Governance & Accountability measures, such as applying European legal and ethical frameworks or integrating transparency guidelines. These provide wide-ranging protection but are often associated with higher organizational complexity. Safety & Environmental Conditions again feature prominently, offering procedural steps such as safety briefings and risk assessments that combine good coverage with practical feasibility. Interestingly, some Physical Ergonomics and Training-related measures also appear among the top 30, highlighting their potential to deliver coverage beyond narrow user comfort concerns.

The cross-analysis of ease of implementation versus issue coverage further reinforced these trends. Governance measures dominate the high-coverage end of the spectrum, while safety measures dominate the high-ease end. Health Risk Management & User Well-being measures generally occupy an intermediate space, offering valuable protections against simulator sickness, fatigue, and related risks, but requiring greater resource investment. Physical Ergonomics & Device Setup and Accessibility & Inclusion measures typically fall in the mid-range, indicating their role as important but complementary safeguards.

An important caveat concerns the XR Training & Organizational Preparedness category. Several measures in this area, such as including XR training in employee onboarding, developing structured training programs, and using pilot testing to refine protocols, were not rated for ease of implementation but nonetheless scored relatively high for both impact and issue coverage. This suggests that their feasibility may be underestimated and that they should remain in consideration for the final recommendations. The same applies to XR Regulatory Strategy & Standards Alignment, where measures such as developing official guidelines or maintaining XR-specific safety standards scored strongly on coverage and therefore represent valuable additions despite missing ease ratings.

Together, these findings indicate that the most promising candidates for Motivate XR are those combining high ease and strong immediate impact in safety, security, and accessibility, complemented by governance measures that offer broad systemic safeguards and training measures that may prove more feasible than currently assumed.

7. RECOMMENDATIONS

In this section, we provide recommendations to address social, ethical and legal issues in Motivate XR. We first propose a categorization of measures based on impact, ease of implementation and issue coverage. This allows to distinguish quick wins and longer-term measures. Next, we discuss measures already applied in Motivate XR from the ones still to be implemented. Finally, an overview of recommended measures is provided.

7.1. PROPOSED CATEGORIZATION AND THRESHOLDS FOR MEASURE SELECTION

In this section, the categorization of measures is proposed, together with the thresholds used to delimit measures that will fall in the different categories.

7.1.1. PROPOSED CATEGORIZATION

Following the cross-comparison analyses, the insights were translated into a clear categorization of measures that can guide the Motivate XR consortium. The analyses have shown that measures vary substantially in terms of their impact, ease of implementation, and issue coverage, with some measures performing strongly across all dimensions while others are limited in scope or more resource-intensive to adopt. To accommodate these differences, we propose a three-tier categorization that balances feasibility with strategic importance:

1. Category 1: High impact, high ease, high coverage

These measures represent “quick wins” for the consortium. They provide strong protection across multiple issues, are relatively straightforward to implement, and are likely to deliver significant benefits in the short term. The focus here is on maximizing value while minimizing barriers to adoption.

2. Category 2: High impact, moderate ease, high coverage (development-related measures)

This category includes measures that are particularly relevant for the design and development of XR technologies. While they may not be as easy to implement as those in Category 1, their high impact and broad coverage justify the additional effort. They represent strategic investments in building responsible XR systems, even if adoption requires specialized expertise or organizational adaptation.

3. Category 3: High impact, moderate ease, high coverage (use-related measures)

The third category mirrors Category 2 in terms of thresholds but focuses on measures tied to the use and deployment of XR technologies in real-world contexts. These measures often address user behaviour, workplace practices, and operational protocols. Although implementation can be challenging, they are essential to ensuring that XR adoption does not create unacceptable safety, health, or compliance risks.

7.1.2. THRESHOLDS FOR SELECTION

The cross-impact comparison performed in Section 6.5 provide a solid basis for defining thresholds to distinguish between these categories. These thresholds are not arbitrary but emerge from the patterns observed in the data.

Impact threshold

The plots show a meaningful concentration of measures scoring above 0.5 on the normalized impact scale. Measures in this range consistently stand out as the most consequential for mitigating risks and improving XR adoption. We therefore set 0.5 as the impact threshold for inclusion in the categorization.

Ease of implementation threshold

For measures that are both high impact and easy to implement, the scatter plot of impact vs. ease shows a significant cluster above 0.5 on the ease scale. This forms the criterion for Category 1. However, there is also a large group of measures with ease scores between 0.3 and 0.5. These cannot be considered “easy,” but remain feasible given appropriate resources and commitment. To capture these measures, which are often critical despite their complexity, we introduce a secondary ease threshold at 0.3. Measures falling below 0.3 are generally excluded from prioritization, as they present disproportionately high barriers without a commensurate increase in impact.

Coverage threshold

Interpreting coverage required more nuance due to the presence of an outlier with a normalized score of 1, while most other measures clustered below 0.6. Despite this skew, a threshold of 0.3 is appropriate, as it distinguishes measures that address a relatively broad set of issues from those that are narrow in focus. Measures scoring below 0.3 can still be valuable in specific contexts, but they do not meet the criteria for general prioritization.

7.1.3. APPLICATION OF THE THRESHOLDS

The application of thresholds for impact (≥ 0.5), ease of implementation (≥ 0.5), and issue coverage (≥ 0.3) results in a refined subset of measures that balance effectiveness, feasibility, and breadth of risk mitigation (see Table 59). The selected measures now span six categories: Physical Ergonomics & Device Setup, Interaction Design & User Interfaces, System Performance & Stability, Safety & Environmental Conditions, Health Risk Management & User Well-being, and Legal Governance & Accountability in XR.

Within Safety & Environmental Conditions, a large cluster of measures continues to stand out, reflecting the strong consensus that ensuring safe use environments and minimizing physical risks are both highly impactful and relatively easy to implement. These include measures such as limiting session duration and enforcing breaks (ID 79, 95), establishing cooldown protocols (ID 80), and conducting safety briefings (ID 83). Their high scores demonstrate that procedural safeguards remain central for protecting users during XR use.

Health Risk Management & User Well-being is also well represented, with measures such as pre-use screening with the Simulator Sickness Questionnaire (ID 98), continuous well-being monitoring (ID 99), and orientation sessions (IDs 107-108). These actions provide targeted safeguards against simulator sickness, fatigue, and discomfort while maintaining relatively high feasibility.

From Physical Ergonomics & Device Setup, the list includes preventive ergonomic testing (ID 18), ergonomic user training (ID 23), and device calibration (ID 17). The addition of re-positioning virtual objects and optimizing field of view (ID 24) further illustrates how ergonomic adjustments can reduce discomfort while achieving higher issue coverage than many other hardware-related interventions.

Design and performance considerations also appear among the prioritized measures. These include the use of appropriate visual contrast in user interfaces (ID 29) and simplifying XR experiences under poor network conditions (ID 70), both of which address common usability risks that partners rated as both impactful and feasible.

Finally, the presence of two governance-related measures emphasizes that accountability is an integral part of XR risk management. Informing users about data handling responsibilities (ID 243) and integrating transparency guidelines into XR design and deployment (ID 246) both scored highly, with stronger coverage values (0.42) than most other categories. This demonstrates that relatively straightforward governance actions can mitigate a broad range of risks, especially those linked to data privacy, trust, and compliance.

TABLE 59: MEASURES MATCHING THE THRESHOLDS FOR IMPACT, EASE OF IMPLEMENTATION AND ISSUE COVERAGE

Measure Category	ID	Measure	Impact score (normalized)	Ease score (normalized)	Coverage score (normalized)
1. Physical Ergonomics & Device Setup	17	Perform initial device calibration and enable real-time adjustments during use.	0,53	0,75	0,34
1. Physical Ergonomics & Device Setup	18	Conduct preventive ergonomic testing for different user profiles before deployment.	0,61	0,67	0,35
1. Physical Ergonomics & Device Setup	23	Train users in proper ergonomic use of XR devices to avoid strain and injury.	0,57	0,88	0,35
1. Physical Ergonomics & Device Setup	24	Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.	0,53	0,63	0,49
2. Interaction Design & User Interfaces	29	Use appropriate visual contrast and avoid overly bright elements to reduce eye fatigue.	0,52	0,75	0,38
3. System Performance & Stability	70	Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.	0,65	1	0,38
4. Safety & Environmental Conditions	77	Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.	0,75	0,75	0,34

4. Safety & Environmental Conditions	78	Ensure headset ergonomics, including balanced weight and adjustable fit, to reduce neck strain and physical discomfort during extended use.	0,58	0,63	0,34
4. Safety & Environmental Conditions	79	Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure. Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.	0,92	1	0,34
4. Safety & Environmental Conditions	80	Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.	0,75	0,88	0,34
4. Safety & Environmental Conditions	83	Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.	1	0,63	0,35
4. Safety & Environmental Conditions	84	Verify whether different PPE (personal protective equipment) is required based on the context and use case.	0,83	0,63	0,35
4. Safety & Environmental Conditions	95	Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.	0,92	1	0,35
5. Health Risk Management & User Well-being	98	Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.	0,64	0,85	0,34
5. Health Risk Management & User Well-being	99	Use test sessions to gauge users' initial adaptation and guide recommendations for further participation.	0,73	0,85	0,34
5. Health Risk Management & User Well-being	107	Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort.	0,56	0,75	0,34
5. Health Risk Management & User Well-being	108	Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.	0,52	0,75	0,34
9. Legal Governance & Accountability in XR	243	Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access.	0,6	1	0,42
9. Legal Governance & Accountability in XR	246		0,6	0,75	0,42

In addition to the measures that combine high impact, high ease of implementation, and strong coverage, a second set of measures emerges when the threshold for ease of implementation is relaxed to scores between 0.3 and 0.5 (see Table 60). These measures maintain strong performance in terms of impact (≥ 0.5) and issue coverage (≥ 0.3), but are perceived as more challenging to implement. They therefore represent candidates for later prioritization under categories 2 and 3, where feasibility is lower but potential benefits remain substantial.

Within Physical Ergonomics & Device Setup, three measures (IDs 2, 6, and 9) focus on hardware design and user adaptation. These range from ensuring balanced weight distribution to

accommodating prescription glasses and leveraging eye-tracking feedback. Their relatively high coverage scores indicate broad relevance across user populations, but technical adaptation requirements explain their lower ease scores.

Interaction Design & User Interfaces also contributes one measure (ID 36), which enables individual calibration of XR interfaces. While highly valuable in tailoring experiences to user needs, this requires additional customization features and integration, which lowers ease of implementation.

Two measures from Health Risk Management & User Well-being (IDs 100 and 109) remain strong candidates despite lower feasibility scores. Both rely on monitoring user discomfort—whether multimodal or real-time behavioural tracking—and while they are highly impactful, their implementation requires continuous monitoring infrastructure and potentially automated intervention mechanisms.

In addition, three measures from XR Training & Organizational Preparedness (IDs 151, 153, 164) are included despite lacking ease-of-implementation ratings. These cover onboarding, structured training sessions, and pilot-based iterative refinement. Their relatively high impact and coverage suggest strong potential for adoption, particularly once feasibility can be more clearly established.

Finally, two measures from XR Regulatory Strategy & Standards Alignment (IDs 258 and 264) appear in the list, despite not being rated for impact or ease. Both stand out for their high issue coverage, addressing systemic legal, ethical, and safety concerns. Developing official guidelines (ID 258) and creating XR-specific safety and ethical standards (ID 264) represent governance-level safeguards that, although more complex to implement, could provide wide-reaching benefits once established.

TABLE 60: ADDITIONAL MEASURES MATCHING A LOWER EASE OF IMPLEMENTATION THRESHOLD

Measure Category	ID	Measure	Impact score (normalized)	Ease score (normalized)	Coverage score (normalized)
1. Physical Ergonomics & Device Setup	2	Design hardware for balanced weight distribution, avoiding heat concentration near the face.	0,57	0,33	0,34
1. Physical Ergonomics & Device Setup	6	Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision correction needs.	0,57	0,33	0,53
1. Physical Ergonomics & Device Setup	9	Use eye-tracking feedback to assist users in correctly positioning the headset.	0,53	0,31	0,34
2. Interaction Design & User Interfaces	36	Allow individual calibration of the XR interface to accommodate user preferences and reduce discomfort during prolonged use.	0,52	0,38	0,34
5. Health Risk Management & User Well-being	100	Integrate multimodal discomfort monitoring (e.g., combining SSQ, heart rate, and behavioral cues) to trigger session termination if thresholds are exceeded.	0,69	0,35	0,34

5. Health Risk Management & User Well-being	109	Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow or trigger session termination if needed.	0,73	0,4	0,34
7. XR Training & Organizational Preparedness	151	Include XR training in onboarding for all new employees to ensure consistent baseline knowledge.	0.55	-	0.64
7. XR Training & Organizational Preparedness	153	Organize hands-on training sessions and courses on XR device usage and interaction principles.	0.74	-	0.48
7. XR Training & Organizational Preparedness	164	Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates.	0.55	-	0.49
10. XR Regulatory Strategy & Standards Alignment	258	Develop official guidelines and training materials on legal, ethical, and safety requirements for all system users.	-	-	0.45
10. XR Regulatory Strategy & Standards Alignment	264	Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback.	-	-	0.49

7.2. MEASURES STILL TO BE IMPLEMENTED

As discussed in Section 5.2, some measures have already been implemented in Motivate XR (see Deliverable D3.3, produced in 2024). In this section, we filter out already implemented measures.

Table 61 shows which measures with high impact, ease of implementation, and issue coverage are already embedded in Motivate XR through general or pilot-specific requirements. Several measures are implemented across all pilots, particularly those related to ergonomics (IDs 17, 24, 78), interaction design (ID 29), and system stability (ID 70). Pilot-specific adoption is also evident, for example in the verification of PPE requirements (ID 95), which has been integrated into four out of five pilots.

This seems to demonstrate that the consortium has prioritized measures directly tied to usability, comfort, and technical stability—ensuring reliable performance and immediate user protection. However, other measures with similarly high prioritization scores, particularly those related to proactive health risk management (IDs 98, 99, 107, 108) and governance or accountability (IDs 243, 246), have not yet been implemented. This indicates that while the current focus has successfully addressed operational and ergonomic safeguards, further work remains in embedding systematic health monitoring, training, and legal-ethical governance into Motivate XR.

TABLE 61: MEASURES ALREADY IMPLEMENTED IN MOTIVATE XR (HIGH EASE OF IMPLEMENTATION)

Measure Category	ID	Measure	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
1. Physical Ergonomics & Device Setup	17	Perform initial device calibration and enable real-time adjustments during use.	X	X	X	X	X
1. Physical Ergonomics & Device Setup	18	Conduct preventive ergonomic testing for different user profiles before deployment.					
1. Physical Ergonomics & Device Setup	23	Train users in proper ergonomic use of XR devices to avoid strain and injury.					
1. Physical Ergonomics & Device Setup	24	Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.	X	X	X	X	X
2. Interaction Design & User Interfaces	29	Use appropriate visual contrast and avoid overly bright elements to reduce eye fatigue.	X	X	X	X	X
3. System Performance & Stability	70	Simplify or shorten XR experiences if network conditions are unstable to preserve user comfort and safety.	X	X	X	X	X
4. Safety & Environmental Conditions	77	Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.					
4. Safety & Environmental Conditions	78	Ensure headset ergonomics, including balanced weight and adjustable fit, to reduce neck strain and physical discomfort during extended use.	X	X	X	X	X
4. Safety & Environmental Conditions	79	Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.					
4. Safety & Environmental Conditions	80	Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.					
4. Safety & Environmental Conditions	83	Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.					
4. Safety & Environmental Conditions	84	Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.					
4. Safety & Environmental Conditions	95	Verify whether different PPE (personal protective equipment) is required based on the context and use case.		X	X	X	X
5. Health Risk Management & User Well-being	98	Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.					
5. Health Risk Management & User Well-being	99	Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.					
5. Health Risk Management & User Well-being	107	Use test sessions to gauge users' initial adaptation and guide recommendations for further participation.					

5. Health Risk Management & User Well-being	108	Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort.	
9. Legal Governance & Accountability in XR	243	Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.	
9. Legal Governance & Accountability in XR	246	Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access.	

Table 62 presents additional measures with lower ease of implementation, several of which have already been integrated across all pilots. Notably, three ergonomic measures—designing hardware for balanced weight distribution (ID 2), ensuring compatibility with prescription glasses (ID 6), and using eye-tracking feedback to support correct headset positioning (ID 9)—are consistently in place. This reflects the consortium’s emphasis on addressing physical comfort and device usability, even when implementation requires design adaptations or hardware considerations.

By contrast, other measures in this group have not yet been adopted. These include more advanced forms of user monitoring (IDs 100 and 109), training-related measures such as onboarding and pilot-based training iterations (IDs 151, 153, 164), and governance or standards-oriented initiatives (IDs 258 and 264). Their absence points to the higher resource demands and organizational alignment required for implementation. While ergonomics-related improvements have been prioritized in the pilots, expanding into these more complex areas would enable Motivate XR to move beyond device-level adjustments and address systemic issues in training, health management, and regulatory compliance.

TABLE 62: ADDITIONAL MEASURES ALREADY IMPLEMENTED IN MOTIVATE XR (LOWER EASE OF IMPLEMENTATION)

Measure Category	ID	Measure	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
1. Physical Ergonomics & Device Setup	2	Design hardware for balanced weight distribution, avoiding heat concentration near the face.	X	X	X	X	X
1. Physical Ergonomics & Device Setup	6	Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision correction needs.	X	X	X	X	X
1. Physical Ergonomics & Device Setup	9	Use eye-tracking feedback to assist users in correctly positioning the headset.	X	X	X	X	X
2. Interaction Design & User Interfaces	36	Allow individual calibration of the XR interface to accommodate user preferences and reduce discomfort during prolonged use.					
5. Health Risk Management &	100	Integrate multimodal discomfort monitoring (e.g., combining SSQ, heart rate, and behavioral cues) to trigger					

User Well-being		session termination if thresholds are exceeded.	
5. Health Risk Management & User Well-being	109	Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow or trigger session termination if needed.	
7. XR Training & Organizational Preparedness	151	Include XR training in onboarding for all new employees to ensure consistent baseline knowledge.	
7. XR Training & Organizational Preparedness	153	Organize hands-on training sessions and courses on XR device usage and interaction principles.	
7. XR Training & Organizational Preparedness	164	Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates.	
10. XR Regulatory Strategy & Standards Alignment	258	Develop official guidelines and training materials on legal, ethical, and safety requirements for all system users.	
10. XR Regulatory Strategy & Standards Alignment	264	Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback.	

7.3. RECOMMENDED MITIGATIONS

This deliverable has outlined the social, ethical, and legal (SEL) framework guiding the MOTIVATE XR project and identified a comprehensive set of stakeholders, issues, and mitigation measures relevant to the responsible development and use of XR technologies. Building on these analyses, this final section provides concrete recommendations to ensure that the technical tools, pilot activities, and overall project implementation remain aligned with the SEL principles established in Work Package 3.

All consortium members are encouraged to familiarise themselves with the full content of Deliverable D3.2, as it provides the foundation for understanding the SEL risks associated with XR and the approaches required to address them. Awareness alone, however, is insufficient. Active steps must be taken to integrate these recommendations into ongoing design, development, and operational processes.

The most effective way to act on these recommendations is through their integration into the user and system requirements, ensuring that SEL considerations are embedded directly into design specifications and development workflows. When revisions are made to the requirements

presented in Deliverable D3.3, partners are advised to consult the full list of recommended mitigation measures in Section 7.2 to verify that all relevant safeguards remain addressed.

The recommended measures are all expected to make a significant contribution to mitigating SEL risks. They differ, however, in their ease of implementation. Measures requiring less effort (“Quick wins”) are generally linked to both technical development and the organisation of pilot and training activities within the use cases, while those demanding greater effort primarily concern organisational, procedural, or policy-related dimensions.

In the following sections, the relevance of each recommendation is described in detail, along with examples of implementation approaches and references to selected guidelines and standards that can support adoption. These examples are provided as suggestions only and should be interpreted in light of the project’s scope and available resources. It is recognised that some proposed actions may extend beyond what can be achieved within the current project, yet they may serve as inspiration for post-project exploitation activities or for future XR initiatives seeking to strengthen their social, ethical, and legal alignment.

Collectively, these recommendations operationalise the SEL framework, translating its principles into concrete actions that safeguard human values and promote ethical, lawful, and socially responsible innovation.

In summary the recommended mitigation measures are as follows:

Quick wins

Conduct preventive ergonomic testing for different user profiles before deployment.

Train users in proper ergonomic use of XR devices to avoid strain and injury.

Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.

Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.

Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.

Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.

Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.

Verify whether different PPE (personal protective equipment) is required based on the context and use case.

Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.

Evaluate users’ well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.

Use test sessions to gauge users’ initial adaptation and guide recommendations for further participation.

Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort.

Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.

Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access

Additional Measures

Organize hands-on training sessions and courses on XR device usage and interaction principles

Include XR training in onboarding for all new employees to ensure consistent baseline knowledge

Allow individual calibration of the XR interface to accommodate user preferences and reduce discomfort during prolonged use

Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow or trigger session termination if needed

Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates

Develop official guidelines and training materials on legal, ethical, and safety requirements for all system users

Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback

7.3.1. CATEGORY 1: 'QUICK WINS'

This section presents the measures that can be considered as “quick wins” for the consortium. These measures provide strong protection across issues, are relatively straightforward to implement, and are likely to deliver significant benefits in the short term.

7.3.1.1. MEASURE 1.A. CONDUCT PREVENTIVE ERGONOMIC TESTING FOR DIFFERENT USER PROFILES BEFORE DEPLOYMENT.

Relevance for Motivate XR

XR head-mounted displays and mid-air interactions can drive neck/shoulder load, visual strain, and balance issues. This is often not a uniform impact across users (sex, stature, prescription lenses, prior conditions). Catching risks *before* rollout reduces dropouts, incidents, and redesign costs, and helps set fit/usage policies grounded in evidence rather than guesswork.

Examples for implementation approaches

- **Define the test matrix:** Cover key user profiles: stature, head/face sizes, glasses/contact wearers, novice vs. experienced XR users, and any job-specific constraints per pilot.
- **Run short, instrumented trials:**
 - Fit: IPD/diopter checks; headset weight balance and strap configuration.

- Workload & symptoms: SSQ (cybersickness), NASA-TLX (workload), brief post-session symptom checklist (eye strain, neck pain, dizziness).
- Posture risk: quick ergonomics screens (RULA/REBA snapshot), simple time-in-posture metrics from headset IMU.
- **Acceptance gates & mitigations:** Define go/no-go thresholds (e.g., SSQ increase, repeated neck flexion $>30^\circ$ for >1 min) and associated mitigations (content tweaks, shorter bouts, hardware adjustments).
- **Integrate with the toolchain:**
 - Authoring: add an “ergonomics review” checklist before publishing.
 - Experiencing: log and analyse aggregated fit data and trial outcomes per pilot.

Relevant guidelines

- ISO 9241 (Ergonomics of human–system interaction: visual display use, input devices, workload, human–centred design ISO 9241-210).
- ISO 11226 (Evaluation of static working postures).
- EN/ISO 6385 (Ergonomic principles in work systems).
- IEEE 3079 (Recommended practice for VR cybersickness) for symptom monitoring.
- EU Display Screen Equipment Directive 90/270/EEC for general visual ergonomics principles.

7.3.1.2. MEASURE 1.B. TRAIN USERS IN PROPER ERGONOMIC USE OF XR DEVICES TO AVOID STRAIN AND INJURY.

Relevance for Motivate XR

Even a well-designed system fails if it’s worn or used poorly. Brief, targeted training reduces symptoms (neck/eye strain, fatigue), speeds acclimation, and lowers support burden. This is especially important for novices.

Examples for implementation approaches

- **Create micro-learning modules (≤ 10 min):**
 - Correct donning/fit (strap tension, crown placement, counter-balance), IPD/diopter adjustment, field-of-view alignment.
 - Safe session habits: progressive exposure, break strategies, hydration, the “20-20-20” eye rest heuristic.

- Safe movement: turning the body vs. neck-only rotations; room scanning; guardian/boundary awareness.
- **Make it in-flow:**
 - First-run onboarding in the experiencing app with interactive fit-checks and quick quizzes.
 - Contextual tooltips in authored content (, e.g., prompts to re-centre or take breaks when workload rises.
- **Provide job-site aids:** One-page posters/checklists at pilot sites; short refresher videos accessible on device.
- **Track completion + outcomes:** Log training completion and correlate with early SSQ/workload to verify effect; use results to tune content and policies.

Relevant guidelines

- ISO 9241-5/-303/-306 (posture and display ergonomics), ISO 9241-210 (human-centred design).
- ISO 45001(OHS management systems) for embedding training in safety management.
- Vendor HMD safety/user guides for device-specific fit and hygiene practices.

7.3.1.3. MEASURE 1.C. PROVIDE REAL-TIME ERGONOMIC FEEDBACK DURING XR SESSIONS TO ALERT USERS OF POOR POSTURE AND REDUCE PHYSICAL STRAIN AND FATIGUE.

Relevance for Motivate XR

Problems often emerge *during* use: sustained neck flexion, awkward reaches, or accumulated visual load. Lightweight, timely feedback helps users self-correct before discomfort escalates, cutting fatigue and incident risk without requiring supervision.

Examples for implementation approaches

- **Signals to monitor (privacy-aware):**
 - **Posture:** head pitch/roll/yaw from the HMD IMU; optional upper-body estimate from hand controllers/inside-out tracking.
 - **Exposure:** continuous session time, active interaction time, cumulative high-tilt duration.
 - **Comfort proxies:** frequent recentering, erratic head motion, repeated menu cancellations (as early strain cues).
- **Feedback design:**

- Tiered cues: subtle on-device nudge (icon or gentle tone) → clearer prompt (“Lift head slightly”) → suggest a short break.
- Rate-limit prompts and allow quick dismiss to avoid annoyance; make thresholds adjustable per user profile.
- **Integrate with Motivate XR stack:**
 - Runtime module in the experiencing tool exposes a simple API (posture. ok, break. suggested) to authored apps.
 - Authoring tools let creators bind cues to scene states (e.g., when objects encourage prolonged overhead gaze).
 - Optional haptic “tap” via controllers or headset.
- **Governance & data:** Log only what’s needed (aggregate posture flags, not raw biometrics), document purpose, and provide opt-in with clear UI (aligns with data-minimization and transparency).

Relevant guidelines

- ISO 11226 (static postures) and EN 1005-4 (postural load) for threshold inspiration.
- ISO 9241 series for feedback/interaction ergonomics and visual comfort.
- IEEE 3079 for managing cybersickness triggers (pair posture/time cues with break prompts).

7.3.1.4. *MEASURE 1.D. LIMIT SESSION DURATIONS AND ENFORCE BREAKS, USING AUTOMATED ALERTS OR BUILT-IN TIMERS TO PREVENT OVEREXPOSURE.*

Relevance for Motivate XR

Extended XR use is strongly associated with eye strain, musculoskeletal load, cybersickness, and reduced situational awareness. Many negative effects can be mitigated simply by enforcing breaks and limiting maximum exposure. Proactive management prevents health incidents, supports safe return to work, and fosters sustainable XR adoption in industrial settings.

Examples for implementation approaches

- **Define safe exposure windows:**
 - Start with conservative defaults (e.g., 20–30 min continuous use, based on SSQ/eye strain studies).
 - Adjust per pilot based on task type: shorter for complex, visually demanding tasks (e.g., aerospace maintenance), longer for low-motion review tasks.

- **Implement timers:**
 - **Experiencing tool:** integrate a session clock with automated break prompts (visual pop-up, subtle tone, or haptic nudge).
 - **Authoring tools:** allow content creators to set task-specific maximum durations or checkpoint-based breaks.
- **Break enforcement options:**
 - **Soft:** reminders with option to snooze/dismiss.
 - **Hard:** automatic pause or session lockout if thresholds exceeded (e.g., for high-risk training).

Relevant guidelines

- ISO/IEC TS 9241-391 (requirements for prolonged head-mounted display use).
- IEEE 3079-2020 (VR cybersickness management).
- EU Display Screen Equipment Directive (Directive 90/270/EEC) (principle of frequent breaks).
- Occupational health recommendations from NIOSH and ACGIH for limiting visual and musculoskeletal strain.

7.3.1.5. *MEASURE 1.E. ESTABLISH COOLDOWN OR RECOVERY PROTOCOLS POST-XR SESSIONS TO MITIGATE RESIDUAL DISORIENTATION OR BALANCE ISSUES BEFORE RESUMING PHYSICAL TASKS.*

Relevance for Motivate XR

Users may experience transient disorientation, reduced balance, or altered depth perception after XR. If they immediately resume safety-critical physical tasks (e.g., operating machinery, working at height), risk of accidents increases. Cooldown protocols give the body and senses time to reset, reducing post-XR incidents.

Examples for implementation approaches

- **Define cooldown length:**
 - Standard minimum: 5–10 minutes.
 - Extend if SSQ/post-session surveys indicate residual effects.
- **Recovery activities:**
 - Quiet rest in a well-lit, stable environment.

- Simple grounding exercises (look at a distant object, walk a straight line, basic stretches).
- Self-checklist: dizziness, blurred vision, instability → if present, delay return to task.
- **Operational integration:**
 - Incorporate cooldown protocols into the training curriculum (WP7) and pilot standard operating procedures.
 - Experiencing tool can prompt a post-session “readiness check” before users confirm they are fit to resume work.
 - Supervisors/trainers can monitor cooldown adherence in safety-sensitive pilots.
 - Documentation: Add cooldown steps to risk assessments and safety manuals.

Relevant guidelines

- ISO 9241-210 (human-centred design: post-use assessment loops).
- IEEE 3079-2020 for identifying and managing cybersickness symptoms.
- Aviation/transport safety analogues (e.g., post-simulator cooldown guidelines used in pilot training).

7.3.1.6. MEASURE 1.F. CONDUCT SAFETY EVALUATIONS AND USER BRIEFINGS BEFORE XR USE, INCLUDING TRAINING ON PROTOCOLS AND RISK AWARENESS.

Relevance for Motivate XR

Even if XR content and devices are technically sound, risks emerge from the environment and user readiness: cluttered rooms, unsafe PPE use, uninformed users. Pre-use safety evaluations and briefings reduce accident likelihood (e.g., collisions, trips, data misuse) and ensure consistent safe practice across pilots.

Examples for implementation approaches

- **Safety evaluation checklist:**
 - Physical space: boundaries clear, obstacles removed, lighting adequate.
 - PPE: headset hygiene, correct safety gear for context (hard hat integration, gloves).
 - System check: firmware updates, boundary/guardian activated, controllers charged.
- **User briefing content:**
 - Expected session duration and break rules.

- Emergency removal protocol (how to quickly take off headset if discomfort occurs).
- Risk factors: cybersickness symptoms, balance loss, visual fatigue.
- Data/privacy reminders if sessions involve logging.
- **Integration with pilots:**
 - integrate into daily toolbox talks or shift handovers.
- **Implementation in tools:**
 - Pre-session checklist module in the experiencing app.
 - Documentation embedded in authoring tool outputs, ensuring every published scenario has a standard briefing section.

Relevant guidelines

- ISO 45001 (occupational health & safety systems, pre-task risk assessment).
- ISO 9241-210 (user-centred risk communication).
- EU OSH Framework Directive 89/391/EEC (employer duty to inform and train on workplace risks).
- Vendor HMD setup and safety manuals as baseline briefing references.

7.3.1.7. MEASURE 1.G. INCLUDE XR-RELATED HEALTH AND SAFETY RISKS IN ORGANIZATIONAL RISK ASSESSMENTS, WITH SUPPORTING DOCUMENTATION AND MITIGATION PLANS.

Relevance for Motivate XR

Organizations often perform formal risk assessments for physical, chemical, and ergonomic hazards, but XR introduces unique risks, e.g. cybersickness, sensory disorientation, privacy/data exposure, and immersive fatigue, that are rarely addressed in standard safety protocols. By embedding XR-specific risks into organizational risk management systems, safety is normalized and consistently monitored across all deployments.

Examples for implementation approaches

- **Update risk registers:** Add XR-specific hazards (cybersickness, disorientation, eye strain, data misuse) to existing occupational safety frameworks.
- **Documentation:**
 - Develop standardized templates for XR risk identification, likelihood/impact scoring, and mitigation plans.
 - Documents XR-specific risks alongside conventional hazards.

- **Mitigation measures:** Link directly to the other recommended quick-win measures.
- **Integration:**
 - Leverage WP7 (training curriculum) to include XR risk assessment in employee safety education.
- **Evaluation:** Reassess XR risks periodically as devices, content, and user groups evolve.

Relevant guidelines

- ISO 12100 (risk assessment principles for machinery, adaptable to XR as a workplace technology).
- ISO 45001 (occupational health & safety management systems).
- EU OSH Framework Directive 89/391/EEC (requirement for employers to include all workplace hazards in assessments).
- HMD safety documents (e.g., Meta, Varjo, HTC Vive guidelines) as input sources for risk listings.

7.3.1.8. MEASURE 1.H. VERIFY WHETHER DIFFERENT PPE (PERSONAL PROTECTIVE EQUIPMENT) IS REQUIRED BASED ON THE CONTEXT AND USE CASE. (ONLY FOR PILOT 1)

Relevance for Motivate XR

When XR is deployed in industrial environments, traditional PPE (hard hats, safety glasses, respirators, gloves) may conflict with XR devices. Workers may need head protection and XR headsets simultaneously, raising fit and safety challenges. Ensuring PPE compatibility avoids undermining either XR performance or core physical protection.

Examples for implementation approaches

- **PPE assessment protocol:** Before XR deployment, assess which PPE is mandatory for each maintenance or assembly task.
- **Compatibility testing:**
 - Validate headset use with helmets, goggles, or masks.
 - Where conflicts exist, explore XR-ready PPE (integrated AR visors, helmet-compatible XR mounts).
- **Standard operating procedures:**
 - Integrate PPE checks into pre-use safety briefings.
 - Document acceptable combinations and any required adjustments (e.g., headset over prescription glasses vs. built-in dioptries).

- **Device development:**
 - Provide feedback to YBQ team to improve ergonomics and compatibility with safety helmets.

Relevant guidelines

- EN 397 (European standard for industrial safety helmets).
- EN 166 (eye protection requirements).
- National aerospace maintenance PPE requirements and similar.
- Vendor guidelines on PPE compatibility (e.g., headset fit over safety gear).

7.3.1.9. *MEASURE 1.I. CONDUCT PRE-USE SCREENING WITH TOOLS LIKE THE SIMULATOR SICKNESS QUESTIONNAIRE (SSQ) TO ASSESS USER SUSCEPTIBILITY TO MOTION SICKNESS OR RELATED CONDITIONS.*

Relevance for Motivate XR

Users vary widely in susceptibility to motion sickness, visual discomfort, and fatigue in XR. Identifying vulnerable users early reduces risk of severe adverse effects, improves safety, and informs adaptive usage (shorter sessions, more frequent breaks, alternative training modes). Screening also generates data to refine XR protocols across pilots.

Examples for implementation approaches

- **Pre-session screening workflow:**
 - Apply SSQ or adapted short forms to new users before training/assistance sessions.
 - Track key symptoms (nausea, oculomotor strain, disorientation).
- **Response protocols:**
 - For high-susceptibility users, limit session durations, increase break frequency, or provide non-immersive alternatives.
 - Store anonymized screening results in the Motivate XR training curriculum database for monitoring and research.
- **Technical integration:**
 - Experiencing tool could embed an automated SSQ survey before XR launch, logging data securely.

Relevant guidelines

- Simulator Sickness Questionnaire (Kennedy et al., 1993).

- ISO 9241-391 (human-system interaction: ergonomics of XR).
- Aviation/military simulator protocols (SSQ and derived checklists are standard practice).

7.3.1.10. MEASURE 1.J. EVALUATE USERS' WELL-BEING CONTINUOUSLY, INCLUDING POST-SESSION SURVEYS (E.G., AFTER 10, 20, 40 MINUTES) TO IDENTIFY ANY NEGATIVE EFFECTS.

Relevance for Motivate XR

XR experiences can cause gradual onset of discomfort—such as nausea, eye strain, or fatigue—that may not be immediately obvious. Continuous evaluation ensures that negative effects are detected early and mitigated before they escalate into health risks. It also produces valuable feedback to refine session design, device ergonomics, and safety protocols.

Examples for implementation approaches

- **Survey protocol:**
 - Deploy short digital surveys (adapted from SSQ or ISO usability questions) after set intervals (e.g., 10, 20, 40 minutes).
 - Automate reminders via the XR experiencing tool.
- **Data use:**
 - Aggregate anonymized well-being scores across pilots to detect recurring issues (e.g., latency-induced nausea).
 - Adapt session length, task intensity, or device adjustments accordingly.
- **Pilot integration:**
 - In aerospace and aluminium pilots: track whether long, technical sessions induce discomfort.
 - In energy distribution and robotics pilots: compare well-being data from field vs. training centre sessions.

Relevant guidelines

- ISO 9241-210 (human-centred design for interactive systems).
- Best practices from NIOSH and military VR protocols, which use symptom tracking for simulator use.

7.3.1.11. MEASURE 1.K. USE TEST SESSIONS TO GAUGE USERS' INITIAL ADAPTATION AND GUIDE RECOMMENDATIONS FOR FURTHER PARTICIPATION.

Relevance for Motivate XR

First-time XR users often need gradual adaptation. Short test sessions identify individual tolerance, reduce risk of severe adverse reactions, and build user confidence. They also help tailor subsequent training, ensuring safe and effective adoption across diverse user groups.

Examples for implementation approaches

- **Structured onboarding:**
 - Run a short “trial session” before immersive training.
 - Monitor behaviour and symptoms (SSQ, observations, or real-time feedback).
- **Adaptive recommendations:**
 - Users who adapt well can progress to longer or more complex tasks.
 - Sensitive users may need shorter, repeated exposures before full participation.
- **Integration with project tools:**
 - Experiencing tool could log test-session data and generate personalized participation guidelines.
 - Pilots can compare adaptation rates across sectors (e.g., aerospace trainees vs. energy workers).

Relevant guidelines

- Simulator adaptation protocols used in aviation training.
- ISO 9241-391 (ergonomic recommendations for immersive environments).

7.3.1.12. MEASURE 1.L. OFFER PERSONAL TRAINING OR ORIENTATION SESSIONS TO HELP USERS ACCLIMATE AND REDUCE THE LIKELIHOOD OF DISCOMFORT.

Relevance for Motivate XR

Orientation training reduces cognitive load and physical strain by familiarizing users with XR controls, ergonomics, and best practices. It prevents discomfort caused by incorrect headset use, poor posture, or misinterpretation of interactions. It also builds user trust and safety awareness, especially important for high-risk or critical pilots.

Examples for implementation approaches

- **Orientation content:**

- Demonstrate safe headset use, calibration, and posture.
- Introduce typical XR risks (cybersickness, disorientation) and coping strategies.
- **Delivery:**
 - Short in-person or remote orientation sessions before XR deployment in pilots.
 - Could be embedded as an interactive XR tutorial (guided “first run” experience).
- **Integration:**
 - Module in the WP7 training curriculum, ensuring standardized delivery across pilots.

Relevant guidelines

- NIOSH VR safety recommendations for user orientation.
- Headset manufacturer onboarding protocols (Meta Quest, Varjo, HTC).

7.3.1.13. MEASURE 1.M. INFORM USERS ABOUT PERSONAL DATA HANDLING RESPONSIBILITIES, INCLUDING POTENTIAL LIABILITIES FOR MISUSE OR UNAUTHORIZED DATA SHARING.

Relevance for Motivate XR

XR applications collect and process sensitive data including biometrics, eye-tracking, interaction logs, and digital identities. Misuse or unauthorized sharing of this data can lead to serious privacy, ethical, and legal consequences, not only for organizations but also for individual users. Clear communication of responsibilities helps establish a culture of accountability, ensures compliance with GDPR and other legal frameworks, and reduces the likelihood of negligent or malicious data practices.

Examples for implementation approaches

- **Policy communication:**
 - Provide concise, accessible guidelines to all XR users (e.g., pilots, trainees, technicians).
 - Clearly explain what data is collected, who is responsible for safeguarding it, and consequences of misuse.
- **Integration into pilots:**
 - Emphasize secure handling of sensitive operational and training data.
 - Stress risks of sharing user/customer data outside authorized systems.
 - Highlight implications of sharing XR-collected behavioural and operational data.

- **Practical delivery formats:**
 - Include this information in user briefings and onboarding training (linked to Measure 1.F).
 - Provide reminders or “just-in-time” notices within the XR experience itself, e.g., before data-sharing actions.
- **Tracking & compliance:**
 - Require user acknowledgment (digital consent or checkboxes) to confirm awareness of data handling rules.
- Record compliance logs for audit purposes, leveraging the back-end platform’s security features.

Relevant guidelines

- GDPR (General Data Protection Regulation) – especially principles of transparency, accountability, and data minimization.
- ISO/IEC 27701:2019 (Privacy Information Management System).
- European Data Protection Board (EDPB) guidance on emerging technologies.
- Ethical frameworks for XR data governance from IEEE and XR Safety Initiative (XRSI).

7.3.1.14. MEASURE 1.N. INTEGRATE TRANSPARENCY GUIDELINES INTO THE XR DESIGN AND DEPLOYMENT PROCESS TO ENSURE USERS UNDERSTAND HOW THEIR DATA IS USED AND WHO HAS ACCESS.

Relevance for Motivate XR

Transparency is a cornerstone of trustworthy XR adoption, especially when XR systems collect sensitive information such as biometric data, eye tracking, or behavioral metrics. Without clear communication, users may underestimate risks or misuse the technology. Integrating transparency guidelines into XR design and deployment ensures that every user knows what data is collected, how it is stored, and who can access it, reducing risks of misuse, liability, and user distrust.

Examples for implementation approaches

- **Design-level transparency:**
 - Integrate data-use notifications directly in XR interfaces (e.g., pop-ups, consent dashboards).
 - Provide layered explanations: short, accessible summaries in XR, backed by detailed policies outside the session.

- **Deployment practices:**
 - Publish transparency guidelines alongside training and onboarding materials.
 - Require organizations deploying XR to disclose data-sharing practices with third parties.
- **Pilot integration:**
 - Test user comprehension of transparency communications in pilots (e.g., do trainees understand which biometric data is being tracked?).
 - Refine based on user feedback.

Relevant guidelines

- GDPR Articles 12–14 (information transparency obligations).
- XRSI Privacy & Safety Framework.
- OECD Principles on AI Transparency and Explainability.

7.3.2. CATEGORY 2: ADDITIONAL MEASURES

This section present measures that are somehow harder to implement, although the impact and issue coverage remain high.

7.3.2.1. MEASURE 2.A. ORGANIZE HANDS-ON TRAINING SESSIONS AND COURSES ON XR DEVICE USAGE AND INTERACTION PRINCIPLES.

Relevance for Motivate XR

Hands-on training is crucial for ensuring safe, effective, and confident use of XR systems. Many potential users may be unfamiliar with XR interaction principles such as gesture controls, calibration, or spatial awareness. Without structured training, there is a risk of user error, reduced adaptation, or physical discomfort (e.g., strain from incorrect device use). For Motivate XR, which emphasizes broad uptake across diverse industrial domains, offering practical training ensures a consistent baseline of user competence. It also supports smoother deployment during pilots by reducing learning curves and preventing misuse.

Examples for implementation approaches

- **Training content:**
 - Cover device setup, calibration, ergonomics, and common troubleshooting.
 - Include modules on safe use (e.g., avoiding cybersickness, posture management, safe physical environment).

- Demonstrate core interaction methods (e.g., gesture-based, controller-based, or voice-based).
- **Delivery methods:**
 - Offer in-person workshops at pilot sites for workers and trainees.
 - Provide parallel remote training modules (video tutorials or interactive simulations) for wider accessibility.
 - Include guided practice sessions in XR itself (e.g., “sandbox” mode for experimentation).
- **Integration:**
 - Integrate as a standard module in WP7’s training curriculum to ensure cross-sector consistency.
 - Use evaluation tools (e.g., pre- and post-training questionnaires) to measure user readiness.

Relevant guidelines

- ISO 9241-210: Human-centred design for interactive systems.
- OSHA and NIOSH recommendations on training for new digital and immersive tools.
- Manufacturer training guidelines (e.g., Meta Quest for Business onboarding, Varjo enterprise training).
- XR Association (XRA) principles on user education and responsible deployment.

7.3.2.2. MEASURE 2.B. INCLUDE XR TRAINING IN ONBOARDING FOR ALL NEW EMPLOYEES TO ENSURE CONSISTENT BASELINE KNOWLEDGE.

Relevance for Motivate XR

When XR is introduced into an organization, employees vary widely in their familiarity with immersive technologies. Similarly, when new employees enter an organisation familiar with XR, the new employee will need to obtain the same familiarity. Inconsistent knowledge increases risks of misuse, discomfort, or safety incidents. Including XR-specific training in onboarding ensures a shared baseline of competence and safety awareness, reducing accidents and making XR adoption smoother across teams.

Examples for implementation approaches

- **Curriculum development:**

- Cover basics of XR ergonomics, session duration guidelines, and organizational safety protocols.
- Tailor modules to different user groups (e.g., trainees, technicians, supervisors).
- **Delivery format:**
 - Provide short XR-based onboarding experiences that allow new employees to learn by doing.
 - Supplement with written or video guidelines for reinforcement.
- **Pilot integration:**
 - Standardize onboarding across all pilots to ensure cross-pilot comparability.
 - Track onboarding effectiveness using user feedback and incident reports.

Relevant guidelines

- EU-OSHA training frameworks for workplace safety.
- ISO 9241-210 on human-centred design, relevant for onboarding usability.
- Existing XR safety onboarding templates from organizations like XRSI.

7.3.2.3. MEASURE 2.C. ALLOW INDIVIDUAL CALIBRATION OF THE XR INTERFACE TO ACCOMMODATE USER PREFERENCES AND REDUCE DISCOMFORT DURING PROLONGED USE.

Relevance for Motivate XR

XR users vary widely in their visual, ergonomic, and cognitive preferences. A fixed interface risks excluding some users or causing fatigue, particularly during prolonged industrial training or operational sessions. Allowing individual calibration supports inclusivity and reduces physical or cognitive strain. Examples are, adjusting brightness, contrast, font size, interaction sensitivity, or field of view. For Motivate XR, which aims for cross-sectoral, customizable interfaces ensure adaptability across user groups and use cases, aligning with accessibility and human-centred design principles. Because requirements differ significantly across domains, partners emphasized that this measure should be implemented and tested directly at the level of the pilots. This allows calibration options to be tailored to the practical demands and user groups of each specific pilot environment.

Examples for implementation approaches

- **Calibration options:**

- Enable adjustable parameters such as brightness, contrast, font size, interaction speed, and input modality (e.g., gestures vs. controllers).
- Provide quick presets for common needs (e.g., “low light mode,” “reduced motion mode”).
- **Training link:**
 - Include calibration guidance in WP7 training curriculum, ensuring users are aware of available adjustments.

Relevant guidelines

- ISO 9241-210: Human-centred design for interactive systems.
- ISO 9241-391: Ergonomics of immersive environments.
- WCAG 2.1 accessibility principles, adapted for XR (e.g., adjustable contrast and scalable UI elements).
- XR Association Accessibility Guidelines (2021), which recommend personalization of XR interfaces for inclusivity.

7.3.2.4. *MEASURE 2.D. MONITOR USERS IN REAL TIME FOR SIGNS OF DISCOMFORT (E.G., DIZZINESS, NAUSEA, IRREGULAR MOVEMENTS), AND ALLOW OR TRIGGER SESSION TERMINATION IF NEEDED*

The measure integrates measure “Integrate multimodal discomfort monitoring (e.g., combining SSQ, heart rate, and behavioral cues) to trigger session termination if thresholds are exceeded” (ID: 100).

Relevance for Motivate XR

Extended XR sessions can cause sudden onset of discomfort such as dizziness, nausea, or disorientation, which may escalate quickly if not detected. While multimodal monitoring solutions combining physiological, behavioural, and subjective indicators were considered, partners highlighted significant concerns: such technical systems raise privacy issues, may require intrusive data collection, and could make users feel overly scrutinized. Instead, the consortium agreed to prioritize human-centred monitoring as a more practical, acceptable, and trust-building approach. In teaching and training contexts, this responsibility would fall to instructors or trainers, who would need specific preparation to recognize early signs of cybersickness and fatigue. By relying on trained human oversight, Motivate XR ensures a balance between user safety, practicality, and user acceptance.

Examples for implementation approaches

- **Human monitoring in pilots:**

- Instructors and supervisors should be trained to observe behavioural indicators such as loss of balance, slowed reaction times, or visibly uncomfortable gestures.
- Trainers in educational pilots should be empowered to pause or terminate sessions if users show early signs of discomfort.
- **System support:**
 - While physiological sensors are not required, headset motion tracking and simple interaction detection can support instructors in spotting anomalies without storing data beyond session duration.
 - Provide users with an easy self-termination option so they can exit sessions quickly if discomfort intensifies.
- **Pilot adaptation:**
 - *Workplace pilots:* especially critical where disorientation could translate into immediate physical risks.
 - *Training pilots:* relevant for onboarding new users unfamiliar with immersive systems, where discomfort is more likely.

Relevant guidelines

- ISO 9241-210 and ISO/TS 8102-1:2021 on human-centred design and safety in immersive environments.
- XR Safety Initiative (XRSI) recommendations for real-time user monitoring.

1 Occupational Health and Safety (OHS) frameworks, such as EU-OSHA guidance, on fatigue and well-being monitoring.

7.3.2.5. MEASURE 2.E. USE PILOT PROGRAMS TO TEST AND REFINE TRAINING, INCLUDING OPTIONS FOR BREAKS, LIMITED TIME EXPOSURE, AND ITERATIVE CONTENT UPDATES.

Relevance for Motivate XR

XR training programs are still novel and experimental in industrial contexts, meaning that risks and best practices are not always fully known. The projects pilots can create a safe testing ground to refine training before post-project roll-out. By integrating structured breaks, limiting exposure time, and continuously updating content based on user feedback, organizations ensure both safety and learning effectiveness.

Examples for implementation approaches

- **Pilot testing structure:**
 - Conduct small-scale test runs of XR training modules in each pilot.

- Collect both quantitative metrics (completion times, error rates) and qualitative feedback (user comfort, fatigue levels).
- **Iterative updates:**
 - Adjust session durations, interaction design, and safety protocols based on findings.
 - Re-test modified versions before full-scale adoption.
- **Scalability:**
 - Establish pilot testing as a standard step in XR training development for post-project use cases and business models.

Relevant guidelines

- ISO 45001 on occupational health & safety management systems.
- ISO/IEC 40180 (quality for learning, education, and training).
- Research-based best practices on XR training evaluation (e.g., Simulator Sickness Questionnaire for exposure thresholds).

7.3.2.6. MEASURE 2.F. DEVELOP OFFICIAL GUIDELINES AND TRAINING MATERIALS ON LEGAL, ETHICAL, AND SAFETY REQUIREMENTS FOR ALL SYSTEM USERS.

Relevance for Motivate XR

XR systems in industrial contexts introduce complex legal, ethical, and safety challenges as described in Chapter 3. Many of these risks are not obvious to end-users. Developing official guidelines and training materials ensures a consistent understanding across organizations of what safe and responsible XR use looks like. It empowers users to act responsibly, reduces organizational liability, and promotes compliance with European frameworks like GDPR, occupational health & safety laws, and emerging XR standards.

Examples for implementation approaches

- **Training integration:**
 - Incorporate guidelines into onboarding modules for all pilots.
 - Provide both digital handbooks and interactive XR-based tutorials.
- **Content design:**
 - Incorporate the recommended mitigations.
 - Ensure materials are role-specific (e.g., developers vs. trainees vs. supervisors).
- **Consortium coordination:**

- Draft guidelines jointly, drawing from expertise across this deliverable, partners and advisory board.
- Validate training content in pilots to ensure practical applicability.

Relevant guidelines

- GDPR (EU 2016/679) for data protection and consent.
- ISO/IEC 27001 on information security.
- XRSI Privacy & Safety Framework (XR Safety Initiative).
- EU-OSHA training guidelines for workplace health and safety.

7.3.2.7. MEASURE 2.G. CREATE AND MAINTAIN XR-SPECIFIC SAFETY AND ETHICAL STANDARDS, INCLUDING REGULAR UPDATES BASED ON EXPERT AND USER FEEDBACK.

Relevance for Motivate XR

General safety and ethical standards (e.g., ISO norms, GDPR) are not tailored to XR-specific risks such as cybersickness, immersive harassment, or risks from blending real and virtual spaces. By creating XR-specific standards, Motivate XR can fill regulatory gaps, set benchmarks for responsible deployment, and establish a leadership role in shaping industry norms. Regular updates based on expert and user feedback ensure that standards stay relevant as XR technologies and risks evolve.

Examples for implementation approaches

- **Framework development:**
 - Establish a working group within the consortium to draft safety and ethics standards specific to XR use cases in the pilots.
 - Align with existing frameworks (e.g., ISO/IEC JTC 1/SC 24 on AR/VR, EU AI Act proposals).
- **Continuous updating:**
 - Collect feedback from pilot evaluations and user surveys.
 - Update standards periodically, documenting revisions and rationale.
- **Practical use:**
 - Integrate standards into both authoring tools (development phase) and training content (user phase).
 - Share outputs with standardization bodies to contribute to European and international policy-making.

Relevant guidelines

- ISO/IEC JTC 1/SC 24: Computer graphics, AR/VR standards.
- IEEE Global Initiative on Ethics of Extended Reality.
- XRSI Safety Framework.
- EU's AI Act (proposed), relevant for ethical oversight of AI-driven XR systems.

8. CONCLUSIONS

This report provides a consolidated overview of the Motivate XR SSH framework, containing the social, ethical, and legal (SEL) issues most relevant to the Motivate XR project and translates them into actionable recommendations. By integrating insights from partner workshops and large-scale academic literature analyses, we have developed a comprehensive map of risks and issues. These were then prioritised and connected to concrete mitigation measures, ensuring that the project not only identifies challenges but also proposes feasible response approaches.

The analysis highlights a wide range of issue areas across domains such as health and well-being, economic, infrastructure, policy, legal and regulatory, and social, ethical, and cultural impacts. These affect diverse stakeholder groups, from trainees and field technicians to the broad population and organisations responsible for XR deployment. Addressing these issues is essential to ensure that Motivate XR technologies are safe, inclusive, and trusted.

A structured set of mitigation measures has been proposed, covering technical adaptations (such as ergonomic improvements and personalised calibration), organisational interventions (including user training, onboarding, and cooldown protocols), and governance-oriented actions (such as transparency guidelines and the creation of XR-specific standards). To guide implementation, the measures were prioritised according to their impact, ease of adoption, and relevance to system and user requirements. This prioritisation resulted in “quick wins” that can be deployed immediately with minimal effort, as well as significant but more effort intensive mitigations:

Quick wins

Conduct preventive ergonomic testing for different user profiles before deployment.

Train users in proper ergonomic use of XR devices to avoid strain and injury.

Provide real-time ergonomic feedback during XR sessions to alert users of poor posture and reduce physical strain and fatigue.

Limit session durations and enforce breaks, using automated alerts or built-in timers to prevent overexposure.

Establish cooldown or recovery protocols post-XR sessions to mitigate residual disorientation or balance issues before resuming physical tasks.

Conduct safety evaluations and user briefings before XR use, including training on protocols and risk awareness.

Include XR-related health and safety risks in organizational risk assessments, with supporting documentation and mitigation plans.

Verify whether different PPE (personal protective equipment) is required based on the context and use case.

Conduct pre-use screening with tools like the Simulator Sickness Questionnaire (SSQ) to assess user susceptibility to motion sickness or related conditions.

Evaluate users' well-being continuously, including post-session surveys (e.g., after 10, 20, 40 minutes) to identify any negative effects.

Use test sessions to gauge users' initial adaptation and guide recommendations for further participation.

Offer personal training or orientation sessions to help users acclimate and reduce the likelihood of discomfort.

Inform users about personal data handling responsibilities, including potential liabilities for misuse or unauthorized data sharing.

Integrate transparency guidelines into the XR design and deployment process to ensure users understand how their data is used and who has access

Additional Measures

Organize hands-on training sessions and courses on XR device usage and interaction principles

Include XR training in onboarding for all new employees to ensure consistent baseline knowledge

Allow individual calibration of the XR interface to accommodate user preferences and reduce discomfort during prolonged use

Monitor users in real time for signs of discomfort (e.g., dizziness, nausea, irregular movements), and allow or trigger session termination if needed

Use pilot programs to test and refine training, including options for breaks, limited time exposure, and iterative content updates

Develop official guidelines and training materials on legal, ethical, and safety requirements for all system users

Create and maintain XR-specific safety and ethical standards, including regular updates based on expert and user feedback

A key outcome of this deliverable is the translation of abstract issue areas into practical safeguards that directly inform Motivate XR's design and deployment. Importantly, the recommendations developed here will be carried forward into Deliverable D3.4, where they will be evaluated and potentially embedded into revised user requirements. This ensures that SEL considerations are not treated as separate or peripheral, but rather as an integral part of the technical, organisational, and regulatory foundations of the project through its SSH framework.

This deliverable therefore marks a significant step forward in aligning XR innovation with societal expectations and values. It demonstrates that by systematically identifying risks, clustering them into meaningful categories, and translating them into actionable recommendations, Motivate XR can help ensure that immersive technologies are developed and deployed in ways that promote safety, inclusivity, and responsible innovation.

APPENDIX

APPENDIX A - ISSUES IRRELEVANT TO MOTIVATE XR

nr.	Issue name
8.	Community Building and Social Participation in Virtual Environments (Topic 12)
9.	Psychological Impacts and Behavioral Addictions in Virtual and Online Environments (Topic 30)
10.	Disinformation and Political Manipulation in XR and Social Media Platforms (Topic 56)
12.	The Impact of XR on Social Narratives and Political Discourses in Contemporary Society (Topic 72)
14.	The Impact of the COVID-19 Pandemic on Virtual Interactions and Social Adaptation (Topic 3)
16.	Parental Concerns and Child Development Risks in the Age of Digital and Social Media Influence (Topic 10)
17.	Impact of Extended Reality on Children's Visual and Cognitive Development (Topic 106)
19.	The Digitization and Preservation of Cultural Heritage in the Age of Extended Reality (Topic 8)
23.	The Use of Virtual Reality for Pain Management and Its Effectiveness in Chronic and Acute Conditions
24.	The Evolution of Telehealth and Patient Care in the Age of Extended Reality (Topic 67)
25.	The Integration of Extended Reality in Medical Operations and Telemedicine (Topic 96)
27.	Technological Advances in Medical Imaging and Surgical Precision Through Extended Reality (Topic 27)
28.	The Role of Extended Reality in Enhancing Intraoperative Navigation and Postoperative Outcomes (Topic 10)
29.	The Integration of XR in Post-Stroke Rehabilitation for Motor Recovery (Topic 33)
33.	The Impact of Cyberbullying, Sexual Content, and Online Aggression on Adolescents (Topic 110)
37.	The Role of XR in Urban Planning and Digital City Design (Topic 63)
44.	Social Relationships, Grief, and Ethical Concerns in Virtual Worlds (Topic 85)
46.	The Impact of Autonomous Vehicles and Driving Simulations on Road Safety and Behavior (Topic 10)
48.	The Ethical Challenges of Immersive Journalism and News Storytelling (Topic 93)

APPENDIX B – ADDITIONAL ISSUES IDENTIFIED IN 2ND SEL WORKSHOP

In this Appendix is the mapping from SEL issues identified in 2nd SEL workshop into the list presented here in D3.2

Issue named in 2nd SEL workshop	Place in D3.2 issue list
Problems with XR glasses in outdoor environments	Environmental challenges impacting AR functionality
3rd party software	Indirectly covered
Dependent to deprecated libraries for XR development	Increased Maintenance Complexity
health concern regarding delay and duration of wearing glasses	Increased Risk of Workplace Health Issues
confusing reality vs xr	Reduced real-world awareness and increased risk of accidents
content uploaded to the MotivateXR platform without IPR	Increased Risk of Intellectual Property Violations
data privacy issue.	Indirectly covered
Data Confidentiality	Lack of data protection and security in XR systems
eye tracking issue	Reduced user privacy due to data collection and usage in extended reality applications
Steep learning curve for inexperienced users of XR technologies	Exacerbated skills gaps and lack of preparedness
Financial accessibility to MotivateXR license and XR HW	Increased financial barriers to access XR technologies
Inexperienced users	Indirectly covered
Cyber security attacks to Platform and headset	Data Security Vulnerabilities in XR-based Infrastructure
slow connectivity to remote services	Network impairments hindering collaborative AR applications
Long training time of XR technologies	Impeded skill development due to technological limitations
Using the XR platform improper applications [i.e. porn]	Challenged Infrastructure Management and Regulatory Oversight
make sure that the battery has a maximum charge and / or a spare battery	Increased Maintenance Complexity
Environmental impact and sustainability issues.	Covered
information about people reaches AI algorithms from AR players (e.g. faces)	Reduced user privacy due to data collection and usage in extended reality applications
scare issue: operators can be scared of being controlled	Surveillance and privacy concerns
Heavy Computational Resources	High implementation and maintenance costs of XR technologies
If accident while using XR, who is responsible ? (MXR, user, Industrial ?)	Created liability concerns related to XR technology
Avoid injuries for users in the working zone (In VR well define the environment of work)	Reduced situational awareness and increased risk of errors in XR systems
without proper UI accessibility some user wont be able to use MotivateXR	Reduced accessibility to jobs and education
Certification did not match with enough documents	Development risk, not SEL issue
Health during using VR/XR tools	Indirectly covered

Limit the time of using VR for medical issues	Mitigation measure, not SEL issue
Adapt colour, contrast for daltonism	Mitigation measure, not SEL issue
End users don't feel that remote assistance is helpful as they don't feel a real person is on the other side	Reduced empathy and social connection in remote XR-based collaboration
anxiety performing at a virtual environment and not in the real one	Increased anxiety and negative emotional responses
Users get mentally exhausted for expending too much time inside virtual environments	Increased fatigue and reduced performance
Social isolation in virtual worlds	Reduced empathy and social connection in remote XR-based collaboration
End users will limit or stop the use of MotivateXR if they feel dizzy	Induced cybersickness and simulator sickness
Dizziness	Induced cybersickness and simulator sickness
Concerns over user safety can make potential users sceptical	Safety concerns due to lack of standardization in AR interfaces
Reduced sense of usefulness or being substituted by machines, as only certified workers can do these tasks and not any worker	Increased Risk of Addiction and Mental Health Issues
New certifications on xr-based industrial operations	Growing divergence from established practices
Monopolization of the technology can block the access to the tool	Increased reliance on third parties
persons with visual impairments can be excluded from using the new technology	Reduced Accessibility to jobs and Education
Virtual training methodology need certified trainers and certified organization	Growing divergence from established practices
End users of MotivateXR could be afraid of using the platform if they don't feel their data is treated properly	Indirectly covered
Tampering with experience	Increased Cybersecurity Risks and Data Vulnerabilities
If something happens, who is accountable? End users could feel that they will be find accountable even if there were some technical problems	Created liability concerns regarding errors in AI-driven XR assistance
Accountability of actions	Created liability concerns related to XR technology
Tracking of the user and the employee in terms of performances while performing the task	Enhanced workplace surveillance and privacy violations through XR
performance could be affected by feeling controlled raising anxiety issues	Negative impacts on employee well-being and job satisfaction due to XR technologies
Resources scattered through the platform: CMS, libraries from each tool, etc.	Technical issue, not SEL issue
End users may stop using the platform if they find difficult to find the correct resource to create their XR experiences	Reduced efficiency and productivity in design processes due to software limitations
AI-based Hand gesture recognition could interpret a different gesture from the real one	Technical issue, not SEL issue
Robots assuming human jobs	Job displacement due to automation and remote operation
Humans could feel that their job is not relevant and they may be substituted for a robot	Job displacement due to automation and remote operation
In environments where human control robots mistakenly recognising actions could lead to wrong operational actions that cause a lot of harm. That will lead to stop using the tool	Increased risk of errors due to augmented scene complexity
Virtual training efficiency - Are classical evaluation methods still relevant for virtually trained technicians ?	Growing divergence from established practices

Not having "real" interactions with remote users in assistance or training (trainers) could reduce the effectiveness as the trainee could feel not really accompanied	Impeded Skill Development and Training Effectiveness
Dependence to the XR tool autonomy (battery) to complete the procedure	Limited transfer of skills from virtual to real-world settings
Non Secure communications may result in information leak	Increased Cybersecurity Risks and Data Vulnerabilities
Loss of autonomy for workers who have been using XR assistance tools ?	Deskilling of workforce due to over-reliance on technology
The quality of KG based augmented manuals are not as good as having the physical manual, and hence not used by the users	Technical limitations impacting realism and performance
AI processing of documents is not trusted for the creation of DSS tools	Reduced accuracy of information in XR systems

APPENDIX C – UPDATED LIST OF RELEVANT ISSUES FOUND IN LITERATURE

In D3.1 issues were found using a big-data method on academic literature on AI. It was manually decided which of these issues were of relevance to the Motivate XR project. After submission of D3.1, it became apparent from the 2nd SEL workshop that the list of relevant issues needed to be updated. Below is the updated list containing the issues that was not found to be irrelevant in the 2nd SEL workshop with an indication of whether or not the list was indicated as relevant in D3.1. It is furthermore indicated what is the closest related issue in the taxonomy presented in this deliverable D3.2 or under what cluster the impact has been added to the taxonomy.

nr.	Issue name	Found irrelevant in 2nd SEL workshop	Relevant in D3.1	Place in D3.2 issue list
1.	The Influence of Avatars on Identity, Social Behaviour, and Representation in Virtual Environments (Topic 16)	No		Altered Social Interaction and Psychological Well-being
2.	The Role of Virtual Reality Exposure Therapy (VRET) in Treating Anxiety and Mental Health Disorders (Topic 40)	No		Limited adoption of XR technologies in healthcare
3.	Body Ownership, Perception, and Idealization in Virtual Environments (Topic 45)	No		Distorted perception of reality and self
4.	The Impact of Distraction and Technology Use on Walking Safety in Adults (Topic 95)	No	Yes	Disrupted spatial perception in augmented reality affecting real-world tasks
5.	The Use of XR in Maternal Health and Pregnancy Monitoring (Topic 97)	No		Reduced accessibility of XR technologies for specific populations
6.	Cultural and Ethical Implications of Digital Twins in Heritage, Farming, and Product Design (Topic 21)	No		Challenged existing legal frameworks governing virtual property
7.	The Impact of Digital Communication on Society and the Post-Truth Era (Topic 66)	No	Yes	Increased vulnerability to political control and manipulation through XR technologies
11.	Gender Representation and Diversity in STEM and Virtual Environments (Topic 60)	No		Amplify existing disparities in STEM
15.	Data Privacy and Security Risks in the Internet of Things (IoT) and 5G/6G Networks (Topic 42)	No	Yes	Vulnerabilities to Distributed Denial-of-Service (DDoS) Attacks in XR Systems
18.	The Integration of XR in Smart Cities and Its Impact on Civic Engagement and Urban Life (Topic 57)	No	Yes	Increased challenges in implementing XR in large-scale urban projects
20.	Social Exclusion and Mental Health Risks in Virtual Environments (Topic 90)	No		Reduced real-world engagement and social skills
21.	The Emotional and Psychological Impact of Immersive Virtual Experiences (Topic 91)	No		Reduced psychological well-being due to immersive XR experiences

22.	The Challenge of Motion Sickness and Sensory Feedback in Virtual Environments (Topic 84)	No	Yes	Reduced user comfort due to VR/AR/MR systems
26.	Participatory Design and User Interaction in XR: Evaluating Inclusivity and Research Practices (Topic 79)	No	Yes	Exacerbated inequalities and digital divide due to XR technologies
30.	Harassment and User Safety in Immersive Virtual Spaces (Topic 73)	No	Yes	Increased risk of harassment and cyberbullying
31.	The Ethical Implications of Immersion and Empathy in Virtual Reality Experiences (Topic 0)	No		Reduced empathy and social connection in remote XR-based collaboration
32.	The Intersection of Virtual and Physical Spaces in Architectural Design and Public Engagement (Topic 18)	No		Inaccurate assessment of physical space in XR environments
34.	The Accessibility of Emerging Technologies (Topic 41)	No	Yes	Exacerbated inequalities and digital divide due to XR technologies
35.	Legal Standardization and Liability in Extended Reality Applications (Topic 98)	No	Yes	Exacerbated inequalities and digital divide due to XR technologies
36.	Privacy and Security Challenges in the Ethical Adoption of Extended Reality Technologies (Topic 32)	No	Yes	Privacy violations and data misuse in XR applications
38.	User Privacy and Data Security Risks in Extended Reality Applications. (Topic 20)	No	Yes	Privacy risks from data collection in XR learning environments
39.	Ethical Challenges of Data Security and Resource Management in Virtualized Cloud Environments (Topic 48)	No	Yes	Data Security Vulnerabilities in XR-based Infrastructure
40.	Ethical Implications of AI-Powered Applications in Medical Extended Reality (Topic 11)	No		Ethical concerns and challenges in using XR in healthcare
41.	The Ethical and Public Consequences of Augmented and Mixed Reality Technologies (Topic 47)	No	Yes	Challenged Data Privacy and Security in XR Systems; Reduced empathy and social connection in remote XR-based collaboration
42.	Privacy and Security Risks in Online Platforms and Information Sharing (Topic 101)	No	Yes	Raised concerns about data privacy and security in XR systems
43.	Human-Robot Interaction and the Ethical Implications of Robotics in Industrial and Social Environments (Topic 19)	No	Yes	Negative impacts on employee well-being and job satisfaction
45.	Privacy and Security Challenges in the Emergent Metaverse Ecosystem (Topic 1)	No		Increased Cybercrimes and Online Harms in Immersive Digital Environments
47.	The Challenges of Leadership and Team Dynamics in Virtual Environments (Topic 77)	No	Yes	Limited physical interaction in remote XR collaboration
49.	Remote Collaboration and Expert Assistance in Healthcare and Mechatronics (Topic 71)	No	Yes	Reduced effectiveness of remote collaboration due to technical and communication barriers

50.	The Transformation of Social Networks and Communication in the Age of Extended Reality (Topic 29)	No	Yes	Reduced empathy and social connection in remote XR-based collaboration
51.	Legal and Intellectual Property Challenges in Virtual Economies and XR Environments (Topic 43)	No	Yes	Challenged existing legal frameworks governing virtual property
52.	Trust and Human-Agent Interaction in Virtual Environments (Topic 15)	No	Yes	Increased user errors and reduced trust in technology

APPENDIX D – ALIGNMENT WITH SEL ISSUES FROM 1ST MITIGATION WORKSHOP AND PIRORITIZATION SURVEY

In the 1st SEL workshop, SEL 80 risks were identified. In the 1st prioritization survey, 47 of these were found to have a combined average risk consequence-likelihood score of 5 or higher. Below table shows how these 47 risks are reflected in the final SEL issues. The colours reflect the consequence and likelihood score with red being the highest score and pale yellow the lowest.

Cluster	Risk	Average consequence	Average Likelihood	Place in D3.2 issue list
Data collection, Protection and Storage	The increased digital use of sensitive documentation and data caused by the Motivate XR solutions increases the risk of cyber theft.	3,50	2,67	Increased Cybersecurity Risks and Data Vulnerabilities
Data collection, Protection and Storage	Data privacy may be compromised by the use of Open-Source software.	3,20	2,80	Increased Cybersecurity Risks in Extended Reality Applications
Data collection, Protection and Storage	The ability of the Motivate XR solutions to capture data causes users to capture more data than they need and thereby increase the risk of breaching privacy and IP.	2,83	3,17	Increased data collection and privacy violations in XR systems
Data collection, Protection and Storage	Since the information is available on an XR device, some users may forget that sensitive documentation should not be taken out of company premises, thereby compromising data security.	3,33	2,50	Increased Cybersecurity Risks and Data Vulnerabilities
Data collection, Protection and Storage	Data may get stolen because the used internet connections are not properly secure.	3,00	2,67	Vulnerabilities to Distributed Denial-of-Service (DDoS) Attacks in XR Systems
Data collection, Protection and Storage	The risk of theft of information (e.g. industrial documentation, private information and analysis thereof) may increase as the XR headsets are more prone to get stolen than stationary computers	3,17	2,33	Data Security Vulnerabilities in XR-based Infrastructure
Data collection, Protection and Storage	Data privacy cannot be guaranteed when data travel around different countries in different serves.	3,00	2,50	Increased Cybersecurity Risks in Extended Reality Applications
Data collection, Protection and Storage	Users may intentionally use the Motivate XR solutions to gather data for purposes different than what they tell data providers and people in their immediate surroundings	3,00	2,50	Raised concerns about data privacy and security in XR systems
Data collection, Protection and Storage	User organizations may not be able to gain access to 3D files that are IP protected, limiting which organizations can get the advantages of using the XR.	2,67	2,67	Exacerbated inequalities and digital divide due to XR technologies
Data collection, Protection and Storage	End users' and user organisations' privacy may get compromised because the end users do not know how to use the privacy functionalities within the tools.	2,83	2,33	Increased Worker Surveillance and Privacy Concerns

Employee/Students Rights and Safety	The safety of workers cannot be guaranteed by current procedures as XR tech is not covered by Health & Safety Department regulations.	3,67	2,50	Safety and Security Risks in XR Applications
Employee/Students Rights and Safety	Use of XR may cause harmful situations due to the users decreased awareness of the surroundings.	3,17	2,67	Compromised safety due to blurred physical-virtual boundaries
Employee/Students Rights and Safety	Recordings and exercise conduction data of trainers or students/trainees may get misused or shared inappropriately.	3,17	2,67	Privacy violations and data misuse in XR applications
Employee/Students Rights and Safety	Prolonged use of XR devices can harm the users.	3,17	2,33	Increased fatigue and reduced performance
Employee/Students Rights and Safety	To ensure safe use of XR, trainees and employees will have to inform their organizations about more health issues than they currently do.	2,67	2,83	Added to cluster Increased Worker Surveillance and Privacy Concerns
Employee/Students Rights and Safety	Connection issues could provoke accidents as end-users don't fully understand remote instructions or even receive them.	2,83	2,50	Increased reliance on unstable network infrastructure
Employee/Students Rights and Safety	Users may perform tasks that carry higher risks than they would otherwise dare to perform because the XR changes their perspective of risk.	3,00	2,33	Reduced understanding of traditional safety measures
Employee/Students Rights and Safety	Standardized training may not fit to the need of all participants' needs (some may e.g. need longer time than others).	2,33	3,00	Decreased personalization of training experiences
Employee/Students Rights and Safety	The users' safety gets compromised due to the use of XR compared to normal task execution (e.g. physical restricted by XR, entering electric environments with XR capture device or headset).	3,17	2,17	Safety challenges in constrained environments
Employee/Students Rights and Safety	Organizations may not be aware on the IP rights connected to content created using the Motivate XR solutions in teaching situations.	2,67	2,67	Insufficient competences in user organizations
Employee/Students Rights and Safety	The XR trigger medical conditions like epileptic episodes .	3,00	2,20	Increased Risk of Physical Health Issues
Employee/Students Rights and Safety	The XR causes motion sickness.	2,50	2,50	Induced cybersickness and simulator sickness
Legal Compliance	Uncertainty of legal, insurance and social security status if remote instructions delivered via XR caused or did not prevent an injury for a professional or student/trainee .	3,60	3,00	Created liability concerns related to XR technology
Legal Compliance	Current legislation is insufficient to identify responsibilities for incorrect use of the XR or use over prolonged periods of time.	3,20	3,40	Ethical Dilemmas Posed by XR Technologies
Legal Compliance	Integration between the Motivate XR solutions and other systems may violate IP and legal requirements.	3,40	3,00	Increased Risk of Intellectual Property Violations

Legal Compliance	3D files will be increasingly requested, making it harder to protect designs with secrecy and patents.	2,83	3,33	Decreased Effectiveness of Intellectual Property Protection
Legal Compliance	Current regulation may not be able to adequately rule in situations where XR and AI content generation are used.	3,00	3,00	Created liability concerns related to XR technology
Legal Compliance	The accountability in case of harmful situations, faulty results or inability to perform contracted job may depend on the status of the internet connection.	3,20	2,40	Increased reliance on unstable network infrastructure
Legal Compliance	Unclear how maintenance of the XR equipment will affect responsibilities.	2,40	3,00	Challenged Infrastructure Management and Regulatory Oversight
Legal Compliance	The Motivate XR solutions may not adhere to cultural norms and legislation in all countries .	2,40	2,83	Reflected indirectly
Organizational Competences	Organizations do not have the knowledge to assess the legal implications of having XR users do things dictated by AI or by people in remote locations (especially regarding harmful situations).	3,33	3,33	Regulatory and Legal Hurdles in XR Adoption
Organizational Competences	Many Health & Safety Departments do not have sufficient knowledge to protect their workers when introducing XR.	3,00	3,17	Increased Risk of Workplace Health Issues
Organizational Competences	Some organizations will not have access to sufficient documentation and therefore be disadvantaged.	3,00	2,83	Enlarge Existing Digitalization Inequalities
Organizational Competences	Improper or missing maintenance of equipment and update of the software may create harmful situation.	3,00	2,83	Increased Risk of Workplace Health Issues
Organizational Competences	The Motivate XR solutions may normalize the decrease in human expertise due to overreliance on digital guidance.	3,00	2,83	Deskilling of workforce due to over-reliance on technology
Organizational Competences	The cost of the necessary equipment (inc. servers, headsets, capture devices etc) could make the tools and the XR not widely accessible to all organizations .	2,67	3,17	Increased financial barriers to access XR technologies
Organizational Competences	Technology may support monopolies as barrier to entry increases .	2,60	3,00	High implementation and maintenance costs of XR technologies
Organizational Competences	User organizations are unable to create the content they need themselves because the Motivate XR solutions are so complex that only specialized companies can use them.	2,67	2,50	Increased development costs and time
Organizational Competences	Education using XR amplify social inequality, as socio-economically challenged groups has lower level of knowledge and digital literacy .	2,83	2,17	Exacerbated inequalities and digital divide due to XR technologies
Societal structures and environmental impact	Cloud serving can have high carbon footprint.	3,40	3,00	Increased energy consumption from cloud-based XR services

Societal structures and environmental impact	The Motivate XR solutions may be designed in such a way that they do not fulfill the technologies' potential to improve the opportunities of impaired people and users with special needs .	3,17	2,33	Deteriorated User Experience and Technological Limitations
Societal structures and environmental impact	Lacking long-term support and longevity of XR software and hardware products will create more waste.	2,83	2,50	Increased energy consumption from XR hardware and infrastructure
Work Content and Technical Reliability	The use of AI to create content makes it harder to ensure the content presented in the XR is indeed correct.	3,40	2,67	Compromised Reliability and Validity
Work Content and Technical Reliability	Automatic translation could introduce misunderstandings and inaccuracies.	3,00	2,83	Compromised Reliability and Validity
Work Content and Technical Reliability	The users may rely on the XR instructions generated by AI so much they don't consider if the content is correct.	2,83	2,83	Compromised Reliability and Validity
Work Content and Technical Reliability	Software updates outside the control of the XR tool providers may make XR tech unstable or unresponsive after initial deployment.	3,17	2,50	Increased Maintenance Complexity
Work Content and Technical Reliability	The remote technician or instructors are not proficient in giving instructions in a way that positively uses the XR.	2,33	3,00	Insufficient Competences in User Organizations

APPENDIX E - FULL LIST OF NEGATIVE ISSUES

This Appendix present the full list of negative issues before creating issue map.

	Category_name	Impact_name	Impact_description
12	Social, ethical, and cultural category	Reduced user privacy due to data collection and usage in extended reality applications	<i>This cluster of consequences highlights the heightened risk of privacy violations stemming from the extensive data collection practices inherent in extended reality (XR) technologies. XR applications, encompassing augmented, virtual, and mixed reality, often collect sensitive user data, including biometric information, location data, and behavioral patterns, without sufficient transparency or user control, leading to concerns about potential misuse and exploitation within the context of Increased Worker Surveillance and Privacy Concerns.</i>
12b	Social, ethical, and cultural category	To ensure safe use of XR, trainees and employees will have to inform their organizations about more health issues than they currently do.	
12c	Social, ethical, and cultural category	End users' and user organisations' privacy may get compromised because the end users do not know how to use the privacy functionalities within the tools.	
13	Social, ethical, and cultural category	Reduced empathy and social connection in remote XR-based collaboration	<i>This cluster of consequences describes the negative impact of extended reality technologies on social interaction and psychological well-being by reducing empathy and social connection, particularly in remote collaborative settings. The consequences highlight how the mediated nature of XR interactions can hinder the development of genuine human connection and understanding.</i>
14	Social, ethical, and cultural category	Reduced real-world skills and experiences due to over-reliance on synthetic environments	<i>This cluster of consequences focuses on how the immersive nature of XR technologies can lead to a decreased reliance on real-world skills and experiences, negatively impacting the development of practical problem-solving abilities and adaptability. This is framed within the context of Altered Social Interaction and Psychological Well-being, as reduced real-world engagement can lead to social isolation and a diminished sense of self.</i>
15	Social, ethical, and cultural category	Blurred boundaries between virtual and physical realities, impacting perception and identity	<i>This cluster of consequences highlights the blurring of lines between virtual and physical realities due to XR technologies, impacting individuals' perception of reality, sense of self, and social interactions. The consequences explore how the immersive nature of XR</i>

			<i>can lead to a distorted understanding of the world and affect identity formation.</i>
15b	Social, ethical, and cultural category	The Influence of Avatars on Identity, Social Behaviour, and Representation in Virtual Environments (Topic 16)	<i>This issue explores how avatars—digital representations of users—impact social behaviours, self-presence, and perceptions of ethnic and gender identity in virtual spaces. The appearance and embodiment of these avatars shape how participants interact, influencing behaviours such as avoidance or engagement, especially among vulnerable groups like the elderly. The way avatars are designed and presented can reinforce or challenge stereotypes, affecting users' sense of presence and connection in digital environments. This raises questions about the ethical responsibility of virtual platforms in promoting inclusivity and addressing the social consequences of avatar representation.</i>
16	Social, ethical, and cultural category	Increased Cybercrimes and Online Harms in Immersive Digital Environments	<i>The rise of extended reality (XR) technologies, encompassing virtual, augmented, and mixed reality, has created new avenues for cybercrimes and online harms, challenging existing legal and safety regulations. The immersive nature of these environments facilitates various offenses, including deception, manipulation, harassment, and identity theft, while also complicating law enforcement efforts due to the unique challenges posed by digital spaces.</i>
17	Social, ethical, and cultural category	Challenged Data Privacy and Security in XR Systems	<i>Extended reality technologies present significant challenges to existing data privacy and security regulations. The collection and use of biometric data, the potential for data breaches, and the lack of robust security measures in XR systems create vulnerabilities that expose users to various risks, including identity theft, unauthorized access to sensitive information, and manipulation.</i>
18	Social, ethical, and cultural category	Insufficient Legal Frameworks for Metaverse Governance	<i>The rapid development of the metaverse has outpaced the creation of adequate legal and regulatory frameworks to address the unique challenges it presents. This lack of clear guidelines creates uncertainty regarding liability, content moderation, data protection, and user safety, hindering the responsible integration of this technology into society.</i>
19	Social, ethical, and cultural category	Safety and Security Risks in XR Applications	<i>The use of extended reality technologies in various settings, including education, healthcare, and entertainment, introduces new safety and security risks. These risks range from physical hazards like cybersickness and falls to security vulnerabilities that can lead to data breaches, unauthorized access, and manipulation of virtual environments. Existing safety regulations often fail to adequately address these unique challenges.</i>
20	Social, ethical, and cultural category	Legal and Ethical Challenges of Digital Identity and Representation	<i>The creation and use of digital identities and representations in XR environments raise complex legal and ethical questions. Issues such as personality rights, the potential for impersonation and identity theft, and</i>

			<i>the blurring of lines between virtual and real-world identities challenge existing legal frameworks and require careful consideration of ethical implications.</i>
21	Social, ethical, and cultural category	Reduced real-world hands-on learning experiences in vocational education	<i>This cluster of consequences highlights the potential for XR technologies to reduce the emphasis on traditional hands-on learning experiences in vocational education and training settings. This can lead to a decline in the development of practical skills and dexterity, potentially impacting the quality of training and expertise in various fields.</i>
21b	Social, ethical, and cultural category	Standardized training may not fit to the need of all participants' needs (some may e.g. need longer time than others).	
22	Social, ethical, and cultural category	Reduced empathy and social connection in remote XR-based collaboration	<i>This cluster of consequences focuses on the potential negative impacts of XR technologies on social interaction and emotional connection, particularly in remote collaboration scenarios. The immersive nature of XR can sometimes lead to a decreased reliance on traditional communication methods and a reduction in empathy and social connection.</i>
23	Social, ethical, and cultural category	Blurred boundaries between virtual and physical workspaces, affecting work-life balance	<i>This cluster of consequences highlights the potential for XR technologies to blur the lines between virtual and physical workspaces, negatively impacting work-life balance. The constant accessibility of virtual workspaces can make it difficult to disconnect from work, leading to stress and burnout.</i>
24	Social, ethical, and cultural category	Created liability concerns regarding errors in AI-driven XR assistance	<i>This cluster of consequences focuses on the legal and ethical implications of using AI-driven XR assistance systems. Errors in AI-driven assistance can lead to accidents or injuries, creating liability concerns for both the developers and users of the technology.</i>
25	Social, ethical, and cultural category	Increased risk of addiction and harmful illusions	<i>This cluster of consequences highlights the potential for XR technologies to create addictive behaviours and harmful illusions. The immersive and engaging nature of XR can lead to excessive use and a detachment from reality, potentially causing psychological harm.</i>
25b	Social, ethical, and cultural category	without proper UI accessibility some user won't be able to use MotivateXR ; persons with visual impairments can be excluded from using the new technology	
43	Health and well-being category	Reduced user comfort due to VR/AR/MR systems	<i>This cluster of consequences describes the negative impact on user comfort and well-being caused by the physical and sensory characteristics of extended reality systems in health and well-being settings. This includes physical discomfort from wearing headsets, motion</i>

			<i>sickness, eye strain, and other physiological symptoms that impair the user's physical and sensory experience.</i>
44	Health and well-being category	Induced cybersickness and simulator sickness	<i>This category encompasses consequences related to cybersickness and simulator sickness, which are forms of motion sickness induced by VR/AR/MR systems. These conditions manifest as nausea, dizziness, disorientation, and other physical symptoms, significantly impacting the user's physical and sensory experience within the health and well-being domain.</i>
45	Health and well-being category	Impaired spatial perception and depth judgment	<i>This group of consequences highlights the distortion of spatial perception and depth judgment caused by XR technologies. In the context of impaired physical and sensory experience, this leads to inaccurate estimations of distances, misjudgements of spatial relationships, and potential safety hazards in real-world applications within the health and well-being domain.</i>
46	Health and well-being category	Reduced real-world awareness and increased risk of accidents	<i>This cluster of consequences focuses on the diminished awareness of the real world and the increased risk of accidents associated with XR technologies. The immersive nature of these technologies can lead to users neglecting their physical surroundings, resulting in collisions, falls, and other safety hazards, thus negatively impacting their physical and sensory experience in health and well-being contexts.</i>
47	Health and well-being category	Increased fatigue and reduced performance	<i>This category groups consequences related to increased fatigue and reduced performance due to XR technologies. Prolonged use of XR systems can lead to physical and mental fatigue, eye strain, and reduced cognitive function, all of which negatively affect the user's physical and sensory experience and their ability to perform tasks effectively within the health and well-being domain.</i>
48	Health and well-being category	Reduced psychological well-being due to immersive XR experiences	<i>This cluster of consequences highlights the negative impacts of immersive extended reality (XR) technologies on users' mental health. The immersive nature of XR can lead to various psychological issues, including anxiety, fear, stress, and even addiction, blurring the lines between virtual and real-world experiences and potentially affecting users' self-perception and daily lives.</i>
49	Health and well-being category	Increased risk of addiction and maladaptive behaviours due to XR use	<i>Excessive use of XR technologies can lead to addictive behaviours, causing individuals to neglect real-world responsibilities and relationships. This can manifest as escapism, where individuals prefer virtual interactions over real-life experiences, potentially leading to social isolation, decreased productivity, and various mental health issues.</i>
50	Health and well-being category	Distorted perception of reality and self	<i>XR technologies can create a sense of presence that blurs the lines between virtual and real-world experiences. This can lead to a distorted perception of reality, impacting users' self-perception, body image, and their ability to distinguish between fantasy and</i>

			<i>reality. This distorted perception can negatively affect mental well-being and social interactions.</i>
51	Health and well-being category	Reduced real-world engagement and social skills	<i>Excessive use of XR technologies can lead to decreased engagement with the physical world and real-life social interactions. This can result in social isolation, reduced physical activity, and a decline in social skills, negatively impacting users' overall well-being and mental health.</i>
52	Health and well-being category	Increased anxiety and negative emotional responses	<i>XR experiences, particularly immersive ones, can trigger or exacerbate anxiety and other negative emotions in users. This can be due to the realistic nature of simulations, exposure to stressful scenarios, or the immersive nature of the technology itself. This can hinder the effectiveness of therapeutic applications and negatively impact overall well-being.</i>
53	Health and well-being category	Exacerbation of pre-existing mental health conditions	<i>XR technologies can worsen pre-existing mental health conditions such as anxiety disorders, phobias, and addiction. The immersive nature of XR can trigger negative emotional responses and reinforce maladaptive behaviours, potentially hindering therapeutic progress and negatively impacting overall well-being.</i>
54	Health and well-being category	Blurred boundaries between virtual and real worlds, affecting work-life balance	<i>The immersive nature of XR can blur the lines between work and leisure, potentially leading to work-life balance issues. Users may struggle to disconnect from virtual environments, leading to excessive use, neglecting real-world responsibilities, and impacting their mental and emotional well-being.</i>
55	Health and well-being category	Increased risk of social isolation and loneliness	<i>XR technologies, particularly those that facilitate remote collaboration or immersive gaming, can lead to increased social isolation and loneliness. Users may prioritize virtual interactions over real-world relationships, potentially impacting their mental health and social skills.</i>
56	Health and well-being category	Negative impacts on cognitive function and decision-making	<i>XR technologies can affect cognitive functions such as attention, focus, and decision-making. The immersive nature of XR can lead to decreased awareness of the real world, potentially resulting in risky behaviours and impaired judgment. This can be particularly concerning in situations requiring focused attention or critical thinking.</i>
57	Health and well-being category	Increased risk of accidents and injuries	<i>The immersive nature of XR can lead to decreased awareness of the physical environment, increasing the risk of accidents and injuries. Users may collide with objects, lose balance, or engage in risky behaviours due to a diminished sense of reality. This is particularly relevant in dynamic environments or when using XR technologies while performing physical tasks.</i>
59	Health and well-being category	Unforeseen psychological and societal consequences	<i>The rapid development and widespread adoption of XR technologies present the potential for unforeseen psychological and societal consequences. The long-term effects of immersive XR experiences on human</i>

			<i>behavior, cognition, and social interactions are not yet fully understood, raising concerns about potential risks to individual and societal well-being.</i>
60	Health and well-being category	Increased risk of harassment and cyberbullying	<i>Social VR platforms can create environments where harassment and cyberbullying can occur, potentially leading to psychological distress and emotional harm for victims. The immersive nature of XR can make these experiences feel more real and intense, exacerbating the negative impacts on users' well-being.</i>
60b	Health and well-being category	Reduced sense of usefulness or being substituted by machines, as only certified workers can do these tasks and not any worker	
61	Health and well-being category	Reduced development of hands-on skills in XR-based training	<i>XR technologies, while offering immersive training experiences, may lead to a decreased reliance on traditional hands-on learning methods. This reduced emphasis on practical skills and dexterity can negatively impact the development of essential competencies in the Health and well-being domain, potentially affecting the quality of care, workmanship, or overall performance in real-world settings.</i>
62	Health and well-being category	Reduced transferability of virtual skills to real-world settings	<i>Skills acquired through XR-based training may not always translate effectively to real-world applications in the Health and well-being domain. This reduced transferability can stem from differences in the virtual and physical environments, limitations of XR technology, or a lack of sufficient practice in real-world settings. This can lead to inadequate preparation for real-world tasks and potentially compromise safety and effectiveness.</i>
63	Health and well-being category	Inhibition of learning and knowledge retention in XR training	<i>Certain aspects of XR-based training in the Health and well-being domain may inadvertently hinder learning and knowledge retention. Factors such as excessive reliance on virtual feedback, high cognitive load, lack of realism, or poorly designed interfaces can negatively impact the effectiveness of training, leading to incomplete skill acquisition or poor long-term retention.</i>
64	Health and well-being category	Reduced access to XR technologies due to cost and accessibility barriers	<i>High costs associated with XR technologies, including equipment, software, and maintenance, create significant barriers to access, particularly for individuals in underserved communities and those with limited socioeconomic resources. This disparity in access limits the potential benefits of XR for health and well-being, exacerbating existing health inequalities.</i>
65	Health and well-being category	Reduced accessibility of XR technologies for specific populations	<i>Certain populations, such as older adults, children, and individuals with disabilities, may face unique challenges in accessing and utilizing XR technologies due to factors like age-related limitations, cognitive abilities, physical impairments, and sensory differences. This unequal</i>

			<i>access exacerbates existing health disparities and limits the potential benefits of XR for these groups.</i>
66	Health and well-being category	Exacerbated health disparities due to unequal access to XR-based healthcare	<i>Unequal access to XR technologies in healthcare settings can widen the gap in healthcare access and quality between different populations, particularly those in underserved communities and rural areas. This disparity can lead to unequal opportunities for diagnosis, treatment, and rehabilitation, exacerbating existing health inequalities.</i>
67	Health and well-being category	Increased ethical concerns and risks associated with XR technologies	<i>The use of XR technologies in healthcare raises several ethical concerns, including patient privacy, data security, algorithmic bias, and the potential for misuse. These concerns can lead to mistrust, inequitable access to care, and exacerbate existing health disparities.</i>
68	Health and well-being category	Limited usability and accessibility of XR technologies for people with disabilities	<i>Many current XR experiences are not accessible to people with disabilities due to requirements for good vision, hearing, and mobility. Lack of accessibility features and functionalities in XR applications and games creates a digital divide and limits opportunities for this population, exacerbating existing health disparities.</i>
69	Health and well-being category	Unequal effects of XR technologies based on individual differences	<i>Individual differences, such as age, gender, and the presence of certain health conditions, can significantly influence the user experience and effectiveness of XR technologies. These differences can lead to unequal outcomes in training, treatment, and other applications, exacerbating existing health disparities.</i>
70	Health and well-being category	Reduced quality of care and human connection due to XR-mediated healthcare	<i>The increasing use of XR technologies in healthcare may lead to a reduction in the quality of care and the human connection crucial for effective healthcare delivery. This can be particularly detrimental for vulnerable populations who may rely heavily on the empathy and personal interaction provided by healthcare professionals.</i>
71	Health and well-being category	Limited adoption of XR technologies in healthcare due to various barriers	<i>Despite the potential benefits of XR technologies in healthcare, several factors hinder their widespread adoption and implementation. These barriers include cost, lack of training, technical challenges, and concerns about efficacy, leading to limited access to potentially beneficial interventions for many individuals.</i>
72	Health and well-being category	Exacerbated health disparities due to unequal access to XR-based education and training	<i>Unequal access to XR technologies in educational and training settings can create disparities in learning opportunities and outcomes, particularly for students in under-resourced schools and those with disabilities. This can lead to unequal access to quality education and career opportunities, exacerbating existing health inequalities.</i>
73	Health and well-being category	Increased risk of negative psychological and social impacts from XR use	<i>XR technologies, particularly in social VR environments, can expose users to risks such as cyberbullying, harassment, and age-inappropriate content. These negative experiences can have significant psychological</i>

			<i>and social impacts, particularly on children and vulnerable populations, exacerbating existing health disparities.</i>
74	Health and well-being category	Limited usability and adaptability of XR applications for diverse user needs	<i>XR applications may not be usable or adaptable to the needs of all end users, especially those with disabilities or other specific needs. This lack of inclusivity and adaptability limits the potential benefits of XR for diverse populations, exacerbating existing health disparities.</i>
75	Health and well-being category	Potential for bias and discrimination in XR applications	<i>XR applications, if not carefully designed and implemented, can perpetuate and even exacerbate existing biases and discrimination in healthcare and other settings. This can lead to unequal access to care, opportunities, and outcomes for certain demographic groups, widening existing health disparities.</i>
77	Health and well-being category	Limited effectiveness of XR-based interventions due to methodological challenges	<i>Methodological difficulties in ensuring the clinical viability and effectiveness of XR-based interventions can limit their widespread adoption and impact. This can hinder access to potentially beneficial treatments for many individuals, exacerbating existing health disparities.</i>
78	Health and well-being category	Reduced effectiveness of XR applications due to technical and usability issues	<i>This category encompasses the negative consequences stemming from technical limitations and usability challenges within extended reality (XR) applications in healthcare, impacting various stakeholders including patients, clinicians, and researchers. These issues hinder the effective implementation and utilization of XR technologies, potentially delaying improvements in patient care, training, and research progress.</i>
79	Health and well-being category	Increased workload and inefficiency for healthcare professionals due to XR integration	<i>The integration of XR technologies in healthcare settings can lead to increased workload and reduced efficiency for healthcare professionals. This is primarily due to the need for additional training, system maintenance, and adaptation to new workflows. The added burden on staff can impact overall productivity and potentially compromise patient care.</i>
80	Health and well-being category	Compromised patient safety and wellbeing due to XR technology malfunctions	<i>Malfunctions or errors in XR systems used in healthcare can directly compromise patient safety and well-being. This includes potential medical complications arising from system failures during procedures, delays in timely medical intervention due to technical issues, and the potential for inaccurate or misleading information provided by the system.</i>
81	Health and well-being category	Ethical concerns and challenges in using XR in healthcare	<i>The use of XR technologies in healthcare raises several ethical concerns, including data privacy, informed consent, responsible use of technology, and potential misuse. These concerns require careful consideration of ethical guidelines and regulations to ensure the responsible and ethical use of XR in healthcare settings.</i>

82	Health and well-being category	Negative impact on mental health and well-being due to XR use	<i>XR technologies, while offering therapeutic potential, can also negatively impact mental health and well-being. This includes the potential for increased anxiety, frustration, discomfort, and a blurring of lines between reality and virtuality, potentially affecting users' sense of self and reality.</i>
83	Health and well-being category	Reduced real-world interaction and social connection due to XR use	<i>Over-reliance on XR technologies can lead to reduced real-world interaction and social connection, impacting various aspects of well-being. This includes a decline in the importance of traditional therapeutic approaches and human interaction, as well as potential negative social consequences in shared virtual spaces.</i>
85	Health and well-being category	Challenges in implementing and evaluating XR interventions in healthcare	<i>Implementing and evaluating XR interventions in healthcare presents several challenges, including the need for rigorous research designs, standardization of treatments, and addressing issues of cost, accessibility, and usability. These challenges can hinder the overall progress and quality of research in this field.</i>
86	Health and well-being category	Blurred boundaries between real and virtual worlds impacting well-being	<i>The immersive nature of XR technologies can blur the boundaries between real and virtual worlds, potentially impacting users' sense of self, reality, and work-life balance. This includes the potential for negative consequences on human experience and understanding of the world, as well as challenges in relating virtual content to the real world.</i>
86b	Health and well-being category	The XR trigger medical conditions like epileptic episodes .	
86c	Health and well-being category	Many Health & Safety Departments do not have sufficient knowledge to protect their workers when introducing XR.	
86d	Health and well-being category	Improper or missing maintenance of equipment and update of the software may create harmful situation.	
115	Economic category	Increased financial barriers to access XR technologies	<i>The high cost of XR hardware, software, development, maintenance, and training limits access for various stakeholders, including educational institutions, small businesses, and individuals, creating financial barriers to adoption and potentially exacerbating existing inequalities.</i>
116	Economic category	High implementation and maintenance costs of XR technologies	<i>Implementing and maintaining XR technologies involves substantial costs, including hardware acquisition, software development, technical support, and training, which can hinder adoption, especially for organizations with limited resources. Technology may support monopolies as barrier to entry increases .</i>

117	Economic category	High development costs and complexity of XR applications	<i>Developing XR applications is complex and resource-intensive, requiring specialized skills, software, and hardware, which increases development time and costs, potentially hindering widespread adoption.</i>
118	Economic category	Reduced in-person tourism due to virtual tourism experiences	<i>The rise of virtual reality (VR) and augmented reality (AR) technologies offers immersive tourism experiences, potentially reducing the number of people visiting physical tourist destinations. This shift in consumer preference can negatively impact local economies that rely on tourism revenue, affecting businesses, communities, and cultural preservation efforts.</i>
119	Economic category	Decreased tourism revenue due to virtual substitutes	<i>Virtual reality (VR) and augmented reality (AR) technologies provide alternative tourism experiences, potentially substituting real-world travel. This substitution can lead to a decline in tourism revenue, impacting local economies, businesses, and employment within the tourism sector.</i>
120	Economic category	Reduced tourism due to virtual museum experiences	<i>The increasing availability of virtual museum experiences through VR and AR technologies may lead to a decrease in visits to physical museums. This can negatively impact the economic viability of museums and the local communities that depend on them for revenue and employment.</i>
121	Economic category	Decreased attendance at real-world events due to virtual alternatives	<i>Virtual reality (VR) experiences can offer alternatives to attending real-world events, such as festivals or performances. This substitution may lead to decreased attendance at physical events, negatively impacting the economic viability of these events and the communities that rely on them.</i>
122	Economic category	Reduced value of in-person tourism experiences	<i>The availability of virtual tourism experiences may lead to a decreased appreciation for in-person travel, potentially impacting the economic viability of destinations that rely on physical tourism. Tourists may find virtual experiences sufficient, reducing their desire or need to travel physically.</i>
123	Economic category	Shift in tourism consumption patterns	<i>The adoption of metaverse and VR/AR technologies may significantly alter consumer behavior in the tourism sector. This shift in consumption patterns could impact businesses and employment within the tourism, hospitality, and events industries.</i>
124	Economic category	Reduced tourism due to virtual travel alternatives	<i>The availability of virtual travel experiences, such as virtual tours and documentaries, may reduce the number of people visiting physical locations, impacting local economies and cultural preservation efforts.</i>
125	Economic category	Challenges to traditional tourism marketing	<i>The integration of AR technology in tourism may necessitate a shift in destination marketing strategies, potentially challenging traditional methods and requiring new approaches to engage tourists.</i>
126	Economic category	Limited VR tourism adoption due to lack of awareness	<i>Insufficient awareness among the population regarding VR's applications in tourism may hinder its widespread adoption and limit its potential to transform the sector.</i>

127	Economic category	Reduced in-person tourism due to virtual experiences	<i>Virtual reality (VR) can provide virtual experiences before, during, or instead of real-world visits to tourism sites, potentially reducing the number of in-person visits and impacting local economies dependent on tourism revenue.</i>
129	Economic category	Decreased tourism due to virtual reality adoption	<i>The widespread adoption of virtual reality tourism might lead to a decrease in the number of tourists visiting physical locations, potentially impacting local economies and communities that depend on tourism revenue.</i>
130	Economic category	Decreased interest in traditional religious tourism	<i>The widespread adoption of VR technology for religious tourism may lead to decreased interest in traditional religious tourism practices, potentially impacting the economic viability of traditional religious sites and the preservation of cultural heritage.</i>
131	Economic category	Reduced tourism revenue due to virtual reality in museums	<i>The widespread adoption of virtual reality in museums may lead to a decrease in in-person visits and a potential decline in revenue for museums that rely heavily on physical attendance, impacting their ability to maintain operations and provide services.</i>
132	Economic category	Potential replacement of real travel by virtual experiences	<i>Virtual experiences, such as Amazon Explore, could potentially replace real travel in the future, thus impacting the tourism industry and related businesses.</i>
133	Economic category	Dissatisfaction with virtual destination experiences	<i>Virtual reality destination experiences may not fully meet tourist expectations, potentially leading to dissatisfaction and a less impactful tourism experience.</i>
134	Economic category	Varied effectiveness of VR in destination marketing	<i>The effectiveness of virtual reality in destination marketing may vary depending on the style of content used, with more active content generally yielding better results than passive content.</i>
135	Economic category	Hindered tourism economic benefits due to virtual tourism	<i>The consumption structure of virtual tourism may hinder the improvement of tourism economic benefits.</i>
136	Economic category	Disconnection from authentic tourism networks	<i>The widespread adoption of virtual reality marketing may lead to a disconnection from authentic tourism networks and experiences, potentially diminishing the value of genuine human interaction and cultural immersion for tourists.</i>
137	Economic category	Negative consequences of augmented reality in tourism	<i>Augmented reality in the tourism sector could negatively affect visitor experience and overall satisfaction.</i>
138	Economic category	Complete replacement of traditional tourism by virtual reality	<i>Virtual reality may completely replace traditional tourism and cause the decline of traditional tourist destinations and related businesses.</i>
139	Economic category	Decreased interest in physically visiting destinations due to VR tourism	<i>Virtual reality tourism may foster a decreased interest in physically visiting destinations, potentially impacting local economies and cultural preservation efforts.</i>
148	Economic category	Reduced hands-on skills development in training	<i>The extensive use of virtual and augmented reality in training programs reduces the development of practical, hands-on skills, potentially impacting trainees' ability to</i>

			<i>perform tasks effectively in real-world settings and potentially leading to job displacement for those whose jobs require such skills.</i>
149	Economic category	Job displacement due to automation and remote operation	<i>XR technologies enable remote control of machinery and automation of tasks, leading to job displacement for workers whose roles are replaced by technology. This is particularly relevant in sectors like mining and manufacturing.</i>
150	Economic category	Reduced need for traditional jobs due to XR-based solutions	<i>The adoption of XR technologies across various sectors reduces the need for traditional roles, leading to job displacement. This impact is observed in sectors such as tourism, publishing, and retail.</i>
151	Economic category	Deskilling of workforce due to over-reliance on technology	<i>XR technologies, while increasing efficiency, can lead to over-reliance on technology and a decline in manual skills, potentially deskilling the workforce and making them vulnerable to job displacement in the long term.</i>
152	Economic category	Job displacement in specific sectors due to XR adoption	<i>The widespread adoption of XR technologies in various sectors leads to job displacement in specific roles. This is evident in sectors such as libraries, manufacturing, and the tourism industry.</i>
153	Economic category	Job displacement and deskilling due to virtual agents	<i>The increasing use of virtual agents in customer service, education, and healthcare reduces the need for human workers, leading to job displacement and potential deskilling of the workforce.</i>
154	Economic category	Reduced need for physical spaces and resources	<i>XR-based training reduces the need for physical training spaces and equipment, potentially impacting the employment of instructors and technicians who maintain these resources.</i>
155	Economic category	Job displacement due to changes in business models	<i>XR technologies cause disruptions in business models, leading to job displacement or the need for workforce retraining. This is particularly relevant in sectors such as online travel agencies and hotels.</i>
156	Economic category	Increased unemployment and economic hardship	<i>XR-driven job displacement leads to increased unemployment and economic hardship for affected workers and communities. This is a broad consequence affecting various sectors and worker groups.</i>
157	Economic category	Exacerbated skills gaps and lack of preparedness	<i>XR technologies may exacerbate existing skills gaps within organizations and leave workers unprepared for the changing job market, hindering the successful adoption and utilization of the technology and potentially leading to job displacement.</i>
158	Economic category	Increased mental workload and reduced productivity	<i>Using XR technologies in certain tasks can increase mental workload, potentially reducing overall productivity and efficiency, which can indirectly lead to job displacement due to reduced output.</i>
159	Economic category	Reduced efficiency and productivity in industrial settings due to XR technology	<i>This cluster of consequences highlights the negative impacts of extended reality technologies on efficiency and productivity in industrial settings. Issues such as misalignment in head-mounted displays, unfriendly interfaces, device discomfort, and technical glitches</i>

			<i>contribute to performance decrements and hinder the widespread adoption of XR in industrial applications.</i>
160	Economic category	Increased cybersecurity risks and financial losses due to XR technologies	<i>This cluster focuses on the economic risks associated with cybersecurity threats and financial losses stemming from the use of XR technologies. Unauthorized access to user accounts, in-app purchases without consent, and vulnerabilities in CMR systems all lead to monetary and other harms for various stakeholders.</i>
161	Economic category	Reduced consumer trust and engagement due to XR marketing and experiences	<i>This cluster highlights the negative impact of XR technologies on consumer trust and engagement, primarily through manipulative marketing practices and unmet expectations. Concerns about manipulative marketing, erosion of trust, discrepancies between expectations and actual experiences, and negative emotions all contribute to reduced consumer satisfaction and adoption of AR/VR technologies.</i>
162	Economic category	Negative impacts on traditional industries and business models due to XR technologies	<i>This cluster of consequences describes how XR technologies negatively affect established industries and business models. The shift towards virtual experiences, reduced foot traffic in physical stores, and the obsolescence of physical products all contribute to decreased profitability and necessitate adaptation for traditional businesses.</i>
163	Economic category	Exacerbated inequalities and digital divide due to XR technologies	<i>This cluster focuses on the negative consequences of XR technologies that exacerbate existing inequalities and widen the digital divide. Unequal access to technology, resources, and digital literacy skills creates disparities in educational opportunities, economic participation, and access to healthcare and other essential services.</i>
164	Economic category	Health and safety risks associated with XR technologies	<i>This cluster highlights the health and safety risks associated with XR technologies, including cybersickness, visual fatigue, and physical discomfort from devices. These risks can lead to reduced productivity, safety concerns, and increased healthcare costs.</i>
165	Economic category	Legal and regulatory challenges posed by XR technologies	<i>This cluster addresses the legal and regulatory challenges arising from the rapid development of XR technologies. The lack of sufficient legal regulation creates uncertainties in business flow, varied law enforcement policies, unresolved legal issues related to virtual property, and new challenges in regulating economic relationships.</i>
166	Economic category	Limited user acceptance and adoption of XR technologies	<i>This cluster encompasses consequences related to the limited acceptance and adoption of XR technologies. Factors such as unmet expectations, technical glitches, limited quality virtual content, usability issues, and lack of awareness all contribute to hindering the widespread use and benefits of XR technologies.</i>
167	Economic category	Negative impacts on employee well-being and	<i>This cluster focuses on the negative consequences of XR technologies on employee well-being and job</i>

		job satisfaction due to XR technologies	<i>satisfaction. Factors such as reduced autonomy, physical discomfort, visual fatigue, and work-life balance issues contribute to decreased job satisfaction and potential health problems.</i>
167b	Economic category	Organizations may not be aware on the IP rights connected to content created using the Motivate XR solutions in teaching situations.; The remote technician or instructors are not proficient in giving instructions in a way that positively uses the XR.	
167c	Economic category	3D files will be increasingly requested, making it harder to protect designs with secrecy and patents.	
167d	Economic category	Some organizations will not have access to sufficient documentation and therefore be disadvantaged.	
186	Scientific and technological category	Reduced realism and effectiveness of XR-based training	<i>XR-based training, while offering many benefits, may suffer from reduced realism and effectiveness due to technological limitations, leading to inadequate preparation for real-world scenarios and potentially compromising the quality of training and safety. This is particularly relevant in fields like medicine and hazardous chemical settings where accurate simulation is crucial for effective skill development.</i>
187	Scientific and technological category	Reduced real-world hands-on learning experiences	<i>Over-reliance on XR technologies in training may lead to a decrease in real-world hands-on learning experiences, potentially hindering the development of practical skills and the ability to apply knowledge in real-world settings. This is particularly concerning in vocational education and professions requiring significant practical skills.</i>
188	Scientific and technological category	Impeded skill development due to technological limitations	<i>Technological limitations of XR systems, such as unclear feedback, complicated navigation, low immersion, and suboptimal learning experiences, can hinder the learning process and impede skill development. This can manifest in various ways, from inadequate preparation for real-world scenarios to a decrease in practical skills and knowledge retention.</i>
189	Scientific and technological category	Insufficient guidance and support for instructors and trainees	<i>Effective integration of XR technologies in educational and training settings requires sufficient guidance and support for both instructors and trainees. A lack of such support can hinder effective implementation, impacting the quality of instruction and the overall effectiveness of training programs.</i>

190	Scientific and technological category	Reduced emphasis on traditional learning methods	<i>Increased reliance on XR technologies may lead to a reduced emphasis on traditional learning methods and hands-on experiences, potentially affecting the development of certain practical skills and the ability to apply knowledge in real-world settings. This shift may also impact the effectiveness of traditional teaching approaches.</i>
191	Scientific and technological category	Inconsistent learning outcomes and effectiveness	<i>The effectiveness of XR technologies in education and training can vary significantly depending on factors such as technological limitations, learner characteristics, and the quality of instructional design. This inconsistency in learning outcomes and effectiveness can hinder the widespread adoption and full integration of XR technologies in various settings.</i>
192	Scientific and technological category	High development and implementation costs	<i>Developing and implementing XR-based training applications can involve high costs, including hardware, software, content creation, and instructor training. These costs can be a significant barrier to widespread adoption, particularly for smaller organizations or institutions with limited resources.</i>
193	Scientific and technological category	Lack of sufficient training for educators and students	<i>Effective use of XR technologies in education and training requires adequate training for both educators and students. Insufficient training can hinder the effective integration of these technologies and limit their potential benefits for learners.</i>
194	Scientific and technological category	Decreased reliance on hands-on skills and practical experience	<i>The use of XR technologies in training may lead to a decreased reliance on traditional hands-on training methods and practical experience, potentially resulting in a decline in practical skills and problem-solving abilities. This is particularly concerning in fields where hands-on skills are essential for effective performance.</i>
195	Scientific and technological category	Limited transfer of skills from virtual to real-world settings	<i>XR simulations, while effective for training, may not always translate into improved performance in real-world settings. This limited transfer of skills can be due to various factors, including differences in the fidelity of the virtual environment, discrepancies in sensorimotor control, and the lack of real-world environmental factors. This hinders the overall effectiveness of XR-based training.</i>
196	Scientific and technological category	Lack of standardized evaluation methods for XR-based training	<i>The lack of standardized evaluation methods for XR-based training makes it difficult to accurately assess the effectiveness of these technologies in achieving desired learning outcomes. This lack of standardization hinders the development of effective training programs and the ability to compare the effectiveness of different XR-based training approaches.</i>
196b	Scientific and technological category	Not having "real" interactions with remote users in assistance or training (trainers) could reduce the effectiveness	

		as the trainee could feel not really accompanied	
197	Scientific and technological category	Reduced reliability of VR/AR/MR research findings due to technology-specific limitations	<i>This cluster of consequences highlights how inherent limitations of VR/AR/MR technologies, such as the artificial nature of virtual environments, variations in hardware and software, and challenges in data collection and analysis, compromise the reliability and validity of research findings in the scientific and technological domain. The artificiality of the environments may not accurately reflect real-world conditions, leading to issues with generalizability. Technical limitations, such as variations in hardware and software, introduce inconsistencies and affect the reliability of research findings. Challenges in data collection and analysis further compound these issues.</i>
198	Scientific and technological category	Reduced generalizability of VR/AR/MR research findings due to artificiality of environments	<i>The artificial nature of virtual environments in VR/AR/MR studies limits the generalizability of findings to real-world scenarios within the scientific and technological domain. Research conducted in these controlled settings may not accurately reflect real-world behaviours, responses, or conditions, thus hindering the translation of research results into practical applications and limiting the broader impact of the research.</i>
199	Scientific and technological category	Reduced research validity due to lack of standardization and methodological rigor	<i>Inconsistent methodologies, lack of standardization in measurement tools and procedures, and insufficient sample sizes across VR/AR/MR studies in the scientific and technological domain compromise the validity of research findings. The absence of standardized evaluation metrics makes it challenging to compare results across different studies, hindering the ability to draw definitive conclusions and limiting the generalizability of findings.</i>
200	Scientific and technological category	Compromised research validity due to limitations in participant recruitment and experimental setup in remote XR studies	<i>Conducting remote XR experiments presents unique challenges that affect the validity of research findings in the scientific and technological domain. Difficulties in recruiting participants with access to specialized hardware, coordinating simultaneous remote participation, and maintaining experimental control compromise the reliability and generalizability of results obtained from such studies.</i>
201	Scientific and technological category	Reduced research validity due to inconsistent terminology and lack of standardized evaluation metrics	<i>The lack of standardized terminology and evaluation metrics in VR/AR/MR research within the scientific and technological domain hinders the comparability and reproducibility of studies. Inconsistent definitions and measurement tools make it difficult to synthesize findings across different studies, limiting the ability to draw robust conclusions and hindering the advancement of the field.</i>
202	Scientific and technological category	Reduced validity of VR/AR/MR research due to	<i>Several confounding factors and biases can affect the validity of VR/AR/MR research in the scientific and technological domain. These include demand</i>

		confounding factors and biases	<i>characteristics, participant expectations, the novelty effect of the technology, and the artificiality of the virtual environment itself. These factors can influence participant behaviour and responses, leading to inaccurate or misleading results.</i>
203	Scientific and technological category	Reduced research reliability and validity due to insufficient data and small sample sizes	<i>Limited data availability, often resulting from small sample sizes in VR/AR/MR studies, compromises the reliability and validity of research findings in the scientific and technological domain. Insufficient data may lead to inaccurate analysis, limit the generalizability of conclusions, and hinder the ability to draw definitive conclusions about the effectiveness of the technologies being studied.</i>
204	Scientific and technological category	Reduced research reliability and validity due to platform-specific challenges and inconsistencies	<i>The use of different VR/AR/MR platforms and hardware in research studies can introduce inconsistencies and affect the reliability and validity of findings within the scientific and technological domain. Variations in hardware and software capabilities, as well as differences in user experiences across platforms, can lead to discrepancies in results and limit the generalizability of conclusions.</i>
205	Scientific and technological category	Reduced research validity due to lack of real-world validation and generalizability	<i>Many VR/AR/MR studies lack sufficient real-world validation, limiting the generalizability of findings to real-life scenarios within the scientific and technological domain. Results obtained in controlled virtual environments may not accurately predict or reflect real-world performance, behaviours, or outcomes, thus hindering the practical application and impact of the research.</i>
205b	Scientific and technological category		<i>The use of AI to create content makes it harder to ensure the content presented in the XR is indeed correct.; Automatic translation could introduce misunderstandings and inaccuracies.; The users may rely on the XR instructions generated by AI so much they don't consider if the content is correct.</i>
206	Scientific and technological category	Reduced fidelity and realism in XR experiences	<i>This category encompasses consequences stemming from the limitations of current XR technologies, resulting in suboptimal user experiences. These limitations manifest as low-fidelity sensory experiences, technical issues with hardware and software, and difficulties in creating realistic virtual environments, all of which negatively impact the effectiveness and usability of XR applications within the scientific and technological domain.</i>
207	Scientific and technological category	Increased development costs and time	<i>The development and implementation of XR technologies in scientific and technological settings are hindered by high costs and lengthy development times. This includes the cost of hardware and software, the time required for content creation and software development, and the complexity of integrating XR technologies into existing workflows. These factors limit accessibility and widespread adoption.</i>

208	Scientific and technological category	Technical challenges hindering implementation	<i>Several technical challenges impede the effective implementation of XR technologies in scientific and technological domains. These include issues with IT infrastructure, software optimization, technology integration, resource allocation, compatibility problems with existing systems, and the need for improved user interfaces. These limitations affect the usability and widespread adoption of XR solutions.</i>
209	Scientific and technological category	Reduced user comfort and usability	<i>The user experience in XR applications is often negatively impacted by factors that reduce comfort and usability. This includes cybersickness, unintuitive controls, discomfort from wearing headsets, and usability issues with software and hardware. These factors can lead to user frustration, reduced engagement, and hinder the widespread adoption of XR technologies in scientific and technological fields.</i>
210	Scientific and technological category	Limited accessibility and adoption	<i>High costs, complex setups, and usability issues contribute to limited accessibility and adoption of XR technologies. This includes the cost of hardware and software, the need for specialized skills and training, and the lack of user-friendly interfaces. These factors restrict the widespread use of XR in scientific and technological settings, particularly for individuals and organizations with limited resources.</i>
211	Scientific and technological category	Challenges in collaborative XR applications	<i>The development and use of collaborative XR applications face significant challenges. These include difficulties in facilitating interaction between users in shared virtual environments, ensuring seamless collaboration across diverse devices, and addressing issues related to networking, content access control, and application isolation. These limitations hinder the effectiveness and widespread adoption of collaborative XR solutions in scientific and technological contexts.</i>
212	Scientific and technological category	Technical limitations impacting realism and performance	<i>Technical limitations in XR systems can significantly impact the realism and performance of applications. These limitations include issues with rendering, latency, graphic quality, and computational power. These factors can lead to a less immersive experience, reduced user engagement, and hinder the effectiveness of XR applications in scientific and technological settings.</i>
213	Scientific and technological category	Reduced user engagement and satisfaction	<i>Several factors contribute to reduced user engagement and satisfaction with XR technologies. These include technical limitations that affect realism and performance, usability issues that make applications difficult to use, and discomfort or side effects associated with XR hardware. These factors can lead to user frustration, decreased motivation, and ultimately hinder the widespread adoption of XR in scientific and technological applications.</i>
214	Scientific and technological category	Lack of standardization and interoperability	<i>The lack of standardization and interoperability across different XR platforms and devices hinders the seamless integration and widespread adoption of XR technologies.</i>

			<p><i>This includes incompatibility between hardware and software, different data formats, and the absence of common standards for interaction and data exchange. These limitations create barriers to the effective use of XR in scientific and technological settings.</i></p>
214b	Scientific and technological category	The Motivate XR solutions may be designed in such a way that they do not fulfil the technologies' potential to improve the opportunities of impaired people and users with special needs .	
215	Scientific and technological category	Reduced efficiency and productivity in design processes due to software limitations	<p><i>In the context of 'Other negative consequences in the Scientific and technological category', several consequences highlight how software limitations in Extended Reality (XR) technologies reduce efficiency and productivity during design processes. This includes difficulties in data management, data conversion complexities, and challenges in integrating XR tools into existing workflows.</i></p>
216	Scientific and technological category	Increased development time and costs due to technological complexities	<p><i>Within the 'Other negative consequences in the Scientific and technological category', multiple consequences point to the increased time and costs associated with developing XR applications. This stems from the complexity of 3D modelling, scene authoring, software development challenges, data conversion complexities, and the need for specialized skills and software.</i></p>
217	Scientific and technological category	Limited widespread adoption due to high costs and resource constraints	<p><i>A recurring theme within the 'Other negative consequences in the Scientific and technological category' is the limited adoption of XR technologies due to high costs and resource constraints. This affects various stakeholders, including educational institutions, businesses, and researchers, hindering the widespread implementation and potential benefits of XR.</i></p>
217b	Scientific and technological category	Amplify existing disparities in STEM	<p><i>This issue explores the disparities between men and women in fields such as STEM, where female representation remains low. The use of XR technology offers opportunities for gender-switching and immersive experiences that can address gender-based inequalities and diversity challenges. However, it also highlights concerns related to sexual violence, gender differences in leadership roles, and how these dynamics are reinforced or challenged in virtual spaces. XR technologies could serve as tools for promoting gender equality and encouraging more women and female scientists to engage in male-dominated fields, but addressing gender-based violence and bias remains critical to creating truly inclusive digital environments.</i></p>

217c	Scientific and technological category	Integration between the Motivate XR solutions and other systems may violate IP and legal requirements.	
311	Environmental category	Increased energy consumption from XR hardware and infrastructure	<i>This consequence focuses on the environmental impact stemming from the high energy demands of extended reality (XR) technologies, encompassing hardware, software, and supporting infrastructure. The increased energy consumption directly translates to a larger carbon footprint, exacerbating environmental concerns within the context of the environmental domain.</i>
312	Environmental category	Increased energy consumption from metaverse infrastructure	<i>This consequence highlights the substantial energy consumption associated with the infrastructure supporting the metaverse, including data centers, networks, and blockchain technologies. The energy intensity of these components contributes significantly to the overall carbon footprint, posing a challenge to environmental sustainability.</i>
313	Environmental category	Increased energy consumption from cloud-based XR services	<i>This consequence focuses on the environmental impact of cloud computing resources used to support XR applications. The energy consumption associated with data storage, processing, and network communication contributes to a larger carbon footprint, raising concerns about the sustainability of cloud-based XR services.</i>
314	Environmental category	Increased electronic waste from XR device production and disposal	<i>The manufacturing and disposal of extended reality (XR) devices, including head-worn displays and related equipment, generate significant electronic waste, negatively impacting the environment and communities. This is exacerbated by rapid technological advancements leading to shorter product lifecycles and a high rate of device obsolescence.</i>
315	Environmental category	Increased environmental impact from XR device materials	<i>The materials used in XR displays, such as high-refractive index materials, may have significant environmental impacts during manufacturing and disposal, adding to the overall electronic waste problem. The environmental consequences of sourcing, processing, and recycling these materials need to be considered.</i>
316	Environmental category	Reduced appreciation for real-world natural environments	<i>The immersive nature of virtual environments, especially those simulating natural settings, may lead to decreased engagement with and appreciation for real-world natural environments. This reduced appreciation can negatively impact conservation efforts and environmental stewardship within the Environmental domain.</i>
317	Environmental category	Increased pressure on sustainable tourism practices	<i>The integration of extended reality technologies in tourism, while offering potential benefits, can inadvertently increase pressure on tourism organizations to create enhanced experiences. If not managed responsibly, this can lead to unsustainable practices that negatively impact the environment and local communities.</i>

319	Environmental category	Sustainability challenges in AR implementation in tourism	<i>Augmented reality technologies in tourism may cause sustainability issues if the local community isn't involved. This can disrupt cultural practices and traditions, harming the cultural heritage and potentially leading to unsustainable tourism practices.</i>
322	Environmental category	Amplified consumerism and climate change due to cognitive capitalism	<i>Cognitive capitalism, stimulated by big data and targeted algorithms, may indirectly amplify climate change through increased consumerism and empowered logistics, thus impacting the environment. This is framed in the context of Indirect Environmental Impacts of Societal Shifts in the Environmental domain.</i>
323	Environmental category	Reduced consideration for environmental impact in design due to focus on immersive experience	<i>The immersive nature of extended reality technologies, particularly in applications like building design, can shift priorities towards aspects like visual appeal and user experience, potentially overshadowing crucial sustainability considerations and leading to environmentally unfriendly design choices.</i>
324	Environmental category	Reduced Climate Change Mitigation Efforts Despite Immersive Content Dissemination	<i>The widespread dissemination of immersive content through extended reality technologies has not resulted in significant improvements in climate change mitigation efforts across various sectors, including environmental, news, and political organizations.</i>
325	Environmental category	Increased environmental damage due to metaverse development	<i>The development and use of metaverse technologies in the environmental domain can lead to increased energy consumption and resource depletion, exacerbating existing environmental problems and negatively impacting the planet and future generations. This includes the indirect consequences of increased carbon emissions and other pollutants associated with the manufacturing and operation of metaverse hardware and infrastructure.</i>
326	Environmental category	Reduced environmental awareness due to over-reliance on AR technology	<i>Over-reliance on AR technology in environmental contexts can lead to a diminished understanding of the natural world, hindering the development of essential environmental awareness and potentially impacting navigation skills when technology is unavailable.</i>
327	Environmental category	Increased CO2 Emissions from XR System Operation	<i>This consequence focuses on the direct and indirect contribution of extended reality (XR) systems to increased carbon emissions, encompassing the energy consumption of hardware and the computational demands of AI techniques used within these systems, thereby negatively impacting the environment.</i>
328	Environmental category	Increased Risks to People and the Environment due to Augmented Reality	<i>Augmented reality in environmental settings may lead to decreased user reaction time and increased cognitive load, resulting in heightened risks for both people and the environment. This is a concern within the broader context of other negative consequences in the environmental category, where XR technologies are used for training and assistance.</i>

364	Infrastructure category	Increased network bandwidth demand for XR applications	<i>The use of extended reality (XR) technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), in infrastructure settings leads to a significant increase in network bandwidth demand. This is due to the high data volume associated with streaming high-resolution video, supporting real-time interactions, and handling complex data processing for immersive experiences. The increased demand strains existing network infrastructure, necessitating investments in upgrades and potentially leading to higher infrastructure costs for organizations and network providers.</i>
365	Infrastructure category	Increased infrastructure costs for XR hardware and setup	<i>Implementing XR technologies in infrastructure projects requires significant investments in advanced hardware, including high-performance computers, specialized sensors, and interaction devices. The planning, configuration, and maintenance of this hardware add to the overall infrastructure costs. Furthermore, the need for dedicated installation spaces and technical expertise increases the financial burden for organizations adopting XR solutions.</i>
366	Infrastructure category	Increased network strain from high user numbers in XR applications	<i>The simultaneous use of XR applications by multiple users, particularly in scenarios with high user density (e.g., commuting), can lead to increased traffic demands on existing network infrastructure, such as microwave technologies. This increased strain can degrade service quality and necessitate upgrades to handle the higher user numbers, resulting in increased infrastructure costs.</i>
368	Infrastructure category	Increased infrastructure costs and limited accessibility in education and healthcare	<i>The implementation of XR technologies in education and healthcare settings often faces challenges related to infrastructure limitations, including network connectivity and physical space management. These limitations, coupled with the need for substantial investments in hardware, software, and training, can lead to increased costs and potentially limit accessibility for students and patients, particularly in underserved areas.</i>
369	Infrastructure category	Infrastructure limitations hindering XR adoption in education	<i>The widespread adoption of XR technologies in educational settings is often hindered by infrastructural and resource constraints. These limitations include insufficient IT infrastructure, suboptimal VR software, and a lack of research on resource allocation and technology integration. Addressing these issues requires significant investments in infrastructure upgrades and further research, impacting the overall costs and accessibility of XR in education.</i>
370	Infrastructure category	Network latency and bandwidth limitations impacting XR performance	<i>Network latency and bandwidth limitations can significantly impact the real-time performance and responsiveness of XR applications, particularly collaborative applications. These limitations can hinder user experience, limit the effectiveness of training and remote assistance, and necessitate investments in</i>

			<i>network upgrades to ensure high-quality immersive experiences.</i>
371	Infrastructure category	Data connection issues hindering XR collaboration	<i>Unreliable data connections can severely impact the effectiveness of XR applications, especially those involving remote collaboration. Interruptions and delays in data transmission can hinder seamless interaction, shared understanding, and the overall success of collaborative projects, leading to potential cost overruns and project delays.</i>
372	Infrastructure category	Network demands of multi-user XR applications	<i>Multi-user XR applications, particularly those involving mixed reality (MR), place significant demands on underlying networks. The need to deliver high-quality immersive material in real time to multiple users simultaneously can strain network infrastructure, potentially leading to performance degradation and increased infrastructure costs.</i>
373	Infrastructure category	Lack of affordable and accessible XR infrastructure hindering e-participation	<i>The lack of affordable and accessible infrastructure for XR technologies can hinder the widespread adoption and accessibility of immersive VR for e-participation. This limitation creates a barrier to entry for many potential users and researchers, impacting the overall effectiveness and reach of XR-based e-participation initiatives.</i>
376	Infrastructure category	Network impairments hindering collaborative AR applications	<i>Network impairments, such as poor connectivity or high latency, can negatively impact the user experience and hinder the success of collaborative augmented reality (AR) applications, especially in remote settings. These impairments can lead to disruptions in collaboration and require investments in robust network infrastructure to ensure reliable performance.</i>
379	Infrastructure category	Increased data consumption and costs from AR/MR/VR applications	<i>Augmented reality (AR), mixed reality (MR), and virtual reality (VR) applications can significantly increase data consumption, putting a strain on network infrastructure and leading to higher costs for both users and network providers. This increased data consumption necessitates investments in network upgrades to handle the higher data volume.</i>
380	Infrastructure category	Network limitations impacting VR website access	<i>Network bandwidth and page rendering effects can limit user experience when accessing virtual reality websites. Even small delays can significantly impact user experience, highlighting the need for robust network infrastructure to support seamless access to VR content.</i>
382	Infrastructure category	Increased data processing demands from Metaverse development	<i>The development and use of the Metaverse will cause a tremendous increase in data, putting immense pressure on the digital world's data processing capabilities. This increase in data volume necessitates significant investments in big data network infrastructure to handle the increased processing demands.</i>

389	Infrastructure category	Reduced access to XR services due to insufficient infrastructure	<i>Inadequate communication infrastructure, particularly in rural areas, limits the accessibility and effectiveness of XR technologies across various sectors, including healthcare, education, and industrial applications. This results in unequal access to services and hinders the potential benefits of XR.</i>
390	Infrastructure category	Increased reliance on unstable network infrastructure	<i>The extensive use of XR technologies increases dependence on stable wireless networks. Unreliable or unstable networks disrupt operations, impacting worker mobility, service delivery, and overall productivity in various industrial and professional settings.</i>
391	Infrastructure category	Challenges in managing and regulating XR infrastructure	<i>The integration of XR technologies introduces complexities in managing and regulating infrastructure, particularly concerning network management, resource allocation, and the governance of virtual environments. This includes challenges in ensuring the quality, accessibility, and security of XR services.</i>
392	Infrastructure category	Limited XR applicability due to infrastructure requirements	<i>The implementation of XR technologies may be restricted by specific infrastructure needs, such as fiducial markers, sensor requirements, and the need for efficient data migration between systems. These limitations can hinder the widespread adoption and applicability of XR across various domains.</i>
393	Infrastructure category	Challenges in integrating XR with existing systems	<i>Integrating XR technologies with existing systems can present challenges, potentially leading to vendor lock-in, interoperability issues, and difficulties in adapting to evolving infrastructure needs. This can hinder flexibility and limit the seamless integration of XR solutions within existing workflows.</i>
394	Infrastructure category	Reliability issues with geo-location systems	<i>Over-reliance on global geo-location systems for infrastructure and utility management can lead to reliability issues. This necessitates the development or integration of local systems to enhance the accuracy and dependability of data for effective infrastructure management.</i>
394b	Infrastructure category	Unclear how maintenance of the XR equipment will affect responsibilities.	
395c	Infrastructure category	Using the XR platform improper applications [i.e. porn]	
395	Infrastructure category	Reduced operational efficiency due to integration challenges of XR technologies	<i>In the Infrastructure domain, integrating XR technologies into existing workflows can cause disruptions and inefficiencies. This includes rethinking design activities, restructuring processes, and overcoming challenges in transferring AR apps into practical settings. The integration may also require significant changes in established workflows, potentially causing disruption to existing practices and hindering seamless innovation diffusion.</i>

396	Infrastructure category	Reduced XR effectiveness for simple tasks	<i>In certain Infrastructure settings, XR technologies like AR may not be the most efficient solution for simpler tasks. Paper-based instructions or tangible interfaces can be more effective, limiting the widespread applicability of XR in these scenarios.</i>
397	Infrastructure category	Impeded operational efficiency due to insufficient infrastructure and skills	<i>The lack of robust technical infrastructure and skilled personnel hinders the effective implementation and utilization of XR technologies in Infrastructure projects. This includes insufficient infrastructure for VR laboratories, the digital divide, and lack of skills among educators and users.</i>
398	Infrastructure category	Increased system complexity and maintenance challenges with XR technologies	<i>Implementing XR technologies in Infrastructure can lead to increased reliance on specialized systems and interfaces, creating new challenges in system maintenance and user training. This increased complexity may require substantial investment and highly qualified IT staff, impacting operational efficiency.</i>
399	Infrastructure category	Reduced operational efficiency due to environmental limitations of XR technologies	<i>XR technologies can be susceptible to environmental factors, such as bright sunlight and dirty conditions, impacting their functionality and accuracy. This can lead to errors and reduced efficiency in Infrastructure projects.</i>
401	Infrastructure category	Reduced operational efficiency due to limitations in XR immersion	<i>Limitations in XR immersion, such as the lack of realistic sensory input (smell, air, noise), and restricted movement for remote participants can hinder effective collaboration and data transmission in Infrastructure projects, reducing operational efficiency.</i>
402	Infrastructure category	Reduced operational efficiency due to space constraints in VR therapy	<i>The implementation of VR therapy can be significantly hindered by a lack of sufficient, private space to administer the therapy effectively, impacting accessibility and widespread adoption and thus operational efficiency.</i>
403	Infrastructure category	Reduced operational efficiency due to technical, organizational, and ergonomic challenges of AR	<i>Augmented reality applications may present technical, organizational, and ergonomic challenges that need to be addressed for successful implementation and widespread adoption in Infrastructure settings. These challenges can hinder productivity and operational efficiency.</i>
405	Infrastructure category	Reduced operational efficiency due to increased cognitive load in mixed reality	<i>Poorly designed mixed reality systems may increase cognitive load and negatively impact decision-making and operational performance for system operators, potentially leading to errors and reduced efficiency.</i>
409	Infrastructure category	Reduced accuracy of information in XR systems	<i>In the Infrastructure domain, inaccurate information provided by XR systems, whether due to technical limitations, environmental factors, or malicious interference, compromises safety and reliability by leading to misinterpretations, errors in decision-making, and potentially hazardous situations. This impacts various stakeholders, including professionals, managers, and end-users.</i>

410	Infrastructure category	Increased risk of errors due to augmented scene complexity	<i>The addition of augmented reality overlays can increase the complexity and clutter of a scene, reducing situational awareness and increasing the risk of errors for users in safety-critical environments such as air traffic control. This compromises safety and reliability by increasing the likelihood of accidents or incidents.</i>
411	Infrastructure category	Reduced situational awareness and increased risk of errors in XR systems	<i>Over-reliance on XR systems can lead to complacency and reduced situational awareness, negatively impacting performance and decision-making in safety-critical tasks. This compromises safety and reliability by increasing the likelihood of human error and accidents.</i>
412	Infrastructure category	Compromised safety due to blurred physical-virtual boundaries	<i>Augmented reality overlays can blur the lines between the physical and virtual worlds, potentially leading to disorientation, distraction, and reduced safety, particularly in transportation settings. This compromises safety and reliability by increasing the risk of accidents.</i>
413	Infrastructure category	Reduced understanding of traditional safety measures	<i>Over-reliance on XR systems for safety-critical tasks can reduce the understanding and application of traditional safety measures, creating vulnerabilities if the XR system fails. This compromises safety and reliability by increasing the risk of accidents or incidents.</i>
415	Infrastructure category	Inaccurate assessment of physical space in XR environments	<i>XR systems may not accurately represent physical space, leading to inaccurate assessments and potentially flawed design decisions in infrastructure projects. This compromises safety and reliability by increasing the risk of errors and inefficiencies.</i>
416	Infrastructure category	Safety concerns due to lack of standardization in AR interfaces	<i>A lack of standardization and the use of unfamiliar languages or symbols in AR interfaces can cause confusion and potentially dangerous consequences, compromising safety and reliability, particularly for pedestrians.</i>
417	Infrastructure category	Safety challenges in constrained environments	<i>The adoption of AR in constrained environments, such as aviation, presents unforeseen challenges in ensuring safety and reliability due to the complexity of validating the technology under such conditions. This compromises safety and reliability by increasing the risk of operational failures.</i>
420	Infrastructure category	Environmental challenges impacting AR functionality	<i>Augmented reality systems can be susceptible to environmental challenges, such as bright sunlight and dirty conditions, which can impact their functionality and accuracy, potentially leading to errors in construction. This compromises safety and reliability by increasing the risk of errors and accidents.</i>
420b	Infrastructure category	Tampering with experience	
425	Infrastructure category	Increased Cybersecurity Risks in Extended Reality Applications	<i>The integration of extended reality (XR) technologies in infrastructure introduces various cybersecurity risks and data vulnerabilities. These risks stem from the reliance on third-party platforms, the nature of data exchange in virtual environments, and the potential for new attack</i>

			vectors specific to XR systems. This includes vulnerabilities to DDoS attacks, man-in-the-middle attacks, data tampering, data loss due to incompatibility, and various authentication issues.
426	Infrastructure category	Data Security Vulnerabilities in XR-based Infrastructure	The use of XR in infrastructure creates new challenges for data security. This includes concerns about data tampering, data loss due to incompatibility between systems, and the exposure of sensitive information through vulnerabilities in third-party libraries and cloud platforms used to support XR applications. The lack of robust security measures in XR systems can lead to significant data breaches and operational disruptions.
427	Infrastructure category	Vulnerabilities to Distributed Denial-of-Service (DDoS) Attacks in XR Systems	The increasing reliance on XR technologies in infrastructure creates new vulnerabilities to DDoS attacks. These attacks can disrupt communication and connectivity, impacting real-time assistance, training, and overall operations. The interconnected nature of XR systems and their dependence on network infrastructure make them particularly susceptible to such attacks.
428	Infrastructure category	Authentication Security Issues in Metaverse Environments	The centralized nature of authentication and identity management in metaverse environments creates various security vulnerabilities. These include impersonation, identity interoperability issues, replay attacks, and server spoofing. The use of inadequate authentication schemes, such as crude 2D methods in XR applications, further exacerbates these risks.
428b	Infrastructure category	The increased digital use of sensitive documentation and data caused by the XR solutions increases the risk of cyber theft	
428c	Infrastructure category	Since the information is available on an XR device, some users may forget that sensitive documentation should not be taken out of company premises, thereby compromising data security.	
428d	Infrastructure category	Non Secure communications may result in information leak	
430	Infrastructure category	Reduced access to XR educational resources due to infrastructure limitations	This cluster of negative consequences highlights the challenges in implementing XR technologies in educational settings due to insufficient infrastructure, impacting access to educational resources and widening the existing educational gap. This is particularly relevant in the context of Other negative consequences in the Infrastructure category, where infrastructural limitations directly hinder the effective integration and

			<i>accessibility of XR technologies in the Infrastructure domain.</i>
431	Infrastructure category	Increased challenges in implementing XR in large-scale urban projects	<i>This category encompasses the difficulties encountered when integrating XR technologies into extensive, long-term urban projects. The procurement, development, maintenance, and utilization of XR in such projects present unique obstacles within the broader context of Other negative consequences in the Infrastructure category, specifically impacting the Infrastructure domain.</i>
432	Infrastructure category	Limited physical interaction in remote XR collaboration	<i>The immersive nature of XR in remote collaboration, while beneficial, can limit direct interaction with physical objects in remote spaces. This is a key concern within the 'Other negative consequences in the Infrastructure category' cluster, affecting the Infrastructure domain by impacting the effectiveness of remote work and collaboration.</i>
437	Infrastructure category	Challenges in managing concurrent access to shared virtual objects	<i>Managing concurrent access to shared virtual objects in collaborative workspaces can lead to conflicts and inconsistencies if not properly addressed. This is a key concern within the 'Other negative consequences in the Infrastructure category' cluster, impacting the Infrastructure domain's ability to support seamless collaboration.</i>
438	Infrastructure category	Challenges related to interaction, space, and navigation in public transportation VR	<i>The widespread adoption of VR in public transportation systems may lead to new challenges related to interaction, space, and navigation. This is categorized under 'Other negative consequences in the Infrastructure category' due to its impact on the Infrastructure domain's ability to support VR in public transportation.</i>
443	Infrastructure category	Addressing challenges related to infrastructure, privacy, security, and ethics in XR	<i>This consequence highlights the need to address challenges related to infrastructure, privacy, security, and ethics in XR implementations. These challenges are categorized under 'Other negative consequences in the Infrastructure category' because they directly impact the Infrastructure domain's ability to support XR technologies responsibly.</i>
444	Infrastructure category	Infrastructural limitations for billing VR services	<i>The healthcare system needs to adapt its billing infrastructure to support virtual reality as a consult service or therapy. This is categorized under 'Other negative consequences in the Infrastructure category' because it directly relates to the infrastructure needed to support VR applications in the Infrastructure domain.</i>
444b	Infrastructure category	Software updates outside the control of the XR tool providers may make XR tech unstable or unresponsive after initial deployment.	

445c	Infrastructure category	Monopolization of the technology can block the access to the tool	
539	Political, legal and regulatory category	Challenged existing legal frameworks governing virtual property	<i>The rapid development of virtual worlds and the integration of real-world currency transactions within these environments have created a complex legal landscape. Existing legal frameworks are struggling to address issues related to virtual property ownership, trade, and the use of real-world currency in virtual economies. This has led to unresolved legal issues and a need for new regulations to govern these emerging digital markets.</i>
540	Political, legal and regulatory category	Created new legal challenges in virtual environments	<i>The increasing use of virtual and augmented reality technologies has created a need for new legal frameworks to address disputes and crimes that occur within these environments. Existing laws are often inadequate to deal with the unique challenges posed by virtual worlds, such as virtual property rights, online harassment, and the jurisdictional complexities of cyberspace. This necessitates the development of new legal doctrines and enforcement mechanisms.</i>
541	Political, legal and regulatory category	Raised concerns about data privacy and security in XR systems	<i>The collection and use of personal data in extended reality systems raise significant concerns about data privacy and security. The immersive nature of XR technologies often involves the collection of sensitive biometric and behavioural data, which can be vulnerable to breaches and misuse. This necessitates the development of robust data protection measures and legal frameworks to ensure user privacy and security.</i>
542	Political, legal and regulatory category	Created liability concerns related to XR technology	<i>The use of extended reality technologies in various settings, particularly in industrial and healthcare contexts, raises significant liability concerns. Accidents, injuries, or errors caused by malfunctioning XR systems or inaccurate AI-driven assistance can lead to legal disputes and financial liabilities for developers, deployers, and users. This highlights the need for robust safety standards, liability frameworks, and insurance mechanisms to mitigate these risks.</i>
543	Political, legal and regulatory category	Increased data collection and privacy violations in XR systems	<i>The use of extended reality (XR) technologies, including augmented reality (AR) and virtual reality (VR), leads to increased data collection, raising significant concerns about user privacy and potential misuse of personal information. This includes the collection of biometric data, location data, and other sensitive information, often without explicit user consent or awareness. The lack of clear regulations and robust data protection measures exacerbates these concerns, particularly in the context of workplace surveillance and public spaces.</i>
544	Political, legal and regulatory category	Enhanced workplace surveillance and privacy violations through XR	<i>The integration of XR technologies into workplaces introduces new avenues for worker surveillance and raises serious privacy concerns. Constant monitoring of worker activities, data collection without consent, and</i>

			<i>the blurring of boundaries between work and personal life are key issues. This can lead to decreased employee trust, potential legal challenges, and a chilling effect on worker autonomy.</i>
545	Political, legal and regulatory category	Privacy risks from data collection in XR learning environments	<i>The use of XR in educational settings raises concerns about the collection and use of student and teacher data. This includes the potential for tracking student behaviour, collecting sensitive personal information, and the lack of clear guidelines on data protection. These concerns highlight the need for robust privacy policies and regulations to safeguard sensitive information in educational contexts.</i>
546	Political, legal and regulatory category	Privacy violations and data misuse in XR applications	<i>XR applications, across various sectors, present significant privacy risks due to the potential for data collection and misuse. This includes the collection of sensitive personal data, such as biometric information and location data, which can be used for surveillance, targeted advertising, or other purposes without user consent. The lack of clear regulations and ethical guidelines exacerbates these concerns.</i>
547	Political, legal and regulatory category	Lack of data protection and security in XR systems	<i>Insufficient investigation, implementation, and evaluation of data protection approaches in XR systems create significant privacy and security vulnerabilities. This includes the potential for unauthorized data breaches, exposure of sensitive user data, and compromise of data confidentiality. The lack of robust security measures and ethical guidelines increases the risk of data misuse and privacy violations.</i>
548	Political, legal and regulatory category	Surveillance and privacy concerns	<i>The Metaverse, with its immersive and interactive nature, presents unique challenges to user privacy and security. The collection of vast amounts of user data, including biometric data and behavioural patterns, raises concerns about potential surveillance and misuse of information. The lack of clear regulations and robust security measures increases the vulnerability of users to privacy violations and data breaches.</i>
549	Political, legal and regulatory category	Privacy risks associated with data collection and usage in XR	<i>The collection and use of personal data in XR applications raise significant privacy concerns. This includes the potential for data breaches, unauthorized surveillance, and the misuse of sensitive information. The lack of transparency and user control over data collection and usage exacerbates these concerns, particularly in the context of data minimization and informed consent.</i>
550	Political, legal and regulatory category	Data privacy and security concerns in XR-enabled remote work	<i>The adoption of XR technologies for remote work raises concerns about data privacy and security. This includes the potential for unauthorized access to sensitive information, data breaches, and the lack of robust security measures to protect employee confidentiality. The need for clear regulations and ethical guidelines is crucial to mitigate these risks.</i>

551	Political, legal and regulatory category	Legal and ethical concerns related to data privacy in XR	<i>The use of XR technologies raises a plethora of legal and ethical concerns related to data privacy. This includes the potential for violating user privacy expectations, the misuse of personal data by companies and governments, and the lack of clear legal frameworks to address these issues. The need for robust regulations and ethical guidelines is crucial to ensure responsible development and deployment of XR technologies.</i>
552	Political, legal and regulatory category	Privacy risks from pervasive surveillance in public spaces using XR	<i>The use of XR technologies in public spaces raises concerns about pervasive surveillance and the potential for privacy violations. This includes the tracking and monitoring of individuals through unique identifiers, the collection of vast amounts of information about the physical world, and the potential for misuse of this data. The lack of clear regulations and ethical guidelines exacerbates these concerns.</i>
553	Political, legal and regulatory category	Data privacy and security risks in healthcare using XR	<i>The integration of XR technologies into healthcare settings raises concerns about data privacy and security. This includes the potential for data breaches, unauthorized access to sensitive patient information, and the lack of robust security measures to protect confidentiality. The need for clear regulations and ethical guidelines is crucial to mitigate these risks.</i>
554	Political, legal and regulatory category	Reduced user privacy and autonomy in XR systems	<i>The use of XR technologies can lead to a reduction in user privacy and autonomy. This includes the potential for increased surveillance, the collection of sensitive personal data without consent, and the lack of control over how this data is used. These concerns highlight the need for robust data protection measures and ethical guidelines to ensure user privacy and autonomy.</i>
555	Political, legal and regulatory category	Ethical risks and threats to privacy from bulk data collection in VR	<i>Bulk data collection in virtual reality (VR) systems poses significant ethical risks and threats to user privacy. The collection of vast amounts of sensitive user information, without adequate safeguards or user consent, raises concerns about potential misuse and surveillance. This highlights the need for robust ethical guidelines and data protection measures to mitigate these risks.</i>
556	Political, legal and regulatory category	Security risks and privacy breaches in XR systems	<i>XR systems are vulnerable to various security risks and privacy breaches, including hacking, unauthorized access, and data breaches. These vulnerabilities can expose sensitive user data and compromise the confidentiality of information. The need for robust security measures and ethical guidelines is crucial to mitigate these risks.</i>
557	Political, legal and regulatory category	Reduced public trust in political processes due to manipulation and bias in XR technologies	<i>The use of XR technologies introduces various risks that can undermine public trust in political processes. These risks include the potential for bias and prejudice in algorithms and content, manipulation of information and images, and the erosion of trust in media and social interactions. This ultimately affects the fairness of legal proceedings, the balance of power, and the ability of citizens to make informed decisions.</i>

558	Political, legal and regulatory category	Undermined democratic governance through corporate and military control of virtual spaces	<i>The commercialization and militarization of virtual worlds, particularly educational spaces, pose a significant threat to democratic governance. Corporate and military interests controlling these spaces can lead to compromised social and educational purposes, potentially shaping individual lives and influencing global power dynamics.</i>
559	Political, legal and regulatory category	Erosion of privacy, security, and independence through XR technologies	<i>The extensive data collection and potential for manipulation inherent in XR technologies pose a significant threat to individual privacy, security, and independence. This can lead to widespread surveillance, control, and exploitation, undermining democratic processes and eroding public trust.</i>
560	Political, legal and regulatory category	Facilitated undermining of state power through virtual communities	<i>The emergence of virtual communities presents a challenge to state power. These communities can facilitate the association of individuals aiming to seize power, implicitly undermining state authority and potentially destabilizing political systems.</i>
561	Political, legal and regulatory category	Reduced democratic participation and engagement due to XR technology limitations	<i>High costs and accessibility barriers associated with XR technologies can hinder citizen participation in democratic processes, particularly in urban planning and governance. This can create a knowledge gap between experts and the public, undermining informed decision-making and eroding public trust.</i>
562	Political, legal and regulatory category	Increased vulnerability to political control and manipulation through XR technologies	<i>The pervasive nature of XR technologies, coupled with their potential for manipulation and control, increases societal vulnerability to political domination. This includes the potential for authoritarian socialization, manipulative influence, and the suppression of dissenting voices, thereby undermining democratic principles.</i>
563	Political, legal and regulatory category	Reduced trust in information and media due to deepfakes and manipulation in XR	<i>The convergence of XR technologies with deepfake capabilities poses a significant threat to public trust in information and visual media. The ability to create realistic but false content can lead to widespread misinformation, impacting individuals' ability to discern truth from falsehood and undermining social and political discourse.</i>
564	Political, legal and regulatory category	Weakened democratic processes through manipulation and control in the Metaverse	<i>The Metaverse presents unique challenges to democratic governance. The potential for manipulation, control, and exploitation within these virtual environments necessitates robust regulations to safeguard individuals and communities. Decentralization could lead to governance by powerful corporations, undermining democratic principles and public trust.</i>
565	Political, legal and regulatory category	Undermined humanitarian communication and colonial legacies through VR	<i>The use of VR in humanitarian communication can inadvertently reinforce colonial legacies and obfuscate power imbalances. A depoliticized hyperreality can trap audiences, hindering effective communication and undermining efforts to address complex political issues.</i>

566	Political, legal and regulatory category	Reduced public trust due to lack of transparency and control in XR governance	<i>Lack of transparency and control in the governance of virtual environments, including the Metaverse, can lead to a decline in public trust. Over-policing and sanitized virtual spaces, coupled with the potential for powerful entities to control these environments, can undermine democratic principles and erode public confidence.</i>
567	Political, legal and regulatory category	Eroded public trust in public services due to data privacy and security concerns in AR	<i>Augmented reality applications in public services raise concerns about data privacy and security. If not implemented with robust measures, these concerns can lead to a decline in public trust in government and public services.</i>
568	Political, legal and regulatory category	Challenged government narratives and fostered alternative perspectives through XR	<i>XR technologies can facilitate the creation and dissemination of critical stories about governments, potentially challenging official narratives and fostering alternative perspectives. This can impact international relations and government control over information.</i>
569	Political, legal and regulatory category	Increased Cybersecurity Risks in XR Systems	<i>The integration of extended reality (XR) technologies in various sectors introduces new vulnerabilities and threats to cybersecurity, potentially leading to data breaches, unauthorized access, and other malicious activities. This is particularly relevant in the political, legal, and regulatory domain, where sensitive information and critical infrastructure are involved. The consequences include the exploitation of XR systems by malicious actors for various purposes, including espionage, sabotage, and disruption of services.</i>
570	Political, legal and regulatory category	Heightened Privacy Concerns in XR Applications	<i>The immersive nature of XR technologies raises significant privacy concerns, particularly regarding the collection, storage, and use of sensitive user data. In the political, legal, and regulatory context, this includes the potential for misuse of biometric data, location tracking, and other personal information. The lack of clear regulations and ethical guidelines exacerbates these concerns, potentially leading to legal challenges and reputational damage.</i>
571	Political, legal and regulatory category	Regulatory and Legal Hurdles in XR Adoption	<i>The rapid advancement of XR technologies has outpaced the development of adequate legal and regulatory frameworks, creating uncertainty and challenges for businesses, researchers, and policymakers. In the political, legal, and regulatory domain, this includes difficulties in establishing clear standards for data privacy, cybersecurity, intellectual property, and liability. The lack of clear guidelines can hinder innovation and limit the widespread adoption of XR technologies.</i>
572	Political, legal and regulatory category	Ethical Dilemmas Posed by XR Technologies	<i>The use of XR technologies raises a number of ethical dilemmas, particularly concerning the potential for misuse, bias, and unintended consequences. In the political, legal, and regulatory domain, this includes issues related to data privacy, algorithmic transparency, and accountability for harmful outcomes. Addressing these ethical concerns is crucial for ensuring the</i>

			<i>responsible development and deployment of XR technologies.</i>
573	Political, legal and regulatory category	Challenges in Military Applications of XR	<i>The application of XR technologies in military settings presents unique challenges related to usability, reliability, and security. In the political, legal, and regulatory domain, this includes concerns about the potential for errors in AI-driven systems, the impact on human decision-making, and the ethical implications of using XR for training and combat simulations. Addressing these challenges is crucial for ensuring the safe and effective use of XR in military operations.</i>
574	Political, legal and regulatory category	Socioeconomic Impacts of Metaverse Expansion	<i>The rapid growth of the metaverse raises significant socioeconomic concerns, including the potential for exacerbating existing inequalities and creating new forms of social stratification. In the political, legal, and regulatory domain, this includes issues related to digital divides, access to technology, and the impact on employment and labour markets. Addressing these concerns is crucial for ensuring that the metaverse benefits all members of society.</i>
574b	Political, legal and regulatory category	New certifications on xr-based industrial operations; Virtual training methodology need certified trainers and certified organization; Virtual training efficiency - Are classical evaluation methods still relevant for virtually trained technicians	
597	Other category	Reduced user satisfaction due to unreliable application performance	<i>This category encompasses negative user experiences stemming from inconsistencies and unreliability in XR applications, particularly concerning the External Authoring Interface (EAI) and its compatibility across different software environments. In the context of impeded user experience and usability, these issues directly hinder effective training, remote assistance, and operational guidance, leading to frustration and decreased user satisfaction.</i>
598	Other category	Impeded user experience due to poor haptic feedback	<i>This cluster focuses on the negative impact of inadequate haptic feedback in XR systems on user experience and usability. In the context of impeded user experience and usability, inaccurate or insufficient haptic feedback directly affects the user's ability to interact effectively with virtual objects, hindering training and remote assistance.</i>
599	Other category	Reduced presence and immersion hindering user experience	<i>This category highlights how factors like poor presence, limited interaction with virtual objects, and distractions from interfaces negatively affect the user's sense of immersion and overall experience within XR environments. Within the context of impeded user</i>

			<i>experience and usability, this diminished sense of presence directly impacts the effectiveness of training, remote collaboration, and operational guidance.</i>
600	Other category	Decreased usability due to irrelevant features and information overload	<i>This category groups consequences related to users being distracted by irrelevant features or overwhelmed by excessive information within XR applications. In the context of impeded user experience and usability, this leads to inefficient task completion, reduced learning effectiveness, and overall frustration.</i>
601	Other category	Reduced usability due to technical limitations and device constraints	<i>This category encompasses usability issues arising from technical limitations of XR devices and their impact on user interaction. In the context of impeded user experience and usability, these limitations directly affect the user's ability to perform tasks effectively, leading to frustration and reduced efficiency.</i>
602	Other category	Increased user errors and reduced trust in technology	<i>This category focuses on the negative impact of XR technology on user error rates and subsequent diminished trust in the technology itself. In the context of impeded user experience and usability, higher error rates and reduced trust directly hinder the adoption and effective use of XR systems for training, remote assistance, and operational guidance.</i>
603	Other category	Impeded user experience due to interaction challenges in virtual environments	<i>This category encompasses usability issues related to the challenges users face when interacting with virtual environments, including navigation, manipulation of virtual objects, and collaboration. In the context of impeded user experience and usability, these challenges directly hinder the effectiveness of training, remote assistance, and operational guidance.</i>
604	Other category	Reduced usability due to physical limitations and environmental factors	<i>This category groups consequences related to physical limitations of XR devices and environmental factors affecting usability. In the context of impeded user experience and usability, these factors directly impact the user's ability to effectively use XR systems, leading to discomfort, reduced efficiency, and limited adoption.</i>
605	Other category	Reduced user engagement and adoption due to usability challenges	<i>This category encompasses consequences related to usability challenges that hinder user engagement and adoption of XR technologies. In the context of impeded user experience and usability, these challenges directly affect the overall success and impact of XR systems.</i>
606	Other category	Negative impact of authentication methods on user experience	<i>This category focuses on how authentication methods, such as PINs and passwords, can detract from the immersive experience and overall usability of XR systems. In the context of impeded user experience and usability, these methods directly disrupt the flow and enjoyment of XR applications.</i>
607	Other category	Reduced efficiency and workflow due to changes in task completion time	<i>This category highlights how XR systems can alter task completion times in virtual environments, potentially impacting overall efficiency and workflow. In the context of impeded user experience and usability, these changes directly affect the productivity and</i>

			<i>effectiveness of XR-based training and operational guidance.</i>
608	Other category	Impeded user experience due to issues with scent delivery in VR	<i>This category focuses on the potential negative impact of scent delivery systems in VR experiences on user comfort and engagement. In the context of impeded user experience and usability, issues such as discomfort and distraction directly hinder the immersive experience and overall usability of VR applications.</i>
611	Other category	Lack of impact of diegetic integration on experienced players' subjective experience	<i>This category highlights the finding that diegetic integration of information in VR games may not affect experienced players' subjective experience. In the context of impeded user experience and usability, this suggests that certain design choices may not improve the user experience as expected.</i>
615	Other category	Increased difficulty of interaction between workers and the system	<i>This category highlights the challenges users may face when interacting with XR systems, leading to increased difficulty in completing tasks. In the context of impeded user experience and usability, this difficulty directly impacts the efficiency and effectiveness of XR systems in professional settings.</i>
616	Other category	Asymmetric interaction in multi-user exergames	<i>This category focuses on the lack of symmetric interaction in multi-user exergames, which can negatively impact the user experience. In the context of impeded user experience and usability, this asymmetry directly affects the enjoyment and effectiveness of multi-user exergames.</i>
617	Other category	Reduced real-world hands-on learning experiences in vocational education	<i>This consequence describes how XR training, while offering immersive experiences, may lead to a decreased reliance on traditional hands-on training methods. This reduced exposure to real-world scenarios and physical tasks can hinder the development of practical skills and potentially impact long-term performance and skill retention among trainees and students. In the context of Compromised Training Effectiveness, this translates to a gap in practical skills and preparedness for real-world situations.</i>
618	Other category	Reduced effectiveness of XR training due to inadequate simulation of real-world scenarios	<i>This cluster of consequences highlights the limitations of XR simulations in perfectly replicating real-world scenarios. The lack of perfect mirroring can lead to a gap in preparedness for actual situations, confusion and disorientation due to limited generalizability, and a disconnect between virtual and real-world experiences, all of which compromise the effectiveness of the training in the context of real-world application. This ultimately impacts the transfer of skills and knowledge from the virtual to the physical environment.</i>
619	Other category	Impeded training effectiveness due to obscured trainer-trainee interaction	<i>This consequence points to the challenges in real-time feedback and guidance in XR training due to the obscuring of the trainee's environment from the trainer. This lack of direct observation and immediate interaction can significantly hinder the effectiveness of</i>

			<i>the training process, impacting both the quality of instruction and the learning experience for trainees.</i>
620	Other category	Increased complexity and reduced effectiveness in XR training development and implementation	<i>This consequence highlights the added complexities in creating effective XR training materials and ensuring a positive learning experience. The challenges extend to tracking learner progress and understanding their learning path, potentially leading to inefficiencies and reduced overall training effectiveness. In the context of Compromised Training Effectiveness, this refers to the difficulties in designing, delivering, and evaluating XR training programs.</i>
621	Other category	Inconsistent effectiveness of XR training compared to traditional methods	<i>This consequence points to situations where XR training may not achieve the same level of effectiveness as traditional methods. This can manifest in various ways, such as comparable performance to conventional training or even a lack of effectiveness in achieving specific training goals. The inconsistent results highlight the need for careful consideration and evaluation of XR training's suitability and effectiveness in different contexts.</i>
622	Other category	Reduced system responsiveness due to technical limitations	<i>This category encompasses the negative impacts stemming from technical shortcomings within XR systems, such as latency, delays, and system errors, which hinder the seamlessness and effectiveness of XR applications in industrial, technical, and professional settings. These limitations directly affect user experience, accuracy, and overall system usability.</i>
623	Other category	Reduced XR system usability due to hardware limitations	<i>This category includes consequences arising from the physical limitations of XR hardware, such as bulky equipment, short battery life, and connectivity issues. These limitations directly impact user comfort, convenience, and the overall practicality of using XR technologies in various professional settings.</i>
624	Other category	Reduced XR system reliability due to software and hardware malfunctions	<i>This category highlights the negative consequences resulting from software glitches, hardware malfunctions, and system crashes within XR systems. These issues disrupt the workflow, compromise data integrity, and negatively impact the overall reliability of XR applications in professional contexts.</i>
625	Other category	Reduced accuracy and precision in XR systems	<i>This category encompasses the negative impacts of inaccuracies and imprecisions within XR systems, such as errors in location tracking, registration issues, and synchronization problems. These limitations directly affect the reliability and usability of XR applications in professional settings, potentially leading to errors and misinterpretations.</i>
626	Other category	Reduced performance due to high computational demands	<i>This category includes the negative consequences of high computational demands on XR systems, such as decreased battery life and reduced frame rates. These limitations directly impact the usability and performance of XR applications, especially in resource-constrained environments.</i>

627	Other category	Reduced user experience due to technical challenges	<i>This category encompasses the negative impacts of various technical challenges on the user experience within XR systems. These challenges include latency, connectivity issues, and hardware limitations, which can lead to frustration and hinder the effectiveness of XR applications.</i>
628	Other category	Reduced accuracy in spatial perception and judgment in virtual and augmented environments	<i>This cluster of consequences reflects the disruption of spatial perception and realism in extended reality (XR) technologies. Users experience difficulties in accurately judging distances, shapes, and spatial relationships in virtual environments compared to the physical world. This can lead to misinterpretations, errors in tasks requiring precise spatial judgment, and reduced effectiveness of XR applications in training or other contexts.</i>
629	Other category	Impaired sense of presence and immersion due to inconsistencies in virtual environments	<i>This consequence stems from inconsistencies and mismatches in XR environments that negatively impact the user's sense of presence and immersion. Factors such as visual quality discrepancies, fixed camera locations, lack of sensory feedback, and incongruence between virtual and real-world elements contribute to a reduced feeling of being truly present in the virtual space, thereby hindering the effectiveness of XR applications.</i>
630	Other category	Altered user interaction and performance due to inaccurate perception of virtual objects	<i>This category highlights how discrepancies in XR environments affect user interaction and task performance. Issues such as underestimation of distances, inaccurate perception of object transparency (due to lighting conditions), and inappropriate occlusion handling lead to errors in user interactions and interpretations of virtual information, impacting the precision and accuracy of tasks performed within XR systems.</i>
631	Other category	Inconsistencies between virtual and physical environments impacting user experience	<i>This consequence focuses on the discrepancies between virtual and physical environments within XR systems. The lack of strong connections between metaverse objects and real-world objects and environments creates inconsistencies that negatively impact user experience, potentially leading to confusion and reduced effectiveness of the XR application.</i>
632	Other category	Reduced effectiveness of XR training and applications due to realism issues	<i>This consequence highlights how issues related to realism in XR applications can negatively impact their effectiveness. The lack of realism in interaction, sensory feedback, and visual fidelity can limit the sense of presence and immersion, hindering the effectiveness of training and therapeutic applications.</i>
633	Other category	Disrupted spatial perception in augmented reality affecting real-world tasks	<i>This consequence focuses on how the use of augmented reality (AR) systems can alter users' perception of spatial relationships in the real world. The alteration of spatial perception can lead to misjudgements of distances and positions, potentially impacting the accuracy and safety of real-world tasks.</i>

634	Other category	Reduced effectiveness of remote collaboration due to technical and communication barriers	<i>This consequence focuses on the challenges encountered in remote collaboration using extended reality technologies, encompassing difficulties stemming from technical limitations and communication barriers within shared virtual environments. In the context of the 'Challenged Remote Collaboration' cluster, this highlights how technological constraints and communication breakdowns hinder the effectiveness of remote teamwork and knowledge sharing.</i>
635	Other category	Increased complexity in managing remote projects and collaborations	<i>This consequence highlights the unforeseen challenges and complexities in managing projects and collaborations across geographical boundaries and time zones when using virtual teams and virtual worlds in extended reality. Within the 'Challenged Remote Collaboration' cluster, this points to the difficulties in coordinating and overseeing remote work, potentially impacting project timelines and outcomes.</i>
636	Other category	Reduced interactive audience engagement in virtual and real-world spaces	<i>This consequence describes the difficulties in achieving effective interactive audience engagement when blending virtual and real-world spaces using extended reality technologies. In the context of 'Challenged Remote Collaboration', this points to the challenges in creating immersive and engaging experiences that seamlessly integrate both physical and virtual participants.</i>
638	Other category	Reduced collaboration effectiveness in XR environments compared to traditional platforms	<i>This consequence focuses on the potential for extended reality platforms (like the metaverse) to be less effective than traditional 2D platforms (like Zoom) for communication and collaboration. In the context of 'Challenged Remote Collaboration', this suggests that the assumed benefits of XR for remote interaction may not always materialize, highlighting the need for careful consideration of the technology's suitability for specific collaboration tasks.</i>
639	Other category	Conflicts and distractions in collaborative virtual environments	<i>This consequence highlights the potential for conflicts and distractions when multiple users interact with and modify shared virtual content in augmented reality environments. In the context of 'Challenged Remote Collaboration', this points to the challenges in managing concurrent modifications and ensuring a smooth collaborative workflow in shared virtual spaces.</i>
640	Other category	Reduced awareness of co-located users in augmented reality	<i>This consequence focuses on the decreased awareness among consulting users of co-located users during collaborative tasks in augmented reality environments. In the context of 'Challenged Remote Collaboration', this highlights the potential for miscommunication and coordination issues due to reduced situational awareness in shared augmented reality spaces.</i>
643	Other category	Unforeseen negative consequences of XR technology	<i>This cluster groups consequences related to unintended and unanticipated issues arising from the use of extended reality technologies. Within the 'Other negative consequences in the Other category', this underscores</i>

			<i>the need for thorough evaluation and risk assessment before widespread adoption of XR systems.</i>
644	Other category	Reduced engagement with interactive media in immersive AR	<i>This consequence highlights the disconnect between increased presence and actual engagement in immersive augmented reality experiences. In the context of 'Other negative consequences in the Other category', this points to the limitations of simply increasing immersion without considering other factors influencing user interaction.</i>
645	Other category	Challenges in VR technology adoption	<i>This category includes difficulties faced by newcomers due to the complexity and variety of VR systems. Within the 'Other negative consequences in the Other category', this emphasizes the need for user-friendly interfaces and better onboarding processes to facilitate wider adoption.</i>
648	Other category	Misinterpretation of AR applications	<i>This consequence describes the misinterpretation of AR applications, particularly in gaming contexts. In the context of 'Other negative consequences in the Other category', this highlights the need for clear communication and understanding of the intended use and functionality of AR applications.</i>
651	Other category	Introduction of new types of faults in socio-technical systems	<i>This consequence highlights the introduction of new types of faults leading to human failures in socio-technical systems due to XR technologies. In the context of 'Other negative consequences in the Other category', this underscores the need for robust error handling and human-centered design in XR systems.</i>
652	Other category	Unforeseen social, economic, or cultural consequences of the metaverse	<i>This consequence highlights the potential for unforeseen negative impacts on society, economy, and culture due to the metaverse. In the context of 'Other negative consequences in the Other category', this emphasizes the need for careful consideration of the broader societal implications of metaverse technologies.</i>
657	Other category	Loss and harm from tight coupling of digital and physical environments	<i>This consequence describes the potential for loss and harm due to the close integration of digital and physical environments in XR systems. In the context of 'Other negative consequences in the Other category', this emphasizes the need for robust safety mechanisms and risk mitigation strategies.</i>
660	Other category	Unclear resources and implications for educators in XR	<i>This consequence highlights the lack of clarity regarding available resources and implications for educators using XR technologies. In the context of 'Other negative consequences in the Other category', this emphasizes the need for better support and guidance for educators integrating XR into their teaching.</i>
664	Other category	Security concerns related to the metaverse	<i>This consequence highlights the security risks associated with the metaverse. In the context of 'Other negative consequences in the Other category', this emphasizes the need for robust security measures to protect users and businesses within the metaverse.</i>

668	Other category	Limited use of VR tools outside of universities	<i>This consequence highlights the limited use and evaluation of VR tools outside of university settings. In the context of 'Other negative consequences in the Other category', this emphasizes the need for wider adoption and evaluation of VR tools in various sectors.</i>
670	Other category	Loss of user experiences in virtual worlds	<i>This consequence highlights the ephemeral nature of virtual worlds and the potential loss of user experiences unless preservation methods are implemented. In the context of 'Other negative consequences in the Other category', this emphasizes the need for mechanisms to preserve and archive user experiences in virtual worlds.</i>

APPENDIX F – PRIORITIZATION SURVEY

MOTIVATE XR SURVEY

During the first year of Motivate XR, we have mapped potential SEL risks of relevance based on the knowhow within the consortium and scientific literature. To understand the severity of the risks, we ask you to help assessing their occurrence likelihood and the severity of their impact on the affected stakeholders. This will help us all focus the efforts correctly to safeguard against the right risks.

Instructions: For each statement below, please **rate (a) the likelihood** that this risk will occur when MOTIVATE XR is deployed **and (b) the size of its impact** if it occurs.

Use a 4-point scale for both ratings, with the possibility of indicating if a risk, from your perspective, is not relevant to the Motivate XR technologies.

Likelihood of occurrence:

0 = not applicable, 1 = unlikely to occur <-> 4 = likely to occur

Impact (severity):

0 = not applicable, 1 = low impact on affected stakeholders <-> 4 = high impact on affected stakeholders

required

Section 1: Environmental Risks

Risks to the sustainability of the natural environment

The manufacturing and disposal of XR devices—including head-worn displays and related equipment—and the specialized materials used in XR displays could generate significant electronic waste and environmental harm due to rapid obsolescence and problematic sourcing, processing, and disposal practices. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The infrastructure and operation of metaverse and XR technologies—including data centres, networks, blockchain systems, cloud computing services, hardware production, and AI computational demands—can consume substantial energy and could contribute significantly to carbon emissions. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Reliance on XR and immersive virtual environments in environmental settings could reduce users' engagement with and understanding of the real natural world, increase cognitive load and reaction-time risks, and potentially undermine environmental awareness and conservation efforts. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 2: Economic Risks

Economical risks to individuals, organizations and society

The adoption of XR technologies could reduce the need for traditional roles through shifts toward virtual experiences and reduced foot traffic, and lead to job displacement. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The adoption of XR technologies could disrupt established business models through shifts toward virtual experiences and reduced foot traffic, and lead to decreased profitability and the need for workforce retraining. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR environments could alter task completion times and impede workflow, and managing virtual teams across geographies and time zones through XR could present unforeseen challenges that impact project timelines and outcomes. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The high costs of XR hardware, software, development, maintenance, and training could limit access for educational institutions, small businesses, and individuals—exacerbating existing inequalities. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4 - likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Using XR technologies in certain tasks could increase mental workload and introduce health and safety risks (e.g., cybersickness, visual fatigue, physical discomfort), which could lower job satisfaction and indirectly lead to job displacement. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4 - likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR technologies could expose stakeholders to economic risks from cybersecurity threats (e.g., unauthorized access, in-app purchases without consent, CMR vulnerabilities). *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4 - likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR technologies could expose stakeholders to economic risks from legal/regulatory uncertainties—such as unresolved virtual property issues and varied enforcement policies. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4 - likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR technologies could expose stakeholders to economic risks from the rising demand for 3D design files, which could weaken trade-secret protections and patent enforcement. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4 - likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Over-reliance on XR can deskill the workforce and widen existing skills gaps, leaving workers unprepared for a changing job market, which could lead to increased unemployment, exacerbated economic hardship, and widen the digital divide. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Organizations unfamiliar with intellectual-property rights for XR-generated teaching content and instructors untrained in XR pedagogy, could risk unintentional infringement and deliver suboptimal guidance. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 3: Health and Well-Being Risks

Risks to human health and well-being

XR systems can cause physical discomfort (e.g., motion sickness, eye strain), distort spatial perception, and reduce real-world awareness—leading to accidents and potential medical incidents. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Excessive XR use can lead to addictive behaviours, social isolation, reduced physical activity, and blurred work-life boundaries, undermining real-world interactions and mental well-being. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR system malfunctions—compounded by insufficient risk expertise and/or lack of maintenance—can compromise safety for both user and surrounding people, and introduce hardware or software hazards. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The immersive nature of XR can trigger or worsen anxiety, distort reality, impair decision-making, and carry unforeseen long-term psychological risks. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR can increase workload and cognitive load for professionals. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR can expose users to harassment, cyberbullying, and inappropriate content, possibly heightening psychological distress—especially for children and vulnerable groups. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR applications can introduce ergonomic and organizational challenges, increase scene complexity, disorient users, and be susceptible to environmental issues and unclear interfaces—all of which could compromise safety. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Traditional safety protocols—designed for non-immersive equipment—often fail to address XR's unique hazards, leaving organizations unprepared to update policies, train staff, and enforce safeguards for immersive and interactive scenarios. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 4: Infrastructure risks

Risks to and derived from infrastructure

Integrating XR into existing workflows can disrupt established practices, may be less efficient than simpler methods for certain tasks, and could limit direct interaction with physical objects in remote collaboration. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR can create new data security vulnerabilities—from authentication flaws to insecure communications and unauthorized access or tampering—which could lead to data breaches, reputational damage, and operational disruptions. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Environmental factors and limited sensory realism could hinder functionality and lead to inaccurate project outcomes. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Network bandwidth and latency can limit cloud-based XR performance; even small delays could degrade user experience. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Inaccurate XR information, over-reliance on XR, and neglect of traditional safety measures could compromise safety and reliability—leading to errors, accidents, and reduced decision-making effectiveness. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Poorly designed mixed reality systems can increase cognitive load and impair decision-making, reducing operational performance. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Lack of adequate IT infrastructure, affordable resources, skilled personnel, private spaces, and clear guidance can hinder XR adoption and accessibility. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Unreliable data connections, integration challenges, and unclear responsibilities can lead to governance issues, cybersecurity vulnerabilities, and conflicts over shared virtual objects can affect system stability. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Monopolistic practices in XR Development and distribution can reduce speed of development and system stability. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Heavy multi-user XR use and dependence on stable wireless networks can strain existing networks, leading to degraded service quality and disrupted operations. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Device glitches, latency, and integration risks in XR systems could undermine reliability and performance in professional settings. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 5: Policy and Governance Risks

Risks to and emerging from existing policy landscape

XR in workplaces and education enables surveillance and data collection that can breach privacy, erode trust, and blur work-life boundaries—especially in the absence of clear ethical guidelines and data protection measures. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Commercialization and militarization of virtual worlds could threaten democratic governance; lack of transparency and central control in the metaverse can erode public trust. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

XR applications in industrial and education contexts can cause accidents or errors (e.g., due to system malfunctions or inaccurate AI assistance), leading to legal disputes and financial liabilities without proper safety standards, liability frameworks, and insurance. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Existing legal frameworks may be inadequate to address disputes, crimes, and virtual property issues in XR environments, necessitating new doctrines and enforcement mechanisms to govern virtual worlds effectively. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Implementing XR-based industrial certifications without updating assessment criteria could undermine the validity of technician qualifications and erode confidence in training outcomes. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Lack of clear liability mechanisms when human error occurs in XR-assisted tasks can leave impacted individuals without legal recourse and expose organizations to prolonged legal uncertainty. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Organizations may lack the capacity or agility to update safety standards and protocols as XR technologies evolve, resulting in regulatory gaps and increased risk of non-compliance with emerging legal requirements. *

	0 - Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 6: Research and Development Risks

Risks to innovation, development and education outcomes

Software and platform limitations, along with collaboration hurdles, could lead to decreased efficiency and increased costs when adopting XR. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Limited skill transfer, lack of standardized evaluation, and trainee isolation in XR training could compromise the training's overall effectiveness. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Technical and design shortcomings—such as rendering/latency issues, spatial mismatches, inadequate haptic feedback, and collaboration conflicts—could impede user experience and immersion. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Reduced realism, over-reliance on virtual experiences, technical constraints, and insufficient support in XR training could impair real-world preparedness. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 7: Social Risks

Risks to human coexistence

Mediated XR interactions could lead to reduced empathy and social connection, blurred work-life boundaries, miscommunication, and coordination issues. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Extensive data collection and immersive environments could lead to increased privacy breaches, cyber-harassment, identity theft, and regulatory gaps. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

One-size-fits-all XR training modules could lead to some participants failing to achieve proficiency. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Reliance on XR training could lead to diminished practical skills, inadequate real-world preparation, knowledge retention issues, workforce engagement problems, and administrative burdens. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Misinterpretation of XR functionality could lead to user confusion and unintended consequences. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Absence of built-in UI accessibility features could lead to exclusion of visually impaired users. *

	0 -Not Applicable	1 - unlikely/ low impact	2	3	4-likely/high impact
Occurrence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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APPENDIX G – CATEGORIZATION OF MEASURES

ISSUE 6

In industrial and collaborative contexts, XR systems—when head-mounted displays are misaligned, interfaces are unfriendly, devices cause discomfort, or technical glitches occur—can hinder efficiency and productivity.

Technical measures

Category	Description
Headset Ergonomics & Physical Comfort	(Improving physical design and comfort of XR hardware)
Calibration & Alignment Accuracy	(Reducing mismatch between virtual and physical worlds)
Robust Tracking & Sensor Fusion	(Ensuring precise and stable tracking of hands, eyes, body, and objects)
Interaction Methods & Input Modalities	(Expanding and improving how users interact with XR systems)
Visual & Sensory Feedback	(Communicating system state and feedback effectively)
Adaptive UI & Content Personalization	(Making interfaces context-aware and user-specific)
Rendering Performance & System Stability	(Preventing technical interruptions and maximizing visual clarity)
Text & Symbol Legibility	(Ensuring critical content (labels, instructions, menus) is readable)
Multimodal Integration & Context Awareness	(Seamlessly combining various sensing and feedback channels)
Industrial-grade Hardware Reliability	(Adapting XR systems for rugged, collaborative environments)

Non-technical measures

Category	Description
User Involvement & Participatory Design	Engaging end-users throughout the design and evaluation phases to co-create more effective and acceptable XR systems. Encourages feedback loops, participatory sessions, and human-centered approaches.
Usability Evaluation & Feedback	Establishing and applying methods to systematically assess the user experience and usability of XR systems. This includes structured testing, standardized questionnaires, heuristic evaluations, and iterative feedback loops involving real users.
Contextual & Real-World Validation	Testing and evaluating XR tools in their actual operational environment to ensure their relevance, usability, and effectiveness under real-world constraints and use cases.
User Training & Support	Equipping users with the necessary knowledge and practice to use XR systems effectively. This includes onboarding, tutorials, guided instructions, and long-term skill development for users and instructors.
Operational Support & Deployment Practices	Ensuring practical readiness and ongoing support for XR use. Involves physical setup, technical assistance, user accommodations, and day-to-day operational maintenance.
Ergonomics & Safety Considerations	Ensuring physical and cognitive comfort, minimizing strain, and addressing safety risks associated with XR device usage. This includes evaluating posture, weight, stressors, workload, and workspace design.

ISSUE 9

Using XR technologies in certain tasks could increase mental workload and introduce health and safety risks (e.g., cybersickness, visual fatigue, physical discomfort), which could lower job satisfaction and indirectly lead to job displacement.

Technical measures

Category	Description
User State Monitoring and Detection	Real-time sensing and interpretation of user physiological, behavioral, and cognitive signals
Adaptive XR Systems and Content to user state or context	Dynamic adjustment of XR experiences in response to the user's state or context to reduce overload or sickness
Visual Ergonomics and Fatigue Mitigation	Reducing visual fatigue, eye strain, and discomfort through display and rendering techniques
Cybersickness Prediction and Prevention	Preemptively detecting and mitigating simulator sickness
Latency, Tracking, and Rendering Optimization	Minimizing motion-to-photon delay and ensuring responsive, stable visuals to prevent disorientation or discomfort
Motion and Locomotion Management	Design of movement and viewpoint control to avoid sensory conflicts
Multimodal Feedback and Interaction Support	Reducing reliance on any single modality (especially vision) to ease cognitive load and reduce strain
Hardware Ergonomics and Physical Comfort	Design and optimization of devices to reduce physical discomfort or long-term strain
User Interface and Information Design	Cognitive offloading through intelligent layout, clear visual cues, and minimalism
Environmental and Contextual Design for Mental Load Relief	Adjusting the immersive environment to reduce mental fatigue and increase comfort

Non-technical measures

Category	Description
Limiting Exposure Time and Providing Breaks	Minimize physical strain and cybersickness by managing session duration, frequency, and including rest periods.
Managing Visual Discomfort and Physical Fatigue	Prevent and mitigate eye strain, posture issues, and general physical discomfort linked to prolonged XR use.
Monitoring and Supporting Psychological & Cognitive Health	Continually track and support user stress, mental health, and emotional well-being while using XR.
Providing Safe Use Guidelines and Training	Establish usage protocols, education, and safety instructions for XR equipment use in industrial or training settings.
Assessing User Well-being Through Questionnaires	Use standardized subjective tools to monitor discomfort, cognitive load, and emotional responses.
Understanding and Addressing Individual Differences	Tailor XR use to account for user variability in susceptibility to discomfort, motion sickness, learning style, etc.
Implementing Feedback Loops and Usability Evaluation	Continuously gather user feedback, iterate on experience design, and refine organizational policies.
Supporting Content Creators with Human-Centered Design Guidance	Provide training and best practices to authors to help them build lower-load, safer, and accessible XR content using Motivate XR.
Workplace and Environmental Ergonomics	Ensure the physical environment and workplace policies align with safe and effective XR use.

ISSUE 10

XR technologies could expose stakeholders to economic risks from cybersecurity threats (e.g., unauthorized access, in-app purchases without consent, CMR vulnerabilities).

Technical measures

Category	Description
Advanced user verification (e.g., biometric, multi-factor, continuous)	Secure and reliable identity verification using biological or behavioral characteristics
Secure Data Transmission and Communication	Encryption, transmission security, and secure communication between components
Data Privacy and Anonymization	Protecting sensitive sensor data, preventing tracking or profiling, anonymizing collected data
Intrusion Detection and Anomaly Response Systems	Real-time or proactive detection of abnormal/malicious activity in XR systems
Secure System and Interface Design	Embedding cybersecurity into the core design of XR interfaces, workflows, and architecture
Platform, Device, and Hardware Security	Ensuring XR devices, firmware, and system layers are protected against physical and low-level attacks
AI-Driven Cybersecurity and Risk Mitigation	Using ML and AI for proactive defense and risk management
Collaborative and Multi-User XR Security	Managing authentication, visibility, permissions, and trust in real-time collaboration and remote assistance scenarios

Non-technical measures

Category	Description
Implement Tailored Risk Management and Security Strategies	Develop and maintain proactive, context-specific strategies to identify, assess, and mitigate cybersecurity risks throughout the XR project lifecycle.
Prioritize Security and Consent in XR Development and Business Logic	Ensure that user consent, privacy rights, and security considerations are embedded into the design and business logic of XR offerings from the earliest stages.
Implement Comprehensive Security and Privacy Controls	Define clear policies and safeguards for data collection, user access, content protection, and behavioral monitoring, aligned with privacy-by-design principles.
Conduct Systematic Security and Privacy Analysis	Regularly perform structured assessments—such as threat modeling, audits, and vulnerability testing—to uncover and address risks related to XR data, devices, and environments.
Ensure Legal and Regulatory Compliance	Align organizational policies and XR deployment practices with relevant laws, regulations, and standards (e.g., GDPR, ISO 27001, ISO 23247), including emerging XR-specific legal risks.
Educate Users on Cybersecurity Risks and Best Practices	Promote awareness and responsible behavior through user-centric education, training programs, and gamified learning to reduce human error and raise security posture.
Address Social Engineering and Privacy Concerns	Identify and mitigate user-targeted threats such as phishing, manipulation, and abuse of personal data, especially in immersive or emotionally engaging XR contexts.

Establish Trust Frameworks and Ethical Guidelines to Guide XR Use	Create transparent governance frameworks and ethical principles to guide XR use, data practices, and stakeholder interactions, helping build long-term trust and credibility.
Promote Stakeholder Collaboration and Governance	Foster cross-sector coordination and shared responsibility among industry, academia, government, and users to co-develop secure, interoperable, and user-respecting XR ecosystems.

ISSUE 15

XR systems can cause physical discomfort (e.g., motion sickness, eye strain), distort spatial perception, and reduce real-world awareness—leading to accidents and potential medical incidents.

Technical measures

Category	Description
Display and Optics Optimization	Minimize visual discomfort through hardware and visual clarity enhancements
Latency Reduction and Rendering Performance	Ensure visual responsiveness to prevent disorientation and nausea
Real-Time User State Monitoring and Adaptation	Sense and respond to physiological or behavioral signs of discomfort
Sensory Conflict Compensation	Align or balance conflicting inputs from visual, vestibular, and proprioceptive senses
Locomotion and Navigation Design	Provide comfort-focused movement interfaces to reduce motion sickness and spatial disorientation
Real-World Awareness and Safety Systems	Prevent collisions, spatial disconnection, and hazards
Ergonomic and Thermal Hardware Design	Minimize physical strain and heat-related discomfort from wearables
Adaptive User Interface and Interaction Design	Reduce cognitive and visual load through intelligent interaction paradigms
Predictive Analytics and Risk Mitigation	Anticipate and intervene in potential user risks before they manifest

Non-technical measures

Category	Description
Usage Scheduling and Rest Protocols	Limit session duration and frequency, encourage breaks, and prevent fatigue or overexposure through structured scheduling.
User Assessment and Screening	Identify and exclude high-risk individuals or adapt experiences based on susceptibility (e.g., motion sickness, age, vision issues, prior VR discomfort).
Training, Education, and User Guidance	Prepare users through pre-use instructions, ongoing guidance, and best practices to safely and effectively use XR systems.
Personalized User Adaptation	Tailor XR experiences based on individual characteristics such as prior VR experience, gender, posture, comfort preferences, and ergonomic needs.
Ergonomic Environment and Equipment Practices	Promote safe and comfortable physical setups and hardware use to reduce strain, improve posture, and mitigate discomfort.

Shared Physical Space Safety Protocols	Prevent physical accidents when multiple XR users are present in the same real-world environment by enforcing spatial awareness, layout design, and supervision protocols.
Safe Locomotion and Interaction Design Policy	Encourage or mandate the use of XR interaction techniques and locomotion methods that reduce disorientation and sickness.
Monitoring, Feedback, and Incident Response	Continuously assess user experience during and after sessions, collect feedback, and respond to adverse effects or complaints.
Standards, Compliance, and Health & Safety Governance	Align with legal, regulatory, and workplace standards; assign responsibilities for XR health and safety oversight.

ISSUE 22

Traditional safety protocols—designed for non-immersive equipment—often fail to address XR’s unique hazards, leaving organizations unprepared to update policies, train staff, and enforce safeguards for immersive and interactive scenarios.

Technical measures

Category	Description
Secure Activity Provenance and Auditability	Enable traceability of actions, assets, and interactions to support arbitration, dispute resolution, and digital rights enforcement
Consent, Privacy, and Boundary Management	Protect users’ autonomy and well-being in immersive environments, especially in social or collaborative XR
Behavioral Moderation and Safety Enforcement	Automatically detect, prevent, and manage harmful or illegal behavior in XR environments

Non-technical measures

Category	Description
Integrating Risk Assessment into XR Design and Use	Perform formal risk analyses on XR use scenarios and training workflows to identify potential hazards, misuse cases, or overlooked safety needs.
Scenario-Based and Context-Specific Safety Training	Create immersive training tailored to specific environments, roles, and risks, enabling realistic learning experiences that reflect actual industrial hazards.
Addressing User Experience Levels and Hazard Perception	Tailor training content to account for differences in safety awareness and hazard recognition between novices and experts, improving user preparedness.
Ensuring Ongoing Competency and Safety Training Refreshers	Maintain long-term user readiness through scheduled refresher training, re-certification programs, and adaptive updates to safety content based on analytics or incident data.
Establishing XR Safety Governance and Compliance Frameworks	Develop and enforce organizational policies, responsibilities, and compliance measures for XR use.
XR Equipment Management and Operational Readiness	Implement systems for tracking, inspecting, maintaining, and updating XR hardware and software.

ISSUE 26

Network bandwidth and latency can limit cloud-based XR performance; even small delays could degrade user experience.

Technical measures

Category	Description
Edge and Cloud Offloading	Reduce round-trip latency by shifting computation (e.g., rendering, tracking) closer to users
Adaptive XR Content and Application Layer Optimization	Dynamically adapt application behavior based on context and network state
Network Prioritization and Protocol Optimization	Ensure real-time XR traffic receives proper network treatment
Wireless and Network Technology Optimization	Improve physical and MAC layer reliability and speed
Predictive and ML-Driven Resource Management	Use AI/ML to anticipate needs and optimize decisions
Advanced Media Encoding and Compression	Reduce payload size while preserving visual fidelity
Multiconnectivity and Load Balancing	Maximize throughput and reliability by distributing load

Non-technical measures

Category	Description
Defining Network Performance Indicators	Establish metrics to monitor and evaluate network performance specifically for XR scenarios, enabling early detection and mitigation of issues like latency and jitter.
Research & Evaluation Methodology	Conduct and design studies that properly account for contextual and methodological variables when evaluating the user experience of networked XR applications.
Human Factors in Latency Perception	Investigate how humans perceive latency in XR experiences, especially in relation to neural responses and sensory feedback delays, to inform tolerance thresholds and experience design.
Planning XR Content Delivery Strategies	Design and structure XR training content with an awareness of bandwidth constraints—using adaptable formats and fallback options to reduce performance risks.
User Training and Familiarization Programs	Improve users' understanding of XR software and best practices to avoid performance-impacting mistakes, particularly in low-bandwidth or high-latency environments.
Infrastructure & Policy Advocacy	Engage with regulators, telcos, and regional initiatives to promote access to high-speed broadband and local 5G networks that support high-quality XR experiences.
Standards & Interoperability Initiatives	Participate in and promote the development of open standards to improve compatibility, reduce latency issues, and support more seamless XR data exchange.

ISSUE 29

Lack of adequate IT infrastructure, affordable resources, skilled personnel, private spaces, and clear guidance can hinder XR adoption and accessibility.

Technical measures

Category	Description
Platform Interoperability and Cross-Device Accessibility	Ensures XR experiences are accessible across various devices and platforms, including mobile, desktop, and HMDs
Cost-Effective XR Hardware and Deployment Strategies	Minimizes financial barriers through affordable devices and practical deployment approaches
Optimized 3D Content and Performance Engineering	Improves efficiency and performance of XR content for various hardware and network conditions
Network Infrastructure and Cloud Delivery	Supports scalable and robust delivery of XR experiences through network and backend enhancements
AI-Powered Assistance, Guidance, and Automation	Utilizes AI to support users in content creation, learning, and problem-solving
System Integration and Interoperability	Enables seamless communication and data flow between systems and tools
Security, Privacy, and Data Protection	Ensures secure usage, collaboration, and protection of personal and proprietary data

Non-technical measures

Category	Description
Early Stakeholder Involvement in XR Planning	Engage relevant stakeholders (e.g., instructors, technicians, managers, learners) early in the XR adoption process to ensure buy-in, identify needs, and foster co-creation of effective solutions.
Proactive Assessment and Strategic Implementation Planning	Conduct readiness assessments, resource planning, and pilot testing to ensure institutions or companies are prepared for effective XR integration.
Financial Models and Cost Management	Develop sustainable funding approaches, cost-sharing models, and financial support mechanisms to reduce adoption costs and enhance affordability.
Establishing Robust Technological and Physical Infrastructure	Ensure adequate and affordable IT infrastructure, physical space, and connectivity to support XR usage, especially in resource-constrained environments.
Standardizing XR Deployment and Support Processes	Create consistent procedures and protocols for device setup, maintenance, onboarding, and technical support to reduce variability and improve reliability across deployments.
Long-Term Expertise Development and Training	Build sustainable capacity by training educators, support staff, and end-users in XR technologies, with pathways for ongoing professional development.
Providing Comprehensive Technology Support	Offer continuous, accessible support services to help users navigate XR tools effectively—covering onboarding, troubleshooting, and in-context assistance.
Adapting XR Learner and Worker Experience Design	Design XR content and interfaces that are intuitive, inclusive, and tailored to diverse user needs—taking into account varying levels of experience, learning styles, physical abilities, and environmental contexts such as limited space, lighting, or mobility constraints.
Promoting Accessibility and Inclusivity in XR	Address barriers to access for disadvantaged or marginalized groups by promoting affordable devices, accessible design, and equitable deployment strategies.
Policy, Governance, and Compliance	Establish organizational or institutional policies to address privacy, data security, health, safety, and ethical use of XR technologies.

ISSUE 37

Existing legal frameworks may be inadequate to address disputes, crimes, and virtual property issues in XR environments, necessitating new doctrines and enforcement mechanisms to govern virtual worlds effectively.

Technical measures

Category	Description
Tokenization of Rights and Virtual Property	Enable ownership, licensing, and secure exchange of virtual goods or assets within XR platforms
Governance Mechanisms and Smart Legal Frameworks	Provide programmable legal structures and self-regulating systems for dispute resolution and platform governance
Privacy-Aware UI and User Empowerment Tools	Improve transparency and comprehension of legal and technical options for users
Platform-Embedded Arbitration and Legal Support Tools	Integrate legal and dispute-resolution procedures within the XR platform itself

Non-technical measures

Category	Description
Enhancing Data Protection and Privacy in XR	Ensure the responsible collection, use, and storage of user data—including biometric and behavioral data—by aligning with privacy regulations (e.g., GDPR), enabling informed consent, and preventing surveillance abuse in XR environments.
Enhancing User Safety and Protection	Protect users from psychological, social, and physical harm in XR settings by establishing usage guidelines, community standards, content moderation practices, and safety-by-design principles.
Safeguarding Perceptual Autonomy and Cognitive Rights	Defend users' rights to control how their perceptions are influenced in XR, by regulating manipulative stimuli, respecting cognitive agency, and preventing exploitative uses of immersive technologies.
Addressing Cybercrime and Security in XR	Develop policies and procedures to prevent, detect, and respond to XR-specific cyber threats, including digital impersonation, virtual harassment, and unauthorized access, ensuring a safe and secure user experience.
Promoting Ethical Considerations and Responsible Innovation	Foster ethical design and deployment of XR technologies by integrating values such as fairness, inclusivity, transparency, and user dignity into Motivate XR's business practices and development roadmap.
Establishing Governance and Accountability Mechanisms	Define clear roles, responsibilities, and accountability frameworks for organizations and users interacting within XR environments, ensuring that virtual actions have traceable consequences and recourse mechanisms.
Establishing Legal and Dispute Resolution Frameworks for Virtual Worlds	Adapt and develop legal doctrines and conflict resolution mechanisms to address disputes, crimes, and ownership issues in XR, ensuring users and stakeholders have legal clarity and accessible enforcement options.
Fostering International and Multistakeholder Coordination	Encourage collaboration among governments, industry, researchers, and civil society to harmonize XR policies across borders, share best practices, and ensure a cohesive, sustainable regulatory approach to virtual environments.

ISSUE 40

Organizations may lack the capacity or agility to update safety standards and protocols as XR technologies evolve, resulting in regulatory gaps and increased risk of non-compliance with emerging legal requirements.

Technical measures

Category	Description
Standardized XR Motion Dataset Accessibility	Provide consistent, interoperable motion datasets to support training, simulation, and benchmarking of safety systems
AI-Powered Hazard Detection and Monitoring Systems	Enable real-time detection of safety risks and violations in XR environments using AI
Synthetic Data Generation and Safety Simulation	Generate synthetic safety scenarios for testing hazard detection models and training protocols
Standards-Aligned Safety Ontologies and Rule Engines	Encode safety standards and legal regulations in machine-readable formats to automate safety validation
Automated Compliance Monitoring and Reporting Tools	Track user interactions and procedure execution against evolving protocols
Adaptive Safety Protocol Update Framework	Provide modular tools that let organizations quickly adjust or deploy updated safety protocols across XR environments

Non-technical measures

Category	Description
Updating XR Safety Standards and Protocols	Ensure organizations have structured processes to regularly revise and align safety protocols and compliance frameworks with rapidly evolving XR technologies and industry standards.
Establishing Safe Operational Parameters for XR Technologies	Define and validate conditions for the safe and effective use of XR devices in industrial environments through testing, risk analysis, and operational guidelines.
Implementing Monitoring and Compliance Mechanisms	Establish continuous monitoring, auditing, and feedback processes to ensure XR applications remain compliant with evolving laws, standards, and ethical norms.
Embedding Ethical and Legal Safeguards in XR Deployment	Implement organizational frameworks to ensure ethical use of XR, grounded in legal standards, human rights, and privacy principles throughout design, deployment, and usage.
Promoting Responsible XR Use Through Organizational Practice	Encourage companies to take proactive responsibility for safe and ethical XR use through internal policies, training, and oversight mechanisms.
Developing Adaptive XR Policy and Governance Frameworks	Create proactive, forward-thinking policy guidelines that anticipate emerging risks and ensure regulatory resilience in the face of XR innovation.
Facilitating Multi-Stakeholder Coordination in XR Regulation	Support cross-sector collaboration to co-create standards, ensure compatibility across domains, and promote sustainable and inclusive XR development.

ISSUE 47

One-size-fits-all XR training modules could lead to some participants failing to achieve proficiency.

Technical measures

Category	Description
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Adaptive Learning Systems	Dynamically tailor training flow and difficulty based on real-time user performance, behavior, or learning history
AI-Powered Content Personalization	Use machine learning to deliver the most relevant micro-content, sequences, and support based on user data
Personalized XR Environment & Interface Customization	Enable tailoring of the training interface and virtual environment to the learner's preferences, abilities, or context
High-Fidelity XR Simulation Modeling	Ensure realistic and context-specific simulation environments to avoid generic, abstract scenarios
Learning Support, Repetition & Self-Regulation Tools	Encourage practice, repetition, and learner control over pace and review
Multi-modal XR Data Analytics	Leverage data from sensors, trackers, and logs to refine learning and adapt scenarios
Collaborative Personalization & Co-Authoring Tools	Allow multiple stakeholders (trainers, AI systems, authors) to collaborate on tailoring experiences

Non-technical measures

Category	Description
Personalizing Instruction to Learner Profiles	Tailor XR content and learning approaches to diverse learning styles, backgrounds, and cognitive needs.
Personalizing Educational Technologies and Interfaces	Customize how educational technology is presented and interacted with, based on user-specific needs and preferences.
Adapting to Learner Progress and Performance	Dynamically adjust content difficulty, sequence, and pace based on the user's real-time performance and learning trajectory.
Enhancing Instructional and Content Quality	Ensure the virtual environment and training materials meet high standards of realism, clarity, and relevance to optimize comprehension.
Using Pedagogical Frameworks for Instructional Design	Apply proven learning theories and structured educational models to guide training module creation.
Aligning Learning with Real-World Contexts and Job Tasks	Mirror real-life situations, tasks, and environments to support skill transfer and contextual learning.
Engaging Experts in Design and Feedback Loops	Involve multidisciplinary experts and trainees in co-design, feedback, and iterative course refinement processes.
Supporting Collaborative and Social Learning	Facilitate peer interaction, shared experiences, and mentorship to enhance learning outcomes in XR environments.
Establishing Assessment and Feedback Mechanisms	Monitor learner progress through structured assessments, automated feedback, and instructor-led evaluations.

ISSUE 50

Absence of built-in UI accessibility features could lead to exclusion of visually impaired users

Technical measures

Category	Description
Voice Command and Speech Synthesis Integration	Hands-free interaction and auditory output of interface elements
Spatial Audio and Auditory Cue Systems	Sound-based spatial awareness, object location, and guidance
Haptic Feedback and Tactile Interfaces	Non-visual physical feedback for interaction and navigation

Customizable and Adaptive Interface Design	User-driven UI personalization and visual accessibility options
Accessibility-Aware XR Authoring Tools	Accessible-by-design creation tools for immersive content
Scene Understanding and AI-Powered Assistance	Real-time environmental interpretation and support through AI
Simulation and Evaluation of Visual Impairments	Testing and training tools to understand and address accessibility needs
Interface Navigation Alternatives	Non-traditional input methods for operating XR systems

Non-technical measures

Category	Description
Universal Design and Inclusion Principles	Embed inclusive design philosophies such as Universal Design and Universal Design for Learning into the foundation of MOTIVATE XR to ensure all user experiences are usable by the widest possible audience from the outset.
Developing and Applying Accessibility Guidelines	Establish clear, actionable, and standardized accessibility practices for XR development, ensuring consistency across all phases and tools within the MOTIVATE XR platform.
Legal and Regulatory Compliance	Align MOTIVATE XR practices with existing legal frameworks (e.g., ADA, CVAA, W3C/WAI) and contribute to the development of accessibility-related standards for immersive technologies.
User-Centered Co-Design and Feedback Integration	Engage visually impaired users and accessibility experts early and throughout the design process, incorporating their feedback in iterative development cycles to ensure usability and relevance.
Simulation and Empathy Tools for Visual Impairment	Use VR simulations and visual impairment emulators to foster empathy among developers and stakeholders, and to better understand the sensory limitations faced by visually impaired users.
Tailored Design for Vision-Specific Needs	Address the unique needs of users with different types of visual impairments by incorporating targeted adjustments in UI, navigation, content presentation, and interaction models.
Inclusive Education and Learning Design	Design XR-based training and learning environments in MOTIVATE XR that accommodate visually impaired learners through adaptive content, appropriate pedagogical methods, and accessibility-focused instructional design.
Accessibility Evaluation and Testing	Implement structured evaluation methods—including usability testing, heuristics, and real-world scenario trials—to continuously assess and improve the accessibility of XR tools and experiences.
Training and Capacity Building for Accessibility	Educate developers, designers, and content creators within the MOTIVATE XR ecosystem on accessibility principles, tools, and inclusive practices to build long-term competence and awareness.

APPENDIX H – OUTCOMES OF IMPACT AND EASE OF IMPLEMENTATION SURVEY

SURVEY

Step 1 - Fill in the information in this table	
Organisation:	...
Name:	...
Working on component 1 "Mobile 3D AI-powered videogrammetry scanner"?	...
Working on component 2 "No code Digital Twin Modelling tool"?	...
Working on component 3 "AI-powered document conversion assistant"?	...
Working on component 4 "Collaborative no-code XR authoring tool"?	...
Working on component 5 "Ubiquitous no-code XR authoring tool"?	...
Working on component 6 "XR AI-powered smart headset with enhanced hands-free control"?	...
Working on component 7 "Remote Training and assistance tool"?	...

Step 2 - Distribute 100 points over the categories of measures you find the most important to address social, ethical and legal issues in MotivateXR (in the cells in red):		
Categories (hyperlink to tab)	Descriptions	Your points...
1. Physical Ergonomics & Device Setup	Ensures that XR hardware is comfortable, safe, and adjustable for prolonged use across diverse user profiles by addressing physical strain, fit, and usage conditions.	...
2. Interaction Design & User Interfaces	Focuses on creating intuitive, adaptive, and multi-sensory XR interfaces that enhance usability, reduce cognitive load, and support inclusive and immersive interaction.	...
3. System Performance & Stability	Addresses the need for reliable, low-latency, and scalable XR system performance across networks, devices, and deployment environments to ensure smooth user experiences.	...
4. Safety & Environmental Conditions	Ensures the physical safety of XR users by managing environmental risks, defining safety protocols, and enabling real-time monitoring and emergency responsiveness.	...
5. Health Risk Management & User Well-being	Protects user health by managing simulator sickness, physical discomfort, and cognitive overload through screening, monitoring, and well-being support before, during, and after XR use.	...
6. Data Security & Access Control	Implements strong cybersecurity practices, data protection measures, and access restrictions to secure sensitive user information and prevent unauthorized system access.	...
7. XR Training & Organizational Preparedness	Supports effective and safe XR deployment through structured training, role-based education,	...

	onboarding, and internal coordination tailored to user capabilities and tasks.	
8. XR Accessibility, Inclusion & Deployment Infrastructure	Ensures XR systems are inclusive, accessible, and equitable by adapting interfaces, infrastructure, and training to diverse user needs, abilities, and operational contexts.	...
9. Legal Governance & Accountability in XR	Establishes organizational structures, policies, and oversight mechanisms to ensure legal compliance, ethical use, and transparent accountability in XR environments.	...
10. XR Regulatory Strategy & Standards Alignment	Aligns XR deployments with evolving regulations and industry standards by creating shared protocols, compliance frameworks, and engagement with legal and regulatory bodies.	...
Total points (should be equal to 100)		

Step 3 - Evaluate measures in the corresponding tabs
<ul style="list-style-type: none"> - Take the two categories that you gave the highest points in step 2 - Go to the corresponding tabs: <ol style="list-style-type: none"> 1. Rate the impact that the measures could have to mitigate social, ethical and legal issues of MotivateXR from 1 to 4 (1= low impact, 4= high impact) 2. For the measures that could be implemented by your organization, rate the ease of implementation from 1 to 4 (1= very easy, 4= very difficult) 3. In columns D to J, we have tried to indicate to which components of Motivate XR each measure could be applied. You may suggest adjustments to this mapping (Not Mandatory)

Tab Interaction Design & User Interfaces (Example)

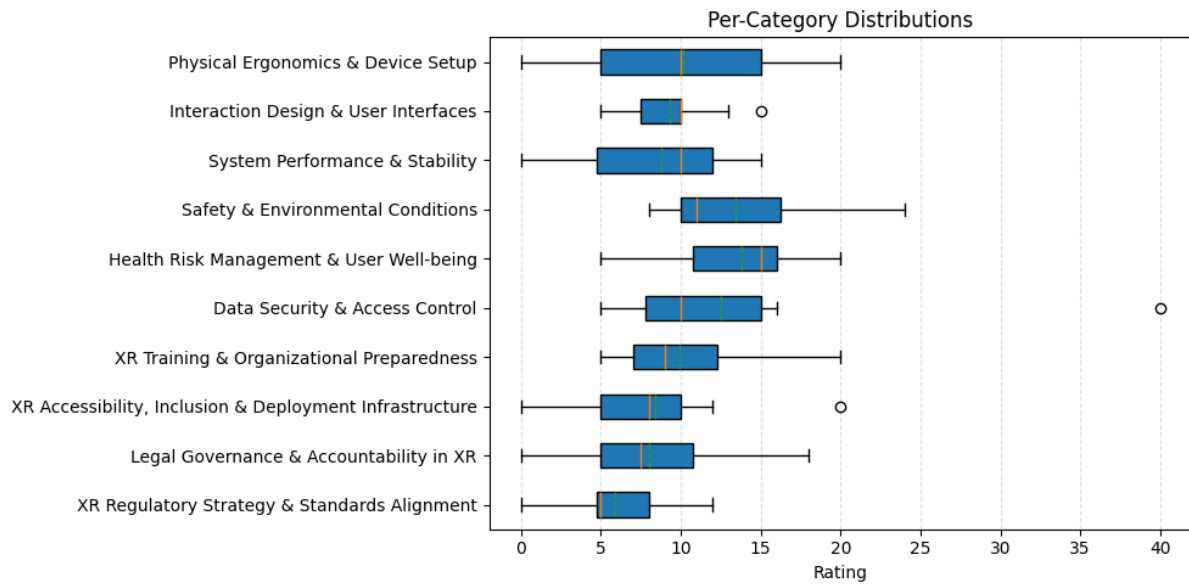
Measures	Rate the impact that the measures could have to mitigate social, ethical and legal issues of MotivateXR from 1 to 4 (1= low impact, 4= high impact)	For the measures that could be implemented by your organization, rate the ease of implementation from 1 to 4 (1= very easy, 4= very difficult)	Specific offline/online relevance		Source
			Rel.	Justify.	
Optimize battery-to-weight ratio to balance comfort with usage time.			Workshop, Papers
Design hardware for balanced weight distribution, avoiding heat concentration near the face.			Workshop, Papers
Use soft padding and adjustable straps to enhance long-term wear comfort.			Workshop, Papers
Reduce device weight and bulk to support prolonged use without causing fatigue.			Papers
Design headset form factors and IPD ranges to			Papers

fit a wider diversity of head shapes, sizes, and gender-related anatomical differences.				
Ensure headsets accommodate prescription glasses or include built-in adjustable dioptres for users with vision correction needs.	...	...		Papers
Implement fit-score metrics during onboarding, including interpupillary distance (IPD) checks and field-of-view alignment.	...	...		Workshop, Papers
Include adjustable focus lenses to accommodate vision differences (e.g., myopia, hyperopia).	...	...		Workshop, Papers
Use eye-tracking feedback to assist users in correctly positioning the headset.	...	...		Workshop, Papers
Integrate dynamic vergence and accommodation adjustment to reduce eye strain and visual discomfort during immersive use.	...	...		Papers
Implement pre-use visual calibration routines based on stereo acuity, eye dominance, and interpupillary distance for optimal fit.	...	...		Papers
Adjust display brightness and contrast automatically or manually to reduce visual fatigue under different lighting conditions.	...	...		Papers
Limit continuous XR session duration to avoid physical fatigue and strain.	...	...		Workshop, Papers
Provide acclimation sessions to help users gradually adapt to XR hardware.	...	...		Workshop, Papers
Add cooling mechanisms or materials to XR headsets to prevent heat build-up around the face during extended sessions.	...	...		Papers
Design the XR system to support thermal comfort	...	...		Papers

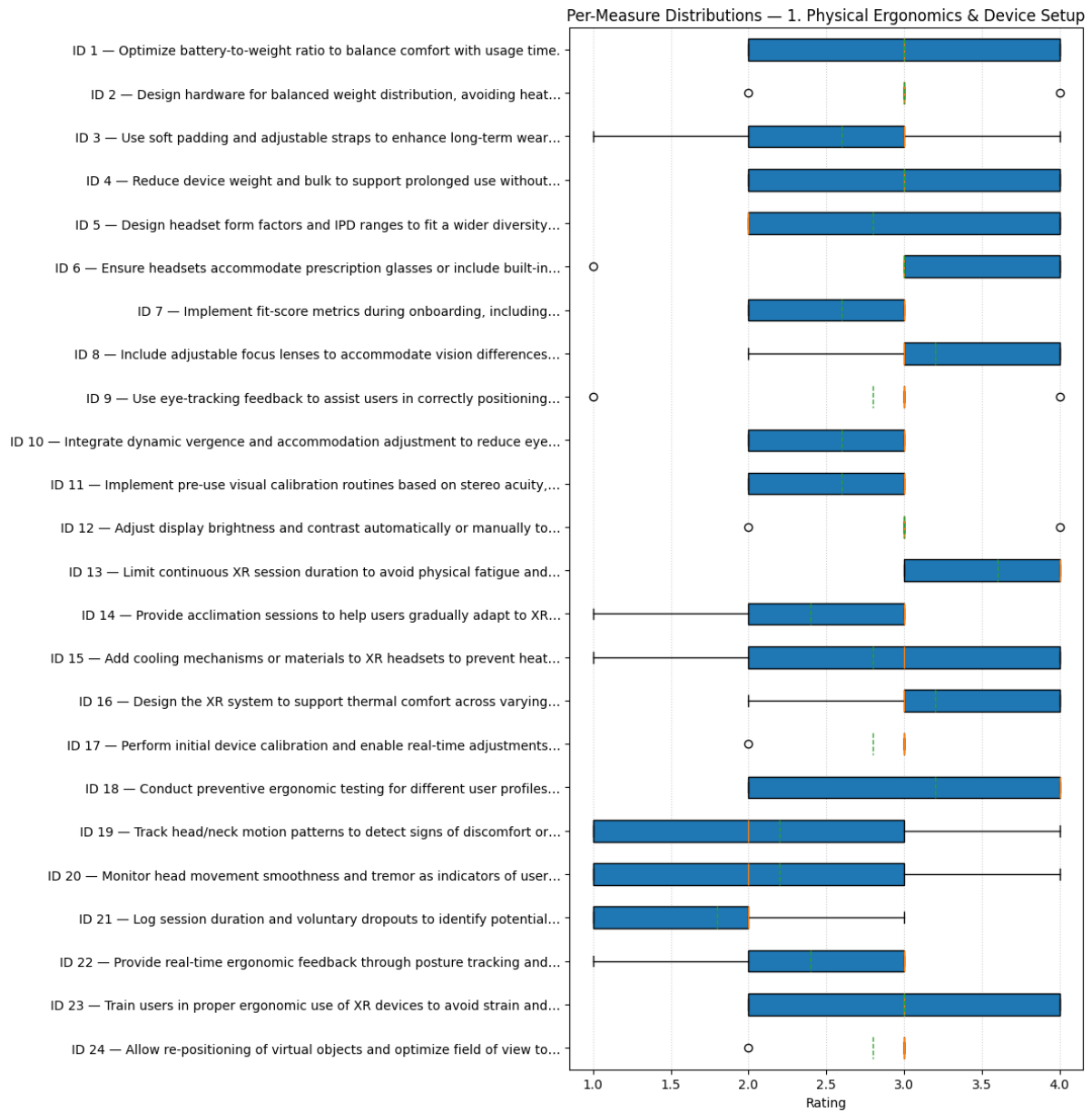
across varying durations, activities, and individual physiological differences.				
Perform initial device calibration and enable real-time adjustments during use.	...	...		Workshop, Papers
Conduct preventive ergonomic testing for different user profiles before deployment.	...	...	online Online tools or dashboards may facilitate user-specific testing.	Workshop, Papers
Track head/neck motion patterns to detect signs of discomfort or strain.	...	...		Workshop, Papers
Monitor head movement smoothness and tremor as indicators of user disorientation or fatigue.	...	...		Workshop, Papers
Log session duration and voluntary dropouts to identify potential ergonomic issues.	...	...	online Typically analyzed centrally via cloud or remote dashboards.	Workshop, Papers
Provide real-time ergonomic feedback through posture tracking and alerts to help users avoid strain during XR interactions.	...	...		Papers
Train users in proper ergonomic use of XR devices to avoid strain and injury.	...	...		Workshop, Papers
Allow re-positioning of virtual objects and optimize field of view to reduce visual discomfort.	...	...		Workshop, Papers

SURVEY OUTCOMES

Distribution of points across measure categories



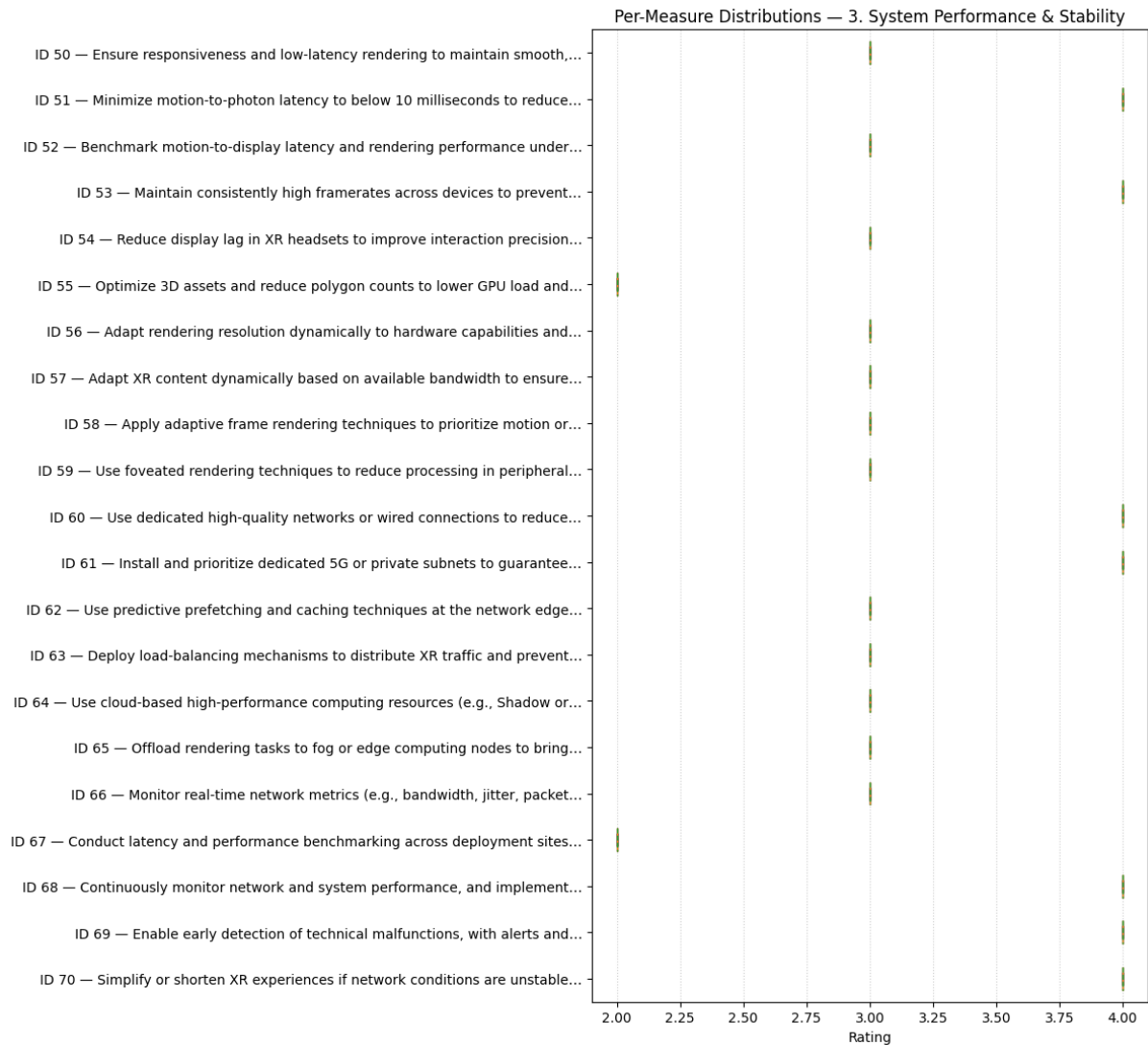
Distribution of points for measures in the category 'Physical Ergonomics & Device Setup'



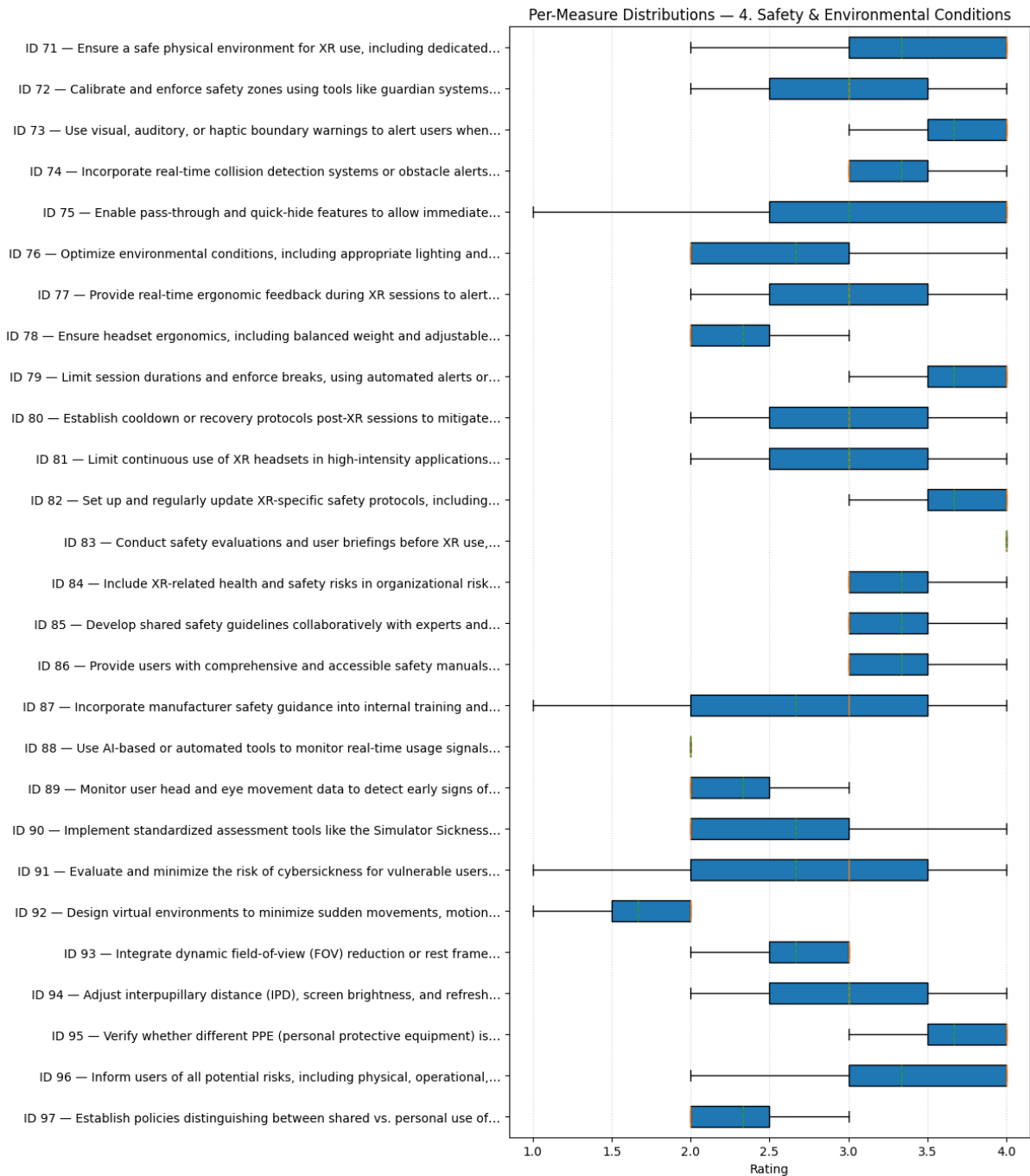
Distribution of points for measures in the category 'Interaction Design & User Interfaces'



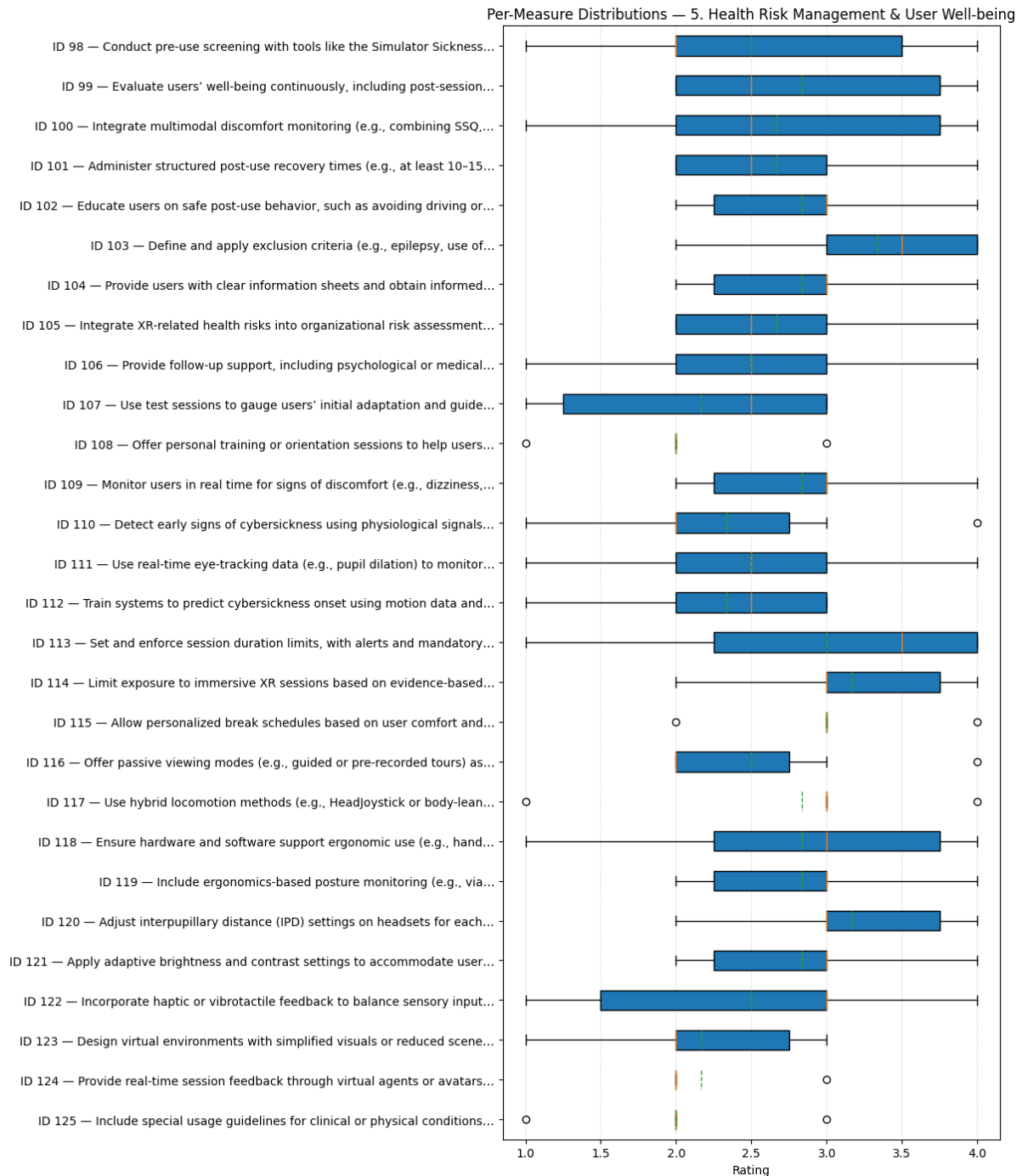
Distribution of points for measures in the category 'System Performance & Stability'



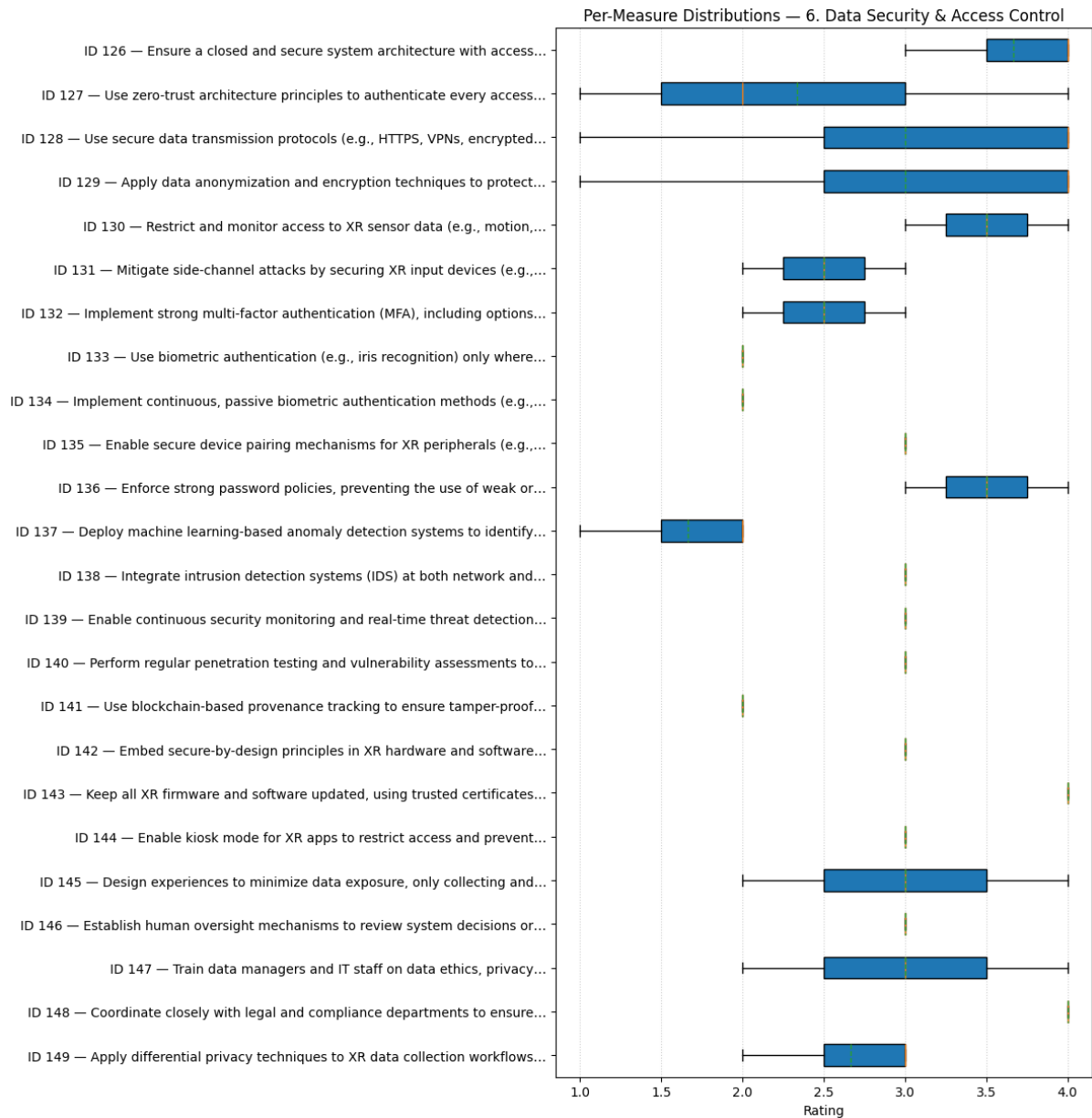
Distribution of points for measures in the category 'Safety & Environmental Conditions'



Distribution of points for measures in the category 'Health Risk Management & User Well-being'



Distribution of points for measures in the category '6. Data Security & Access Control'



Distribution of points for the category 'XR Training & Organizational Preparedness'

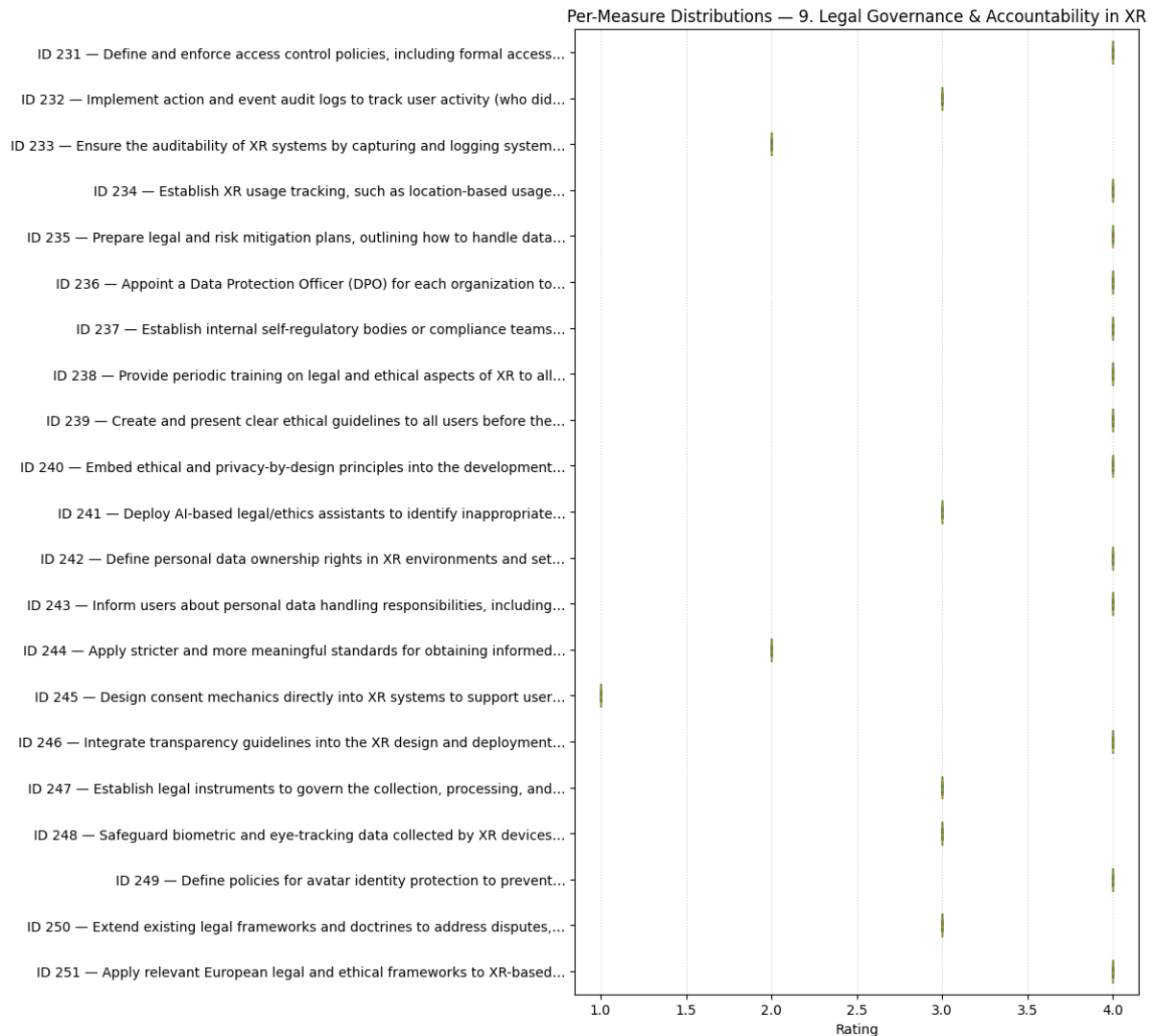


Distribution of points for the category 'XR Accessibility, Inclusion & Deployment Infrastructure'

Per-Measure Distributions — 8. XR Accessibility, Inclusion & Deployment Infrastructure



Distribution of points for the category 'Legal Governance & Accountability in XR'



Distribution of points for the category '10. XR Regulatory Strategy & Standards Alignment'

(No score have been attributed by partners)