Pixels to Reality: A Maturity Spectrum of Immersion

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***Abstract*—The Metaverse is the extreme level of digital existence for an organization, offering immersive experiences that can boost innovation and engagement. However, the absence of planning frameworks makes it difficult for organizations to strategize their metaverse initiatives. This paper introduces a comprehensive and structured framework to evaluate and enhance immersive applications across six key factors. This preliminary research aims to assist organizations in identifying gaps in their immersive systems, offering strategic insights to enhance their presence in the metaverse.**

Keywords—Metaverse, Immersive systems analysis, Strategic planning

I. Introduction

Digital transformation refers to the integration of digital technology into all areas of business. Businesses vary in their maturity of digital existence, spanning from basic web presences to fully integrated digital operations [1]. COVID-19 disrupted physical business operations and accentuated the need for strong digital presence. An effort to remain competitive in the evolving digital landscape also contributes to the drive for achieving a higher degree of digital presence.

At the peak of this digital existence is the metaverse [2]. While augmented reality (AR) and virtual reality (VR) have been around for decades, metaverse has seen a surge in popularity since 2021 [3]. Metaverse provides unique opportunities for innovation, engagement, and growth, allowing businesses to build stronger customer relationships and experiment with new business models [4] [5]. This innovation jumps ahead from digital existence to immersive existence. Achieving an ideal immersive existence is complicated due to the lack of frameworks for effectively evaluating and strategizing immersive operations [6] [7].

The existing literature on immersion highlights several key themes and gaps. Studies like [8] and [9] emphasize the importance of objective metrics for assessing immersion but note inconsistencies in definitions and evaluation approaches. One school of thought identifies immersion as a psychological state [10], while the other argues that we can define immersion as a quality attribute of a system [11]. Quantifying immersion based on these different views leads to differences in methodologies and scope. These studies often focus on specific aspects, such as sensory engagement or hardware characteristics, without providing a multi factor system evaluation framework [12] [13].

The central research question guiding this study is: *How can organizations evaluate and enhance their immersive capabilities to establish a meaningful presence in the metaverse?* Addressing this question will contribute to the broader discourse on digital transformation and immersive technologies. This paper proposes a multifaceted and practical approach that addresses the need for a strategic planning tool for immersive existence. Following the principles of design science research, we also developed a prototype of an immersive analysis tool, which applies this framework and methodology.

Section 2 and 3 describe the six factors framework for analyzing immersive solutions. Section 4 describes the factors that needs to be considered for immersive implementations. Section 5 provides the methodology with examples. Section 6 introduces SPACE eFactory and how it is used in strategic planning and immersive solutions analysis. Section 7 & 8 identifies future directions for this research.

II. Key Factors of Immersion

[11] argue that immersion is the objective level of sensory fidelity a virtual environment provides, determined by factors such as the display technology, the graphical and auditory quality, and multi-sensory engagement. Immersion creates a *sense of presence*, or the psychological state where individuals perceive themselves as *being physically present* in a non-physical world. [14] finds that higher immersion leads to a stronger sense of presence. The key question is, *given a system, what identifiable factors enhance this sense of presence for its users?* Here we present different factors that contribute to immersion, as reported in the literature.

A. Realism:

Realism is fundamental to immersive experiences. The degree of realism affects user immersion and engagement. [11] defines the concept of *presence* in virtual environments as *the sense of being there*. [15] discuss the importance of realism in creating convincing virtual experiences, enhancing the sense of presence. [16] reports that higher graphical fidelity enhances the sense of presence, making virtual experiences more convincing.

B. Interactivity:

Interactivity is a key driver of engagement in immersive environments. [17] highlights the role of interactivity in virtual reality, defining it as the degree to which users can influence the form or content of the virtual environment in real-time. [14] found that increased interactivity in VR systems leads to higher levels of presence and user satisfaction.

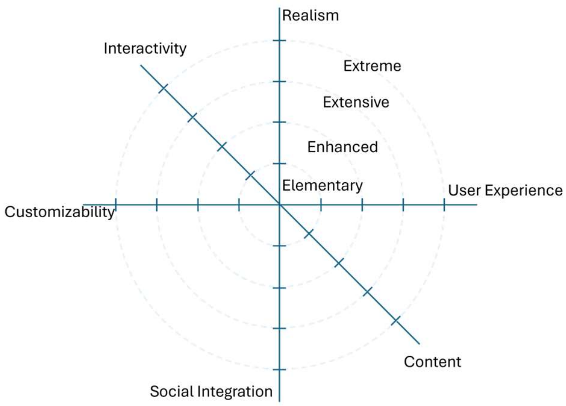

Fig. 1. Maturity spectrum of Immersion

C. User Experience:

User experience (UX) is the quality of overall interaction of the user with the system, influencing satisfaction and usability. [18] highlights that enhanced UX, particularly with human-like digital humans and interactive environments, increases user comfort and intimacy, thereby improving immersion in the virtual world. [19] indicates that enhanced UX is essential for maintaining user engagement in virtual environments.

D. Content Availability and Quality:

The availability of diverse and high-quality content is crucial for success of immersive applications. According to [20], content quality significantly enhances the immersive experience. [21] [18] stress the importance of content in creating an improved immersive experience, noting that a lack of immersive content is a major barrier to user engagement and technology adoption.

E. Social Integration:

Being able to connect with other users within the immersive system enhances user engagement. [22] highlights the importance of social integration in enhancing user experience and engagement. [23] reports several research findings corelating social engagement in virtual environments with sense of presence.

F. Customizability:

Customizing the VR environment leads to more personalized immersive experience. [24] emphasize the importance of customizability in creating personalized and effective immersive experiences. [22] discusses how customizable avatars can impact social interactions and emotional expressions in VR, underlining the importance of personalization in immersive experiences.

TABLE I. EXAMPLES FOR IMMERSION MATURITY SCALE

Factor	**Stages of Maturity**			
	Elementary	***Enhanced***	***Extensive***	***Extreme***
Realism	Primarily 2D, Simple graphics	3D environments, better graphics	Lifelike graphics, High resolution displays	Photorealistic graphics
Interactivity	simple UI, Limited input	responsive UI, More inputs	sophisticated UI, multi-sensory feedback, motion tracking	Seamless interactivity, Full-body tracking, Haptic feedback, Thought control
User Experience	limited immersion and engagement	Greater immersion, better UI	strong presence, and immersion	Exceptional UX, unparalleled immersion, lifelike environments
Content Availability	Limited content, basic applications, and experiences	Growing libraries, wider range, indie and small studio content	Extensive libraries, professional-grade content	Vast ecosystems, high-end applications, AAA games, top-tier studio content
Social Integration	Limited multi-user support	Voice chat, Interactive avatars	realistic avatars, spatial audio	Lifelike avatars, Real-time interaction,
Customizability	Avatar personalization, Simple environmental settings	Detailed avatar creation, advanced settings	Dynamic environments, personalized UI	Adaptive environments, AI-driven personalization

III. MATURITY SPECTRUM OF IMMERSION

The maturity spectrum of immersive technologies ranges from basic systems to advanced, cutting-edge solutions. This staged spectrum mirrors stages found in models such as the Capability Maturity Model Integration (CMMI) [25]. However, these models do not fully address the unique aspects of immersive technologies. The proposed model aims to address intricacies of immersion by focusing on the six factors with qualitative stages.

Table 1 categorizes key factors of immersion across four maturity levels: Elementary, Enhanced, Extensive, and Extreme. Each cell within the table outlines the specific characteristics associated with a particular factor at the given maturity level. We can see how each factor evolves from simple to highly advanced implementations.

A. Elementary Immersive Technologies

Elementary immersive technologies serve as the foundational elements of the metaverse, offering initial experiences with limited interactivity and realism. These technologies are accessible and user-friendly, making them ideal for beginners and casual users. Examples include 2D virtual environments [26] and Mobile AR [27].

B. Enhanced Immersive Technologies

Enhanced immersive technologies provide improved user experiences with better interactivity and visual fidelity. They are more immersive and offer a greater sense of presence compared to entry-level technologies. Examples include standalone VR headsets [28] [29], and advanced AR on mobile and wearable devices.

C. Extensive Immersive Technologies

Extensive immersive technologies offer a high level of realism and interactivity, providing users with a more profound sense of immersion. These technologies often require more sophisticated hardware and software. [15] notes the high levels of presence and immersion provided by tethered VR systems in psychological research. [30] discusses the applications of MR headsets in medical training and surgery planning.

D. Extreme Immersive Technologies

Extreme immersive technologies represent state-of-the-art technologies. Many of the technologies are in a research and development phase and are not yet available for implementation. [31] provides insights into the development and potential of haptic feedback systems. [32] investigate the impact of ultra-high-resolution displays on user experience and applications in professional fields. [33] discuss the advancements and future possibilities of brain-machine interfaces.

IV. Application and Problem Space

The use of immersive technologies depends on the problem an organization is trying to solve. The functional and quality parameters of the problem provide evaluation criteria helping choose the best suited technologies.

Immersive technologies can address a wide range of business problems. For example, in education, such technologies provide realistic simulations that enhance learning outcomes [34]. In healthcare, immersive technologies are used for surgical planning, patient rehabilitation, and medical training [35]. Retail and marketing use these technologies to create engaging shopping experiences [36]

A. Scope of the Application

The scope of the application defines the breadth and depth of the immersive technology solution. This may include the number of users, geographical reach, and need for integration with existing systems. For example, a global virtual training program requires more robust infrastructure than a local virtual showroom. Understanding the scope helps determine resources, timeline, and impact.

B. Complexity of Applications

Complexity includes the nature of the problem, hardware requirements, and technology needs. For example, virtual surgery would need precision hardware and software. Simpler applications, like virtual tours, may require less precision but still would need quality visuals.

1) Hardware Requirements: High-fidelity immersive solutions often demand powerful computing systems, high-resolution displays, motion tracking sensors, and haptic feedback devices. For example, developing a virtual reality training program for astronauts requires hardware capable of delivering realistic simulations that can replicate the conditions of space. This level of complexity necessitates significant investment in both technology and expertise.

2) Technological Complexity: Certain application requirements may necessitate the use of advanced technologies, adding complexity to achieving higher levels of immersion. For instance, artificial intelligence (AI) can enable the personalization of immersive experience. However, integrating AI effectively within a virtual reality (VR) environment is essential. This involves ensuring seamless communication between AI systems and VR platforms to dynamically render graphical and multi-sennsory content based on user interactions. Despite the benefits, technical challenges such as low latency and high-performance standards must be addressed to fully realize such synergy's potential.

C. Social Implications and Responsibilities

Immersive technologies change how people interact, potentially increasing isolation or changing social norms [37]. Organizations must use these technologies ethically by promoting positive interactions and addressing mental health impacts.

V. Immersive Solution Analysis

To implement immersive technology solutions effectively, organizations need a structured analysis methodology. We can use the above-mentioned framework for this analysis. We may evaluate requirements of a solution as well as assess the existing solutions based on degree of sophistication for the six factors. This can also be used in evaluating the gap and identifying strategic direction of the initiative.

A. Methodology

The methodology can be explained using a simple model. Each factor is evaluated on a scale of 0-4, where **0** represents **None**, **1** represents ***Elementary***, **2** represents **Enhanced**, **3** represents **Extensive** and **4** represents **Extreme**. Let R represent **Realism**, I represent **Interactivity**, UX represent **User Experience**, C represent **Content Availability**, SI represent **Social Integration**, and CU represent **Customizability**. Factor scores are calculated by evaluating each factor on a five-point (0-4) scale through a series of analytical questions. Score S for a factor F can be calculated as the average score of the questions Q_i.

$$S_F = \frac{\sum_{i=1}^{N} Q_i}{N}$$

Overall score can be defined as the sum of the scores for each factor.

$$S = S_R + S_I + S_{UX} + S_C + S_{SI} + S_{CU} \quad (1)$$

This score can be normalized using the maximum score of ***24*** (based on maximum score of 4 on all six factors):

$$S^* = \frac{S}{24} \quad (2)$$

We can use this model to find scores for existing solutions ($S_R^a, S_I^a, S_{UX}^a, S_C^a, S_{SI}^a, S_{CU}^a$) and the target solutions ($S_R^b, S_I^b, S_{UX}^b, S_C^b, S_{SI}^b, S_{CU}^b$) . Gap can be defined as the difference between the current mode of operation and future mode of operation for any factor ***F*****:**

$$\Delta_F = S_F^b - S_F^a \quad (3)$$

For example, the gap for Realism can be calculated as:

$$\Delta_R = S_R^b - S_R^a$$

Overall Gap Score:

$$\Delta = \Delta_R + \Delta_I + \Delta_{UX} + \Delta_C + \Delta_{SI} + \Delta_{CU} \quad (4)$$

Similarly, a normalized gap score can be calculated as:

$$\Delta^* = \frac{\Delta}{24} \quad (5)$$

An organization ***O*** has a number business functions ***BF,*** e.g., CRM, HR. A single immersive solution may enable immersion for a single or sometimes a few BFs. Multiple BFs might need several different immersive solutions. Each BF has a different weightage W_{BF} based on its relative requirement of immersion. The Combined score S_O for the organization would be the weighted average score.

$$S_O = \frac{\sum_{BF=1}^{N}(W_{BF} \times S_{BF})}{N} \quad (6)$$

B. Examples

In this section we will follow a few scenarios with a specific scope and see how we can use the methodology for analysis. For the sake of brevity, we will not go into the details of the questionnaire for each system. The function of the questionnaire is to gather tacit information about the system that may impact quality of immersion. By analyzing the reported features, we can score a system. We will also not go into the enterprise-wide score.

1) A psychotherapy solution: The immersive Cognitive Behaviour Therapy (CBT) solutions leverage VR technology to treat anxiety and other psychiatric disorders effectively. One important technique is exposure therapy. It includes exposing the patient to a controlled environment that would trigger anxiety, and counseling the patient through it. *[38]* describes a system that creates realistic, controlled environments that enhance exposure therapy. *[39]* highlights a system with high environmental fidelity and the control it offers over therapy settings, enabling tailored and progressive sessions. *[40]* emphasize the importance of interactive and customizable VR experiences, which are crucial for improving therapeutic outcomes. These features combined makes the VR-based CBT therapy a powerful tool in mental health treatment.

We analyze different features of such a system to see how this impacts the factors of immersion.

- High-quality visuals and audio create immersive, lifelike environments for therapy. Realism: Extensive (3)
- Users can interact with the environment and objects, with real-time biofeedback Integration. Interactivity: Enhanced (2)
- Intuitive interface with personalized therapy plans, session scheduling, and progress tracking. User Experience (UX): Extensive (3)
- Wide range of CBT modules with regular updates and a comprehensive resource library. Content Availability: Enhanced (2)
- Interaction with real and virtual therapists, along with group therapy options. Social Integration: Enhanced (2)
- Options to adjust settings and personalize therapy activities, with detailed progress tracking. Customization: Enhanced (2)

Following (2), total Score would be 3 + 2 + 3 + 2 + 2 + 2 + 2 = 14. Normalized score based on (3) is 14 /24 = 0.58.

a) Imagining a better Solution: Let us imagine improving such a system by using AI to continuously adjust therapy based on user feedback and progress, making each session more effective and tailored to individual needs *[41]*. Also, if we implement AI-powered virtual therapists and avatars that can adapt in real-time to user interactions, providing personalized responses and dynamic guidance throughout the therapy session. Adding these two features change the score of the system.

- System aims to use AI to adapt the content dynamically. This increases the complexity of the solution. It also makes the interaction to the system high definition, and hence increases interactivity to a small degree. Content: Extreme (4), Interactivity: Extensive (3)
- Use of AI personalized avatars as per the therapeutic need of the individual. Customizability: Extreme (4)

Other factors remaining the same, the score would be 3+3+3+4+2+4 = 19, with normalized score of 19/24 = 0.791.

*b) Gap Analysis:*By comparison of assumed current mode of operation and future mode of operations we can evaluate the gap between the two systems.

It follows that the Gap score is $\Delta = 3 - 3 + 3 - 2 + 3 - 3 + 4 - 2 + 2 - 2 + 4 - 2 = 5$. And normalized gap is $\Delta^{*} = \frac{5}{24} = 0.21$

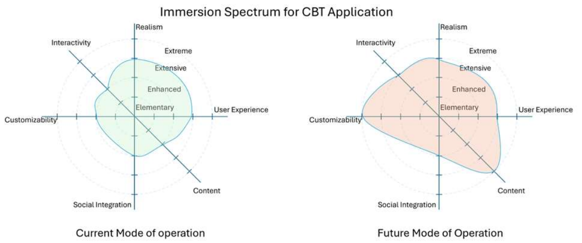

Fig. 2. Two states of an immersive psychotherapy application

2) An Immersive Education Initiative: The LINDSAY Virtual Human Project, developed at the University of Calgary, consists of two main software components: LINDSAY Presenter and LINDSAY Composer. This project aims to create an advanced tool for modeling and visualizing human anatomy in 3D using 2D interfaces like laptops and tablets. Here we analyze the features as described by *[42]*.

- LINDSAY Presenter is a 2D environment, and utilizes high-resolution 3D human anatomy mesh data, which provides detailed and accurate anatomical models. Realism: Elementary (1)
- The software allows users to interact using 2D interface with 3D anatomical models by dragging and dropping parts from a searchable atlas. Users can add labels, hyperlinks, and text boxes to create presentations and tutorials. Interactivity: Elementary (1)
- The user interface of LINDSAY Presenter incorporates common presentation software conventions, making it intuitive and easy to use. Features like text boxes, hyperlinks, and line drawing enhance usability. User Experience: Elementary (1)
- The LINDSAY Presenter provides a comprehensive anatomical atlas, enabling users to access detailed anatomical structures and systems. This content is fully searchable and can be incorporated into presentations and tutorials. Content Available: Extreme (4)
- Presenters allow its user to share web-based links to share their presentation. Social Interaction: Elementary (1)
- The system supports the creation of personalized tutorials and quizzes, catering to different learning styles and needs. Customizability: Enhanced (2)

Overall Score can be represented as 1+1+1+4+1+2 = 10, and normalized score as 10/24 = 0.41

a) Addition of AR: The anARtomy application, as described by *[43]*, is another project closely related to the Lindsay project. It uses Meta SpaceGlasses to move from a 2D VR into a 3D virtual reality. Let's analyze its features as an add-on to the existing system.

- The 3D anatomy models are projected onto the user's body surface, allowing them to view their own muscles and tendons through Augmented Reality. Realism: Extensive (3), User Experience: Enhanced (2)
- Interaction with AR objects occur entirely within a virtual space using hand gestures. Interactivity: Extensive (3)

Other factors remaining the same, score would be 3+3+2+4+1+2 = 15, and normalizing it would be represented as 15/24= 0.625.

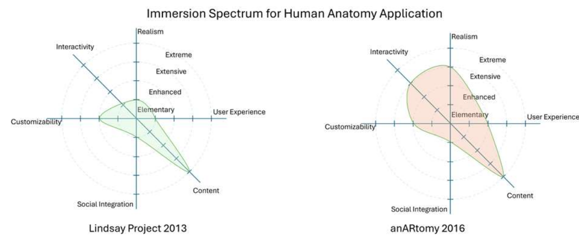

Fig. 3. Gap Analysis of Immersive Anatomy System

b) GAP Analysis: Comparing the two the Gap Score would be calculated as 3 – 1 + 3 – 1 + 2 – 1 + 4 – 4 + 1 – 1 + 2 – 2 = 5. Normalized Gap score would be 5/24 = 0.21.

VI. TOOL FOR STRATEGIC ANALYSIS

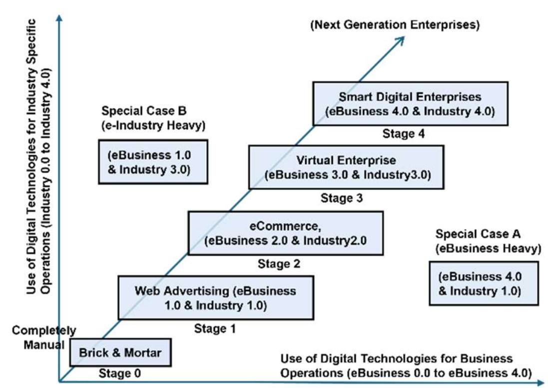

Fig. 4. Digital Transformation Stages

As part of previous research, the authors of this were part of the development of a toolset, known as the SPACE eFactory [44], [45]. It has evolved into a robust platform for computer-aided planning, engineering, and management through a partnership with the United Nations initiative on Small Island Developing States. This toolset weighs the latest digital technologies to expedite the achievement of the UN Sustainable Development Goals (SDGs) in over 100 countries, focusing on essential needs such as food, education, health, public safety, and welfare.

A. Business Strategic Planning

The eFactory has a pattern driven approach to strategic planning. The Patterns repository has Industry Patterns, Country Technology Profiles, and Business Processes and services patterns.

The country profile has a wide range of parameters, such as, Technology Readiness indicators, Economic indicators and many more. These parameters define the context of the environment a plan needs to consider.

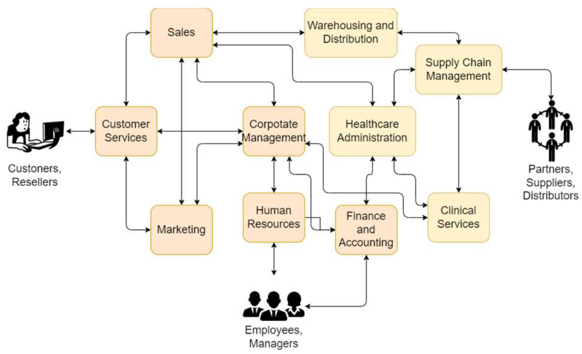

Fig. 5. Healthcare industry Pattern

The industry patterns refer to a collection of business functions, the stakeholders, and their common interactions. For example, a healthcare industry pattern contains all the common functions such as, sales, HR, finance etc. IT also has industry-specific functions, such as Emergency Services, Pharmacy etc. Similarly, The Business Process or Service Patterns go further into the details of each process or service.

The eFactory enables Strategic analysis or planning at any level of granularity. And for different aspects. For example, the digital Transformation Advisor can be consulted for digital transformation of a few services, or the entire organization.

B. Digital Transformation Advisor

Digital Technologies and Transformation Advisor is one of the pipelines in this eFactory. It frames the evolution of digital technologies within organizations using a two-dimensional model that examines both business and industry operations. This model is represented in a diagram where the X-axis shows the progression of digital technologies in business operations (eBusiness 0.0 to eBusiness 4.0), while the Y-axis indicates their use in industry operations (Industry 0.0 to Industry 4.0). Organizations are plotted as points on this chart, reflecting their adoption and integration of digital technologies in various operational facets.

This stage-based model provides a simple yet effective means to evaluate and classify the progress of industrialization and digital adoption across different regions. It highlights how digital maturity can vary significantly, with some regions or sectors lagging while others lead in technological integration. Although the model is useful for broad classification, it does not specify any particular digital technology, focusing instead on the overall level of digital integration and its impact on business and industry operations.

C. Immersion Analysis Tool

The Immersion Analysis Tool is an extension to the digital transformation analysis tool that specifically deals with immersive transformation of business operations. It is designed to systematically evaluate and enhance the immersive capabilities of organizations seeking to establish or improve their presence in the metaverse. It can assist with a single immersive service as well as the immersive footprint of the entire organization. Some of its features include:

- *Factor Assessment*: Each of the six key factors is assessed using questionnaires tailored to capture the nuances of each factor in different environments.
- *Scoring*: The tool employs a straightforward scoring system that rates each factor on a scale from 0 to 4. A collective score of the system based on all six factors suggests the quality of any initiative.
- *Dashboards*: The tool includes interactive dashboards that provide real-time visualization of the assessment results. These dashboards allow organizations to easily interpret their scores, identify gaps, and track progress over time.
- *Benchmarking*: Organizations can use the tool to benchmark their immersive capabilities against industry standards or competitors.

VII. FUTURE DIRECTIONS

Immersive technology planning and implementation is a relatively new and evolving area of strategic analysis. Evaluating an initiative and assessing the target outcomes an organization aims to achieve involves a complex interplay of technological, organizational, and user experience factors. The complexity arises from the need to integrate cutting-edge technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) into existing business processes while ensuring these technologies deliver tangible value [14], [16].

In this research, the equal weight of factors may not fully align with the specific requirements of different solutions. Future research should develop a dynamic weightage framework, allowing organizations to customize the importance of each factor based on their needs.

The current evaluation lacks granularity. Future research should expand the criteria to include more detailed sub-factors and metrics, capturing the nuances of each factor. For instance, within Realism, metrics could evaluate advancements in haptic feedback, environmental soundscapes, and biometric integration.

The general framework may not fully account for sector-specific needs. Research should focus on developing industry-specific modules that consider unique challenges and regulatory environments. For example, in healthcare, research could explore compliance with patient privacy regulations, while in education, it could investigate alignment with pedagogical best practices.

Another area that needs attention is the psychological effects of immersive applications. Extended use of VR and AR can lead to issues such as addiction, desensitization, and altered perceptions of reality. These implications should be part of the trade-of analysis. The framework should incorporate measures for monitoring and mitigating these psychological impacts. This could include strategies for limiting exposure time, providing mental health resources, and designing content that promotes psychological well-being [37].

VIII. Conclusion

This paper has proposed a framework for evaluating and planning immersive initiatives of an organization. It applies design science research and proposes a software tool that can assist in such analysis. This research serves as a preliminary report on the ongoing research as part of the SPACE eFactory. More research is needed in broadening the scope of the framework as well as empirical evaluation of the tool.

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