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Creative Technologies & Augmented Reality for Business Sustainability - A Literature Review for Impacts, Opportunities and Benefits

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***Abstract*— Creative technologies and specifically Augmented Reality (AR) technology's role in helping to solve technological challenges, push forward new novel business models, boost circularity, and enhance sustainability, which are all part of the core focus areas of this study. Currently, the widespread adoption is still limited due to high implementation costs, technical complexity, and a shortage of skilled professionals. Literature review on AR & creative technology solutions, covering sectors like teaching & education, industrial maintenance & operations, asset manufacturing, e-commerce, and health & wellbeing, was conducted. Largest academic publications index databases, inc. IEEE Xplore, Google Scholar, and Scopus were used. The study clarifies the impacts and benefits of AR and Createch from a sustainability perspective. We specifically focused on the effectiveness and usability of augmented reality in problems reduction, enhancing productivity, and improving the engagement of end-users in industrial services. AR was found to facilitate immersive training, to reduce product return rates through virtual previews, and to personalize user interactions, leading to increased operational agility and innovations. AR supports sustainability by promoting eco-friendly behavior & optimizing resource usage, and it enables lean production practices. Targeted recommendations for adding to adoption and mitigating growth barriers include investing in scalable, cost-effective AR solutions, improving technical infrastructure, developing industry-specific AR applications, and increasing specialized training for AR expertise. These strategies are essential for full AR's potential realization for sustainability enhancements and business practices transformations, for strategic asset management, and to support long-term innovations too.**

Keywords—Creative Technologies, Augmented Reality, Circularity, Sustainability, Impact of digitalization, Digital transformation, Technological Barriers

I. INTRODUCTION

The availability of novel process-focused and modern tools, technologies, and digital solutions has significantly improved efficiency[1], communication [2], well-being [3], work-life balance, and remote-work solutions [4]. These advancements have also had a significant impact on daily professional work-life [5] activities, collaboration [6], innovation [7], the tools we utilize for industrial design [8], and even our personal lives [9] There is a mass improvement in global digitalization [10], and it is generating disruptive change within organizations [11]. Digital technology's integration into daily lives has significantly transformed how we innovate and communicate, work, study, entertain, and conduct business [8]. However, digital transformation and digital-level asset management [12] have their own non-tangible and real-life implementation limitations. [13] has identified a lack of data protection, privacy matters, and trust issues vs. AI control matters as barriers to digitalization. [14] identified 12 barriers, including inadequate and unreliable data, a lack of reference structure and standards, difficulty integrating systems, poor technological maturity, cybersecurity risks, and inappropriate infrastructure. Also, [15] indicated a lack of an efficient plan and technology disruption as a challenge.

Digitally sustainable business models [115] are one of the keyways for digitalization to support sustainability [16]. They serve as catalysts for ecological changes, optimizing their favorable environmental effects by incorporating digital technology into their fundamental business processes [17]. Digital technology makes it possible to change several aspects of ecological sustainability, like pollution control [18, 19], waste management [20,21], sustainable urban development [22, 23], sustainable manufacturing [24,25], and to modernize waste reduction and sustainability management efforts in general [7]. Overall, digitalization leads us toward a sustainable future [26]. Augmented Reality (AR) and digitalization have shaped society and business to enhance sustainability performance, in well-being [27], healthcare [28], and entertainment [29], education [30], and human cognition [31]. AR also improves businesses in production and design [32], maintenance [33], tourism [34], and ethical collaboration support [35]. However, studies on AR applications and their sustainability transformation potentials

remain fragmented, and a systematic understanding of AR's effectiveness and challenges has been limited. To address this gap, we had the following objectives. Objective 1: Examine ways in which AR can transform traditional business processes by enhancing efficiency, accuracy, and user experience. Objective 2: Explore contributions of AR technology to sustainable practices across various industries, emphasizing eco-friendly applications and resource optimization. Objective 3: Identify key technical barriers that hinder the widespread adoption of AR and propose strategies for overcoming these challenges in different sectors.

II. Research Methodology

Through literature review and analysis, we identify AR roles & present Fig. 1 for the research focus and our contribution area, in the context of how Augmented Reality (AR) is transforming traditional business processes, technical barriers to widespread adoption, and contributing to a sustainable future.

Search Term

The search terms were selected based on the goal of the study, emphasizing AR use and benefits & limitations, deployment matters, and sustainable future building. The core search term "Augmented Reality" was connected to "AR in business" to capture the impact of AR research on traditional business processes. Additional search terms were: "healthcare", "AR in "education", maintenance", "retail", and "tourism'' etc to get industry-specific results to be included. Then we also searched with keywords like "adoption challenges", limitation barriers, and sustainability. The search strategy was applied to the title, abstract, and keywords of papers to ensure that only relevant studies were included. We used Google Scholar, IEEE Explore, Scopus, ScienceDirect, and Taylor&Francis databases.

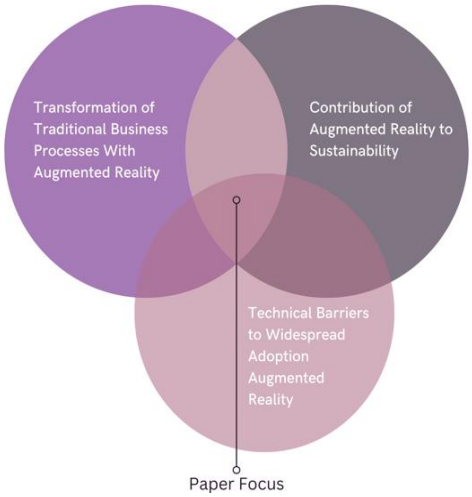

Fig. 1: Research Focus

III. Data Collection & Analysis

The selected papers were reviewed to extract relevant data. The data extraction focused on the following aspects:

Applications: How AR technology is being applied in various business processes.

Benefits: The advantages this technology brings to business operations and sustainability efforts.

Challenges: The technical, organizational, and ethical challenges associated with its deployment.

Sustainability Contributions: How does this technology contribute to building a sustainable future

IV. Augmented Reality Applications

Augmented Reality (AR) technology overlays digital information onto the user's real-world environment. AR has a wide range of applications across multiple industries and business operations, including utilization for understanding and presenting materials effectively in the education sector [36], customer engagement and user experience improvement in e-commerce [37], product promotion and unique offers in product marketing [38], by making the whole current generation experience into new levels, with interactive and immersive contents in gaming and entertainment [39], offering new options for professional e-sports [117]and entertainment sector. In business environments, the adoption of AR is evidenced by the development of customized AR applications, which meet specific goals [40]. AR also helps streamline the product design process [41]and has the potential as a marketing tool in trade, marketing, and product promotion [38], [42] have highlighted the benefits of augmented reality (AR) in the Architecture, Engineering, and Construction (AEC) sector through examples of its applications in safety training [43], visualization [44] communication [45] By integrating it into supply chain processes, businesses can improve efficiency and reduce costs [46]. In the retail industry, companies can utilize this technology to create an enhanced consumer experience and support marketing activities [47]. The tourism industry can benefit from the use of AR technology by not only digitally conserving the site content but also having a positive impact on the economy and user experience [48]. The following will cover applications of AR across various industries.

A. AR in E-commerce and Shopping

In the field of e-commerce, AR has become an innovation and experience-enhancing tool, providing creative ways to enhance the online purchasing experience [49] and become part of other sustainable innovations forward driving forces [103] and green growth providing solutions [114]. It makes shopping more immersive and engaging by enabling customers to experience things in their settings [119]. One of the primary drawbacks of e-commerce is the inability of buyers to physically engage with things before making a purchase, which can be solved by this technology that allows users to virtually try products before deciding to buy [118]. The boundaries between real and digital retail environments are being reshaped by the integration of AR and VR technology in online businesses, giving consumers more creative and entertaining ways to engage with online purchasing platforms [52,53]. Studies have shown that it can not only improve consumers' perceptions and influence e-commerce behaviors by offering an authentic product experience [54] but also plays a significant role in increasing the effectiveness of e-commerce platforms by offering customers a real feel of product information in terms of size, fit,

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and performance [55]. This technology has positively influenced the shopping experience by providing consumers with the necessary information that helps with purchase decisions and reduces cognitive load, which results in a better user experience [56]. Research has looked into using augmented reality (AR) technology to help people overcome their fear of online purchasing, with a focus on how important it is to address customer confidence in online shopping by using AR solutions[57]. Finally, AR can also be used to enhance brand-consumer interactions in the context of brand storytelling. A recent study [58] showed that AR-enhanced brand storytelling leads to a higher perceived flow than regular brand storytelling. Subsequently, this was found to lead to higher brand attitudes and stronger key associations with the brand.

B. Augmented Reality in Manufacturing and Maintenance

The manufacturing and maintenance sector has been paying considerable attention to AR, particularly in the area of operations improvement. Its utilization in industrial processes has been termed Industrial Augmented Reality (IAR) [59], with manufacturing [60], assembly [61], product design [62], maintenance [63], and training [64] being identified as important areas of application. Research suggests that it can be used at every product lifecycle stage, from planning and design to manufacturing, quality control, and maintenance tasks [65]. Using AR-based instructions improves maintenance operations and lowers errors and task completion times [66]. AR is used in many automotive industry domains, e.g. in operator support and training, as well as in several ergonomic-related areas [67], and is expected to increase, when we move towards autonomous vehicles and machinery [116].

C. Augmented Reality in Health Care

In the healthcare industry, AR has a wide range of possible applications, including surgical planning [68], remote surgery [69], robot-assisted surgery [70], surgical navigation [71], and medical education and training. AR-integrated wearable devices and glasses are being used to educate and train healthcare professionals [72]. With improved viewing capabilities during medical operations, this technology helps surgeons perform more accurate and successful treatments [73]. Research has shown that this technology improves clinical nursing education as a supplementary platform for skill development alongside theoretical learning [74]. AR has transformed healthcare education by providing interactive learning opportunities that make learning new skills [75] and refresher courses [76] fun and engaging.

However, this technology has revolutionized the healthcare industry, enhancing patient care, medical education, and overall healthcare delivery innovations. It provides novel ways of interacting with patients, doctor-patient communication [77], and communication between family and patients in nursing homes [78]. The effective integration of AR into other technologies and many different healthcare environments enables technology-based transformation of the healthcare sector and improves the standard medical systems.

Augmented Reality in Education

Augmented Reality (AR) offers promises to improve learning outcomes [79]. This technology overlays digital information in the real world, providing interactive and immersive learning opportunities. Research has explored AR in education in terms of effectiveness, advantages, challenges, and specific application areas in different educational levels and subjects. [80] found that for a visual art course, the use of AR boosted student motivation and engagement, leading to better learning outcomes with less mental effort. Using (AR) in computer programming classes produces faster problem-solving, better academic performance, and a stronger understanding of the material [81]. Additionally, it can visually represent programming concepts in 2D or 3D, explain abstract ideas such as code commands, and help students understand debugging processes [82]. By incorporating AR and a game-based approach, the game playing offered significant progress in programming skills, especially for those with lower prior programming knowledge [83]. For design education, AR provides enhanced learning experiences, improved understanding, and compelling narrative and visuals [84]. Overall, AR is essential in learning outcomes improvements, while enhancing teaching and learning activities and converting conventional education into technology-enhanced education [85].

D. Augmented Reality in Libraries & Museums

AR technology is increasingly being explored in library settings to enhance user experiences and provide innovative services. The integration of this technology in libraries reflects the current trend toward user-centric services, which focus on creating memorable and customized experiences for library users [86]. It can reduce students' library anxiety, enhance the effectiveness of library orientation, and provide an immersive library experience [87]. Additionally, [88] found that the use of AR in libraries enhances users' knowledge and understanding of a particular topic, having a beneficial impact on their learning. By [89], librarians are becoming more interested in utilizing AR's benefits to improve their service, as AR could boost user engagement and make library tours scalable, and AR can be an innovative tool for digitalizing the museum experience. Research conducted by [90] showed that the use of AR in museums enhances individuals' understanding of social, historical, and geological contexts. It is being used in science, art, and history museums, helping people to learn better [91].AR apps in museums improve visitors' interest with pictures and sounds of real objects, which helps to understand the cognitive and affective impacts on visitors [92]. The use of AR in science museums changes how people learn and see exhibits, adding to interest and personalization [93]. It has been found to stimulate learning motivation among museum visitors, suggesting its potential to improve educational outcomes [94]. This technology is also being incorporated into museums to enhance visitor experiences while also supporting cultural heritage preservation and distribution sustainably [95].

V. Limitations and Barriers To Augmented Reality Utilization

In the era of Industry 4.0, various sectors, including healthcare, manufacturing, education, and e-commerce, have experienced significant growth in adopting AR. Even though this technology has several advantages, its application also has various limitations (See Fig. 2). To implement AR in any sector, skilled technicians are required for both hardware and software maintenance [96,97], which have indicated limitations like a small display of an AR system, standardization in hardware or software, and the cost of maintenance. In the healthcare sector, more specifically during surgery, image quality and accuracy, glitches, and technical interruptions have been identified as limitations [98]. In construction, finding the accurate position of the user [99] and finding the fundamental element in low light are considered to be the primary barriers [100]. In maintenance, accurate tracking of the object, installation of a Head-mounted Display (HMD), processing speed, and data integration were key challenges [101]. Limited interaction facilitates, difficulty with realistic object manipulation [102], technical headset issues [113], software crashes, data loss, device costs, and lack of educational content are barriers to implementing AR in the education sector. In the automotive industry, the complexity of creating AR content and hardware issues is seen as limiting broad consumer adoption of AR applications [104].

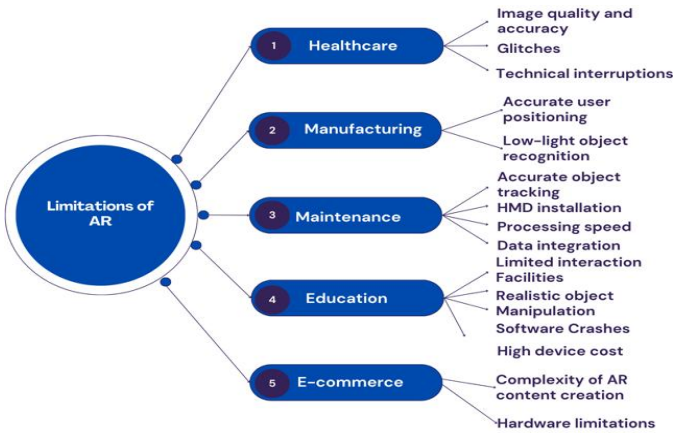

Fig. 2: Limitations of AR

VI. Augmented Reality's Contribution to Sustainability

In the context of sustainability, studies have shown potential for promoting sustainable behavior [105] & sustainable educational practices [106]. Lean culture and AR contribute to sustainable development by boosting production processes and lowering work-related accidents, emissions, and resource consumption [107]. AR applications are capable of drawing and retaining customer attention by increasing the noticeability of sustainable products to consumers [108]. AR has also been used to teach people about sustainable engineering [109], help students with special needs learn better [110], and make sustainable food choices [111], which all showcase contribution possibilities. AR also helps maximize public accessibility while avoiding physical interference through virtual exploration of cultural heritage locations [112].

VII. Discussion

Because of a lack of a holistic understanding of AR business processes transformation for the creation of a sustainable future and AR spearhead barriers, we analyzed relevant studies to address the issues. The following summarizes & discusses the findings, specifically, in addressing the objective - *To examine the ways in which AR can transform traditional business processes by enhancing efficiency, accuracy, and user experience.* Findings demonstrate AR to facilitate business transformation in a wide range of ways, including efficiency increases by lowering error and completion time [66], and visualizing product design [62]. Cost reduction can be helped through AR-based training [64] with supervision needs and physical resources reductions during training, cutting costs, and allowing faster productivity for employees. With virtual product testing, and digital design processes, the E-commerce sector can have lower return rates [49,50,118,119], and AR can enhance user experience by providing consumers with an authentic product experience [54], help reduce cognitive load [56], and help overcome online shopping fears [57]. Additionally, AR-driven storytelling can provide consumers with a personalized brand experience [58]. AR also helps to perform tasks accurately and efficiently, e.g., doctors & operations in the medical sector [73]. In education, AR can make learning more fun& interactive [79]. It can accelerate the process of digitalization of an organization by helping them in manufacturing, assembly, maintenance [60,61,62,63], operator support, and training [67]. Also in communication, AR e.g. transforms healthcare by improving doctor-patient interactions in nursing homes [77, 78] and gives a better personalized experience to consumers. In museums, one can get personalized, more interactive, and engaging exhibits [91,92,93]. In short, AR helps organizations in the creation of an interactive and dynamic environment, leading to significant improvements in user interaction, training, and decision-making, and a better experience.

Reflecting on the findings for our second objective - *To explore the contributions of AR technology to sustainable practices across various industries, emphasizing eco-friendly applications and resource optimization.* It can be stated that AR can contribute to sustainability across a wide range of industries and sectors. AR can promote sustainable behavior by encouraging individuals to adopt sustainable behaviors and eco-friendly practices [105]. It promotes sustainable educational practices by facilitating educational methods and offering immersive learning experiences [106]. It can also lead to lean culture practices and process improvement by aiding in reducing work-related accidents, emissions, and resource consumption, thereby improving production efficiency.

In terms of the third objective - *To identify the key technical barriers that hinder the widespread adoption of AR and propose strategies for overcoming these challenges in different sectors*, although augmented reality (AR) is a technology with the potential to revolutionize industries, operational and

technological obstacles do seem to prevent its broad implementation. High cost of maintenance is one of the major obstacles, and another obstacle is the lack of skilled technicians [96] for system maintenance. Installation and data integration issues could be vital, too, in terms of the mass implementation of AR technology. AR presents exciting opportunities for innovation across industries, significant limitations need to be addressed first. For example, incorporating AR deployment simplification advances, like cloud-based AR, lightweight AR apps, and hardware comfortability and price reduction measures. Additionally, the technology does not appear to be ready for widespread adoption in a large workforce population, as the practicality of the tools remains limited. AR solutions are still finding their golden nuggets era, looks like we would need more automation, in similar ways like robotic process automation (RPA) has helped many other technology sectors to release human resources to more value adding tasks [51], we need something similar to AR context, potentially artificial intelligence solutions, to do compatible resource release to boost up AR deployments. The discussed problems are comparable to early smartphone times in initial market introductions. Before market penetration and a set of killer apps, value for both private and work life, and significant price reductions, mass market adoption gives us to wait for itself, as it seems to be for AR too.

VIII. Conclusion

We provide a foundation for future research and follow-up empirical studies to investigate successful AR transformations towards a more sustainable future, as well as strategies to overcome barriers to AR adoption. Augmented reality has great potential to revolutionize established business procedures, support sustainability, and improve user experiences. The results show that by offering interactive, real-time insights into business operations, including training, e-commerce, and manufacturing, augmented reality greatly increases operational efficiency, lowers costs, and improves decision-making. Furthermore, AR is essential for fostering sustainable behaviors and practices and personalizing customer experiences, especially in the retail and healthcare sectors. To fully utilize AR's, several obstacles like high costs, technological complexity, and a shortage of trained individuals must be overcome. Overall, AR works as a transformative tool, driving innovation and sustainability towards the Industry 5.0 era.

Strategic ideas were suggested for using AR in sustainable company transformation. Scalable AR technologies can cater to business demands that need priority by organizations. One way to do this is by implementing cloud-based AR platforms, lowering initial infrastructure costs, and providing wider access to AR capabilities. Close collaboration with AR developers enables the creation of specialized solutions tailored to industry-specific requirements, such as safety-enhancing tools for construction, immersive product previews for retail, or precise training for healthcare. Customized solutions boost AR's efficacy & relevance, increasing its impact and adoption. Investments in extensive training programs are needed to develop a qualified workforce to guarantee a seamless transition into the era of mainstream AR use. A consistent supply of AR specialists might be required to handle the expanding demands of this cutting-edge technology. And by promoting eco-friendly consumer behavior or visualizing resource-efficient procedures, AR presents special chances to support sustainable corporate practices.

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