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Virtual Reality as a Catalyst in Advancing Inclusive Design for Social and Cultural Sustainability in Architecture

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Abstract

This review article explores the convergence of Virtual Reality (VR) and architectural design from an inclusive lens. It underscores the crucial role of VR in serving as a catalyst for the incorporation of social and cultural sustainability principles in architectural projects. The exploration is guided by inclusive design principles, which encompass several aspects such as accessibility, cultural sensitivity, diversity and inclusivity, user-centered design, and empathy. These concepts serve as the basis for further investigation into the potential of VR technology to enhance and heighten these features within architectural design, therefore promoting the progress of social and cultural sustainability. The review article highlights the profound impact that VR may have, going beyond mere visualization to generate architectural experiences that are immersive, interactive, and empathetic. These experiences are designed to take into account diverse perspectives and needs.

Keywords: *Virtual reality, Architectural design, Social sustainability, Cultural sustainability, Inclusive design, Diversity, Cultural sensitivity, Empathy*

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1. Introduction

Architecture encompasses more than mere building design. It involves the design of spaces that establish how we engage with the built environment, forming our daily experiences and lives. The significance of architecture transcends its aesthetic appeal, encompassing social inclusion and sustainability. The task at hand involves more than the physical construction of structures; it encompasses the development and establishment of societies (Singh *et al.*, 2023). Designing for the entire population, encompassing diverse wants and requirements, presents a complex and intellectually engaging task. The process of architectural design involves shaping individuals' desires by considering various essential variables, such as fit, function, safety, budget, sustainability, regulatory requirements, and physio-psychological and social needs. Through design, these factors are considered to give form to people's aspirations (Zallio and Clarkson, 2021). The establishment of a theory of "cultural sustainability" in architecture necessitates a foundation rooted in a

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comprehensive definition of architecture that acknowledges and incorporates diverse cross-cultural contexts and values. It is crucial to avoid an excessive reliance on Western concepts of architecture, including the prevailing Euro and North American traditions, in order to foster a more inclusive understanding of what constitutes architecture and what qualifies as high architecture (Memmott and Keys, 2015). The concept of sustainable development has gained acceptance in various scientific, policy, and public practice domains since its initial definition in the United Nations Brundtland Commission report 'Our Common Future.' This report described sustainable development as a form of development that satisfies present needs while safeguarding the capacity of future generations to fulfil their own needs (Burton, 1987; McManus, 2014; Cassen, 1987). Diverse interpretations have come up about the concept of sustainable development, but it has generally been recognised as encompassing the harmonization of three fundamental pillars: the economic, social, and environmental pillars or imperatives (Connelly, 2007). The aforementioned 'pillars' were initially established during the Sustainable Development Summit held in Johannesburg in 2002 by the United Nations General Assembly. Over time, these pillars have undergone further development, leading to the current understanding of sustainable development as encompassing environmental responsibility, economic viability, and social equity. This understanding was reaffirmed by the United Nations General Assembly in 2005.

The existing body of literature pertaining to architecture and sustainable development primarily emphasizes the technological, climatic, planning, and material dimensions of sustainable design and construction. These issues predominantly revolve on the environmental and economic aspects of sustainability. Moreover, they are extremely responsive to quantitative measurement, analysis, and project evaluation (Memmott and Keys, 2015). Within the wider discourse on sustainable development, the social aspect has also been acknowledged as a crucial element in obtaining desired results (Boström, 2012). However, it has not received the same level of attention and advancement as the first two pillars. As architectural practices evolve, the significance of designing spaces that resonate with diverse cultural backgrounds and social dynamics is becoming increasingly evident. Beyond mere visualization, virtual reality enables users to interact with and inhabit designs, fostering a deeper comprehension of the interactions between people, spaces, and cultures.

Can virtual reality serve as catalyst for integrating social and cultural sustainability into architecture? Or is it just a fancy presentation tool. One prevalent obstacle encountered in the architectural design process is the need to establish a representational medium that effectively enables comprehension and allows communication among all relevant stakeholders. For example, it is common for clients and end-users involved in the construction process to encounter challenges in comprehending and fully grasping conventional design mediums including 2D plans, elevations, sketches, and 3D models. However, their participation and comments play a vital role in achieving a result of superior quality (Sateei *et al.*, 2022). Virtual Reality (VR) is regarded as one of the most promising technologies of the present decade, with its potential being nearly limitless (Suryawinata and Mariana, 2022). VR is a significant asset and facet of our future. It is a means by which the past, present, and future can be experienced, felt, and touched (Halarnkar *et al.*, 2012). Virtual reality has consistently garnered significant attention within the industrial sector, particularly in the context of sustainable architecture. Virtual reality has emerged as a significant subject of interest among prospective engineers, particularly in the domains of modeling, visualizing, and engaging with intricate information structures and concepts. It enables researchers to perform real-time analytical investigations on the green building indicator, a fundamental aspect of sustainable building (Suryawinata and Mariana, 2022).

The word "virtual reality" was officially established and gained widespread recognition in the late 1980s, subsequently evolving into a fully-fledged industry by the late 1990s (Paranandi and Sarawgi, 2002). Since the late 1960s, when Ivan Sutherland constructed the first advanced VR system with help from ARPA (Negroponte, 1995), there has been considerable anticipation over the potential consequences of this breakthrough for architects. In a *New York Times* interview conducted in 1968, Coons made a statement regarding the future capabilities of architects. He expressed that within a few years, architects would possess the ability to enter a room and manipulate their hand movements to generate a luminous plane or surface (Wauters *et al.*, 2014). It is possible to construct a structure using light, enabling individuals to navigate around it and modify its appearance. Virtual reality has the potential to provide architects with a seamless interface for navigating, making spatial assessments, and manipulating three-dimensional physical environments (van Dam *et al.*, 2000). As a result, there is cause to be positive about its application to architecture (Paranandi and Sarawgi, 2002). This review paper examines the intersection of VR and architectural design, focusing specifically on inclusive strategies for promoting social and cultural sustainability by introducing the concept of

inclusive design and outlining the role of virtual reality as a catalyst for integrating social and cultural sustainability into architectural projects. The utilization of virtual reality extends beyond the mere creation of virtual models, encompassing its potential as a tool for fostering empathy, expanding perspectives, and celebrating the diverse range of human experiences.

2. Inclusive Design Principles

The concept of inclusion encompasses more than just the creation of a functional design for those with disabilities. It also involves a comprehensive study of human behavior, socialization patterns, lifestyle choices, and methods of accessing physical spaces. Inclusion is influenced by and contributes to the development of frameworks that encompass extensive social movements, thereby occupying a prominent position in the consciousness of designers (Zallio and Clarkson, 2021). Inclusive Design neither constitutes an entirely new category of design, nor does it represent a distinct specialism. The design approach commonly employed by designers involves ensuring that their products and services effectively cater to the demands of a diverse population of individuals, regardless of their age or abilities.

The concept of Inclusive Design originated in the mid-1990s, it was a culmination of various efforts, experiments, and insights that can be traced back to the 1960s and earlier. The objective of the endeavour was to establish a connection between design and societal requirements, while also questioning prevalent yet incorrect beliefs regarding ageing, disability, and social equity (Keates and Clarkson, 2002). The concept encapsulates the ideology that constructed surroundings ought to be planned with the purpose of inclusively accommodating a diverse array of abilities, cultures, and backgrounds. This section provides an overview of the principles underpinning inclusive design in architectural contexts. It discusses how factors such as accessibility, cultural sensitivity, community engagement, and diversity play vital roles in creating spaces that serve a broad spectrum of users.

2.1. Accessibility

The concept of "accessibility" within the discipline of architectural design refers to the development of spaces that are inclusive and accommodating to individuals of all backgrounds, regardless of their age, gender, disability status, or any other relevant variables. The concept incorporates the concepts of universal design, with the goal of removing barriers that may result in the exclusion of individuals, therefore fostering inclusivity and social integration (Singh *et al.*, 2023).

The conceptualizations of accessibility have undergone significant transformations in recent decades. Within the field of design, there has been an increasing recognition among designers that the process should incorporate considerations for the diverse spectrum of abilities and conditions that individuals may possess. Accessibility refers to the capacity to physically reach, gain entry to, and utilize a building, area, service, or media. This statement implies a more expansive understanding of accessibility that extends beyond physical accessibility. It encompasses elements such as communication, services, and signalling. Integral accessibility aims to achieve a similar objective, but places greater emphasis on its significance for all individuals (Wauters *et al.*, 2014). A walkway that is free of barriers provides advantages not just to wheelchair users, but also to individuals who are elderly, pregnant women, and individuals who are responsible for pushing a pram, such as parents or grandparents. The concept of universal design emerged as a result of the disability rights movement during the 1960s. It encompasses seven design principles aimed at achieving a design that is accessible to all individuals, regardless of their abilities, throughout their whole lives, without the need for modifications or specialized design (Wauters *et al.*, 2014).

The adoption of novel concepts and methods to accessibility in architectural practice appears to be relatively constrained at present. Research indicates that professional architects tend to primarily consider their own experiences while evaluating a scenario, hence displaying a lack of empathy towards prospective customers (Imrie, 2003). Virtual reality technology can be a great tool in fostering empathy amongst architects, through the simulation of different user experiences, scenarios and instances.

The concept of accessibility in architectural design revolves around comprehending and addressing the varied requirements and abilities of all those who utilise a space. This encompasses a wide range of persons, including those with disabilities, the elderly, kids, pregnant women, and individuals experiencing temporary impairments, among other groups. The acknowledgement is made that there exists a wide range of human capabilities and characteristics, and it is imperative that the physical surroundings are designed in a manner that accommodates and represents this multiplicity.

The concept of accessible design is rooted in the philosophy of 'universal design,' a term introduced by architect Ronald Mace. The notion of universal design involves the design of things and surroundings in a manner that maximises their use for all individuals, without requiring any modifications or specialized design. The concept comprises seven fundamental principles:

1. Equitable Use: The design demonstrates practicality and commercial viability for individuals with varying abilities.
2. Flexibility in Use: A broad range of personal preferences and skill levels are supported by the design.
3. User-Friendly and Intuitive Interface: The design of the system is straightforward and can be comprehended effortlessly, irrespective of the user's level of expertise, knowledge, language proficiency, or present level of focus.
4. Perceptible Information: The design successfully conveys essential information to the user, irrespective of environmental circumstances or the user's sensory capacities.
5. The design of the system prioritizes the reduction of hazards and mitigates the negative outcomes resulting from inadvertent or unplanned acts.
6. Minimal Physical Exertion: The design allows for efficient and comfortable usage with a reduced level of weariness.
7. Adequate Dimensions and Proportions for Accessibility and Utilization: Sufficient dimensions and proportions are allocated to facilitate approach, reach, manipulation, and utilization, irrespective of the user's physical dimensions, posture, or mobility.

Within the field of architecture, these fundamental principles are manifested through the incorporation of diverse architectural aspects. For instance, the inclusion of ramps and lifts caters to individuals with limited mobility, while tactile paving and Braille signage are implemented to accommodate the visually impaired. Additionally, visual alarms are installed to assist those with hearing impairments, and clear, intuitive signage is provided to enhance accessibility for all individuals, among: The objective is to establish a constructed environment that enables all users to navigate with autonomy and assurance.

Nevertheless, it is imperative to acknowledge that accessibility within the realm of architecture extends beyond the mere incorporation of physical design components. Additionally, it encompasses a dedication to promoting social inclusivity and acknowledging the fundamental entitlement of every individual to engage actively in societal affairs (Singh *et al.*, 2023)

2.2. Cultural Sensitivity

The concept of cultural sustainability necessitates the comprehensive integration of environmental, economic, and social sustainabilities. The interactions between humans and their environment, economy, and society encompass a range of culturally distinctive elements, including values, beliefs, attitudes, knowledge, and behavior (Memmott and Keys, 2015). Cultural diversity manifests in the many expressions and structures of human experiences, ideas, and concepts across different regions of the world. As the significance of culture increases in the context of sustainable development, it is crucial to acknowledge and discern cultural variations. This includes recognizing cultural notions that are applicable and pertinent to both non-Western and Western societies. This awareness becomes particularly important when engaging in cross-cultural endeavors to design environments for individuals (Ratna *et al.*, 2007). Within the realm of architecture as a professional field, the awareness and examination of cultural differences emerged prominently during the 1970s. This development took place within the multidisciplinary domain of people-environment studies, which was commonly referred to as man-environment studies at the time. Notably, a select group of esteemed architectural researchers, including Amos Rapoport, Paul Oliver, and Ross Thorne, actively participated in this endeavor.

Scholars examining the dynamics between individuals and their surroundings have expressed interest in understanding the connections between behaviors and various psychological factors such as perceptions, cognition, attitudes, and values towards the environment. Additionally, they seek to comprehend the reasons behind the similarities and differences in the behaviors of individuals from diverse cultures in relation to the physical environment (Altman and Churchman, 1994).

Culture is widely recognised as a significant factor in the realm of people-environment studies, particularly in relation to the design, experience, and comprehension of architectural and urban spaces. This is due to the fact that living environments and settlements often embody and perpetuate the behaviors and values for which they were originally constructed (Rapoport, 1969; Michelson, 1970). Architecture serves as a cultural artefact that mirrors the beliefs and behaviors of both its creators and occupants. The promotion of well-being can be fostered by the availability of a harmonious connection between architecture and its occupants. Psychological distress arises from a lack of compatibility (Memmott and Keys, 2015). Virtual reality technology is a proven tool that can facilitate the development of such a connection.

2.3. Diversity and Inclusivity

The utilization of suitable language is a crucial component of an all-encompassing training process that guides professionals towards adopting an inclusive approach in their working practices. The utilization of terminology such as "master bedroom" instead of "principal bedroom" In a home context, the primary bedroom has traditionally been referred to as the master bedroom. The origin of the term "master bedroom" can be traced back to the historical period of slavery in the United States. Currently, it is more advisable to refer to it as a "suite" or "principal bedroom" as it serves as the primary area designated for sleeping (Zallio and Clarkson, 2021).

Based on the geographical and socio-cultural circumstances, it is evident that interior spaces, architectural structures, urban areas, and transportation systems often fail to offer an inclusive experience for all individuals. In metropolitan areas such as London, contemporary architectural structures and recently established public areas exhibit a notable degree of inclusivity, notably catering to individuals with physical limitations. However, when one moves towards rural areas and smaller cities, the number of issues faced tends to increase, while the level of Inclusive design practice tends to decrease.

One potential explanation pertains to the substantial quantity of heritage and listed structures, which present a greater array of difficulties compared to their contemporary counterparts. However, it is important to note that this is not the sole contributing element. The societal structure, encompassing its sociocultural context and educational system, presents additional complexities. Education and awareness are integral components of the social context, serving as fundamental resources that enable individuals to comprehend disparities, demonstrate empathy towards marginalized groups, and embrace diversity. Multiple comments underscored the significance of including inclusive education into the early stages of schooling, commencing from pre-school, and thereafter expanding throughout the educational curriculum, encompassing all disciplines until the college level. Insufficient attention is devoted to the education of individuals in the fields of Inclusive Design (ID), Universal Design (UD), and Design for All (DfA) within STEM disciplines. This dearth of both formal and informal education contributes to misunderstandings regarding the concepts of accessibility, Inclusive design, equity, and diversity.

The absence of formal education and the use of suitable terminology have resulted in a pervasive lack of awareness, which has become an inherent aspect of contemporary culture. The emergence of public discourse surrounding disability and discrimination has been a relatively recent phenomenon, mostly attributable to legislative measures such as the Disability Discrimination Act and the Americans with Disabilities Act. Regrettably, a significant number of individuals continue to conflate Inclusive design with the notion of handicap. There is a prevailing misperception among clients and certain experts that the implementation of Inclusive design in the design process could result in higher costs (Zallio and Clarkson, 2021).

2.4. User-Centered Design

The UK Department of Trade and Industry (DTI) has provided a definition for inclusive design, which states that it is a business objective whereby designers strive to ensure that their products and services cater to the requirements of a broad range of individuals. In order to achieve the goal of meeting the DTI objective, it is imperative for firms to embrace design methodologies that are expressly focused on the needs and preferences of users, or at the very least, demonstrate sensitivity towards user perspectives (Newell and Gregor, 2002). The area of usability design, which is relatively recent, has witnessed the emergence of numerous strategies aimed at attaining usability in popular items namely those intended for able-bodied consumers. Usability engineering offers a comprehensive array of strategies and methodologies for the development of products that prioritize usability (Keates and Clarkson, 2004).

3. Virtual Reality's Role in Architectural Design: An Inclusive Lens

Virtual Reality (VR) refers to a computer-generated depiction of an image or environment that enables user interaction through the utilization of specialized software or electronic gear (Suryawinata and Mariana, 2022). According to (Abdelhameed, 2013), Virtual reality is a technological innovation that substitutes the sensory information derived from the physical world with computer-generated sensory data through simulation. One way in which it aids in the facilitation of instruction is by creating a setting that enables individuals to engage in firsthand encounters with various scenarios and occurrences, as opposed to relying just on their imagination. Virtual reality technology enables users to experience sensory experiences such as hearing, sight, and tactile sensations by means of various devices, including glasses, headsets, and sensor-equipped gloves or controllers (Suryawinata and Mariana, 2022).

The most prevalent application of virtual reality in architecture has been to improve the experience of walking inside or around an unbuilt structure. Researchers in the field of VR have made significant efforts to enhance the efficacy of VR as a tool for design development and exploration (Abdelhameed, 2013).

The advancement of virtual reality technology is progressing rapidly, transitioning from static visual representations to the immersive experience of 360° panoramic views, and now extending to interactivity with building components and materials. One of the notable advancements in technology is the emergence of Mixed Reality (MR) technology, which allows for the augmentation of real-world visuals with digital elements. Virtual reality technology offers users the ability to immerse themselves in a simulated environment through visualizations. On the other hand, mixed reality (MR) allows for the overlay of digital data onto the physical world (Gebczynska-Janowicz, 2020).

The integration of virtual reality technology into the architectural design process initially provoked scepticism. The initial concern pertained to the utilization of complicated software. The difficulties in acquiring proficiency in the technology may potentially deter individuals who are considering becoming users. Consequently, there has been a widespread use of software within the construction sector. Many virtual reality (VR) software are compatible with 3D and Business Information Modeling (BIM) file formats that are widely used by architects. Some examples of such applications include Revit, SketchUp, Rhino, 3ds Max, Navisworks, and ArchiCAD (Yilei *et al.*, 2019). The second issue was related to the financial implications associated with the procurement of equipment required to facilitate virtual reality (VR) experiences, which proved to be exorbitantly expensive during prior times. Currently, there exist three primary categories of connection types: connections to computers, standalone devices, and mobile phones (Yilei *et al.*, 2019).

These devices are equipped with either a cable or wireless connection and are paired with specialized Head Mounted Display (HMD) devices, such as helmets or glasses. In recent years, there have been notable modifications observed in the field of virtual reality (VR) applications. Various VR devices, including Oculus Rift, Samsung Gear VR, HTC Vive, Microsoft HoloLens, and Google Cardboard, have played a significant role in popularising VR technology and enhancing its accessibility for users. This enhances the accessibility of virtual reality technology for both professional architects and students. Furthermore, VR apps can be accessed on various common mobile devices, including smartphones and tablets that possess advanced features such as high-resolution screens, robust computational capabilities, and motion sensing capabilities (Gebczynska-Janowicz, 2020). The mobility of these devices enables the utilization of apps in various locations (Milovanovic *et al.*, 2017). Due to extensive study and practical applications conducted in the last 20 years, numerous domains within architectural design have been recognized as suitable for the integration of VR technology, alongside various applications within the construction sector. The most significant benefits encompass the following aspects:

3.1. Enhanced Communication Through Immersive and Interactive Technology

Immersion and interactivity are the fundamental pillars of virtual reality. When a user is immersed in a VR experience, they are completely enveloped by the environment, giving them the impression that they are in there (Schuemie *et al.*, 2001). To manipulate events within a virtual world by physically moving one's body and triggering appropriate responses within the virtual environment is a typical instance of interactivity (Achten *et al.*, 1999). Immersive Virtual Reality (VR) has demonstrated its potential as a viable alternative or supplementary form of representation. In contrast to conventional design media, immersive virtual reality enables all stakeholders to engage with and understand prospective buildings from a self-centered, egocentric standpoint, thereby more accurately simulating a real-life experience. Particularly, for

those who lack specialized knowledge in the field, such as users of buildings, research has demonstrated that this approach offers an additional dimension of comprehension and awareness regarding spatial concepts (Sateei *et al.*, 2022).

Virtual reality systems provide the capability to not only visualize the virtual environment but also serve as a valuable tool for constructing the design model and its corresponding surroundings, commonly referred to as the virtual environment. Designers and architects have incorporated virtual reality technology into the design process and architectural construction, utilizing it to investigate the spatial linkages and environmental context of a design. Virtual reality is utilized to enhance the design process by offering designers a comprehensive visualization of spatial relationships among design components, hence reducing reliance on abstract mental imagery. Virtual reality possesses a distinctive characteristic that facilitates the establishment of spatial and topological linkages within a design (Abdelhameed, 2013). It also helps in coordinating construction projects among designers, contractors, and investors and streamlining the construction process and minimizing design defects during the execution stage, as the technology facilitates on-site visualization for construction planning and as-built verification (Milovanovic *et al.*, 2017).

3.2. Historical Preservation

Virtual reality has the capability to generate a simulated architectural environment as a substitute for the physical one (Gebczynska-Janowicz, 2020). There has been an increasing scholarly and public interest in the utilization of virtual reality technology for the purpose of reconstructing historical sites and locations. In the modern day, digital technology has the capability to unveil historical occurrences in regions linked to significant historical events. Therefore, virtual reality has the potential to facilitate a deeper comprehension of historical events and broaden access to a diverse array of historical information. Applications designed for mobile phones and tablets enable users to access Augmented Reality (AR), which is a technology that superimposes computer-generated data onto the actual world. The creation of a visual collage serves to facilitate a stronger connection between the present observer and historical periods. Utilizing contemporary technologies, it becomes feasible to establish novel educational routes within historical regions. Virtual reality applications facilitate the implementation of virtually recreated buildings in their original locations. The reconstruction of historical buildings often evokes minimal expense and avoids generating controversy (Gebczynska-Janowicz, 2020).

3.3. Empathy and Understanding

Virtual reality have the potential to foster a heightened sense of empathy and understanding among designers, stakeholders, and users. VR technology has the capability to conduct a wide range of simulation tests, including those related to weather conditions, social interactions, accessibility, airflow dynamics, diverse cultural experiences and more (Suryawinata and Mariana, 2022). By utilizing VR, it becomes possible to gain precise insights into the behavior of a building under various circumstances fostering proper understanding through empathy during the design process (Jamei *et al.*, 2006).

3.4. Iterative Design and Feedback

The implementation of inclusive design frequently necessitates iterative methodologies that entail ongoing enhancements informed by user feedback. Virtual reality technology has facilitated the ability of designers to immersively visualize and evaluate novel architectural settings prior to undertaking physical construction. In contrast to static images or animation videos, virtual reality enables users to navigate inside a simulated environment, allowing for the evaluation of its advantages and flaws (Gebczynska-Janowicz, 2020). In contemporary practice, virtual reality has gained significant traction as a tool for design visualization. This is mostly due to its inherent advantages, namely the cost-effectiveness and ease with which design form and solutions may be evaluated inside a virtual environment, as opposed to the construction or modification of physical models (Abdelhameed, 2013).

3.5. Reduction of Carbon Footprint and Wastage: Real-Time Photorealistic Virtual Reality (VR)

Rendering capabilities have the potential to decrease the need for physical prototypes in the design process within the design and manufacturing industries. This reduction in physical prototypes can lead to a decrease in material wastage, particularly in the creation of architectural mock-ups (Suryawinata, 2010). The utilization of virtual reality in the creation of building mock-ups mitigates the generation of waste often associated with conventional building mock-ups. When

virtual reality-based architectural mock-ups become obsolete and unnecessary, they do not need to be discarded and treated as waste, like traditional mockups. Consequently, the carbon footprint can be diminished as a result of the limited quantity of waste produced from the generation of digital material. Indeed, the utilization of virtual reality technology in constructing mockups offers significant environmental benefits by minimising trash generation and concurrently decreasing the expenses associated with waste management (Suryawinata and Mariana, 2022).

3.6. Inclusive Collaborative Design

Increased participation in the design process and the opportunity to engage future users of the designed objects in the creation of the final design is one of the great benefits of virtual reality (Petrova *et al.*, 2017). The achievement of innovative results in architectural or construction projects necessitates the incorporation of collaboration as a crucial determinant of success (Blayse and Manley, 2004). The design team typically engages in interaction and collaboration among its members in order to incorporate the contributions of everyone into the ultimate result. Furthermore, it is imperative to engage in collaboration with external stakeholders, including customers and suppliers, during each iteration. This collaborative approach allows for the refinement of original work and the adaptation of the design to address any bottlenecks identified by these external parties. The implementation of open collaboration in architectural or construction projects can be extended to many stages within the design process. These stages encompass activities such as concept creation, evaluation, real design or modification, as well as final testing and refinement (Ehsani and Chase, 2006).

Table 1: This Table Directly Links the Roles of VR in Architecture to the Specific Principles of Inclusive Design that it Progresses

VR's Role in Architecture	Inclusive Design Principles Directly Progressed
Immersive and Interactive Experience	Progresses Empathy and Understanding by allowing architects to experience and understand the spatial relationships within a design, reducing reliance on abstract mental imagery.
Historical Preservation	Progresses Cultural Sensitivity by enabling the reconstruction and preservation of historical sites and locations, promoting a deeper understanding of historical contexts.
Iterative Design and Feedback	Progresses User-Centered Design by actively engaging users in the design process through real-time evaluation and feedback gathering within VR environments.
Reduction of Carbon Footprint and Wastage	Progresses Reduction of Carbon Footprint by minimizing the need for physical prototypes and reducing waste generation in the design and testing process.
Inclusive Collaborative Design	Progresses Diversity and Inclusivity by involving diverse stakeholders, promoting collaboration, and incorporating a broad range of perspectives in the design process.

4. Conclusion

In the field of architectural design, where the built environment has a significant impact on the lives of individuals, fostering inclusivity, cultural sensitivity, and social sustainability is of the utmost importance. This review demonstrates that Virtual reality (VR) is a powerful ally in attaining these objectives. Through an investigation of inclusive design principles, we have outlined how VR technology can revolutionize architectural practices.

The concept of accessibility, previously confined to physical aspects, has now expanded to include communication and services. Virtual reality technology provides architects with a tool to better understand and empathise with individuals who possess a wide range of abilities. The recognition of cultural sensitivity, which involves the acknowledgment of culture's significance in the field of design, is exemplified through the use of VR technology. VR's capacity to replicate historical and cultural environments provides a platform for enhancing comprehension and appreciation of legacy. The promotion of diversity and inclusivity is emphasised in the virtual reality (VR) technology due to its ability to provide a wide range of perspectives and user avatars. This facilitates the process of

identification and representation. Virtual reality brings user-centered design principles to life, ensuring that spaces meet the specific requirements of prospective occupants. Moreover, VR facilitates the process of iterative design and provides immediate feedback, resulting in a decrease in the need for physical prototypes and a reduction in waste generation. This aspect is of utmost importance in the effort to mitigate environmental effect. The facilitation of inclusive collaborative design is achieved through the practice of open collaboration, hence strengthening the overall design process.

In summary, VR is not just a fancy presentation tool; it is also a disruptive tool that is influencing the direction of design. It serves as a means of connecting designers, users, and cultures, thereby establishing environments that possess not only functional qualities but also demonstrate empathy, sustainability, and inclusivity. The growing advancement of architectural practices highlights the increasingly apparent significance of virtual reality (VR) in fostering social and cultural sustainability. When utilised with careful consideration and intention, this technology possesses the capability to fundamentally transform our understanding, development, and occupation of the constructed world. Architects and designers have the potential to make substantial contributions to the creation of a more egalitarian, culturally diverse, and socially sustainable world by using virtual reality (VR) as a catalyst for inclusive design. In the context of addressing the multifaceted issues of the contemporary day, virtual reality (VR) emerges as a potent instrument for materializing the inclusive and sustainable architectural goals that lie ahead.

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